HAZARD NOTE

bushfire&natural HAZARDSCRC

ISSUE 52 OCTOBER 2018

TOPICS IN THIS EDITION | FORECASTING | FLOOD | MODELLING

NEW FLOOD MODEL TAKES RAPID, REGIONAL APPROACH

ABOUT THIS PROJECT

The *Using realistic disaster scenario analysis to understand natural hazard impacts and emergency management requirements* project is part of the Scenarios and Loss Analysis cluster. By analysing past emergencies to fully understand their impacts, this project has helped emergency managers plan for natural hazards that might have a similar impact in the future. It is now in its utilisation phase.

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SUMMARY

A rapid, regional-scale modelling approach to estimating flood hazard and exposure in Australia has been developed. Its application will help overcome a national void in vital information about flood risk. At present, this information is largely confined to areas where detailed flood modelling has already been undertaken and is constrained by the computational limitations of hydraulic-based models when operating over large spatial scales. This fine-resolution modelling depends on good quality baseline data, which is lacking in many rural areas. The model is based on a practical, reduced-physics approach, with nationally available datasets that estimate flood risk over large areas. This approach relies on less detailed but more critically important physical calculations, and suits less complex floods. The model is also innovative in the way it couples existing modelling components and tailors them to the needs of emergency managers. The model could be applied to emergency planning and resource allocation on a national scale.

Above: THIS RESEARCH HAS DEVELOPED A NEW MODEL FOR ESTIMATING FLOOD RISK, AND TESTED IT BY RUNNING A CASE STUDY ON A 1986 FLOOD IN THE HAWKSBURY-NEPEAN VALLEY. PHOTO: NSW STATE EMERGENCY SERVICE.

CONTEXT

This project used a reduced-physics approach to investigate how exposure to river flooding in Australia can be estimated rapidly and over large spatial scales. Its findings support emergency response and planning requirements.

BACKGROUND

The impact of severe rainfall is often measured in terms of flood risk at the peak of the storm. Less attention is given to how flooding evolves during a storm. Asymmetric or staggered flooding across a wide region can pose a significant challenge to emergency services, and local-scale (albeit high resolution) flood modelling provides a limited platform for preparedness in this regard.

To address this, this project has developed a regional-scale modelling method that can predict the time-varying exposure to flooding over large areas, while still accounting for local variations in catchment and river channel properties. It used the Hawkesbury-Nepean catchment in western Sydney as a case study to test the model. This area is well studied in terms of flood risk; it is data-rich, flood-prone and constitutes one of the largest coastal catchments in New South Wales, taking in roughly 20,000 square kilometres, with approximately 70,000 people living in flood-prone areas (NSW Office of Water, 2014). This made it an ideal test ground to develop the model.

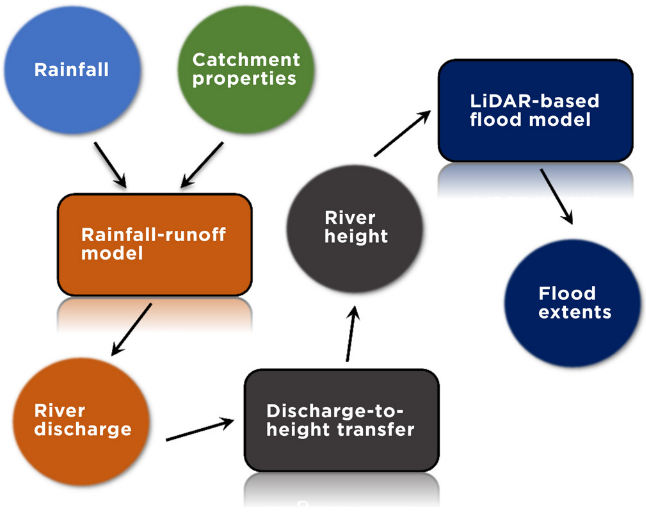


Figure 1: FLOW CHART ILLUSTRATING MODELLING APPROACH.

