Australian Disaster Resilience Handbook Collection

HANDBOOK 7

Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia

Australian Institute for
Disaster Resilience

Cover images, clockwise from top: An aerial view of the 2011 Brisbane River flood (photo: iStock); Lismore CBD floods due to the impact of ex-tropical cyclone Debbie (photo: NSW SES); a flooded road (photo: iStock).

AUSTRALIAN DISASTER RESILIENCE HANDBOOK COLLECTION

Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia

Handbook 7

Australian Government
Attorney-General's Department

Edited and published by the Australian Institute for Disaster Resilience, on behalf of the Australian Government Attorney-General's Department.

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History of the Australian Disaster Resilience Handbook Collection

The first publications in the original Australian Emergency Manual Series were primarily skills reference manuals produced from 1989 onwards. In August 1996, on advice from the National Emergency Management Principles and Practice Advisory Group, the Series was expanded to include a more comprehensive range of emergency management principles and practice reference publications.

In 2011, Handbooks were introduced to better align the Series with the *National Strategy for Disaster Resilience*. Compiled by practitioners with management and service-delivery experience in a range of disaster events, the handbooks comprised principles, strategies and actions to help the management and delivery of support services in a disaster context.

In 2015, the Australian Institute for Disaster Resilience (AIDR) was appointed custodian of the handbooks and manuals in the series. Now known as the Australian Disaster Resilience Handbook Collection, AIDR continues to provide guidance on the national principles supporting disaster resilience in Australia through management and publication of the Collection.

The Handbook Collection is developed and reviewed by national consultative committees representing a range of state and territory agencies, governments, organisations and individuals involved in disaster resilience. The Collection is sponsored by the Australian Government Attorney-General's Department.

Access to the Collection and further details are available at the Australian Disaster Resilience Knowledge Hub at www.knowledge.aidr.org.au.

Australian Disaster Resilience Handbook Collection (2011 –)

Handbook 1 Disaster Health

Handbook 2 Community Recovery

Handbook 3 Managing Exercises

Handbook 4 Evacuation Planning

Handbook 5 Communicating with People with a Disability: National Guidelines for Emergency Managers

Handbook 6 National Strategy for Disaster Resilience: Community Engagement Framework

Handbook 7 Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia

- **Guideline 7-1** Using the National Generic Brief for Flood Investigations to Develop Project Specific Specifications
- **Guideline 7-2** Flood Emergency Response Classification of the Floodplain
- **Guideline 7-3** Flood Hazard
- **Template 7-4** Technical Project Brief Template
- **Guideline 7-5** Flood Information to Support Land-use Planning
- **Guideline 7-6** Assessing Options and Service Levels for Treating Existing Risk
- **Practice Note 7-7** Considering Flooding in Land-use Planning Activities

Handbook 8 Lessons Management

Handbook 9 Australian Emergency Management Arrangements

Handbook 10 National Emergency Risk Assessment Guidelines

Guideline 10-1 National Emergency Risk Assessment Guidelines: Practice Guide

Handbook 11 renamed Guideline 10-1 National Emergency Risk Assessment Guidelines: Practice Guide

Handbook 12 Spontaneous Volunteer Management

Australian Emergency Management Manual Series

The most recent list of publications in the Manuals series includes 46 titles.

The manuals have not been reviewed since 2011 or earlier and the Manual Series is undergoing a review which will see relevant Manuals move into the ADR Handbook Collection or other collections, or be archived. Current and past editions of the Manuals will remain available on the ADR Knowledge Hub at www.knowledge.aidr.org.au.

Manual Series Catalogue: 2004 - 2011

Manual 1 Emergency Management Concepts and Principles (2004)

Manual 2 Australian Emergency Management Arrangements (superseded by Handbook 9)

Manual 3 Australian Emergency Management Glossary (1998)

Manual 4 Australian Emergency Management Terms Thesaurus (1998)

Manual 5 Emergency Risk Management – Applications Guide (superseded by Handbook 10)

Manual 6 Implementing Emergency Risk Management – a Facilitator's Guide to Working with Committees and Communities (superseded by Handbook 10)

Manual 7 Planning Safer Communities – Land-use Planning for Natural Hazards (2002, currently under review)

Manual 8 Emergency Catering (2003, archived)

Manual 9 Disaster Medicine (replaced by Handbook 1)

Manual 10 Recovery (replaced by Handbook 2)

Manual 11 Evacuation Planning (replaced by Handbook 4)

Manual 12 Safe and Healthy Mass Gatherings (1999)

Manual 13 Health Aspects of Chemical, Biological and Radiological Hazards (2000)

Manual 14 Post Disaster Survey and Assessment (2001)

Manual 15 Community Emergency Planning (1992)

Manual 16 Urban Search and Rescue – Capability Guidelines for Structural Collapse (2002)

Manual 17 Multi-agency Incident Management (replaced by AIIMS)

Manual 18 Community and Personal Support Services (1998)

Manual 19 Managing the Floodplain (superseded by Handbook 7)

Manual 20 Flood Preparedness (2009)

Manual 21 Flood Warning (2009)

Manual 22 Flood Response (2009)

Manual 23 Emergency Management Planning for Floods Affected by Dams (2009)
Manual 24 Reducing the Community Impact of Landslides (2001)
Manual 25 Guidelines for Psychological Services: Emergency Managers Guide (2003)
Manual 26 Guidelines for Psychological Services: Mental Health Practitioners Guide (2003)
Manual 27 Disaster Loss Assessment Guidelines (2002)
Manual 28 Economic and Financial Aspects of Disaster Recovery (2002)
Manual 29 Community Development in Recovery from Disaster (2003)
Manual 30 Storm and Water Damage Operations (2007) (information may not be appropriate to all situations)
Manual 31 Operations Centre Management (2001)
Manual 32 Leadership (1997)
Manual 33 National Land Search Operations (2014) (refer to the Land Search Operations Manual website)
Manual 34 Road Rescue (2009)
Manual 35 General and Disaster Rescue (2006)
Manual 36 Map Reading and Navigation (2001)
Manual 37 Four-wheel-drive Vehicle Operation (1997)
Manual 38 Communications (1998)
Manual 39 Flood Rescue Boat Operation (2009)
Manual 40 Vertical Rescue (2001)
Manual 41 Small Group Training Management (1999, archived)
Manual 42 Managing Exercises (superseded by Handbook 3)
Manual 43 Emergency Planning (2004)
Manual 44 Guidelines for Emergency Management in Culturally and Linguistically Diverse Communities (2007)
Manual 45 Guidelines for the Development of Community Education, Awareness and Education Programs (2010)
Manual 46 Tsunami Emergency Planning in Australia (2010)

Acknowledgements

This handbook is the result of a review of the original *Australian Emergency Management Manual: Managing the Floodplain*, which was prepared by a team of experienced flood planners from around Australia.

The review was conducted by the National Flood Risk Advisory Group (NFRAG), a reference group of the Australian – New Zealand Emergency Management Committee (ANZEMC), which was chaired by Andrew Lea (State Emergency Service, Tasmania). Major General Hori Howard, the former chair of NFRAG, was instrumental in establishing this review.

The review was led by Duncan McLuckie (NSW Office of Environment and Heritage), as the primary author, with input from the members of NFRAG and, in particular, Michael Edwards (Victorian Department of Environment and Primary Industries).

NFRAG members consulted within their jurisdictions and with key industry groups including the Floodplain Management Association, Engineers Australia and the Planning Institute of Australia. Important contributions were made by attendees from industry and government at a national workshop on the guideline in October 2012. Assistance was also provided by Mark Babister and staff at WMAwater, and Dr Chas Keys.

The membership of NFRAG during the period of the review included:

- Tasmania—Andrew Lea, State Emergency Service, Tasmania
- Australian Capital Territory—Tony Graham, ACT Emergency Services
- New South Wales—Duncan McLuckie, Office of Environment and Heritage
- Northern Territory—Lakshman Rajaratnam, Department of Land Resource Management
- Queensland—Dean Misso, Department of State Development, Infrastructure and Planning
- South Australia—Chrissie Bloss, Department of Environment, Water and Natural Resources
- Victoria—Michael Edwards, Department of Environment and Primary Industries
- Western Australia—Richard Bretnall, Department of Water
- Australian Government —Attorney-General's Department, Bureau of Meteorology, Geoscience Australia, Treasury
- Australasian Fire & Emergency Service Authorities Council and Australian Council of Emergency Services—Steve Opper and Belinda Davies, NSW State Emergency Service
- Australian Buildings Code Board—Ron de Veer and Lam Pham
- Australian Local Government Association—Allan Ezzy and Ian Dinham
- insurance industry—Karl Sullivan, Insurance Council of Australia
- National Risk Assessment Measurement and Mitigation Subcommittee of ANZEMC—Ed Pikusa
- research community—John Handmer, RMIT University.

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Preface

Flooding is a natural phenomenon that occurs when water covers land that is usually dry. Floods can have a devastating impact upon communities.

Effective flood risk management can enable a community to become as resilient as practicable to floods. This is achieved through planning and preparing for, responding to and recovering from flooding. This requires a coordinated, multidisciplinary approach across all levels of government and between agencies with different responsibilities. It also requires the support of a range of non-government organisations and industry professionals in a wide range of activities and fields (such as land-use planning) and the active engagement of the community.

The goal of increased resilience to floods requires the management of the flood impacts on both existing developed areas of the community and areas that may be developed in the future. Generally, this involves a combination of flood mitigation, emergency management, flood forecasting and warning measures, land-use planning, and infrastructure design considering the local flood situation and the associated hazards. Decision makers in these areas, insurers and the general public require access to information on flood risk to make informed management and investment decisions.

The *National Strategy for Disaster Resilience*, adopted by the Council of Australian Governments on 13 February 2011 (COAG 2011), outlines the increasing regularity and severity of natural disasters. Australian governments recognised that a national coordinated and cooperative effort is required to enhance Australia's capacity to withstand and recover from emergencies and disasters. A disaster resilient community is one that works together to understand and manage the risks that it confronts. Disaster resilience is the collective responsibility of all sectors of society, including all levels of government, business, the non-government sector and individuals. If all these sectors work together with a united focus and a shared sense of responsibility to improve disaster resilience, they will be far more effective than the individual efforts of any one sector.

This handbook has been developed with consideration of the *National Strategy for Disaster Resilience* (COAG 2011), and the findings of state and national reviews following the multiple flood events of 2010 to 2012 that resulted in widespread flooding. It is intended to provide broad advice and guidance on all important aspects in managing flood risk in Australia.

It is supported by a series of publications on flood management whose review was instigated and managed by the National Flood Risk Advisory Group (NFRAG), a reference group of the Australian – New Zealand Emergency Management Committee (ANZEMC). These publications form part of the Australian Disaster Resilience (ADR) Handbook Collection and include:

- *ADR Manual 20 Flood Preparedness* (AIDR 2009)
- *ADR Manual 21 Flood Warning* (AIDR 2009)
- *ADR Manual 22 Flood Response* (AIDR 2009)
- *ADR Manual 23 Emergency Management Planning for Floods Affected by Dams (AIDR 2009)*

This series provides guidance on best practice principles as presently understood in Australia, rather than describing current varied practice. In this handbook, the term 'best practice principles' is taken in its broadest sense to mean the underlying principles that need to be considered when managing flood risk and formulating floodplain management plans, leading to effective, equitable and sustainable land use across Australia's floodplains.

This handbook should be used in conjunction with its companion technical guidelines and supporting documents and any relevant jurisdictional equivalents. Every attempt has been made to adopt a national approach to terminology, policy and guidance arrangements. This handbook and its supporting guidelines replace:

- *ADR Manual 19 Managing the Floodplain,* prepared in 1998–99 by a team of experienced floodplain managers from around Australia as part of the development of the original Emergency Management Australia series guidelines on managing flooding.
- *Floodplain Management in Australia: Best Practice Principles and Guidelines*, prepared for the former Standing Committee on Agriculture and Resource Management (former SCARM) of the former Agriculture and Resource Management Council of Australia and New Zealand (former ARMCANZ) (SCARM Report No. 73, 2000).

Users of this handbook and its supporting flood risk management guidelines should also refer to the technical advice provided on flood estimation in the latest version of *Australian Rainfall and Runoff: a guide to flood estimation* (Australian Rainfall & Runoff, Engineers Australia).

HOW TO USE THIS HANDBOOK

Types of flood events covered

This handbook provides advice on management of flooding within the floodplains and catchments of waterways due to the following type of flood events:

- Catchment flooding from prolonged or intense rainfall (e.g. severe thunderstorms, monsoonal rains, tropical cyclones). Sources of catchment flooding include rivers and other watercourses, local overland flow paths and groundwater systems.

Coastal flooding due to tidal- or storm-driven coastal events, including storm surge in lower coastal waterways. This can be exacerbated by wind-induced wave generation. Tsunamis are a specific type of coastal event, which are dealt with in *Australian Disaster Resilience Manual 46 - Tsunami Emergency Planning Australia* (AIDR 2010) (and are not considered in this handbook).

- Combinations of both catchment and coastal flooding in the lower portions of coastal waterways where both can be produced by the same storm or a series of storms. How these sources of flooding interact and which is dominant will vary with the location and configuration of the catchment, floodplain and waterway, and the specifics of the storm cells.

This handbook applies to the management of floods in urban and rural areas, including water flowing overland through urban areas to waterways. Its use in different locations should consider the different issues that need to be considered. For instance, in rural floodplains, the scale of flood-dependent ecosystems means that environmental issues and maintenance of flow to these areas is important and needs additional consideration. The duration of flooding is also important to many crops, and needs to be considered in addition to peak flood levels when examining changes to the floodplain. Local overland flood catchments respond quickly to rainfall and specific flood warnings are not generally possible and there may be little or no time to evacuate. Overland flow paths are often ill-defined and may follow roads, go through private property, or be inhibited by buildings and fences. Localised management measures to enable water flow or reduce the vulnerability of property may therefore be necessary to manage flood behaviour and associated risk.

Target audience

This handbook aims to provide advice to those with roles in understanding and managing flood risk and its consequences on the community. This may include emergency management practitioners, flood risk managers, land-use planners, engineers, hydrologists, infrastructure providers, and policy and decision makers, within both government and the broader industry. It aims to inform national best practice, and State and Territory guidance.

Use with jurisdictional advice, supporting guides and Australian Disaster Resilience Handbook Collection

This handbook provides a framework for the management of flood risk. It should be read and interpreted holistically in a manner consistent with the underlying philosophies outlined in the vision, principles and key objectives (Chapter 1), and with reference to its supporting guides and other relevant guides including the Australian Disaster Resilience Handbook Collection.

Guides directly supporting Handbook 7

- Guideline 7-1 Using the National Generic Brief for Flood Investigations to Develop Project Specific Specifications (see Template 7-4)
- Guideline 7-2 Flood Emergency Response Classification of the Floodplain
- Guideline 7-3 Flood Hazard
- Template 7-4 Technical Project Brief Template (for use with Guideline 7-1)
- Guideline 7-5 Flood Information to Support Land-use Planning (see Practice Note 7-7)
- Guideline 7-6 Assessing Options and Service Levels for Treating Existing Risk
- Practice Note 7-7 Considering Flooding in Land-use Planning Activities (for use with Guideline 7-5)

Relevant national guidelines include, but are not limited to the following publications in the Australian Disaster Resilience Handbook Collection:

- Manual 7 *Planning Safer Communities: land-use planning for natural hazards*
- Manual 20 *Flood Preparedness*
- Manual 21 *Flood Warning*
- Manual 22 *Flood Response*
- Manual 23 *Emergency Management Planning for Floods Affected by Dams*
- Manual 43 *Emergency Planning*
- Manual 45 *Guidelines for the Development of Community Education, Awareness and Engagement Programs*
- Handbook 2 *Community Recovery*
- Handbook 10 *National Emergency Risk Assessment Guidelines*

Users of this handbook should consult the relevant State or Territory agencies for advice on additional material that supports best practice. States and Territories are encouraged to build on this handbook with administrative and technical guidance to suit their needs. Guidance should be kept up to date and made readily available. Administrative guidance for a jurisdiction should:

- outline governance arrangements and linkages
- outline the relevant legislative and policy framework
- refer to relevant technical guidelines
- outline other material that supports best practice
- include a ready reckoner of alternate terms to those in this handbook where necessary
- outline support available to government entities with primary responsibility for managing flooding in an area, called floodplain management entities in this handbook, to understand and manage their risks.

Technical guidelines may be developed at a national, State or Territory level to provide more detailed information on technical matters to supplement the general advice contained herein.

Users of this document should also refer to the technical advice provided in the latest version of *Australian Rainfall and Runoff: a guide to flood estimation* (Australian Rainfall & Runoff, Engineers Australia).

Handbook structure

This handbook provides an outline of best practice and a vision for managing the flood threat to communities inhabiting floodplains in Australia and discusses how to apply information. It comprises four sections:

- Section A: Overview of flood risk management in Australia
  - Chapter 1 contains an introduction to best practice flood risk management
  - Chapter 2 discusses the need for and evolution of flood risk management
  - Chapter 3 outlines how holistic management can be best achieved using a fit-for-purpose risk management approach, such as the flood risk management framework
  - Chapter 4 outlines the key responsibilities of government, the non-government sector and individuals in the community for understanding and managing flood risk
- Section B: Understanding flood behaviour, flood risk, and treatment options
  - Chapter 5 discusses flood behaviour
  - Chapter 6 describes flood risk
  - Chapters 7–9 discuss treatment options for flood risk to existing and future developments
- Section C: Floodplain-specific management process
  - Chapters 10–13 outline the steps in the floodplain-specific management process
- Section D: Additional materials
  - Chapter 14 contains an abbreviations and acronyms list, and a glossary
  - Chapter 15 contains a list of references.

SECTION A

Overview of flood risk management in Australia

The multiple flood events of 2010 to 2012 provide a reminder of the devastating cost of flooding to the community. While these impacts cannot all be eliminated, understanding flooding and considering it when making decisions can reduce both the growth of risk due to new development and enable informed decisions on managing risk to existing development, where practical, feasible and cost-effective to do so.

It should also be remembered that floods can be of significant benefit to the community by delivering water to flood dependent ecosystems, improving soil moisture contents for agriculture and providing inflows to water supply dams.

