DEVELOPING A PRACTICAL SHELTER IN PLACE POLICY: A CASE STUDY IN FAIRFIELD

S Molino[1], L Gray[2], F Dall'Osso[1]
[1] Molino Stewart, Parramatta, NSW
[2] Fairfield City Council, Sydney, NSW

Following the Second World War, the urban growth of Sydney spread into the Fairfield Local Government Area (LGA) throughout the 1950s, 1960s and 1970s and took place with little consideration of flooding. Although some flood mitigation works had already been constructed, it was the impacts of the 1986 and 1988 floods which focused attention on flood mitigation.

The LGA has significant exposure to flooding because it is bounded by the Georges River and Prospect Creek and is dissected by their tributaries as well as some tributaries of South Creek. There are also significant areas of overland flow.

The LGA has been at the forefront of using detention basins, house raising, planning instruments and community education to mitigate flood impacts. Nevertheless, there remains a legacy of urban areas with significant flood risks.

In more recent years, urban redevelopment has taken place with multi-unit housing replacing single dwellings on large blocks and older industrial sites being redeveloped for housing. The rate and density of urban consolidation is accelerating under the Sydney Metropolitan Strategy. This presents both a challenge and an opportunity in regard to managing flood risks.

Risk to life has become an issue of considerable debate in recent decades. The NSW SES promotes evacuation with "shelter in place" (SIP) only for existing development where evacuation cannot be effected safely. However, a blanket ban on sheltering in place for new development would not be practical in Fairfield LGA, where warning times are short. Such a prohibition would sterilise large areas from redevelopment.

Furthermore, redevelopment presents an opportunity to reduce the risks associated with isolation through the implementation of appropriate structural and non-structural flood prevention measures. In this paper, we present a preliminary draft methodology for developing a Shelter-in-Place Policy, including quantitative analyses, to identify appropriate risk thresholds, and to guide redevelopment in Fairfield LGA while appropriately managing risk to life.

Introduction

Fairfield City Council, located in south-western Sydney, straddles parts of the Prospect Creek, Georges River and Hawkesbury-Nepean River catchments, and is home to approximately 190,000 people (Figure 1).

The south eastern part of the LGA has the greatest flood hazards as this is where Prospect Creek and Cabramatta Creek meet the Georges River. This is the area most at risk from mainstream flooding, particularly south of the Granville railway line, where the flooding behaviour is predominantly driven by the Georges River (Figure 2).

