Infoworks 2D – a new dimension to flood modelling

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Abstract:

This paper outlines some initial testing undertaken on the new Infoworks CS model which uses a 2D overland flow model instead of traditional 1D flood cones. This paper outlines a novel approach for generating rural runoff on the 2D mesh. In addition, some of the issues associated with linking the 1D and 2D models and the modelling of open channels are discussed.

1 Introduction to the combined 1D 2D Infoworks CS model

Infoworks CS has developed as a 1D model for representing drainage networks. The model is based upon nodes where water may enter and leave the model and links which transfer water between nodes. A multitude of node and link types exist allowing users to effectively model all the features of a drainage network. Flooding in the 1D model has historically been represented by the use of flood cones at manholes. As the water level exceeds the manhole cover level water continues rising into a conical vessel.

These representations of flooding were a simplification which took no account of topography around the manhole which may act to allow over ground flow and re-entry into the 1D system elsewhere.

Conversely 2D modelling packages are able to cope well with flood flow over a surface but cannot model a 1D drainage network. Hence the integration of a 2D model into Infoworks has allowed flooding due to an overwhelmed drainage network to be modelled accurately.

Infoworks 8.5 has the capacity to allow flow in a 1D system to flood into a 2D surface where it will move over the surface and either re-enter the 1D system, flow to the edge of the 2D model or pond in any low areas.

2 Applying Infoworks 2D to a challenging site

HR Wallingford has conducted research into the application of Infoworks 2D in modelling flooding on a site with a particular set of challenges.

The goal was to produce a model which can be used to simulate extreme (10,000 year) through to moderate flood events successfully. This is a tough challenge since typically extreme events would be modelled using a 2D only flow model such as TuFLOW which ignores the detailed hydraulics of pipes and channels. Smaller events would historically be run through an Infoworks 1D pipe model to observe system flooding with less attention to overland flow. This model aims to combine overland flow with a piped system with workable simplifications.

Furthermore the site has a significant upstream rural catchment which produces fluvial flooding and the catchment and site contain open channels, culverts and a piped storm system on the site itself.

In building a model using Infoworks 2D a number of different approaches may be taken in modelling rural runoff, river channels and piped drainage networks. The approach is divided into 3 main themes tackled over the following pages:

- Generation of rural runoff is required to supply realistic flood flows upstream of the site so that the correct flows and timings enter the site.
- River channels will convey a proportion of the total flood flows in the rural catchment hence should be included in the model. The proportion of river flow will decrease with increasing flood severity.
- The site drainage network should be included in the model to correctly simulate the effect of the drainage system during flood events. Again any piped system will have decreasing effect with long return period storms.

