Floodplain Development – What Merits Assessment?

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Abstract

The NSW Government's Floodplain Management Manual promotes the assessment of floodplain development based on merit rather than a minimum standard such as the '1 in 100' level, which continues to be perceived as adequate in many high risk areas. The full merits based approach is considered best practice for the management of flood risks in Australia. However, it has rarely been properly undertaken in practice. Some recent Land and Environment Court decisions and independent reviews of development proposals by the author shed some light on what issues are critical in making merits based assessments.

The paper discusses:

- Five critical thresholds which need to be understood about each development;
- Flood, development and human factors which influence flood risks and some of the interdependencies between those risks;
- Options for changing or influencing the flood, development and human factors to mitigate risk;
- The tools available for evaluating the probability and consequences of the factors which influence flood risks and some of the knowledge gaps and limitations of those tools.
- Criteria which need to be considered when assessing whether flood risks are tolerable; and
- Some of the difficult questions of equity which risk management can pose.

The application of some of the above are discussed in relation to recent case studies.

1 HISTORICAL APPROACH TO FLOODPLAIN PLANNING

Until recently floodplain planning was usually done in one of two ways:

- The floodplain was left unprotected and a flood planning level was determined below which development was prohibited or significantly restricted, and above which it was unrestricted. Traditionally this has been set at the expected 1% flood level plus a freeboard as the minimum habitable floor level.

- Alternatively, floodplain protection was afforded by way of levees which were designed to prevent inundation from floods up to some specified height above an expected flood level. Development behind the levees was unrestricted.

In either case the implicit assumption in the planning was that the only question that merited consideration was “what is a tolerable chance of properties being flooded?” and presumably floor levels or levee heights were determined according to the answer to that question.

What the consequences of more severe flooding might be did not appear to merit assessment.

In the last decade or so, the merits based approach to floodplain planning has gained credence in NSW with practitioners, if not necessarily with politicians. However, I would argue that in practice we have struggled with applying a true merits based approach.

More often than not the main focus of the decision making has continued to be what should the minimum habitable floor level be. Whilst there is a recognition that it does not necessarily need to be set at the 1% level, most of the creative thinking has gone into clever building techniques which we can employ which would permit less critical development or parts of buildings below the 1% level.

In the last few years, the NSW State Emergency Service (SES) has broadened our collective minds by forcing developers and local governments, sometimes through the Land and Environment Court, to consider personal safety issues for the full range of potential floods. Its officers have developed the very useful evacuation timeline tool to assist in this regard.

I suggest that these are progressive but insufficient steps towards full merits based floodplain planning.

2 A BROADER APPROACH

My thesis is that there are at least five critical thresholds which need to be understood about a proposed floodplain development before a full merits based decision can be made. Three relate to property and two relate to people.

In understanding these thresholds we need to come to grips with the risks involved in each. By risk I mean both the likelihood and consequences of flooding as they relate to each of these thresholds. We need to recognise that we can be more certain about some of the risks than others. We also need to understand what determines those risks and which of those factors we can control and which are beyond our control. Finally, we need to consider what factors would influence the tolerability or otherwise of those risks recognising that there are interdependencies between the risks which means each cannot be considered in isolation.

Table 1 summarises these ideas and they are elaborated upon in the following sections.

3 FIVE CRITICAL THRESHOLDS

There can be considerable benefits in developing a floodplain but floodplain development carries with it significant risks which must be carefully considered before proceeding. Those who bear the risks are not necessarily those who get the benefits.

There are social, economic and environmental risks to consider. The environmental issues are often site specific and so it is difficult to make a comprehensive list of all environmental issues which need to be assessed. The social and economic issues on the other hand are common to all floodplains and what varies is the risks associated with them.

The direct and indirect social and economic consequences of flooding are myriad. They include property damage, injury, loss of life, clean up costs, temporary accommodation costs, business closure, unemployment, loss of memorabilia and pets, stress and stress induced illness. Some of these consequences are easier to quantify than others and some can be expressed in monetary terms. There is a continuum of risks from the minor consequences of frequent floods to the extreme consequences of rare floods.

When confronted with so many quantifiable and non-quantifiable variables over such a broad spectrum of probabilities, a full merits based assessment can appear to be a daunting task.

Table 1: Minimum Considerations for a Full Merits Based Assessment

CRITICAL THRESHOLDS	**FACTORS AFFECTING FLOOD RISK - LIKLIHOOD OR CONSEQUENCE**			**POTENTIAL FACTORS INFLUENCING RISK TOLERANCE**
	Flood factors	**Development parameters**	**Human factors**	
Above floor flooding	Flood peaks and durations and their probability	Floor level, Number of buildings	Unapproved modifications	Social & economic effects of flooding Number of properties affected Financial ability of occupants to recover Benefits of development Cost of mitigation
Substantial but repairable property damage	Flood durations, depths, velocities and critical combinations and their probability	Location of buildings, Building design, Number of buildings	Unapproved modifications Actions in response to flood warning	Social & economic effects of damage Number of properties affected Financial ability of owners to recover Benefits of development Cost of mitigation
Irreparable structural damage	Flood durations, depths, velocities and critical combinations and their probability	Location of buildings, Building design, Number of buildings	Unapproved modifications	Social & economic effects of building failure Number of properties affected Financial ability of owners to recover Benefits of development Cost of mitigation

