National Hydrology Seminar 2007: GIS in Hydrology

Application of Remote Sensing (Digital Terrain Models) in Flood Risk Assessments

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Abstract:
The manipulation and adjustment of Digital Terrain Models (DTMs) such as LiDAR allows scope for a wide variety of desk based studies to assist modelling and data applications for Flood Risk Assessments. These techniques are suitable for use across a number of different scales of study from Strategic Flood Risk Assessments and Catchment Flood Management Plans to site specific Flood Risk Assessments.

This paper will explore several of these techniques in more detail focusing on the change in risk due to factors such as development and climate change as well as the flood risks to people through hazard mapping.

The following techniques will be presented in more detail with case studies provided to illustrate each example and provide a level of context:

1. Determining existing flood plain volumes prior to development and the associated potential loss in storage volume from the development of new buildings and any required land raising measures to comply with legislation.

2. Identifying the effect of a standard percentage flow increase due to climate change such as that outlined in *Planning Policy Statement 25: Development and Flood Risk*, on existing lateral flood extents in areas prone to existing flooding without using detailed 1D or 2D modelling.

3. The use of 2D modelling outputs for hazard mapping and determining risks to people through the application of a velocity/depth matrix as outlined in the *Defra R&D Guidance: Flood Risks to People: Phase 2 FD2321/TR2.* This results in easily interpreted visual guidance categories outlining the potential risks.

Royal Haskoning have successfully developed and applied the above techniques to support existing strategic and more detailed hydraulic model based studies. This enables the efficient delivery of solutions that are fit for purpose providing a valuable insight into flood risk both now and in the future.

Determination of flood plain volumes:

Planning Policy Statement 25 (PPS25):Development and Flood Risk recommends that if flood plain volumes are removed from one area through development, space must be allowed for in another area to ensure that there is not a net reduction in flood storage capacity, which may affect this site or other sites downstream. Assessment of the loss of flood plain volume due to development is therefore a key aspect in determining how much storage volume should be provided for mitigation and attenuation options for flood risk management.

Using the outputs from either a 1D or 2D hydraulic model enables the maximum water elevation for a particular return period or flow to be determined. The model needs to be built to take account of out of bank flow, and 1D models such as ISIS or HEC-RAS should include storage areas or reservoirs to allow overland flow to be simulated. These water levels are then used to flood a Digital Terrain Model (DTM) of the area to be developed, to assess the extent of flooding that may occur.

For 1D models, the maximum water surface elevations at cross sections in the model are used to create an interpolated layer covering the channel extents to just beyond the top of bank locations. The creation of a Triangulated Irregular Network (TIN) creates a continuous surface along the extents of the modelled channel, representative of the changes in elevation along the longitudinal profile of the hydraulic model. This TIN is then converted to a grid to allow it to be mosaiced along with a grid of the maximum water surface from the reservoirs or storage areas. This results in a grid based dataset of maximum water elevation covering the whole study area.