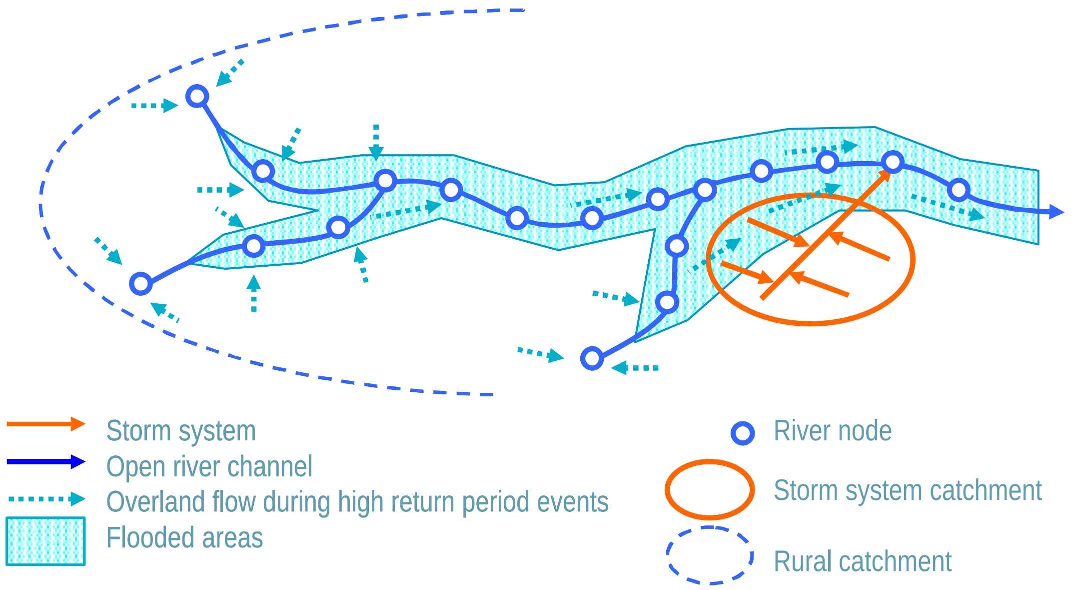


Figure 2.1 - Illustrative plan of the catchment showing the main drainage systems and flooding processes

2.1 Generating rural runoff in the upstream catchment

In a typical Infoworks model runoff from a subcatchment enters the subcatchments node and passes directly into a 1D drainage element. This system will be preserved for the piped storm system on the site itself.

In the upstream catchment runoff has been placed directly onto the 2D mesh. This is then routed by the mesh topography towards the site itself. Placing runoff directly on the mesh is not possible in Infoworks CS 8.5, therefore rainfall must be applied to a 1D subcatchment and arrive at a node.

The method uses a grid of subcatchments with associated 2D nodes covering the rural area. All the nodes are linked to an outfall by sluices which are set to have an opening height of zero, i.e. no water can pass through. This has the effect that any rainfall arriving at the node cannot pass through the sluice and hence floods out onto the 2D mesh where its routing is determined by the topography of the 2D mesh.

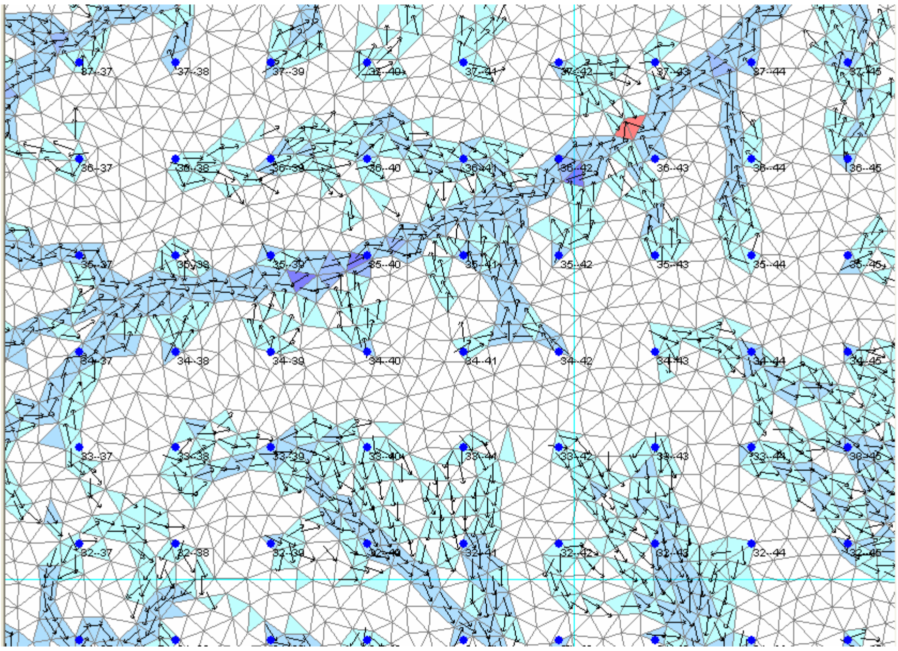


Figure 2.2 – Screenshot of rural runoff on mesh occurring from 1D nodes at the centre of 1ha subcatchments (not shown). Arrows indicate flow direction, colour indicates depth of water.