Failure of Co-ordinated evacuation strategy	Peak flood height. Rate of rise of floodwaters, Probability	Location of buildings, Number of buildings, Road network design	Ability of emergency Services to resource & manage; Action of public in response to flood warning	Number of evacuees affected Availability of alternative means of evacuation (self-rescue) Impact on regional evacuation Benefits of development Cost of mitigation Cost of rescue by emergency services
Failure of self-rescue	Peak Flood height Rate of rise of floodwaters, Probability	Location of buildings, Building and urban design Topography	Willingness and ability to walk from building	Number of lives lost Benefits of development Cost of mitigation Cost of rescue by emergency services

I would suggest that the task can be simplified somewhat by assuming that there are five critical thresholds which influence the magnitude of the social and economic effects of flooding. When these thresholds are crossed there is a quantum leap in direct and indirect, tangible and intangible damages. The focus then needs to be on the chances of these thresholds being crossed and the number of properties or people affected at these thresholds.

The following discusses each in turn.

3.1 PROPERTY

3.1.1 Above floor flooding

There is no doubt that the chance of above floor flooding is one of the critical thresholds in determining what is appropriate floodplain development. In the past it was considered to be the only threshold worth considering when estimating tolerable property risks. However, it is only one of the five but still warrants elaboration.

Once floodwaters enter buildings, floor coverings, stock, furniture, fixtures and fittings which are not water resistant are suddenly wet and often need to be cleaned, repaired or replaced. Homes suddenly become uninhabitable and remain so until they have been thoroughly cleaned. Temporary accommodation needs to be found. All of these damages can be given monetary estimates. However, less quantifiable are the significant human costs in stress and disruption and even indirect health impacts which arise from vacating buildings for lengthy periods, cleaning up and having property invaded by flood waters.

The chance of this happening and the number of properties and people affected is therefore a critical consideration in assessing the merits of floodplain development.

3.1.2 Substantial property damage

Simply considering the chance of above floor flooding without considering how deep it can become and the probabilities associated with those depths is to ignore the fact that as the depth of flooding increases the direct and indirect damages increase also.

The Hawkesbury Nepean Floodplain Management Strategy (HNFMAC, 1997) and many subsequent documents use the diagram in Figure 1 to illustrate that the likelihood of above floor flooding alone is not sufficient in planning a floodplain. It shows that the depths of rarer floods vary considerably between floodplains.

Figure 1: Comparative Flood Risks for Properties with Floor at 1 in 100 Level.

