A Blueprint for Modelling Sewers and Implementing SuDS

Bob Fleming, Scottish Water, bob.fleming@scottishwater.co.uk
Gwen Rhodes, m^2/Stantec, gwen.rhodes@stantec.com,
Ricky Mitchell, m^2/Stantec, ricky.mitchell@stantec.com
Chris Digman, m^2/Stantec, chris.digman@stantec.com

Abstract

Scottish Water compares sustainable storm water management options (green and blue infrastructure) with traditional sewer designs (grey infrastructure) when implementing drainage improvement schemes such as flooding and unsatisfactory intermittent discharge (UID) projects. However, it is perceived that sustainable green and blue infrastructure solutions have higher costs and may therefore be discarded early on in the optioneering phase. The designs are generally based on the hydraulic modelling outputs, and catchment performance knowledge suggests that the flood volumes / flows predicted by the model are often conservative. If this was the case, then the design of interventions could be smaller and allow the sustainable types of solution to be more viable and become the preferred intervention.

Scottish Water and SEPA advocate the use of sustainable solutions to manage flood risk, reduce pollutant loads discharged to the environment, make urban drainage more resilient to climate change whilst creating more greenspace. Software enhancements, new data and tools in the industry in recent years allow more detailed catchment representation. It is believed that adoption of these enhanced software tools will provide a ‘truer’ picture of flooding needs, and the subsequent intervention required.

Scottish Water and SEPA are working together to further their understanding of fundamental modelling practices. As part of a suite of projects, the Blueprint for Sewers project aims to analyse such tools, methods and software enhancements, highlighting where they could be better used in current modelling practice. A key aspect of the project is to compare many of the modelling elements with measured data, therefore providing a good comparison and make recommendations of how these techniques may improve the representation of flooding. The study uses the Kirkcaldy catchment with a verified model and historic rainfall and flooding data for validation of the recommendations. Topics explored include: gulley and lateral modelling, limiting inflows from roof drainage, manhole size representation, spatial rainfall assessments, permeable and impermeable roughness factors, system controls, surface definitions, and techniques for modelling SuDS. This should enable a better representation of flows in the network and flood risk predictions whilst allowing for a more balanced assessment of sustainable drainage solutions against conventional solutions to be adopted.

Introduction

Scottish Water works collaboratively with many stakeholders to promote sustainable storm water management but often finds these schemes are not promoted. This is often due to cost and spatial scale of the measures required as a result of the large predicted flood volumes not being reduced enough to significantly reduce the flood risk with the use of such measures. Scottish Water working with SEPA have signed a Sustainable Growth Agreement (SGA)[1] where one of the key elements is to make “Scottish Towns and Cities more resilient to Climate change”. This means that the promotion and use of SuDS will become paramount going forward. The SGA is investigating three areas; planning, construction and modelling to investigate on how processes could be changed to remove some of the obstacles that are prohibiting the installation of such measures. Only the modelling aspects will be discussed in this paper.

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(1) https://www.sepa.org.uk/media/360985/scottish-water-sga.pdf

Approach

Scottish Water has promoted the use of SuDS in its capital programmes as interventions for flooding and UID schemes however, the numbers promoted with such schemes have so far had limited successes. The reason for this is many but some of the main issues are thought to cover;

1) Tight programmes of delivery meaning consultants are unwilling to try innovative approaches for fear of failure (and the resulting contractual risk) or that it is not possible due to other stakeholder and practicality factors to achieve implementation.

2) Modelling software abilities have greatly improved in recent years especially in the 2D environment allowing more of the natural drainage processes to be modelled but these modelling opportunities do not seem to be being adopted by consultants.

3) Modelling specifications are not covering what values or process would be acceptable for use within a Scottish Water project to support adoption of 2 above

4) Promotion of SuDS scheme relies on an understanding of a wider range of surfaces than before within a catchment which contribute flows, and the ability to model them to a better standard

5) Model verification is seen as main factor in model confidence, however model inlet points are modelled simplistically and don't reflect what's actually happening on the surface, during flooding events significant amount of flow is on the surface and do not enter the network, no consideration on accuracy of these flows is undertaken.

6) Scottish Water specification like many other Water Utility specification have model verification standards for 1D models but lack what is acceptable for 2D verification. When promoting SuDS, these overland flow elements need to have robust modelling to promote confidence in the proposed intervention.