Management of flood risk is essential to limiting the impacts of flooding on the community in balance with maintaining the benefits of occupying the floodplain to society and the benefits of flooding to the environment. This section provides an overview of flood risk management in Australia.

Management of the floodplain should be based on best practice. The goal is to have flood risk management that is sustainable, provides long-term benefits for the community and environment, and improves community resilience.

Chapter 1 contains an overview of best practice and Chapter 2 describes why flood risk management is necessary. Chapter 3 describes the flood risk management framework, which aims to promote strategic management of flood risk and information sharing.

Chapter 4 outlines the roles and responsibility of various community members, including government, and how they contribute to managing flood risk to the community.

CHAPTER 1

Introduction to best practice in flood risk management

In a nutshell...

This handbook aims to encourage those with responsibility for managing flood risk to work towards achieving best practice. It does this by:

- outlining a vision for best practice
- outlining key principles to consider in risk management
- providing a robust and flexible framework for managing flood risk
- outlining key objectives that support best practice.

This handbook aims to encourage practice that works towards the following vision for flood risk management in Australia.

Floodplains are strategically managed for the sustainable long-term benefit of the community and the environment, and to improve community resilience to floods.

Best practice requires the consideration and management of flood impacts to **existing** and **future** development within the community. It aims to improve community flood resilience using a broad risk management hierarchy of avoidance, minimisation and mitigation to:

- limit the health, social and financial costs of occupying the floodplain
- increase the sustainable benefits of using the floodplain
- improve or maintain floodplain ecosystems dependent on flood inundation.

Best practice promotes understanding flood behaviour so that the full range of flood risk to the community can be understood, effectively communicated and, where practical and justifiable, mitigated. It facilitates informed decisions on the management of this risk, and economic investment in development and infrastructure on the floodplain.

Neither this handbook, nor its predecessors, argues the need for a sophisticated or consistent understanding of flood behaviour across all areas of Australia, as this is neither practical nor necessary (Queensland Flood Commission of Inquiry, 2012). The degree of effort required, and approaches used, to understand flood behaviour will vary depending upon the complexity of the flood situation, and the information needs of government and the community to understand and manage flood risk. These techniques can also vary within a catchment, with more sophisticated techniques used in areas with concentrated exposure to risk (e.g. urban areas) and simpler techniques used in areas where developed is more widespread (e.g. rural areas).

Flood risk management efforts may be prioritised considering the scale of potential growth in risk, primarily due to new development in the floodplain, and the scale of existing flood risk to the community. This may promote sustainable urban and rural land-use planning practices that are fully cognisant of flood risk, and limit growth in risk to acceptable levels. It may also facilitate the treatment of risk (where practical, feasible and cost-effective) to limit the exposure of the existing community to flooding to more tolerable levels. Treatment may involve a combination of flood mitigation, emergency management, flood warning and community awareness – together with infrastructure design, and strategic and development scale land-use planning that considers the flood situation and associated hazards.

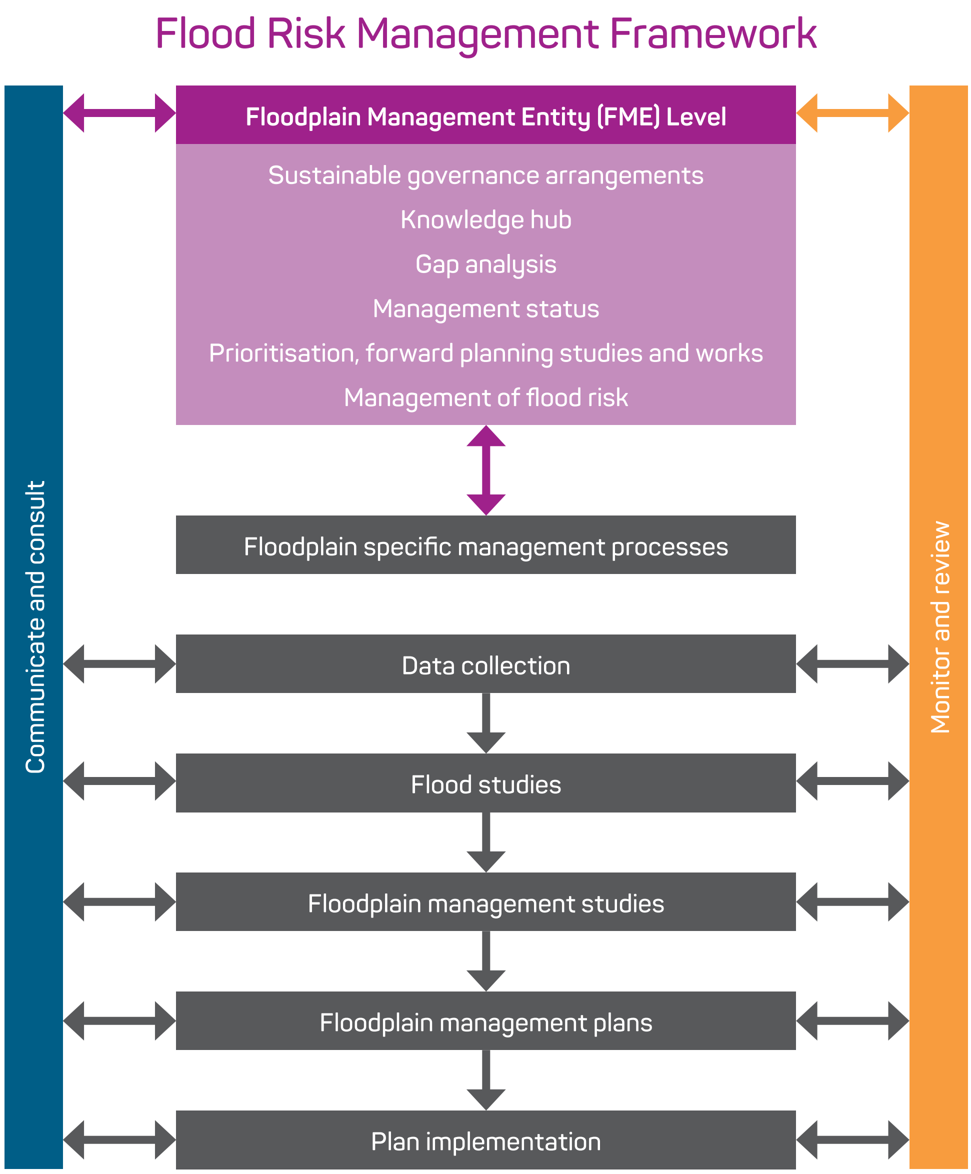


Figure 1.1 The flood risk management framework

1.1 The flood risk management framework

The flood risk management framework is outlined in Figure 1.1 and discussed in Chapter 3. It promotes a risk management approach that facilitates the effective understanding and management of flood risk within a floodplain management entity (FME) service area. An FME is the government entity with primary responsibility for managing flood risk at a location. Other agencies may have complementary responsibilities in areas such as emergency management. The framework encourages the FME to collect, improve and disseminate the best available information on flood behaviour, and associated risks to the community, decision makers and other agencies with a responsibility for managing flood risk. This information may be derived from a floodplain-specific management process and other sources (e.g. historic events and other studies), and by applying approaches of different degrees of sophistication that are fit for purpose. The framework, and its knowledge hub and communication strategy support the availability of this information so that flood risk can be better understood and managed.

The framework builds upon the floodplain management process described in *Floodplain Management in Australia: best practice principles and guidelines* (SCARM 2000) and associated practices that have proved effective and efficient for decades. It provides flexibility for FMEs, which have different levels of resources and information, to manage flood risk and work to improve their knowledge and management practices considering the scale and complexity of the flood threat faced by their communities.

1.2 Principles of a best practice approach to flood risk management

The following sections describe key principles of a best practice approach to flood risk management, upon which the framework is based.

1.2.1 A cooperative approach to manage flood risk

State and Territory governments have a shared responsibility with all levels of government for managing flood risk to local communities. This can be outlined by providing clear and continuous governance arrangements and legislative, financial, logistical and technical support to FMEs in consideration of the full range of flood risk. Each State and Territory should develop and promote a comprehensive flood risk management policy supported by appropriate legislation, regulations, standards, guidelines and planning policies that clearly and unambiguously define the responsibilities and liabilities of all involved agencies. Decision makers at all levels need to be aware of their duty of care for decisions made with respect to the use of the floodplain, and for developing and implementing plans to manage flood risk.

This handbook supports this approach by providing the flood risk management framework (Figure 1.1). Thehandbook can also be supplemented with appropriate administrative and technical guidance developed by jurisdictions, either independently or cooperatively where desired. It supports cooperation in understanding and managing flood risk within a catchment which is important where land use or flood risk management practices in one FME may influence the flood risk in another FME, including across State or Territory boundaries.

1.2.2 A risk management approach

The approach outlined in this handbook is consistent with *Australian Disaster Resilience Handbook 10 - National Emergency Risk Assessment Guidelines* (NERAG) (AIDR 2015), and *ISO 31000:2009 Risk Management – Principles and Guidelines* (International Organization for Standards, 2009). The NERAG provides a contextualised approach for the conduct of risk assessments for emergency events and is consistent with *ISO 31000:2009*.

Where considered more appropriate to the situation, equivalent risk management approaches to those outlined here can be used where consistent with NERAG and *ISO 31000:2009*.

A risk management approach enables investment to be focused on understanding and managing flood risk where it is needed most. Studies and management effort can be targeted considering the current knowledge, the scale of flood risk to existing development, and the potential for growth in flood risk through increased development within the floodplain. Plans to manage risk are 'live documents' and need to be regularly reviewed to ensure that they are current, able to be implemented and consider lessons that may be learnt from any recent flood events.

1.2.3 A proactive approach

A proactive approach involves actively managing the risks of occupying the floodplain. This involves considering the full range of flood risk early in the process of developing strategic land-use plans and in managing risk to the existing community and to infrastructure.

It promotes the development and implementation of sustainable plans to manage flood risk effectively so that the existing community is more resilient to flooding. The community is encouraged to contribute to the understanding of flood behaviour and how risks are managed. Risks may be reduced by treatments where these are practical, feasible, economical and a priority within an FME service area. Community resilience may be improved by increased protection or because the community is better informed on flood risks and how to respond to the flood threat.

Understanding the development capability of the land in relation to the full range of flood risk and considering this in strategic land-use planning can lead to more sustainable floodplain development and improved resilience of future development in communities to flooding. This can lead to areas being set aside from intensification of development:

- to perform their flow conveyance, storage and environmental functions
- to limit the impacts of development on flooding to the existing community

- where flood hazard to new development is not able to be effectively managed.

In areas suitable for intensification of development, the flood risk to the community is managed by limiting the types of development allowable at specific locations considering flood hazard and using development conditions to reduce residual risk to acceptable levels.

Impacts of flooding on infrastructure are managed by using design standards that limit their vulnerability to flooding.

1.2.4 A consultative approach

Public consultation is an important element of understanding and managing flood risk. It can facilitate:

- understanding of flood behaviour by tapping into community knowledge on historic floods
- informing the community of the flood threat they face and how and when to react to this threat
- developing sustainable floodplain management plans that have broad community support.

1.2.5 An informed approach

Knowledge and experience of previous flood events is a starting point for understanding flood risk. However, using this information without understanding the potential range and severity of flood events at a location can result in poor management decisions – leaving the community unsustainably exposed to risk. Information from historic flood events can be improved using investigative techniques and more sophisticated modelling to increase understanding of these events, facilitate extrapolation to provide a greater understanding of the range of flood behaviour and risk, and enable assessment of treatment options to inform management decisions.

It is important that this knowledge be maintained – and, where necessary, improved – so that lessons from previous events and investigations can be used to manage risk into the future. The degree of knowledge required for effective management of risk varies with the:

- exposure of the community to the risk
- potential for growth in risk due to new development
- potential for change in flood behaviour
- complexity of the flood situation
- information needs of decision makers, risk managers and the community.

FMEs need to understand their existing information on flood risk and the knowledge necessary to manage flood risk in their communities so that they can identify knowledge gaps. Examining ways to fill these gaps can inform the scope of investigations. The Queensland Flood Commission of Inquiry (2012) provides advice on a hierarchy of information for use in managing flood risk (discussed in Section 3.3.1).

1.2.6 Supporting informed decisions

It is important that flood information is readily accessible to government (including decision makers, flood risk managers, land-use planners, emergency managers), non-government entities (including infrastructure providers, insurers) and the community to provide the basis for informed decisions on investing in floodplains and managing flood risk.

1.2.7 Recognition that all flood risk cannot be eliminated

The community and government need to recognise that living in the floodplain has an inherent risk, and a residual risk will always exist even after management measures, including mitigation and land-use planning measures, are implemented. The level of this risk will vary depend on how exposed areas of the floodplain are to flooding, the development controls that were in place when the area was developed, and the measures implemented to manage flood risk.

1.2.8 Recognition of individual responsibility

Individuals within the community need to recognise that they are responsible for informing themselves about flood risks and the need, availability and coverage of flood insurance; being aware of how to respond to a flood threat in consideration of community response plans; and heeding the advice of relevant government and emergency management personnel during flood events.

1.3 Key objectives for achieving best practice in flood risk management

The effort required to achieve best practice will vary depending upon the area of interest and current flood risk management practice. It begins with bringing together current knowledge of flood risk and its management, and communicating this to decision makers, risk managers and the community. Where necessary, it then identifies and fills gaps in knowledge and management practices, so that risk can be better understood and managed.

The degree of sophistication necessary to improve knowledge and inform management will vary depending upon the current level of knowledge, the complexity of the flood behaviour in the area and the exposure of the community to flood risk. Improvements in knowledge and management of flood risk are likely to occur over time, depending on need and available resources. Efforts are likely to be concentrated on where flood problems are known to exist and need management, where knowledge is insufficient to understand and manage risk, where exposure is high, or where growth of exposure due to future development is likely to be high.

The flood risk management framework (Figure 1.1 and Chapter 3) provides a robust, fit-for-purpose approach to managing flood risk, and enables an understanding of existing knowledge on flood risk and current management practices. These features can be used to create a platform that works towards achieving the vision and best practice management. To help accomplish this, five key objectives have been identified:

1. develop sustainable governance arrangements for managing flood risk, so that responsibilities for managing this risk are assigned and clearly understood. Sustainable governance arrangements are discussed in Section 3.1
2. make information on flood risk readily available (discussed in Section 3.3), so that government, risk managers and community can make informed risk management and investment decisions
3. understand flood behaviour (Chapter 5) and risk (Chapter 6) to recognise the impacts of floods on the community and enable effective decisions to be made on flood management
4. understand (Section 5.2) and maintain (Chapter 7) the natural flood functions of flow conveyance and storage of the floodplain to enable effective flood risk management and minimise environmental impacts
5. manage flood risk (Chapters 7–9) to improve community resilience to flooding, and to handle the potential growth of this risk through development and redevelopment, and future changes to floodplain topography and climate.

CHAPTER 2

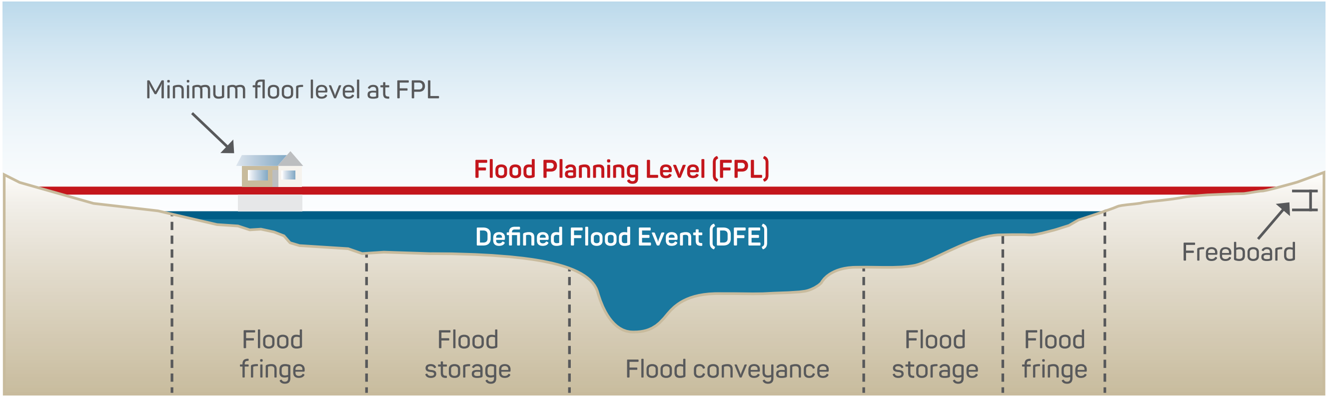
The need for flood risk management

In a nutshell…

Floods are part of the Australian landscape. They occur in many parts of Australia, and their severity varies widely between locations. Floods are of many types and are caused by different mechanisms. They may be exacerbated by human occupancy and activity in the floodplain. Floods have both positive and negative impacts. Positive impacts include inflows to water supplies, sustaining flood-dependent ecosystems and improving soil moistures and fertility for farming. Negative effects mainly occur due to human occupancy of the floodplain, without which there is no flood risk to the community. These negative effects include human fatalities and injuries, as well as economic damage, disruption of individuals' lives and communities' function, and environmental damage. Historically, flood damage is greater than that of any other natural hazard. However, it is also the most manageable disaster, because its behaviour and location can be estimated and considered in decisions. Flood risk management practices vary considerably in Australia. However, it is possible to discern a general trend in which practice has become more strategic in focus. We have recognised that flood risk management must deal with both existing and future development in the floodplain, and must involve the application of the skills of practitioners in many disciplines.

