A collaborative approach to solving pluvial and sewer flooding utilising 2D overland flow modelling to develop a sustainable solution

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Introduction

Clear Environmental Consultants was commissioned by Severn Trent Water Asset Creation to investigate reported sewer flooding in Selly Oak, Birmingham. Customer questionnaires suggested that pluvial runoff from the local cemetery was a significant contributing factor in the cause of the flooding. From consultations with catchment stakeholders it was identified that this area had also been highlighted as an area of significant flood risk by Birmingham City Council as part of their hotspot analysis as part of the Birmingham Surface Water Management Plan. Therefore it was agreed by both parties to work collaboratively in the delivery of a holistic flooding scheme.

This paper focuses on 2D overland flow modelling in InfoWorks ICM, the application of infiltration to the 2D mesh and also the benefits of partnership working between Severn Trent Water (STW) and Birmingham City Council (BCC).

Project Description

Catchment Area Description

The local catchment is located within the Minworth catchment, with an area of 125 hectares and a population of 4226. The sewerage network is mostly partially separate with the foul network discharging to the Bournbrook Trunk sewer and the storm network discharging to the Bourne Brook Watercourse.

Model Upgrade

As part of the Minworth SMP process, this area of the catchment had been upgraded to STW AMP 5 specification. However, in order for the model to be fit-for-use for designing a flooding scheme, the local catchment was upgraded to a WaPUG Type III model with detailed manhole surveys, contributing area survey and flow survey completed.

A total of 11 flow monitors were installed across the local catchment in both the combined and storm systems. Initial assessment of the flow survey data suggested significant slow response flows. Therefore, slow response flows were modelled as part of verification.

2D Modelling

As previously mentioned initial investigations suggested that pluvial runoff was a significant factor in the cause of the flooding. Therefore a 2D model of the area was created in order to fully replicate all flooding mechanisms.

The area experienced significant flooding in September 2008. Following this event, a number of customer questionnaires were returned and included photographs, measures of flood depths and pluvial runoff routes. This information was used to calibrate the 2D model. Unfortunately STW did not have any rain gauges installed in the area at the time of this storm, therefore a nearby EA rain gauge, located at Frankley, was used in order to replicate the storm in September 2008. An event from June 2012 which had no customer flooding reported was also simulated, using more local rain gauges, in order to improve confidence in the model.

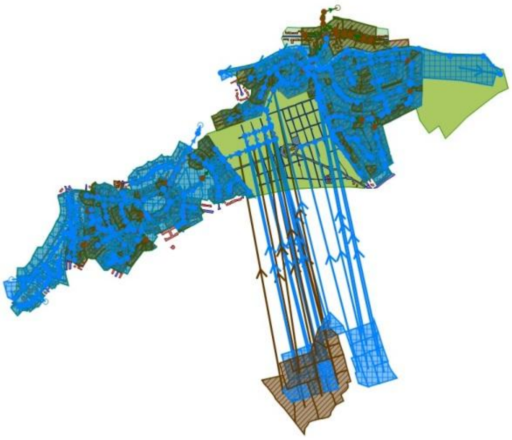

Figure 1 Model Subcatchments

The flooding questionnaires advised that a significant proportion of the flooding was a result of pluvial run-off from the nearby cemetery. Therefore, this was to be replicated using the 2D model. At present it is only possibly to apply rainfall to an entire 2D mesh or outside the subcatchments on a 2D mesh. Therefore, in order to model sewer flows whilst also modelling pluvial flows along the mesh, the subcatchments –have been moved outside of the mesh (as shown by Figure 1) but with values relevant to the cemetery. An initial run was undertaken using the rainfall from the EA rain gauge, simulated to fall directly on to the cemetery.

The results showed a significant over prediction of flood depths in the flooding area compared to the flooding questionnaires. This was because ground infiltration had not been replicated by the model and in effect was allowing 100% fixed runoff from the entire cemetery area. In order to replicate this, infiltration zones were modelled on the cemetery.