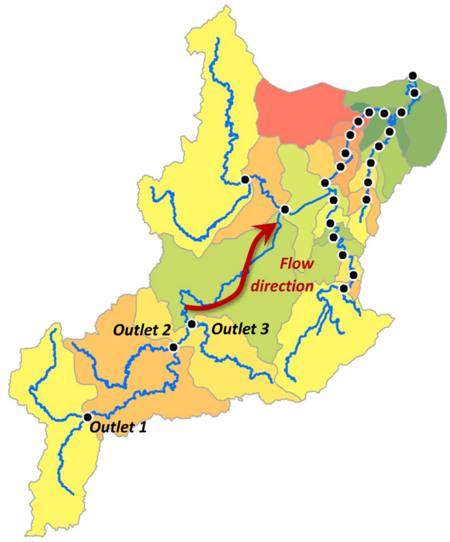


Figure 2: AN EXAMPLE OF THE SEMI-DISTRIBUTED RAINFALL-RUNOFF APPROACH SHOWING SUB-CATCHMENTS, OUTLET POINTS (BLACK DOTS), RIVER CHANNEL AND FLOW DIRECTION. IN THIS MODEL, HYDROGRAPHS (SHOWING THE DISCHARGE OVER TIME) AT EACH OUTLET ARE AGGREGATED IN THE FLOW DIRECTION.

BUSHFIRE AND NATURAL HAZARDS CRC RESEARCH

Most metropolitan areas in Australia already have detailed flood studies and management plans in place, and it was important that this project did not replicate these. After consultation with the NSW State Emergency Service, it became clear that a regional-scale, rapid assessment of flood risk was needed in NSW.

A modelling approach was developed to address this. Accordingly, a coupled rainfall-runoff model/river system model/ LiDAR-based (Light Detection And Ranging) flood model framework was developed (Figure 1, above).

A rainfall-runoff model combines rainfall data and simple descriptors of catchment physical properties (slope, soil type, land use, area and shape) to estimate the river discharge response to rain falling on the catchment. Here, a semi-distributed, curve-number based rainfall-runoff model was used, which divides the catchment into a series of sub-catchments, thus accounting for spatially varying rainfall which are particularly important for large catchments (see Figure 2, above right).

The rainfall-runoff model also incorporates a simple, river system model, which simulates accumulated flows between adjacent sub-catchments and base flow. River discharge is then converted to equivalent river heights according to a synthetic rating curve method, at each sub-catchment outlet point. The LiDAR-based flood model then interpolates a sloped flood plane between each outlet point. This is intersected with the underlying topography, and hydraulically constrained to the river channel, to produce an estimate of the flood hazard extent (Figure 3, page 3).

The result is a flood surface that can be superimposed on an aerial image and intersected with geolocated asset data for mapping and risk assessment at each timestep through the storm.

The model was applied to the Hawkesbury-Nepean catchment in western Sydney. After consulting NSW SES, the researchers decided to construct a flood scenario around the August 1986 East Coast Low, which caused widespread flooding in the Nepean Valley.

The rainfall intensity of the 1986 storm was up-scaled to an annual exceedance probability of approximately one per cent (that is, a one per cent chance of a flood occurring in any year) while the spatial pattern and progression of the rain front across the catchment was retained. Flood hazard and exposure information was output at six-hourly intervals through the storm.

Information can be presented in two forms for the end-user. First, as a set of zonal flood maps with accompanying infographics that visualise the estimated extents of flooding (Figure 4A, page 3) and the number and type of properties at risk from flooding, at each timestep through the storm (Figure 4B, page 3).

The static data in figure 4 can also be presented in animation form, where the user selects different areas and animates the evolution of the flood height at these locations. Figure 5 (page 4) shows a still of such an animation for four locations in the Nepean Valley at midnight on 7 August 1986.

