Chapter Five: Flood

Floodwaters on the South Brisbane freeway in Brisbane, Queensland, January 1974
Photo courtesy: Bureau of Meteorology.

Flood

Australia has long been called the land 'of droughts and flooding rains' (Mackellar 1911, p. 9). Historical records of floods date back to at least 1790, when the first flood fatality was recorded in Australia (Blong 2005). Since then, there have been over 2300 flood-related fatalities.

The estimated total cost of flooding during the period from 1967 to 1999 is $10.4 billion, equating to an average annual cost of $314 million (BTE 2001). A comparison with economic costs from other natural disasters confirms that flooding is the most costly natural disaster in Australia.

While vulnerability is increased through development in floodplains, the potential to gain significant benefits by effective management of flood risk is higher than for other hazards, as floods are restricted to definable areas and people directly influence flood risk.




Home contents thrown out following a flash flood in Melbourne, Victoria, January 2004
Photo courtesy: Geoscience Australia/Miriam Middelmann.

Flood damaged railway bridge over the Burdekin River, Queensland, January 1917
Photo courtesy: John Oxley Library/75246.

People receiving food after being made homeless by a flood, Charleville, Queensland, April 1990
Photo courtesy: Emergency Management Australia.

A devastating flood in Maitland, New South Wales, February 1955
Photo courtesy: NSW SES.

In Australia, floods are predominately caused by heavy rainfall, with La Niña years experiencing more floods on average than El Niño years. The process of analysing the flood risk from rainfall is described in this chapter. A number of gaps in the information are identified, including the uncertainties surrounding the potential influence of climate change on flood behaviour.

Flood risk analysis is an integral component of flood risk management. Though riverine flood hazard assessments have been undertaken for many years, the extension of this to consider the flood risk is less well developed. Many government and non-government agencies and groups play an important role in flood risk management, with state and territory governments having a major statutory responsibility in managing flood risk.

Hazard Identification

A 'flood' is described in *Floodplain Management in Australia. Best Practice Principles and Guidelines* as (SCARM 2000, p. 97):

'Relatively high water levels caused by excessive rainfall, storm surge, dam break or a tsunami that overtop the natural or artificial banks of a stream, creek, river, estuary, lake or dam.'

However, this definition does not convey the important concept that it is only when water is where it is not wanted that a flood is an issue.

Floods in Australia are predominately caused by heavy rainfall, though extreme tides, storm tide (covered in Chapter 4), tsunami (covered in Chapter 10), snow melt or dam break can also cause flooding. Rainfall can cause riverine and/or flash flooding. It can also exacerbate local drainage problems and cause groundwater to rise above the natural surface. This chapter focuses on flooding as a result of heavy rainfall.

There are a number of factors that influence whether or not a flood will occur. These include the volume, spatial distribution, intensity and duration of rainfall over the catchment; catchment conditions prior to the rainfall event; ground cover; topography; groundwater tables; the capacity of the watercourse or stream network to convey the run-off; and tidal influence. Development within the catchment and floodplain, and works which retard flows (e.g. dams and detention basins) or confine flows (e.g. levees) also influence whether or not a flood will occur.

Flooding from rainfall generally falls into the two broad categories, flash floods and riverine floods, that are described briefly below.

Flash Flood

Flash floods can occur almost anywhere, and result from a relatively short, intense burst of rainfall, for example during a thunderstorm. During these events the drainage system may be unable to cope with the downpour and flow frequently occurs outside defined water channels. Areas with low-capacity drainage systems, whether natural or artificial, are particularly vulnerable to flash flooding.

Although flash floods are generally localised, they pose a significant threat to human life, because of the high flow velocities, unpredictability and rapid onset of such events. Warning times for flash floods are short, with flash floods usually occurring within six hours of a rainfall event. Flash flooding is exacerbated in areas where there is a high proportion of impervious or near impervious surfaces which promote run-off. For example, highly developed urban areas have a high amount of impervious surfaces in the large areas taken up by roads and roofs. Areas where loss of vegetation has occurred, because of bushfire or activities such as overgrazing, also have a high amount of near-impervious surfaces.

Some recent flash flood events include the floods in the Hunter and central coast regions of New South Wales in June 2007, southeast

An abandoned car on a flooded road near Wyong, central coast region, New South Wales, June 2007
Photo courtesy: NSW SES.

Queensland and northeast New South Wales in June 2005, and in central west New South Wales in November 2005 (EMA 2007).

Riverine Flood

Riverine floods occur following heavy rainfall when watercourses do not have the capacity to convey the excess water. They occur in relatively low-lying areas adjacent to streams and rivers. In the flat inland regions of Australia, floods may spread thousands of square kilometres and last several weeks. In the mountain and coastal regions of Australia, flooding is often less extensive and of shorter duration, with higher flow velocities.

The spatial distribution of short-duration rapid-onset floods and long-duration slow-rise floods is shown in Figure 5.1. The Great Dividing Range in eastern Australia provides a natural separation of slower, wider rivers flowing west from faster, narrower coastal rivers flowing east.

In some cases natural blockages at river mouths may also cause flooding of estuaries and coastal lake systems or exacerbate riverine flooding in tidal sections of rivers. Examples of natural blockages include storm tide, high tide and sand berms which constrict river entrances.

Recent examples of riverine flood events include the floods in Gippsland, Victoria, in June–July 2007, the northwest Northern Territory in March 2007, and Katherine, Northern Territory, in April 2006; and on the New South Wales mid-north coast in March 2006 (EMA 2007). Details of severe riverine flood events across Australia are provided in SCARM (2000).

Cost of Floods

Floods frequently cause millions of dollars worth of damage, affecting both urban and rural environments and people's livelihoods. Both riverine and flash floods result in costly damage to residential, commercial and industrial properties. Damage to transport, power and telecommunications infrastructure also causes severe cost and disruption to the community. Riverine floods can cause huge cost to rural enterprises. For example, during the floods in Lismore, New South Wales, in 1974 the agricultural cost slightly exceeded the cost to buildings (BTE 2001). As well as having a huge economic cost, floods can also cause physical, psychological and emotional health costs, through death, injury, isolation and displacement.