The infiltration zones used Horton's infiltration model. Horton's equation states that infiltration starts at a constant rate f_0 and if the rainfall supply exceeds the infiltration capacity, infiltration tends to decrease in an exponential manner with time t. When the soil saturation level reaches a certain value, the rate of infiltration is capped at the rate f_c. (Gupta, 2001)

$$f_t = f_c + (f_0 - f_c e^{-kt})$$

Where fp = the infiltration capacity (depth/time) at some time t
k = a constant representing the rate of decrease in f capacity
fc = a final or equilibrium capacity
f0 = the initial infiltration capacity

To determine the value of the parameters to be used for the infiltration zones the results from borehole surveys were used. The borehole survey contractors stated that "the three boreholes have identified **made ground** ranging from 1.30m to 3.60m below ground level onto **superficial deposits comprising sand and gravel** to depths ranging from 6.70m to 7.90m onto mudstone." This description is similar to the description of Hydraulic Soil Group (HSG) B "Soils with moderate infiltration rates when thoroughly wetted. These consist chiefly of soils that are moderately deep to deep, **moderately well drained to well drained with moderately fine to moderately course textures.** These soils have a moderate rate of water transmission" (United States Department of Agriculture, 1986). The HSGs were related to in order to define values for the parameters to be used for Horton's infiltration model. The table below, which is found in InfoWorks ICM help section, gives values for the parameters for each soil group.

Hydraulic Soil Group	**f_0 (mm/hour)**	**f_c (mm/hour)**	**k (1/hour)**
A	250	25.4	2
B	200	12.7	2
C	125	6.3	2

D	76	2.5	2

Table 1: SCS Soil Parameters (InfoWorks ICM 5.5.5)

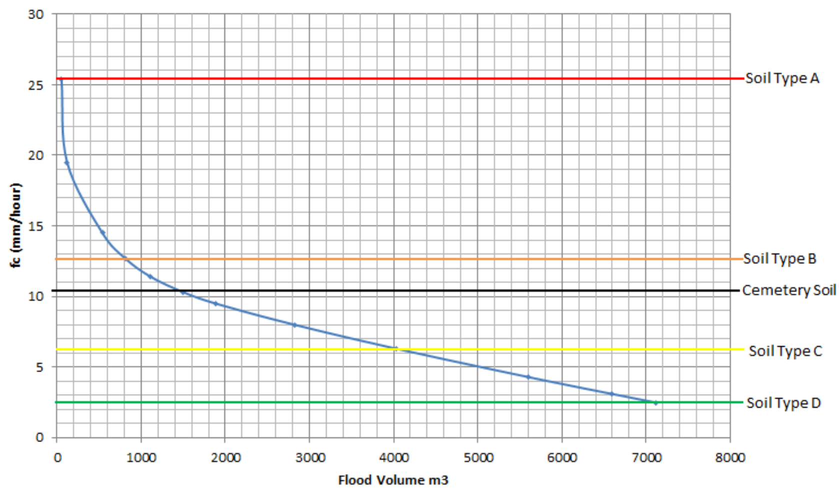

Figure 2 Graph showing the change in flood volume with Horton soil parameters

The problem with assigning single values to the four soil groups is that it is unlikely that the properties of any particular soil will adhere to the values in Table 1. Figure 2 shows how changing the values of the Horton parameters in this model affected the flood volume predicted during the September 2008 event. This graph shows that a small change in the soil parameters can have a significant effect on the run-off from the cemetery. This is due to the large area of the cemetery, a small change in the infiltration rates results in an extensive change in the volume infiltrating across the area of the cemetery. Given that the top layer of soil was made ground fill, It was agreed with the client PM that the values given in the table do not represent the soil properties of the cemetery, and that the soil should be classified somewhere between B and C.

The September 2008 flooding simulation was run on the model with the infiltration zones. The results of this simulation showed a significant under prediction of flood depths compared to the flooding questionnaires. It is believed that the reason for this significant difference is due to the initial conditions of the soil in the cemetery. Closer inspection of the EA rain gauge data showed that there had been constant low intensity rainfall for the previous three weeks. Therefore the simulation was run again with the initial soil water content percentage set to 100%. The results of this simulation gave an improved match to the observed flood depths from the flooding questionnaires.

