APPENDIX L HYDRAULIC AND HAZARD CATEGORISATION

FLOODPLAIN RISK MANAGEMENT PROCESS Appendix C										
Floodplain Risk Management Committee	→	Data Collection	→	Flood Study Preparation	→	Floodplain Risk Management Study Preparation	→	Floodplain Risk Management Plan Preparation	→	Floodplain Risk Management Plan Implementation
Appendix D		Appendix E		Appendix F		Appendix G		Appendix H		Appendix I

L1 Introduction

The personal danger and physical property damage caused by a flood varies both in time and place across the floodplain. Floodwaters flow swift and deep at some locations, whilst in other places they are shallow and slow moving. The variation of degree of hazard and flood behaviour across the floodplain over the full range of potential floods needs to be understood by flood prone landholders and by floodplain managers.

To achieve effective and responsible floodplain risk management, it is necessary to divide the floodplain into areas that reflect, first, the impact of development activity on flood behaviour and second, the impact of flooding on development and people. Division of flood prone land on these two bases is referred to as 'hydraulic categories' and 'hazard categories' respectively.

In this manual, hydraulic and hazard categories are used to determine appropriate types of land development in flood-prone areas. As such, the determination of these categories is an essential element in the formulation of a floodplain risk management plan.

This manual recognises three hydraulic categories of flood prone land (floodway, flood storage and flood fringe) and two hydraulic categories (low hazard and high hazard). Division of the floodplain on the basis of these two effects produces the following six categories of flood-prone land:

1. Low Hazard - Flood Fringe
2. Low Hazard - Flood Storage
3. Low Hazard - Floodway
4. High Hazard - Flood Fringe
5. High Hazard - Flood Storage
6. High Hazard - Floodway

This appendix describes the various hydraulic and hazard categories, discusses significant factors which affect these categories and provides guidelines for their determination.

L2 Purpose of the Categories

At the outset, it should be realised that hydraulic and hazard categories are tools to assist in the preparation of an appropriate floodplain risk management plan (a strategic planning document). They are not to be used for the assessment of development proposals on an isolated or individual basis. Such ad hoc analysis cannot take into account the cumulative impact of gradual on-going development over time, a key issue to be addressed in a floodplain risk management plan. Rather, hydraulic and hazard categories are to be used for assessing the suitability of future types of land use and development in the formulation of floodplain risk management plans.

Both hydraulic and hazard categories need to be determined in the floodplain risk management study for inclusion in the adopted floodplain risk management plan.

L3 Hydraulic Categories

For the purpose of this manual there are three hydraulic categories of flood prone land:

- floodways;
- flood storage; and
- flood fringe.

Floodways are those areas where a significant volume of water flows during floods and are often aligned with obvious natural channels. They are areas that, even if only partially blocked, would cause a significant increase in flood levels and/or a significant redistribution of

flood flow, which may in turn adversely affect other areas. They are often, but not necessarily, areas with deeper flow or areas where higher velocities occur.

Flood storage areas are those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. If the capacity of a flood storage area is substantially reduced by, for example, the construction of levees or by landfill, flood levels in nearby areas may rise and the peak discharge downstream may be increased. Substantial reduction of the capacity of a flood storage area can also cause a significant redistribution of flood flows.

Flood fringe is the remaining area of land affected by flooding, after floodway and flood storage areas have been defined. Development in flood fringe areas would not have any significant effect on the pattern of flood flows and/or flood levels.

In determining appropriate hydraulic categories, it is important that the cumulative impact of progressive development be evaluated, particularly with respect to floodway and flood storage areas. Whilst the impact of individual developments may be small, the cumulative effect of the ultimate development of the area can be significant and may result in unacceptable increases in flood levels and flood velocities elsewhere in the floodplain.

L4 Determination of Hydraulic Categories

In all but the simplest flow situations, the results of a flood study will be required to determine hydraulic categories. A flood study involves a detailed hydraulic analysis of flood behaviour for a range of flood severities up to the PMF, and generally involves the use of numerical or physical models (see Appendix F). A flood study provides details of peak depths and velocities across the floodplain, the pattern and timing of flooding, etc.

It is impossible to provide explicitly quantitative criteria for defining floodways and flood storage areas, as the significance of such areas is site specific. The following guidelines, although general, are given to assist in the delineation of flooding and flood storage areas:

Floodways are areas conveying a significant proportion of the flood flow and where partial blocking will adversely affect flood behaviour to a significant and unacceptable extent. It is essential that this be investigated across the full range of potential floods as the definition of the floodway is one of the critical steps in the floodplain risk management process.

