DO YOU WANT YOUR PIPES CLEANED? THE VALUE OF 'REAL WORLD MODELLING'

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ABSTRACT

Based on the author's experience in forensic flood assessment, hydraulic modelling, stormwater design and real world observations, this paper will discuss the importance and potential value of key decisions when undertaking a model build project.

Using recent project examples, this paper will assess the impacts of simplifying the real world, whether modelling an urban river separate from the Stormwater networks that feed it, excluding network assets like sumps, or not accounting for an asset's operational condition. This paper will also explore the potential value of whole system modelling.

KEYWORDS

Forensic flood assessment, hydraulic modelling, real-world behavior, asset maintenance, stormwater

Introduction

Through the authors experience investigating real flood events using hydraulic models, there is a common theme; this is that there are often many contributing factors to a flood and it is not just about pipe capacity. These factors are sometimes overlooked when assessing the systems level of flood risk, which can result in under-estimated flood risk when compared to a real world event. It can also lead to overestimation of flows when historic events are used for model calibration, and thus incorrect design responses.

To recreate the observed flooding, existing models are sometimes found lacking, requiring a change in scale or methodology in order to better represent what happened.

These short falls are often due to the scope of the model build, or use of an approach with particular limitations.

In order to make robust decisions around flood risk and asset management, it is important to understand how model scope and maintenance condition can impact on results. This paper will assess the impact of such decisions and the potential risks and benefits associated with them using some real world examples. The term 'real world' modelling refers to a model scope and scale designed to replicate what actually happens in a flood event by including, for example, operational issues and additional sources of inflow like sewer overflows.

Note that due to the sensitivity of some projects the author has been involved in, this paper will not discuss the particulars of the project, only the lessons learnt.

Level of Detail

There are a number of options available when assessing network performance and flood risk. These typically include:

- Assessing an urban river in isolation of the contributing networks
- Assessing an urban pipe network in isolation of the receiving environment
    - Trunk network only – a skeletal simplified model
    - Pipes larger than X mm diameter only
    - All pipes excluding sumps and sump leads
    - All pipes and sumps (including sump leads)

Further to this, model simulations and model validation / calibration may often exclude operational condition at the time as well as other potential sources of inflow (e.g. fluvial flooding over SW assets or wastewater overflows to the SW network).

All of these decisions are important when assessing system performance and flood risk and the consequence of these decisions need to be understood. The following sections explore some of these options and their potential risks / benefits using a range of real life and theoretical examples.

Urban River in Isolation

When an urban river is modelled in isolation, it is typically assumed that run-off can enter the river without restriction and that flood storage is limited to the functional flood plain.

Often rivers are assessed in terms of Annual Exceedance Probabilities (AEP) of 2% and higher. However, often the historic stormwater network is not designed to convey events of this magnitude, resulting in overland flow or surface ponding in the upstream catchments. Not allowing for this effect can result in over-prediction of fluvial flow and over-stated fluvial flood risk.

Also, when a river is assessed in isolation, the floodplain is limited to the historic flood plain, particularly where constrained by embankments or walls. In reality, the fluvial flooding may limit Stormwater inflows and trigger the storage of water behind such structures outside of the defined floodplain.

I have found on several prior projects that modelling the urban watercourse and the urban Stormwater network together can result in a dramatic change in flood flow from prior more traditional studies that looked at the urban river in isolation. In one project we found that the pipe network significantly limited inflow even assuming perfect working condition. This was most notable in this situation due to the flat terrain of the catchment and lack of defined overland flow paths. In this case it reduced the flow significantly, resulting in minimal flood risk (in line with historical information) contrary to prior studies.