Figure 1: Fairfield LGA

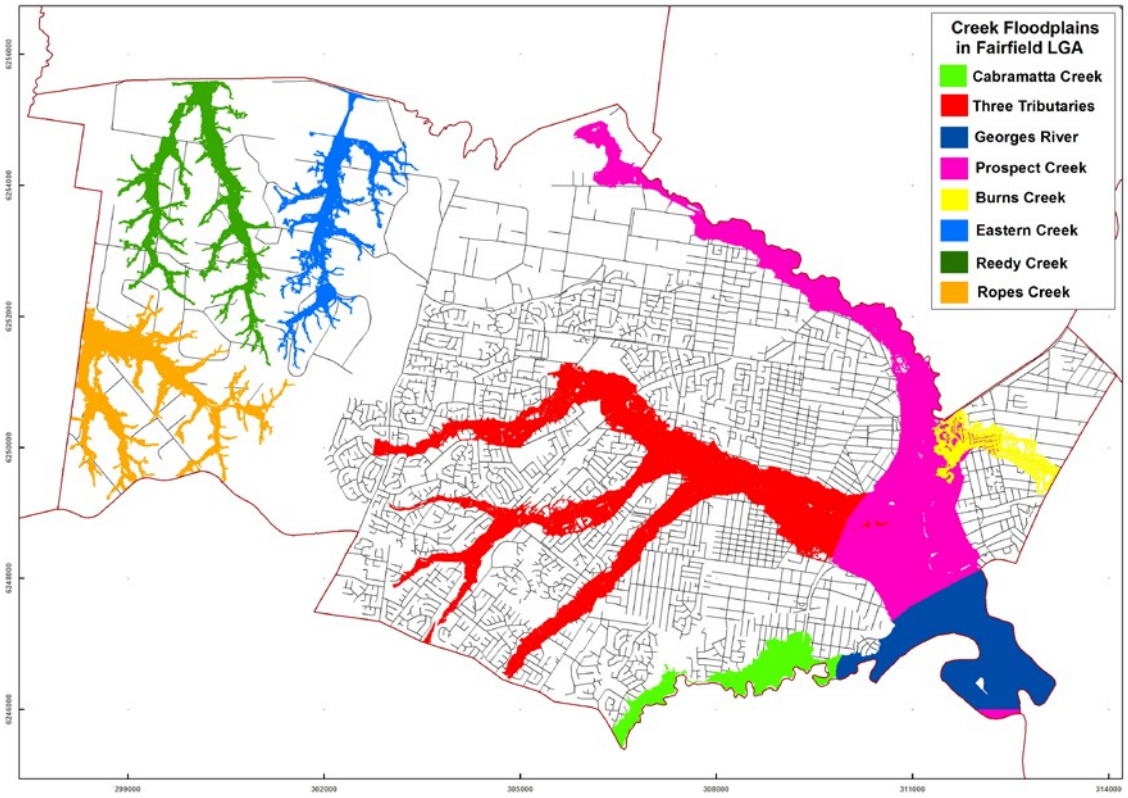

Figure 2 Floodplains within Fairfield LGA

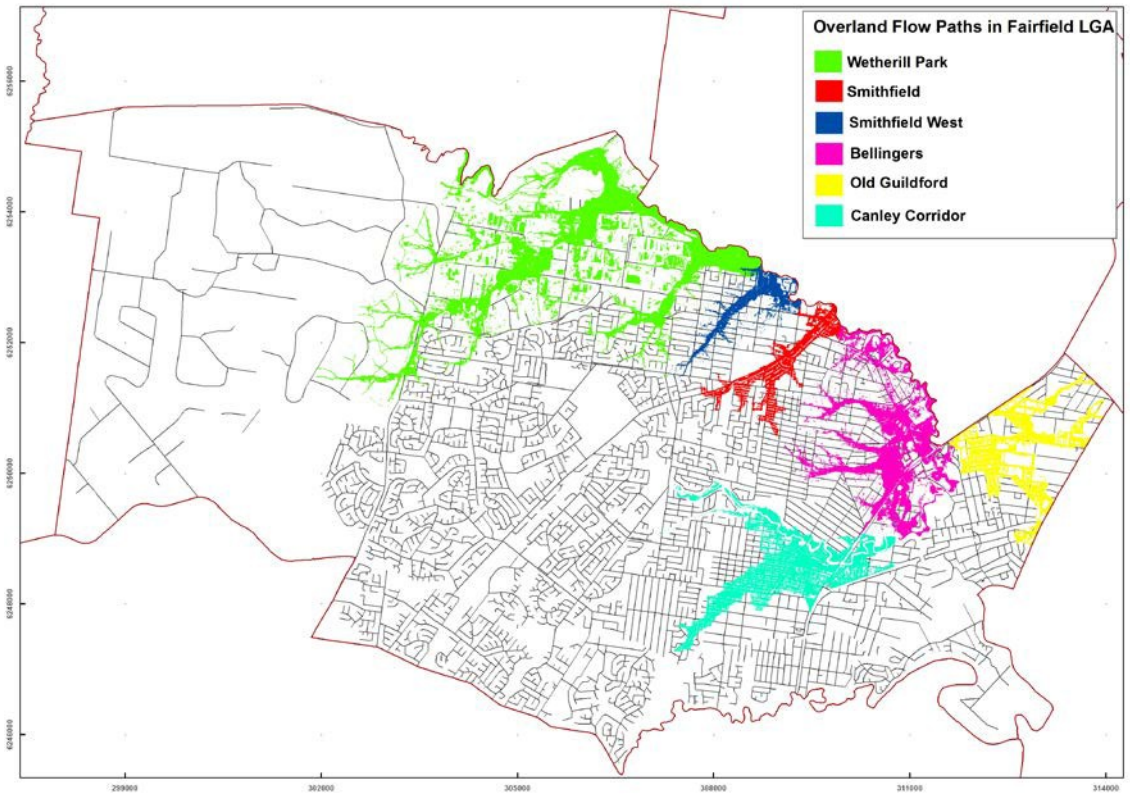

Figure 3 Overland flows within Fairfield LGA

In addition to the Georges River and its main tributaries, the LGA is also exposed to flooding from minor creeks, such as Burns Creek and Orphan School Creek and its tributaries (Green Valley Creek and Clear Paddock Creek), located respectively east and west of Prospect Creek, and from six overland floodplains, all discharging into Prospect Creek (Figure 3). These are:

- Wetherill Park
- Smithfield
- Smithfield West
- Bellingers (Fairfield CBD)
- Old Guildford
- Canley Corridor

Flood studies show that as of September, 2012, 4,399 properties are at risk from mainstream flooding in a 1% AEP flood event, and 14,415 (25% of registered land parcels in the LGA) are at risk during a probable maximum flood (PMF).

Additionally, it is estimated that 5,122 properties are affected by overland flooding during the 1% AEP event, with up to 8,257 at risk in the PMF.

Note that these numbers include properties at risk of both mainstream and overland flooding so there is some double counting. Rural properties in the South Creek catchment were not part of the SIP investigations.

Project Objectives

The aim of the project was to:

- evaluate the suitability of SIP as a preferred flood response in Fairfield LGA
- identify areas where SIP would not be appropriate
- recommend development controls to reduce risk to life to as low as reasonably practical where SIP is proposed.

The project went through the following steps:

- A review of existing Australian and NSW State policies related to flood emergency response strategies and SIP.
- An analysis of the flood behaviour in the study area and delineation of areas not suitable for SIP
- A review of the risks associated with SIP and practical considerations to reduce those risks
- Recommended guidelines to minimise risk to life where SIP is proposed.

SIP Guidelines and Policy

Emergency Management Australia (EMA) Manuals and Handbooks

EMA Manual 20 – Flood Preparedness (Commonwealth of Australia, 2009) includes a dedicated section discussing SIP as an alternative to evacuation, in case of flash flooding. Specifically, the Manual states that:

Evacuation is a suitable strategy only when, by evacuating, people are not exposed to greater risks than they would face by remaining where they are.

EMA concludes by recommending a mixed strategy to be adopted, where shelter in place is to be preferred over evacuation only if "evacuation is likely to be more dangerous than sheltering in place".

EMA's Handbook 7, titled "Managing the floodplain: a guide to best practice in flood risk management in Australia", refers to SIP as "a last option, normally only appropriate for existing flash flood environments". The Handbook indicates that buildings suitable for sheltering in place should be designed to resist flood impacts (up to the PMF), and have a habitable floor area above the PMF level.

