Chapter 1.

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1. Introduction

1.1. Background

The safety of people in floods is of major concern in floodplain management. Analysis of the circumstances around individual flood fatalities, both in Australia and internationally, shows that most flood fatalities occur outside of buildings with people either wading or driving vehicles through floodwaters (French et al, 1983, Coates and Haynes, 2008). While floodplain management activities aim to reduce the risk of flooding, ongoing human activity in floods is largely unavoidable as significant areas of existing development and transport infrastructure in Australia remain flood prone.

The best contemporary advice from emergency managers is that people should completely avoid entering floodwaters. Recent analysis of the Queensland floods in 2011 by the Queensland Commission for Children, Young People, and Child Guardian (CCYPCG, 2012) and the Queensland Fire and Rescue Service, 2012 has reinforced the conclusion that floodwaters are extremely dangerous to both people wading and driving vehicles of all types in floods.

Irrespective of this advice, it is apparent that there are numerous circumstances and associated human behaviours during flood emergencies, which might cause people to either wade or drive into floodwaters. Once exposed to flood flows outdoors, the safety of people is compromised when flood flow forces exceed their ability to remain standing or when the vehicles they are travelling in become unstable by becoming buoyant or losing traction.

It is incumbent on the floodplain management process to reduce the risk to life to as low as reasonably practicable. The responsibility for floodplain planning in Australia varies with jurisdiction, but generally falls to local government. Interpretation of flood data into the floodplain planning process is the responsibility of these various planning entities. Nationally, guidance for best practice in floodplain management is provided by the commonwealth government via the Emergency Management Australia publication “Managing the Floodplain: A Guide to best Practice in Floodplain Risk Management in Australia” (NFRAG, 2012). While NFRAG (2012) references The Engineers Australia “Australian Rainfall and Runoff Guidelines” (ARR) methods and techniques, ARR itself does not provide direct guidance for floodplain planning or management.

Figure 1.1. Defining Flood Risk (after NFRAG, 2012)

1.2. Use of this Report

This report provides advice on the interpretation of flow behaviour as a flood hazard in respect of people and vehicle safety on floodplains. In this regard, the report is useful for the assessment of the consequences or impacts of flood when assessing aspects of flood risk, as illustrated in Figure 1 1.

This report provides information to assist with the interpretation of flood data where floodwaters interact with people and vehicles. The specific scope of this report is to:

1. Prepare examples illustrating the assessment of hazard for people and vehicles using the information presented in the ARR revision Project 10 reports (Cox et al., 2010, Shand et al., 2011) prepared by WRL, UNSW; and

2. Preparation of figures, suitable for inclusion in ARR that will provide information suitable for assessment of the hazard to people and vehicles during flood events.

2. Flood Hazard

Hazard can be defined as a source of potential harm or a situation with potential to cause loss. In relation to floodplain management, the hazard is flooding which has the potential to cause damage or harm to the community. Flood hazard needs to be assessed by taking into account a range of factors. The usual starting point in a flood hazard assessment is to quantify the hazard provisionally by mapping the area inundated and the flow behaviour characteristics within the inundation area. The flow behaviour characteristics are typically parameterised by the flood depth (d) and velocity (v) which can be unified into a single hazard parameter by the product of the variables (v*d).

Ultimately the flood hazard assessment needs to take into account a range of other social, economic and environmental factors, though these are often more difficult to quantify. Additional factors that can add to the provisional hazard and need consideration to ascertain the flood hazard beyond the provisional estimate are:

- Effective warning time;
- Rate of rise of floodwaters;
- Duration of flooding;
- Evacuation problems;
- Isolation from flood free land;
- Effective flood access;
- Type of development; and

- Community flood awareness;

2.1. Flood Hazard Assessment

2.1.1. How is Provisional Flood Hazard Assessed?

The baseline datasets that underpin floodplain risk management studies are typically developed using numerical floodplain models (see Figure 2 1). Contemporary flood plain models are usually a two dimensional (in plan), depth averaged representation of floodplain flows. The model outputs are typically maps of flood depth (see Figure 2 1 b) and flood velocity (speed and direction), which can be interpreted into maps of flood surface level and flow (discharge) distribution across a floodplain. These maps are typically available as a time series of flow behaviour for the duration of a flood event, but presentation in reports is generally as enveloped maxima.

The accuracy of the representation of flow behaviour in the model is reliant on the availability and accuracy of the input data, the availability of suitable calibration data for historical flood events for calibration and verification of the model and the skill of the model operator. Project 15 of ARR (EA 2012) provides best practice advice on the preparation of numerical models.

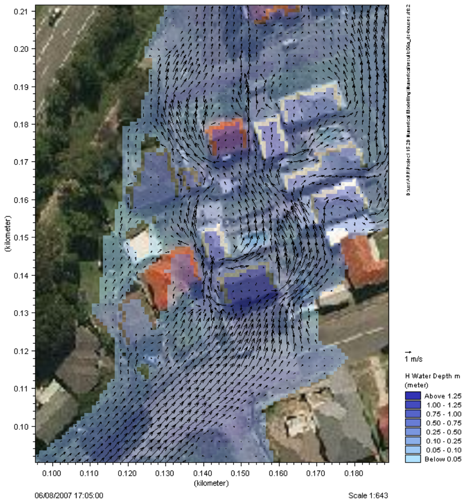
Smith and Wasko (2012) completed a review of numerical flood modelling techniques in urban environments as part of the review of ARR. This study compared numerical model outputs against a calibrated physical model of part of the Merewether Heights floodplain in Newcastle, which was seriously affected by flash flooding in June 2007. Smith and Wasko (2012) concluded that:

- Correctly applied, numerical models provided an adequate representation of flood surface levels and flood inundation extents for setting Flood Planning Levels;
- When modelled at a suitable resolution, numerical models provided a reasonable representation of flow distributions through the floodplain;
- Numerical models sometimes under-estimated flow velocities in complex urban environments including under-estimation of flow speeds between and around buildings;
- Provisional flood hazard estimates (v*d) in urban environments could be underestimated by numerical models, particularly if the model spatial resolution was not adequate.