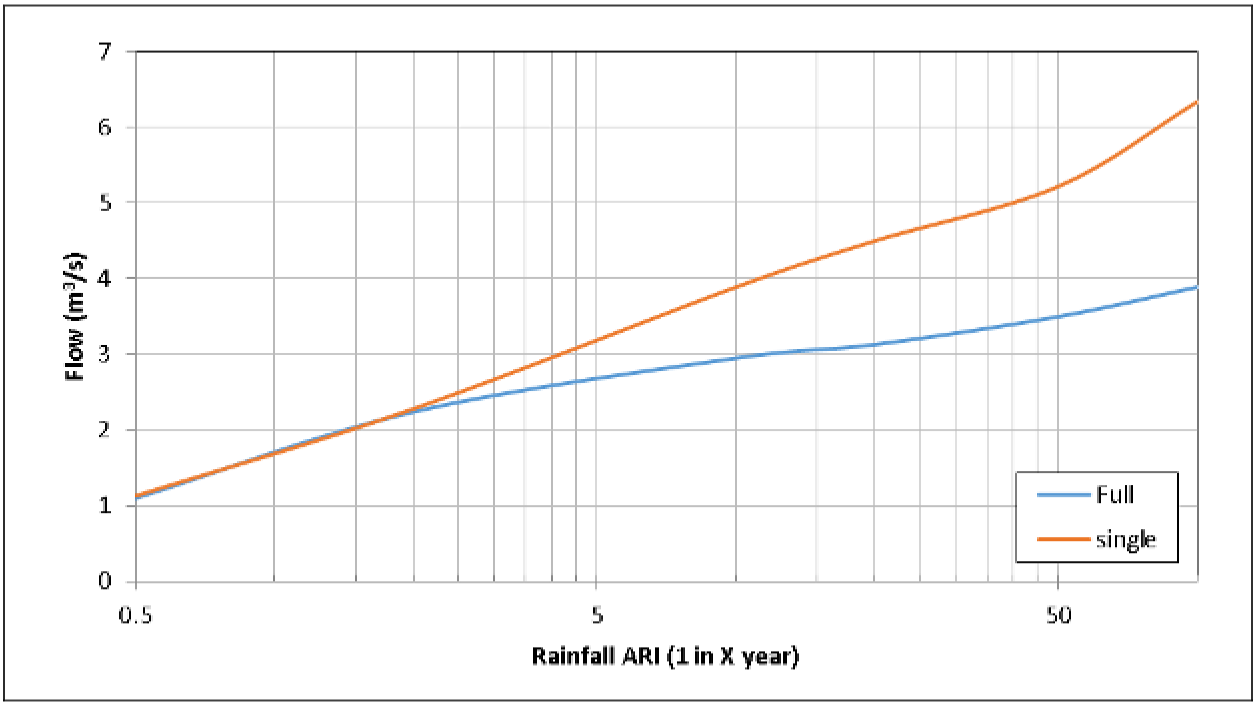

Figure 1 – divergence of flows comparing a complete model of both urban and river system 'full' with model of the river system alone 'single'. Note how they diverge once the SW networks LoS is met.