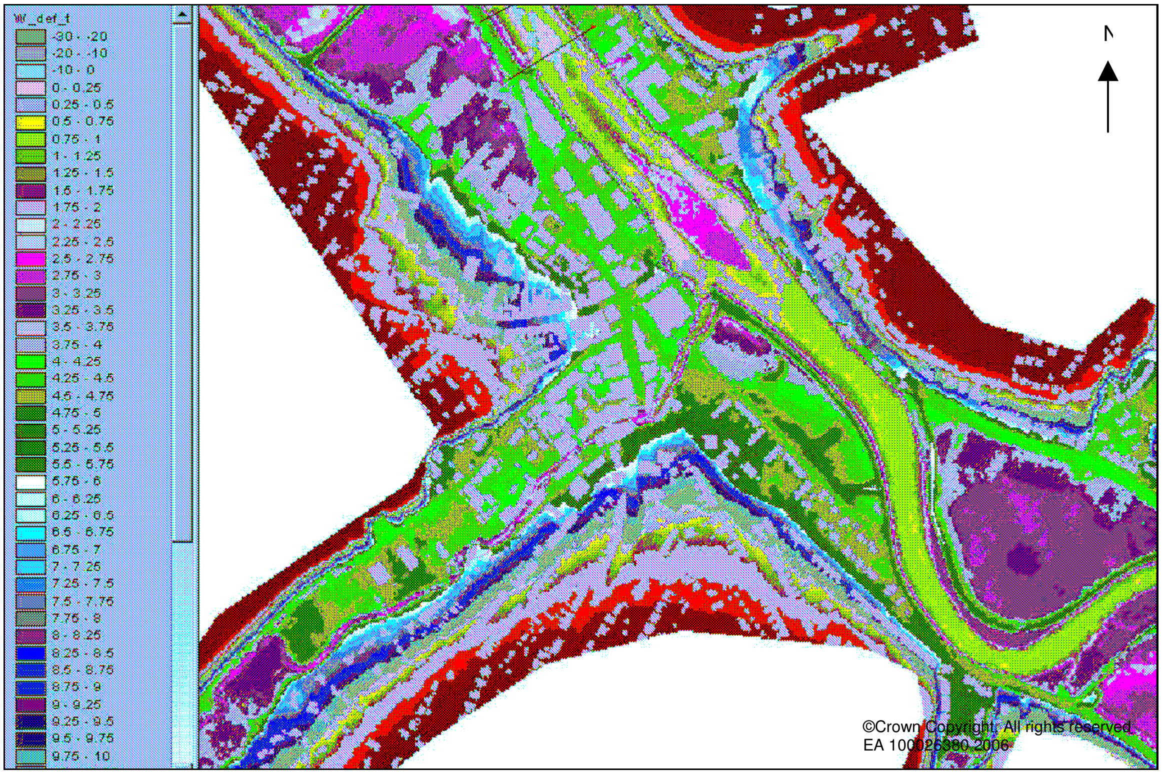
For 2D models the grid output of water depth can be used as long as the resolution cell size is adjusted to match the cell size of the underlying DTM.

The DTM data used for flood plain volume analysis is generally Light Detection and Ranging (LiDAR) data which is available from the Environment Agency and provides extensive coverage across England and Wales. Grid resolution varies from 0.5m to 2m with a RMS (Route Mean Square) vertical accuracy of +/- 0.15m. Both bare earth (DTM) models and Digital Elevation Models (DEMs) are available with the DEM taking account of building heights, structures and vegetation.

For flood plain assessment a bare earth DTM is used with the buildings added back in. This prevents misleading results through the presence of trees and other large areas of vegetation that may be present in the DEM potentially distorting the flooded extents but allows for the presence of flow rates around buildings to be accounted for. A buildings polygon dataset such as OS MasterMap is attributed with suitable building heights relative to the surrounding topography before being converted to a grid and combined with the underlying DTM grid. This creates a ‘building relief’ dataset as shown in Figure 1. The proposed area of development can also be added to the buildings polygon dataset using information from planning documents and Master Plans to build a 3D projection of the built environment in the future. Adapted DTM datasets can be created for both pre and post development works.

The area of interest is then ‘flooded’ with the grid of maximum water elevations by subtracting the water levels from the adjusted DTM dataset. The positive values from the resulting grid are the areas where flooding will potentially occur.

Figure 1: Buildings dataset stamped onto LiDAR DTM



By making an assessment of the fill volume of an area using the maximum water elevation grid before and after adjustment of the underlying DTM for increased development the difference due to post development building volume can be calculated. This area is normally the storage area or reservoir held within the 1D model. This allows the potential loss of flood plain volume to be calculated. These calculations can be carried out using a tool such as Profile Extractor.

Connectivity within the DTM is assumed as walls and barriers are not taken account of unless they are in the DTM as earth banks or specifically added to the data through the adjustment of the DTM.

