ABSTRACT

The advent of two dimensional flood modelling and the availability of air-borne laser scanning survey data have given flood risk practitioners the ability to map inundation over the majority of our urban landscape, albeit at very shallow depths. As the model resolutions become finer, the areas of shallow inundation grow larger (particularly with the inclusion of rainfall on the two dimensional model grid).

Difficulties arise when public flood maps are prepared based on this modelling. These difficulties are typified by the following questions that often emerge during floodplain risk management committee discussions:

• Should all inundation in a 100 year flood event be mapped as “flooding”?
• At what inundation depth should special flood controls be applied and at what depth is it sufficient to fall back on normal building controls, (e.g. BCA)?
• What terminology should be used to describe this inundation to the public?
• What notations should be provided on Section 149(2) and 149(5) certificates?

Communities can become very angry if all inundation is classified as flooding (as has been the practice with riverine flooding derived from more traditional one dimensional models). This is especially so in shallow overland flow areas distant from recognised watercourses. The public outrage in these areas will demand a different approach.

This paper presents a pragmatic solution which balances Council’s responsibility to carefully manage the floodplain without unnecessarily classifying shallow inundation areas as ‘flooding’ and incurring the wrath of the community due to the perceived impacts on property values or by triggering planning restrictions that provide no beneficial flood risk management return.

INTRODUCTION

Within the past five years or so, the use of two dimensional (2D) flood modelling and the availability of comprehensive ground level data, has made it possible to model shallow inundation over large areas of our urban landscape.
The use of 2D flood models such as TUFLOW, SOBEK, MIKE21, RMA, etc., have become common place in NSW, especially for modelling the more complex flood behaviour that occurs in urban areas. It is now more likely that new flood studies will utilise a 2D model rather than the older 1D model such as MIKE11 and HEC-RAS that were the industry standard up until the turn of the century. As the speed of computers has increased, it has also been possible to employ finer 2D model grids such as 2m-5m, throughout urban areas.

Often the underlying stormwater pipe infrastructure is also modelled including the exchange of flows between the surface system and the pipe network. In some cases, it is also possible to introduce rainfall directly onto the cell grids. As the stormwater pipe system extends generally to every street in an urban area, the models now often cover the entire catchment.

There is also now much better topographical data available to describe the surface of urban areas. This has usually been derived from airborne laser scanning (ALS) systems such as those provided by companies like AAM Hatch and Fugro. Whilst the specifications for the ALS data vary, it has been the authors’ experience that the vast majority of data points have accuracies better than ±0.15m vertically on clear ground, and horizontal spacings of about 1m are typical.

One of the outcomes of flood modelling using the above techniques is the ability to predict inundation in areas well away from watercourses. It shouldn’t come as any surprise that the above techniques can produce model output with very shallow inundation over large parts of our urban areas. The depths can be less than say 0.1m or 0.3m, with the shallower depths affecting greater areas.

Theoretically, if rainfall is present, inundation should be occurring in every part of a catchment, even on top of a hill, albeit at very shallow depths.

THE DILEMMA — WHEN IS SUCH INUNDATION, ‘FLOODING’?

The issue which is the focus of this paper concerns the presentation of these model results for shallow areas of inundation distant from watercourses. In particular, should this inundation be referred to as ‘flooding’? More importantly, should such inundation be included on flood maps.

The Views of the Community

Rightly or wrongly, communities have a perception of ‘flooding’ which is generally related to the inundation associated with rivers and creeks when they break their banks. When the general public use the term ‘flooding’ they usually imply a depth that has some consequence. Whilst they may accept that at the edge of a flooded river, even shallow depths of inundation could be referred to as ‘flooding’, if the inundation is not associated with a watercourse but is merely resulting from shallow localised ponding, other terms like ‘ponding’, ‘drainage’, ‘overland flow’ or ‘inundation’ may be more appropriate rather than ‘flooding’.

The community perceive that flood classifications influence property values and flood risk practitioners need be under no misapprehension, that inappropriate classification of properties as ‘flood prone’ will incur the wrath of the community and their elected representatives. The classification of land as ‘flood liable’ may also trigger the application of planning controls or complicate what would otherwise be very minor development applications. Practitioners therefore need to tread carefully.

Guidance within the NSW Manual

When referring to inundation, the NSW Floodplain Development Manual uses a variety of terms of which the following are relevant to the current discussion:
**flooding:** relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.

