



2D flood modeling in Scotland

Flood defence schemes have become very topical in the UK. But flood defence can itself contribute to the severity of flooding. So drainage systems become vital. Juan Gutierrez Andres presents here a drainage modeling study, showing the superiority of 2D models.

The last summer flooding came at a time of increasing warnings about the future frequency and intensity of weather and climate-related hazards, and revealed a range of critical vulnerabilities to the public such as the effects of sewer surcharges, utility failure and flood surges, each of which produced significant concern.

In some cases, flood defences will modify the natural existing drainage of the catchments. This means it might be necessary to find solutions to flooding problems that might be caused by the flood defences themselves and that have never occurred before. This was the case in Brechin, on the east coast of Scotland.

Following severe flooding on the River South Esk in November 2002, a flood defence scheme along the north bank of the river was proposed by Angus Council. HR Wallingford was commissioned to carry out a drainage modelling study to estimate pumping station requirements to prevent flooding behind the floodwalls and bunds during periods of high river water levels.

1D overland flow paths and flood mapping were initially used to present the areas that would be affected by the flooding. Presenting at the Wallingford Software International User Conference, Juan Gutierrez Andres, of HR Wallingford's Water Management Group, explained: "One issue was the potential to cause new drainage problems if the town were to be isolated from its natural drainage route."

The proposed solution: the theory

There are two types of models that can be considered: 1D and 2D.

A 1D model gives a good approximation of the flooding process and locations, although the model process and construction is lengthy and based on a number of simplifying assumptions. Flood cones and links do not always accurately

represent the storage on the catchment surface - for example the definition of the flood cone shapes is never satisfactory in representing flood depth-extent relationships and requires a great deal of effort to get these as accurate as possible.

The 2D model facility is a much more flexible approach, although the requirement of data such as walls, buildings and detailed ground models is significant. InfoWorks CS 2D is very quick to build and fully integrated with the below-ground system. It gives a certain degree of confidence in the definition and identification of the overland flow paths not provided by the 1D approach.

The 2D model: unexpected results

The box contains a brief case study describing how the 1D model was built.

In the new model the 1D overland links were removed, as were the mapping objects such as the flood compartments and points. A GIS platform was used to pre-process and clean buildings layers as polygons that would be defining voids in the meshing process.

A 2D mesh was generated, which included high definition roughness zones to accurately identify road surfaces, and the new InfoWorks 2D model was then run using the worst anticipated conditions to see how the area flooded.

The results were unexpected. The modelers were puzzled initially as more or less the same flooding areas were identified, but the floodwaters were deeper than the 1D model had predicted - it had always been assumed that because the 1D model was a simplified representation of the real situation that the depths in the artificial flood cones created by the 1D model would be greater than in reality.

The team began to try to understand the discrepancy by analyzing the

original 1D model results in more detail. Effectively overland flows had been represented by creating a surface network on top of the pipe network – a series of wide, shallow channels to represent roads in parallel to the pipe network, in which water could flow. In areas where no roads existed, such as parks, depressions or other unused areas, a ponding effect was represented using modelling tools as storage nodes.

A connection between the roads and storage nodes was used to represent the topography underneath, so that the areas could fill with different volumes of water. This difficult and complex process is not needed in the 2D model, which does this automatically – the hydraulics of the whole overland process are completely changed.

The next step was to define buildings within the new 2D mesh, something that would have been complicated, if not impossible, in a 1D model. With the buildings sited within the model, deeper levels of flooding were generated because there was less room for the floodwaters, but still lower flooding was predicted than in the original 1D model. The model was representing a 100-year return period rainfall of 18 hour duration, so why was there such a large difference?

Superiority of 2D modeling: in theory and practice

The answer became clear from examining the two sets of model results more closely. The two apparently independent areas of flooding were in reality linked in some circumstances. They had not been connected in the 1D model, but the 2D model clearly identified an additional flow route. In most storm scenarios the two areas of flooding remained separate, but during extreme events a flood path was created between the buildings and the two areas were thus linked, reducing flood depths in the higher area and increasing them in the lower one. In addition, the 1D overland network was providing unrealistic additional storage.