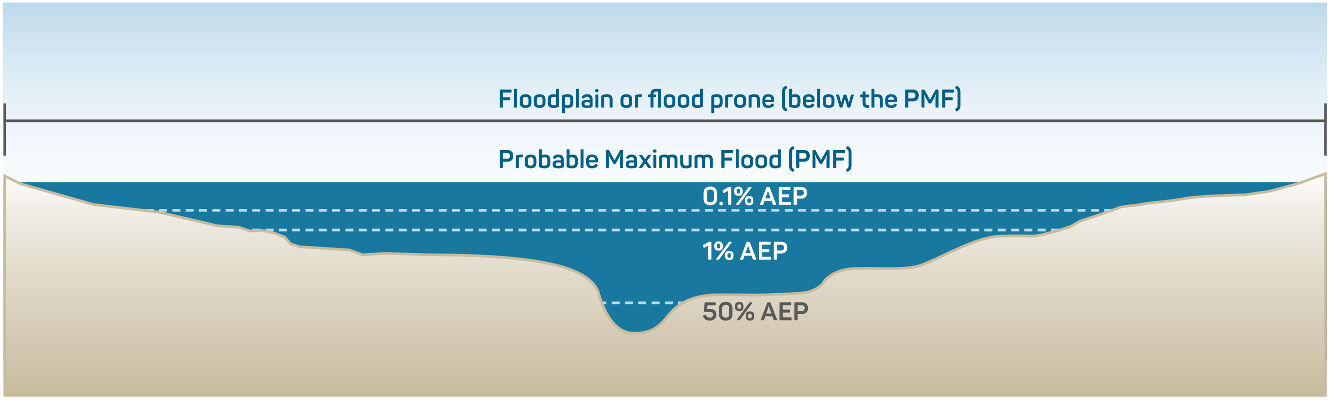
Floods are natural phenomena that occur when water covers land that is usually dry. Floods vary greatly in size and frequency. Small floods may cause a local nuisance in an area each year, or even more often. Larger floods causing significant community impacts may occur at the same location any number of times in a lifetime or, in some cases, not at all. These larger floods are often treated as key events in determining minimum development standards and may be referred to as **defined flood events (DFEs)**. The **probable maximum flood (PMF)** is the largest flood event that could possibly occur in a particular location. It exceeds virtually all flood-related development standards and overwhelms many flood mitigation works, resulting in significant impacts on the community. It causes the largest scale of flood emergency and is therefore often used for emergency management planning. The extent of the PMF defines the largest area deemed to be inundated by floods and generally defines the **floodplain**. These terms are illustrated in Figures 2.1 and 2.2.

Floodplains are important as commercial, social and ecological arteries of the nation. Historically, most of Australia's towns and cities were located on floodplains. This was principally due to reasons associated with water supply, transportation, waste disposal, amenity or recreation; because they were suitable points for river crossings; or to act as service centres for surrounding rural areas. Regular flooding improves agricultural land by increasing soil moisture, recharging groundwater and depositing fertile silts. These benefits mean that a significant proportion of Australia's extensive agricultural output is produced on floodplains.



Note: flood conveyance, flood storage and flood fringe areas vary with the severity of the flood event

Figure 2.1 Defined flood event showing some key terms



AEP = annual exceedance probability

Figure 2.2 Floodplain and probable maximum flood

Floods also produce many deleterious community impacts, especially in urban areas where – for all intents and purposes – there are no beneficial effects of flooding.

Transport-related infrastructure, mining operations and industry are also often partly or completely located on floodplains, which both exposes them to flood risk and raises the possibility that they may contribute to alteration of the natural flood regime.

Since 1788, there have been more than 2300 flood-related fatalities in Australia. Many of these deaths were in isolated incidents. However, a number of floods involved multiple fatalities, including 89 at Gundagai, New South Wales, in 1852; 65 in the Clermont area, Queensland, in 1916; and 47 in Brisbane and Ipswich, Queensland, in 1893 (Coates 1999).

Between 1997 and 2008, there were more than 73 flood-related fatalities (Fitzgerald et al. 2010), and in January 2011, floods in southern Queensland claimed 33 lives (Queensland Floods Commission of Inquiry 2012).

Australia-wide, the overall death rate due to floods decreased from around 24 per 100,000 people per decade in the 1800s, to 0.04 per 100,000 per decade during the 1990s and the first decade of the 21st century. Although the general trend has been for a reduction in flood fatalities, spikes in deaths still occur from time to time, as in 2011. The continuation of the downward trend in deaths, even without any increase in event severity, relies upon continued improvements in flood risk management, land-use planning, building and emergency management practices.

Although deaths have declined, the economic damage caused by floods in Australia has continued to grow as a result of the increasingly intensive human use of floodplains. The built environment, with its public and private infrastructure and buildings, is highly susceptible to the impacts of flooding. The annual average natural disaster relief costs of floods in Australia was $377 million in natural disaster declared areas between 1967 and 1999 (BTRE 2001). The broader cost of floods to the community could be expected to at least double these figures.

The total economic exposure of communities to flooding in Australia is in the order of $100 billion (extrapolated from BTRE 2001, McLuckie et al. 2010). It is estimated that the 2011 Queensland floods temporarily depressed gross domestic product growth by up to 1% (Reserve Bank of Australia 2011). These effects are significantly higher than those of any other type of natural disaster experienced in Australia at the time of publication.

There are hundreds of thousands of dwellings, and large areas of agricultural, commercial and industrial development located within floodplains in Australia. This large scale of development makes the nation and many of its communities vulnerable to flooding. Increasing the scale of development and supporting infrastructure on floodplains can also affect flood behaviour, which may add to the detrimental effects of flooding on existing communities. In many areas, the negative impacts of flooding on communities have been reduced during recent decades. The flood risk management activities guided by predecessors to this handbook – including *Floodplain Management in Australia: Best Practice Principles and Guidelines* (SCARM 2000) and State counterparts – along with the associated efforts of all levels of government to consider flood hazard and behaviour through the floodplain management process have contributed greatly to this trend. The reduction has been uneven, though, both within and between the States and Territories. It is important that these efforts to manage the negative consequences of flooding continue. The exposure of existing developments to flood risk, the growth of flood risk through increased development and redevelopment of floodplains, and the changes in flood behaviour need to continue to be managed.

2.1 Floods and flood hazard

Floods create hazardous conditions to which humans are particularly vulnerable. If floodplains were unoccupied and unused, flooding would not create a risk to the community. It is the human interaction with the floodplain and the associated exposure to flood hazard that creates flood risk.

Fast-flowing, shallow water or slow-flowing, deep water can unbalance people and sweep them away. Similarly, floodwaters can result in significant impacts on the built environment. Structures can be undermined, or have their structural and non-structural elements damaged or destroyed by floodwater and debris. The contents of structures are generally vulnerable to contact with floodwater and can also be severely damaged or destroyed.

Infrastructure required for community functioning is vulnerable to flooding. Road surfaces and substructures, rail lines, airfields, and electrical, water, sewerage, stormwater and communication systems are all susceptible to damage from flooding. Moreover, human-made structures and development can exacerbate the damage caused by flooding. They may alter flood paths, depths and velocities of flow, and add debris to floodwaters.

The safety of people and the susceptibility of development and infrastructure to damage are primarily linked to flood behaviour, which will vary across the floodplain, between flood events of different sizes and across different floodplains. Therefore, it is important to understand the full range of potential flood behaviour to comprehend the vulnerability of the community to flooding. This understanding underpins decisions on managing floodplains.

Flood behaviour varies significantly in Australia (see Figure 2.3). This is in response to differences in location, the types and prevalence of extreme weather, catchment and floodplain topography, vegetation, existing development, the nature of infrastructure in the catchment and on the floodplain, and the features of the waterway. For instance, coastal rivers generally have shorter duration floods that rise sharply compared to inland rivers downstream of the headwaters, where floodwaters generally rise and fall relatively slowly and can last for up to weeks or months.

Significant local flooding can also occur as water flows overland within catchments to watercourses and rivers. This can occur both in urban areas, where artificial drainage (i.e. stormwater) systems are overwhelmed, and in rural areas, where both natural and artificial drainage channels surcharge. Like its predecessor (SCARM 2000), this handbook does not replace the latest version of Australian Rainfall & Runoff (Engineers Australia 1999) in dealing with stormwater systems and local drainage. It does, however, provide a risk-based approach for investigating and managing local overland flooding issues where they may have significant impacts for the community.

For a particular floodplain, flood behaviour can be studied, and the likely location, type and scale of effects for a range of floods can be determined within reasonable accuracy to inform its management. With floods, it is not a matter of if, but when, the flood will occur. Understanding flood behaviour, including potential alterations due to changes in climate or catchment development, enables us to assess the likely impact of flooding on the community and examine options to manage the community's exposure to flood risk.

Source: based on Middelmann et al. (2007)

Figure 2.3: Flooding mechanisms across Australia

2.2 The evolution of floodplain management in Australia

Floodplain management, defined as a deliberate effort to reduce the harmful effects of flooding, commenced early in the occupation of Australia. Its beginnings can be seen in the early 1800s; in particular, in the 1810 edict of Governor Lachlan Macquarie, which followed a series of fatal and damaging floods in the Hawkesbury – Nepean Valley west of Sydney. The edict assigned each settler whose farm was within the influence of known flooding an allotment on high land within a township for a dwelling, office, garden, storage and stockyard. The assignment was on the clear understanding that these allotments were to be inseparable from the farms – that is, they were to be part of the ownership of the farm. Macquarie's intention was that settlers would live on the allotments, commuting to their actual farmlands to tend their animals and crops.

However, seven years and several floods later, there is evidence that the expected change in behaviour had not occurred. A subsequent 1817 edict by Macquarie indicated that the settlers had ignored frequent advice to move their residences to townships on high ground, and had consequently incurred further flood losses. The second edict expressed the hope that recent losses would spur settlers into action to protect their own futures, and indicated that those who followed the advice provided would obtain favourable consideration and protection from the government.

Floodplain management in Australia evolved from this point through a number of phases whose timing varied in different areas. Some change involved the efforts of individuals, but over time, all levels of government became involved in flood management initiatives.

Since the mid-19th century, farmers in some areas built levees to keep floodwaters off their land, and some communities constructed levees and drains to exclude floodwaters and speed drainage after heavy rains. Severe flooding in the 1950s resulted in the construction of substantial flood mitigation works in eastern Australia, particularly in New South Wales. Further severe floods in the eastern states in the 1970s caused large-scale and widespread damage, and a further focus on flood mitigation, including dam construction to reduce, at least in part, downstream flood impacts. At the same time, Western Australia initiated a floodplain management program and the Northern Territory adopted an interim floodplain management policy. These initiatives were not all effective, largely because:

- there was a lack of appreciation of the range of potential flood severity for many years
- attempts to manage floods were generally uncoordinated
- there was little understanding of the varying types of approach that were best suited to particular environments.

In addition, some measures that were taken in earlier times exacerbated the damage done by flooding to both development and the environment.

Despite such failures, flood mitigation works did reduce negative impacts of flooding in many areas. Yet community exposure to flood risk had, in many instances, continued to grow, because floodplain development continued to intensify. The importance of land-use planning and development controls for the effective management of flood risk was gradually recognised. The focus on structural flood mitigation works was broadened to include development controls aimed at reducing the growth of unsustainable flood risk to the community.

There has also been an increased focus on environmental issues and on taking a more holistic approach to floodplain management. Since the 1970s, and particularly since the early 1980s, floodplain management in Australia has included:

- adopting a risk management approach that considers the impacts of the full range of floods up to, and including, the PMF
- using different land-use planning practices to limit the risk that will be created through the future development of floodplains
- recognising, communicating and managing the residual risk that continues to exist where the protection provided by development controls and/or flood mitigation works are overwhelmed
- developing more accurate and timely flood warning and emergency management capabilities
- developing recovery planning to improve community responses to, and recovery from, flood disasters
- considering cultural and environmental issues and community views when assessing flood mitigation and other flood risk management measures.

This increasingly strategic approach to flood risk management continues today. It requires a coordinated multidisciplinary effort across all levels of government, and between agencies and departments with different responsibilities. It also requires the support of non-government organisations and professionals in a wide range of industries. It is ideally undertaken by the interactive efforts of multidisciplinary teams of hydrologists, floodplain managers, engineers, emergency response managers, land-use planners and environmental managers who engage with and consult the community. The outcome is advice to decision makers on how to manage the risk of flooding to the existing and future community, and to the supporting built environment in consideration of community aspirations.

Using a strategic approach allows robust management plans and measures to be developed, which can consider changing risk due to influences such as better data, improved analysis methods, changing climate and intensification of development. Such an approach supports sustainable management and long-term community resilience.

However, even today flood risk management practice varies greatly around Australia, not just at a state or territory level, but at regional and local levels, as floodplain management entities are at different points on a path towards best practice. This variation occurs due to various factors, including societal, governance and resourcing priorities, and the differing severity of flood risk across Australia.

The *National Strategy for Disaster Resilience* (COAG 2011) outlines that, given the increasing regularity and severity of natural disasters, Australian governments have recognised that a national, coordinated and cooperative effort is required to improve Australia's capacity to withstand and recover from emergencies and disasters. A disaster-resilient community is one that works together to understand and manage the risks that it confronts. Disaster resilience is the collective responsibility of all sectors of society, including all levels of government, business, the non-government sector and individuals. If all these sectors work together with a united focus and a shared sense of responsibility to improve disaster resilience, they will be far more effective than the individual efforts of any one sector.

CHAPTER 3

The flood risk management framework

In a nutshell...

The flood risk management framework provides a basis for a floodplain management entity (FME) – the government agency with primary responsibility for managing flood risk in the area to improve management of flood risk for its community. The framework can help FMEs to:

- understand flood risk management roles and responsibilities, and engage the relevant agencies in understanding and managing risk
- understand relevant legislation, regulations, policies, directions and guidance
- consider the community profile, including vulnerability and exposure to flood risk
- gather and use the best available information
- assess gaps in knowledge and manage flood risk, and make informed decisions about these issues
- develop and implement plans to improve knowledge and management of flood risk
- make informed decisions on development within the floodplain
- consult with the community and key stakeholders.

This can provide the basis for informed decision making by the community, flood risk managers, land-use planners and emergency managers for managing floods or investing in development on the floodplain. There are many treatment options available; however, they must be chosen carefully to suit individual locations within the floodplain, and consider the full range of potential flooding and its impacts upon the community and built environment.

Risk management processes assist risk managers to identify and analyse risks systematically, and to develop measures to treat them, where necessary. The aim is to produce more reliable planning and greater certainty about management outcomes, and to improve decision making. *ISO 31000:2009* (International Organization for Standards 2009) provides a detailed guide for developing a principle-based risk management framework and implementing a risk management process. The value of this approach is incorporated into ADR Handbook 10 NERAG, which has been considered in developing the flood risk management framework to help manage flood risk across a floodplain management entity (FME). The flood risk management framework is illustrated in Figure 3.1.

An understanding of flood risk is generally developed for an individual floodplain or catchment. Risk management is generally undertaken based upon the administrative boundaries of an FME, which may span multiple catchments and involve a range of different types of flood problems. The framework supports managing flood risk across an FME by:

- providing a basis for establishing, monitoring, maintaining and communicating the sustainable governance arrangements with which the FME manages flood risk (Section 3.1). This includes relevant roles and responsibilities and the legislative and policy framework
- considering the profile of the community living in the floodplain. Community vulnerability and exposure to flooding may influence management decisions. It is therefore important to understand the community profile, as different sections of the community are more vulnerable to floods
- providing a structure for the FME to oversee flood risk management, and to access available technical and policy advice from relevant State or Territory agencies (Section 3.2)

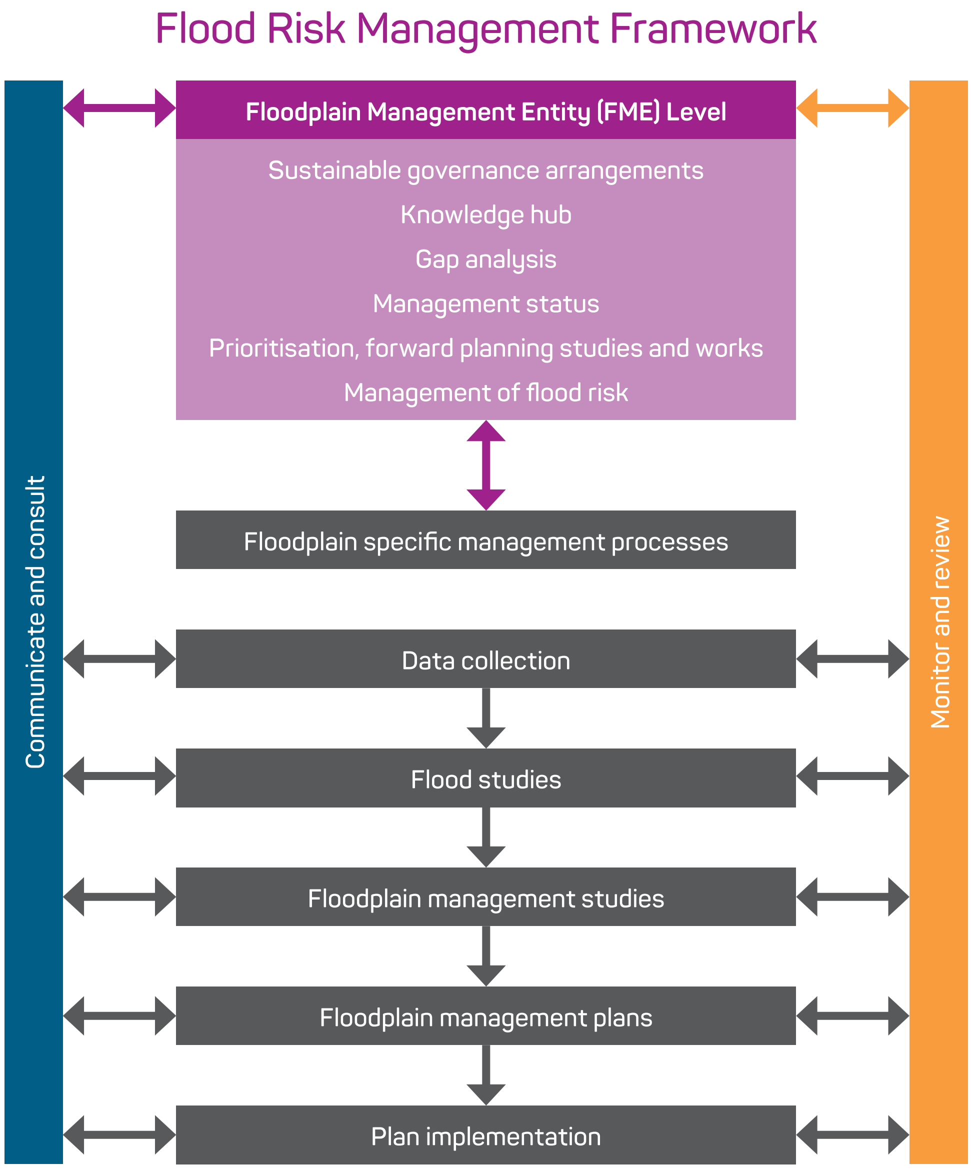


Figure 3.1: The flood risk management framework

- providing the basis for collating, maintaining, using and sharing the best available information on flood risk and management, through the knowledge hub (Section 3.3). The framework promotes the communication of this information within government to inform decision makers in land-use planning, flood risk management, flood forecasting and warning, emergency response and recovery management. It also provides the basis for communicating information to the community in a consistent format, which promotes improved community knowledge of, and resilience to, flooding
- outlining the importance of consulting the community (Section 3.4) to gather their knowledge of flood risk and obtain input on strategies to manage this risk
- providing a basis for monitoring and reviewing the current knowledge and management of risk, and assessing and prioritising efforts and resources to fill gaps in the short and long term (Section 3.5)
- linking floodplain-specific management processes to management of flood risk at an FME level. Existing studies provide the basis of current knowledge and future studies can address gaps in knowledge or flood risk management in the short and long term (Section 3.6).