**mainstream flooding:** inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.

**local overland flooding:** inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.

**local drainage:** smaller scale problems in urban areas. They are outside the definition of major drainage …

**major drainage:** councils have discretion in determining whether urban drainage problems are associated with major or local drainage. For the purposes of this manual major drainage involves:

- floodplains of original watercourses (which may now be piped, channelised or diverted), or sloping areas where overland flows develop along alternative paths once system capacity is exceeded; and/or
- water depths generally in excess of 0.3m (in the major system design storm as defined in the current version of Australian Rainfall and Runoff). These conditions may result in danger to personal safety and property damage to both premises and vehicles; and/or
- major overland flowpaths through developed areas outside of defined drainage reserves; and/or
- the potential to affect a number of buildings along the major flow path.

The Manual specifies that a Council can exercise its “discretion” in setting criteria to determine what constitutes major drainage. Whilst it is clear that the Manual considers inundation from ‘major drainage’ to be ‘flooding’, it’s been the authors’ experience that to automatically refer to such inundation as ‘flooding’, and to display it on flood maps, may create unnecessary angst amongst the community, particularly those who are concerned with potential impacts on property values.

**Further Guidance from the Manual**

The Manual also goes on to say that:

- it is often impossible to define a meaningful boundary between local overland and mainstream flooding;
- local drainage problems can generally be minimised by adoption of general urban building controls requiring a minimum difference between finished floor and finished ground levels (to cope with shallow water depths) and adequate site drainage; and
- overland flow paths associated with major drainage problems should be subject to information on Planning Certificates under Section 149 of the EP&A Act ….. However, Councils are not obliged to convey information on local drainage problems on Planning Certificates …

**Approach Adopted by the Authors**

The authors’ approach is consistent with the Manual however avoids referring to inundation resulting from ‘major drainage’ as ‘flooding’ but rather refers to this as ‘overland flow’. Local drainage areas are not shown at all on flood maps.
When mapping flood risk, major drainage areas are classified as separate ‘overland flow precincts’, rather than as ‘flood risk precincts’. The authors’ approach is summarised in Table 1 below.

Table 1: Authors’ Terminology for Flood Maps and Flood Risk Maps

<table>
<thead>
<tr>
<th>Inundation Classification as per NSW Manual</th>
<th>Approach Adopted by Authors for Mapping</th>
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<tbody>
<tr>
<td>Category</td>
<td>Sub-category</td>
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<tr>
<td>Mainstream Flooding</td>
<td></td>
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<tr>
<td>Local Overland Flooding</td>
<td>Major Drainage</td>
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<td></td>
<td>Local Drainage</td>
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PRACTICAL ISSUES WITH MAPPING THE LIMITS OF OVERLAND FLOW

Issues to be Considered
In mapping the boundary between ‘local drainage’ and ‘major drainage’, there are a number of issues that must be addressed:

1. *what hydraulic criteria are to be used to determine the boundary?* The Manual does not provide any prescriptive rule but suggests that depths around 0.3m could be used. However it suggests that other factors should also be considered including the damage potential of the flows, the personal safety risks, the areal extent and the potential to affect a number of buildings along the flow path. Clearly it is a choice that a local Council must make having considered the factors, and different councils will come up with different hydraulic criteria. Nevertheless it is likely that the adopted criteria will typically be a depth, or a combination of depths and velocities;

2. *what consideration should be given to floods rarer than the standard flood?* While the depth criterion of 0.3m relates to the standard flood (typically the 100 year ARI event), where there is significant variation in depth up to the PMF and this has substantial implications for damages and personal safety, then a flood risk precinct approach may be more appropriate;

3. *what controls will be used in the local drainage area to prevent floor level inundation?* The Manual refers to “general urban building controls requiring a minimum difference between finished floor and finished ground levels (to cope with shallow water depths) and adequate site drainage”. The reality for most councils is that these controls are those specified in the Building Code of Australia (BCA) which is discussed further below;

4. *what techniques are available to automate the boundary definition in a GIS?* As geographical information systems (GIS) are normally used to prepare the input to, and to view the results from 2D models, it would be preferable for the boundary between local drainage and major drainage to be easily ‘queried’ of ‘defined’ in a GIS; and

5. *public perceptions.* The classification of private property as flood prone is a very sensitive issue which must be carefully managed to minimise unnecessary public
angst whilst providing a proper policy framework from which to manage flood risks consistent with a Council’s responsibilities under the Manual.