Such buildings are generally constructed to "replace flood-affected development of the same density", which implicitly rejects the idea of redeveloping a flood-affected area to increase its population density, even if the new buildings are suitable for sheltering in place. The reasons behind this approach are the additional risks associated to sheltering in place:

> *Even in the case of shelter in place, occupation during a flood may be without water, sewerage, electricity, communications and other services, and the house will be isolated (and there is no safe duration of isolation). These factors all increase the risk of a need for rescue or on-site assistance due to, for example, the need for medical attention, on-site risks such as house fire (exacerbated by lack of electricity and difficult to extinguish*

due to isolation) and the need for basic supplies. These factors can impose additional loads on emergency services during floods.

NSW Government

Section 117 (2) of the Environmental Planning and Assessment (EP&A) Act 1979 permits the Minister for Planning to issue directions in relation to the making of Local Environmental Plans (LEPs). Several of these have been issued including Direction No. 15 (2007) – Flood Prone Land, included in Planning Circular PS07-033. The Circular also comprised a Guideline, titled "Guideline on development controls on low risk areas—Floodplain Development Manual".

The Guideline indicates that councils should use the 1% AEP flood event to determine Flood Planning Levels (FPL) for residential development, and that no other flood controls should be adopted above the 1% AEP event level, unless there are exceptional circumstances. As development controls in relation to sheltering in place would be applied to development above the 1% flood level, any Council in NSW wishing to apply such controls would need to demonstrate that exceptional circumstances apply in its particular case.

Fairfield City Council was granted exceptional circumstances status due to its flood history and likelihood of severe flood effects above the 1% AEP.

The NSW Floodplain Development Manual (FDM) (DECC, 2005) is built upon a risk management approach. It promotes quantification of the probability and the consequences to determine the risk. The manual promotes management measures to reduce the risk, either by decreasing the probability, the consequences or both.

Appendix N of the FDM discusses evacuation. Although there is no explicit reference to SIP as a valid emergency response alternative, the FDM recommends that in planning evacuation strategies Councils and SES must consider "*the time available to complete evacuation before inundation occurs or evacuation routes are lost*".

Appendix N goes on to say in relation to private flood response plans,

> *"Any form of response planning, but private planning in particular, is unreliable as a long term risk mitigation measure…Implementation of a plan depends explicitly on a thorough understanding of the risk and of the roles and responsibilities of participants. To experienced emergency managers these are areas well known for their uncertainty and the SES trains and practices continually to minimise their impact. Businesses and households will have a much lower capacity to undertake the necessary training and practice and so the plans they own will be much more prone to failure."*

NSW State Emergency Service

The NSW SES does not support SIP as a primary emergency response and has articulated that position through a number of publications by SES personnel (Opper and Toniato, 2008, Opper et al. 2011,) and through the Australasian Fire and Emergency Service Authorities Council (AFAC, 2013).

The NSW SES holds that evacuation is the preferred emergency response for floodplain communities, where this can safely be achieved before the arrival of floodwaters. Where this

is not possible it might be safer to remain inside the building, though sheltering-in-place has a number of direct and indirect risks associated with it. The NSW SES does not support intensified new development which relies upon sheltering in place to manage risk to life.

Local Government

To date, few NSW Councils have adopted a flood management policy that specifically addresses the issue of SIP. Three existing SIP policies in NSW are:

Tweed Shire Council - Flood Risk Management Policy – version 1.0, 2007. Specifies necessary flood emergency controls for different types of land including sheltering in place using an appropriate PMF refuge.

Pittwater Council - Pittwater 21 Development Control Plan, Appendix 15 Flood Emergency Response Planning Policy for Development in Pittwater.

The purpose of the policy is to establish "*minimum requirements for evacuation and shelter-in-place strategies for new developments, including additions and alterations to existing developments*". The most appropriate emergency response strategy is to be proposed (by the developer) and assessed (by the Council) in consideration of:

- The flood hazard to life, which is based on the flood behaviour in a PMF.
- The land use, which accounts for the number and demographic of people exposed to flood risk in each building-use category.

Newcastle City Council - Flood Policy, 2003. It acknowledges the flash flooding nature of the catchments and allows SIP for new developments where there is insufficient time to evacuate safely.

The policy analyses the risk to property and to life, with the latter being assessed using the PMF and five "Loss of Life Hazard Categories" (L1 to L5). The life hazard categories are obtained by combining warning availability, possibility to evacuate, rate of rise of floodwaters, flood duration, type of escape route, nature of encasing floodwaters, evacuation needs and evacuation problems. The life hazard categories are then cross compared with five hydraulic behaviour classes to determine whether evacuation or SIP is the appropriate response strategy.

Practical Considerations

The reasoning behind the NSW SES position on sheltering in place makes perfect sense for new developments which can be relatively frequently isolated by high hazard floodwaters for a few days. These present serious indirect risks to life because of the challenges of maintaining essential services and supplies, the chance of medical and fire emergencies not being able to be responded to and the likelihood that stranded building occupants will want to be rescued or try and traverse floodwaters themselves. There is also the risk that people will try and traverse floodwaters to reach their dwelling which is isolated but not flooded. The more frequent the flooding and the longer its duration the greater the chance of these incidents occurring.

Ironically, it is developments of this nature which have been approved by the Courts in Queensland (Arora Constructions v Gold Coast City Council) and NSW (Neate v. Shellharbour (2007) and Neate v Wollongong City Council (2006)).

However, a blanket ban on any sheltering in place for new development would see developments which are isolated for a few minutes by low hazard flood water in PMF not being approved. Such developments clearly do not pose a significant risk to life.