This chapter provides advice on the development and implementation of the flood risk management framework.

3.1 Developing sustainable governance arrangements

The success of risk management depends on '...*the effectiveness of the management framework providing the foundations and arrangements that will embed it throughout the organisation at all levels' (AS/NZS ISO 31000 Risk Management – principles and guidelines).*

Therefore, to manage flood risk effectively, it is important to determine the administrative, legislative and policy framework within which flood risk needs to be managed. The development, monitoring, maintenance and ready availability of sustainable governance arrangements that support partnerships in the effective management of flood risk is a key objective in achieving best practice in flood risk management. This involves developing sustainable governance arrangements that consider the roles and responsibilities outlined in Chapter 4. These arrangements need to:

- provide clarity about and communicate flood risk management roles, responsibilities and liabilities, ensuring that the various roles and responsibilities of government, the community, industry and non-government organisations are defined and integrated effectively across the prevention, preparedness, response and recovery phases of managing floods
- outline effective links between flood risk management, flood forecasting, flood warning, emergency management and land-use planning in decision making, to manage the full range of flood risk to the existing and future community
- encourage a proactive and cooperative approach across governments to manage flood risk before events happen (e.g. by land-use planning, mitigation works, flood warnings, building controls and emergency management planning) rather than focusing on emergency response and recovery
- encourage the local community and individuals to take responsibility for their actions when developing the floodplain and responding to flood events
- outline the support available to local communities to help with flood risk management
- encourage the development of performance indicators, and the monitoring, review and continuous improvement of the understanding and management of flood risk.

Sustainable governance arrangements should also outline the legislative and policy framework that contributes to flood risk management to the local community. This framework needs to identify relevant Australian, State or Territory, and local:

- legislation, regulations, standards, codes, policies and directions
- administrative and technical guidance
- land-use planning strategies
- statutory planning instruments and development control plans and policies
- emergency management plans
- recovery arrangements.

State and Territory governments have a shared responsibility with all levels of government for managing the flood risk of local communities within their jurisdictions. However, as governance arrangements vary between jurisdictions it is recommended that they each develop, monitor, and maintain guidance that outlines these arrangements and make this readily accessible within their jurisdiction.

This advice could be used to inform local governance arrangements, which should also outline local roles and responsibilities and any local standards, policies, guidance, direction and plans that influence the management of flood risk. Where State or Territory advice is not available, consultation with relevant agencies should provide an understanding of the assistance available, the legislation and policies to be considered, and the information they need to fulfil their management role.

3.2 Overseeing the flood risk management framework

The FME responsible for managing flood risk would generally develop local governance arrangements and develop and implement the flood risk management framework for its service area. This would generally be managed from within the FME and be overseen by an administrative committee that can make decisions on cross-catchment priorities, and forward plans and budgets for studies and works. It should also be able to provide input into strategic land-use planning processes.

For floodplain-specific studies, a flood risk management committee may be established to oversee development and implementation of management plans. This committee needs to be fit for purpose for the scale and scope of the problem it is addressing and the associated investigations. The flood risk management committee would be overseen and advised by a FME administrative committee, who would consider recommendations from the flood risk management committee in their decision making.

The membership of a broad flood risk management committee could include a balanced mix of:

- FME staff, to provide the technical knowledge, and project management and administrative skills needed to develop and implement the management plan
- representatives from other agencies with responsibilities for supporting management plan development and/or implementing decisions
- decision makers, who may include elected representatives of the relevant FME administrative committee, who are likely to be making management decisions
- community representatives from affected residential and commercial areas or key community groups, who provide a direct linkage to the community and thus facilitate consultation. They have a legitimate role in representing community concerns and issues, and in fostering community ownership of the management plan. They should not be seen as having a conflict of interest that would affect impartiality.

Where the catchment boundaries go beyond the FME service area, and development or flood risk management within different FMEs will influence flood behaviour in each other, consideration should be given to establishing a joint committee with representatives of each FME. This can result in a more holistic appraisal of flooding and associated issues across the catchment, and help the successful implementation of management strategies.

A flood risk management committee can provide a focus and forum for the discussion of technical, social, economic, cultural and environmental issues, and for the distillation of possibly differing viewpoints on these issues into a management plan. It could advise the FME on progress in developing the plan and any issues arising during the process. It would also inform the community on the process, and facilitate community consultation at appropriate points in the investigations.

Flood risk management committee membership is likely to change during the development and implementation of the plan to reflect the requirements of particular points in the process. It is likely that only a small group of agencies directly responsible for implementing or supporting the implementation of the plan will oversee implementation. The FME would be expected to inform the community on progress in implementing the plan and associated issues.

A flood risk management committee may be supported by a sub-committee involving technical staff of the FME and other relevant agencies.

Where established, the sub- committee could support the committee on technical issues, in particular hydrology and hydraulics, flood mitigation, emergency management and land-use planning. It could be considered as the 'engine room' to establish and drive the process for the broader committee.

3.3 Making flood information readily available and reusable

Making flood risk information readily available and useable is essential to delivering the vision for flood risk management in Australia. It facilitates informed decisions by government, industry and the community on managing flood risk and investing in the floodplain. To achieve this, it is important to:

- make the best available information on flood risk openly, transparently and inclusively available to promote community flood resilience and support informed decision making. This information may go beyond that available within reports which generally contain a summary of the key information derived from an investigation.
- encourage procurement and publishing practices that use the least restrictive intellectual property and copyright licenses to support sharing, linking and reuse of information that benefits multiple stakeholders
- collect and maintain data – including post-event data collection and information, and outputs from floodplain-specific investigations – to achieve a better understanding and management of flood risk into the future
- encourage use of consistent terminology and mapping standards to help achieve a better understanding of flood risk by the community
- develop information to aid the understanding and strategic management of flood risk and provision of this information to key end users and decision makers (e.g. flood risk managers, emergency managers, land-use planners, infrastructure providers, insurers and the community) in a format that suits their needs and is consistent with the level of flood risk
- support initiatives that inform education and engagement measures that will enhance community resilience to flood
- highlight that it is the responsibility of the local community and individuals to inform themselves about their flood risks.

Table 3.1: Hierarchy of comprehensive to simplistic information development methodsa

Complex to simple	Output	Method type
1	Flood maps that depict flood characteristics (including extents, flood function and hazard)	Study deriving all modelled probabilities, flood function, hazards and evacuation
2	Flood maps that depict a number of different levels of flood likelihood	Study deriving maps for all modelled probabilities
3	Single probability flood map. For example, 1% annual exceedance probability, AEP, probability flood map	Study deriving in single probability flood map; for example, 1% AEP flood map
4	Simplified flood modelling	Simplified assessment based upon readily available or derivable information
5	Mapping of historic events accompanied by a flood frequency analysis	
6	Mapping of historic events without a flood frequency analysis	
7	Maps based on topographical or geological information	

a Considers the Queensland Flood Commission of Inquiry (2012)

3.3.1 Establishing and maintaining a knowledge hub

Up-to-date knowledge of flood risk and its management is essential to facilitate informed decisions on investment in the floodplain, and to manage gaps in knowledge and management. At an FME scale, the best available information on flood risk and its management is likely to be derived from collating data from different sources, and developed using different methodologies and to different standards. A hierarchy of complex to simplistic methods of data collection is provided in Table 3.1.

A knowledge hub can aid collation of knowledge on flood risk and its management within an FME service area and communication of this information to the community and decision makers. It can bring together information from historic events and floodplain- specific studies (Chapters 10–13) and more simplified methods, and incorporate knowledge on proposed and implemented treatment measures. It can provide a basis for identifying knowledge and management gaps.

Conveying flood risk information is best achieved through spatial tools, such as maps with supporting information. The ability to aggregate, convey and use this information for monitoring understanding and management of risk can be improved if:

- the information is transparent and openly available
- the basis, limitations and context are clear
- consistent terminology and formats are used
- output is generally tailored to broad end-user needs
- there is differentiation between degrees of impact
- treatment measures and their limitations are considered
- the information is monitored, maintained and continually improved
- the information avoids inadvertently giving the impression that no flood risk exists in an area when risk may exist above an arbitrary design standard
- it considers factors that may affect risk significantly into the future.

Developing a knowledge hub may be simple – for example:

- Bring the best available flood information into one location with a simple plan outlining where information exists (see Figure 3.2), a source for the data for further investigation and an understanding of the quality of the data. This may include a combination of information from historic floods and flood investigations of varying qualities. It is important to consider the quality and limitations of different sources in their use in managing risk
- Develop an understanding of the vulnerability of the community to the flood threat, and how this may vary across the floodplain and between catchments. This may be derived from studies and historic data, and can help inform decisions on the need for further investigations and management
- Develop an understanding of the current measures in place to manage flood risk (mitigation measures, land-use and emergency management planning), so that these are understood and can be considered in decision making. It is also important to understand proposed measures recommended in studies that have not been implemented

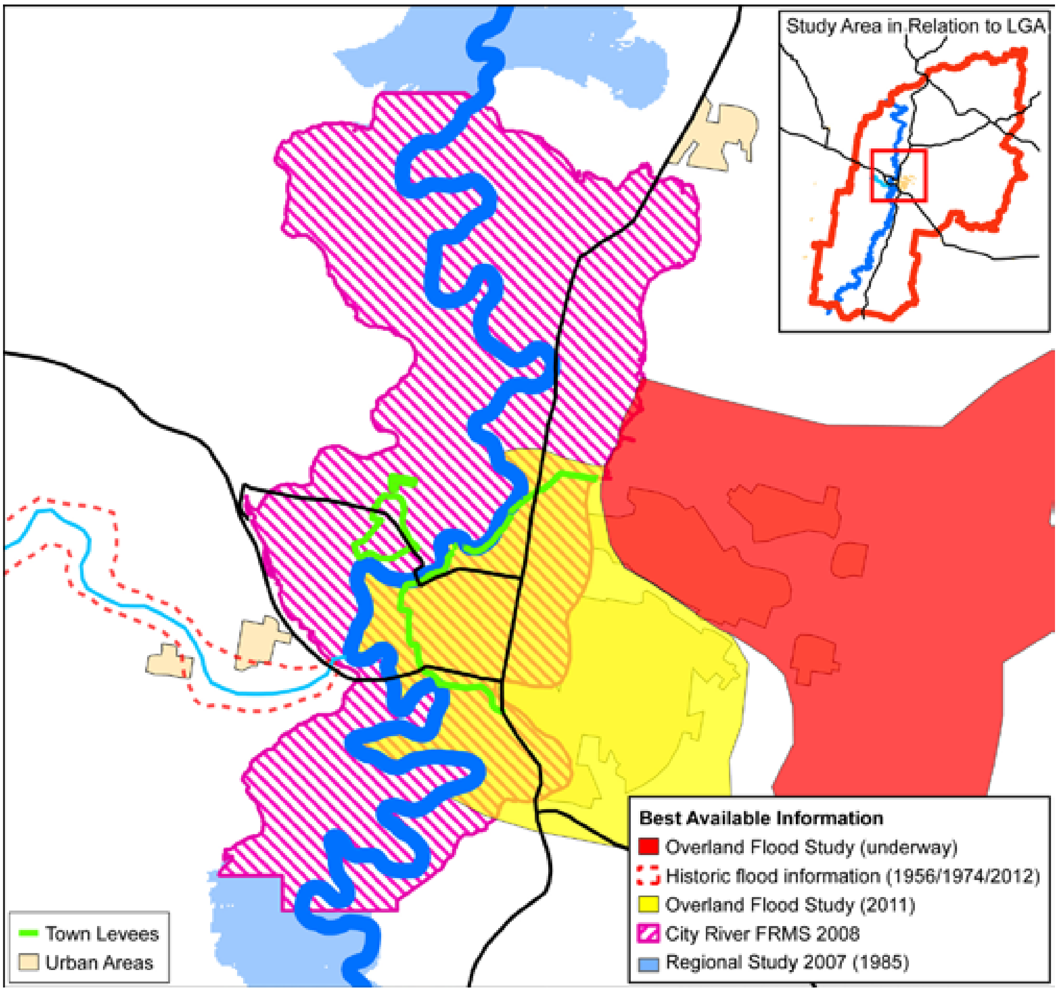


Figure 3.2: Example of best available information from different sources

- Maintain a register of data so that updates and changes can be tracked and communicated as necessary. Data are likely to be of varying quality, so when aggregating data, it is important to identify their source and reliability so that these are readily understood. This should include the methodology used to obtain or analyse the data, so the end users can determine to what degree they can rely on the information. The register should identify any intellectual property limitations on the data.

If the FME considered it necessary, the knowledge hub could be more sophisticated, such as a spatially based database of information. The hub could also store other relevant data (Queensland Flood Commission of Inquiry 2012), including the data listed as necessary for the completion of a flood study. Specifications for data collection should aim to enable the broad use across government where feasible, practical and cost-effective.

The knowledge hub should be updated where improved knowledge on flood risk or its management becomes available, and as treatment measures are implemented. It should be maintained with the best available information and reference current investigations so these can be considered, where warranted. Updating the hub's information may trigger the need for updated advice to the community and stakeholders. This may be facilitated with the development of a communication plan (Section 3.3.4) outlining when and how different stakeholders are informed.

3.3.2 Data storage

Significant amounts of data are collected during the floodplain-specific management process and for the development of a knowledge hub. The long-term storage of these data, the associated formats and means of providing ready access to the information should be considered as part of the specification for data collection (Chapter 10).

Each jurisdiction should consider whether such a system is centralised or locally based, or a mixture of the two, and what form of data-sharing agreements are appropriate. This is particularly important for emergency management agencies who respond to major flood events covering large areas, where flood data and intelligence needs to be shared. Key considerations will be the source, type, and format; data custodianship; and availability.

As a minimum, data storage could involve a repository of raw data (with appropriate management of any copyright issues), which can then be processed when required (e.g. for a flood study). This could be supplemented by more comprehensive spatially based processed data in a format that enables them to be readily used for studies and other purposes (e.g. generating maps). Data should be collected and stored in a manner that enables production of outputs from the process, and in formats to suit the interaction with relevant government databases and information systems. Information should be made readily available to those involved in managing flood risk, and specifying and completing flood investigations.

3.3.3 Using the information in the knowledge hub

The information in the hub could be used for a range of strategic purposes, such as for developing an FME-wide or broader scale understanding of the flood risk and how this is being managed. This provides an opportunity to identify and assess gaps in knowledge and management (both in coverage and in adequacy) so that consideration could be given to how these can be managed. This can inform forward planning, including resources allocation to improve knowledge and management of flood risk.

The knowledge hub could also inform the development of land-use planning, flood risk management and emergency management planning strategies, inform decisions to invest in public and/or private infrastructure and development within the floodplain and on insurance.

Managing gaps in knowledge

It is likely that there will be gaps in the knowledge of flood risk across an entire FME. These gaps may relate to the availability of data, the quality of the available data and the data's ability to support effective management through land-use planning, flood risk management, and emergency response and recovery. The significance of these gaps will depend upon a range of factors, which could include:

- the existing settlement and investment patterns, and, therefore, the scale of existing development within the floodplain and its exposure to flood risk
- the future settlement and investment patterns, and, therefore, the scale and desired location of future growth within the floodplain
- the capability of the existing data to support effective management measures to limit the flood risk to existing and future property and ensure that the impacts of new development on flood behaviour and the associated flow-on effects to existing development are effectively managed
- the existence of effective management measures.

Gaps in knowledge need to be identified and understood so that these can be managed to limit growth of risk through new development within the floodplain. A strategy to deal with gaps needs to be developed, and may involve assessing the relative priority for detailed investigations considering the significance of the gaps.

Identifying gaps could also involve instigating simplistic or interim approaches to identify broad areas of interest where flood risk needs to be considered in land-use and flood emergency response planning. This can inform development decisions to limit growth of flood risk in the short term, while further consideration is given to the long-term management needs. Such approaches may include the conservative use of the best available information and simplified methods that allow rapid evaluation of flood risk, at the expense of reliability and a full understanding of flood risk. These methods have a very valid place in informing the knowledge hub to support interim arrangements and may represent the first step in addressing flood risk that can be improved over time. They may also be adequate, within their reliability limits, to provide sufficient information to manage flood risk in locations where flood risk, population and development pressure is limited.

The type of simplified method selected (see Table 3.1 for a hierarchy of mapping outputs) needs to be fit for purpose for the circumstance for which it is proposed to be used. The benefit in using simplified methods in appropriate situations means that an FME may be able to:

- limit growth in risk – these approaches may require proposals for new development and major investment projects to undertake detailed flood investigations early in their feasibility assessments to ensure they are appropriately located and conditioned. This will facilitate effective long-term management of on-site risk and limit impacts to other development
- prioritise funding for detailed studies in locations at higher risk, improve the baseline flood information available in lower risk areas and continue to improve the FME-wide understanding of flood risk over time.