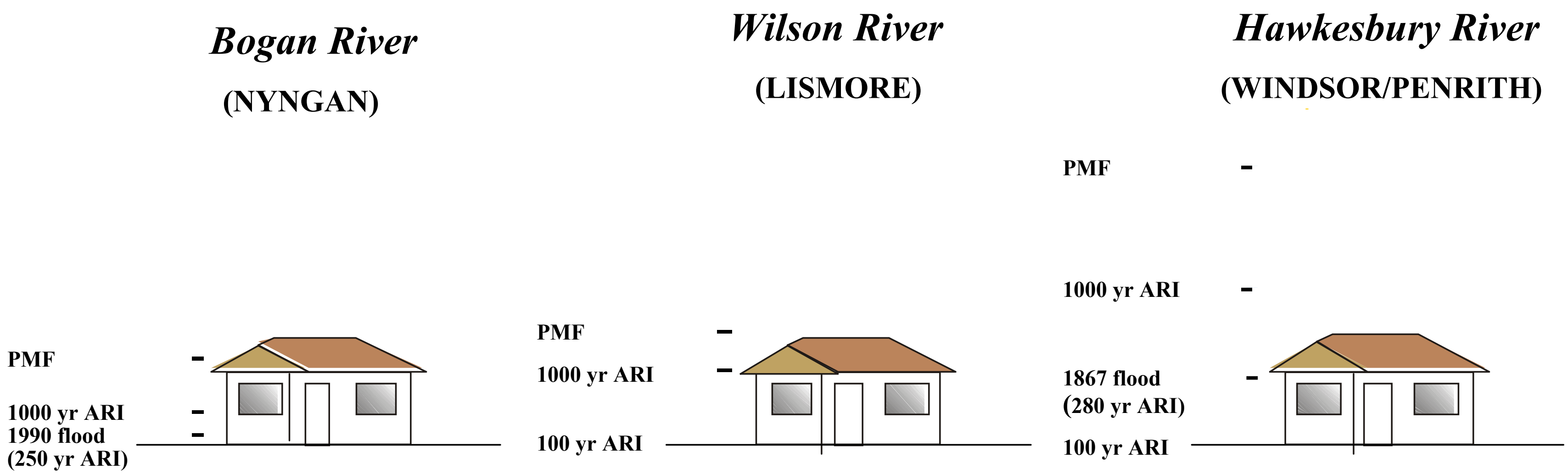
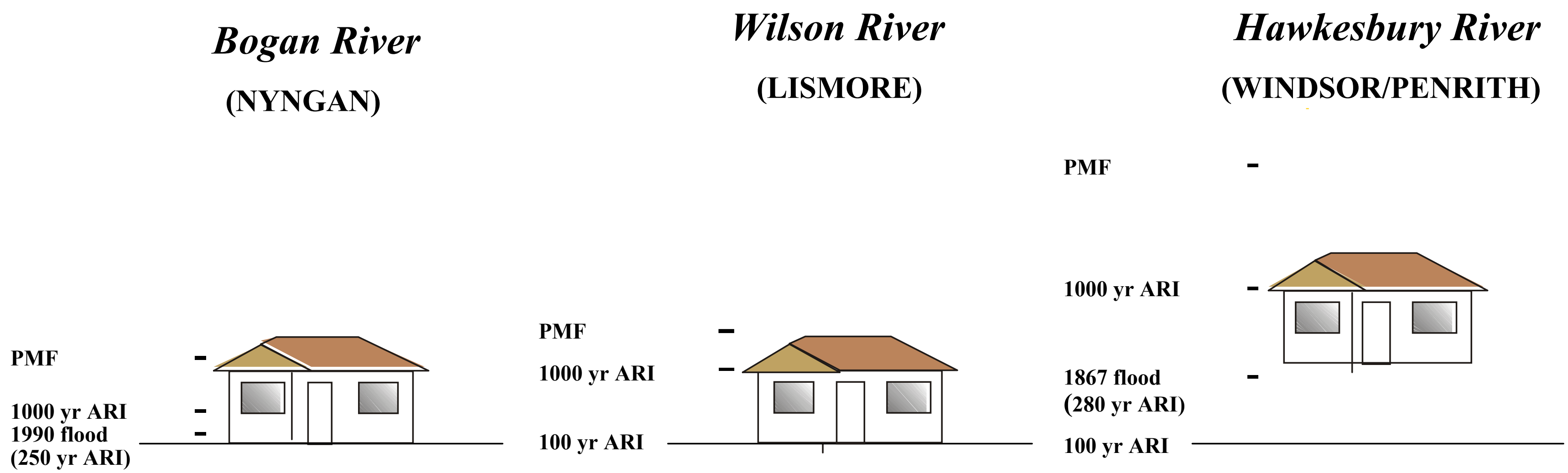


Figure 2: Comparative Flood Risks for Properties with Ceiling at 1 in 1000 Level.



What has not been made clear is how to use this information.

If we consider that as the depth of above floor flooding increases, the tangible and intangible costs increase gradually but once the water reaches the ceiling then all of the remaining contents are written off and wall and ceiling linings, insulation and electrical wiring can no longer be protected. While all of these things can be rectified, the cost is significantly more than if a few centimetres of water were flowing over the floor. Furthermore there is no safe refuge inside. I would therefore suggest that the probability and consequences of ceiling depth flooding is the next threshold which needs to be considered as it represents the maximum reparable property damage that is likely.

Perhaps a diagram like that in Fig 2 would be useful in conveying the idea here. If we consider what is a tolerable risk of above ceiling flooding, then the minimum habitable floor level may be determined by deduction. For example, if society will tolerate a 1% chance of having the floor flooded but only a 0.1% chance of the water up to the eaves then in some floodplains the latter will determine the minimum floor level and in other floodplains it would be the former.

Of course simply building houses with four metre high ceilings would not be an appropriate way to mitigate this risk but two storey construction may be, as discussed in Section 4.2.

3.1.3 Building failure

The next major quantum leap in damages occurs when buildings fail. This failure may be a spectacular building collapse but equally as costly is the incipient failure of critical structural members or the widespread failure of non-critical items but which requires virtual complete rebuilding. For example, if contemporary brick veneer dwellings are subject to a long period of inundation, masonite wall bracing may critically lose strength and wall and ceiling linings and insulation require replacement or brick work buckle under differential water pressure. This can all occur with very low velocity flooding and cannot be repaired without significant demolition and renovation.

When this happens residents and businesses are thrown into not only a much higher level of tangible damages but the intangible damages increase manifold, as people come to terms with the complete loss of the family home or business and the need to relocate for a long period, if not permanently. In most cases such a failure could represent the complete loss of a person or family's most valuable asset and cause a personal financial crisis from which they never recover. The stress of such loss can have devastating emotional and health effects for many years.

It is therefore important to understand the probability and consequences of building failure.