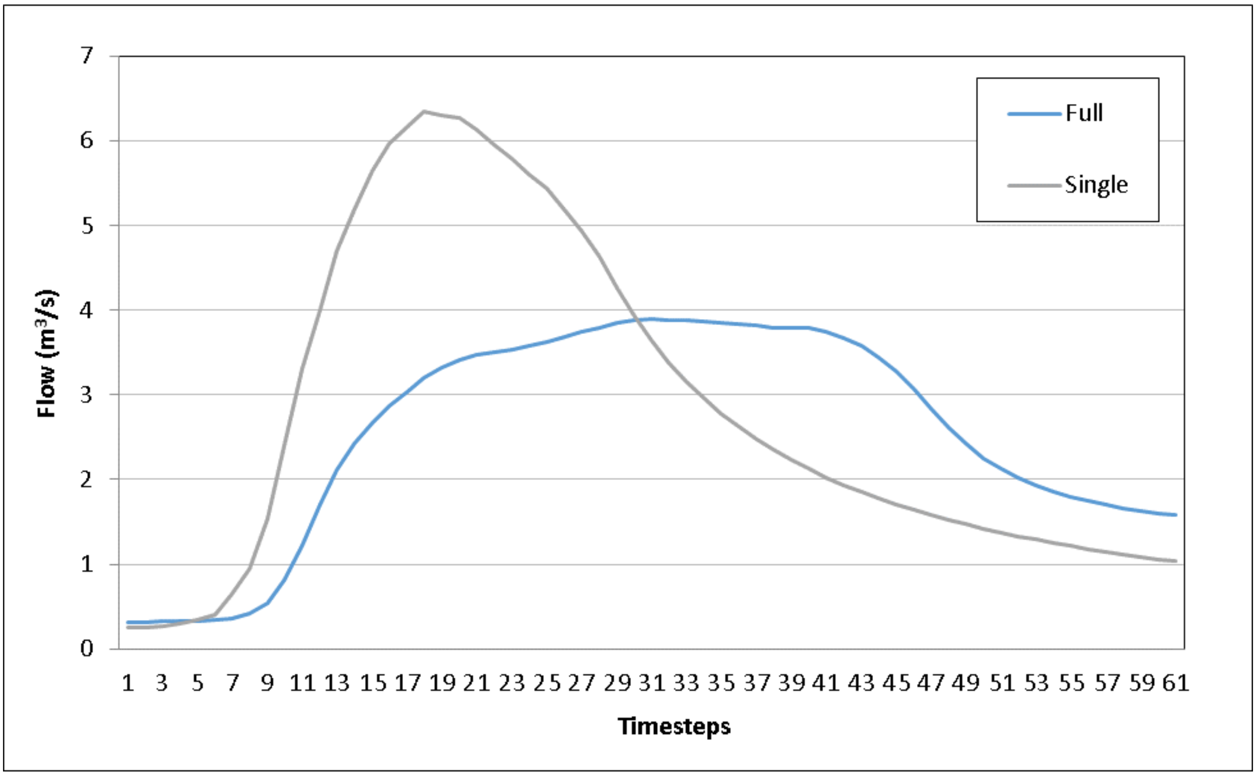

Figure 2 – comparison of the flow hydrograph with the urban network included and excluded – note how the 'full' model attenuates the peak discharge.

In another project, modelling the stormwater network and river together resulted in significantly different flooding from a prior study. The prior work had considered the river in isolation and showed large areas of flooding along the river corridor. The 'whole network' model however reduced the floodplain along the river, whilst identifying additional areas of flood risk away from the river; though within the valley floor. The areas of flooding predicted away from the river were corroborated by historic information.

Greenspaces

Run-off from large park areas are often routed direct to the Stormwater network. In reality if these are flat they don't contribute in such a direct manner, and often will pond significantly before discharging to the network via overland flow.

By adopting the right hydrological approach it is now possible to re-create this observed effect. This is achieved through a combination of traditional 1D hydrology (lumped Rainfall Run-off Models) for impervious areas directly connected to the network and a 2D hydrological model combined with 2D surface hydraulics and a 3D Digital Elevation Model (DEM) for un-connected greenfield areas.

The latter approach is essentially 'Rain on Grid' flood modelling, only it covers pervious area only and includes a run-off volume model for surface losses. Opus have developed this technique in lieu of traditional methods which fail to capture this mode of flooding observed in real life events. Adoption of novel approaches to hydrology such as this can result in improved model results, but it does rely on a skilled hydraulic modeler who understand how new technological improvements can be used appropriately.

Trunk System / Pipe sizes excluded

In my experience excluding pipes under a certain diameter doesn't really save any money on a modelling project. The model build process today is streamlined using SQL and GIS tools, so as the data set gets larger, the work involved doesn't increase significantly (though there may be computer / software limitations).

By excluding elements of the network upstream, attenuation of flow and surface flood storage can be lost which can result in spatial errors in flooding. In one such example, Opus took an existing MIKE11 model of a waterway and trunk SW pipes and built in the rest of the pipe network previously omitted. This change resulted in a reduction in predicted flooding along the waterway itself, whilst highlighting previously un-assessed areas of flooding upstream in the network. Much of this 'new' upstream flooding was only nuisance flooding contained within the road, but was enough to reduce the downstream flooding that was more significant. In some cases this could be the difference between taking action or not and could avoid expensive capital works that are not actually required.

Sumps

Sumps are often not included in Stormwater network models (often being roading assets), but these are typically the main points of inflow. Their inlet capacity and condition is critical to understanding what the system does in a 'real' flood event.

Sumps on grade have limited capacity to intercept flow (theoretical capture efficiency is generally over-stated based on field testing) with sumps in sag-points often having to capture the excess flow. This can lead to some pipelines receiving more flow than expected, and others not enough (particularly during events >10% AEP). The by-passing of sumps is particularly important for steep catchments where velocities in the channel are higher. Testing of sump capture using hydrants can shows how easily they can be by-passed by flow.