Flood storage areas - those areas outside floodways which, if completely filled with solid material, would cause peak flood levels to increase anywhere by more than 0.1 m and/or would cause the peak discharge anywhere downstream to increase by more than 10%.

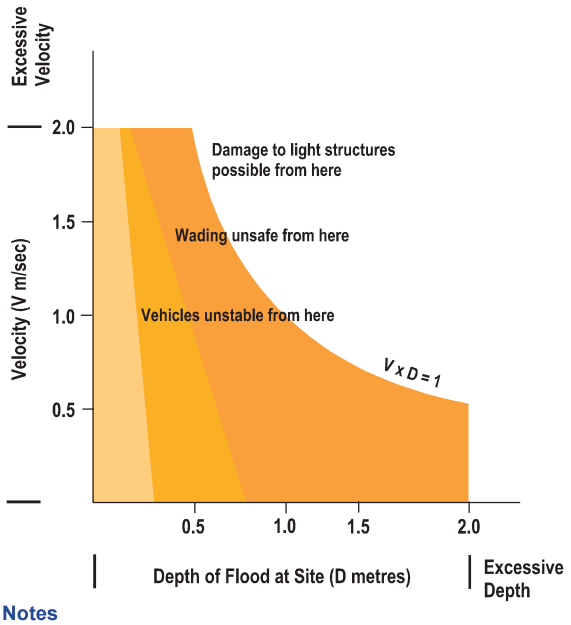
Areas being tested by the above criteria should be treated as contiguous entities, having regard for topography and location within the overall flood-prone area. They must not be separated or considered in a piecemeal fashion.

L5 Determination of Hazard Categories

Hazard categories are broken down into high and low hazard for each hydraulic category. These can be defined as:

- high hazard possible danger to personal safety; evacuation by trucks difficult; able-bodied adults would have difficulty in wading to safety; potential for significant structural damage to buildings.
- low hazard should it be necessary, truck could evacuate people and their possessions; able-bodied adults would have little difficulty in wading to safety.

A comprehensive analysis of flood hazard to establish risk can only be made from within the strategic framework of a floodplain risk management plan. The plan requires the detailed results of a flood study and an assessment of all the factors in Section L6, such as flood warning, flood awareness, flood readiness, possible evacuation problems, etc. The process involves firstly evaluation of hazard level from pure hydraulic principles, and then refining the hydraulic hazard category in light of other relevant factors affecting the safety of individuals. Figures L1 and L2 have been prepared to allow initial hazard categorisation on hydraulic considerations alone. Figure L1 shows approximate relationships between the depth and velocity of floodwaters and resulting hazard. This information has been used to define the provisional low and high hazard categories of Figure L2.

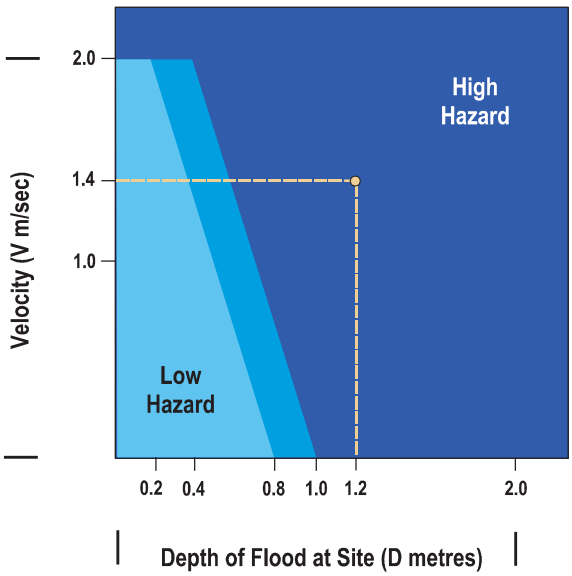


Notes

1. At velocities in excess of 2.0 m/s, the stability of foundations and poles can be affected by scour. Also, grass and earth surfaces begin to scour and can become rough and unstable
2. The velocity of floodwaters passing between buildings can produce a hazard, which may not be apparent if only the average velocity is considered. For instance, the velocity of floodwaters in a model test has risen from an average of 1 m/sec to 3 m/sec between houses.
3. Vehicle instability is initially by buoyancy.
4. At floodwater depths in excess of 2.0 meters and even at low velocities, there can be damage to light-framed buildings from water pressure, flotation and debris impact.