Figure 1.2. Example of a Flood Study Depth Map (after Smith and Wasko, 2012)

a) Physical model

Figure 1.3.

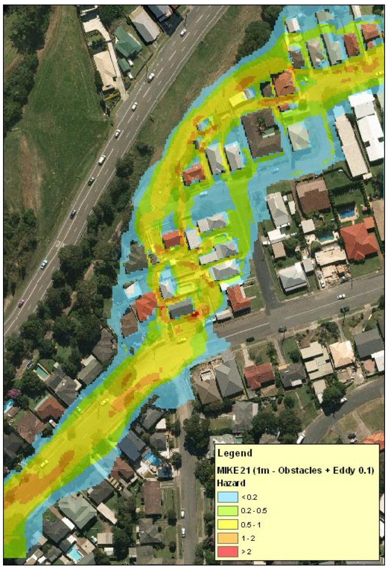


b) Numerical Model – Depth Map

2.1.2. Example of a Flood Study Depth Map (after Smith and Wasko, 2012)

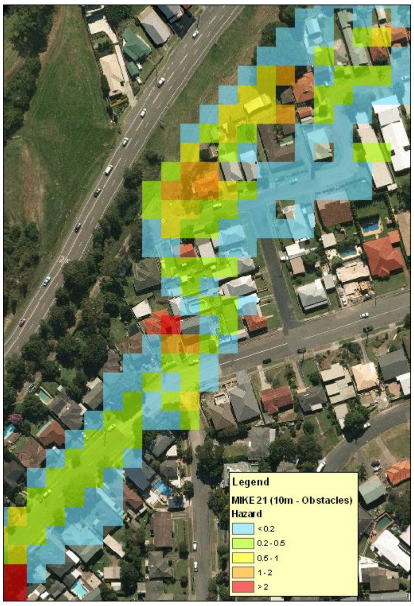
Figure 2 2 compares provisional flood hazard (v*d) estimates at two model grid resolutions, 1 m and 10 m, for the Merewether model for the 2007 flood event. The figure shows that at the 1 m grid resolution, which best matched the flood velocity and flow distributions of the physical model (Figure 2 1a), the flood hazard estimates are significantly higher than at the 10 m grid resolution.

Figure 1.4. Comparison of Provisional Flood Hazard Estimates from Numerical Models at Differing Grid Resolutions (after Smith and Wasko, 2012)



a) 1 m grid resolution

Figure 1.5.



b) 10 m grid resolution

An important conclusion of the Smith and Wasko (2012) study was that 2D numerical model outputs might require further interpretation in order to ensure that suitable, representative, flood behaviour information was being applied in planning and management decisions.

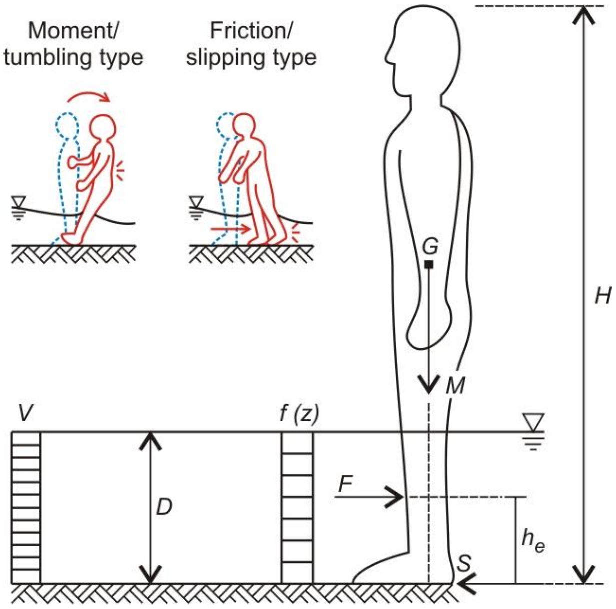
2.2. People Stability

The two recognised hydrodynamic mechanisms by which people may lose stability in flood flows include moment instability and friction instability (refer Figure 2 3). Cox et al. (2010) presents more comprehensive discussion, but in brief, moment (toppling) instability occurs when a moment induced by the oncoming flow exceeds the resisting moment generated by the weight of the body (Abt et al., 1989). This stability parameter is sensitive to the buoyancy of a person within a flow and to body positioning and weight distribution. Frictional (sliding) instability occurs when the drag force induced by the horizontal flow impacting on the legs and torso is larger than the frictional resistance between a person's feet and the ground surface. This stability parameter is sensitive to weight and buoyancy, clothing type, footwear type and ground surface conditions.

Additionally, loss of stability may also triggered by adverse conditions, which should be taken into account when assessing safety such as:

- **Bottom conditions**: uneven, slippery, obstacles;
- **Flow conditions**: floating debris, low temperature, poor visibility, unsteady flow and flow aeration;
- **Human subject**: standing or moving, experience and training, clothing and footwear, physical attributes additional to height and mass including muscular development and/or other disability, psychological factors;
- **Other issues**: strong wind, poor lighting, etc.

Figure 1.6. Typical modes of Human Instability in Floods (after Cox et al, 2010)



Determining safety criteria for people requires an understanding of the physical characteristics of the subjects along with the nature of the flow (Figure 2 3):

- The measure of physical attributes for human stability analysis is best represented by the parameter H.M (mkg), the product of subject height (H; m) and mass (M; kg) (Cox et al., 2010);
- The measure of flow attributes for human stability analysis is D.V (m^2s^{-1}) value, determined as the product of flow depth (D, m) and flow velocity (V, ms^{-1})

While distinct relationships exist between a subject's height and mass and the tolerable flow value, definition of general flood flow safety guidelines according to this relationship is not considered practical given the wide range in such characteristics within the population.