The sluice invert is set at the manhole ground level. The manhole therefore fills during initialisation and there are no initial rainfall losses in the manhole filling with rainfall before flooding.

2.1.1 Routing of rural runoff in the 2D mesh

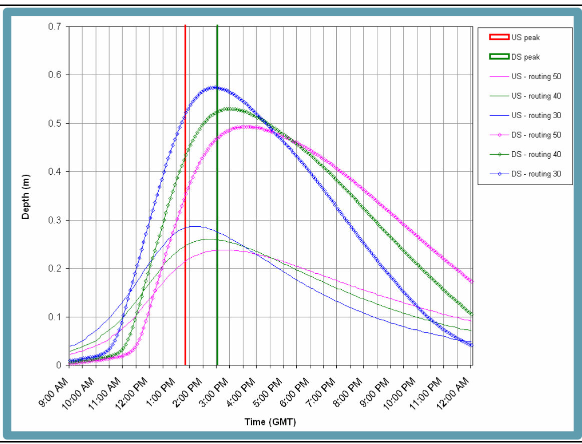
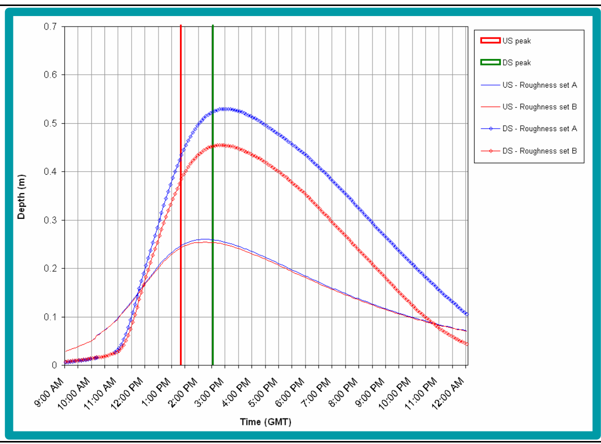
Routing of 2D rural flow

Controlling the delivery runoff and its movement around the mesh is important in calibrating depths and timings against observed events. Two options exist for the calibrating of rural runoff and both are used in this model;

- Routing model and coefficient in 1D subcatchment. This routing coefficient delays the rainfall which arrives at the subcatchment from arriving at the node. Traditionally this has represented the time taken for rainfall to route across roads, roofs and pervious areas into the manhole. Here this will be used to represent the period between rainfall hitting the catchment and surface runoff occurring. This is a valid approach since rainfall is delivered to a single point using IWCS whereas in TuFLOW there is no 1D routing but rainfall is distributed evenly over the grid cells.
- Roughness zones on the 2D mesh. The use of different Manning's N roughness values in different portions of the mesh can be used to simulate different surfaces such as roads, floodplains and crops. These will be used to control the response of the catchment to runoff and hence downstream hydrograph shape.

Calibration of rural runoff in the mesh

The combined use of routing coefficients and roughness zones may be used to ensure that modelled flooding on the site matches observations from calibration events. Routing coefficients can be applied to delay the arrival of peak conditions on the site while roughness zones can be used to ensure that flood depths, velocities and timings are correct as the flood moves across the site.

<table>
<tr><th>Effect of changing routing coefficient in subcatchment</th><th>Effect of changing roughness in mesh</th></tr>
<tr><td>
</td><td>
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<tr><td>Keeping roughness in the model constant and changing the routing value in the rural catchment leads to a faster response and greater peak depths with lower routing values both at the upstream and downstream end of the site</td><td>Keeping routing values constant in the model and roughnesses constant in the rural area but changing the roughnesses on the site itself.
Depth and timing is the same at the upstream end of the site since all parameters kept the same upstream of the site. At the downstream end the effect of raising roughness is to slow down the peak but increase its depth</td></tr>
<tr><td colspan="2">N.B. US = upstream end of site DS = downstream end of site</td></tr>
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2.2 Modelling open channels

The most important concept in understanding how water is transferred from 1D to 2D is that water can only pass vertically between the systems through special nodes, where flooding is set to “2D”. There is no system for transferring water laterally between 1D open channels and 2D mesh and this interface is the most challenging system to represent in Infoworks 8.5.