Proposed Solutions

There are two components to solving this flooding problem; solving the sewer flooding and solving the pluvial flooding. The advantage of this being a collaborative project with STW and BCC is that the two problems could be solved with a combined solution. Historically, STW would have only considered their responsibility to protect properties from the public sewer.

As the flooding is caused by more than one factor, a number of solutions are required and are currently being developed. These are listed below and visualised by Figure 3. As surface water run-off is a significant factor, there is an emphasis on using sustainable drainage systems.

1) Sewer flooding
    a) Upsize the network at the flooding manhole location
    b) Bifurcate flows away from the flood location
2) Pluvial run-off
    a) Improve overland routing within the cemetery toward strategically place gullies
    b) Swales and infiltration trenches to catch run-off from the cemetery

c) Create an infiltration pond in the large open green space north of the cemetery to store run-off from the cemetery, as well as the bifurcated sewer flows, and allow infiltration into the ground.

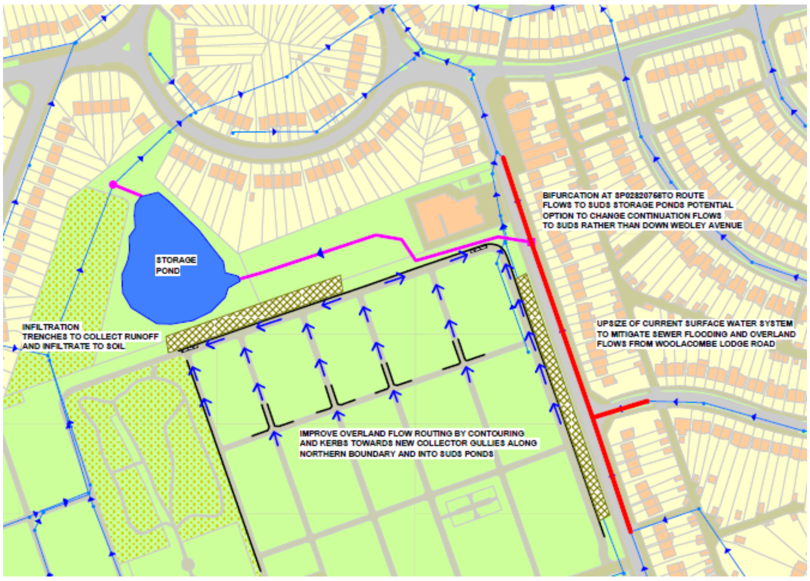

Figure 3 Proposed Solutions

These are likely to be the solutions to the problem, however this is still ongoing work, so a solution is yet to be finalised.

A Collaborative Approach

Historically STW would have only considered their responsibility to protect properties from flood from the public sewer system. However this would have still left the properties at risk of pluvial flooding from the cemetery. Similarly if BCC were to solve the pluvial run-off problem from the cemetery, some properties will still have been affected from the sewer flooding. Therefore, There is a joint responsibility to work together to prevent flood risk independent of its source. Collaborating also prevents repetition of work, if both parties were to solve the two problems separately, the cost would be more expensive for STW and BCC. Reducing the cost is important to ensure that the project is cost beneficial to both parties and that the project is delivered.

Severn Trent have outlined in their business plan to undertake at least 21 collaborative projects in AMP6 of which this is one. It is hoped that this project will be seen as a benchmark to which future collaborative projects will be measured.

Conclusions

- Collaboration between Severn Trent Water and Birmingham City Council enables a solution to be developed for this flooding problem at reduced cost and greater efficiency to both parties.
- The flooding problem is caused by both sewer flooding and pluvial runoff, and therefore a number of solutions are required to fully solve the problem
- Where there is a problem with significant amount of runoff, sustainable drainage systems provide a long term solution which can manage flow rates and are sympathetic to the environment.
- Sewer and overland flow modelling software still has its limitations and caution should be taken when embarking on a project which is likely to use the software's more advanced features.

References

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