3.2 PEOPLE

3.2.1 Evacuation failure

The SES has rightly pointed out in recent years that floodplain development needs to take into consideration the ability of people to evacuate safely. To this end it has developed a model which enables it to estimate the time required to safely evacuate people by vehicle in an orderly fashion. This is definitely a critical consideration in planning and no new development should proceed where it cannot be demonstrated that there is sufficient time to evacuate people ahead of floodwaters

As discussed later in this paper, although any development must be designed such that orderly vehicular evacuation should be theoretically possible, there can be no guarantees that such evacuation will go according to plan in an actual flood.

For this reason it is important to understand the risk of evacuation failure. What is the likelihood of it happening and what would be the consequences? In particular, does failure result in people being placed in a life threatening situation from which they need to be rescued?

3.2.2 Self rescue failure

Should orderly evacuation not be possible for whatever reason, we need to understand what other options are available to them. In particular we need to know whether self rescue is possible and by what means. This covers people leaving the food affected area by some means other than motor vehicle. Can they rescue themselves by either boat or by walking? What is the chance of them not being able to do so and what are the consequences of them not being able to do so? Are they simply stranded in their home without essential services, are they stranded on high ground without shelter or are they inundated by flood waters? Self rescue failure can either result in inconvenience, discomfort or loss of life and the chance of this happening needs to be known. This becomes the fifth critical threshold in floodplain planning.

It is possible to argue that there is a sixth consideration and that is rescue failure. What is the chance that the emergency services cannot rescue them. I would suggest that any development should be designed on the assumption that emergency services do not rescue them. That is, we need to assume there is 0% chance of people being rescued so that in planning we do not become reliant upon rescue to manage the risk to life. This is not to suggest that emergency services would not try if the need arose but rescue should not be expected or relied upon.

4 FACTORS AFFECTING RISK

The probability and consequences for each of the critical thresholds are dependent upon a number of factors. Some of these factors relate to the nature of flooding at the locality, some are influenced by the nature of the development and others are strongly influenced by human behaviour. It is important to understand what factors influence the risks, how certain we can be that they will be as predicted in an actual flood and which ones can be controlled or influenced. Through this understanding, risk management strategies can be explored.

4.1 FLOOD FACTORS

Traditionally the main flood factor that planners have been interested in is the peak flood height and its probability. While this is important in planning, it is not the only flood factor which needs to be considered.

The peak flood height will determine whether above floor flooding occurs or whether above ceiling flooding occurs. It will indicate whether evacuation routes will be cut and whether people who do not evacuate will be stranded or submerged.

However it is also important to know the duration of flooding. This will determine how long people may need to be evacuated and buildings vacated, how long people might be stranded by floodwaters and will also have an impact on how badly damaged property becomes.

Velocity is another important factor both in terms of property damage and personal safety. It has long been recognised that different depth and velocity combinations need to be considered and the most critical combination may not necessarily be at the peak height or the peak velocity.

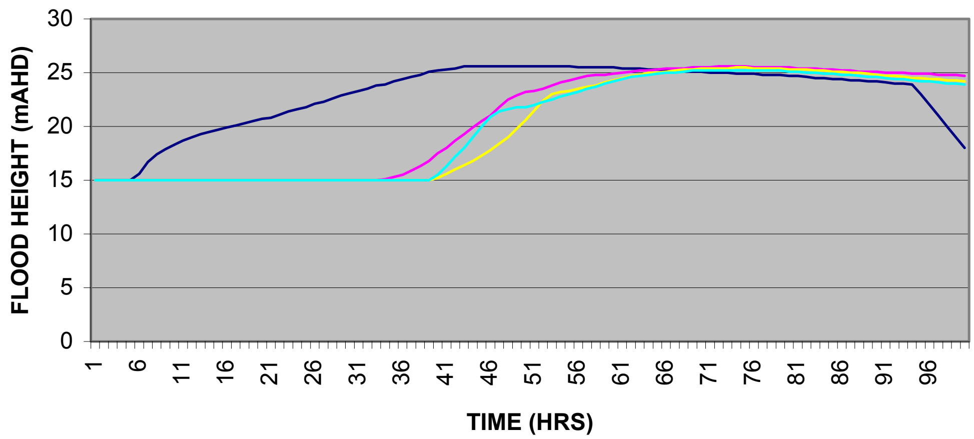
These latter flood parameters are being given increasing attention.

What has been given less attention than it deserves is the rate of flood rise. This is critical to assessing the consequences for both planned evacuation and self rescue. While data is usually available about rate of flood rise it is usually based on historic events or modelled design floods. While useful, these neither give an indication of the full range of rates of rise which are possible nor the probability of those rates of rise.

For example simply taking the rate of rise of the design 1% flood does not give the rate of rise which has a 1% chance of occurrence. It simply is one rate of rise which could occur in reaching the 1% peak level.

Figure 3 illustrates this important issue which is often overlooked. This is discussed further in Section 5.1.

Figure 3: Variable Rates of Rise for Similar Flood Peak



Risks associated with flood factors can be mitigated by changing flood behaviour through mitigation dams, off river storages, levees, diversion channels and the like. It should be stressed that these are really risk transfer strategies. They transfer floodwaters to an alternative location where the consequences are more tolerable.