In order to define safety limits, which are applicable for all persons, hazard regimes are defined based on H.M for representative demographics. Each classification is based on laboratory testing of subject stability within flood-waters. The following suggested classifications are:

- Adults, where H.M > 50 mkg;
- Children, where H.M = 25 to 50 mkg; and
- Infants and very young children, where H.M < 25 mkg. (Cox et al., 2010)

Several hazard regimes are recommended based on D.V flow values for each H.M classification. The hazard regimes as suggested from laboratory testing of subject stability and response within variable flow conditions are:

- Low hazard zones where D.V < 0.4 m^2s^{-1} for children and D.V < 0.6 m^2s^{-1} for adults;
- A Significant hazard zone for children exists where flow conditions are dangerous to most between D.V = 0.4 to 0.6 m^2s^{-1};
- Moderate hazard zone where conditions are dangerous for some adults and all children is defined between D.V = 0.6 to 0.8 m^2s^{-1} for adults. This is inferred to define the limiting working flow for experienced personnel such as trained rescue workers;
- Significant hazard zone where flow conditions are dangerous to most adults and extremely dangerous for all children is suggested between flow values of D.V = 0.8 to 1.2 m^2s^{-1}; and
- Extreme hazard where flow conditions are dangerous to all people is suggested for D.V > 1.2 m^2s^{-1}.

Recent research (Cox et al., 2010) concludes that self-evacuation of the most vulnerable people in the community (small children and the elderly) will be limited by relatively placid flow conditions. D.V as low as 0.4 m^2s^{-1} would prove problematic for those most vulnerable in the community.

The hazard regimes for tolerable flow (D.V) as related to physical subject presence (H.M) are presented in Figure 2 4 and Table 1.

Table 1.1. Flow Hazard Regimes for People (Cox et al, 2010)

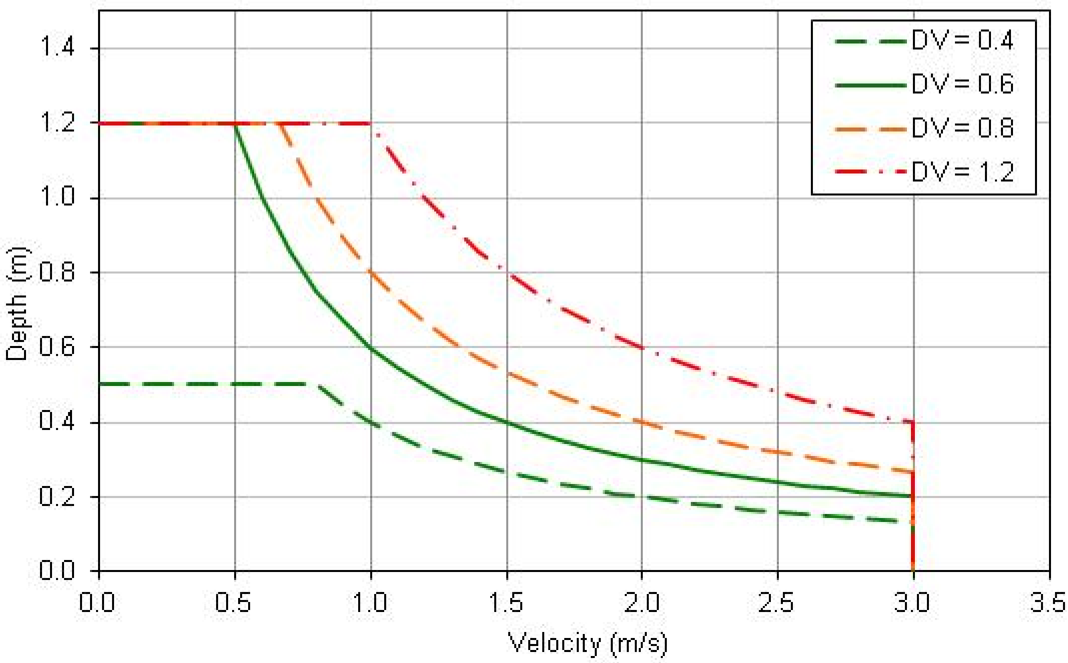
DV (m^2s^{-1})	Infants, small children (H.M $\leq$ 25) and frail/older persons	Children (H.M = 25 to 50)	Adults (H.M > 50)
0	Safe	Safe	Safe
0 – 0.4	Extreme Hazard; Dangerous to all	Low Hazard	Low Hazard
0.4 – 0.6	Extreme Hazard; Dangerous to all	Significant Hazard; Dangerous to most	Low Hazard[1]
0.6 – 0.8	Extreme Hazard; Dangerous to all	Extreme Hazard; Dangerous to all	Moderate Hazard; Dangerous to some[2]
0.8 – 1.2	Extreme Hazard; Dangerous to all	Extreme Hazard; Dangerous to all	Significant Hazard; Dangerous to most[3]
> 1.2	Extreme Hazard; Dangerous to all	Extreme Hazard; Dangerous to all	Extreme Hazard; Dangerous to all

[1]Stability uncompromised for persons within laboratory testing program at these flows (to maximum flow depth of 0.5 m for children and 1.2 m for adults and a maximum velocity of 3.0 ms^{-1} at shallow depths).

[2]Working limit for trained safety workers or experienced and well equipped persons (D.V < 0.8 m^2s^{-1})

[3]Upper limit of stability observed during most investigations (D.V > 1.2 m^2s^{-1})

Figure 1.7. Safety Criteria for People in Variable Flow Conditions (After Cox et al, 2010)



2.2.1. Physical considerations

There is a lack of test data for infants and very young children as well as frail/older persons (Cox et al., 2004). These populations are unlikely to be safe in any flow regimes and as such, care is required in locating aged care and retirement villages as well as childcare centres and kindergartens.

