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Modelling Real-Time Control of WWTP influent flow feeding based on scarce data

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Summary of key findings

In order to comply with the effluent norms, wastewater operators need to avoid hydraulic overload of their wastewater treatment plants (WWTP), as this can entail the wash out of activated sludge from the secondary settling tanks. This can become a problem when extending existing transport infrastructure.

The presented study demonstrates the use of real-time control (RTC) to reduce the load to the WWTPs capacity while restricting the overall overflow volume to a minimum. It shows the feasibility of accurate modelling despite the limited availability of information on the catchment through the adoption of a parsimonious simulation approach, the relocation of spatial system boundaries and the creation of required input data through reverse modelling. Special attention was paid to the accurate modelling of pump hydraulics and control.

Simulation results showed that, compared to the scenario where no control is implemented, the increase of spill flows could be restricted to an acceptable level when limiting the total influent flow to the WWTP to its capacity without necessitating further mitigation measures in the sewer network. The developed RTC algorithm is in operation on the full scale system since 2013.

Background and relevance

The overall value and wide range of possibilities of use of RTC has been extensively described in literature during the last decades (Schilling, 1989; Schütze et al., 2004). The here presented study discusses the specific case of use of RTC to alleviate the detrimental effects of a hydraulically overloaded WWTP in combination with low data availability.

It has been carried out for the catchment of Olsene, situated in western Flanders, Belgium, where the WWTP receives wastewater from five different pumping stations (PS) that directly pump into the WWTP (no influent works present). Two of these PS were only recently connected, increasing the number of connected person equivalents (PE) from 13,000 to 23,500. With a maximum capacity of 21,000 PE the WWTP is confronted with the risk of hydraulic overloading during times when all 5 PS are working at their maximum capacity. Several other WWTPs in Flanders are faced with comparable problems or are expected to do so in the near future.

Many recent applications of WWTP influent modelling rely on modelling approaches integrating the full urban catchment including rainfall-runoff and hydraulic or conceptual modelling of the sewer system. In contrast, the modelling approach used for this case study is limited to the essential parts of the considered system. For each of the 5 catchments the model is composed of the PS and a volumetric storage unit that emulates the storage behaviour of the main collectors drained by these PS. As detailed catchment data was not available for adequate surface runoff modelling, it was opted to relocate the spatial boundaries of the system (Vanrolleghem et al., 2005) and use the sum of all inflows to the collectors as model input. This input was generated by reverse modelling (see e.g. Leonhardt, 2014) from the available historic data set of monitored pump flow and by the implicitly available information (via water level monitoring) on the activated storage volume. Further, detailed pump characteristics have been implemented based on an analysis of the historical water level and flow data available to allow for accurate evaluation of the RTC algorithms. These include switch-on and -off delay and the dependence of the pumping rate on the water level in the pump pit.

Results

The composed model has been used to evaluate two different concepts of control for the limitation of the total influent flow of the WWTP while keeping the expected increase in total CSO volume at the CSO locations of the PS to a minimum. The first one uses a frequently applied approach to flow limitation problems in form of the application of time slots. For each single PS there is a predefined time interval during which it is switched on followed by an interval during which it is inactive, again followed by an active interval and so on. By varying the ratio of the switched on interval to the total cycle time for each individual pump, the resulting mean total flow to the WWTP can be tuned. The second approach is a global control concept with one central controller continuously retrieving information about the current state of each of the PS and sending flow set points to the PS in the order of the urgency to evacuate the collector. Filling degrees (as e.g. described by Dirckx et al., 2011) of each collector are used to prioritise the decision whether or not a pump has to be switched on (and at what flow).

As the following figure exemplarily shows, the pump behaviour during wet weather is accurately simulated both in terms of switch on time of the pump and the nonconstant maximum pumping rate.