7) Consultants in house tools make model build efficient, but these tools are not being adapted to emerging software abilities. This produces a traditional model build which in turn then need model updates to allow viable comparison of SuDS measures in any optioneering stages

The SGA gave Scottish Water the opportunity to investigate how changing modelling activities along with adoption of new software abilities could be used to alter how our model builds are undertaken. The SGA project will allow investigation into technical issues, identify knowledge gaps, establish what works well and what modelling approaches should be adopted by Scottish Water to enable adoption of SuDS. The main benefits of the project will be the ability to explore different approaches and be innovative with new software tools to establish good practice without a project timeline stifling the decision-making process.

Methodology

The agreed approach with m^2 was to use an existing Scottish Water model built to existing model build specifications this would give a baseline position. The Kirkcaldy model was identified as a suitable catchment as it had recently been verified to latest Scottish Water specifications, the catchment has a good distribution of housing types and ages, industrial commercial areas, rural runoff, a small watercourse as well as sufficient numbers of flooding areas along with a suitable number of modelling ancillaries to make the study a robust test on catchment variables.

This selected model would then be used to work through a series of discreet evaluations task which would test out a variety of new software abilities or different model build approaches. These discrete evaluation tasks would then be compared against the existing model performance with outcomes reported in a series of technical user notes.

Once all the tasks have been completed a review phase of the findings is planned to look into the effectiveness, value and benefits to the model performance and understanding of flooding mechanisms. Furthermore, how these changes would benefit the assessment of SuDS measures in future optioneering will be considered.

Where discrete evaluation tasks are identified as being beneficial in improving model performance, they will be amalgamated into a combined evaluation model scenario. This amalgamated model will then have a verification process undertaken to compare the difference in performance between the existing baseline model and revised model.

Once verification process has been reviewed and satisfied with the model performance the project will then follow an optioneering element to investigate how the changes that have been made in the model could influence the adoption of SuDS measures.

The outcome of above approach through the study findings will inform future Scottish Water modelling specifications. This in turn will hopefully reduce the barriers mentioned earlier and lead to the promotion of more SuDS interventions which will meet the main objectives of the SGA in making "Scotland's Towns and Cities more resilient to climate change" by the promotion of Blue Green Infrastructure.

Modelling topics investigated and key learning to date

To achieve the outcomes identified, a range of topics were proposed and discussed with Scottish Water. An agreement was reached of the topics of greatest interest and priority. Many of these topics could have full studies on their own, but a specific achievable angle was taken forward for each. Part of each investigation was to identify further work that could be carried forward at a later time. The topics were grouped under five areas; Rainfall Analysis, Runoff Modelling, Increased Model Detail, Solution Modelling, and Watercourse Modelling. To support the assessment of each topic, literature reviews and input from industry experts were collated to gather recent relevant work and identify solutions and approaches.

Rainfall Analysis

All drainage models are reliant on the rainfall data applied. Rainfall varies by geography, frequency, duration, intensity and continues to change with time as our climate changes. However, we must strive to apply the most appropriate rainfall data for the analysis of drainage and flooding challenges and development of solutions. Design rainfall is moving to the latest FEH13 data. Radar rainfall is often readily available.

As part of this project, topics investigated include the use of spatial rainfall and a review of historic data with FEH13 data. The spatial rainfall assessment utilised tipping bucket data and radar rainfall data. This data was combined to create a better rainfall data set that varied with time and geographic location. The revised rainfall was used to rerun the verification events. The results showed some changes to the fits and a new method for understanding verification or historical data. This new method helps to reduce one of the key uncertainties of an input parameter in modelling and will result in better decision making during the verification process.

> Rainfall analysis topics:
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> - Comparison of FEH99 vs FEH13
> - Spatial rainfall verification approaches

Increased Model Detail

The level of detail included in an urban drainage model can vary widely based on the purpose of the study, the stage of a project, the available data, model runtime, model stability, and the time and money available for development of a model. Modellers must decide when it is appropriate to increase the level of model detail. A review of a range of topics including roof drainage, laterals, manhole sizes, retail parks / simplified areas, and gullies was undertaken to establish which factors limited the model, to identify when to include the added detail, and to identify fundamental changes that are needed going forward.