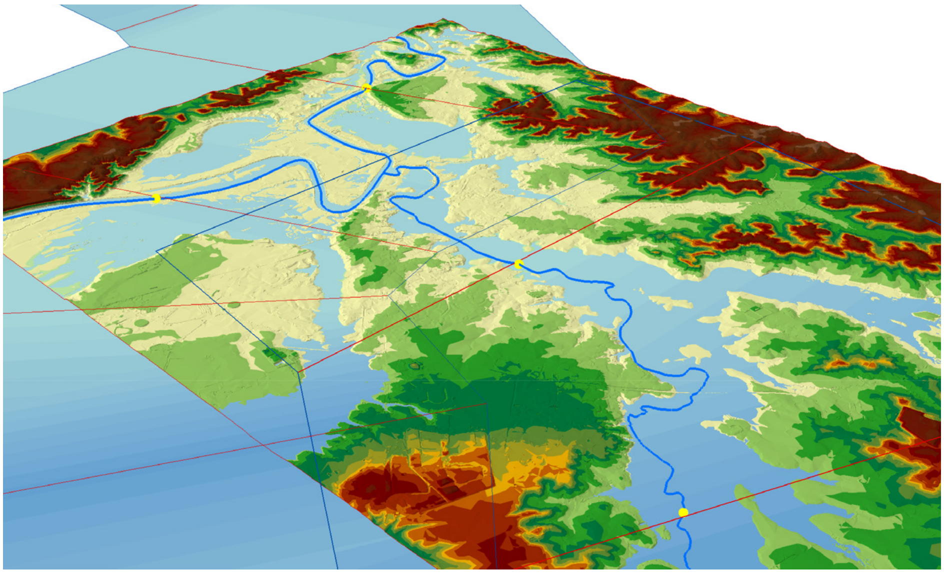
RESEARCH FINDINGS

Scenario evaluation

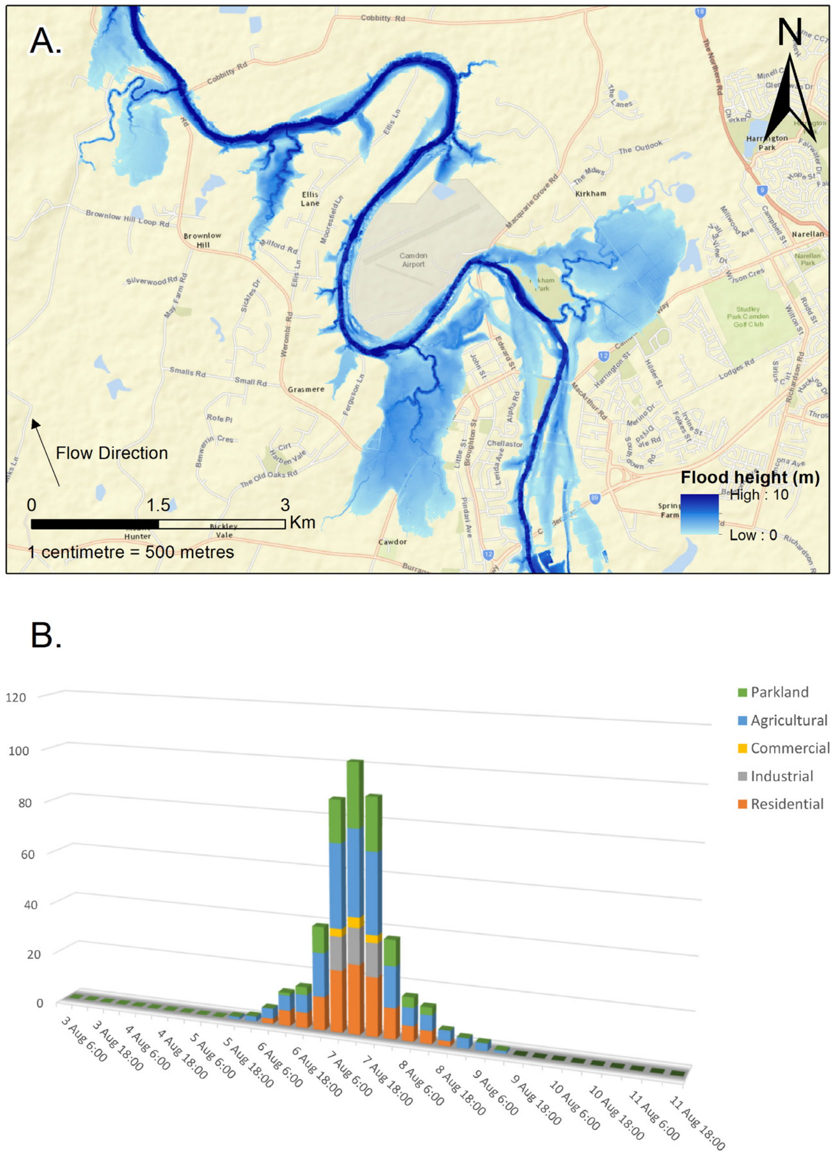
This modelling approach allows plausible flood scenarios to be generated over a large scale, and the risk to be explored through the life cycle of the flood. The scenario assumed drawdown from the Warragamba Dam consistent with historical events, and average baseflow conditions prior to the storm. Only riverine flooding was considered.