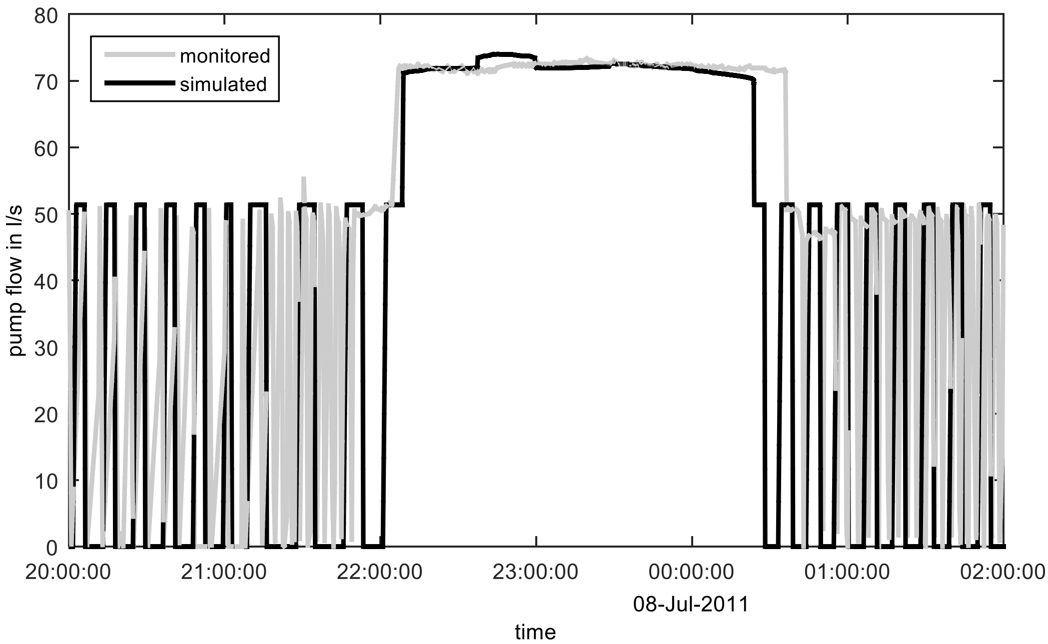

Figure 1.1 Model validation: Exemplary comparison between monitored and simulated pump flows for the base scenario

Model results show that, while both RTC concepts can reliably ensure the influent flow limitation to the WWTP, the global control shows better performance with respect to flow equalisation. When applying local control based on time slots the flow during one cycle can vary quite severely. A further advantage of the global control algorithm is its possibility to directly alter the desired maximum capacity. This allows to fully integrate the control algorithm into the supervisory system of the WWTP. The fact that the timeslot based local control cannot adequately react to unbalanced input caused by spatially variable rainfall forms its biggest disadvantage compared to the global control strategy.

Regarding the impact on the receiving waters, it was found that, while the application of global control increases the expected CSO volume by about merely 23 % with regard to the current situation, local control results in an almost twice as high increase: 40 %. Improvement beyond these values would require currently unrealistic measures further upstream in the system.

Based on these results, the global algorithm has been implemented into the real live system in 2012, using the time slot control as a fallback strategy in the event of communication failures. During a performance evaluation of the system after 1 year of operation it became apparent that both the wear and tear of the pumps, but also temporary obstructions (sand, sludge, blockage) that had not been explicitly modelled, required further refinement of the control algorithm. The finally implemented solution makes use of an alternating set point for the maximum allowed total flow in order to dynamically compensate for temporary or permanent losses in the actual pump capacities. This algorithm is successfully in operation in the full scale system since 2013.

Discussion

A simple and robust real time control algorithm has been developed based on a very limited amount of data for 5 PS that drain a rather small catchment directly into a WWTP. As the aim of the study was to limit the inflow to the during wet weather overloaded WWTP focus was on algorithms for the influent pumps, not the entire system. The subsequent increase of total CSO volume in the transport system was met by a second order goal function to restrict this value.

Despite the lack of detailed catchment data, the modelling results proved to be of good accuracy. The explicit modelling of catchment rain-runoff and detailed sewer system was not required to simulate WWTP influent flow and estimate CSO volumes. This could make the adopted modelling approach valuable for an extension of existing modelling toolboxes such as e.g. the extended BSM2 platform (Saagi et al., 2014) as an option for cases where integrated control of sewer system and WWTP through pump control is relevant, but data availability is limited.

The predicted increase of CSO volume was deemed acceptable given the now safe operation of the WWTP without necessitating further mitigation measures in the sewer network. This lead to a joint decision with the Flemish Environmental Agency to implement the RTC algorithm into the full scale system. The fact that futher potential for improvement of the RTC algorithm was only detected after implementation into the full scale system highlights the importance of close long term follow up after the initial evaluation phase.

In its design, the developed algorithm is applicable to any WWTP fed by PS or regular screw pumps, or to any combination of parallel working PS with a downstream flow limitation. It thus offers a solution for a quick implementation and a robust operation open to any wastewater operator confronted with comparable challenges. Investigations for the deployment in another case study are ongoing.

References

Dirckx, G., Schütze M., Kroll, S., Thoeye, C., De Gueldre, G., Van De Steene, B. (2011) Cost-efficiency of RTC for CSO impact mitigation, *Urban Water Journal*, 8, 6, 367-377

Leonhardt, G., (2014) Development and application of software, sensors and reverse models for urban drainage systems, *PhD*, University of Innsbruck, Austria

Saagi, R., Flores-Alsina, X., Fu, G., Benedetti, L., Gernaey, K.V., Jeppsson, U., Butler, D. (2014) Benchmarking integrated control strategies using an extended BSM2 platform, *13th Int. Conf. on Urban Drainage*, Sarawak, Malaysia

Schilling, W. (1989) Real-Time Control of Urban Drainage Systems. The state-of-the-art., IWA Publishing, ISBN: 9780080401454

Schütze, M., Campisano, A., Colas, H., Schilling, W., and Vanrolleghem, P. A. (2004) Real-time control of urban wastewater systems – where do we stand today? *Journal of Hydrology*, 299, 335-348

Vanrolleghem, P., Benedetti, L., and Meirlaen, J. (2005) Modelling and real-time control of the integrated urban wastewater system. *Environmental modelling and software*, 20(4), 427-442