Records for flood fatalities extend back further than the records for any of the other hazards considered in this report. From 1790 to 2001, there were 2292 recorded flood fatalities (Blong 2005), with flood fatalities commonly related to attempts to cross flooded creeks, bridges and roads. As noted in Chapter 2, the annual death toll from floods decreased substantially during that period, particularly during the 1800s, with improved warnings and flood awareness playing major roles. However, awareness of the risk posed by floods needs to be continually raised to further reduce the number of flood-related fatalities.

The more recent severe flood events leading to fatalities include floods on the east coast of New South Wales in 2007 (eight fatalities); in the Gympie–Maryborough area, Queensland, in 1999 (seven fatalities); in eastern New South Wales in 1989 (nine fatalities), and in Katherine, Northern Territory, in 1998 (three fatalities) (EMA 2007).

The total cost of flooding in the period from 1967 to 1999 has been estimated at $10.4 billion. This equates to an estimated average annual economic cost of flooding of $314 million (BTE 2001). At the time of writing, few companies provide flood insurance, contributing to difficulties in estimating the costs of floods, though the cost is likely to be underestimated rather than overestimated.

Loss caused by flooding varies widely from year to year. The annual economic cost of floods in Australia is shown in Figure 5.2 over the 33-year period to 1999. The figure also shows the number of flood events in Australia each year during the same time period. Events included in the database have a total cost of equal to, or over $10 million per event, with widespread flooding classed as a single event. This figure illustrates that loss due to flooding each year is dependent not only on the number of floods, but also on flood severity.

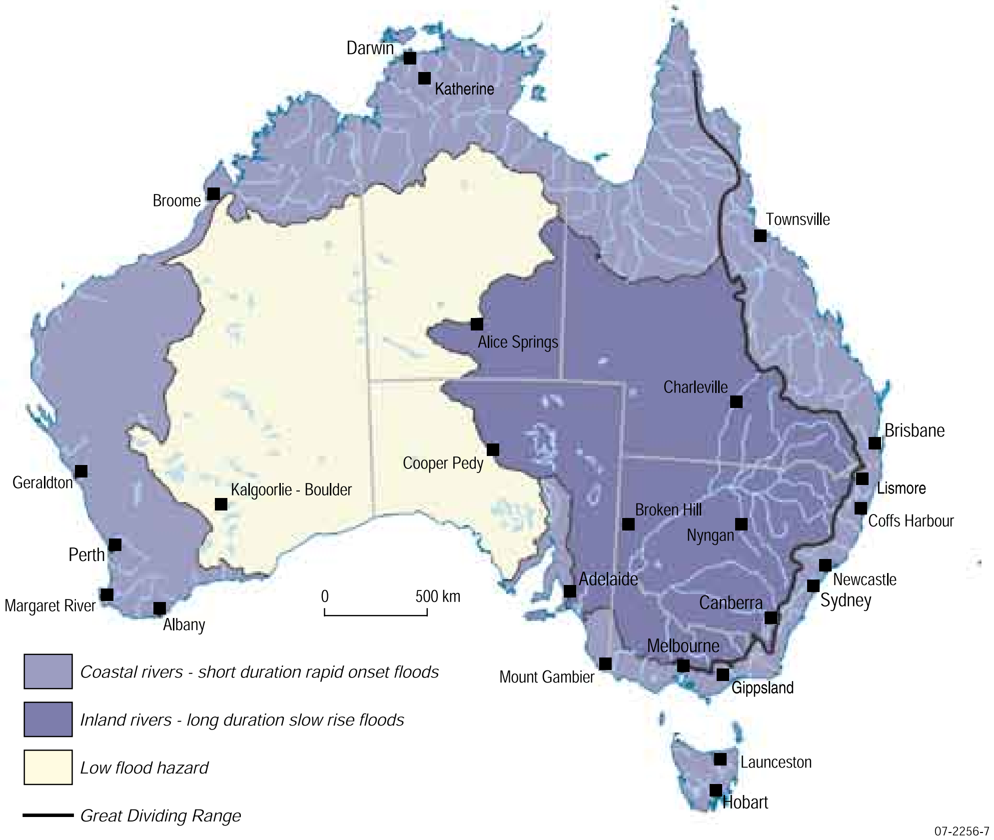


Figure 5.1: Flood potential in Australia
Source: Geoscience Australia.

Other factors, such as location and the nature of development, also play a role in determining loss.

Floods are not solely negative phenomena, as they are part of a natural cycle. Floods can have significant environmental and social benefits, particularly in areas which have suffered a long drought. Floods are important to the long-term viability of ecosystems, species and populations and the maintenance of ecosystem function. Floods encourage breeding, spawning, seed dispersal and germination, and increase the food source for aquatic birds (Handmer and others 2002). Floods may also increase agricultural productivity through the deposition of soils and nutrients and the provision of water for irrigation.

Potential Influence of Climate Change

The potential impact of climate change and variability on floods is being studied at various levels. Several organisations with responsibility for water resources have been active in trying to understand the impact of climate change.

Current projections suggest that average rainfall is likely to increase in the north of Australia and decrease in the south. The intensity of the extreme daily rainfall event is likely to increase in many parts of the country (McInnes and others 2003; Whetton and others 2002; Walsh and others 2001; Abbs 2004; Hennessy and others 2004). Rainfall intensity is a significant influence on the magnitude of flooding, as are antecedent conditions: for example, a dry catchment generates less run-off.

While most climate models do not provide information at the resolution required by hydrologists and planners, there are techniques which can downscale the results to localised regions. These techniques can identify regions where significant rainfall increases are likely to result in increased flooding (e.g. Abbs and others 2007).