Derived from laboratory testing and flood conditions which caused damage.

FIGURE L1 - Velocity & Depth Relationships



Notes

The degree of hazard may be either -

- reduced by establishment of an effective flood evacuation procedure.
- increased if evacuation difficulties exist.

In the transition zone highlight by the median colour, the degree of hazard is dependant on site conditions and the nature of the proposed development.

Example:

If the depth of flood water is **1.2 m**
and the velocity of floodwater is **1.4 m/sec**
then the provisional hazard is **high**

FIGURE L2 - Provisional Hydraulic Hazard Categories

These categories are provisional because they do not reflect the effects of other factors that influence hazard. In effect, the two diagrams provide a starting point for the determination of hazard categories. When the other factors that affect hazard are identified and qualified, the provisional hazard categories of Figure L2 should be revised if necessary to develop true hazard categories.

For instance, the impacts associated with a particular hazard category, in an existing developed area, may be reduced if an effective local flood plan is developed, implemented and maintained under the guidance of the SES.

However, even plans with effective in-built maintenance mechanisms (such as local flood plans prepared under the guidance of the SES) cannot be guaranteed to overcome flood risk nor do they change the degree of hazard itself, ie. if they do not work effectively the level of hazard is unchanged. Maintenance of local flood plans and floodplain risk management plans is necessary to ensure that they remain appropriate in the light of future changes within the catchment and in management policies, procedures or practices.

It should be noted that evacuation measures proposed in private or site specific flood plans (see Section N7) for individual developments, outside the development types considered appropriate in the management plan, is not an appropriate measure to rectify adverse impacts, to manage the consequences of inappropriate decisions or to override the management plan. Therefore private or site specific flood plans should not form the basis for development consent.

It may be necessary to increase the hydraulic hazard classification derived from Figures L1 and L2, from low to high, if there are substantial difficulties associated with the evacuation of people and their possessions. In assessing these aspects, it is necessary to consider the difficulty of the conditions that could be expected if an extreme flood occurred.

Figure L2 is presented as a tool to assist in the development of hazard categories in floodplain risk management plans. It is not appropriate to use Figure L2 to determine the hazard implications of individual developments. Flood hazard, like flood hydraulics, needs to be assessed on an integrated and strategic basis across the entire flood prone area, not on an isolated basis associated with individual developments.

To use Figure L2, it is necessary to know the average depth and velocity of floodwaters at various places in a flood prone area. The depth of floodwaters is the difference between the flood level and the ground level. The velocity of floodwaters is obtained from the results of a flood study, or pending the completion of such studies, from an assessment of available flood information or data.

As part of the floodplain risk management study, it may be appropriate for council to prepare 'hazard maps', which define areas of low and high hazard across the flood prone area for the potential range of floods. Detailed maps may also be prepared for floods associated with the FPLs and the PMF, with less detailed maps for other floods as required. Such maps can be used to assess the consequences of the hazard for existing and future development areas on flood prone land.

L6 Factors Which Determine the Flood Hazard

Provisional flood hazard categorisation based around initial hydraulic evaluations does not consider a range of other factors that influence flood hazard. Therefore provisional hazard categorisation should be used with the following factors, (which are discussed in detail below) to determine true hazard categories:

- size of flood;
- effective warning time;
- flood readiness;
- rate of rise of floodwaters;
- depth and velocity of floodwaters;
- duration of flooding;
- evacuation problems;
- effective flood access; and
- type of development.

Other factors, such as the complexity of the stream network and the inter-relationship of flows between streams will need to be considered, as appropriate.

L6.1 Size of the Flood

The size of a flood and the damage it causes varies from one event to another. Small floods generally cause minor damage and community disruption. Mid range floods can cause significant disruption and damage. Large floods, although rare, can cause massive damage and disruption. Unfortunately, it is impossible to predict in advance when flooding will occur. Also, there is no guarantee that, if a major flood has occurred recently, another perhaps larger flood will not occur in a relatively short period of time (see Table A1).