For physically and/or mentally disabled people, a similar intolerance criteria to the very young children and frail/older persons should be applied as subjects are considered vulnerable to all flow values. This is because while the H.M values may be similar to regular adults, they are clearly at a physical (e.g. muscular development, control of limbs) and/or psychological disadvantage (e.g., cognisant of the real/perceived danger, inability to cope with external stimulus).

Emergency personnel tasked with carrying evacuees should be aware that the additional H.M gained by carrying a person is not necessarily a benefit to their stability. This was demonstrated in a particular laboratory test of human stability criteria, Jonkman and Penning-Rowsell (2008) who note that their test subject (a trained stuntman) considered balancing in the flowing water more difficult when carrying extra weight such as a child or elderly person.

It should also be noted that while these criteria are based on experimental data for loss of stability for persons wading in floodwaters, it is also inherently dangerous to swim through floodwaters. Swimming through floodwaters should not be attempted.

2.2.2. Psychological/behavioural considerations

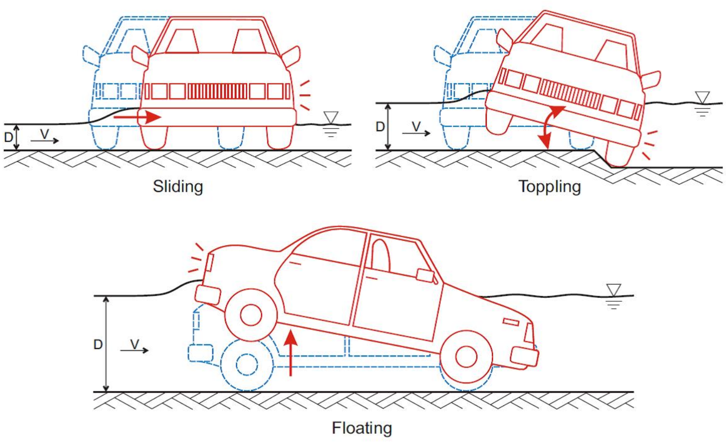
A person's ability to withstand flood flows is affected by their mental disposition, perception, specific training and experience.

Where specific training has been undertaken or a subject has recent and relevant experience, personnel are able to tolerate situations of high D.V (Jonkman and Penning-Rowsell, 2008). A limiting working flow of D.V = 0.8 m^2s^{-1} is suggested for experienced personnel such as trained rescue workers. These personnel should, where possible, be equipped for dangerous flow conditions with safety restraints, floatation aids and other safety apparatus, and be trained to cope with high D.V situations. It is trained emergency personnel who are likely to be instructing, driving and guiding evacuation paths, and consequently to whom the upper limit of safety design criteria is directed.

2.3. Vehicle stability

The two recognised hydrodynamic mechanisms by which stability of vehicles is lost include buoyancy or floating and friction instability or sliding instability (refer Figure 2 5). More comprehensive discussion is presented within Shand et al. (2011) but briefly, vehicle floating instability occurs when the upward buoyancy force exceeds the downward force exerted by the vehicle mass. This instability is dominant in low velocity, high depth flows. Frictional or sliding instability occurs when the horizontal force exerted on one or more car panels is greater than the vertical restoring force, which is dependent on the vehicle mass, buoyancy and the friction between the car tyres and road surface.

Figure 1.8. Typical Modes of Vehicle Instability (after Shand et al, 2011)



Note that in the context of this discussion friction instability is associated with slow moving or stationary cars as distinct to hydroplaning, which occurs when a vehicle at high speed encounters very shallow, evenly distributed water covering a road, typically a highway or freeway. Hydroplaning is not considered further within this report.

Determining safety criteria for vehicles requires an understanding of the physical characteristics of the vehicle along with the nature of the flow (Figure 2 5).

The measure of physical attributes for vehicle stability analysis is the vehicle classification as based on length (L, m), kerb weight (W, kg) and ground clearance (GC, m). Three vehicle classifications are suggested:

- Small passenger: L < 4.3 m, W < 1250 kg, GC < 0.12 m
- Large passenger: L > 4.3 m, W > 1250 kg, GC > 0.12 m
- Large 4WD: L > 4.5 m, W > 2000, GC > 0.22 m

The measure of flow attributes for vehicle stability analysis is D.V m^2s^{-1}, determined as the product of flow depth (D, m) and flow velocity (V, ms^{-1})

Limiting conditions exist for each classification based on laboratory testing of characteristic vehicles. The upper tolerable velocity for moving water is defined based on the frictional limits, and is a constant 3.0 ms^{-1} for all vehicle classifications.

The upper tolerable depths within still water are defined by the floating limits:

- Small passenger vehicles: 0.3 m
- Large passenger vehicles: 0.4 m
- Large 4WD vehicles: 0.5 m

The upper tolerable depths within high velocity water (at 3.0 ms^{-1}) are defined by the frictional limits:

- Small passenger vehicles: 0.1 m
- Large passenger vehicles: 0.15 m
- Large 4WD vehicles: 0.2 m

While specifically equipped vehicles may remain stable in water of greater depths, the intention of the presented criteria is to focus on the more vulnerable of typical vehicle types in common use.

Note that for all flow conditions in all vehicle classes, the proposed vehicle safety criteria remain below the moderate hazard criteria for adults (Cox et al., 2010). This ensures that adults occupying vehicles are, in principle, safe if exiting a vehicle in floodwaters with attributes within the specified hazard ranges.

During flood events, the majority of flood deaths are vehicle related, more than half of all deaths during floods in the United States are vehicular-related (Gruntfest and Ripps, 2000). Regardless of how often people see the power of water in flash floods or are notified through community advertising that driving through high water is dangerous, there remain sections of the community who will continue with ‘business as usual’ irrespective of the flooding conditions (Gruntfest and Ripps, 2000).