The Intergovernmental Panel on Climate Change Fourth Assessment Report highlights the potential impacts of climate change on sea level rise (Meehl and others 2007). Any rise in sea level has the potential to have a significant impact on flood behaviour and levels where storm tide,

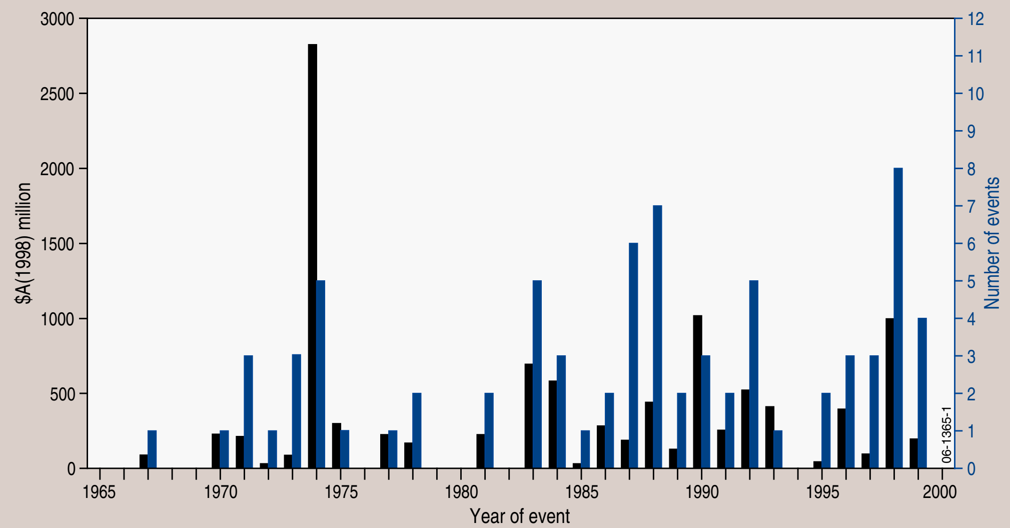


Figure 5.2: Annual cost and number of floods in Australia, 1967 to1999
Source: Based on BTE (2001), Figures 3.15 and 3.17.

high tides and/or constricted or closed outlets to the ocean influence flood behaviour.

Risk Analysis

Flood poses a risk only when it has the potential to impact on an element of tangible or intrinsic value, such as buildings, infrastructure or people. People directly influence flood risk. For example, the construction of new development in the floodplain, or changes in floodplain topography, may raise flood levels at another location. The increase in impervious areas also contributes to a greater volume of run-off and potentially larger peak flood flows. As further development occurs in floodplains, the number of elements exposed to flooding increases. However, effective mitigation strategies may help in reducing flood risk.

The development of the more hazardous parts of the floodplain can be a negative catalyst which transforms a 'hazard' into a 'disaster'. As the population in affected areas increases, so to does the potential scale of a disaster.

The most severe example of urban flooding in Australia occurred in Brisbane–Ipswich in 1974. Three floods prior to the 1974 floods (in 1841, 1844 and 1893) were, however, significantly greater in magnitude at the Brisbane City gauge. Had those floods occurred later in history, their economic impacts would have been far more damaging than those of the 1974 flood.

This highlights the importance of thoroughly analysing the risk in order to more effectively identify and implement appropriate mitigation strategies, and to plan and prepare for the response and recovery phases for when a flood does impact on communities.

Because flood damage is costly and the Australian population has settled very close to rivers, for the supply of water and transport, riverine flood hazard assessments have been undertaken regularly in Australia since the early 1950s. Therefore, the technology is well matured, and most areas affected by riverine flooding have undergone some assessment.

The extension of flood hazard assessment to a risk analysis that looks more objectively at likelihood and consequence is, however, much less widespread, and there are heavily populated urban areas for which no such analysis of flood risk has been made. This deficit is exacerbated by the fact that urban centres are more affected by flash flooding.

In many instances, assessments have led to structural and non-structural mitigation measures. Such measures are usually framed around a 'flood standard' expressed in terms of the annual exceedence probability (AEP). AEP is a statistical benchmark used for flood comparison, defined as the probability of a flood event of a given magnitude being equalled or exceeded in any one year (Pilgrim 2001).

Flood risk management, of which risk analysis is a component, is described in SCARM (2000) and other documents (e.g. DIPNR 2005). The approach is not prescriptive and requires

Flooding in Melbourne St., South Brisbane, Queensland, February 1893
Photo courtesy: John Oxley Library/66106.

Buildings destroyed by a flood in Ipswich, Queensland, February 1893
Photo courtesy: Hughes Collection/Ipswich Historical Society/A. Geertsma/B. Taylor.

Filling sandbags to form flood barriers at Lakes Entrance, Bullock Island, Gippsland, June-July 2007
Photo courtesy: CFA Public Affairs.

identifying and managing the full range of flood risks, in partnership with the stakeholders at risk of flooding and in consideration of local issues.

The 1% AEP flood or the largest known historical flood (plus an appropriate safety/error margin) is typically used for placing restrictions on new developments requiring planning or building permits. Likewise, it is typically used for determining the design standard for structural flood mitigation works. However, increasing recognition is being given to the use of a more robust risk assessment to justify the need for a higher or lower standard.

Increasingly, more extreme floods (e.g. 0.2% AEP) or the probable maximum flood (PMF) are used as the development controls for the building of critical facilities such as hospitals, emergency services, police facilities, power stations and water treatment plants (e.g. Queensland Government 2003).

The more extreme floods are also used to provide essential information on the scale and extent of the problem for emergency response planning. They can also be used to identify facilities that may need special consideration in an emergency response. Examples of such facilities include nursing homes, child care centres and high-security correctional centres.

A comprehensive risk analysis of the full range of flood risk, including damage by rarer floods and by the more common floods, enables a better balance in assessing overall risk. It also better takes account of the natural cycle of floods and the impact of structural measures already undertaken.