The conclusion drawn was that it is critical to have a good understanding of the catchment. In a 1D model, it is necessary to look carefully at the ground model - at the ponding areas and roads, to find where overland flows occur.

1D InfoWorks CS model – Case Study

The team had to make certain assumptions to undertake the investigation. The existing 1D InfoWorks CS model did not include many factors needed for the flood risk analysis project. The work needed a better tool than flood cones Mr Gutierrez explained: "We needed something more dynamic - flood cones do not mimic real life natural flows." The team considered using an external 2D model but eventually built a 1D model using InfoWorks CS.

The project involved identifying areas that could flood and defining the flood route. The ground model was very important. The user, working from a digital ground model or GIS map layers, needed to define the overland flood paths. An existing detailed survey of the river flood plain was also available that covered the particular area of interest, so although the area outside the flood plain remained simplified, within it good definition was obtained.

The model identified two independent areas of flooding that would have required pumping at extremely high rates and was not the solution. Instead, the consultancy looked at different combinations of pump rates and storage volumes but this was not a feasible option either, because of the lack of space to build a storage tank and the high gradient of the area. An additional solution was tested, sealing the downstream end of the main culverted streams of the catchment. This solution provides enough head to discharge overland flows regardless of the levels in the River South Esk, and therefore reduces pumping rates significantly and avoids mixing water from the combined system with the storm system.

It was found that the model was very responsive to the assumptions that were made. "We had to be sure the assumptions were true," Mr Gutierrez explained and was recommended that additional data, through further survey work, would provide greater confidence in the model results". It was at this point that the 2D solution became available.

"A 1D model can be used to give more or less a good answer but you have to be careful," Mr Gutierrez noted. "A 1D pipe model can be integrated with the above-ground system but you need to understand flood paths and flooding areas." Important issues include the definition of flood cones, storage volumes in overland flood links and flow directions at complicated road junctions. This detailed understanding of the catchment is not quite so necessary with a 2D model, which solves these problems automatically for the entire surface.

Conclusions

The main conclusion of the comparison between 1D and 2D was consistently a greater depth of prediction in the 2D. This can be partially explained by the reasons given above, but it is believed that 2D allows a greater flood volume than 1D modeling, possibly due to the two methods being governed by different equations linking the surface and below ground systems.

Both simulations were stable and consequently, there was no creation of volumes due to

instability problems. 2D modeling is believed to be more realistic with fewer assumptions than 1D, and in addition the definition of the flood extent is more conservative.

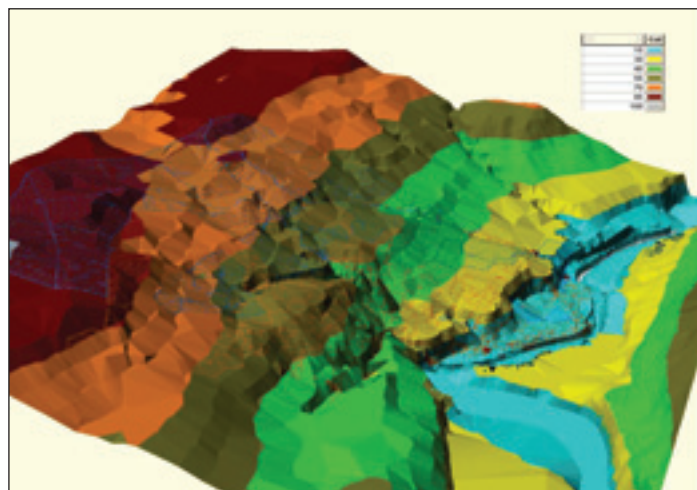
The 2D model is much better, provides a great deal more information and is very user-friendly. Once the data is ready, it is quick to build, Mr Gutierrez explained. To fully integrate the overland flows with the below ground system communication between the 2D and 1D models is of paramount importance. InfoWorks 2D provides this link and therefore gives a good degree of confidence about the overland flow paths.

Nonetheless, surface modelling will always have a higher degree of uncertainty than below ground modelling, where it is possible to calibrate model prediction with observed results. Historical flooding records, skilled modelers and a good understanding of the catchment will be essential in using InfoWorks CS 2D in an urban environment.

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Layout of proposed flood defences



Brechin digital ground model (3D view)