Three key findings from this scenario highlight the importance of a time-dependent and regional-scale approach to flood risk management:

1. Flooding can occur in different places at different times throughout a storm, because of the different causes of local flooding (for example, direct surface runoff or floodwater routed from rainfall upstream);
2. There can be a significant lag time between the end of rainfall and end of flooding. Likewise, there can be a significant lead time between the start of rainfall and elevated river levels. Both have risk management implications and – in this case – both resulted from the effect of stormwater routing from upstream sub-catchments that were separated a large distance away from the downstream valley;
3. This can lead to staggered flooding. In the scenario developed, by the time the Hawkesbury-Nepean catchment began to flood, over 700 addresses were already flooded from South Creek and associated tributaries.



▲ Figure 3: A LIDAR-DERIVED DIGITAL TOPOGRAPHY IS INTERSECTED WITH A SLOPE FLOOD PLANE, INTERPOLATED BETWEEN LINES (RED) PERPENDICULAR TO DISCHARGE OUTPUT POINTS (YELLOW DOTS), TO DERIVE FLOOD EXTENTS THAT HAVE A HYDRAULIC CONNECTION TO THE MAIN RIVER CHANNEL.



▲ Figure 4: (A) EXAMPLE FLOOD MAP FOR A SECTION OF THE NEPEAN RIVER AT THE PEAK OF THE FLOOD SCENARIO, AND (B) A TIME SERIES OF THE NUMBER OF ASSETS AT RISK OF FLOODING THROUGH THE EVENT, SHOWN PER ASSET TYPE.

END-USER STATEMENT

In areas impacted by East Coast Lows where there is limited or no flood information, NSW SES will be able to utilise outputs from this flood modelling technique to inform prevention, planning and response. The broad view of an entire catchment that this technique provides better enables the timing and varied consequences throughout a catchment to be considered.

NSW SES would support testing on another catchment against a historic storm or flood, as well as further verification and calibration of this technique.

– Ailsa Schofield, Acting Manager, Emergency Risk Management NSW State Emergency Service

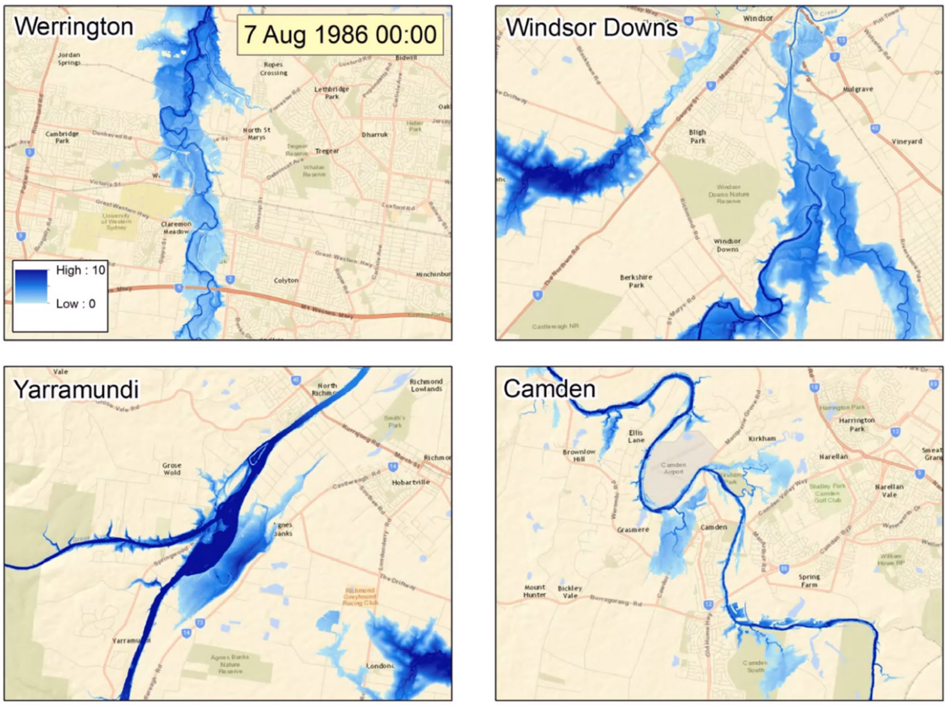
Method evaluation

This model system can indeed be a valuable, regional-scale tool for flood risk assessment, but it requires significant preparation time for any one catchment prior to implementation. Once configured for individual catchments, the flood response and exposure estimates can be obtained across a wide region (tens of thousands of square kilometres) within minutes – making large-scale flood modelling achievable, even with modest computational resources.