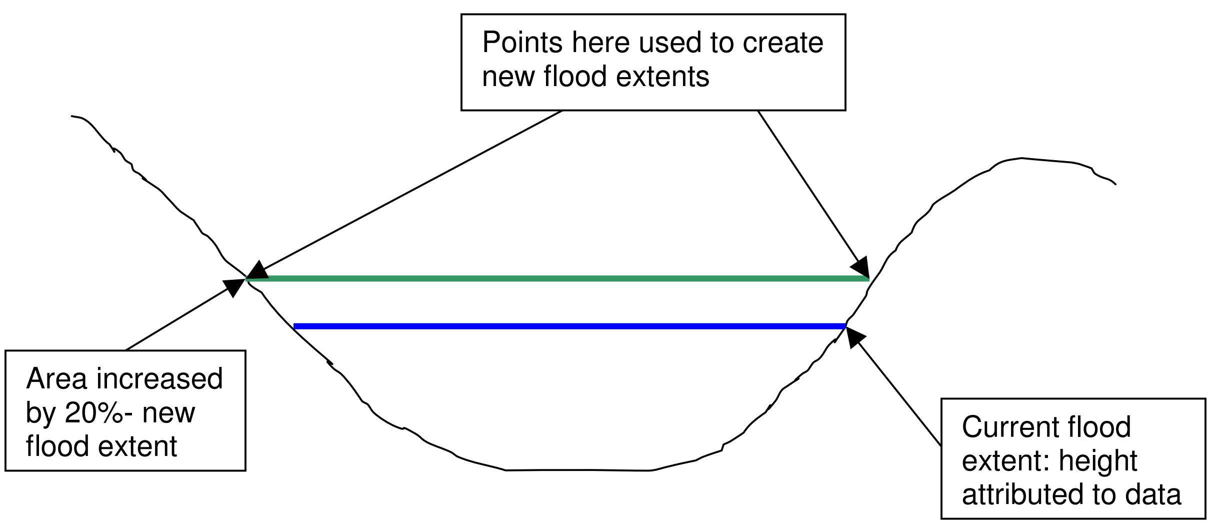
Effects of a standard percentage flow increase on lateral flood extents:

The possible impacts of climate change on fluvial flows are still being investigated. The latest guidance given by Defra *Flood and Coastal Defence Appraisal Guidance FCDPAG3 Economic Appraisal: Supplementary Note to Operating Authorities- Climate Change Impacts*, October 2006 and contained within PPS25 suggests dealing with climate change by increasing the magnitude of peak flows by up to 20% from 2025 to 2115. Assuming river flows are increased by 20% as a result of climate change, new future fluvial flood extents based on existing current scenario flood data can be created based on LiDAR DTM data as part of a broad scale methodology. This can be done without detailed hydraulic modelling and is therefore suited to strategic level studies. An example of where we have used this method is the Tamar Catchment Flood Management Plan (CFMP).

The locations to investigate were identified through analysis of known flooding hotspots (using the Flood Reconnaissance Information System (FRIS), an Environment Agency dataset). The lateral increases in each of the areas affected by a 1% annual probability flood in each flooding hotspot were calculated using Flood Zone 3 extents. This is known as the lateral increase in flood extent expected due to climate change.

Cross sections were created as a polyline dataset for the extent to be mapped, perpendicular to the river channel and at 50-100m spacing. These cross sections were then attributed with the average height above sea level for the meeting point between cross section and current flood extent. This was not always equal on the right and left bank so an average was taken for each cross section to provide the mean flood extent water elevation level at each cross section as indicated in Figure 2. The flow increase was then determined based on the nature of the study i.e. 10%, 20% or 30%.

Figure 2: use of flood extents to determine water elevations



The cross sectional area (CSA) for the flood extent level average (at each cross section) is calculated using Profile Extractor for each of the cross sections along the channel length.

This CSA can then be increased by the required percentage flow increase to determine a new water elevation level for the increased flows. By attributing each cross section with the projected future water level a TIN can be created for these water surface elevations to create a continuous surface along the extents of the channel.

The area was then 'flooded' with the grid of maximum water elevations by subtracting the water levels from the adjusted DTM dataset as before. The positive values from the resulting grid are the areas where flooding will potentially occur. An example of these extents is given in Figure 3.