There are several key stages to analysing risk. The first two stages in the risk analysis process involve assessing the likelihood of flooding by developing an understanding of flood behaviour through modelling studies using floods of different frequencies. Outputs from such studies include maps showing the extent of flooding and, in some cases, other information such as the variations in water depth and flow velocity across the floodplain.

The third stage looks at the consequences of the full range of flood risks by assessing the exposure and/or vulnerability of the elements at risk of inundation, such as people, buildings and infrastructure. It also examines how risk can most effectively be managed to inform decision making.

All stages require making important decisions relating to the choice and scope of the modelling. The selection of models depends on variables such as catchment characteristics, the purpose of the modelling, budget, data available and time constraints. A model is only a representation of what may happen; therefore, the results will vary depending on the different models used and assumptions made. The issue of risk versus cost, including the concept of 'tolerable' risk (as described in Chapter 3), also needs to be considered when collecting data. The accuracy of the digital elevation data is often the greatest constraint for inundation consequence modelling.

The stages of likelihood and consequence analyses, and the broad data requirements involved in each, are described in more detail in the following sections.

Likelihood Analysis

Flood behaviour modelling is used to determine the likelihood of flooding for a given area, and is usually commissioned by flood management agencies from local or state government. The modelling is often undertaken by consultants because of the specialist technical nature of the work.

Modelling flood behaviour is technically a two-stage process. The first stage involves estimating the flood potential or probable flood flows. This may be done by combining flood frequency analysis (where sufficient flow data is available) and/or the use of artificial 'design' sets of rainfall data applicable to the area with a rainfall run-off model, to estimate design flood hydrographs for various frequencies and durations of events. This stage is commonly known as the 'hydrologic analysis'.

The Engineers Australia publication *Australian Rainfall and Runoff* (Pilgrim 2001) provides guidance on methods for estimating design floods, including estimates of applicable design rainfall. The hydrological component of the model needs to consider historical data. The model may be calibrated and verified, often in combination with hydraulic modelling, which is described below.

The second stage, called the 'hydraulic component', involves evaluating the hydraulic behaviour of flood flow through the area of interest. Hydraulic models are calibrated and verified against historical flood levels, flow data, rainfall data and even public recollections about what areas were affected, to ensure that modelled flood behaviour reflects reality.

Many hydrological and hydraulic models are available in the market, and often the selection is based on familiarity by the user, along with the broad characteristics or geometry of the particular floodplain. Some of these models have been reviewed by the Manly Hydraulics Laboratory (2006), and the more frequently used models have been identified by Middelmann and others (2005b).

The hydraulic models may be one dimensional or two dimensional (or combinations of these), and the flow analyses may be based on either steady states (i.e. inputs are not time dependent) or unsteady/dynamic states (i.e. inputs are time dependent). The impacts from structures such as levees and dams are required to be incorporated into the hydraulic modelling component. The Australian Flood Studies Database (GA 2007) provides a record of flood studies undertaken nationally since 1980.

Data requirements

It is essential that good records of both rainfall and stream gauge data are available for acceptable flood hazard modelling. In some cases, information on tides may also be required. Cross-sectional data of the channel and survey information that captures the floodplain geometry are essential, including data relating to the surface roughness of channels and floodplain areas. Details of environmental and human influences, including the storage capacity of various parts of the floodplain and features that influence flow behaviour, such

A railway station flooded at Maitland, New South Wales, February 1955
Photo courtesy: NSW SES.

as raised roads and levees, are also important. Ideally, these data are sourced from bathymetric and land surveys of the area concerned.

A model is only as good as the data it contains; therefore, the availability of high-quality and appropriate data is paramount. The number and distribution of rainfall and stream flow gauging stations, their history of operation, and the reliability of data can significantly affect the uncertainty around the estimates. Where possible, the model should be calibrated against several historic floods, using information such as historical flood levels and discharges and flood photography. As the floods of interest generally relate to rare events, the calibration data should focus on these in particular.

Consequence Analysis

At the most simplistic level, an assessment of consequence may be made for any elements, such as buildings or infrastructure, that essentially become 'wet' in a flood. As more data on both the hazard and the elements exposed become available, more sophisticated estimates can be made. This also requires the development and application of appropriate models, such as stage damage curves, to estimate vulnerability. Some of the broad types of models for flooding are briefly discussed in this section.

Floods cause damage not only directly, by inundation, erosion or 'washing away' of facilities, but also indirectly, off-site. The flooding or isolation by flood waters of critical facilities such as hospitals places pressure on the services provided by these facilities to communities in other areas. Flood damage to infrastructure can cause power outages and disrupt communication services for people living outside the inundated area. It may also have sewage and water supply implications and, therefore, health implications. Floods can cut off vital transport links, causing general disruption and isolation, particularly in remote communities.

Direct damage costs for residential buildings are typically estimated using engineering vulnerability models such as stage damage curves. Curves have been developed which estimate flood damage to building structure and/or to building contents, based on the depth (i.e. 'stage' height) of over-floor flooding. Though the structural and contents curves available worldwide are produced in different ways, they typically indicate a sudden increase in damage as soon as water goes over the floor.

From 1980 to 2004, the most commonly used stage damage curve in Australia was ANUFLOOD (Middelmann and others 2005b), though subsequent work using insured loss data suggests that ANUFLOOD significantly underestimates flood damages (Blong 2002).

Examples of specific damage studies that have been conducted with the use of geographic information system (GIS), survey and property data include two studies done for areas in Queensland: Gold Coast City (Betts 2002) and southeast Queensland (Middelmann and others 2001), and a study for Perth, Western Australia (Middelmann in draft).

Factors other than water depth influence damage. The flow velocity, the length of time for which an area is inundated, building materials, and the amount of sediment in the water also influence damage. Contents loss can be reduced where sufficient flood warning is given and contents are able to be moved to elevations above the flood level.

