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The use of 2D surface flow model to produce pluvial flood maps

Due to climate change, precipitation will increase and heavy rain events are assumed to become more intense (climateguide.fi). Because of that it's important to pay more attention to pluvial flood risk management. According to the flood risk legislation (620/2010), it's the responsibility of the municipalities. They have to review the preliminary flood risk assessment by the end of 2018. SYKE has produced a Preliminary Pluvial Flood Map to help municipalities to assess the risk. So far about 180 municipalities and 15 rescues services have registered to use a pluvial flood map service published in March 2018. It shows the potential flood hazard areas caused by heavy rain for two rain events.

The Preliminary Pluvial Flood Map was produced for almost all urban and suburban areas in Finland by using a numerical surface flow model which utilize GPU-computing. The most important input data for the model was KM2 2x2 m digital elevation model (DEM) produced by National Land Survey of Finland (NLS) but also other GIS-data, for example land use and imperviousness degree, was used: Corine 2012 land use to define roughness coefficient (Manning-n) and Soil Sealing (EEA) with Corine to define infiltration.

A semi-automated ArcGIS model was used to prepare the original KM2 DEM for surface flow modelling. Firstly, culverts were automatically burned at the crossings of the streams and roads (NLS topographic database and Digiroad). The diameter was based on the culvert registry or the size of the stream. The flow equations were modified at the locations of the culverts so that the diameter was taken into account correctly. Secondly, the ground elevations at the locations of the buildings were raised higher level in order to avoid the flow through them. Despite the modifications, there are still a lot of errors due to missing culverts. Because of that municipalities have had an opportunity to correct the culvert data in the map service. So far the model has been run again and the flood maps updated three times based on the corrections.

Flood hazard areas were modelled using two different rain events: 4-hour event with the probability of 1/100a and a modified 4-hour event which was based on the observed rain event in Pori 2007. The 1/100a precipitation values for one and three hours rain events quantified by Finnish Meteorological Institute were used to define the modelled 1/100a event. Therefore, it can be considered as 1/100a rain event also for 1-hour and 3-hours precipitation. The maximum water depth and flow velocity during the whole computation period in each cell were stored to be used for the production of the flood maps.

The production of the Preliminary Pluvial Flood Maps was done in 6x6 km map-sheet divisions (UTM10). A buffer area of 1 km was added around each sheet to be able to interpolate the results at the border of different sheets. For that reason the calculation area for each sheet was 8x8 km. Totally Preliminary Pluvial Flood Maps were produced for areas of 50 000 km^2 (1400 6 x 6 km UTM10 map sheets). The time dependent precipitation intensity was assumed to be same for the whole calculation area and same precipitation values were also used in different parts of Finland. The area was assumed to be flooded if the calculated maximum depth in a cell was more than 0,1 m.

The flow simulation in the model is based on an algorithm presented by Bates (Bates et.al. 2010. A simple inertial formulation of the shallow water equations for efficient two dimensional flood inundation modelling). Because of the relatively small cell size (2x2 m) a small time step had to be used. At the beginning of the calculation it was 1 second and it was decreased during the calculation depending of the calculated maximum depth. The Froude number in the model was limited to be 0,95 or lower, so super critical flow couldn't be modelled. That limitation was not assumed to be crucial. A GPU-version of the solution algorithm using CUDA C programming language was developed to produce the flood maps. A relatively inexpensive computer with two GeForce GTX 1080 GPUs (2560 cuda cores) was used. For one GPU it took about 15 to 20 minutes to calculate one precipitation scenario for one UTM10-sheet.

More information: www.ymparisto.fi/hulevesitulvat.