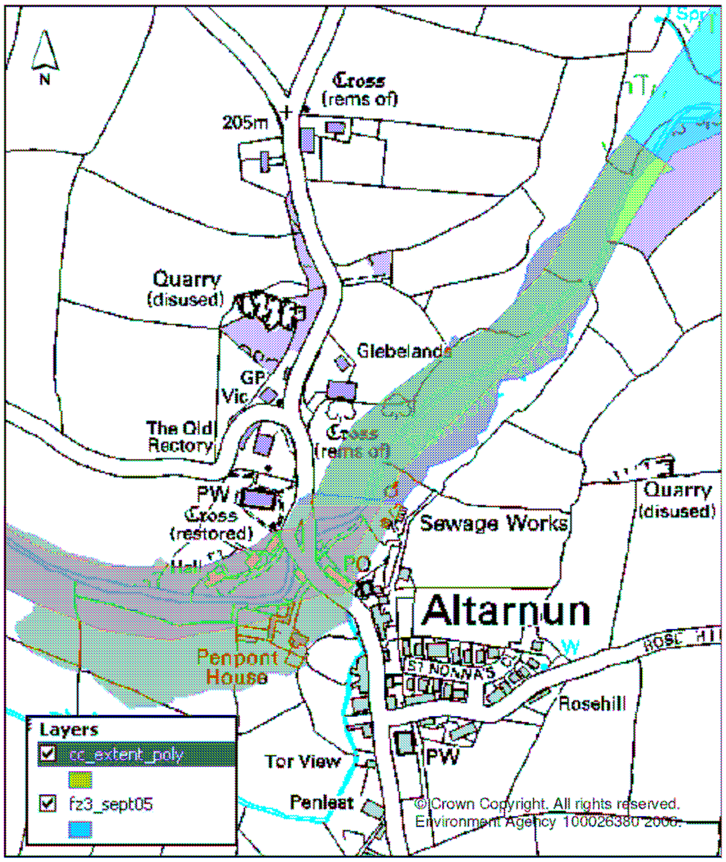


Figure 3:
Climate change extents for Altarnun, Tamar catchment for 1.0% annual probability flood. The orange area represents the climate change scenario.

By digitising around these flooded areas a new lateral flood extent due to climate change can be created. A visual check followed by manual adjustment to the new flood extents should be carried out to verify and look for any situations where the new flood extent may be below the original flood extent due to the horizontal differences between left and right banks.

2D modelling outputs for hazard mapping

Using 2D hydraulic modelling software, flood events of different magnitudes can be modelled in order to find maximum flood extents and estimates of likely depths and velocity of moving floodwater. This can be used to create Flood Hazard mapping to provide an overview of flood risk to people within the study area. Presenting flood risk in this way means that the impact of flooding can be easily understood. Flood Hazard mapping can be used to assess the flood risk at specific sites of existing and potential development in order to inform the allocation of development sites within the Local Development Framework (LDF) process. This enables us to define the possible access/egress routes available under flood conditions, the consequences of infilling flood plain and viable mitigation measures and provide a general overview on the safety of the site for redevelopment based on flood risk.

The degree of hazard that floodwaters present to people (and to vehicles and property) is a function of both velocity and depth. The hazard rating used in our work is set out in the report *Flood Risk Assessment Guidance for New Development Phase 2, Framework and Guidance for Assessing and Managing Flood Risk For New Development (FD2320/TR2) HR Wallingford (October 2005).* The velocity/depth matrix used as part of this study is given in table 1.

Table 1: Flood Hazard Matrix*

Velocity (m/s)	**Depth (m)**											
	0.05	**0.10**	**0.20**	**0.30**	**0.40**	**0.50**	**0.60**	**0.80**	**1.00**	**1.50**	**2.00**	**2.50**
0.00												
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*The green colour code is not specified in FD2320/TR2 and has been employed in order to show maximum flood extent

Grids of depth and velocity can be directly output from the model or can be created from a point dataset of x,y,z values using a grid interpolation methodology. This information will be created from the underlying DTM used within the model. By analysing the combinations of outputs of grids of depth and velocity from a 2D model the hazard rating for any location within the study area can be determined. This allows hazard ratings within different areas to be easily compared.

Hazards are generally categorised into the following four degrees of hazard: low, moderate, significant and extreme. The colours in Table 1 correspond to the degree of flood hazard in

