Modelling Blue-Green approaches to stormwater management

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1. Introduction

Severn Trent (SvT) is investing an unprecedented £76 million in nature-based solutions in Mansfield. This ground-breaking project will manage flood risk to communities and positively impact stormwater discharges. The Mansfield Sustainable Flood Resilience Green Recovery project is an innovative urban Flood Risk Management Scheme, which will deliver 58,000m3 of storm water storage equivalent by spring 2025. This additional storage resilience equates to 60% of the increase in storm flows between 2020 and 2050. This increase in flows is largely due to climate change increases for the 10-year storm event, and also includes additional flows as a result of development growth and urban creep. The delivery of this storage will be through thousands of individual Rain Gardens, Bioswales, Permeable Paving and detention basins (e.g., Figure 1).

Figure 1 - Ravensdale Shops Rain Garden visualisation

2. Begin with the end in mind

SvT's ethos for the Green Recovery programme was to challenge 'norms', to dream and deliver big. For modelling, time has been our biggest challenge. The ambitious delivery programme of construction completion by 2025 has meant we have had to rethink how we approach modelling for the project, as a traditional modelling approach would have extended beyond the completion date.

We had to go back to basics and ask ourselves where we were heading with this project. Rather than following a standard modelling approach we considered the ethos 'Begin with the end in mind'[1]. This meant we were able to focus on what were essential needs verses outputs that were 'nice to have'. This concept is one that often modellers struggle with, as we often want to produce all the outputs for a modelling study without pausing to challenge ourselves on what is essential. On reconsidering the project needs, and reflecting on the unique delivery model that was being developed, we knew we needed to develop a model strategy that enabled the scheme designs to progress quickly, and also

[1] Steven Covey, 7 habits of highly effective people

consider the long-term reporting needs, demonstrating the benefits of SuDS to flood risk and overflow activations in the catchment.

3. Model Strategy

A multi-stranded, proportional modelling approach was developed, focussing on a range of scales and detail to inform the scheme through different phases. Six strands were developed to create the modelling strategy, as shown in Figure 2. These strands broke down what might traditionally be included in a modelling approach, but by considering project need, a flexible, adaptable and more sustainable modelling approach was developed. In collaboration with project partners Arup, University of Sheffield, and EPG Ltd this new approach has been made possible,

A key decision which enabled flexibility in the modelling approach, was model SuDS interventions after the features were constructed on site. This is radical, as usually we model designs before they are built. To 'proceed at speed', and to ensure that interventions could be constructed quickly, SvT and project partners AECOM and ARUP developed the 'SuDS Volume Calculation Tool'.

This tool goes back to basics with the modified rational method[2]. The tool determines the m^3 benefit from each intervention, from inputs such as contributing catchment area, infiltration rates, outflow controls and intervention layer make up. At completion, each intervention has a contributing catchment area (m^2), intervention area (m^2), effective volume (m^3) and network equivalent storage benefit (m^3).

The SuDS Volume Calculation Tool development has enabled the scheme to proceed at pace, meaning that upfront modelling was replaced by calculation of overland flow rather than modelling. In turn this has enabled us to create a more dynamic and creative modelling strategy. The strands of the modelling strategy address different project needs for each phase of the project and at different scales, whilst balancing project need with proportionality.