Furthermore, there are locations where existing development has a low probability of above floor flooding by high hazard floodwaters but no practical means of escape to a location above the PMF either off site or in the existing building. Redevelopment affords a means of creating a safe, on-site shelter but to provide a shelter above the PMF higher density dwellings need to be constructed. There is therefore a trade-off between reducing the risk to individuals and increasing the number of individuals at risk.

Further flaws in a blanket ban on sheltering in place can be illustrated by considering the nature of flooding in Fairfield LGA. Fairfield has several creeks which border or traverse the LGA and numerous overland flow paths which lead to those creeks. The ones for which flood studies have been completed are shown in Figure 2 and Figure 3. Given the small size of the LGA it is anticipated that during an extreme rainfall event all of these catchments will be flooding significantly, as was the case in 1986 and 1988, which were not extreme events.

When the PMF extent of all of the creek and overland flow paths are placed on the same map (Figure 4) it is clear that much of the LGA is and those areas which are not flooded are effectively isolated by floodwaters.

When the NSWSES concerns are looked at one by one the following emerges.

Loss of Essential Services

Loss of services such as electricity, gas and telecommunications are likely to happen at a network level when a substation, pressure reduction station, telephone exchange or mobile phone tower gets flooded or damaged by associated wild weather. The loss of services will not discriminate between flooded properties and non-flooded properties in Fairfield LGA.

Lack of Basic Supplies

Water supply in Fairfield is unlikely to be lost during a flood and if it is, it too will not discriminate between flooded and non-flooded properties. The duration of flooding is such that people are unlikely to run out of food or medications.

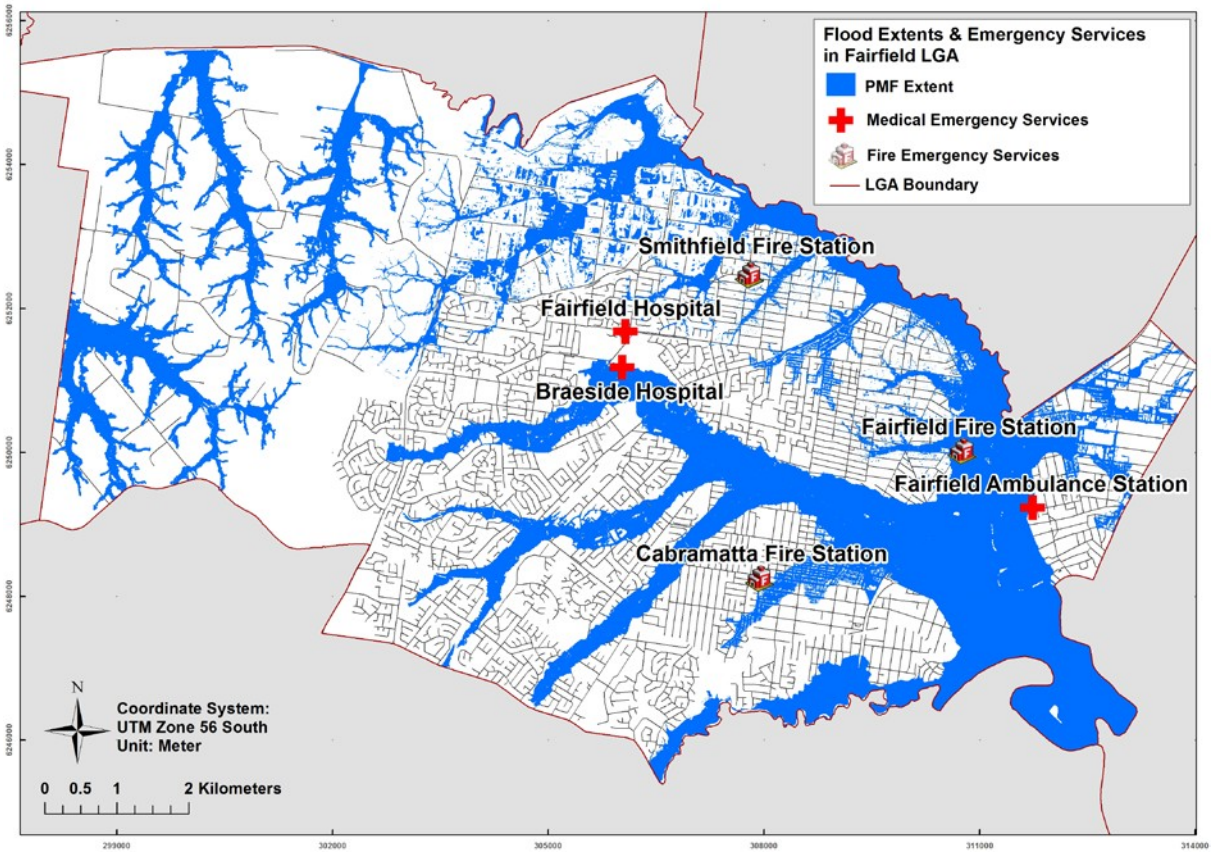

Figure 4: Health and Fire Facilities in relation to flood extents

Traversing Floodwaters

While there is a risk that people will try and traverse floodwaters to leave or enter dry premises which have flood waters surrounding them, there is no evidence to indicate that this will be more likely should the water be lapping at the base of the building or at the end of the street. If people who live in Fairfield are wanting to get home to a dry dwelling, they are just as likely to risk travelling through floodwaters to get there, whether their dwelling is in the floodplain or not. The most hazardous places to traverse floodwaters in the LGA are where roads cross the creeks not only where there is development.