Research has been undertaken in Australia to assess how different building types are affected by various flood depths and velocities. Dale and others (2004) built on Black's (1975) research in the United States which described the combinations of water depth and velocity theoretically required to move a house subject to flooding off its foundations. Because the weight of the structure is a key factor in whether a house will move off its foundations in floodwaters, a house with brick veneer walls was found to be more resilient than a house with fibro walls. Roof type was also found to play a role, with buildings with tile roofs heavier and therefore more resilient than buildings with steel roofs (Dale and others 2004).

The economic cost resulting from flooding of commercial or industrial buildings can greatly exceed the cost from flooding of residential buildings (Booysen and others 1999). For example, damage to commercial and industrial buildings and contents was more than double residential damage in the 1974 Lismore flood (BTE 2001).

However, damage costs for commercial or industrial buildings can be more difficult to estimate, because the cost of damage greatly depends on the function and contents of the building. Therefore, estimates of damage on a site-by-site basis, through interviews of individual businesses, are more accurate than estimates using stage damage–type curves. Damage estimates based on floor area and the susceptibility of a building to flood damage were, however, developed for commercial properties by Smith (1994), for use in lieu of site-specific data.

Indirect damage costs, such as loss of production, revenue or wages, are more difficult to model than direct costs. Other indirect costs include clean-up and repair costs and the impact from loss of services. Residential clean-up time as a function of flood depth is shown in Figure 5.3, based on SMEC (1975). As with stage damage curves, the greatest increase in clean-up costs occurs as soon as the water goes over the floor.

Prior experience of flooding at a location appears to reduce overall stress both during and after an event. Prior experience also appears to have an impact on physical health. A study of

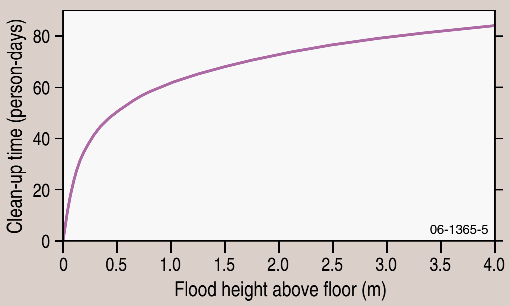


Figure 5.3: Residential clean-up time as a function of flood depth   Source: BTE (2001), Figure 4.6.

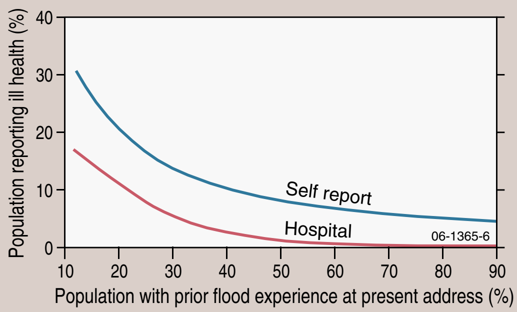


Figure 5.4: Health impact of floods as a function of prior flood experience   Source: Based on BTE (2001), Figure 4.7.

A rural road flooded in the Moree area, northwest New South Wales, December 2004
Photo courtesy: NSW SES.

populations in Queensland (Handmer and others 1986) found that those with prior experience of flooding at their current address were less likely to report ill health in the aftermath of severe flooding, as shown in Figure 5.4.

Data requirements

Determining consequence requires information on the flood hazard and the actual elements or facilities potentially subject to flooding. This may include the location and elevation of buildings and infrastructure such as power and telecommunications, and the location of people.

Defining the extent of the area of inundation and the variation in susceptibility to damage across the floodplain is essential in order to understand the potential consequences of flooding and how the particular components of exposure can be managed.

The most simplistic form of risk analysis looks at what elements are located within the flooded area. At a more detailed level, knowledge of the depth of over-floor flooding in relation to the elements at risk, such as buildings, is required, and information on building type can be useful. A digital elevation model (DEM) of suitable resolution may be used in conjunction with water surface elevation information to estimate water depths at specific points of interest.

A more rigorous risk analysis requires additional information on hazard parameters such as flow velocities and duration of inundation. It also requires more detailed information on the elements at risk, to assess their vulnerability.

The information required will vary depending on the damage model to be used, but may include information such as floor area, floor height, wall type, roof type and floor type. Data on commercial and industrial buildings may be collected through interview. Information on the location of critical facilities, such as ambulance stations and state emergency services, is also needed.

Unsteady or dynamic flood modelling, where inputs are time dependent, is essential in a more detailed risk analysis, to provide a good understanding of the variation in flood consequences. This approach will assist in estimating the time (after the onset of heavy rainfall or the commencement of flooding) before a particular element or group of elements at risk is flooded. Dynamic modelling should also estimate the length of time for which the elements at risk, such as roads and bridges, are inundated.

Identification of highly vulnerable groups of people, such as people with disabilities, is also important. Caravan parks sited on floodplains create a special risk category (Yeo 2003). In many cases, mobile caravans occupied by travelling people have been progressively replaced by semi-permanent 'relocatable' structures occupied by socioeconomically disadvantaged people.

Information Gaps

Although significant work has been undertaken over previous decades, there are still important information gaps relating to flood risk analysis. These include standards in modelling and reporting, risk from flash flooding, influence of climate change, vulnerability research, research into making buildings more flood-resistant and post-disaster assessment. Lack of data, such as high-resolution DEMs, rainfall records and streamflow records, though not specifically covered below, remains an issue in some areas.

Lack of Standards in Modelling and Reporting

Flood likelihood information is more comprehensive than the likelihood information available for many other hazards. However, there are large discrepancies in the information currently used. Flood investigations use a wide range of appropriate models: the selection of a model depends on the location, the flood type, the intent and budget of the study and the data available. There are no nationally accepted, consistent standards for models and approaches, or for the analysis and reporting of risk.

National guidance for reporting on risk analysis could be considered in light of the National Risk Assessment Framework (NRAAG 2007) and the need to compare risks between locations and hazards. This national guidance could also address general standards and methodologies and set some minimum standards or benchmarks for studies for particular purposes.