4.2 DEVELOPMENT PARAMETERS

Development parameters are those over which there is greatest control and therefore the greatest scope for using them as a means of risk mitigation.

Obviously the ground floor level of buildings is an important development parameter in determining the chance of above floor flooding occurring. However the number of buildings affected is another development parameter which will determine the consequences of such flooding.

Building design and materials will determine the chances of substantial property damage or building failure. For example a two-storey home allows occupants to move contents to the second floor in advance of a flood or even have the most vulnerable rooms on the top floor. Recent research has also found that the highest local velocities occur when floodwaters reach the eaves of a building after which flow becomes three dimensional and velocities drop (pers. comm., Alan Jeffery, DIPNR). The height of eaves can therefore be influential on the probability of building collapse.

Flood resistant materials reduce the chance of building damage and even building orientation and shape can improve a building's resistance to damage or collapse.

Locating buildings away from high velocity areas can also reduce the consequences of flooding. In a similar vein the orientation and spacing of buildings and fences can also influence velocities either locally or more broadly and this needs to be considered.

But development parameters have a significant influence on personal safety as well. For example, the number of exiting road lanes will determine how long it takes the population to evacuate by vehicle and this can be a critical limitation to total development size. The levels of those roads also needs to be considered because this will be critical in determining the time at which evacuation routes are cut and therefore the total time available for vehicular evacuation. Ideally the evacuation routes need to have a rising grade from each building to above the PMF level so that evacuees will always be travelling ahead of rising flood waters and not face the risk of having the route cut before they arrive. The risk of the route being cut by the river coming by another route or by local water flooding needs to be taken into consideration. Building multiple evacuation routes so that a blockage of one does not totally prevent evacuation is another idea worth considering.

If people are unwilling or unable to evacuate by vehicle in the time available, the question of whether they can self rescue, generally by walking out, needs to be considered. Development parameters which are influential here are the topography between the building and the point to which they must evacuate. Also is that evacuation point going to allow them to keep moving to an staffed evacuation centre or will they be stranded above the flood waters but have to provide shelter, food and medical attention themselves?

4.3 HUMAN FACTORS

Floodplain planning needs to recognise that owners and occupiers of buildings on a floodplain will not necessarily behave in an entirely rational way even if they have and understand the information which engineers, planners and emergency service personnel have when the planning is taking place. Human factors are the least predictable and most difficult to control of all of the factors which influence flood risks.

Whilst, behaviours can be influenced before and during a flood with development controls, education and preparedness strategies, warning systems and flood emergency plans, there are limitations to how human behaviour can be controlled.

The risks and consequences of human behaviour different to that which is assumed or planned must be understood if an informed, merits based decision is to be made.

For example we have all seen development where minimum habitable floor level standards have resulted in houses raised a couple of metres above the ground only to have owners illegally turn the under house area into living space at some later date.

If flood resistant designs or building materials are specified for new buildings, how do you prevent modifications being made in the future with inappropriate materials or which compromise the design objectives?

If the design of the whole development is dependent on a particular urban layout or the use of particular types of fencing to ensure local depths and velocities do not exceed critical thresholds how do you ensure that the designed flow paths remain unobstructed in perpetuity when property owners and occupants are likely to make modifications without thinking about the consequences that their actions could have on flooding?

And what of risk to life issues? How will people respond to the evacuation message and what are the risks and consequences of them not responding appropriately?

4.4 SOME INTERDEPENDENCIES

The interdependence of some of these factors should not be overlooked.

For example, one way of mitigating the risk of significant property damage is to specify that all development in the floodplain needs to be two storeys or more. This however can have a psychological effect on building occupants who may think that they can evacuate vertically above the floodwaters rather than horizontally away from the floodwaters. The risks associated with this human response to a development factor will depend very much on the flood factors and whether the upper storey of a building is a safe haven or a death trap, should the flooding depths and velocities be such that the building is submerged or collapses.

Another example is where ground floor levels are elevated above natural ground level to reduce the probability of above floor flooding. This can give people the impression that the building has been designed to be flood free. When they are told to evacuate they may not respond to the message until floodwaters have entered, or are about to enter, the building. Self rescue then becomes difficult if they step out of a building into neck-deep water!

5 TOOLS FOR ASSESSING CHANCE AND CONSEQUENCE

There are a number of models available, or which are being developed, for assessing the risks of floodplain development. Each model is built around a set of assumptions about flood, development and human factors. It is important that each of models used in floodplain planning is tested with a range of assumptions to see how sensitive the outputs are to those assumptions.

Only flood models explicitly consider probabilities at this stage. The other types of models use the flood probabilities to generate the probabilities of particular outcomes. However, there are all sorts of probabilities attached to different assumptions used in the models even if those probabilities are poorly understood or not calculated. It is important not to assume that the worst case scenario is certain to happen which would be too conservative, nor to ignore some of the possibilities which may result in taking too great a risk.