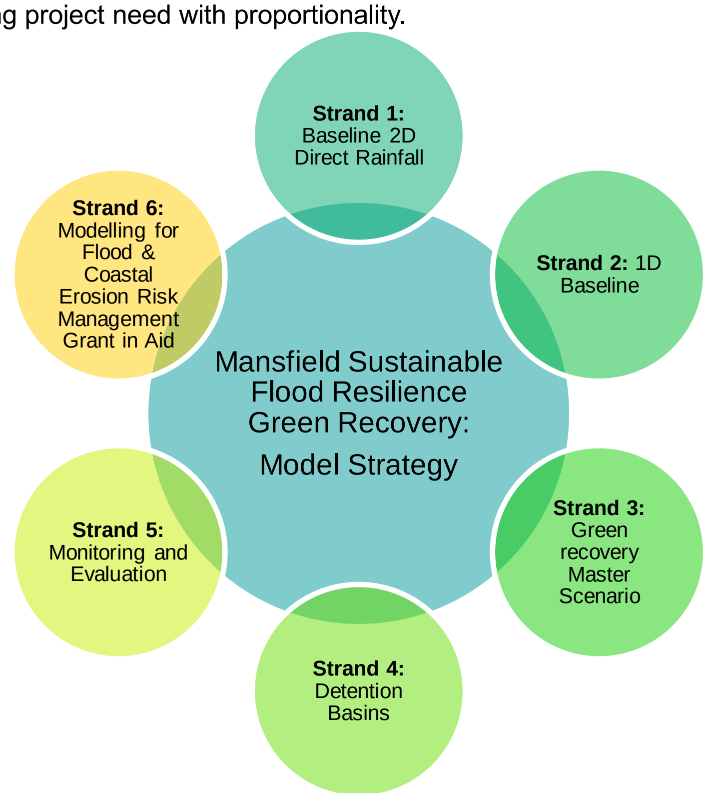

Figure 2 - Multi-stranded model strategy

[2] https://eprints.hrwallingford.com/37/2/Volume4_Modified_Rational_Method.pdf

1.1 Strand 1: Baseline 2D Direct Rainfall

AECOM developed a series of detailed 2D models and a joined 2D model which covers the entirety of the Mansfield Catchment. The project 'need' was to provide the Engineering teams with surface water flood depths and extents for the 10-year event, so that the SuDS features being designed would intercept overland flow paths (Figure 3).

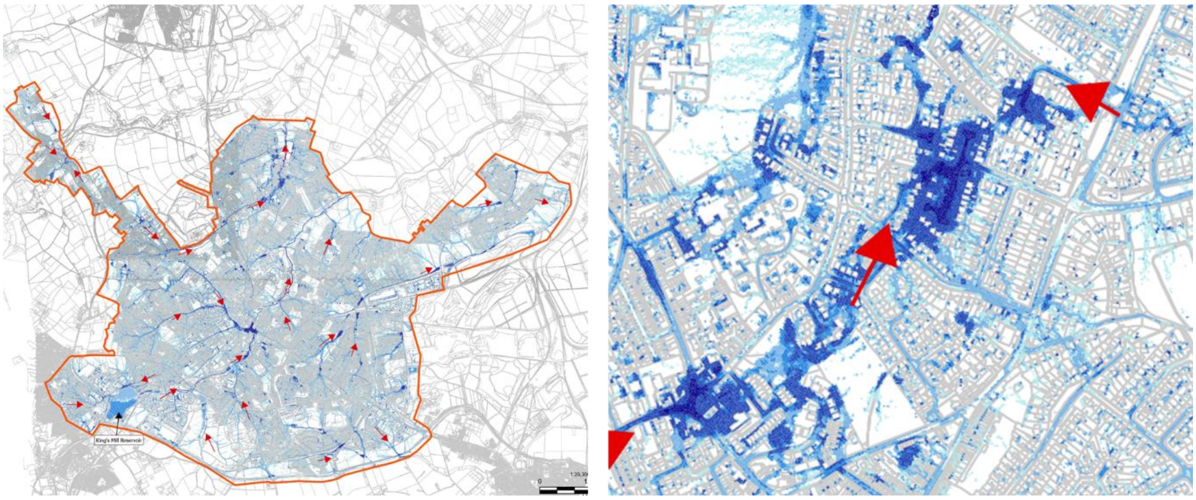

Figure 3 - 2D Direct Rainfall model outputs

This modelling pushed the limits of the ICM software being used, due to the size and complexity of the 2D model being built. We collaborated with the software developers at Innovyze, about the issues we were facing, which led to additional script to resolve our immediate issues, and in turn this led to software bug fixes for 'clip meshing' in the 2024 version of ICM.

Results of these models were cross-checked against other sources of data to ensure their accuracy, and to ensure that model assumptions particularly regarding roughness and infiltration values were representative. These included borehole water levels, geology and soil mapping, results from ground investigations as well as site visits and mapping sources. Sensitivity testing of the model was undertaken to ensure assumptions were realistic for the catchment being considered. The flood extents were verified using photographic evidence from recently recorded flood events combined with Maintenance Operative's catchment knowledge. The success of this modelling was recently captured in the aftermath of storm Barbet, as interventions placed using the 2D modelling outputs significantly reduced highway flooding, as shown in Figure 4.