Medical Emergencies

There is a large public hospital in Fairfield but as can be seen in Figure 4 it is isolated from many of the non-flooded areas of Fairfield. There is a private hospital nearby but it may be affected by flooding. There are other public hospitals at Westmead, Liverpool and Bankstown but it would be necessary to cross Prospect Creek or the Georges River to reach any of them. Furthermore, the ambulance station is on the opposite side to Prospect Creek to Fairfield hospital and it is in the Prospect Creek floodplain. While access to hospital during a flood is a legitimate concern for those sheltering in place, it is not really any different for many of those in the LGA who are outside the floodplain.

Fire Emergencies

As with medical emergencies, many parts of Fairfield would be isolated by floodwaters from being reached by fire appliances although there are a number of fire stations so the problem is not as severe. And, as with the ambulance station, there is a fire station within a floodplain. The other difference here is that should there be a fire in a building that is not surrounded by floodwaters then the occupants can leave the building without risking entering directly into hazardous floodwaters.

Evacuation

The rate of rise and extent of flooding in the most extreme events in Fairfield means that emergency evacuation centres may not get set up and evacuees would generally have to take shelter in other private premises. Because the floodplain is so extensive and not well understood by the community, there is a risk that people will evacuate to premises that in turn need to be evacuated.

Finally, most of the flood affected areas are residential and most of the occupants, if at home, are likely to want to remain within their dwellings rather than evacuate.

Existing Risks

The reality is that many of the existing residential, commercial, industrial and institutional buildings in Fairfield LGA which can be flooded do not have suitable safe refuges for occupants in the full range of floods which can affect those buildings. Some may pose a significant risk to life to occupants in events smaller than the 1% AEP event.

Incentives to Rebuild

The most effective way to remedy the flood shelter deficiencies in existing buildings is for them to be rebuilt. While there is a renewal of housing and commercial stock going on throughout Fairfield, the rate of renewal is slower in areas where it is only possible to replace like for like, and even then there is a preference for renovation over rebuilding. In fact, any planning controls requiring an existing building to be replaced with a like building with a higher floor level can be a barrier to building replacement.

More rapid rebuilding takes place when intensification is permitted and the financial benefits of redevelopment cover the costs of making premises safer to shelter in during a flood. While such redevelopment reduces the risk for each individual occupying a building at a particular location it does increase the number of individuals exposed to that risk.
The challenge of any redevelopment within a floodplain is finding an appropriate balance between reducing the risk to individuals and increasing the number of individuals at risk.

Fairfield's Approach

Fairfield City Council is investigating if permitting redevelopment within the floodplain can deliver socio-economic benefits generally as well as reduce risks to individual lives during a flood, even where evacuation is not practical.

It also recognises the NSW SES's legitimate concerns about indirect risks to lives when people SIP. However, as outlined above, many of these risks in Fairfield LGA are similar whether development is on the floodplain or outside it.

Having determined that some development with SIP is appropriate, the next consideration was where on the floodplain is that appropriate and are there mitigation measures which must be incorporated in a development.

Risk quantification was used to determine where intensification should be prohibited and what form of mitigation measures should be adopted in other areas.

The particular flood parameters which were used to quantify risk were:

- flood probability
- flood hazard
- isolation duration.

These were mapped across the LGA and draft "risk to life" zones with accompanying draft risk to life development controls were developed. In addition, consideration was given to the type of development and whether the occupants had higher than average risks due to either their vulnerability or the likelihood that they would try to traverse floodwaters.

Flood Probability

In accordance with the NSW FDM, as advised by the NSW SES and consistent with other NSW council policies, the PMF was adopted to define the limits of the risk to life analysis. The next smallest event available universally across the LGA was the 1% AEP event and it is also used to set flood planning levels. Finally, 5% AEP event, which was also universally available, was used to define areas most likely to flood.

Flood Hazard

Flood hazard, the product of flood depth and velocity, was classified using the method proposed by McLuckie et al (2014) (Figure 5). It was acknowledged that it is advisable not to walk or drive through floodwaters of any depth or velocity, but it was also recognised that even with shelter in place provisions in place some people may choose or need to traverse floodwaters. For example

- Fire appliances may need to reach a burning building
- Ambulances may need to reach people needing hospitalisation

- People may decide to enter or leave a building through floodwaters despite advice to the contrary.

As flood hazard classes H1 and H2 are not a threat to the stability of large vehicles and pedestrians, it was assumed that these categories would pose less of a risk than higher hazard categories should people decide to traverse floodwaters. Given the low probability of the PMF, H1 or H2 flooding in this event was considered to have an acceptable risk to life as the consequences of people entering such water are most likely to be benign.

Where isolation by a flood hazard of H3 (or higher) would occur during a PMF, duration was also taken into consideration in determining the threshold between tolerable and unacceptable risk to life.

In the case of the 1% AEP flood, given the probability of event it was recommended that isolation by flooding in any category would be unacceptable. A case could be made however that such isolation is tolerable and this is currently under consideration by Council and sensitivity testing using the 1% AEP instead of the PMF was being undertaken at the time of writing.

Isolation by the 5% AEP flood was identified as definitely being unacceptable.