Increased model detail topics:

- Limit discharge from roof drainage
- Test impact of including private laterals
- Manhole amendments
- Gully modelling
- Retail and new developments

Analysis has shown that roof drainage standard designs limit flows reaching the drainage network. Laterals often provide adequate capacity as the high intensity rainfall would have been spilled at the roof drainage point, but could be overwhelmed depending on the amount of other (non roof) area that is connected. Manholes chambers and shafts are calculated by defaults, which do not take into account design standards of the time period constructed or depth and inappropriately link shaft and outlet pipe size. Sections of models such as retail parks with on-site attenuation may be oversimplified resulting in models under estimating existing storage and could lead to a significant reduction in flooding. Gully modelling is becoming more common as GIS layers of gulley locations and better LiDAR data become available. There is a range of aspects to modelling these structures such as consideration for the type of gulley, use of head discharge relationships to control flow in, use of orifices to model short pipes, review of ground models to ensure flow will reach the gullies, and review of mesh size which can impact inflow. In addition, sensitivity testing must be completed related to gulley blockages, which will change with season and conditions.

Understanding when these detailed pieces of a model should be considered is critical. Carrying out endless surveys or adding in the minutiae of detail would greatly increase project cost and time. Recommendations are provided on when detail is required and on efficient ways of adding data.

Runoff Modelling

Runoff modelling topics:

- Surface runoff modelling
- Apply rainfall directly to mesh
- Permeable roughness parameters
- Ground models
- UKWIR groundwater modelling
- Soil types and infiltration
- Zones
- Partially separate areas

Rainfall hits the ground surface and then either enters the drainage system, runs overland and enters the drainage system elsewhere, enters the drainage system and the exits it somewhere else, or stays on the surface and does not ever enter the drainage system. The type of surface that the rainfall lands on will affect how much is absorbed and how quickly it moves across to a nearby area. These various rainfall runoff scenarios can be replicated to help understand natural flow paths.

Recent industry work has developed the UKWIR runoff model, which separates permeable and impermeable response, provides many more options related to surface types, and utilises the much more detailed HOST soil data. The uptake of this new runoff model across the industry has been limited.

In addition to the option of this different runoff model, rainfall can also be applied directly to the mesh. This relies on a good ground model built from LiDAR data and possibly improved with topographic. Losses and wetting of the surface are important characteristics to consider and include. Surface type data is becoming more readily available with land use and improved mapping data. This surface type data can be used to adjust surface runoff characteristics and utilise mesh roughness zones and infiltration zones.

Solution Modelling

A goal of this project is to support the implementation of green infrastructure SuDS solutions rather than simply traditional, grey below ground solutions. To improve the modelling and understanding of SuDS solutions, methods of modelling SuDS will be investigated, methods for modelling localised property level solutions will be analysed, options for utilising systems controls, methods of evaluating results using a GIS or data analytics tools, and opportunities for better visualisation.

> Solution modelling topics:
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> - Replicating SuDS in InfoWorks ICM
> - Localised flood mitigation measures
> - Evaluating Microdrainage approaches to SuDS replication
> - System controls
> - Tools for analysing 2D results

This work has not yet been completed, but will support the more rapid assessment of SuDS solutions with greater confidence to their performance.

Watercourse Modelling

Watercourses can be modelled in detail in integrated models or more coarsely on the mesh surface. Structures within watercourses can be modelled in various levels of detail depending on the type of model. Other important aspects include the agreement of the watershed catchment, boundary conditions, any survey requirements, and the hydrological approach to watercourse modelling. These decisions will lead to a reasonable approach and solutions that can be taken forward.

> Watercourse modelling topics:
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> - Probability distribution functions
> - Directly onto the mesh
> - Level of detail for restrictions and features

This work has also not yet been completed. As an industry, integrated models will continue to gain importance as urban drainage modelling and watercourse modelling align to find shared solutions. Partnership working across the water company, local authorities, and regulatory agencies requires having tools to jointly look at problems and deliver solutions.

Conclusion There is a growing agenda to retrofit green solutions. The models used in promoting these interventions must be built to mimic the natural processes more robustly whilst more accurately predicting the nature and scale of the problem. With a wider range of software tools available, it allows the modelling of these processes better than before. The Industry needs to continually challenge previous practice and grow with the software abilities to reap these rewards.

The work being undertaken in this SGA project will hopefully make a small step towards the goal of retrofitting more SuDS as part of Scottish Water projects and expand the knowledge within the industry as a whole.