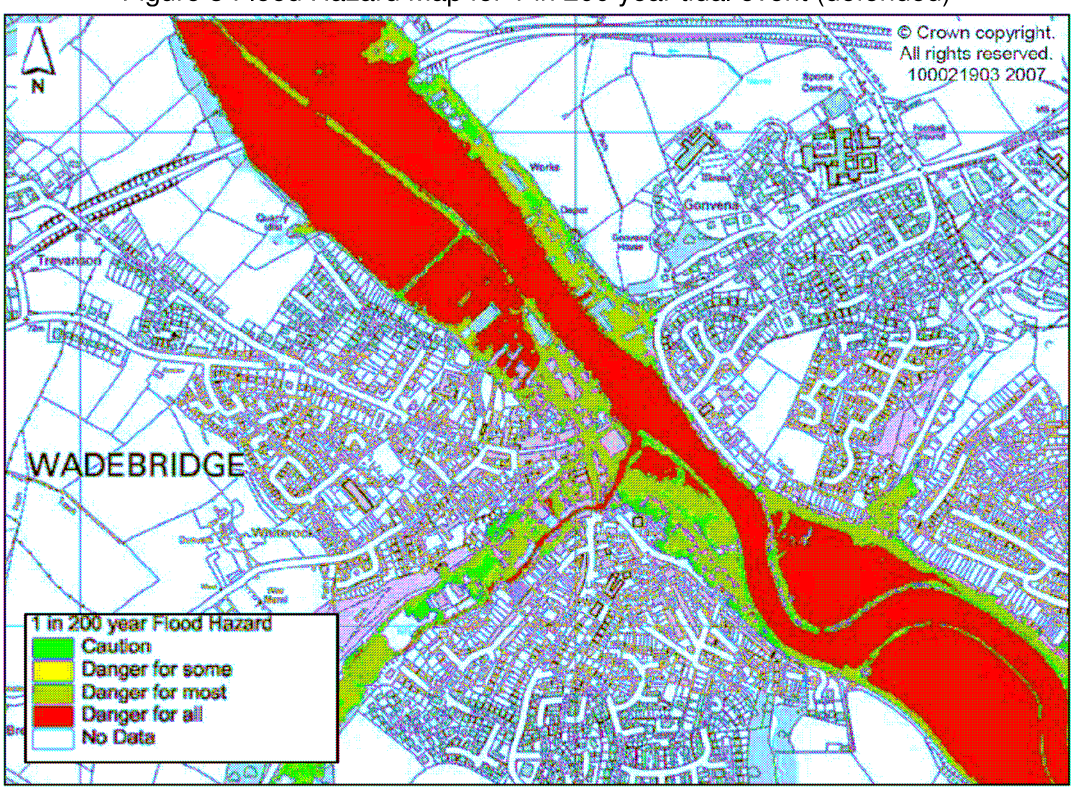
Table 2 and are based on the increasing severity of the combination of depth and velocity and its potential severity of risk. As a simplified explanation danger classifications are based on the groups of people that should be considered as falling into these danger classifications. These groups of people are given in the description column of table 2.

Table 2: Description of Hazard categories

Degree of flood hazard	Colour Code	Description
Low		**Caution**
Moderate		**Danger for Some** Includes children, the elderly, and the infirm
Significant		**Danger for most** Includes the general public
Extreme		**Danger for All** Includes the emergency services

We have created a series of SQL (Standard Query Language) queries that assess both data sets in order to categorise the flood risk in terms of Caution, Danger for Some, Danger for Most and Danger for All. The hazard becomes increasingly dangerous to people as depths and velocity increase. These queries are applied to data points from grids of velocity and depth and attributed with the appropriate hazard matrix rating. This enables us to build up a hazard map across the study area which can be given a thematic legend to represent these risks spatially as shown in Figure 3.

Figure 3 Flood Hazard Map for 1 in 200 year tidal event (defended)



Further queries and analysis can be carried out using these thematic maps such as the percentage of new development within an extreme flood risk area. This mapping can also be used to usefully inform the EA's flood warning service and local emergency planning arrangements for potential development sites

Conclusions

This paper whilst by no means a definitive guide to the use of Remote Sensing within Flood Risk Assessments, provides an outline methodology for three key areas at this level of study. A significant amount of assessment can be carried out as part of a desk based study to inform the FRA process and provide key information as to the potential effect of development on the existing flood plain, the impact of flow increases through climate change and changes in land use practice as well as the potential risk to people particularly vulnerable groups in society. This enables all levels of the FRA process, as set out in PPS25 to provide a more informed solution to the developer, the Environment Agency and the local planning authority. This can provide significant benefits to the amount of time and resources required to deliver an FRA whether it has been carried out at the Regional, Strategic or Site-specific level.