Models and approaches

Comparison of flood risks is difficult at a national level, because of the variation in models and approaches used, especially regarding hazard and building damage models. For example, Middelmann and others (2005b) found that less than 60% of the damage studies they assessed provided details such as which damage curve or model was used for the damage estimation, a critical factor in comparing loss estimates.

Substantial differences can be found in hazard determinations (Middelmann and others 2005a) and damage estimates (Blong 2002), depending on the model used. Selection of the most appropriate data for the purpose and location is therefore important.

Though factors other than depth of inundation play a role in determining the level of damage, they are rarely incorporated in a risk analysis. An analysis of published Australian flood risk studies to 2004 found that only 11% of damage assessments incorporated velocity and no studies incorporated duration of inundation (Middelmann and others 2005b). The substantial additional cost incurred to collect, implement and analyse this data, and the paucity of damage curves for combinations of velocity and water depth, may be the reasons for this. Work by Dale and others (2004) is a step towards remedying this situation.

Reporting of damage

The reporting of damage also varies significantly. Only 23% of damage assessments in the Australian Flood Studies Database gave both the number of properties with over-floor flooding and the number of properties with water at least on the property (Middelmann and others 2005b). Forty percent of damage assessments made no comment on the number of properties affected, but gave either an average annual damage or a total damage cost.

The latest published estimate of the number of residential properties in Australia susceptible to mainstream river flooding by the 1% AEP event is approximately 170,000 (Leigh and Gissing

Flooded central business district in Lismore, New South Wales, March 1974
Photo courtesy: NSW SES.

2006). Due to the differences in reporting in flood studies, no consistent risk measure could be used. Some areas have not had any form of risk analysis undertaken. Just in New South Wales, a state where much has been done to identify the flood risk, the study identified 26 towns and communities for which studies may be required. No estimates have been made of the numbers of properties affected at other levels of probability, because of the extremely limited data.

Understanding the potential impact from a full range of flood probabilities through to the PMF is important from an emergency management perspective. It is also important for identifying and implementing appropriate mitigation strategies.

Another hindrance when making a comparison nationally is that flood studies and risk assessments have been undertaken over a long period in history. Therefore, the impact of recent development is not reflected, nor have the most up-to-date flood levels available been used, highlighting the issues of data maintenance and currency. In some areas, though flood water levels may have been estimated, maps of the extent of inundation may not have been produced. The affects of factors such as water depth, velocity and duration are also often not considered.

In general, councils should review their flood management plans after a major flood event, or when there has been, or needs to be, a significant change in the management of the floodplain. This may involve updating the modelling, which provides an opportunity to collect additional data.

Risk from Flash Flooding

Currently, limited data is available on the risk posed by flash flooding, though the number of properties at risk from flash flooding is likely to far exceed the number at risk of riverine flooding.

The number of properties in the Melbourne area affected by flash flooding has been estimated by Melbourne Water (2006) to be more than 82,000. The same document estimated the average annual damages for flash flooding to be $215 million for Melbourne alone, compared to an estimated $30 million for riverine flooding. Clearly this is a significant problem for Melbourne, and one that is likely to be mirrored in most other heavily urbanised areas of Australia.

Much greater research is required to understand and manage the risks from flash flooding. The analysis of areas at risk from flash flooding can follow essentially the same process as for riverine flooding. However, the level of uncertainty surrounding the risk analysis is larger. Local impacts are difficult to predict, because of the complexity in assessing local overland flow path effects. Variable factors such as drains being temporarily blocked (sometimes by large objects such as cars) and flow paths being impeded, and other local occurrences including land use changes, create potential complexities that are hard to model other than by way of broad contingency allowances.

Influence of Climate Change

The development of new housing and infrastructure should factor in potential increases in flood risk arising from any increases in extreme rainfall and sea level rise as consequences of climate change. Various levels of government are analysing these changes to see how they can be factored into planning processes. Awareness of the changed flood risk enables local councils to implement new flood mitigation strategies, respond through land use planning, minimise future risk in emergencies and engage with and educate the community. An example of a preliminary study is that of the Gold Coast City Council (Rahman 2007).

Regional changes in peak rainfall intensity should also be determined directly, rather than through downscaling techniques. The impacts of changes in average rainfall on catchments are also important in determining the overall changes in flood risk.

Vulnerability Research

There are a number of gaps in the knowledge of structural vulnerability to flooding. Most existing structural vulnerability research considers loss caused by wetting of components to various heights (i.e. stage damage curves). Loss caused by partial structural damage (i.e. the failure of a component of the structure, such as a wall panel, door or window) is rarely considered. Complete structural failure, requiring a complete rebuild, is also rarely considered.

The work on residential structures tends to focus on particular housing types and materials. There is, therefore, an opportunity to broaden research to cover more residential structure types. Refinement of the curves currently in use, and examination of their sensitivity to changes in flood risk, are also important.

The majority of work to date has focused on residential premises, leaving gaps in vulnerability modelling of commercial and industrial premises.

There is a critical need to look at the potential secondary consequences of flooding from both a community risk perspective and an environmental risk perspective. Floods affecting sites that store hazardous materials, for example, pose unique and significant risks. Inundation of sewerage facilities poses significant health risks.

While there have been some attempts at modelling vulnerability connected to timeliness of

The Hunter River in flood at Morpeth, New South Wales, June 2007
Photo courtesy: NSW SES/Phil Campbell.

evacuation, such as in the Hawkesbury–Nepean catchment downstream of the Warragamba Dam in New South Wales (Opper 2004), this is another issue that needs more investigation.

Making Buildings More Resistant to Floods

Research into developing flood-resistant building materials to withstand flood loads or other actions is only beginning. Research could also be undertaken into the optimal location of electrics and telecommunications in flood-prone buildings. Many documents referenced by the Building Code of Australia have provisions relating to structural actions and the durability of components subject to site and soil conditions; however, this information is not specifically located in sections relating to flood inundation.