Figure 3 – two examples of sumps being by-passed by flow from a hydrant test (courtesy of Eric Thorn, Opus)

If sump inlet capacity is not modelled, all flow is often assumed to enter the network. This can in some cases result in differences in flooding and flow rates in the piped network. There is value in understanding the pipe networks performance if all flow can enter, but it is also just as important to understand what happens when it cannot.

What maintenance condition are the sumps typically in across a catchment? Can you be sure 100% of the sumps are clear of blockage at any given time? In a real life event, there are often blocked or partially blocked sumps which contribute to the observed flooding. Scenarios around sump blockage or limited capture need to be considered.

Figure 4 – an example of double sump blocked with silt, gravel and debris (courtesy of Eric Thorn, Opus)

Operational Condition

Generally hydraulic models are based on asset data from GIS and lack data on the networks operational condition. They typically predict flooding for a system in a perfect state of maintenance.

This creates two problems. Firstly, in an historic event used for calibration / validation there may be many factors affecting the flood, such as: silt in pipes, private structures affecting flow, screen or sump blockage, or wastewater overflows. If a model is calibrated/validated to an event of this nature without allowance for these, then the model may end up replicating the flooding through over-estimated flow. This may then in turn lead to incorrect decisions based on those flows.

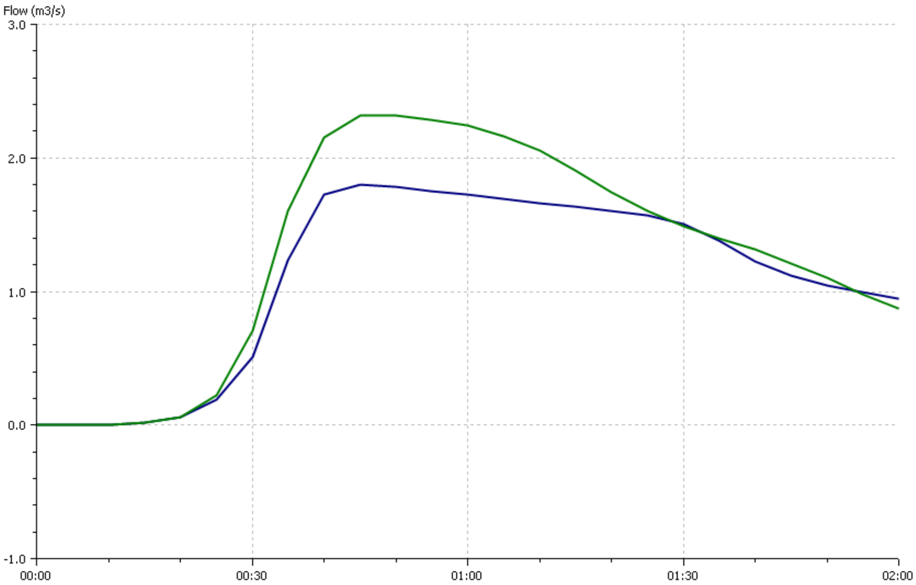

Figure 5 – comparison of a network discharge with silt included and excluded (the missing volume is lost to overland flow)

In one example of condition affecting flooding root intrusion within a pipe was found to be causing a significant frictional loss (equivalent to n=0.075). This was large enough to regularly flood a low point upstream to a reasonable depth. However, when the model did not include the root intrusion, the street did not flood anywhere as badly as was observed and instead another location downstream was predicted to flood which did not flood in real life.