Figure 4 - Eakring Road, Before and After Rain Garden (Left Nov 2022, Right Storm Barbet 2023)

1.2 Strand 2: 1D Baseline

Whilst our model strategy focus was to create a bespoke set of solutions for the project, it was important to Severn Trent that the catchment model was treated as an asset itself.

Once the scope of the baseline model upgrades had been defined for the purposes of the Mansfield Sustainable Flood Resilience Green Recovery project, we worked closely with the DWMP (Drainage and Wastewater Management Plan) consultant, Pick Everard, who are undertaking a Water Framework Directive study in the same catchment. This enabled the combined planning of surveys between the two projects, ensuring no duplication of effort, facilitated best practice concerning data sharing.

As a result of this collaboration, the baseline model has been reverified and upgraded throughout the catchment, creating a new baseline model which can be used to benchmark current network performance with increased confidence.

1.3 Strand 3: 1D Scheme "Green Recovery Master Scenario"

The SuDS Volume Calculation Tool enabled each intervention's storage equivalent to be calculated as a static 'snapshot'. However, to understand the cumulative impact of the interventions, these need to be modelled dynamically. This will enable SvT to understand the holistic catchment impact of the scheme with relation to flood risk and activations of overflows, and this modelling will support future Blue-Green infrastructure projects for SvT.

We are currently creating the 'as-built' Green Recovery Master Scenario and will continue to do this over the next 18 months. The approach is shown in Figure 5.

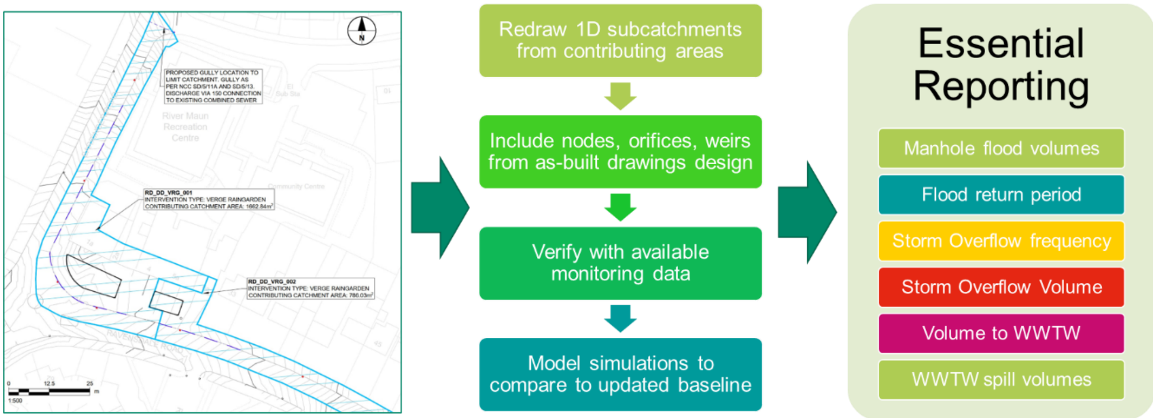

Figure 5 - Interventions Modelling

These SuDS interventions will be modelled as 1D objects in the network. This approach has been taken given that we have considered what would be 'nice to have' versus 'essential' for reporting of catchment performance. We have also considered computer power and current software limitations for other types of catchment model (such as a 1D-2D linked model) which would hinder the development of the Green Recovery Master Scenario by adding additional complexity to the model. The testing phase of our 1D approach for modelling SuDs is just starting, in consultation with University of Liverpool and University of Sheffield, to work together to see how results of monitoring and lab tests can be incorporated into our 1D modelling approach.

1.4 Strand 4 Detention Basins

A significant part of the intervention mix in Mansfield is the inclusion of detention basins. A Detention Basin Strategy was developed using initial modelling outputs along with datasets concerning known flooding history and ICM RUBY scripts. Sites were ranked with GIS, using a Red-Amber-Green framework to prioritise sites for further investigation, and highlight confidence in the supporting data of each site. Following the development of the Detention Basin Strategy, 13 basins across the Mansfield catchment were taken forward to outline and detailed design.