2.3.1. Vehicle modernisation and scale

A limiting aspect of the advice provided in this report is that vehicle stability data sets are limited to dated laboratory data (Shand et al., 2011). The properties of contemporary vehicles have significantly changed vehicle stability criteria through modified buoyancy properties (e.g. improve dust sealing), weight and ground clearance. These changes apply to all scales of vehicles from small passenger to large commercial vehicles.

As a result, the hazard criteria provided in this report are identified as interim recommended limits based on interpretation of existing information. The criteria presented here are subject to change once acceptable data for modern vehicles becomes available.

2.3.2. Stability Criteria for Vehicles

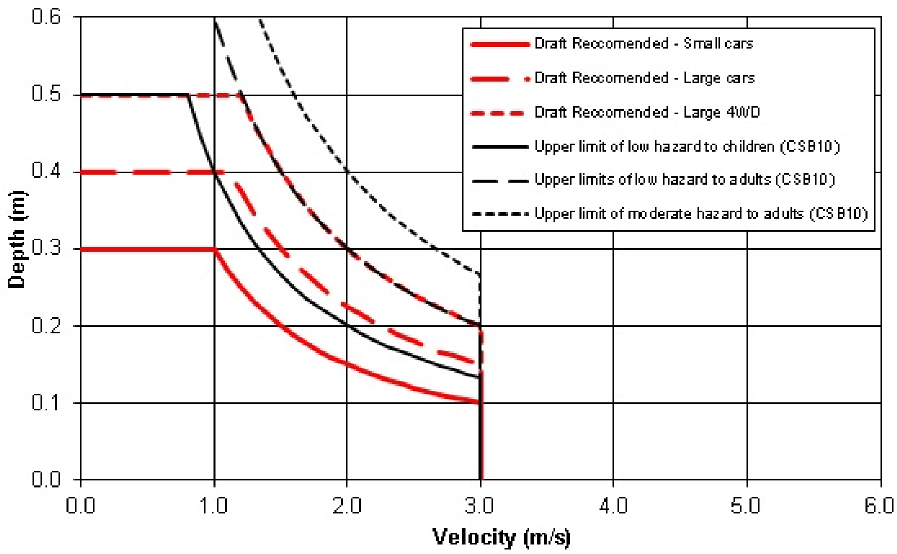
Stability criteria based on the best available information for stationary small passenger cars, large passenger cars and large 4WD vehicles in various flow situations are presented in Figure 2 6 and Table 2.

Table 1.2. Interim Flow Hazard Regimes for Vehicles (Shand et al, 2011)

Class of vehicle	Length (m)	Kerb Weight (kg)	Ground clearance (m)	Limiting still water depth[1]	Limiting high velocity flow depth[2]	Limiting velocity[3]	Equation of stability
Small passenger	< 4.3	< 1250	< 0.12	0.3	0.1	3.0	DV
Large passenger	> 4.3	> 1250	> 0.12	0.4	0.15	3.0	DV
Large 4WD	> 4.5	> 2000	> 0.22	0.5	0.2	3.0	DV

[1]At velocity = 0 ms^{-1}; [2]At velocity = 3.0 ms^{-1};[3]At low depth.

Figure 1.9. Interim Safety Criteria for Vehicles in Variable Flow Conditions (After Shand et al, 2011)



and et al (2011) concludes that the available datasets do not adequately account for the following factors and that more research may be needed in these areas:

- Friction coefficients for contemporary vehicle tyres in flood flows;
- Buoyancy changes in modern cars;
- The effect of vehicle orientation to flow direction (including vehicle movement);

- Information for additional categories including small and large commercial vehicles and emergency service vehicles;

3. Hazard Assessment for Floodplain Management and Planning

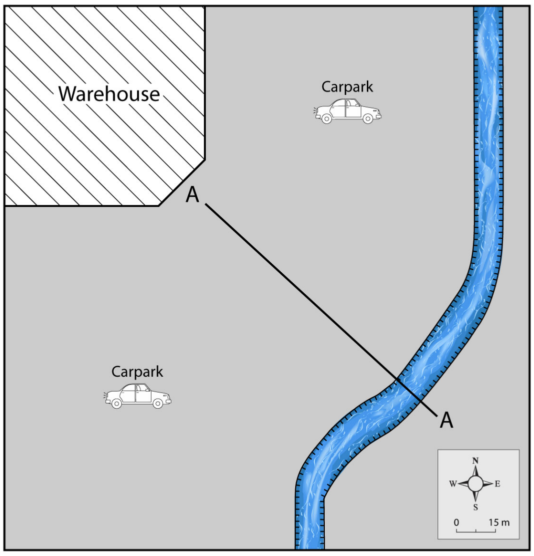
This section provides practical examples of the interpretation of flood hazard criteria for people and vehicle stability in a floodplain management context. The examples are not intended to be a comprehensive analysis of all possible circumstances, rather provide representative case studies, which illustrate the practical interpretation of flood hazard criteria in floodplain planning and management.

3.1. Example - Warehouse Car Park

A large multinational retailer has identified an existing industrial area in an inner city suburb as a suitable site for re-development as a warehouse-style retail outlet. The site is gently sloping from the northwest to the southeast and, having been previously prepared for development, is clear of vegetation. An aging, concrete-lined channel runs along the eastern side of the site.

The retailer has submitted a development application, illustrated in Figure 3 1, which conceptually has a warehouse building situated in the northeast corner of the site with the area between the building and the concrete-lined channel earmarked as a car park.