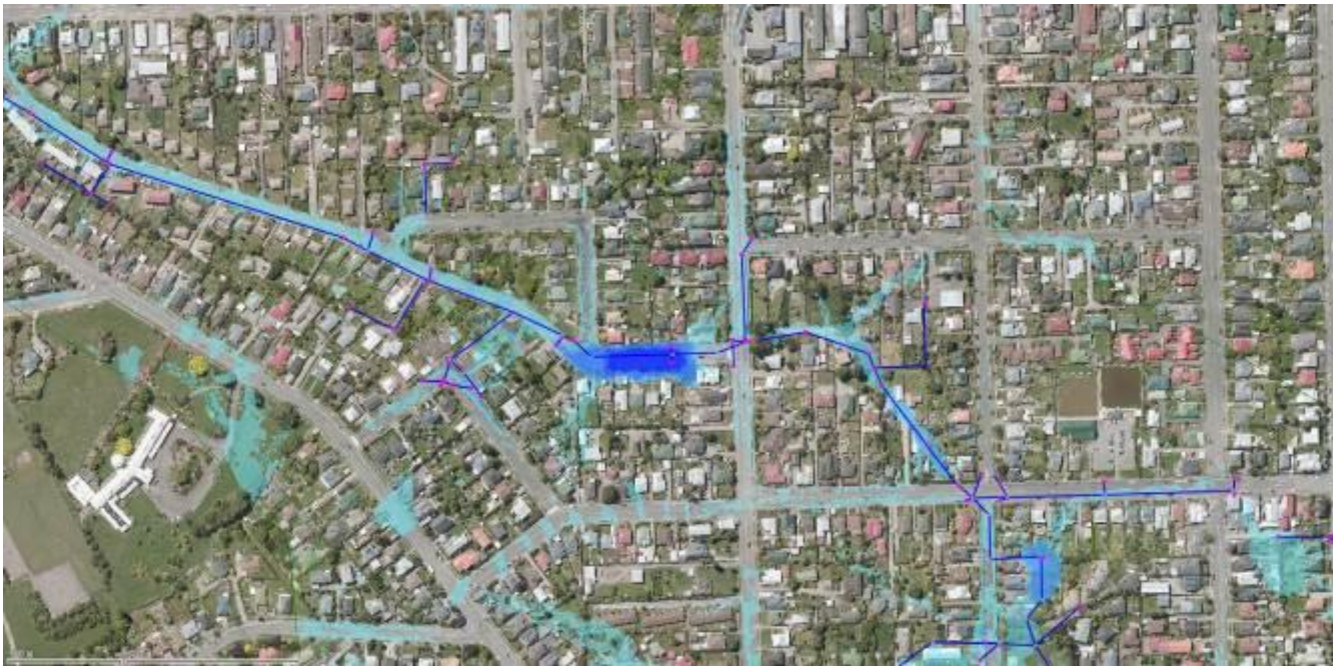

Figure 6 – predicted flooding with observed root intrusion included

Figure 7 – predicted flooding without the root intrusion included

Including model scenario to assess variability in flood risk due to operational condition is an important tool to understand the risks and potential consequences. This information can then be used to specifically target maintenance where most sensitive to condition.

Ponding hazard mapping (derived from LiDAR using 'Rain on Grid') can be used to identify key risk areas such as areas with no overland flow path that would flood if the sump inlet was blocked.

Can you be sure at any given time that the Stormwater network is free from root intrusion, silt accumulations, sewer overflows (formal and informal), by-passing sumps and blocked sumps? This is unlikely given the level of maintenance required, so it should be considered even from a sensitivity perspective.

Conclusion

It is my experience that to correctly understand flood risk and your network, modelling the entire system in full will provide the best results, especially when looking at a large capital outlay. This has been technically feasible for some time now (subject to scale). Simplified networks are likely to over-estimate flood risk in some areas whilst missing it altogether in other areas.

Including operational information such as CCTV, flow monitoring data, wastewater overflows and assumptions around sump or screen condition will provide a more realistic representation of what might happen in 'what if' scenarios and better model validation / calibration. With recent advances in technology stochastic flood modelling can now be employed to visually map confidence or uncertainty.

Once operational sensitivity and the associated flood risk are understood this can then lead to more targeted and effective network maintenance.

If you are planning renewals, upgrades or flood relief schemes, having the best understanding of your network and its 'typical' operational condition (and variations of) is essential to make sure decisions are made robustly. Correctly scoping any hydraulic modelling to support this and having the right data is key to achieving this.

So what can be done?

- Correctly scope the modelling and consider incorporating real world conditions - seek professional advice if you are unsure of what you need.
- Ensure the hydrological approach is appropriate for the outcomes required
- Ensure you have the right data to understand the networks operational condition
- Consider flow monitoring to improve your understanding of hydraulic operation – again seek professional advice to ensure this is properly scoped (obtaining spot calibrations during wet weather is important for good results).
- Consider sensitivity testing or stochastic flood mapping to understand the risks and uncertainties associated with model parameters and operational condition