Flood damage to the Mitchell Highway near Nyngan, New South Wales, April 1990
Photo courtesy: Emergency Management Australia.

Post-disaster Assessment

Post-disaster assessments provide valuable information on losses, which may be used in areas such as model development and disaster management. The development and use of a consistent survey for the collection of post-disaster information nationally would enable more robust comparisons between events and locations. It would also assist in developing a more accurate assessment of the cost of floods in Australia. The data collected would also assist in demonstrating the effectiveness of mitigation strategies and provide vital information for the development of flood damage models.

Routine post-disaster assessments were recommended in the high level report to the Council of Australian Governments *Natural Disasters in Australia. Reforming Mitigation, Relief and Recovery Arrangements* (COAG 2004).

Roles and Responsibilities

Responsibility for the management of flood risk cuts across all levels of government, non-government agencies and groups, and the general community. State and territory governments play a particularly important role in managing flood risk, including a major statutory responsibility.

'Flood risk management' is essentially the way in which the likelihood and consequences of flooding are dealt with. Flood risk management is succinctly described in SCARM as (2000, p. 5):

'the analysis of the risk exposure of a flood-prone community; that is, a flood risk analysis, followed by the identification and implementation of appropriate measures to manage existing, future and residual flood risks to acceptable levels.' **[emphasis in the original]**

This section attempts to describe the various expectations of the different stakeholders in managing flood risk effectively.

Australian Government

The Australian Government's overarching goal in the management of flood risk is to ensure the economic and social health of Australia (SCARM 2000). The Australian Government provides financial assistance for flood studies, warning systems and mitigation measures, through its funding programmes aimed at reducing the risk of natural disasters. Following a disaster, the Australian Government also provides financial assistance to those suffering from the impact of the disaster. It also plays a role in raising broad community awareness of flood risk.

The Australian Government takes a lead role in the provision of flood warning services. It also plays a significant role in developing and managing rainfall data collection networks, and is the source of design rainfall information that is essential for flood estimation and warning. The government supports research into flood-related aspects of risk analysis, including post-disaster surveys, and invests in the development of new technology, such as remote sensing. The Australian Government also maintains the Australian Flood Studies Database.

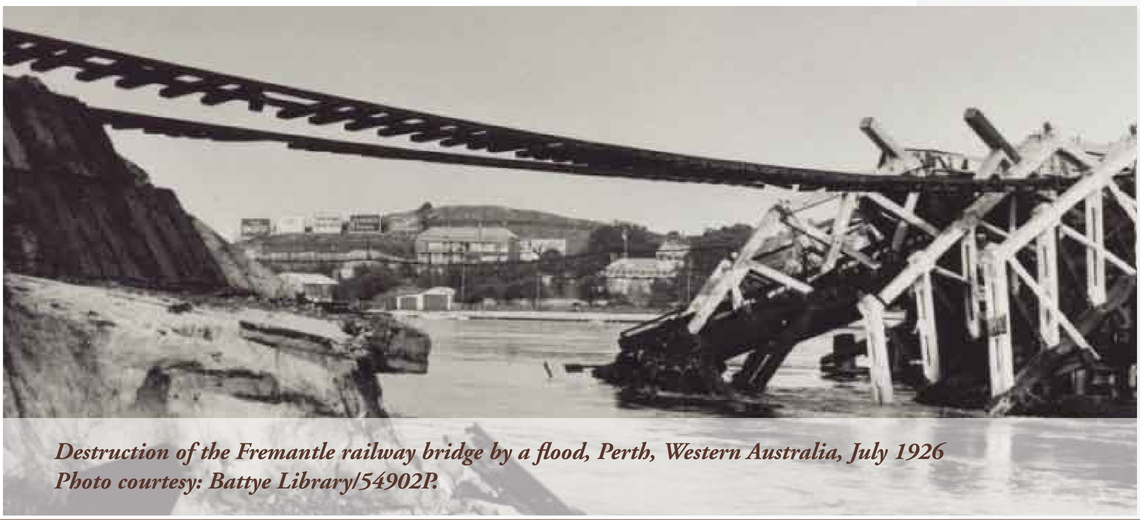
State and Territory Governments

State and territory government agencies play important roles in flood management in Australia. These roles encompass areas of technical, policy and financial support. The different types of agencies and their key roles are briefly described below; for further detail, the reader is referred to SCARM (2000).

Some state and territory variation exists in the roles played by the agencies, and some states and territories delegate greater responsibility to local agencies. A number of state and territory government agencies have developed their own flood management strategies, including guidance materials (DIPNR 2005; DNRE 1998; WRC 2004). They also play a key role in managing stream gauge networks essential for flood estimation.

Water resource agencies

Water resource agencies provide advice on flooding and floodplain behaviour, and maintain the expertise to deal with the technical aspects of flooding behaviour. They are often also involved in coordinating and funding research into specific aspects of flooding. Their primary function in relation to floods is to facilitate and guide local agencies in flood management, particularly in the development and implementation of flood management plans.



Destruction of the Fremantle railway bridge by a flood, Perth, Western Australia, July 1926
Photo courtesy: Battye Library/54902P.

Submerged houses by a flood in Ipswich, Queensland, January 1974
Photo courtesy: Hughes collection/Ipswich Historical Society/Philip Willey.

Water resource agencies provide guidance regarding flood modelling and help local agencies on definitional issues. They advise other state agencies, especially those involved in planning, transport and emergency services. They also advise and assist in relation to flood forecasting and warnings and the assessment of grants.

Land use planning agencies

The planning agency in each state and territory broadly administers the local planning system and the preparation of regional and special issue plans. It also oversees the development of local planning instruments which encompass planning requirements for flooding. The state planning agency liaises with the state water resource agency on appropriate floodplain development, and manages relevant documentation, including flood maps.