L6.2 Effective Warning Time

The effective warning time, or actual time available for people to undertake appropriate actions (such as raise pumps, lift or transport belongings and/or evacuate) is always less than the total warning time available to the emergency services. This is because of the time needed, firstly, to alert people to the imminence of flooding (by radio, loud-hailer, television, word of mouth or other means), and secondly, to have them begin effective property protection and evacuation procedures.

The consequences of flooding can be reduced if adequate time is available and is well utilised. However, even if people are fully evacuated along with transportation of possessions, a flood will generally still cause significant damage to the structural fabric of buildings, to stock and crops, to urban infrastructure and still wreak substantial community disruption. People are temporarily displaced from their homes and workplaces, flood-affected buildings need to be cleaned and restored, and transported possessions have to be returned. The whole process costs time and money and endangers lives and affects health.

Total available warning time is determined largely by catchment characteristics. The larger the catchment and the slower the rate of rise of floodwaters, the longer the available warning time. Some towns on the large western rivers of NSW have warning times measured in weeks. In contrast, warning times for coastal rivers and coastal areas in New South Wales are often

less than 6 hours. In small steep catchments, there is often no available warning time, as the catchments respond too quickly. In some cases, little or no advice may be available as to the expected height of floodwaters (especially for small catchments or river reaches affected by ocean tides).

In large catchments, flood warnings can be based on rates of rise and peak water levels at upstream gauges. In smaller, quicker responding catchments, flood warnings need to be based on rainfall measurements. These days, automatic monitoring equipment is available to measure water levels and rainfalls. In the smallest catchments, warnings need to be based on predictions of likely rainfall made before the rainfall occurs.

L6.3 Flood Readiness

Flood readiness greatly influences the time taken by flood-affected people to respond in an effective fashion to flood warnings. In communities with a high degree of flood readiness, the response to flood warnings is prompt, efficient and effective. The formulation and implementation of plans for the evacuation of people and transportation of possessions promote flood readiness. The community as a whole knows what to do on receipt of a flood warning, people as individuals know how to respond, residents and property owners have developed personal evacuation plans and can implement them effectively on receipt of a flood warning. Flood readiness is discussed in Section J3.

The SES is responsible for leading the development of local flood plans for flood prone areas of New South Wales. There is a section of each local flood plan that deals with flood readiness and sets out how promotion will be achieved (see Appendix N for details).

L6.4 Rate of Rise of Floodwaters

The rate of rise of floodwaters affects the consequences of the flood. Situations in which floodwaters rise rapidly are potentially far more dangerous and cause more damage than situations in which flood levels increase slowly.

Typically, the rate of rise of floodwaters is more rapid in small, steep catchments than in their larger, flatter counterparts. The enormous catchments of the western rivers of NSW have very slow rates of rise. At Bourke, for example, the rate of rise of floodwaters is typically less than 0.1 metre per day and it may take up to several weeks for flood levels to peak. In contrast, the rate of rise of floodwaters in coastal rivers is far more rapid, and can be greater than 0.5 metres an hour.

L6.5 Depth and Velocity of Floodwaters

The threat to personal safety and to gross structural damage (ie. houses being washed away) caused by floods, depends largely upon the speed and depth of floodwaters. These, in turn, are dependent upon both the size of the flood and the hydraulic characteristics of the river and its floodplain.

The ability to safely wade or drive through floodwaters is very dependent on depth and velocity. The greater these factors become, the greater the danger to people, animals and vehicles being swept away. Consequently, depth and velocity are important considerations in formulating evacuation procedures for developed areas and in considering new development in flood-affected areas. In assessing the safety of wading, a number of factors other than depth and velocity need to be taken into account: is the ground surface even; are depressions, potholes, fences or major stormwater drains present, etc.?

As the depth of floodwater increases, caravans and buildings of light construction will begin to float. In these circumstances the buildings can be severely damaged when they settle unevenly in receding floodwaters. If the flood velocity is significant, buildings can be totally destroyed and cars and caravans can be swept away. In certain areas, the build up of debris and the impact of floating logs can cause significant structural damage to buildings and bridges.

The rate of flood water movement and the height that a flood will reach are related to the three dimensional shape of the catchment. An important factor that tends to increase the depth of flooding, and hence the overall degree of flood damage, is the presence of obstructions to the movement of floodwaters.

Such obstructions include buildings, embankments and bridges, areas built up by land-fill, and the blocking effect of inappropriate trees, shrubs, fences and debris. The increase

in flood levels depends upon the velocity of the floodwaters and the degree to which they are obstructed. However, appropriate trees and shrubs have long term ecological benefits that must be taken into consideration when assessing the flood impacts.