However, the model's reduced-physics approach does not account for dynamic aspects of flooding, such as non-linear flows, backwater effects or bank erosion. This makes it unsuitable for localities where such processes may dominate. Away from complex topographies, however, models similar to the one developed by this research have been shown to produce comparable results to 2D hydraulic-based models (Teng *et al.*, 2015).

Only limited validation was possible within the time constraints of the project. Comparisons with gauged flood heights indicated the model replicated observed discharge and flood levels reasonably well (within 10 to 15 per cent in the Nepean Valley during the 1986 flood). However, further validation and calibration is undoubtedly required.

The research team found that the most sensitive component of the modelling process was the conversion of river discharge to overbank flood heights. This is dependent on the river-channel cross-sectional area



▲ Figure 5: A STILL OF AN ANIMATION OF THE FLOOD EVOLVING AT FOUR SEPARATE LOCATIONS IN THE NEPEAN VALLEY THROUGH THE STORM, SHOWING MODELLED CONDITIONS AT MIDNIGHT ON 7 AUGUST 1986.

because it controls the in-channel capacity to store floodwaters. However, in most cases, channel depth is unknown. As a result, the cross-sectional area can only be estimated empirically or by extrapolation from the nearest surveyed section, and remains a major calibration parameter.

HOW IS THE RESEARCH BEING USED?

This modelling approach makes a simplified and large-scale assessment of flood risk based on rainfall, physical catchment properties and exposure information. While it is not the first time such model components have been applied to flood risk assessment, the way in which the model couples each component and presents information for the user maximises benefit for emergency management requirements. Because all the required datasets are nationally available, and minimal computational effort is needed, the method can be applied to any catchment, or set of catchments, in Australia.

The model is currently being used to look at the role of cross-catchment flood correlations in determining regional to national-scale flood risk. As one catchment floods, there is a conditional probability that another catchment will also flood to a similar, or different, magnitude. An improved understanding of these inter-dependencies between neighbouring, or even geographically disparate catchments, could significantly help statewide emergency services in dealing with flood risk and resource allocation.

FUTURE DIRECTIONS

The research team is discussing with NSW SES how this research could support their planning and resource allocation for riverine flooding over large areas. There is scope for further research comparing these results to the detailed flood studies already conducted across the Hawkesbury-Nepean valleys.

From a research perspective, the impact of clustered storms, rather than large magnitude flooding in isolation, is generating greater interest. The occurrence of a series of lower-intensity storms separated by only short intervals can lead to a greater cumulative hazard than expected, and may result in lower preparedness. The impact of clustering on flood risk – and how storm clustering may change with a changing climate – is an area that requires more research attention.

This model also has potential applications for the insurance industry, government agencies and other organisations involved in flood risk and land use planning. For example, the development of an interactive tool as the model is rolled out nationally could provide more accurate, timely assessments of flood impacts.

Finally, this method may also be of use for assisting first-pass mapping of rural floodplains where little baseline information is currently available.

FURTHER READING

Mortlock TR (2017) *Event-based modelling of flood hazards and impacts during extreme east coast low storms utilising a rapid, regional-scale approach*, Bushfire and Natural Hazard CRC.

NSW Office of Water (2014) *Hawkesbury-Nepean Valley Flood Management Review — Stage One: Review Report*. Sydney NSW: NSW Department of Primary Industries, Office of Water.

Teng J, Vaze J, Dutta D and Marvanek S (2015) Rapid flood modelling in large floodplains using LiDAR DEM, *Water Resources Management*, 29, 2619-2636.

The Bushfire and Natural Hazards CRC is a national research centre funded by the Australian Government Cooperative Research Centre Program. It was formed in 2013 for an eight-year program to undertake end-user focused research for Australia and New Zealand.