Road and rail transport agencies

Road and rail transport agencies have a responsibility to protect road and railway infrastructure against floods and to ensure that the infrastructure does not detrimentally increase flood levels and, thereby, flood hazard. They do this by liaising closely with the state water resource agency and local agencies.

Emergency management agencies

Emergency management agencies have the statutory responsibility to coordinate flood emergency operations, including warning the community. Associated with this is the expectation that they will help local agencies in the preparation of flood emergency response plans, though the actual responsibility varies across the states and territories. The development of these plans is considered critical to protect life and property, and requires input from various sources (including the relevant local government agency, state water resource agency and emergency services agencies).

Emergency management agencies are assisted in their response operations by flood forecasts from the Bureau of Meteorology. They also receive assistance and advice on flood behaviour from the state water resource agencies, to inform their flood response planning. Emergency management agencies also have a responsibility as combat agencies, for example in evacuation and rescue, and in some states and territories they have a responsibility in coordinating recovery operations.

Local Government

The expected role of local government in flood risk management varies across the country, as does legislation covering this aspect. The roles are invariably linked to storm water and flood management.

Generally, local government has the primary responsibility for managing the impact of flooding in their local area. Activities include undertaking flood risk assessments and implementing planning controls, and developing and implementing plans to mitigate flood risk. Local government also provides assistance to emergency services in times of flood, and make members of the community aware of the risks posed by flooding and ways to reduce the risk to themselves. Local government therefore materially contributes to the management of flood risk.

In most urban areas, councils or the territory government are responsible for local flood management, including risk assessment. In rural areas, the responsibility is sometimes shared with other groups such as state government agencies, catchment management authorities and river trusts. In the greater Melbourne area, councils are responsible for drainage and flooding issues for catchments up to 60 hectares in size, and Melbourne Water takes responsibility for all the larger catchments. Flood management outcomes are sometimes addressed through a floodplain management committee (SCARM 2000).

Industry, Coordinating Groups, Professional Bodies and Research Institutions

A number of professional bodies, coordinating groups and industry bodies play an advocacy role in flood risk management. There is a mix of informal and formal groups. Some function at a national level, such as the National Flood Risk Advisory Group (NFRAG 2006), Engineers Australia and the Insurance Council of Australia. Other groups are state-based or locally based, such as the state flood warning consultative committees (FWCC 1987), state flood policy committees and state emergency management committees.

The Floodplain Management Authorities is a key industry stakeholder representing about 80 organisations, primarily in New South Wales (FMA 2007). It provides opportunities for the discussion of issues in flood management and the sharing of experience across the industry. Numerous consulting companies are involved in flood hazard and risk assessment on behalf of government and non-government agencies. Research into different aspects of flood hazard and risk assessment is also conducted by various universities, cooperative research centres and CSIRO.

Elderly residents are evacuated from a nursing home near Wyong on the Central Coast, New South Wales, June 2007
Photo courtesy: NSW SES/Kim Palmer.

An aerial view of the flooded Richmond River High School in Lismore, New South Wales, June 2005
Photo courtesy: NSW SES/Phil Campbell.

Property Developers

Developers are required to prepare applications which address the provisions or conditions relating to development in a floodplain. Generally, the developer is required to undertake sufficiently detailed flood, economic and environmental studies to demonstrate that the proposal has no adverse flood or environmental effects and meets relevant performance standards.

Courts and Legal Institutions

The courts and other legal institutions, such as administrative appeals tribunals, play a significant role in settling disputes between developers, councils and other opposing parties regarding applications for development in a floodplain.

Media

The media play a vital role in delivering the message behind flood warnings to the community. In the event of an emergency, radio broadcasts are particularly effective in warning the community. The media are also very much involved in raising community awareness of flood hazard in general.

General Community

Individuals have a basic responsibility to be aware of any flood risk faced by themselves, their families and their communities. Ideally, individuals should know what to do during a flood event and understand how a flood height at a flood reference gauge will affect their individual property. At a minimum, members of the general community should at least have the knowledge to understand the advice of the relevant authorities during a flood event. Awareness raising requires input from agencies dealing with flood management and emergency response.

A specific knowledge of the location of evacuation routes and how to respond to flood warnings is vital for community safety. The community should also have a more general understanding that extreme floods occur, including in areas where development is being approved by the local agency. They should also understand that measures such as structural flood mitigation works can rarely, if ever, fully alleviate the flood risk.

Irrespective of the level of flood risk, vulnerability of a community is greatly reduced when individuals are able to obtain relevant information and are committed to meeting their responsibilities.

Conclusion

Floods have been estimated to contribute 29% of the average annual natural hazard damage in Australia, costing around $314 million each year. Records for flood fatalities extend back further than records for any other hazard, with over 2300 fatalities since 1790.

Because of the huge cost imposed on the community by floods, it is vital that the risk of flooding in Australia from a full range of flood events, including the potential impact of climate change, is determined. All levels of government, as well as non-government agencies and groups and local communities, play an important role in flood risk management, with state and territory governments having a major statutory responsibility, and local government generally having primary responsibility for managing the impacts of flooding in their local area.

The models used to assess risk are only as good as the data used in their development. The development of detailed, calibrated and verified flood modelling is therefore essential in order to accurately assess exposure. This requires good records of data such as rainfall, stream gauge and tidal information, flood photography and historic flood levels. High-resolution topographic and bathymetric data are also required, along with detailed information on environmental and human influences on flood flows and storages.

To assess consequence, information on the elements of risk and a high-resolution DEM are also required. While many factors contribute to vulnerability, knowledge of the depth of over-floor flooding is the minimum data requirement. Information on velocity and duration of inundation is required for a more rigorous analysis of flood risk.

Further work in areas such as flash flood risk, vulnerability model development, post-disaster assessment and climate change is also important. Guidance in modelling, damage reporting, and research into making buildings more resistant to floods are also areas for further work.

Flooding at Rosebrook, Victoria, March 1946
Photo courtesy: Glenelg Hopkins Catchment Management Authority.