**Observations from Typical 2D Model Output**
Figure 1 below shows output from a 2D model of an urban area. The results are for part of the City of Ryde where TUFLOW was applied using ALS data meeting the typical specifications noted above. All underground pipe drainage was simulated in TUFLOW with local catchment hydrographs (derived from DRAINS models) added across the TUFLOW model grid. A 3m grid was used in TUFLOW.

The depths contours shown in Figure 1 are typical of the model results for urban overland flow areas not only in Ryde but many other Council areas.

The spotted depth pattern in the shallow inundation areas originates largely because the 3m grid adopted in the modelling, is much coarser than the underlying topographic data. When the inundation depths are calculated as the difference between the modelled flood level (on a 3m grid) and the topographic surface (typically 1m), smaller ‘holes’ can be seen.

![Figure 1: Depth Contours Produced by Model of Overland Flow Area](image)

Another factor influencing the depth pattern is the accuracy of the modelled flood level and the accuracy of the ALS spot levels. It is often accepted that the flood level accuracy in such situations might be ±0.3m. As the ALS spot level accuracy is ±0.15m, not a lot of confidence can be put in the depth contours shown in Figure 1, particularly for depths less than 0.3m. Consequently there is likely to be a significant amount of ‘noise’ in the depth contours. Such modelling is also generally unable to account for small scale ground features and structures that may have an important influence on local flood behaviour (e.g. fences, BBQs, raised gardens, paths, etc).
Potential Public Outrage
There is little doubt that if a Council was to publish flood maps classifying properties as ‘flood prone’ based on all the inundation depths shown in Figure 1, there would be some public outrage. Clearly where there is some noise and uncertainty in the modelled depth information, Council’s need to use the model results cautiously and must be very careful in the presentation of model results to the public.

BCA Floor Level Controls for the Local Drainage Area
Before deciding on which depth contour to pick as the boundary of local drainage and major drainage, the viability of the BCA controls to prevent inundation of floors in the local drainage area has to be considered.

The BCA requires that slab-on-ground floor levels should be a minimum of 100mm above finished ground levels in low rainfall intensity areas or sandy, well drained areas; or otherwise a minimum of 150mm (including when the adjacent area is impermeable)\(^3\).

However:
1. this only applies to Class 1 buildings (i.e single dwellings) and does not include other types of residential buildings or non-residential buildings;
2. ‘low rainfall intensity areas’ are areas where the 5minute 20 year ARI rainfall is less than 120mm/hr. (Most urban areas would not qualify);
3. whilst the BCA recognises that the slab height might need to be varied to account for “run-off from storms”, “local topography”, “the effect of excavation on a cut and fill site”, and “the possibility of flooding”, in the absence of Council policies and/or mapping, it is unlikely that requirements in excess of the 100mm and 150mm would be applied; and
4. the BCA does not provide any freeboard. Ground level changes of the order of 150mm can occur over time through top soiling or vegetation growth and other means.

Consequently, from a flood risk management perspective, there is little confidence that the BCA provisions are sufficient to avoid floor inundation especially where depths exceed say 100mm, (and then only for single dwellings).

In this regard the Manual’s inference that inundation depths of less than about 300m can be normally managed by “general urban building controls” is poorly founded. (It is probable that these comments were added to the Manual prior to 2001, before the adoption of the BCA and at a time when conditional building approvals were required from Councils).

Using GIS to Filter Model Results to Delineate Overland Flow Boundaries
In completing flood studies of overland flow areas for a number of urban Councils, some of the authors have found that the following techniques are useful in delineating overland flow boundaries in GIS data sets:

- defining max depths;
- subtracting nominal amounts from flood levels before mapping;
- ignoring depths that occupy areas less than a specified maximum area; and
- various methods for smoothing the resultant flood depths including resampling of the flood grids and surface levels.

Whilst some methods may have worked reasonably effectively in one catchment, the overriding conclusion from these studies has been that no one method works everywhere, and in many catchments, it is not possible to derive sensible boundaries to overland flow areas without some form of visual interpretation and verification.
ADOPTED MAPPING APPROACH
Considering the issues raised above, the authors recommend the following approach to mapping be considered. It has recently been adopted by the City of Ryde for the Eastwood and Terry’s Creek catchment after extensive community consultation. It comprises:

1. **Proximity to watercourses.** Areas adjacent to watercourses or open drains are mapped as ‘flooding’ irrespective of the depth involved.