Figure 2.3 below illustrates flooding of a 1D channel due to the presence of a culvert restriction. Flood water exits through the channel nodes, passing over the culvert in the 2D mesh.

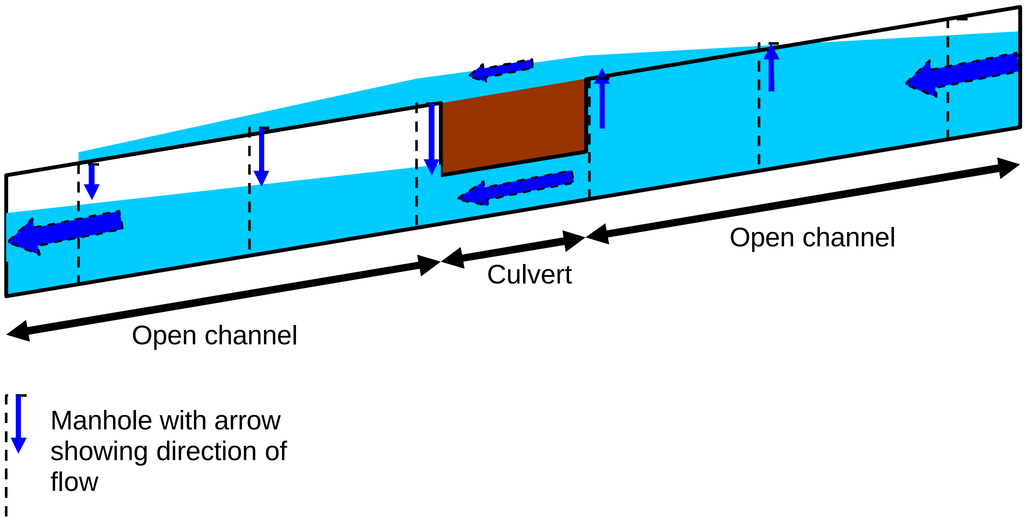

Figure 2.3 - Illustrative explanation of the 2D/1D interface

The main problem presented by the incorporation of a 2D mesh is the modelling of open channel flow. Both 1D links and nodes and a 2D mesh surface may be used to represent open channels and both have distinct advantages and disadvantages as described in the table below.

	1D channel model with overlying 2D mesh to represent surrounding area	**2D mesh used for channel and surrounding area**
1	Computationally faster than 2D mesh channel for large volumes	Computationally slow since large volumes are required to pass through small mesh triangles used to represent channels
2	1D channels may be built with a high degree of survey accuracy	2D channel resolution is at the mercy of the quality of the ground model and the mesh triangle sizes used
3	Culverts may be modelled in 1D and associated flooding allowed to pass into surrounding 2D mesh	Culverts must be modelled in 1D, this requires transfer of channel flow from 2D to 1D, difficult in practice
4	Flow into the 1D channel can only occur at 2D flood nodes. Nodes must be closely spaced to ensure all 2D surface flow is picked up flowing back into 1D channel.	The 2D channel is linked to the surrounding mesh allowing water to pass in and out of the channel as required hydraulically

Open channels in the upstream catchment and more importantly adjacent to the site will convey a proportion of flood flows. This proportion will be less significant with large storms. However, with lower return periods accuracy in modelling channel conveyance becomes more important.