However, in most locations, particularly where populations are larger, the floodplain is more complex and development pressures are greater. Simplified methods may not provide sufficient information for the long-term management of the floodplain. Because these methods do not provide robust estimates of flood probability or flood risk, they need to be used in a conservative way or may fail to protect parts of the community. Where they are used in a conservative way, they often foster strong community resentment because reasonable use of the floodplain is restricted. Simplified methods, therefore, should not be used as the basis for not undertaking detailed flood investigations where a major community is at risk, existing risk is not adequately managed, redevelopment is occurring or major mitigation investments are being considered.

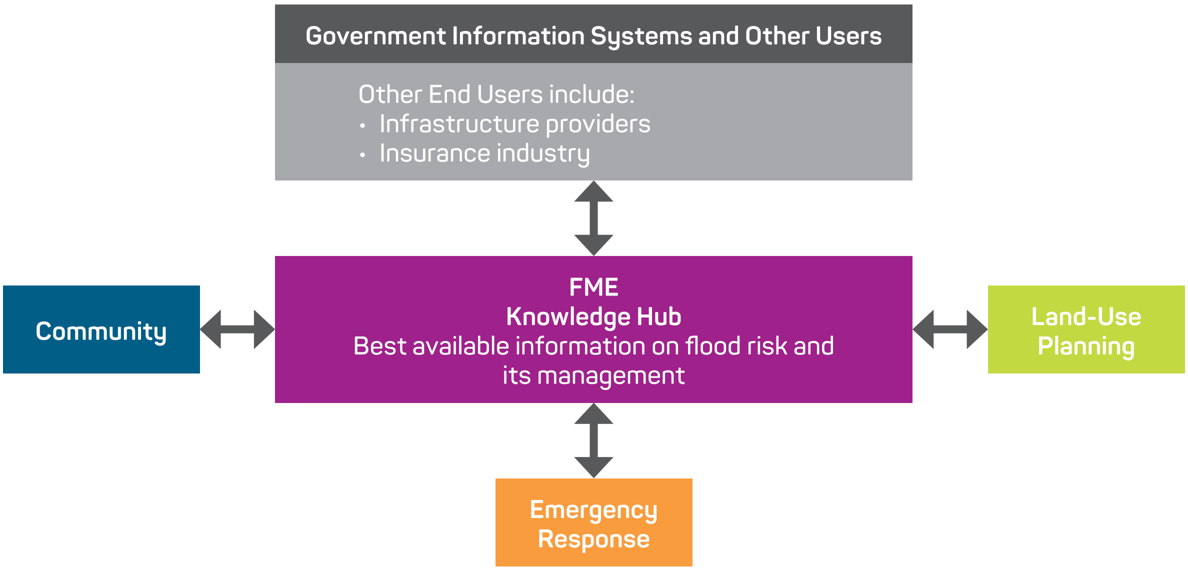


Figure 3.3 Communication from the knowledge hub

It also important to recognise that the use of the information derived from these methods beyond their reliability limits could result in ill-informed decisions leading to poor risk management outcomes. In addition, these methods may be limited in meeting the needs of end users such as emergency managers, land-use planners and flood risk managers, particularly where unique local conditions require a detailed understanding of flood risk. These methods are also generally unable to deal with cumulative catchment or floodplain changes, which may impact on flood behaviour and risk to existing development.

Therefore, in the long term, simplified methods used conservatively, and with clear knowledge and understanding of their limitations, are only likely to be adequate to deal with flood risk management in areas with little existing risk exposure and little potential for future settlement or investment growth. Beyond these limits, more rigorous approaches, such as outlined in the floodplain-specific management process (Section 3.6), provide a more informed basis to manage flood risk through a process of continuous improvement.

Finally, gap identification could include developing and implementing a prioritised forward plan to progress detailed investigations through the floodplain-specific management process (see Section 3.6 and Chapters 10–13).

Managing gaps in flood risk management

Flood risk management and land-use and emergency response management planning may contain gaps, which could result in levels of residual flood risk that are unacceptable to the community.

The knowledge hub can provide a basis for understanding existing and proposed treatment measures, and identifying where additional treatment may be necessary. This information can be used to create a prioritised forward program of investigations that can assess and recommend practical, feasible and economically viable options to reduce residual risk.

Making informed decisions on treatment options relies on a detailed understanding of flood behaviour and its impacts, and the effectiveness, benefits, costs and limitations of various management measures. Options are usually assessed in a floodplain management study (Chapter 12) or equivalent assessment. The treatment of risk, including the selection of options, is discussed in Chapter 7. Where the knowledge hub includes information on proposed treatments, this may assist with the FME-wide prioritisation of treatment options.

3.3.4 Communicating information from the knowledge hub

Communication is fundamental for sharing information about flood risk within government and to the community. This information can inform flood risk management, emergency management, land-use planning and investment decisions. It is also an essential element of floodplain-specific management process. The knowledge hub aims to support communication by providing a basis for developing and maintaining the best available information on flood risk and its management within the FME, and making this information available to decision makers in government and the community (Figure 3.3).

A simple communication plan may facilitate dissemination of information. This plan may identify when and how to make information available to different stakeholders and the community, such as through a website or provided directly to those managing government systems. The plan may also identify key points where proactive communication is important. For example, it is important that land use, emergency management and recovery planners are made aware of the construction of treatment measures as these may change the management of and/or response to floods.

3.4 Consultation

Consultation is fundamental to the successful delivery of flood risk management to the community. It should be undertaken with internal and external stakeholders during all stages of the floodplain-specific management process. It may also play an important role in developing an improved understanding of historic floods to feed into gap analysis. Design and implementation of an effective consultation strategy should enable:

- gathering information from the community, stakeholders and other agencies so that a reasonably clear picture can be put together about historic flooding, and the vulnerability of people and the built environment to past floods
- understanding the information needs of those who have a role in managing flood risk or facilitating community recovery
- gathering information on treatment options that the community may feel will reduce their flood risk and gauge community support for potential options
- informing the community and key groups on the progress and outcomes of studies, and on management decisions.

It is important to ensure that all those who need to be involved (i.e. those with responsibility for managing flood risk and those with a vested interest in its management, such as property owners) are kept informed and invited to contribute to the process to establish a common understanding of flood risk and how decisions are made. Effective engagement will improve risk management. Stakeholders may tend to make judgements about risk based solely on their own perceptions. These perceptions can vary due to differences in values, needs, assumptions, concepts, concerns and degrees of knowledge. Stakeholders' views can have a significant impact on the decisions made, so it is important that differences in their perceptions of risk be identified, recorded and addressed.

3.5 Monitoring and review

Monitoring and review is an important part of managing flood risk, and completes the risk management framework. These steps ensure that assumptions, methods, data sources, results and reasons for decisions are subject to regular checks. These checks should consider changes in our understanding of flooding, its impacts or its management, lessons learnt from flood events, and trends in changes of exposure or vulnerability. Such checks keep the overall understanding of flood risk and management measures relevant and up to date. These checks also assist with reporting against key performance indicators (KPIs). Establishing KPIs can help assess progress toward understanding and managing flood risk. KPIs will differ depending upon the roles and responsibilities in managing flood risk, and may include the:

- percentage of area that is zoned for development within the floodplain where flood information is available for strategic land-use planning and to the community
- percentage of developed area in the floodplain supported by emergency management plans
- percentage of properties that have experienced above-floor flooding in key flood events
- number of high-priority treatments identified in management plans, and the percentage implemented
- number of properties that are protected by mitigation works and the level of protection provided.

The agreed processes and outputs of monitoring and review should be recorded and reported. They form an important part of the review cycle for the risk management framework. The FME should develop systems to monitor risk and management gaps so that these can be prioritised and addressed.

Monitoring should help provide up-to-date advice to decision makers and others on the effectiveness of flood risk management, and where implementation may be impeded. Any setbacks with successful implementation may mean the management plans need to be reviewed to see if the obstacles can be overcome or whether other options may be viable and require further investigation.

3.6 Floodplain-specific management process

Floodplain management in an FME relies on consolidated knowledge of flood risk and its management from historic information and studies, which generally relate to a more limited area such as a catchment, floodplain or study area.

The floodplain-specific management process (Figure 10.1) is a portion of the flood risk management framework (Figure 3.1) that generally aims to consider flood risk in detail at the floodplain scale rather than at an FME scale. It is a mature risk management process that, when used, has provided the information necessary to support informed decision making across the spectrum of land-use planning, emergency management and flood risk management for specific floodplains for decades. Where considered more appropriate to the situation, equivalent risk management approaches can be used (see Section 1.2.2).

The process involves a series of related interdependent steps aimed at developing and implementing a management plan to manage risk in a specific area. Section C provides general guidance on how to implement the process. However, as the flood behaviour, topography, development conditions, population and social context of each floodplain are unique, the application of the process needs to be flexible to be fit for purpose. For example, the complexity of modelling methods can vary with the flood behaviour and exposure of the current and potential future community to flooding. There are also situations where some process stages may be combined into a single project for cost and time efficiency. In such projects, strong 'hold points', beyond which work cannot progress without approval, are recommended at critical points in the project. For example, it would be unwise to evaluate flood mitigation options before the community has validated the results of modelling against a known flood, as individuals or communities may dispute the model results.

The process and its stages generally lead to improved information on flood risk and management options which can feed into the knowledge hub. The knowledge hub can then enable dissemination of this information to the community and relevant stakeholders, as well as facilitate forward planning and cross-catchment prioritisation of risk management projects.

3.7 Considering other related management processes

Good floodplain management cannot occur in isolation. It is important for the FME and those overseeing the flood risk management framework to interact with other management and planning processes (such as land-use, infrastructure, emergency management and catchment management planning) occurring within the catchment. The information available and decisions made will influence one another. Therefore, it is important for those responsible for these processes to effectively engage and communicate to ensure that information is shared and decisions are cognisant of other relevant issues. To facilitate informed decision, flood investigations to inform strategic land use or infrastructure planning should be cognisant of existing flood information and be undertaken prior to, or in the early stages of, the planning process. This can ensure that flood conveyance and storage are considered in decisions, any changes to the flood risk to existing development are managed, and the residual risk to the new development or infrastructure is managed.

CHAPTER 4

Roles and responsibilities

In a nutshell…

Managing flood risk to the community requires cooperation across all levels of government, and between the government and non-government sector. States and Territories have a shared responsibility with all levels of government for managing flood risk. They do this through administrative arrangements, which vary between jurisdictions. It is important for State and Territory policy frameworks to delineate clearly responsibilities and linkages across all necessary prevention, preparedness, response and recovery functions. This may require legislation.

The review *Natural Disasters in Australia: reforming mitigation, relief and recovery arrangements* (COAG 2002) outlines the benefits of cooperation between all levels of government. More recently, the Council of Australian Governments recognised that a national, coordinated and cooperative effort is required to increase Australia's capacity to withstand and recover from emergencies and disasters. Disaster resilience is a shared responsibility (COAG 2011); in 2011, Police and Emergency Management Ministers committed to leading governments towards a national, integrated approach to building disaster resilience, and delivering sustained behavioural change and enduring partnerships across Australia (Police and Emergency Management Ministers Meeting Communiqué 2011). The Standing Council on Police and Emergency Management (SCPEM) is now responsible for implementing the *National Strategy for Disaster Resilience* (COAG 2011).

Flood risk management is complex, and therefore requires access to a range of different skills and disciplines, which reside in a variety of agencies and across government levels. Government flood risk managers may use in-house or outsourced hydrology and hydraulics skills to provide information on flood behaviour, which is then used to:

- understand the impacts of floods on the community
- analyse mitigation and management options by flood risk managers
- investigate, design, construct and maintain mitigation works by engineers
- inform land-use planners, so they can consider varying flood hazard and flood function in establishing zonings, and develop controls in planning instruments
- improve flood predictions and warnings by flood forecasters
- improve flood intelligence, and incorporate this into emergency management planning and response activities by emergency managers
- inform agencies involved in flood recovery to help them locate recovery centres and determine the resources needed to assist the community in flood recovery
- facilitate informed decisions for floodplain development or flood risk treatment
- provide information to the community on flood risk and emergency response.

These different activities require specialist skills, because flood risk management needs to inform a variety of decision makers and the community. For example, flood risk managers need a range of technical, hydrologic, hydraulic, negotiation and consultation skills to understand and manage flood hazard, facilitate trade-offs within the community, educate the community about flood risk, develop management strategies and investigate, design, construct and maintain mitigation works. Land-use planners need expertise in town planning, strategic land-use planning and conflict resolution given that they need to manage competing land-use objectives. Emergency response managers need skills in emergency response planning and logistics, community education and data management. Flood recovery managers require knowledge in financial and social counselling.

4.1 Government responsibility

Australian governments are working collectively to incorporate the principle of disaster resilience into aspects of natural disaster arrangements. The *National Strategy for Disaster Resilience* (COAG 2011) identified that governments, at all levels, have a significant role in strengthening the nation's resilience to disasters by:

- developing and implementing effective, risk-based land management and planning arrangements and other mitigation activities
- having effective arrangements in place to inform people about how to assess risks and reduce exposure and vulnerability to hazards
- having clear and effective education programs so people understand what options are available to them, and what the best course of action is when responding to an approaching hazard
- supporting individuals and communities to prepare for extreme events
- ensuring the most effective, well-coordinated responses from emergency services and volunteers when a disaster hits
- working in a swift, compassionate and pragmatic way to help communities recover from devastation, and to learn, innovate and adapt in the aftermath of disastrous events
- developing and reporting against KPIs as discussed in Section 3.5.

For these roles to be undertaken effectively in relation to the flood risk, governments at all levels must develop an appropriate, coordinated policy framework. Relevant agencies across all levels of government should be linked by this framework, and include:

- overarching and coordinating roles that provide high-level advice to facilitate management of flood risk at a local level, which are generally undertaken by a State or Territory government (however, the Australian Government may also have a role; see Section 4.1.1)
- direct management roles to manage flood risk at the local level, which are generally carried out by the relevant FME (often a local government or catchment management authority; see Section 4.1.1)
- supporting roles that provide essential but specific assistance in management of flood risk at a local level, which are generally undertaken by the Australian Government (see Section 4.1.2).

Some roles and responsibilities are shared across levels of government; these are discussed in Section 4.1.3.

4.1.1 State and Territory governments and floodplain management entities

Best practice encourages arrangements that enable local problems to be managed locally, but in a broadly consistent manner across the jurisdiction. This develops local community resilience to flooding impacts. High-level policies and activities support consistency in dealing with flood hazards at the local level (though this may be managed by regional, State or Territory agencies).

State and Territory governments have a shared responsibility with all levels of government for managing the flood risk of local communities within their jurisdictions. However, governance arrangements for land-use planning, flood warning, flood mitigation, emergency response and recovery vary between jurisdictions. Therefore, it is recommended that each State and Territory identify clearly the specific roles and responsibilities in legislation, or binding management arrangements within a policy framework. The arrangements need to:

- be continuous and consistent across local and regional boundaries
- cover the full range of roles that influence effective flood risk management outcomes
- be sustainable and facilitate cooperation on issues that may have cross-boundary (including State and Territory boundaries) implications as far as flood behaviour, flood hazard and community impacts are concerned.

This advice could be in the form of an administrative guideline that outlines clearly any jurisdictional arrangements that fulfil the roles and responsibilities outlined in Sections 4.1.1 to 4.1.3, and identify any associated agreements.

Overarching and coordinating roles

These roles are generally undertaken by the State or Territory governments; however, the Australian Government may also have a role.

Leading, monitoring and maintaining the legislative, policy and administrative framework for flood risk management

It is recommended that each State and Territory develop, monitor, and maintain guidance that outlines sustainable governance arrangements (see Section 3.1) and make this readily accessible within their jurisdiction. To facilitate implementation of flood risk management policy this guidance should:

- set strategic direction as a basis for implementing flood policy. This handbook provides general best practice advice. However, it is recommended that States and Territories provide more specific direction in key areas, including flood risk management, land-use planning, flood emergency management planning, and response and recovery from floods

- identify relevant legislation in a single document, although consolidated legislation could be considered for dealing with flood risk management matters. Indemnities provided under this legislation may be considered under specific circumstances if certain principles are followed
- define, in a single document, the responsibilities of the various State or Territory agencies, and local government in flood risk management, and indicate how these roles will be coordinated
- identify the lead agencies and cross-agency linkages with respect to key aspects of flood risk management (i.e. management and mitigation, emergency management planning, land-use planning, flood warning and gauges, and recovery management)
- define flood emergency management roles and responsibilities of relevant State and Territory agencies, and local government in emergency management legislation
- define consent authorities and control mechanisms for dealing with land-use and emergency management planning matters in the floodplain, and identify appropriate mechanisms for coordination within catchments
- outline responsibilities for monitoring knowledge of floods and their management, and the dissemination of this information within government and to the community
- define and monitor progress towards KPIs
- outline responsibilities for education of the community about flood risk and how to respond to a flood threat.

Supporting direct management of flood risk by floodplain management entities

State and Territory governments should assist the direct management of flood risk by FMEs by encouraging and supporting:

- the development and implementation of floodplain management plans by FMEs as an effective way to understand and manage flood risk
- the use of the best available information to manage flood risk at all times, including during the development of management plans
- the cooperation of FMEs within a catchment (including across State and Territory boundaries) where they may influence the flood risk of other FMEs
- the accessibility of information on flood risk to the community, and the availability of information and its management within government
- consultation with the community and key stakeholders.

Supporting effective land-use planning, and development and building controls

Strategic direction for managing flood risk to future development should include guidance on land-use planning and building controls, such as:

- setting overall planning directions through standard documentation
- managing State- or Territory-significant development
- undertaking strategic planning a scale above local planning (i.e. regional planning)
- reviewing local planning for consistency with jurisdictional planning directions
- establishing building controls and having input into national building codes.

National codes, standards and intergovernmental agreements may also provide support.

Flood emergency management planning and response

Each State or Territory is responsible for emergency planning and response to flood events at a jurisdictional level. They may also provide strategic direction and guidance on the emergency management at a regional, district or local level, which may involve:

- identifying general roles and responsibilities in flood emergency management, including management committees
- establishing and maintaining flood intelligence systems
- establishing and maintaining emergency management plans for flooding
- undertaking or assisting with community education on floods
- reviewing flood intelligence and emergency management planning after floods, so that plans can be improved.

Specific advice may also be provided to improve community resilience in response to a particular flood threat. Community members need to know how they can help themselves, and protect lives and property when emergency responders are unavailable. Advice can also help communities by adding value to flood predictions and warnings.