Figure 1.10. Schematic of Proposed Warehouse Development



The local council as the consent authority has identified a series of development constraints including flooding criteria. Amongst other criteria, the development must have:

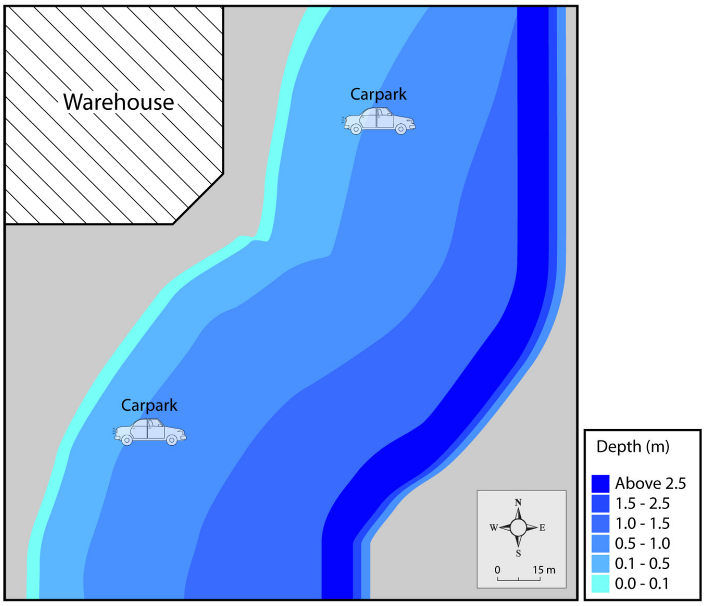
- All retail floor space above the designated flood planning level defined as the 1% Annual Exceedance Probability (AEP) flood surface plus 500mm freeboard;

- A flood free evacuation route for floods above the flood planning level; and

- All car park areas compliant with ARR flood hazard criteria for vehicle stability;

As there was no existing flood study, following consultation with Council, the developer engaged an experienced flood consultant to undertake flood modelling of the site to estimate 1% AEP flood behaviour. Flood modelling of the site for the 1% AEP event completed using industry best practice guidance as provided by ARR reference “Two Dimensional Modelling in Urban and Rural Floodplains” (EA 2012) predicted that while the warehouse building met the flood planning criteria, the car park was inundated by floodwaters. Figure 3 2 illustrates the extent of flood inundation for the existing site.

Figure 1.11. 1% AEP Flood Depth Map – Existing Site

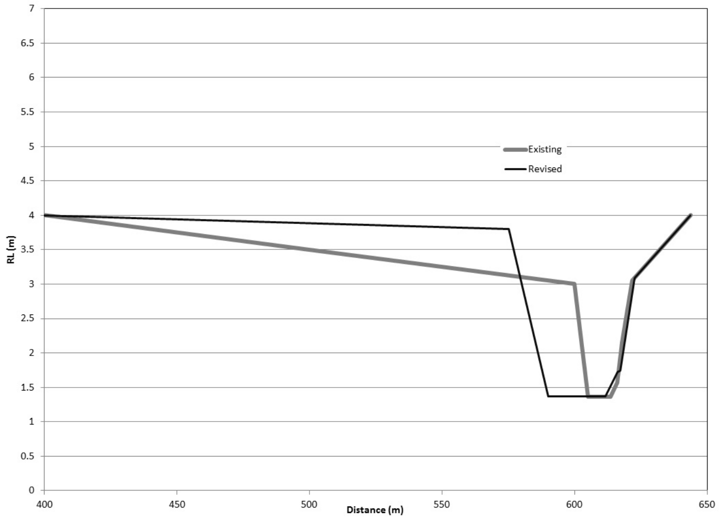


Interrogation of the flood model results to determine provisional flood hazard as the product of flood depth (D) multiplied by flood velocity (V) showed that the peak flood hazard (D.V) corresponded with the maximum inundation of the site at the peak of the flood hydrograph. Provisional flood hazard for the 1% AEP flood on the existing site as illustrated by Figure 3 3 showed that flooding in most of the area identified for car parking exceeds the ARR stability criteria for small cars defined in Table 2 and illustrated in Figure 2 6. In Figure 3 3 areas coloured blue indicate locations where small cars are likely to resist being moved by flood flows, whereas areas coloured green through red indicate areas where small cars are very likely to be pushed across the floodplain by floodwaters, with the flow having the potential to move larger cars closer to the creek channel.

Figure 1.12. 1% AEP Provisional Flood Hazard Map – Existing Car Park

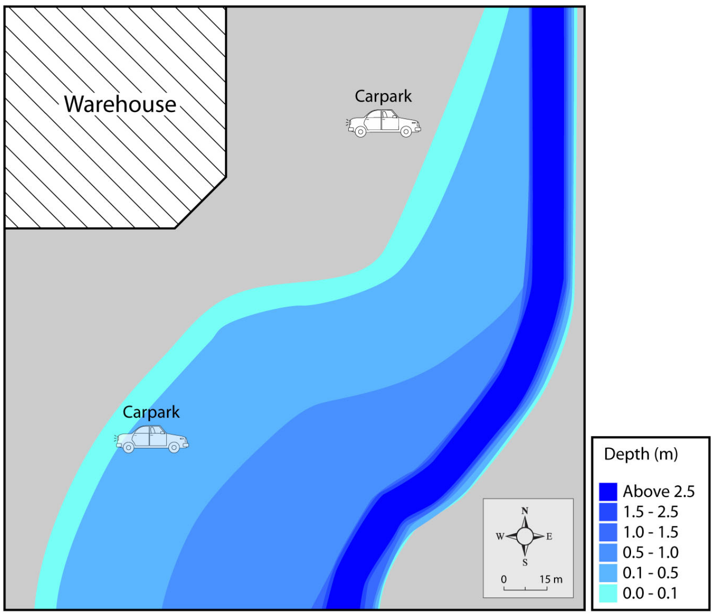
As the concrete lined channel had low environmental value, Council was not opposed to the developer's proposed adjustment of the channel flow conveyance capacity to reduce the proportion of overbank flow at the site. The developer, in consultation with the flood consultant ran a range of cut and fill scenarios through the flood model aimed at expanding the channel capacity while raising the relative ground level of the car park to the flood peak. Figure 3 4 shows the adjustment of the channel and overbank area through the car park on the longitudinal section identified as 'A-A' in Figure 3 1.