5.1 FLOOD MODELS

These are the most mature of the models available for floodplain planning and have become the backbone of this work for many years. These models have become more sophisticated and more accurate in recent years but the outputs which are generated need to be tailored to the flood risks which are being considered.

For example, a modelled design flood which provides a 1% flood peak cannot necessarily be used to a rate of rise which would have a 1% chance of occurrence. Yet the chance of a range of rates of rise will be critical in determining evacuation and self rescue failure risks.

Even flood peak outputs often focus on probabilities up to the 1% level and then the PMF is thrown in for good measure. Where there are significant differences between depths, velocities or rates of rise in the PMF compared to the 1% design flood it may be important to have information about several events in between.

Some flood models are better than others in providing information on velocities. This can be particularly important where building failure risks need to be considered carefully and are sensitive to building location and spacing.

5.2 FLOOD DAMAGE MODELS

There are several models available which can be used for estimating flood damages. These generally work on some sort of relationship between overground flood depth and damage values and above floor flood depths and damage values.

These provide useful guidance but must be constantly updated because on average, households are increasing the number of items within a home and an increasing number of household items and items in commercial premises have electronic components which are more susceptible to flood damage.

5.3 BUILDING FAILURE MODELS

It seems that the most often cited reference for forecasting building failure is the work of Black (1975). There are two problems with relying upon Black's models for building failure. Firstly there have been questions raised about the methodology (Sangrey et al 1975). Secondly it was based on rural buildings in the USA which were constructed prior to 1975, some of which were as small as seven squares.

Even if the methodology were correct, the types of buildings built throughout Australia today are very different to those upon which Black's model is based. Applying this model to proposed floodplain development should be done with caution.

As discussed earlier in this paper, some of the materials used in contemporary brick veneer buildings could result in structural failure of buildings in zero velocity floodwaters which are relatively shallow compared to the failure thresholds in Black's model.

As far as I am aware, at this stage there are no published alternative models available for estimating building failure although the Department of Infrastructure Planning and Natural Resources has commissioned the CSIRO and Newcastle University to undertake research into building failure modes of modern Australian buildings due to flooding (pers. comm., Alan Jeffery, DIPNR).

5.4 EVACUATION MODELS

The NSW SES has led the way in developing models for assessing the ability of communities to evacuate ahead of floodwaters. These models have been used by the SES to resource and plan their warning and evacuation strategies.

They are increasingly being used to evaluate the merits of new floodplain developments.

While the model is applicable for both purposes, there are subtle differences which need to be understood when applying it in those different situations.

When used for planning the evacuation of existing development, the number of evacuees and the development configuration are fixed. Changes to the road network may not be possible or affordable. Essentially it becomes a matter of using the model to work out how to do the best possible with the resources available.

With a new development on the other hand, a deliberate and informed decision has to be made as to whether to expose people to flood risks. Exploring the full range of possible scenarios and testing assumptions becomes a much more critical exercise.

My view is that in most aspects the SES model is conservative or realistic with its assumptions. There are two areas however where careful testing of assumptions and the evaluation of the consequences is needed. These are now discussed.

5.4.1 Rate of Flood Rise

The SES has tended in the past to use the rate of rise of the modelled PMF when determining the estimated worst case rate of rise. Planning has then been done around this rate of rise. The question which needs to be asked is "which PMF should be used?" Often the flood engineers have determined the "worst" PMF based on the specific problem which they were asked to consider. This may be the PMF which creates the greatest flood peak or the PMF for which a dam needs to be designed. Using either does not necessarily result in the worst rate of flood rise. Furthermore it needs to be recognised that such rates of rise can occur on the way to flood peaks more likely than a PMF.

5.4.2 Warning Response Time

The SES model assumes that people do not respond immediately to a warning but take a couple of hours before they believe it and then an hour to prepare to evacuate. The SES would be the first to acknowledge that many people take much longer than two hours to respond to a flood warning and in fact many will not acknowledge a need to evacuate until the floodwaters begin to enter the building. It is my view that failure to respond appropriately to a flood warning is the most likely cause of evacuation failure.

5.5 SELF RESCUE MODELS

I am not aware of any widely used or accepted models for assessing this risk and I have therefore developed my own simple model which considers the ability of people to walk out if they wait until the flood waters are at their feet.

As a first step in applying this model, I following a similar classification to that used by the SES in developing the Hawkesbury Nepean Flood Emergency State Plan (SES 2000). It classifies the floodplain into areas that are:

- accessible by road - a walking route ahead of rising flood waters to flood free land is available along the road network out of these areas;
- accessible by overland travel – to walk out of these areas a person would have to walk overland ahead of rising floodwaters;
- Islands which remain above the PMF level – evacuation routes from these areas are cut by rising flood waters but stranded people can walk to higher ground on the resulting island ahead of the rising floodwaters;
- Islands which submerge – initially stranded people can retreat to higher ground but if the flood rises high enough the island is overwhelmed; and
- Land locked areas – these are generally in gorges where there is no practical way off the floodplain.