Information systems to support decision making

States, Territories and the Australian Government may maintain information systems to:

- support flood risk management
- help inform and monitor knowledge on flood risk and/or risk exposure
- help monitor the implementation of flood risk management plans

- provide information to support strategic planning or the establishment of effective emergency management resources, such as flood intelligence systems
- outline flood risk exposure to the government
- share information on flood risk within government and to the community.

Direct management roles

Direct management roles manage flood risk at the local level, generally within an FME. These roles may be within local government or may be undertaken at a regional level (e.g. catchment management authorities), or at a State or Territory level. FMEs within a catchment should explore the opportunity for formal or informal collaborations to manage flood risk where changes in one FME may affect flood behaviour in another.

Flood risk management, land-use planning, development and infrastructure provision

Most roles in flood risk management, land-use planning, development and infrastructure provision are undertaken at the municipal or regional scale. They should consider the policy framework and directions outlined above. The roles may be the responsibility of more than one agency; regional strategies may also be prepared to guide policy and investment decisions, and collectively involve:

- bringing together and maintaining the best available information on flood risk and its management to facilitate the
  - identification of knowledge and management gaps
  - prioritisation of future studies and treatment measures
  - use of strategic and development scale land-use planning, to update flood intelligence and inform emergency management and recovery planning
  - provision of the best available information to the community
  - review of flood risk management, land-use and emergency management planning as new information becomes available or treatment measures are implemented
  - monitoring of KPIs
- collecting data after flood events, and for studies and updating the knowledge hub; this improves knowledge of flood risk and its management
- investing in developing, implementing and reviewing management plans to update knowledge and management practices, and inform and review decisions
- developing and implementing operation, maintenance and monitoring plans for works
- considering community flood risk in new development decisions in investigating, implementing and maintaining new or refurbished infrastructure.

Flood emergency management

Local roles in emergency management planning and response to flood threats include:

- developing and maintaining local flood intelligence
- undertaking emergency management planning in relation to flooding
- informing the community on how and when to react during a flood threat
- working closely with flood warning agencies to monitor the potential for floods
- responding to floods and coordinating agencies with a responsibility in flood threats
- reviewing emergency management planning in the aftermath of flooding
- providing feedback on problems during events to responsible agencies.

Local flood recovery

Roles in local flood recovery include restoration of essential and community services, facilities and infrastructure, with assistance from State, Territory and Australian Government agencies under Natural Disaster Relief and Recovery Arrangements (NDRRA). They may also include responsibility for managing financial assistance, for providing temporary accommodation and for providing counselling services.

4.1.2 Australian Government roles

There are a range of essential services that are generally established at higher levels of government to support flood risk management at a local level. These are generally undertaken by the Australian Government; however, State and Territory governments may also have a role.

Flood prediction and warning services, and associated infrastructure

In general, the Australian Government is responsible for providing weather forecasts, monitoring situations likely to lead to flooding, making flood level predictions and issuing flood warnings. Flood warning arrangements, which set out the roles and responsibilities of all levels of government, have been developed and operate under the guidance of flood warning consultative committees within each State and Territory. These arrangements are essential to enable effective warnings to local communities and emergency management agencies.

The Australian Government operates rainfall and some river gauging networks to inform flood predictions, forecasts and warnings. It disseminates this information via the internet and mass media. It also provides direct advice to agencies responsible for local flood emergency management, who may use flood intelligence to give more specific advice to the community on local effects and how to respond to the flood threat. Gauge networks may be supplemented by gauges managed by other levels of government.

Data management

The Australian Government maintains national scale earth observation data such as satellite imagery. The available satellite imagery includes up to 30 years of nation-wide archives of medium and low resolution data useful for the analysis of broad-scale flooding, and some higher resolution images for more detailed studies in specific areas. It also maintains and distributes best available national scale digital elevation models for public access (for example, national 9, 3 and 1 arc-second digital elevation models), and significant areas of high resolution elevation data (LIDAR) for whole of government use.

The Australian Government also derives aggregated national exposure information about residential, commercial and industrial buildings from available statistical and geospatial datasets. It maintains the Australian Flood Studies Database (being expanded through the National Flood Risk Information Project) and the national climate data archive. The Australian Government is also responsible for compiling and delivering Australia's water information and providing design rainfall information for use in flood risk studies. The Australian Government also plays an important role as both an aggregator and publisher of flood information and data.

Conservation of natural resources and environmental values of national significance

The Australian Government provides legislation for matters of national and international environmental significance. This legislation needs to be considered when assessing the impacts of proposed flood mitigation works.

4.1.3 Shared roles and responsibilities

There are a range of roles that have varied or shared responsibilities between the Australian, State or Territory, and local governments depending upon current agreements and jurisdictional arrangements. Service-level agreements or partnerships should be established between the parties involved to document the services provided. These should be clearly articulated in State and Territory administrative arrangements.

Managing gauges and supporting systems to inform flood warning

Owners of river level and key automatic rainfall gauges that provide information to flood predictions and warnings services should ensure that gauges are maintained so that they remain functional (within operational parameters) during a flood. Owners of gauges may also be responsible for:

- maintaining and adding to their gauging networks to provide additional data to support the development of flood predictions and warnings for the community
- monitoring of gauges and gauging of river flows during flood events
- developing and maintaining storage systems and making data available within government.

In the case of flash-flood warnings, local agencies are responsible for ensuring that local systems are in place, where warranted, to inform flood monitoring and/or prediction so that flood warnings can be issued.

Funding coordination and management

The Australian Government and, where relevant, States and Territories, coordinate financial support under relevant funding programs within their eligibility criteria, and establish administrative arrangements to provide effective and efficient access to funds for priority projects. Eligible organisations, such as FMEs, can apply for financial support through such programs to assist with developing and implementing floodplain management plans. Funding is generally provided through partnership arrangements where more than one or all levels of government contribute.

The NDRRA help alleviate the financial burden of natural disasters on State, Territory and local governments, and the community. This assistance is comprehensive and includes emergency food, clothing and accommodation for individuals; clean-up and recovery loans and grants for businesses and primary producers; recovery funds for communities; and the repair or replacement of essential public infrastructure. These arrangements are outlined in *Australian Disaster Resilience Handbook 9 - Australian Emergency Management Arrangements* (AIDR 2014).

Recovery after a flood

Helping a community recover from a flood event is essential to improving long-term community resilience to flooding. People's ability to recover their homes and contents will frequently rely upon assistance from both the government and non-government sectors.

A coordinating committee, consisting of representatives from relevant agencies, may be established to respond to a large-scale event following a natural disaster declaration. A lead agency for each area of recovery should be identified. 'One-stop shop' arrangements for government and non-government assistance may assist in community recovery.

Effective and timely support to the community can be aided by mobilising for flood recovery as soon as response operations begin to provide support to the community. Flood recovery arrangements need to consider the degree of access available to, and take up of, flood insurance within the impact area. *Australian Disaster Resilience Handbook 2 Community Recovery* (AIDR 2013) should be considered in recovery planning.

Research and training

Responsible agencies should cooperate in the establishment of research and training programs to improve the knowledge and understanding of the consequences of floods, and how these can be managed effectively.

National coordination and cooperation in best practice

NFRAG is an advisory group that has facilitated national coordination and cooperation in best practice flood risk management since 2005. NFRAG is a reference group of the Australian – New Zealand Emergency Management Committee (ANZEMC), and provides advice on strategic leadership in flood risk management and expert technical advice to ANZEMC and its sub-committees. It identifies, promotes and provides advice on nationally consistent best practice and promotes research into improving the quality of flood risk management. NFRAG facilitates communication between emergency, flood risk and land-use managers, and other stakeholders. NFRAG aims to augment community resilience to flooding.

NFRAG brings together technical representatives actively involved in flood risk management in their jurisdictions with other key stakeholder groups. Membership includes technical representatives from each State and Territory, and the Australian Government, Australian Local Government Association, Australian Council of State Emergency Services, Australian Building Code Board, Insurance Council of Australia and research community. NFRAG works in collaboration with other groups such as Engineers Australia on areas of mutual interest.

4.2 Community responsibility

Communities should be responsible for following the direction of emergency management and recovery agency's before, during and after a flood event, and to seek their assistance where required. Therefore, it is important that the community has both access to information to appraise their flood risk as well as input into how this risk is managed.

4.2.1 Role of individuals

The *National Strategy for Disaster Resilience* (COAG 2011) indicates that 'disaster resilience is based on individuals taking their share of responsibility for preventing, preparing for, responding to and recovering from disasters' (COAG 2011, p. v). Individuals need to be aware of the flood threat they face and what to do about it. They can draw on guidance, resources, government policies and other sources, such as community organisations, to obtain information and assistance. FMEs are generally responsible for informing the community of their exposure to flooding. Agencies responsible for local flood emergency management should also inform the community on how to prepare for, and how and when to react to, a particular flood threat.

The disaster resilience of people and households is significantly increased by active planning and preparation for protecting life and property, based on an awareness of the threats relevant to their locality. It is also increased by knowing and being involved in local community disaster or emergency management arrangements, and – for many – being involved as a volunteer. Individuals are expected to remove themselves from potential harmful situations where directed. They also need to be aware of the need, availability and coverage of flood insurance for their property.

4.2.2 Role of business

The *National Strategy for Disaster Resilience* (COAG 2011) states that businesses can play an important role in supporting community resilience to disasters. They provide resources, expertise, infrastructure and many essential services upon which the community depends. Business' roles are key in helping the community maintain continuity of services following a disaster.

4.2.3 Role of insurers

Flood insurance is an important tool to help individuals recover after a flood event. Where suitable information on flood risk exists, insurers have a role in facilitating the provision of flood insurance to property owners whose risks fit within the limitations set in insurers' individual portfolios.

4.2.4 Role of non-government organisations and volunteers

The *National Strategy for Disaster Resilience* (COAG 2011) highlights the critical role that non-government and community organisations (often volunteers) play in strengthening disaster resilience in Australia. Australians often turn to them for support or advice during a disaster. The dedicated work of these organisations is critical to helping communities to cope with and recover from a disaster. Governments partner with these organisations to communicate the disaster resilience message and to strengthen community disaster resilience.

SECTION B

Understanding flood behaviour and flood risk, and treatment options

Treating flood risk is essential to limiting two sources of risk: the flood risk associated with existing development, and the flood risk introduced by future development.

Understanding flood risk in sufficient detail is essential to give the different agencies with a responsibility for managing flood risk the ability to fulfil their roles effectively.

Simplistic approaches to understanding flood behaviour, as described in Section 3.3.1, have their place in improving knowledge, particularly where gaps in knowledge exist. However, they have limitations. An adequate understanding of flood behaviour (Chapter 5) and flood risk (Chapter 6) can inform:

- decisions to manage flood risk to existing development and prioritise competing management efforts within a catchment and a floodplain management entity service area (Chapters 7 and 9)
- strategic land-use planning processes (Chapter 8) to limit growth of flood risk using zonings that consider both the flood function of the land and the potential to interfere or alter this function, and the drivers for flood hazard and its relative severity
- development conditions within zonings to limit growth in residual risk (Chapter 8)
- emergency response management planning (Chapters 8 and 9).

CHAPTER 5

Understanding flood behaviour

In a nutshell...

Understanding flood behaviour is essential for understanding and managing flood risk, and includes comprehending the:

- range of potential flooding and the implications of a changing climate
- flood function of the area, particularly conveyance and storage of water
- variation in flood hazard within the floodplain – this depends upon flow depth and velocity, and the interaction of the flood with the landscape, which can isolate areas from flood-free land and result in difficult evacuation situations.

Flood behaviour depends upon a range of factors, including the source of flooding, and catchment and floodplain location, size, shape, topography, vegetation, underground geological features and development. Understanding flood behaviour is essential to assessing risk and making informed management decisions. Key components to adequately understanding flood behaviour include understanding: the probability of flooding (Section 5.1); flow conveyance and storage functions of the floodplain (Section 5.2) and the variation in the drivers and degree of flood hazard within the floodplain (Section 5.3).

Long-term changes in catchment and floodplain use may adversely affect the flood regime, which may be a result of cumulative changes in:

- land use (increased scale or density of development)
- rural practices (such as stocking or cropping types)
- topography (due to filling or reshaping)
- environment (riparian, floodplain and catchment vegetation)
- water table levels
- flood mitigation infrastructure
- other infrastructure (road and rail).

These changes should be considered when assessing future flood behaviour considering forward infrastructure plans and the development of existing zoned land.

It is also important to understand how changes in climate may alter the flood regime within the planning horizon or the design life of development and/or infrastructure. These may include changing sea levels, which alter the tidal regime and adversely affect flood behaviour in coastal waterways; the frequency and severity of flood-producing rainfall events; and antecedent catchment, floodplain and waterway conditions that may have impacts in all areas (see Section 5.4).

5.1 Flood probability

Managing flood risk relies on an understanding of the full range of flood events, typically from the 10% annual exceedance probability event to the probable maximum flood, though the needs of individual studies vary.

The probability of a flood occurring affects the risk of exposure to that threat. In some areas of Australia, flooding does have some seasonality. However, over much of Australia, floods of any size can occur in any year, and at virtually any time during the year.

Flood studies (Chapter 11) provide a sound technical basis for developing calibrated and verified models, which consider historic floods. Models can be extrapolated to understand the full range of flood behaviour, the probability of occurrence of different sized floods and the impacts of floods of different probabilities. Models can also provide an understanding of the probability of the occurrence of events of a similar size to key historic events.

There is broad industry consensus that the best way to express probability when talking to the community about flood risk is using percentage AEP. AEP refers to the probability each year of a certain size event being exceeded and reinforces that there is an ongoing flood risk every year. The term average recurrence interval (ARI), where probability is expressed as a return period in years, is actively discouraged as it may mislead the community about ongoing flood risk after an event.

Although the probability of a flood of a given size occurring remains the same from year to year (unless the flood regime is altered or new data lead to a revision of statistical estimates), the chance of such a flood occurring at least once in any continuous period increases as the length of time increases. Table 5.1 shows the probability of experiencing various-sized floods at least once or twice in a lifetime.

Annual exceedance probability (%)	Approximate Average recurrence interval (years)	Probability of experiencing a given-sized flood in an 80-year period	
		At least once (%)	At least twice (%)
20	5	100	100
10	10	99.9	99.8
5	20	98.4	91.4
2	50	80.1	47.7
1	100	55.3	19.1
0.5	200	33.0	6.11
0.2	500	14.8	1.14
0.1	1,000	7.69	0.30
0.01	10,000	0.80	0.003

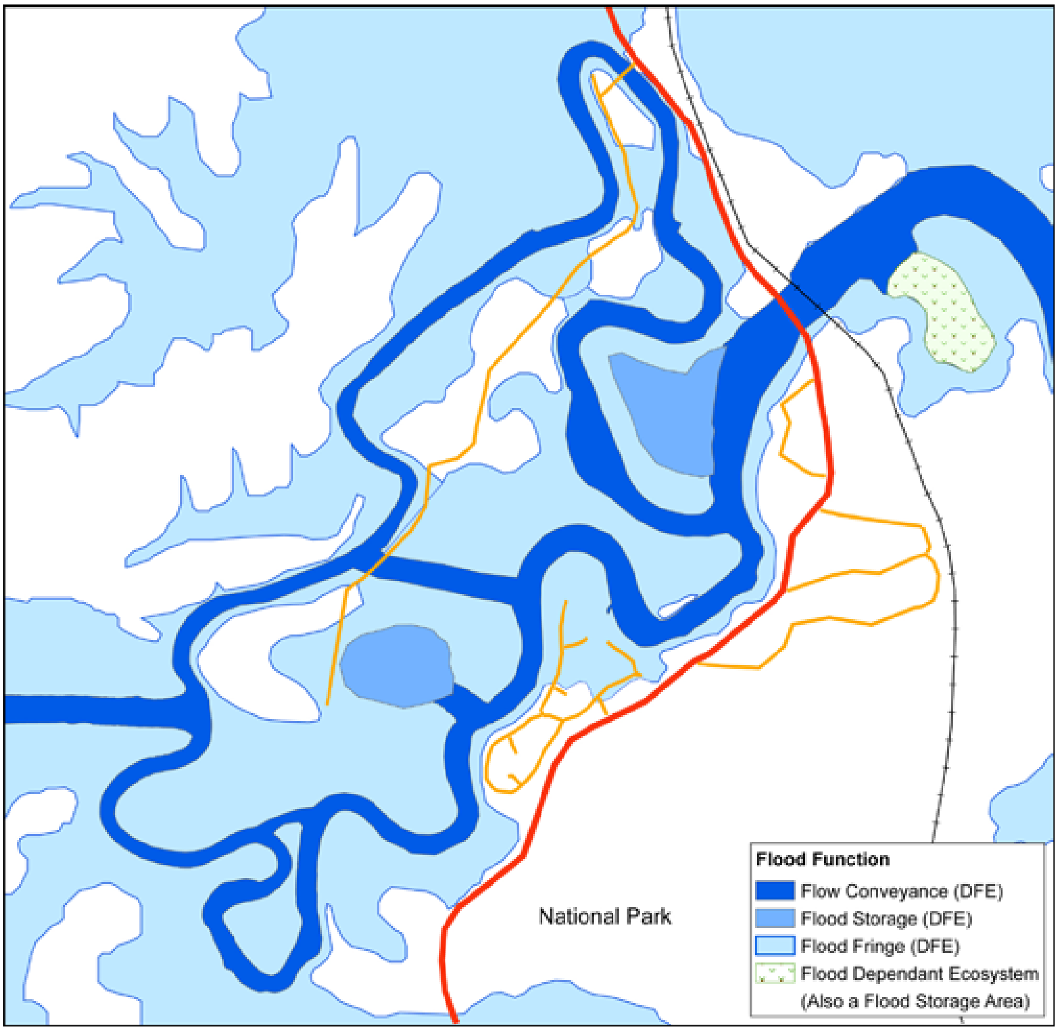
Table 5.1: Probability of experiencing a given-sized flood one or more times in 80 years

5.2 Flood function

Maintaining the flood function of the floodplain is a key objective of best practice in flood risk management in Australia (Section 7.1.2), because it is essential to managing flood behaviour. The flood function of areas of the floodplain will vary with the magnitude in an event. An area which may be dry in small floods may be part of the flood fringe or flood storage in larger events and may become an active flow conveyance area in an extreme event. In general flood function is examined in the defined flood event (DFE), so it can be maintained in this event, and in the PMF so changes in function relative to the DFE can be considered in management.