Figure 1.13. Comparison of Car Park Cross Sections (A-A)



This section is representative of a balance between the minimum volume of earthworks to meet the car parking capacity criteria for the development. The car park area adjacent to section A-A was graded to meet the natural surface areas outside of the development site. Flood modelling for the revised site including the proposed earthworks is presented in Figure 3 5. The flood model results show that the site inundation area is significantly reduced.

Figure 1.14. 1% AEP Flood Depth Map – Revised Carpark



Importantly, analysis of the provisional flood hazard as presented in Figure 3 6 shows that flood hazard for the area designated as car park in the conceptual site design now meets the ARR flood stability criteria for small vehicles. It is now unlikely that cars inundated by floodwaters in the 1% AEP flood will be pushed across the floodplain and potentially into the channel creating a possible downstream blockage hazard.

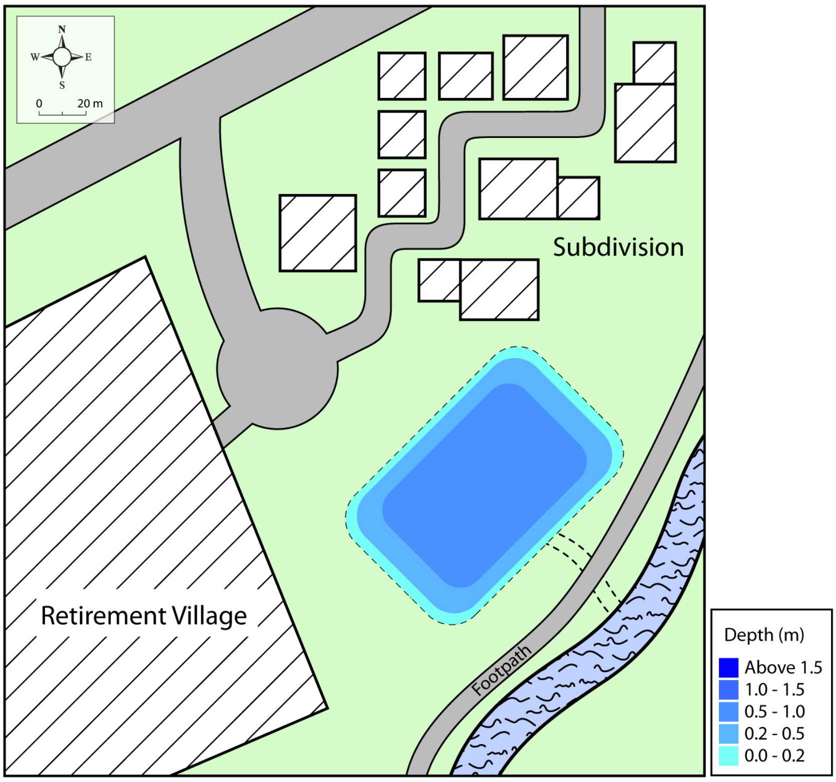
Figure 1.15. 1% AEP Provisional Flood Hazard Map – Revised Car Park

3.2. Example - Detention Basin

Council's conditions of consent for a proposed retirement village development require that on-site detention be provided so that peak flows from the site in floods up to the 1% AEP event remain similar to existing local runoff conditions.

The developer considers that a centralised detention basin on the site can be designed to have a dual use and integrated into the site grounds as a bowling green when not operating as a detention basin. Figure 3 7 illustrates the proposed design.

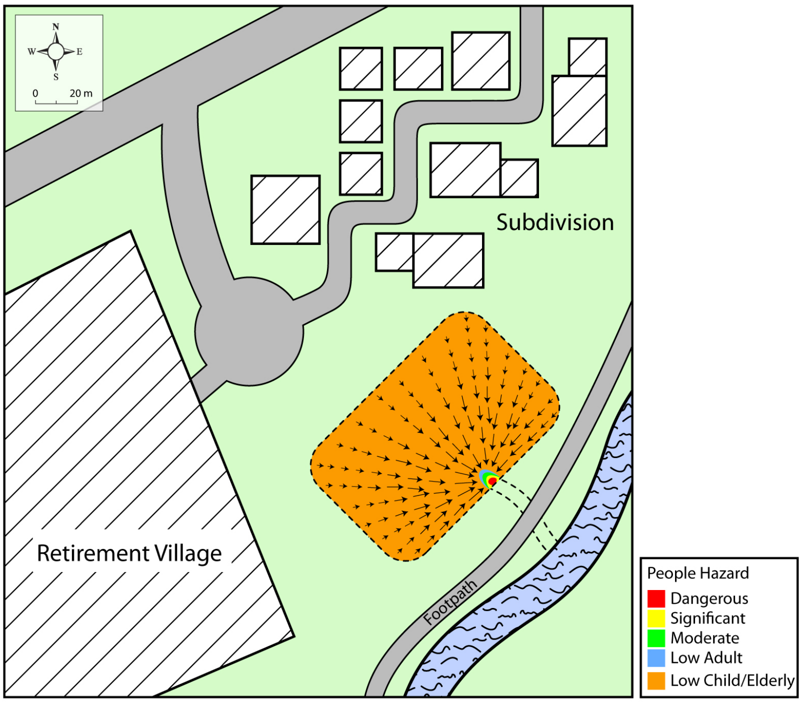
Figure 1.16. 1% AEP Flood Depth - Proposed Flood Detention Basin



As the catchment contributing runoff to the site is steep, Council's flood expert considers that there is some risk in a dual purpose design for the basin due to flash flooding in prevailing thunderstorms. Council's advice is that the developer engage a qualified flood expert to determine whether the basin meets the ARR hazard criteria for people safety.