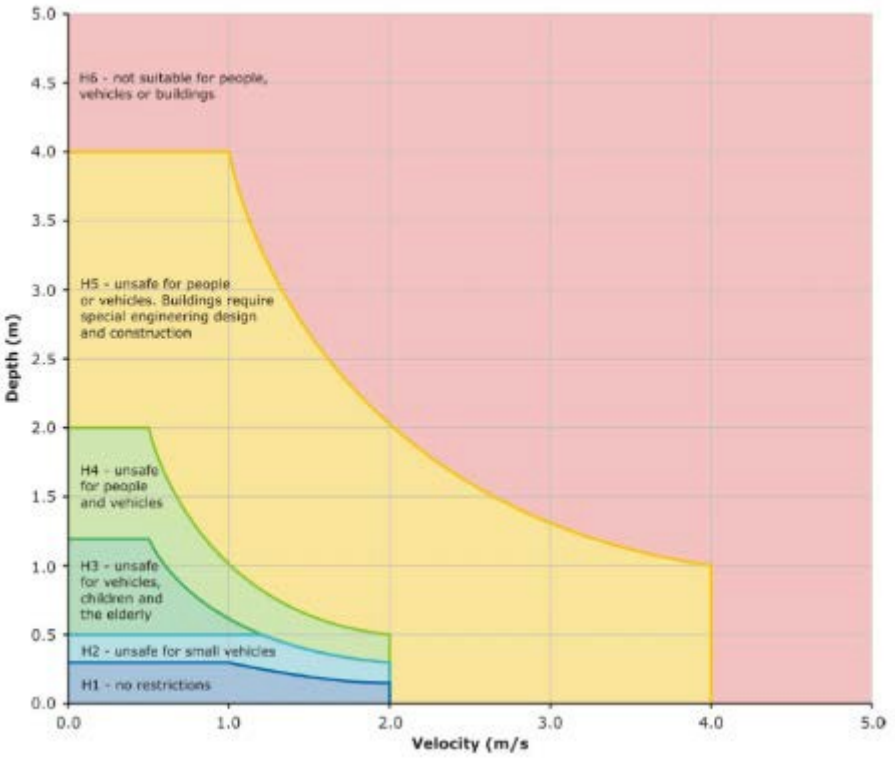

Figure 5 Flood hazard classification proposed by McLuckie et al. (2014). In categories H1 and H2 there is no risk to pedestrians.

Duration of Isolation

Australasian Fire and Emergency Service Authorities Council (AFAC) states that there is, “no known basis for determining a tolerable duration of isolation” (AFAC, 2013). While that statement is correct, it does not mean that any duration of isolation should be unacceptable.

To take an extreme case, it would be clearly unreasonable to suggest that it is unacceptable for an occupied building to be isolated for five minutes by ponded ankle deep water during a PMF. At the other end of the spectrum it is clearly unacceptable for an occupied building to be isolated for days by high hazard floodwaters in a 10% AEP event.

To arrive at acceptable, tolerable and unacceptable risk to life thresholds for the attribute “duration of isolation” the following logic was used.

According to the NSW SES Timeline Evacuation Model (Opper et al, 2009), at least two hours are required by the general population to act in response to a perceived flood threat. This means that if someone is isolated in a building by floodwaters for less than two hours, by the time they have initiated an evacuation the isolation would have ceased.

There is a low probability that people would try and exit the building during this time. There would also be limited opportunity for people wanting to enter the building to do so and many people are likely to be willing to wait for up to two hours.

It was determined that if isolation exceeds two hours, the probability of people wanting to leave or enter a building would increase significantly although that may depend on how they are using the building.

In addition to this, the longer the isolation is, the higher is the probability of secondary risks associated with SIP, such as accidental fires, medical emergencies, need for food, need to access telecommunications.

The second isolation duration threshold which was selected was eight hours. Eight hours is the typical duration of a night’s sleep, or a work shift and in many situations the isolation could come and go and the building occupants have no need to enter or leave the building in that time. A duration of isolation of between two and eight hours was therefore classified as tolerable although less tolerable than less than two hours of isolation.

Accordingly, in this category it is necessary to put in place mitigation measures to reduce the desire of occupants to leave the building as well as to reduce the likelihood of secondary risks to lives.

In some cases, particularly where the flooding is primarily driven by large creeks (e.g. Prospect Creek), the duration of isolation with flood hazard greater than H2 can exceed 8 hours. If the isolation exceeds eight hours, it was considered that the likelihood of building occupants trying to leave would increase significantly.

It was recommended that these durations of isolation be applied in a PMF to determine what was acceptable, tolerable and unacceptable. At the time this paper was written sensitivity testing was being undertaken to see what difference it would make if the 1% AEP event was used to define these thresholds.

Development Type

The type of building and the occupants' relationship with it can have a significant influence on whether they are willing to shelter within the building or they will want to leave. People are generally more likely to be willing to shelter within the residential dwelling where they live than in a commercial, industrial or institutional building where they shop, work or study.

Residential buildings can be occupied at any time of day while other buildings are often vacant for 50% of the time or even more. This means that the probability of people being isolated within a non-residential building is significantly less than people being isolated in a residential building.

A further consideration is the vulnerability of the occupants of a building. There are likely to be more vulnerable people (children, elderly, people with disabilities) in residential buildings than in commercial buildings and the occupants of non-residential buildings are likely to be awake when flooding occurs.

People in health care and aged care facilities are more vulnerable to stressors, are more likely to require acute medical care and may be dependent on electrically driven life support or enhancement devices. At the same time, these facilities have trained medical staff, stocks of medications and food. They also often have emergency power supply arrangements.

These matters were also taken into consideration when determining appropriate development controls within various flood isolation risk zones.

Suggested SIP Policy and Controls

Using the abovementioned thresholds, four "risk to life" zones were mapped. These are shown in Figure 6 for the PMF. Equivalent mapping for the 1% AEP flood had not been completed at the time of writing.