Understanding flood behaviour is a first step. This is generally developed in the flood study (Chapter 11), where flood function should be assessed at a strategic scale to allow for consideration of cumulative impacts of potential changes. Flow conveyance and flood storage are the key flood functions (Figure 5.1). Flood behaviour is sensitive to changes in topography, development and infrastructure crossing the floodplain that may alter flood functions, and lead to increased upstream flood levels, redistributed flood flows or increased downstream flood flows and levels. These impacts may have ramifications for the broader community. Breaking down the floodplain considering these functions identifies the areas of the floodplain where flood behaviour is particularly sensitive to change. This information can be used to limit adverse impacts on flood behaviour through strategic planning (limiting development in to areas where it is compatible with flood function), infrastructure planning and design, and to inform flood mitigation decisions.

Flow conveyance areas (Figure 5.1) are a fundamental element of the floodplain and are generally continuous. They flow from the upper reaches of the catchment (on the main waterway and its tributaries) to the catchment outlet and generally extend to at least the banks of waterways. They may flow into larger waterbodies, such as lakes, and re-emerge to convey flows from the waterbody to the ultimate outlet. They are often, but are not necessarily, areas where flow is deeper or velocity is greater. Floodwaters are temporarily stored in flood storage areas (also shown on Figure 5.1) during the passage of a flood, which can reduce downstream flood flows and impacts. The remaining area of land inundated by the flood is generally known as the flood fringe, which can often be safely developed without significant adverse flood impacts if flood hazard (Section 5.3) can be managed effectively.



DFE = defined flood event

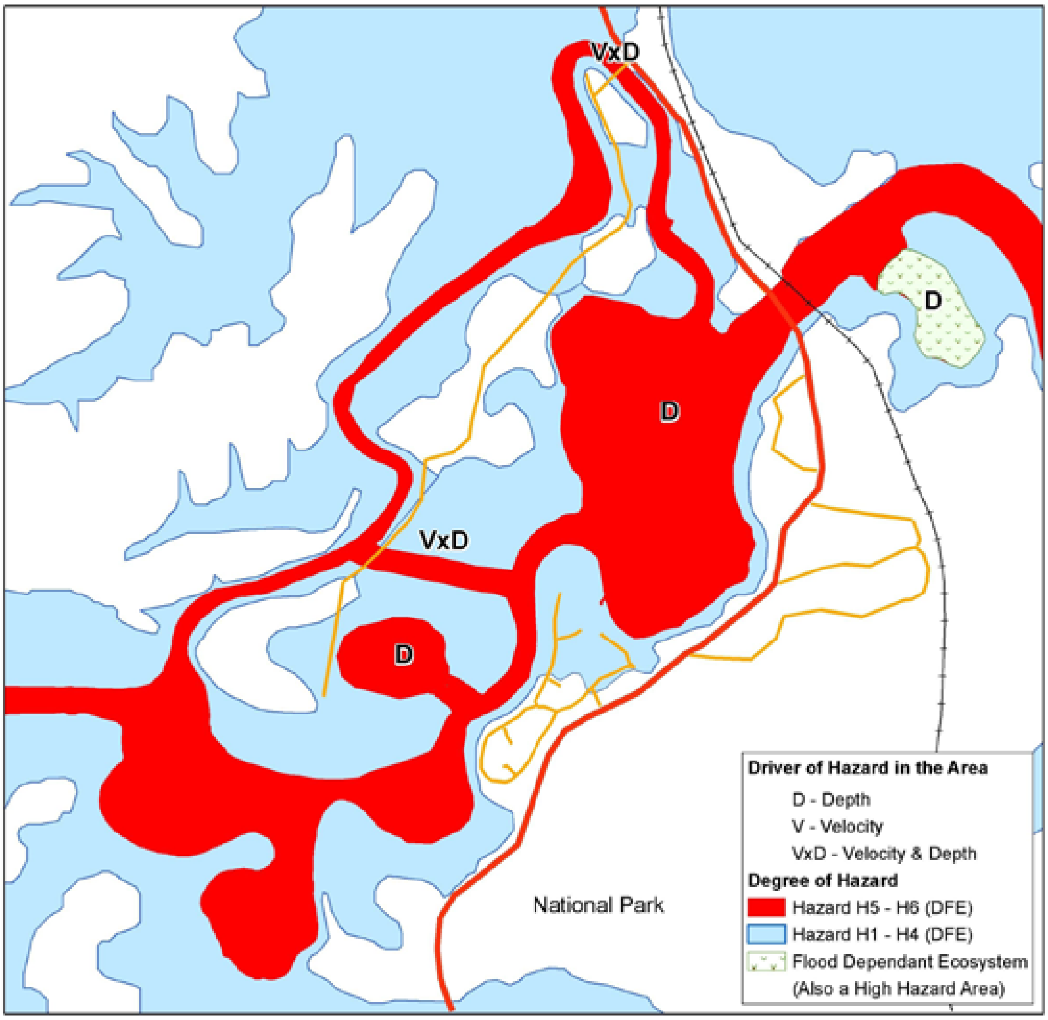
Figure 5.1: Breakdown of the floodplain into flood functions

5.3 Flood hazard

Flood hazard varies with flood severity (i.e. for the same location, the rarer the flood the more severe the hazard) and location within the floodplain for the same flood event. This varies with both flood behaviour (velocity and depth, rate of rise of floodwater and the timeframe from rainfall to flooding) and the interaction of the flood with the topography. It is important to understand the varying degree of hazard and the drivers for the hazard (Figure 5.2), as these may require different management approaches. Flood hazard can inform emergency and flood risk management for existing communities, and strategic and development scale planning for future areas.

5.3.1 Velocity of floodwaters

Relatively high-velocity, low-depth floodwaters can be dangerous, as they can sweep people off their feet, carry cars away and cause damage to light structures. Even flood waters with low velocities can be dangerous with greater water depth. Velocities are generally derived from hydraulic models (Section 11.4). Care needs to be taken when comparing velocities from models that use different grid resolution or treat obstructions differently. Average velocities vary with the model and the grid resolution, and can be increased significantly by obstructions. Localised areas of high velocity may also occur around buildings, bridges, culverts and other structures which may not be shown by models.



DFE = defined flood event

Figure 5.2: Variation in the drivers and degree of flood hazard

5.3.2 Depth of floodwaters

Deep floodwaters can be dangerous because they can destabilise people and cars, and carry them away, resulting in injuries and fatalities. For instance, 1.2 m-deep water with no velocity is sufficient to prevent able-bodied adults from wading. If flow velocity increases or individuals have any physical limitations, they can be destabilised by much lower water depths. Cars can become unstable at very low depths.

5.3.3 Combination of velocity and depth of floodwaters

The effects identified above can be combined to identify significant hazards to people, property, development and infrastructure. Velocity and depth of flow are dependent upon the size of the flood, and the hydraulic characteristics of the waterway and floodplain. The higher the depth or velocity, the greater the danger of people, animals and vehicles being swept away. An uneven ground surface and any depressions, potholes, fences or major stormwater drains can all reduce the safety of wading. These are important considerations in formulating evacuation procedures for developed areas and in considering new development in flood-affected areas. As depth increases, caravans and lightly constructed buildings can float. This can lead to severe damage if they settle unevenly in receding floodwaters or in total destruction if velocity is significant. Debris can cause significant structural damage to buildings and bridges, and block flow paths and structures diverting water away from normal flow paths. This increases flood levels and damage.

Australian Disaster Resilience Guideline 7-3 Flood Hazard provides a method for breaking down the floodplain based upon the varying combinations of velocity and depth considering the associated impacts on people, vehicles and buildings.

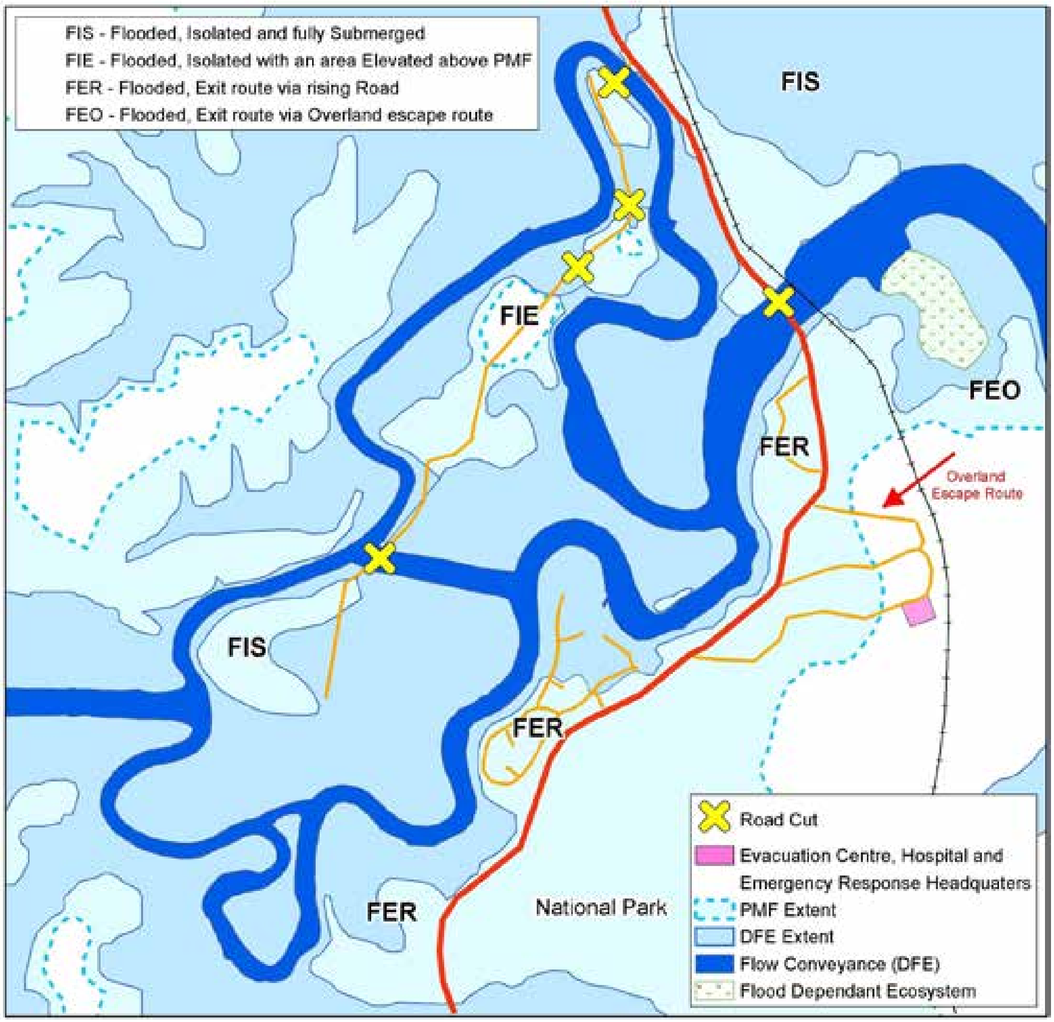


Figure 5.3: Areas with different emergency response classifications

5.3.4 Effective warning time

The consequences of flooding can be reduced if adequate time is available and is used well. The total warning time available is largely determined by catchment characteristics – that is, the larger the catchment and the slower the rate of rise of floodwaters, the longer the time available. For communities in the lower reaches, warnings are often based on rates of rise and peak water levels at upstream gauges, and can vary from hours to days to weeks.

In small, steep catchments and for overland flooding from heavy local rain, there is often no warning time due to the speed of catchment response. Advice may not be available on the expected height of floodwaters.

Effective warning time is the time available for people to undertake appropriate actions, such as lifting or transporting belongings and evacuating. It is less than the total warning time available, because time is needed to mobilise resources, alert the community to the imminent flood threat, and have them begin property protection or evacuation. Effective warning time is influenced by technology (automatic monitoring equipment is generally used to measure water levels and rainfall) and procedures (flood warnings based on rainfall measurements or predictions rather than river levels in quick-response catchments) that can 'buy time for action', but which provide less certainty of the scale of impact of the flood.

5.3.5 Rate of rise of floodwater

A faster rate of rise can potentially result in more danger and damage to the community. It is typically more rapid (0.5 m/hour) in small, steep catchments where floods might peak within hours of rainfall compared to larger, flatter inland rivers (less than 0.1 m/hour), where it could take up to several weeks for flood levels to peak in some locations.

5.4 Emergency response classification

Flooding can isolate parts of the landscape and cut-off evacuation routes to flood-free land or locations where community facilities are available to support evacuated residents in a flood event. This can result in a dangerous situation, because people may see the need to cross floodwaters to access services, employment or family members. Many flood fatalities result from the interaction of people, often in vehicles, with floodwaters. Any situation that increases people's need to cross floodwaters increases the likelihood of an injury or fatality.

Floodplain areas can be classified in regards to isolation and access considerations in a way that informs emergency response management (see *Guideline 7-2 Flood Emergency Response Classification of the Floodplain*). This classification provides the basis for understanding the nature, seriousness and scale of isolation problems. Figure 5.3 shows several different categories. These include flooded isolated and submerged areas (FIS, also known as low flood islands LFIs), the most dangerous isolation scenario.

The area is first isolated from flood-free land and then completely inundated by floodwater as the flood continues to rise. In this situation, people either have to evacuate before the loss of access or be rescued after access is cut, or they may drown.

Another category shown is flooded isolated elevated (FIE or high flood islands, HFI). These are similar to FIS areas, however, a portion of the site remains flood free in a probable maximum flood (PMF) providing flood-free land for people to retreat to if they do not evacuate before the loss of access. However, they may be without services and shelter for an extended period, need assistance with critical supplies, and may need rescue where medical conditions warrant. Other classifications shown include FER, where the area is flooded but there is an exit route by road, and FEO, which is similar but the exit route is overland rather than by road.

5.5 Impacts of a changing climate on flood behaviour

A changing climate is expected to affect both catchment and coastal flooding. Depending upon the location, this may alter the frequency and scale of flooding and its associated impacts due to both sea level rise, and changes to annual, seasonal and flood-producing rainfall events. This might affect catchment flood events in areas across Australia, and coastal flooding in the lower portion of coastal waterways where coast and catchment flooding can interact. Flood investigations provide an opportunity to assess and report on the potential impacts of change on flood behaviour, the risk to the community and the adaptability of management measures to change. Impact assessments should consider relevant government and industry guidance, and the best available, broadly accepted information on the potential scale of changes. The impacts of changes to rainfall and sea level rise should be considered separately, to understand the drivers of change, and in combination, to assess the potential cumulative impacts.

CHAPTER 6

Understanding flood risk

In a nutshell...

Flood risk is a combination of the likelihood of occurrence of a flood event and the consequences of that event when it occurs. It is the human interaction with a flood that results in a flood risk to the community. This risk will vary with the frequency of exposure to this hazard, the severity of the hazard, and the vulnerability of the community and its supporting infrastructure to the hazard. Understanding this interaction can inform decisions on which treatments to use in managing flood risk.

The *International Standard on Risk Management* (ISO 31000:2009) defines risk as the effect of uncertainty on objectives, whereas risk analysis is a systematic approach to understanding the nature of and deducing the level of risk. In November 2011, the Standing Council on Police and Emergency Management agreed to the use of the *NERAG* as outlined in ADR Handbook 10 as the nationally consistent methodology for the future assessment of risk for priority hazards.

In flood risk management terms, risk results from the interaction of the community with flooding through human occupation or use of the floodplain. Flooding affects the health and safety of individuals and communities living in the floodplain. It also affects the built environment and other interests that support them. Exposure to flood hazard varies significantly between and within floodplains, and between flood events of different magnitudes. People, buildings and infrastructure are not all the same, and their vulnerability to flood varies significantly within these individual elements and between element types.

There are generally three types of risk to be managed in flooding. These are:

- **Existing flood risk.** This is the risk associated with current development in the floodplain. Knowing the likelihood and consequences of various scales of floods to the existing community provides the basis for determining existing risk. Understanding this risk can assist with decisions on whether to treat this risk and, if so, how.
- **Future flood risk.** This is the risk associated with future development of the floodplain. Knowing the likelihood and consequences of flooding can inform decisions on where not to develop (where new development may affect flood behaviour, where this may impact upon risks to existing development, or where hazards are high and cannot be managed), and where and how to develop the floodplain (to ensure risk to new development and its occupants are acceptable). This information can feed into strategic land-use planning.
- **Residual flood risk.** This is the risk remaining, in both existing and future development areas, after management measures such as works, land-use planning and development controls are implemented. Unless the probable maximum flood is used as the basis for development controls or works (and works do not fail), a flood risk will still remain. Residual risk can vary significantly within and between floodplains. Emergency management and recovery planning, supported by systems and infrastructure, can assist to reduce residual risk.

Risk analysis involves developing an understanding of the nature, driver for, and level of risk to rank the relative seriousness of risks. Risk analysis can then be used to inform decisions on both the acceptability of residual risk, and the effective and efficient use of scarce resources to better understand and treat risk. Therefore, risk analysis involves understanding the likelihood of events (Section 5.1), generally measured in terms of annual exceedance probability, and the severity of their consequences.

Table 6.1: Example qualitative risk matrix

Likelihod of consequence	AEP range (%)	Level of consequence				
		Insignificant	Minor	Moderate	Major	Catastrophic
Likely	>10	Low	Medium	High	Extreme	Extreme
Unlikely	1 to 10	Low	Low	Medium	High	Extreme
Rare to very rare	0.01 to 1	Very low	Low	Medium	High	High
Extremely rare	<0.01	Very low	Very low	Low	Low	High

Risk: Very low Low Medium High Extreme

AEP = annual exceedance probability

Flooding has consequences to the community, and to the built and natural environments (Sections 6.1–6.3). Consequences vary with location in the floodplain and depend upon the element (community or built environment) under consideration. Likelihood and consequences can be combined to assign a relative risk rating for an event through development of a risk matrix or other tool. This should involve an assessment of the confidence of likelihood and consequence, which considers factors such as the divergence of opinion, level of expertise, uncertainty, quality, quantity and relevance of data and information, and limitations on modelling. Table 6.1 provides an example risk matrix. Section 6.4 provides some advice on assessing consequences. Chapter 7 discusses the need for treatment of risk and prioritisation of efforts across a floodplain and a floodplain management entity service area.