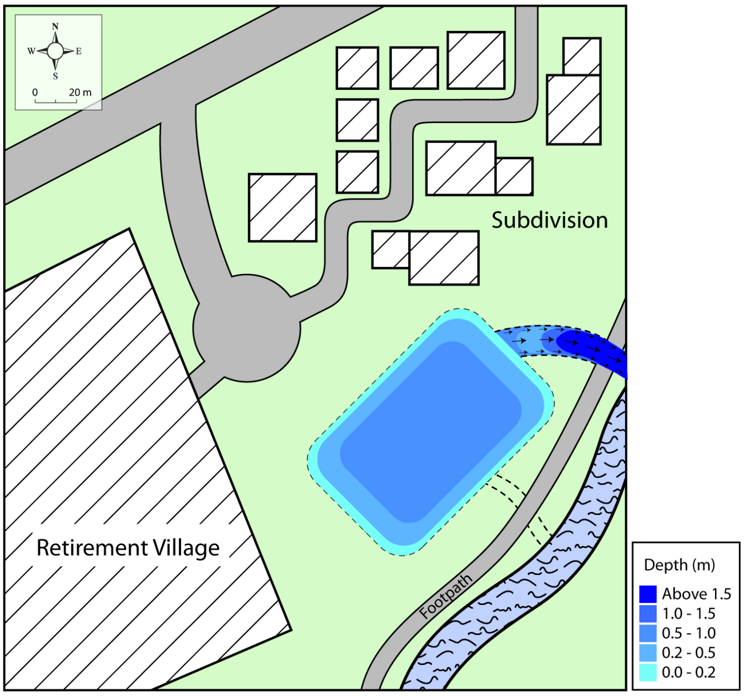
The basin design philosophy is that the local catchment stormwater will collect both overland flows and also surcharge from the pit and pipe stormwater system. If the basin capacity is exceeded, flows spill at a designated location and flow overland to the adjacent creek channel. Flows that remain in the basin discharge through a grated pit in the lowest location in the basin floor.

Figure 1.17. 1% AEP Provisional Flood Hazard Map - Proposed Flood Detention Basin



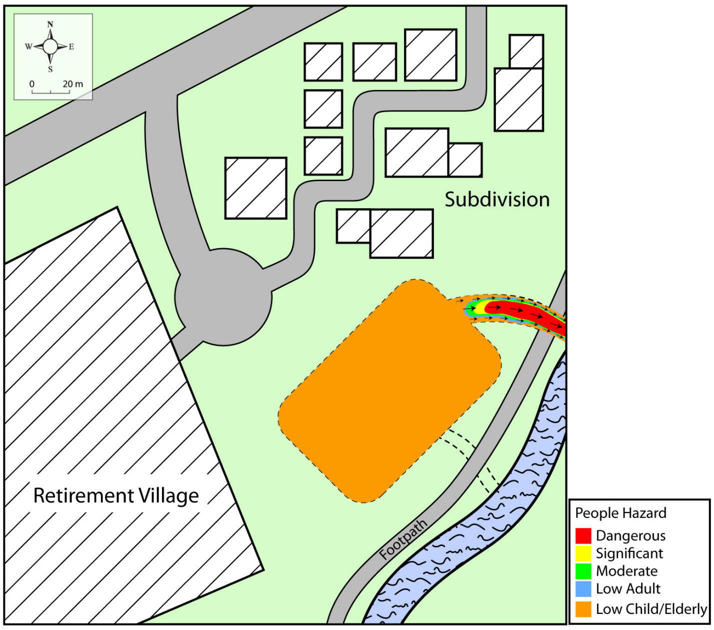
An assessment of the provisional flood hazard (flood depth multiplied by the flood velocity) is presented in Figure 3 8. When compared to flood hazard criteria presented in Table 1 and Figure 2 4 the provisional hazard meets the safety criteria for the elderly in most areas of the basin. This is because at full capacity, the basin is no greater than 0.5m deep. Analysis shows that a dangerous flood hazard is likely to occur near to the basin's outlet pit when the basin begins to drain at full capacity.

Figure 1.18. Basin Overflow Spillway – Flood Depth



Further analysis of the full design presented in Figure 3 9 shows that when the basin capacity is exceeded overflows will cross a public footpath adjacent the creek reserve. Provisional flood hazard analysis of the overflow path presented in Figure 3 10 shows that the flood hazard in the flow path will exceed the people stability criteria for adults and be a dangerous hazard to passing pedestrians.

Figure 1.19. Provisional Flood Hazard Map – Basin Overflow Spillway



As a result of the analysis, Council consent criteria require signage to be placed in appropriate locations informing residents of the retirement village and the public passing the site on the public footpath of the dual purpose use of the basin and the danger of entering floodwaters when the basin is inundated. Further, Council's consent criteria require that the developer upgrade the footpath to include a bridge of suitable span over the basin spillway flow path so that safe thoroughfare of the footpath can be maintained during flood conditions.

4. Conclusions and Recommendations

Recent flood events on the east coast of Australia in 2010 and 2011 have highlighted that people continue to be exposed to dangerous and life threatening flow conditions in urban and rural floodplains. While floodplain management activities are continually decreasing the community's exposure to floodwaters, ongoing human activity in floods is largely unavoidable while significant areas of existing development and transport infrastructure in Australia remain flood prone.

This report has summarised and explained limitations of recent analysis of flood stability thresholds for pedestrians and vehicles in floodwaters. Proposed flood hazard criteria based on the stability of people and vehicles in flood flows as described by recent reports for Australian Rainfall and Runoff have been summarised.

The presented floodplain management examples demonstrate the practical application of the criteria. While not exhaustive of all cases, the examples show how the criteria can be pragmatically applied to reduce the community's exposure to flood danger.

4.1. Recommendations

The flood hazard criteria provided in this report are interim as they are based on limited and dated information. This report should be updated immediately on the availability of improved vehicle stability criteria based on testing of contemporary vehicles. This being the case, users of this report should ensure that they are using the most up to date information.

5. References

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