- Green Zone (negligible risk to life) where in a PMF floodwaters would not exceed a hazard level of H2.
- Yellow Zone (low risk to life), where in a PMF floodwaters would exceed a hazard level of H2 for less than 2 hours.-
- Orange Zone (medium risk to life), where in a PMF floodwaters would exceed a hazard level of H2 for a duration of between two and eight hours

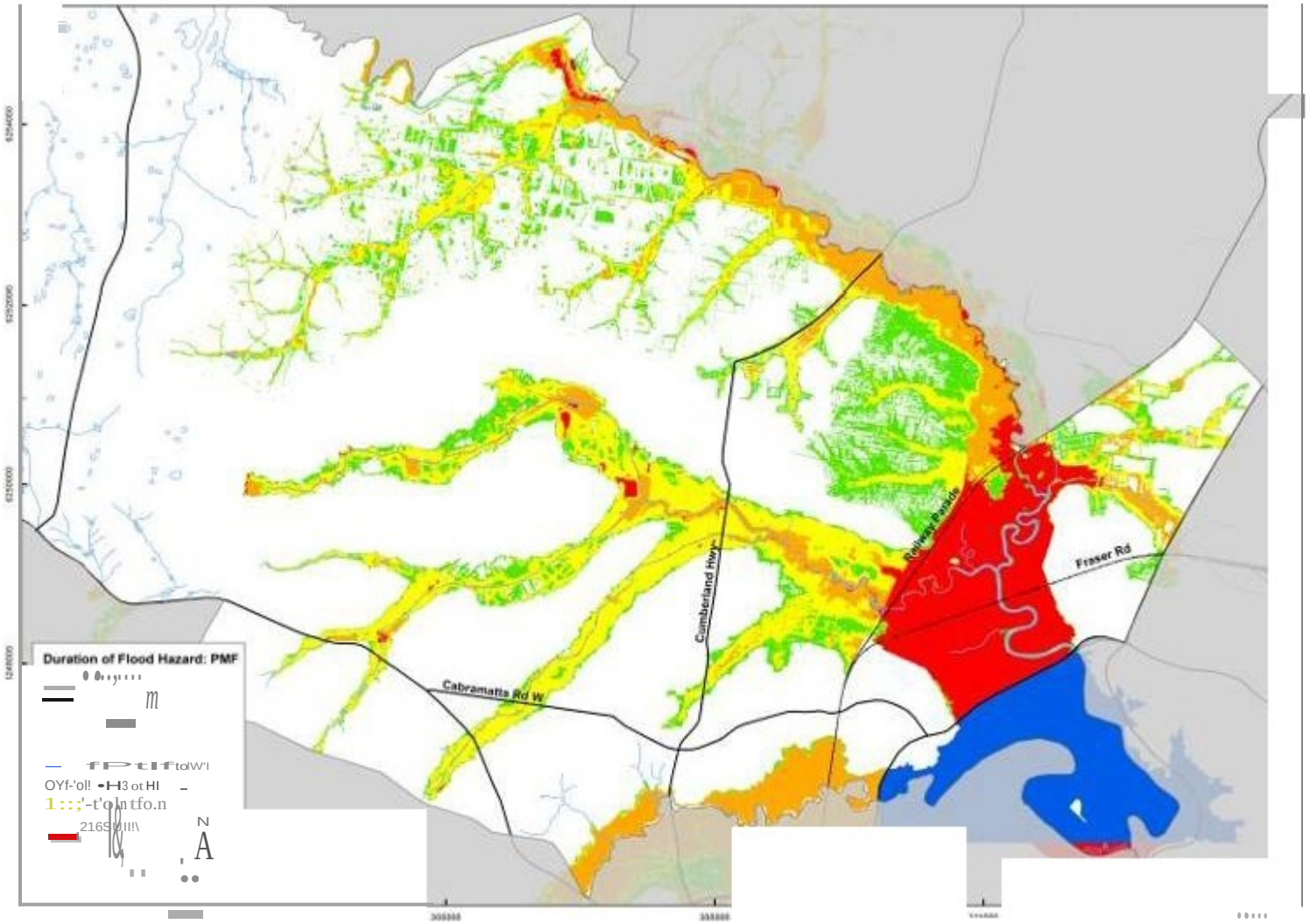

Figure 6 Flood Risk to Life Zones -Whole LGA

- Red Zone (high risk to life). These are areas where in a PMF floodwaters would exceed a hazard of H2 for longer than eight hours.

Areas affected by Georges River flooding were excluded from the analysis because it was already known that there areas can be subject to high hazard flooding for days.

Development controls were then proposed for each of four different development types within these four zones. The four development types have been chosen to align closely with the land use categories in Schedule 2 of Chapter 11 of the Fairfield Citywide DCP 2013. They are:

- Residential Replacement – residential development as defined by DCP but where a building is being replaced by a building with the same number of bedrooms
- Residential Intensification – residential development as defined by DCP but where the occupancy potential of the lot is being increased
- Commercial or Industrial – as defined by DCP
- Critical or Sensitive – this combines both Critical Uses and Facilities and Sensitive Uses and Facilities from the DCP

Table 5 is a reference matrix setting out recommended risk to life development controls for each development type within each risk to life zone. Table 6 provides a list of each of the risk to life controls with an explanation of the rationale behind the control.

It should be noted that the mapping shows the extent of the risk to life categories but any one development may straddle more than one risk to life category. Where this is the case then it is the risk to life category where the building's common pedestrian egress is situated which determines the risk to life planning controls which apply to the development.