As an example, one of these basins was Linnet Drive Basin, which AECOM were commissioned to undertake detailed design for. The modelling team developed a site-specific model for the basin in InfoDrainage to enable design and construction. AECOM was one of the first consultancies in the partnership to embrace InfoDrainage, which is relatively new modelling software. This basin is now completed on site, and provides 850m^3 of storm water storage, which will be entirely removed from the combined sewer system. This will have direct positive impacts on flooding mechanisms downstream, including both the sewer network and River Maun. Other benefits to residents include increasing social value through additional recreational landscaped space in school areas such as additional picnic benches.

An area that required an alternative approach was the Oaktree suburb of Mansfield. This area is an entirely separated sewer system with repeated severe flooding at the downstream part of the catchment. The idea for this suburb was to ‘slow the flow’ through the catchment, by adding additional storage capacity at key locations. Model testing showed that for a scheme to be successful in eliminating this flood risk, multiple basin sites would need to be considered throughout the suburb. In addition, given that these basins would influence the same network, they would need to be considered together to create a fully optimised and holistic solution. Therefore, an integrated model was required, so Innovyze ICM was selected as the appropriate software for the task. This approach added value, as the design for the three basins could be optimised more efficiently through combined model runs for the sites.

Once detailed design is completed for these models (either ICM or InfoDrainage), these will be incorporated into the Green Recovery Master Scenario, completing the model lifecycle.

1.5 Strand 5: Monitoring and Evaluation

SvT are working with the University of Sheffield, with support from the University of Liverpool and project partners EPG Ltd and Arup, to establish a monitoring programme to better understand the performance of the SuDS interventions.

To date, there have been several activities undertaken onsite, these include:

- Hydraulic Conductivity testing of growing media by Sheffield University
- Rain garden performance testing at Court House by Sheffield University
- Performance testing of permeable paving with EPG Ltd
- Installation of a local rain gauge – critical for performance assessment and model verification
- Rain garden inlet performance testing with Arup and Galliford Try, using a 1:1 scale physical model

Looking ahead, monitoring will be undertaken to understand the performance of each SuDS type. In addition, the monitoring programme will be expanded to take account of benefits for surface water flooding and sewer overflows. Once the monitors are in place, a WIRe[3] PhD student at the University of Sheffield will evaluate monitoring data until 2026. This data will be invaluable to SvT and the industry, as it will provide a long-term record of how SuDS features perform over time and provide vital data to support the verification of how SuDS features are modelled in our ‘Green Recovery Master Scenario’.

1.6 Strand 6: Modelling for Flood & Coastal Erosion Risk Management Grant in Aid Application

Part of OFWAT’s determination for the Mansfield project was that £9million in Partnership funding needed to be found. Therefore, as well as the detailed modelling of SuDS interventions, we have been developing approaches to model SuDS for the project at a strategic scale. This has been done

[3] https://www.cranfield.ac.uk/themes/water/wire-cdt

with a view to preparing an Outline Business Case (OBC) to apply for Environment Agency Flood & Coastal Erosion Risk Management Grant in Aid (FCERM GiA) funding.

For an initial assessment of properties which may benefit from the Scheme (OM2s) We have used our 1D baseline model and reduced the contributing area across the catchment to represent the addition of 58,000m^3 of SuDS storage. This was very high-level given that not all the interventions have been identified in the project, however we based the reduction in contributing area on an assessment of potential opportunity within subcatchments. Once we had generated 1D flood volumes from manholes, we paired these volumes with a 2D mesh to enable an assessment of flood depths for properties.

Once flood depths had been ascertained, the Partnership Funding calculator was used to estimate that the Mansfield scheme could attract up to £3million in FCERM GiA. In addition, we undertook an assessment of the Blue-Green benefits of the scheme, using the Ciria B£st [4]tool. This showed that the benefits to the environment and community far outweighed the flood risk benefits by approximately 70:30. This shows that the scheme is more than just a flood resilience scheme. These initial results did also show initial reductions in storm overflow activations.

4. Conclusion

The project team are on a continuing learning journey. A lot has been pioneered and learned since 2021, however the next 18 months will prove just as exciting and challenging particularly for the modelling and monitoring of the project.

From the data and evidence we have seen to date, we do strongly believe that sustainable solutions are part of the answer to managing flood risk to urban communities and storm water discharges. What we learn on the project will be pertinent to AMP8 and beyond.

[4] https://www.ciria.org/CIRIA/Books/ciriabest.aspx