Classifying the floodplain into these areas is the first step in determining the chances of self rescue success and the consequences of failure. It is also useful in determining the consequences of evacuation failure.

6 FACTORS INFLUENCING RISK TOLERANCE

The most fundamental question which needs to be asked about floodplain development is “Are the benefits of developing the floodplain worth the risks involved?” What makes floodplain planning difficult is that there is a high level of certainty about the benefits (although they are not necessarily assured) and a great deal of uncertainty about the costs. Will flooding occur, how often and what will be the consequences?

The second question which leads on from the first is “How far down into the floodplain is it worth developing?” The historical approach taken in Australia has been to consider the whole floodplain worth developing until a flood comes along and forces a reality check. The response has been to then decide how much higher in the floodplain should certain development be placed now that the possibility of flooding is apparent.

That approach sprang from a failure to understand the magnitude of possible flooding and the frequency with which it could occur.

Now that our understanding has improved, it would be more appropriate that we start at the PMF and work our way down into the floodplain, determining at what point the risks exceed the costs of further encroachment.

The benefits are often easily quantifiable in monetary terms although there are significant social benefits in floodplain development, particularly when the demand for land is high and the floodplain is located close to established developments.

We have already looked at what risks need to be considered in contrast to the benefits but how does one decide at what point do the risks exceed the benefits. Ultimately this becomes a subjective judgement but having both probabilities and consequences quantified for the factors listed above help inform decision making and compare options.

I would argue that it is not adequate to simply compare the present value of economic benefits with the present value of annual average damages. While such an approach is useful for determining the net economic benefit of floodplain development it is only one factor which should be considered in determining whether the benefits exceed the risks.

For example such an economic approach considers the distribution of costs and benefits to be carried by the whole of society and to be distributed equally over time.

The reality is that those involved in the development usually reap most of the economic benefit now, while those who purchase the developed properties and live or work in the floodplain bear most of the economic costs at some later date when a flood occurs.

The ability of individuals or businesses to bear the costs of a flood is an important consideration. Many individuals or business would never be able to recover financially, should a building fail due to flooding, so the chance of this happening and the number likely to be affected are important considerations.

The absolute number of people likely to be impacted is critical in understanding the answers to several important questions. How many people are likely to have to evacuate, where will they go and how will they be looked after? It is much easier to temporarily house 15 people than 15,000.

Another critical consideration is what happens when organised evacuation fails. How many people are stranded and are they able to self rescue? If they are not able to self rescue, what is the maximum number of lives likely to be lost?

Evacuation failure can occur due to a number of factors as discussed previously. What must not be overlooked is the fact that the lead emergency service agency for floods is the SES which relies heavily on volunteers. How many volunteers do they need to supply to make evacuation work? Can they be confident that that many will be willing to help in the future? And will they be able to get to where they are needed if flooding locally and elsewhere cuts transport routes?

In relation to the above, it is not sufficient to consider the development under consideration in isolation. Are there other parts of the floodplain, or even adjacent floodplains which are likely to require evacuation at the same time as the area now under consideration for development? What demands does that place on emergency services and road infrastructure?

Furthermore, does using emergency service and infrastructure resources to evacuate new development compromise the safety of those who already rely upon these resources for their evacuation or self rescue?

7 SOME RECENT CASE STUDIES

Some recent development proposals shed some light on how some of the above factors can be taken into consideration in merits based floodplain planning.

7.1 SAYER V HASTINGS COUNCIL

In this case there was a proposal for a rural residential development, the whole of which could be overwhelmed in a large flood. The evacuation route would be cut early in a flood and therefore safe evacuation was dependent on an early response. The proponents of the development designed a flood emergency plan with early warning system and evacuation strategy to get residents out ahead of the rising floodwaters.

The Court accepted expert evidence from the SES which propounded the argument that human failings could cause the emergency plan to fail and that the likely consequences of failure would be loss of life in floods exceeded a certain magnitude. Self rescue was not an option once the evacuation route was cut.

In this case the court decided that the human life risks were too great to allow the development to proceed.

7.2 KAHLER V TAMWORTH COUNCIL

A similar argument about the likelihood of human failings in implementing a flood management plan was relied upon when Tamworth City Council refused consent for a tyre service centre.

In this case however, the consequences of failure of the flood emergency plan would be different. In terms of loss of life, even were the staff at the tyre service centre not to realise that flooding was occurring until it entered the property, they would be able to walk slowly for a short distance and still get to high ground ahead of the fastest rising PMF. The court found this risk to be acceptable.

In terms of property damage, the owner of the tyre service centre would be responsible for maintaining and implementing the flood management plan and would be the one most likely to suffer loss should the plan fail. Although it was not explored in the court proceedings, it could be argued that in this case the owner is making an informed commercial decision and the owner must determine whether the risk of flood management plan failure is acceptable or not. The owner makes an economic gain from being in this location but also is the one who suffers economic loss in a flood. Of course, without Council advising of the flood risk, the need for such a plan and what needs to be covered in such a plan, the owner is unlikely to be fully informed of the risks.