L6.6 Duration of Flooding

The duration of flooding or length of time a community, town or single dwelling (for example, a farmhouse) is cut off by floodwaters can have a significant impact on the costs and disruption associated with flooding. For example:

- an extended period of isolation in stressful situations can exacerbate post-event anxiety and trauma-related disorders;
- shortages of water and food may occur thereby placing high demands on limited emergency services; and
- medical emergencies may occur with treatment delayed or at worst prevented.

The duration of flooding generally correlates with the rate of rise of floodwater, typically, being longer in larger, flatter catchments and shorter in the smaller, steeper ones.

L6.7 Evacuation Problems

The levels of damage and disruption caused by a flood are also influenced by the difficulty of evacuating flood-affected people and property. Evacuation, may be difficult because of:

- the number of people requiring assistance;
- the depth and velocity floodwaters;
- wading problems, which can be exacerbated by uneven ground, fences, debris, localised high velocities, etc.;
- mobility of people – children, the aged, disabled people and the ill are less able to evacuate through floodwaters than healthy adults;
- the distance to flood-free ground;
- the inability to contact emergency services;
- bottlenecks, ie., the large number of people and great volume of goods that have to be moved over roads which cannot cope with the increased volume of traffic;
- the time of day and existing weather conditions (dark, rain, wind, etc.); and
- the lack of suitable evacuation equipment such as boats, heavy trucks, helicopters, etc.

Consideration of the impact on evacuation strategies of increased occupation of the floodplain is one of the key tests of cumulative impact in preparing management plans.

L6.8 Effective Flood Access

The availability of effective access routes from flood prone areas and developments can directly influence personal danger and potential damage reduction measures. Effective access means an exit route that remains trafficable for sufficient time to evacuate people and possessions, or any other appropriate boat-based or air-based means of evacuation. Specific problems can occur with cul-de-sac residential developments on rising land where the access road runs downhill from the properties, as the floodwaters rise, road access is cut off.

Access is generally divided into two categories, pedestrian and vehicular. The provision of road access that is trafficable in all weathers will assist in reducing the flood hazard and enhance the effectiveness of emergency services. Pedestrian access is far less effective due to problems with moving the aged, children and disabled.

It is essential that the consideration of access routes extend beyond the FPL. For example, in potentially hazardous developments (such as isolated high spots of land and canal subdivisions which can become inundated in floods larger than the event used to derive the FPL), provision should at least be made for access routes in extreme flood events. Access routes do not have to be above the PMF level but be at a level of flood protection that, in combination with effective warning time, development type and flood duration, provides adequate time for evacuation and reduces risk to acceptable levels. Without such access, the risk to personal safety of the entrapped and their rescuers may be unacceptable.

Further, care should be taken to evaluate the suitability of proposed evacuation routes and measures under a rare flood event, possibly the probable maximum flood (PMF) event.

Arrangements and evacuation routes, which may be suitable for flood events up to a flood used for determining the FPL, may become unsafe or inoperable for rare floods.

A potentially hazardous situation develops when rising floodwaters isolate an area of land, leaving it as an island in a sea of floodwater, prior to ultimate inundation.

Thus, while the filling of a flood prone block of land may render the property itself 'flood free' for the flood event on which the FPL is based, the property may become isolated if the access road is flooded, ie, in effect the filled land becomes an island. This isolation can cause significant additional danger to personal safety due to the potential for these islands to be completely inundated in rarer floods (see Figure G1).

Rescue by boat, helicopter or large vehicle may be necessary, so putting the rescuers lives at risk. Whilst such a situation may not develop for 'normal' floods, a check should be made to see whether or not rare flood events cause islands to develop, or even worse, to be later submerged.

L6.9 Type of Development

The degree of hazard to be managed is also a function of the type of development and resident mobility. This may alter the type of development considered appropriate in new development areas and change management strategies in existing development areas.

The following factors can affect the initial hydraulic assessment of hazard:

- the existence of special evacuation needs;
- level of occupant awareness;
- isolated residential development;
- hazardous industries or hazardous storage establishments;
- potential for damage and danger to personal safety; and
- development over watercourses.

