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a real case study with a complex internal overflow structure

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Diagnosing the location of uncertainty in urban drainage models with hydrologic and hydraulic signatures: a real case study with a complex internal overflow structure

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Highlights

- Hydrological and hydraulic signatures are a useful tool to diagnose uncertainties in digital twins
- Signature scatter plots successfully diagnose erroneous model input
- Events which are difficult to simulate need to be highlighted for end users

Introduction

Utilities are starting to apply digital twins of urban drainage systems in their daily operation, where observations from sensors are applied together with simulation models to provide information on e.g. documentation of service levels or combined sewer overflows or to analyze when to make predictive maintenance (Pedersen et al., 2021a). The uncertainty in the simulation models needs to be addressed and explicitly highlighted, as non-expert users often expect high confidence of the simulation model in digital twin for all processes and situations. Such accuracy and precision is however rarely the case in reality, where model estimates and in-sewer observation can deviate significantly. Typically, a model is calibrated heuristically based on observation from a limited period and considered validated, but caution needs to be taken as there are many other uncertainties that can affect you model results. By applying signatures (Gupta et al., 2008) to models and observations we can identify uncertainties in integrated urban drainage models (Pedersen et al., submitted). Uncertainties can be classified into four locations: context, input (external forcings or system attributes), model structure (conceptual as physical attributes or processes, mathematical as the spatial and temporal variability, and equation or computational uncertainty) and parameter uncertainty (Gupta et al., 2012; Walker et al., 2003). In this work, we show how hydrologic and hydraulic signatures can be used to diagnose uncertainties in integrated urban drainage models with a real-world example of a complex sewer overflow structure.

Methodology

The hydraulic structure analysed here is an internal overflow structure, in which there are several inflows, a rule-based controllable valve regulating the outlet and an internal weir in case of excess water. Information about the structure is based on construction drawings, observations and rule settings in a SCADA system, and an asset database. The model used is implemented in the integrated urban drainage model software Mike Urban with the MOUSE engine, with a setup as described in (Pedersen et al., 2021b). Rain input are from nearby rain gauges. The period analysed is app. two years, January 2019 to October 2020. A level-meter is located just in front of the valve.

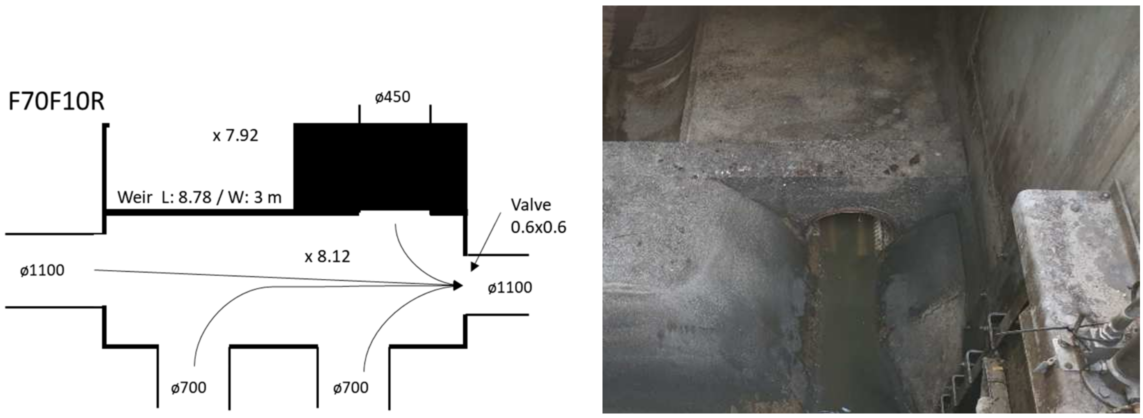

Figure 1: Drawings of the structure of interest and a photo from the site.

Initially the utility company VCS Denmark had a model (original model) with invert level in the daily flow chamber set to 7.92 because the asset database registers the lowest level in the entire structure as the invert level. The invert level followed in the models even though this level is located in the weir chamber and not the invert level of the daily flow chamber, which has an invert level of 8.12. This was changed in the modified model where also the control rules of the valve were changed to react to a new invert level, and minor adjustments in the catchment area were furthermore made.

Events were identified and signatures calculated according to (Pedersen et al., submitted). As an example highlighted here, the signature 'peak level' was calculated as the maximum level in one event for both modelled results and for observations and is compared.

Results and discussion

Calculating the signature "peak level" for multiple rain-induced events (Figure 2A) showed that something was not correct in the model. No model values below 8.12 appeared, which is not unusual but some clusters around 8.12 were seen. Examining the old drawings showed that there was a system input error in the model as the invert level was not correct. Simulating the same period with the changes described above including the updated invert level (invert level = 8.12) and thereby also top of the pass-forward pipe gave the numbers in Figure 2B. Minor reduction in the areas upstream gave less high peak levels than before.