Two approaches may be taken to modelling channels. The first is modelling them in the 2D mesh. This approach was not adopted since the very fine mesh triangles required and low resolution of the DTM relative to channel size would result in a very long runtime and poor representation of the channel profile. Furthermore, the 2D engine is designed for flow over broad, shallow cross-sections rather than typical channels.

The adopted approach is the use of a 1D channel extending from downstream of the site up to main tributaries above the site. This channel can be modelled accurately based on survey data and readily updated. The channel is modelled using 2D nodes so that it can pick up water passing over the 2D mesh and convey it in the channel. During a flood event the channel will quickly become full and flow will then continue in the floodplain on the 2D mesh.
Culverts and bridges which represent restrictions in flow can be modelled accurately in 1D. Any flow which cannot pass through a structure will be flooded from the upstream 2D manhole in the channel.

2.2.1 Considerations:

Filling and returning flow to a 1D channel
The use of 1D channels presents a problem in that flow can only pass in and out of the channel at nodes. Therefore when the channel meets a restriction flow will pass into the 2D. It is important to ensure that the correct volume returns to the channel after the restriction. This is dependant on the mesh topography in the area. The most effectively way of ensuring realistic returns is the placement of sufficient 2D manholes in the channel downstream.

At the upstream end of the 1D channel sufficient manholes must be placed in series to ensure that the channel is in equilibrium with the 2D mesh by the site it reaches the site where conveyance volumes become important.

2.3 Modelling the site drainage system

Infoworks CS has the capacity to integrate its 2D surface flow model with a standard 1D drainage network. This in turn improves the accuracy of flooding from low return period storms of which the existing drainage system conveys a significant proportion of total flood flows.

The drainage system is modelled as a standard 1D piped storm system with subcatchments draining to the drainage network. Manholes are be set as 2D to allow flooding onto the 2D over the site.

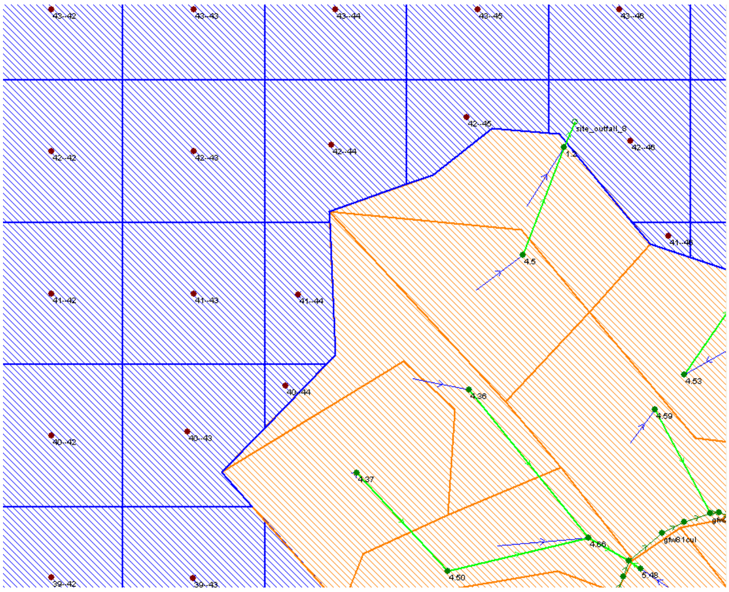

Figure 2.4 - Drainage system modelled using traditional 1D piped system (orange) surrounded by rural runoff subcatchments (blue). The mesh triangles are not shown here.

3 Conclusion

This paper has outlined an approach to generating rural runoff using a novel application of the new 2D surface flow model in Infoworks CS. The paper also comments on some of the issues and simplifications surrounding the modelling of open channels required for the most suitable modelling of the test site catchment. The initial testing which went into the development of this approach has proved extremely useful in understanding the capabilities of this cutting edge software.
The approach represents a very considerable improvement on the previous 1D only Infoworks and gives a much greater degree of flexibility than other 2D modelling packages.