Applying the controls based on the isolation of the pedestrian egress will encourage building designs which have the lowest possible risk of isolation in a particular location. It is also likely to encourage the consolidation of lots or the elevated connection of developments so that they require less onerous development controls. This will achieve better risk to life outcomes.

Consideration could also be given to offering planning control concessions such as increased building heights or floor space ratios to developments which remove existing, inappropriate development from areas with high risks to life.

While some of the recommended controls require habitable floor areas above the PMF, in many locations this can be achieved by building at the FPL because the PMF is less than 0.5m higher than the 1% AEP. Where the PMF is less than 2.5m above the 1% AEP any requirement to have shelter above the PMF will be achieved by habitable floors on the first floor and above.

Status

It must be stressed that these were a draft set of suggestions from the consultants to the Council at the time of writing and sensitivity testing using the 1% AEP event has been requested as well as mapping of the impact of such development controls across the LGA.

Table 1. Recommended risk to life controls for development type and risk to life category.

	GREEN ZONE PMF, Hazard ≤ H2	YELLOW ZONE PMF, Hazard >H2, Duration < 2h	ORANGE ZONE PMF, Hazard >H2, 2h< Duration <8h	RED ZONE PMF, Hazard >H2, Duration >8h
Residential Replacement	1, 2	1, 2	1, 3	1, 4
Residential Intensification	1, 2	1, 4, 5	1, 4, 5, 6, 7, 8	not suitable
Commercial/Industrial	1, 2	1, 5, 6, 7	9	not suitable
Critical and Sensitive	not suitable	not suitable	not suitable	not suitable
For developments located across two or more "risk to life" classes, the correct class is assigned based on the location of the development's pedestrian access/egress point.				

Note: Controls ID numbers refer to Table 6 which has a full description of each proposed control

Table 2. Description of the proposed risk to life controls. The ID number refers to Table 5

No.	Control description	Rationale
1	Building structure capable of resisting PMF forces	As shelter in place is the preferred flood response strategy, any building must be able to remain standing in any flood. Meeting this requirement may be achievable through standard construction methods in areas with less than a H5 category.
2	Designated SIP refuge above PMF level having floor area > 10% of habitable floor area	Very low probability of isolation by low hazard flood waters. Need to provide enough space for all the building occupants to be reasonably comfortable during very short period of

No.	Control description	Rationale
		isolation In locations where the PMF is less than 0.5m above the FPL, this requirement will be satisfied by all habitable floors. In locations where the PMF is less than 2.5m above the FPL, this requirement will be satisfied by all habitable floors on second floor or above.
3	Designated SIP refuge above PMF level having floor area > 20% of habitable floor area	Longer duration of isolation requires more space to shelter above reach of PMF. In locations where the PMF is less than 0.5m above the FPL, this requirement will be satisfied by all habitable floors (see Figure 8) In locations where the PMF is less than 2.5m above the FPL, this requirement will be satisfied by all habitable floors on second floor or above (see Figure 8).
4	All habitable floor levels above PMF	This ensures that occupants have full use of dwellings during a flood and are unlikely to want to leave.
5	Flood free access to pedestrian egress at 1% AEP flood level or higher.	With a pedestrian egress outside the reach of the 1% AEP event, isolation would only occur in low probability (i.e. AEP <1%) events. The extent of the area to which this applies can be seen in Figure 9.
6	A Flood Emergency Response Plan (FERP) is required (responsibility of building owner or Body Corporate).	The FERP will provide guidance to the building occupants on the appropriate flood emergency response detailing (as a minimum): warning system, response triggers, emergency contacts, designated SIP refuge, risks associated with sheltering in place. The building owner or body corporate will be legally responsible to ensure the FERP is established, practiced, maintained and updated
7	Building to include: (a) Alternative power source, with capacity for at least 8h for essential needs (b) Automatic fire suppression	(a) Keeps building functional and reduces probability of people wanting to leave, reduces risk of improvised lighting, cooking and heating being used which in turn reduces risk of fire (b) In the event of a fire reduces the risk of

No.	Control description	Rationale
	system in all building (c) Emergency telecommunication system (d) Toilet facilities accessible to people with disabilities (e) First-aid kit (f) Emergency supplies kit	the fire spreading and the building having to be evacuated (c) Allows emergency contact to be made outside to assess changing flood and weather situation and to communicate with emergency services if needed (d) All building occupants are catered for (e) Ability to meet some medical needs
8	Accessible via helicopter for medical emergencies	In the event that a critical medical emergency occurs on site there is access by helicopter (weather permitting)
9	Only allowed in mixed-use, high-rise buildings only where ground floor is commercial and levels above are residential. Ground floor level below FPL is acceptable if protection from substantial property damage in 1% event can be achieved. Access to the building's SIP refuge, or flood free pedestrian egress to Green Zone or flood-free zone.	This permits street level shops which may be below FPL but commercial premises occupants have direct access to all of the SIP facilities available to the residential occupants above

Conclusions

Evacuation is not a practical flood response in all locations and sheltering in place can be a better alternative in some circumstances. Redevelopment which caters for sheltering in place can be used to reduce existing risk to life for individuals who currently occupy the floodplain but it is likely to increase the number of individuals at risk.

Quantified risk analyses can be used to delineate areas of acceptable, tolerable and unacceptable risk using flood probability, flood hazard and flood duration data from flood models.

Development controls can be imposed which seek to manage the residual secondary risks to life caused by flood isolation to ensure that risks remain tolerable.

Further work is required to determine the appropriate thresholds to be used when determining appropriate life risk categories.

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