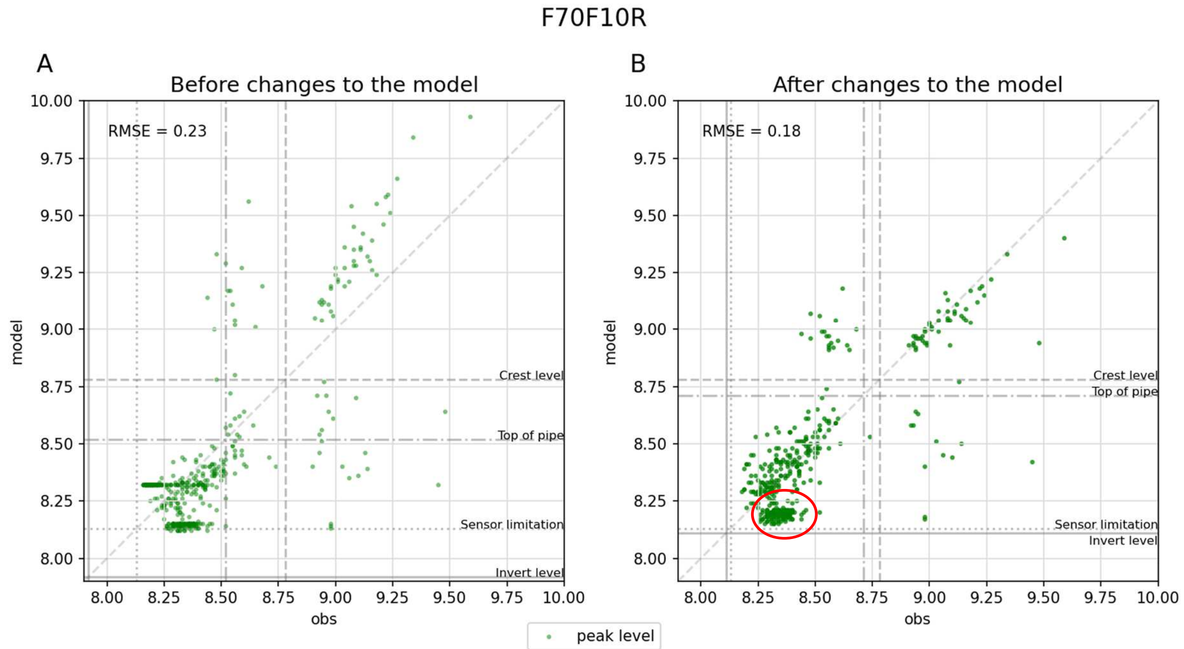

Figure 2: Multi-event comparisons of modelled vs. measured values of the signature 'peak level'. A is before changes were made to the model (original model), and B is after changes were made to the model (modified model). Red circle highlight a cluster.

The large gap without peak levels around the crest level is due to the valve controlled by rules indicating that the valve will be closed when the level comes near the crest level, and the water quickly accumulates in the structure with peak levels well above the crest level.

The root-mean-square-error (RMSE) was calculated for the signature 'peak level' of the events. RMSE decreases slightly (from 0.23 to 0.18) when changes are made to the model, and visually the graphs for the modified model (Figure 2B) look as expected with events around the identity line and some that do not simulate the event at all. An explanation to those either indicating observed overflow but not modelled and vice versa could be that we still overestimate the runoff in the model, and therefore we see modelled overflow and not observed. Those events that has an observed overflow but not a modelled overflow can be due to rain uncertainty, but it could also be due to anomalies in the sewer network causing hydraulic conditions which are not possible to describe with an "ideal" model of the urban drainage system. These special events need to be identified. As an example, a cluster in Figure 2B (red circle) around modelled value 8.20 is seen, which may be due to the description of the structure with a manhole (diameter of 1.25 m) and not a basin with a channel in the bottom. Therefore, the model may overestimate the volume at low levels giving lower modelled peak levels in these situations. With higher levels this may be outweighed.

With increasing automation of equipment in urban drainage system, where many decisions rely on results from model simulations, we need to be aware of the many locations of uncertainty that occur in models as well as the uncertainties in observations. Calculating several signatures to the models and observations, in addition to 'peak level' also e.g. 'time of peak level', 'duration above crest level', 'area under curves' (a surrogate volume) can help identify different locations of uncertainties (Pedersen et al., submitted). To make informed decisions from the models we need to expose the uncertainty for the different situations and locations and accept that our models may not answer all questions.

Conclusions and future work

Signatures can be used to systematically diagnose characteristics of the models and observations in order to guide where the uncertainty is located. By acknowledging the different model uncertainties and observation uncertainties, we can make better and more robust models that can help providing results to inform decisions. With signatures we are able to diagnose errors in the models, but we are also able to quantify and communicate the performance of the models.

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