7.3 TAMWORTH COUNTRY MUSIC FESTIVAL

It is interesting to contrast what happens at the Tamworth Country music festival with the Tamworth Tyre Centre case.

The Country Music Festival is held over the January long weekend each year and up to 11,000 visitors camp in grounds on the floodplain. If these people are only there for eight hours each night and only for the three days of the long weekend, there are 20 times as many person hours spent in the floodplain at this location than at the tyre service centre if all three staff were on site 12 hours per day, 365 days per year.

When it is considered that: the campers are visitors; they have a high likelihood of being asleep when occupying the site; 11,000 people need to evacuate at the same time; and the site is almost 10 times more likely to flood than the tyre service centre, it is apparent that the risk to life at the camping grounds exceeds that at the tyre service centre. Nevertheless, the campers are there each year, presumably because the Council considers that the economic benefits of these visitors in this location at that time to be worth more than the risk to life.

From a property loss perspective, the economic beneficiaries of the tourism are not the campers whose property is at risk of loss.

7.4 PITT TOWN

Pitt Town is a small village in the Hawkesbury Nepean Valley whose evacuation route is cut off in a 2% flood and then remains an isolated island even up to the PMF. Hawkesbury Council had before it a development proposal for additional residential subdivision.

The SES modelled the evacuation of Pitt Town using its evacuation model for the Hawkesbury Nepean and found that there would be capacity to evacuate more residents although not as many as the largest development option which was proposed. The Council has decided to exhibit a plan for about 650 additional residential blocks.

A question which the community will need to consider in this case is what impact is the development likely to have on the safety of existing residents.

The SES modelling showed that if the evacuation of existing residents went according to plan there would be three hours to spare after the last resident was evacuated. However, another way of looking at this is to say that there is a three hour safety margin in the SES model to accommodate the plan not going according to plan. While most of the assumptions in the SES model are conservative, the unexpected could result in some or all of that three hour safety margin being lost.

Each additional person who moves into Pitt Town is reducing the evacuation safety margin for each person who already lives in Pitt Town.

7.5 PENRITH LAKES

This is a proposed large scale urban development north of Penrith on the Nepean River floodplain. The largest scale option which has been investigated on this site is a 4,900 lot residential development along with commercial development providing 1,500 jobs.

This has raised a number of interesting issues, resolution of which could set some precedents throughout the Hawkesbury Nepean Valley and also throughout the state.

For example, using the SES evacuation model and the assumptions used elsewhere in Flood Emergency Plan for the Valley, it can be demonstrated that more than 15,000 people could be evacuated from the floodplain ahead of a flood rising as fast as the 72 hour PMF if sufficient exit roads are built. However, a 24 hour PMF could rise twice as quickly and up to one third of the people may not have time to evacuate. The question is being asked: “What is an appropriate risk of evacuation failure?”

In fact how is evacuation failure measured? For the Penrith Lakes to safely evacuate it must be given priority on the road system over people evacuating from other locations in the floodplain. Depending, on the relative timing of flooding downstream and the response times of evacuees, evacuees could be waiting in queues for up to five hours with traffic queued for many kilometres. If however more favourable relative timings occur and/or traffic flows more quickly than has been assumed in the SES model, then there may be no queuing. Are long traffic queues an evacuation failure and is it equitable for existing floodplain residents to have to wait in traffic queues for several hours while more recent settlers on the floodplain are evacuated?

Another consideration has been the likelihood of building failure. It would appear that in floods up to the 1 in 500 event, most, if not all, buildings would remain standing but before the PMF level is reached all buildings would fail. Further modelling would be needed to ascertain the precise chance of building failure at different locations. The question is being asked: "Is less than a 1 in 500 chance of building failure tolerable for 5,000 buildings or does an even lower risk need to be specified? Furthermore, what controls are appropriate for building materials, design and subdivision layout to ensure that building failure is kept to a tolerable risk?

8 CONCLUSIONS

Full merits based floodplain planning is in its infancy and the range of factors which needs to be considered in determining floodplain risk is much broader than has been traditionally investigated. In addition to above floor flooding probabilities, it is important to understand the probability of above ceiling flooding and the likelihood of building failure. Furthermore, despite recent developments taking planned evacuation into consideration, the risk of it failing and the availability and risk associated with self-rescue also need to be considered.

Some of the tools such as flood models and evacuation models which have been used for many years in floodplain planning need to be used in additional ways to get improved information about flood risks and consequences. Other models such as building failure models and self rescue models need to be better developed and published so that an industry wide standard approach can be adopted for their use.

When making floodplain planning decisions, the approach needs to be taken of how far down into the floodplain is development worthwhile. At what point do the risks exceed the benefits and is there something which can be done to manage the risks without substantially diminishing the benefits so that development can proceed further into the floodplain?

Determining the tolerability or otherwise of risks requires a very broad consideration of factors which not only includes the property and people that will reside on the floodplain because of the new development but how they will affect the risks of others who are already on the floodplain.

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