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Implementation of reactive and predictive real-time control strategies to optimize dry stormwater detention ponds

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Dry detention ponds have been widely implemented in U.S.A (National Research Council, 1993) and Canada (Shammaa et al. 2002) to mitigate the impacts of urban runoff on receiving water bodies. The aim of such structures is to allow a temporary retention of the water during rainfall events, decreasing runoff velocities and volumes (by infiltration in the pond) as well as providing some water quality improvement from sedimentation.
The management of dry detention ponds currently relies on static control through a fixed pre-designed limitation of their maximum outflow (Middleton and Barrett 2008), for example via a proper choice of their outlet pipe diameter. Because these ponds are designed for large storms, typically 1- or 2-hour duration rainfall events with return periods comprised between 5 and 100 years, one of their main drawbacks is that they generally offer almost no retention for smaller rainfall events (Middleton and Barrett 2008), which are by definition much more common.
Real-Time Control (RTC) has a high potential for optimizing retention time (Marsalek 2005) because it allows adopting operating strategies that are flexible and hence more suitable to the prevailing fluctuating conditions than static control. For dry ponds, this would basically imply adapting the outlet opening percentage to maximize water retention time, while being able to open it completely for severe storms.
This study developed several enhanced RTC scenarios of a dry detention pond located at the outlet of a small urban catchment near Québec City, Canada, following the previous work of Muschalla et al. (2009). The catchment's runoff quantity and TSS concentration were simulated by a SWMM5 model with an improved wash-off formulation. The control procedures rely on rainfall detection and measures of the pond's water height for the reactive schemes, and on rainfall forecasts in addition to these variables for the predictive schemes.
The automatic reactive control schemes implemented here increased the pond's TSS (and associated pollution) removal efficiency from 46% (current state) to between 70 and 90%, depending on the pond's capacity considered. The RTC strategies allow simultaneously maximizing the detention time of water, while minimizing the hydraulic shocks induced to the receiving water bodies and preventing overflow. A constraint relative to a maximum time of 4 days with water accumulated in the pond was thus respected to avoid mosquito breeding issues. The predictive control schemes (taking rainfall forecasts into consideration) can further reinforce the safety of the management strategies, even if meteorological forecasts are, of course, not error-free. With RTC, the studied pond capacity could thus have been limited to 1250 m3 instead of the 4000 m3 capacity currently used under static control.

References

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