2. **Local drainage areas** are determined as those areas distant from watercourses and open drains where depths are less than 0.1m–0.2m typically. Final mapping of this boundary definition is manually drawn after considering the various depth contours such as those in Figure 1. In the case of Ryde, these local drainage areas are not classified in any of Council’s planning instruments. It was ultimately determined that it was politically unacceptable and impractical to control floor levels other than through the BCA (which is acknowledged to be somewhat inadequate). Nevertheless the history of this type of above floor level inundation in the LGA was not a significant issue. Further if floor level inundation was to occur, there are likely to usually be relatively inexpensive adjustments that could be made to ground levels within a property to avoid similar inundation in the future. In addition, as there are no planning controls applied in these areas, no Section 149 notations are issued in respect of this type of inundation.

3. **Overland flow areas** are determined where the depths of inundation are less than 0.3m–0.5m typically. In many cases it may not be possible to delineate such a boundary line exactly, and it may be more appropriate to identify affected lots only (see Figure 2 below). Again this mapping process is based on various depth contours but ultimately will require manual drafting. Planning controls in this overland flow precinct are similar or less restrictive than those normally applied to flood risk precincts, (e.g. floor level controls with 0.3m freeboard rather than 0.5m, and no evacuation controls given the relatively shallow depth of inundation). Section 149 notations relating to the controls in the overland flow precinct are applied. Flood level estimates from the modelling are used for flood level control.

4. The remaining inundation areas are mapped as **flood risk precincts** including those adjacent to watercourses and open drains.

CONCLUSIONS

(a) In a rainfall event, every part of the surface of a catchment will be inundated, albeit to very shallow depths. All inundation cannot be referred to as ‘flooding’ otherwise every property in a catchment would be flood prone!

(b) The classification of properties as flood prone is a very sensitive community issue. Councils need to be careful in not unnecessarily classify properties as flood prone, whilst fulfilling their responsibilities as floodplain risk managers under the Manual.

(c) Most modern flood studies now have the capability to map inundation throughout urban catchments, including shallow inundation on overland flow areas distant from recognised watercourses. Modelling of shallow inundation is not an exact science. Depth maps will likely contain significant uncertainty and ‘noise’.

(d) The NSW Manual assumes that very shallow inundation areas which it refers to as ‘local drainage’ will not be referred to as ‘flooding’ and that existing general building controls (i.e. not flood controls) will be sufficient to prevent floor level inundation. Such controls are typically those of the BCA and these are limited and unlikely to prevent inundation in many situations. Nevertheless it is impractical to revise the BCA or to develop additional local policies to better manage floor levels relative to the inundation depths.
(e) The noise and variability apparent in modelled depths in shallow inundation areas make it difficult to use standard GIS filtering techniques to automatically delineate local drainage and major drainage areas. The authors' experience is that a single set of depth or depth and velocity criteria, cannot be used. Manual drafting and application of 'professional judgement' are still necessary.

(f) The authors have developed a system for flood level and flood risk mapping in these shallow inundation areas based on a review of these issues for many urban Councils. The system recognises the sensitive nature of flood prone land classifications and avoids use of the term 'flooding' for overland flow paths. The system has recently been adopted by the City of Ryde for the Eastwood and Terry's Creek catchment.

(g) The adopted system comprises:

(i) **Local Drainage**
- depths typically less than 0.1m–0.2m
- not shown on flood maps
- no controls other than BCA
- no notations on Section 149 certificates

(ii) **Major Drainage**
- depths typically less than 0.3m–0.5m
- referred to as 'overland flow' not 'flooding'
- mapped on a lot basis given uncertainty in accurate delineation of area
- flood risk maps use separate 'overland flow precinct' with less restrictive controls than the normal flood controls applicable within 'flood risk precincts'
- included on Section 149 certificates
TAKE-HOME MESSAGES

Flood modelling tools and terrain data have become more sophisticated. Today we have the ability to automatically generate flood extents and delineate flood risks at the push of a button. Take care however. The raw model results need to be interrogated cautiously particularly in shallow inundation areas to ensure that the true flood risks are accurately mapped and separated from those associated with overland flow. If we don’t get this right, we can expect outrage from the community as properties are inappropriately classified and planning restrictions are unnecessarily triggered.

REFERENCES