L6.9.1 Special Evacuation Needs

General evacuation problems are discussed in Section L6.7. This section relates to the requirement to consider the specific evacuation needs from particular types of development such as aged, disabled and childcare facilities, mobile homes and caravan parks, isolated houses, schools, hospitals, and community centres.

An increase in the hydraulic hazard category for these development types is often necessary due to the requirement for:

- additional and different resources to evacuate; and
- additional effective warning time.

This may well mean that these development types are precluded from an area of the floodplain satisfactory for normal residential development.

PLATE 14 - Caravan Damage
(Photo courtesy "News & Sunday Mail")

L6.9.2 Level of Occupant Awareness

Caravan and mobile home parks, motels, hostels and hotels can all involve occupants (both short and long term) who are not conversant with flood risk management strategies for the development. The management (manager, operator or licensee) is responsible for providing advice on what to do during a flood, enabling occupants to act appropriately.

For existing establishments this may require the preparation, maintenance and promotion of a flood emergency response plan for the site. The plan should rely on resources under control of the management and occupants, rather than on external parties, such as the SES or council. Occupants should be advised of the flood emergency response plan and their responsibilities in a flood event. Copies of the plan should be available to occupants and provided to the SES for their information and reference in the local flood plan, if SES consider

this appropriate. Preparation of these plans for existing developments should be encouraged because of their potential to reduce flood risk (to both property and personal safety).

It must be noted that flood emergency response plans, where they do work effectively, reduce the flood risk (both the property and personal safety) but not the hydraulic hazard category in specific events.

Due to the transient nature and special needs of occupants, such plans should not be used as the basis of development consent for new developments of this type.

L6.9.3 Isolated Residential Development

Generally in lowering the density of development the evacuation assistance required is also reduced due to the lower number of people at risk. However, in the instance of rural residential developments proposed a reasonable distance inside the floodplain, the location generates special evacuation needs, due to the length and uncertainty of the evacuation route. Rural residential developments are often proposed as a low density alternative where normal residential developments are considered inappropriate due to flood impacts or other development constraints, such as servicing by infrastructure. However, where these are proposed with poor evacuation routes, the combined hazard level will often mean that they are inappropriate.

PLATE 15 - Isolated House

L6.9.4 Hazardous Industries or Hazardous Storage Establishments

Where a site within the floodplain involves an existing hazardous industry or hazardous storage establishment as defined in SEPP33, the potential affect of flooding of these materials can affect the hydraulic hazard category. If, due to escape of materials resulting from, or damage by, floodwater the potential is there for:

- a public health risk; or
- medium to long term (after the flood event has ended) environmental damage;

which results in an increased risk during floods. This increased risk can be reduced by having mechanisms and written procedures in the local flood plan to manage them.

It is important to encourage proper management of hazardous materials. Written procedures and appropriate mechanisms to manage this risk should be required or the materials should be re-located to a place they can be effectively managed, either within or outside the floodplain.

L6.9.5 Potential for Danger to Personal Safety and Damage

Certain types of development have a higher potential for damage in flood events than others and may present a danger to personal safety. There may be damage to structures themselves or associated damage to other structures in downstream areas (even in the low hydraulic hazard areas). These types of developments include mobile home and caravan parks. Caravans not removed, and mobile homes not tied down can result in downstream damage and danger to personal safety due to their mobility.

These factors, together with risk minimisation strategies, should be considered when determining the hazard category for these types of sites. This should be considered along with other associated factors, as indicated above, in hazard determination for these sites and in risk minimisation strategies.

L6.9.6 Development over Watercourses

Careful consideration needs to be made of proposed developments over watercourses. These developments should be assessed in terms of their potential impacts on hydraulic hazard, both within and external to the site, in events up to and including the probable maximum flood. Particular care should be taken in relation to increased danger to personal safety and impact on external resources for flood evacuation (such as the SES and council).

Existing developments should have properly prepared and maintained flood emergency response plans to assist in risk minimisation. These plans should rely, wherever possible, on the resources of the individual occupants and not on external evacuation resources. Occupants need to be made aware of the plans. The responsibility for preparation and maintenance of these plans (including regular reminders) lies with the managing agents or body corporate for the site. Copies of these plans should be provided to the SES for their information.

As indicated above, flood emergency response plans cannot be relied upon to be effective in all flood events and therefore cannot be considered to reduce the hydraulic hazard. At best they reduce flood risk in events where they operate effectively. As such, flood emergency response plans should not form the basis of development consent.