6.1 Consequences to the community

The flood-affected community can be regarded as those people who reside, work on or traverse the floodplain.

The social implications of flooding on people's lives are many and varied, and cannot all be readily quantified. These include fatalities, health influences, disruption and financial implications. Community vulnerability can change with the population at risk, community composition, and the logistics of flood warning and emergency response.

The larger the population at risk, the greater the number of people that need to be warned and, if possible, self-evacuate. Vulnerability increases if people need additional support to evacuate. This can include those in hospitals, nursing homes, corrective facilities, people with mobility limitations, older people, and children in schools and child care facilities. Vulnerability also increases as emergency-response logistics become more difficult – that is, less warning time and time to evacuate, less resources to assist and more limitations on evacuation routes.

6.1.1 Fatalities and health issues

The most serious consequence of flooding is the risk of fatality to individuals who may interact with hazardous flood situations.

Humans are particularly vulnerable to drowning in floods. Other causes of fatalities include flood-induced stress (potentially leading to cardiac failure), electrocution and problems resulting from a lack of essential medicines. In recent years, a high proportion of flood-related deaths in Australia have occurred on flooded roads. Fatalities also result from people being swept away while crossing rivers, stormwater channels, overland flow paths or other flooded areas. While evacuation can reduce the risk to life, the evacuation of elderly people can lead to an increase in mortality rate. Although the number of flood-related fatalities is declining in general, the continuation of this trend relies upon continued improvements in flood risk and emergency management practices, strategic land-use planning practice and community education.

Floods can result in hospital admission spikes. The June 2007 storm on the New South Wales Central Coast resulted in 10 fatalities and evacuation of more than 6000 residents. It also resulted in 180 emergency department presentations for hypothermia, fractures, lacerations, dyspnoea (breathlessness), and joint and limb pain, with one in five resulting in admission. The event also had public health implications, through effects on wastewater disposal systems, drinking water supplies and food outlets (Cretikos et al. 2007). Flood-related health concerns such as mosquito-borne illnesses, and exposure to moulds, toxins and contaminants, may be felt for some time after an event. Many flood-affected residents also attribute a variety of physical and psychological health problems to flooding. Survey responses (Handmer & Smith 1983) indicate that these include a worsening of existing pre-existing health problems, emotional and psychological problems that continue well after floodwaters recede, and anxiety leading to stress. Any sudden onset of flooding and the absence of warning can exacerbate the situation.

6.1.2 Community disruption

Flooding can last for minutes to months and cause significant disruption to communities and households. The degree of disruption depends upon the size of the flood, its impacts on community services and infrastructure, and the time needed to restore services.

Direct impacts depend upon whether the community or individual households are isolated and inundated. Flooded homes might be unfit to live in for lengthy periods and, in the worst cases, need demolition. Either case requires temporary accommodation, which can be in short supply and at inflated prices due to post-event demand. People might have to temporarily relocate some distance from home, education and workplace, even though financial commitments to the home continue. Clean-up, drying-out, and restoration and replacement can take weeks or months. Surveys indicate that the average disruption to normal life in a house flooded above floor level is two to three months. It can, in some cases, take years, and it is not uncommon for flood-affected residents to feel that they will never get their lives back to normal.

Indirect impacts on the community might include loss of services, even when areas may not be flooded. Water, sewerage, electricity and communications infrastructure, if inundated, may be out of service for extended periods. Community and business services may be flooded or isolated from the community or suppliers, and may not be able to operate.

6.1.3 Financial impacts

Financial losses from properties and building damage affect the financial health of households. A family home is usually the largest purchase in a person's life. For the majority of families, it is both their principal asset and is associated with their largest debt. It is also likely to contain the majority of their possessions. The size and effect of financial impacts depend on the severity of flooding, the susceptibility of the house and contents, current and projected future income, financial assets and debt, and capacity to recoup the losses sustained. For a single storey dwelling, 1.5 m of water on the floor would result in the loss of most personal possessions, contents and fittings, and structural damage to the house, particularly if the flow velocity was high. The short-term consequences of flooding are generally catered for in emergency response and recovery plans, and through assistance provided to individuals and families through natural disaster relief arrangements. Long-term recovery relies upon the ability of households to recover financially. This depends upon available finance and insurance, and continued employment or income generation.

6.2 Consequences to the built environment

Consequences to the built environment are related to impacts on individual properties and on community infrastructure.

6.2.1 Buildings

Contemporary houses are not generally designed to be flooded above floor level. Their exposure to flooding is generally managed by setting minimum floor levels to limit the frequency of flooding, but does not remove the risk from larger floods. Flooding can result in significant damage to the contents, fabric and structure of buildings – and, in severe cases – loss of the structure itself. The scale of impact is influenced by the depth of flooding above the ground and floor level, the velocity of flow, and the design of the house. For example, contemporary houses are predominantly constructed from either brick veneer or double brick. Both rely on an internal load-bearing wall constructed of either a timber, light-gauge steel frame or another brick wall to support the roof structure. Brick walls may fail due to brickwork cracking, wall(s) bowing, external brick wall(s) collapsing, and the frame snapping or bending due to the following forces exerted on buildings:

- hydrostatic forces associated with pressures of still water, which increase with depth
- hydrodynamic forces associated with the energy of moving water
- impact forces associated with floating debris moved by water.

Wave action produced by wind, boats or motor vehicles can add to loadings.

6.2.2 Infrastructure

Floods can result in damage, disruption and loss of infrastructure, which can delay community recovery. These impacts can include:

- interference to community infrastructure, such as power, sewerage, water and communication, due to damage to the supply source, treatment facilities or distribution infrastructure
- damage to roads and other transport infrastructure, such as rail lines and airports
- damage to flood mitigation infrastructure, including levees, spillways and associated structures; failure of these structures may exacerbate flood impacts
- damage to dams, which can significantly increase the negative consequences of floods; therefore, the management and monitoring of dams by owners considers flood impacts and the consequences of dam failure
- damage to, or loss of, waterway infrastructure, such as bridges.

6.3 Consequences to the natural environment

Floods can have significant environmental impacts. They can erode waterways, and cause conditions that lead to fish deaths through oxygen depletion or a temporary build-up of naturally found toxins. Significant environmental impacts may also result from the flooding of industrial and mine sites, particularly those using or producing hazardous materials. Floods can be beneficial to the environment by providing water to flood-dependent ecosystems, depositing fertile silt on farmland and increasing soil moisture content.

The study of the consequences of floods on the natural environment is an important and specialist area not covered by this handbook.

Impacts of flooding on the natural environment can be an important element in the development of a floodplain management plan for a rural area or it may be more effectively considered as part of integrated catchment management which is considered in the development of a management plan.

6.4 Assessing the scale of consequences

Flood risk assessment should make use of the data and tools available. Hydrologic, hydraulic and vulnerability models are important to understanding the range and complexity of potential flood behaviour and impacts. The value of understanding historic flooding, and calibrating and verifying models considering historic floods, cannot be underestimated.

The severity of consequences of flooding on the community can be assessed based upon the frequency and scale of tangible and intangible impacts. Tangible impacts are financial in nature and can be readily measured in monetary terms. They include the direct damage caused by goods and possessions getting wet, and indirect damages, such as the loss of wages and extra outlays incurred during clean-up operations and in the post- flood recovery period.

Intangible damages include fatalities, the increased levels of emotional stress, and mental and physical illness caused by flood episodes. A flood is a traumatic experience for many victims, leading some to suffer nightmares, for example, for considerable periods. There is the sense of personal loss and despondency caused by the destruction of memorabilia (photographs and precious items) and official documents, or the loss of pets. There is also the stress caused by additional financial outlays to replace flood- damaged possessions. Stress may also be caused by families functioning differently – separating family members, living in temporary accommodation or children attending different schools. Intangible damages cannot be quantified in financial terms.

Nevertheless, they are real and represent a significant cost to a flood-affected community or individual, and can be long lasting. Most studies acknowledge intangible damages, but do not attempt to quantify them. However, it may be possible to approximate intangible damages by, for example, estimating how many flood-affected people may require additional medical treatment for depression, the ecological cost of the loss of a local environmental feature, or the additional assistance required by the community to recover.

The assessment of damages can help focus risk management efforts by providing important information on the severity and location of impacts. Any reduction in impacts resulting from the implementation of treatment measures provides advice on their relative cost-efficiency through cost–benefit analyses.

CHAPTER 7

Treating flood risk

In a nutshell...

Treating risk involves developing an effective management plan. This relies upon a detailed understanding of the local flood situation and its impacts on the community, and an understanding of the treatment options available and their limitations. There is no single treatment or set of treatments to manage the full range of flood risk that are valid for all communities. In addition, flood risk does not necessarily remain constant. Unless effectively managed, flood risk can change significantly with alterations to catchment and floodplain development, the geomorphology and topography of the floodplain, catchment and floodplain vegetation, and infrastructure on the floodplain. Risk can also vary with a changing climate. Growth of risk can be managed by limiting risk to new development.

Reducing risk to existing development needs to consider the efficient and effective use of scarce resources. Residual risks need to be understood, and managed or accepted.

Risk treatment generally draws on one or more of the strategies of risk prevention or avoidance (limiting or negating exposure to the hazard), risk reduction (by mitigating the consequences of the hazard) and/or risk acceptance (accepting the risk that exists). Occupation of floodplains and management of the associated risks is, in many respects, a balancing act. It involves acknowledging that living on the floodplain comes with an inherent risk and understanding what adverse impacts the community is prepared to accept in return for the benefits of living on the floodplain. Knowing the consequences of the full range of flooding can inform decision making on risk reduction to the existing community to more tolerable levels and limit the growth of risk resulting from new development.

Although there is a common vision for managing flood risk, there is no single blueprint that can be applied in all flood environments. The most effective means of achieving sound management outcomes is to formulate and implement risk-based management plans through the floodplain-specific management process (Section 3.6) or an equivalent process for a study area, generally at the catchment or floodplain scale. This encourages a balanced consideration of social, economic and environmental issues, and consultation to make informed decisions. Balanced management plans need to address risk to existing and future development, and remaining residual risk in a comprehensive manner that considers all factors affecting floodplain use.

A plan should outline the recommended approach to managing flood risk to future development including residual risk (Chapter 8) and existing development including residual risk (Chapter 9). Existing risk is often managed by treatment measures that aim to reduce risk. Growth in future risk is principally limited through land-use planning in consideration of flood risk. Residual risk is limited by managing existing and future risk. It may be further reduced through effective community response to a flood threat, facilitated by evacuation infrastructure, flood warning, emergency management planning, community education and through assistance with community recovery.

The objectives of treating risk are discussed in Section 7.1. The remainder of the chapter discusses where risk treatment may be warranted (Section 7.2), the selection and prioritisation of options (Sections 7.3 and 7.4), and managing risk to community infrastructure and utility services (Section 7.5).

7.1 Objectives of treating flood risk

Treatment of flood risk needs to consider two key objectives of best practice – managing flood risk and maintaining the flood function of the floodplain.

7.1.1 Managing flood risk

Managing flood risk is important to improve community resilience to flooding and limiting flood risk growth (from increased floodplain development, and changes to climate and floodplain topography). Achieving effective management involves encouraging or promoting the:

- management of existing, future and residual flood risk for local communities using the range of treatments available
- engagement with, and active participation of, the local community in managing the flood threat they face
- inclusion of flood risk management outcomes in policies, planning instruments and forward plans
- strategic planning and use of floodplains as valuable and sustainable resources capable of multiple uses of benefit to the community. These uses should be compatible with the flood function and flood hazard, and aim to limit the impacts of flooding on damage to property and infrastructure, and the wellbeing, health and safety of the future floodplain community. Strategic planning should consider long-term climate, cumulative land-use and demographic changes that are expected to influence risk
- identification, assessment and implementation of feasible, practical and effective options to treat intolerable risks to the existing community, considering their social, environmental and economic benefits and costs, and their sustainability
- cross-catchment prioritisation of treatment efforts by floodplain management entities to ensure efficient and effective allocation of scarce resources to treat flood risk
- sustainable emergency management practices that consider long-term climate variation, and cumulative land-use and demographic changes
- management of flood risk to infrastructure and the design of new infrastructure to limit its impacts on flood behaviour; key infrastructure for emergency response and recovery needs to be fit-for-purpose when required
- continued aid to the community in recovering from the impacts of floods.

7.1.2 Maintaining the flood function of the floodplain

Maintaining the flood function of the floodplain is essential to ensure that the floodplain can perform its natural functions of flow conveyance and storage. Understanding (Chapter 5) and maintaining these natural functions (Section 8.1) are essential to effective management. Maintaining flood function involves encouraging:

- maintenance or improvement of the capability of the floodplain to perform its natural function of conveying and storing floodwater
- land uses that are compatible with the flood function of the specific area of the floodplain
- maintenance of the capability of the floodplain to supporting floodplain ecosystems dependent on inundation
- floodplain and catchment management practices that are ecologically sustainable.

7.2 Does risk warrant treatment?

ISO 31000:2009 states that risk evaluation is a process of comparing the results of risk analysis with risk criteria to determine whether the risk and its magnitude are acceptable or tolerable. Decision makers often use the risk evaluation process to determine if further analysis is required to:

- improve confidence in estimates or understanding of risk
- decide if risks are either broadly acceptable or intolerable
- decide if action is needed to treat the risk.

The need to treat risk will depend upon whether the current level of residual risk is acceptable to the community. What level of risk is acceptable will depend upon who is asked, what their experience of floods has been and when they are asked. Accordingly, governments may make decisions in the 'public interest', yet remain mindful of the general need for a consistent standard. They may come to a decision in consultation with the community and in consideration of what may be considered reasonable general practice. In the flood context, this advice is often linked to flooding likelihood being a statistical probability. The selection of this standard is discussed in Section 7.2.1.

	Coastal lake	Inland river	Coastal river
Flooded when flood exceeds 1% event	2000 buildings	800 buildings	1000 buildings
Length of evacuation route	2km	160km	200m
Typical catchment response to rainfall	Hours to days	Days to weeks	Hours to days
Typical flood duration	Days	Days to months	Days

Note:
Houses conceptually shown at the 1% AEP level to indicate comparative flood levels which are to scale relative to houses.

AEP = annual exceeance probability; PMF = probable maximum flood

Figure 7.1 Variation in the range of flood risk

When examining treatment options to reduce risk to existing development, it is not always practical, feasible or cost-effective to meet a general standard for protection applicable to new development. Lower standards of protection may provide significant reductions in the existing exposure of communities to frequent flood risk, and present a more feasible, practical and cost-effective solution. Treatment priorities should consider the current residual risk, and the relative benefits and costs of treatments of differing standards. This is discussed further in Section 9.4.

7.2.1 Setting general local standards

The selection of a general local standard, often based upon a single or several defined flood events (DFEs), is traditionally concerned with limiting growth in risks by limiting the frequency of exposure of new development and its inhabitants to hazardous flood situations. This is a risk management decision that involves balancing the flood risk and the costs of living with this risk alongside the benefits of occupying the floodplain in consideration of a reasonable level of service to the community. It is the community, not the land developer, who takes on this long-term risk, and the members of the community who may have their lives and their homes at risk. This decision is generally reflected in the selection of a DFE as the basis for general property protection.

Selection of a DFE should consider the full range of flood events, and take into account standards and guidance from government and industry. It can reflect what government and the local community may accept as a general standard that allows for a reasonable compromise between living on the floodplain and accepting the consequences of this choice. In Australia, the 1 % AEP flood (plus a freeboard, see Section 7.2.2) is often used in government guidelines and policy instruments to define the standard up to which general development controls are applied to new standard residential development to limit growth in risk. A residual risk remains from floods larger than 1 % annual exceedance probability events as outlined in Table 5.1. Suffering the economic impact of rarer events may have been seen as tolerable by default. However, residual risk varies, because the range of floods (see Figure 7.1) and the consequences of the same magnitude of flood can vary greatly between locations.

Therefore, there can be locations where adopting the general standard for development controls may result in a residual risk that is intolerable to the community. In these circumstances, additional localised development constraints may be warranted to reduce residual risk further. In addition, certain community groups and the types of development they inhabit may be more vulnerable to flooding and may need additional constraints. For example, aged care homes and hospitals can be difficult to evacuate and, therefore, may best be located where emergency response is relatively straightforward. Also, the likelihood of needing to react to a flood may also be reduced by using increased protection levels. This can lead to areas with development controls based upon their location (see Figure 8.1).

The decision on an acceptable level of flood risk for general standards also depends upon the element at risk. Governments generally provide additional support or implement additional measures (e.g. flood warning systems, emergency management planning and infrastructure to support emergency management) in excess of general standards to further reduce the threat to community members. Key community infrastructure such as power supplies, communication centres, emergency response headquarters and evacuation centres may also require additional protection to ensure that they are fit for purpose in emergency response and recovery. Once selected DFEs are generally used to derive information to inform management and land-use planning process, which includes:

- identifying areas where flood function (conveyance and storage) are important to facilitate decisions on how to maintain flood function and reduce the potential for significant impacts upon existing flood behaviour
- defining flood planning levels (FPLs) with the addition of an appropriate freeboard (Section 7.2.2) and, hence, the flood planning area, which provides an indication of where the majority of general flood-related development controls will apply.

7.2.2 Freeboard

Freeboard is added to flood levels to provide reasonable certainty of achieving the desired level of service from setting a general standard or DFE. It should be estimated in studies considering the following factors:

- uncertainties in the estimates of flood levels. These can arise from the relatively short record of past floods (and storm surges in coastal waters), together with uncertainties and simplifications in the models used to predict flood flows and flood levels.
- local factors that can result in differences in water levels across the floodplain. These factors can often not be determined in flood modelling, because they are too difficult, complex or expensive to incorporate.
- wave action is not considered in hydraulic models. Models assume flat surfaces and do not replicate the undulations in surface levels occurring in flood events. Waves can result from local factors, wind from meteorological events, movement of boats and vehicles through flooded areas, and coastal processes. In areas with long flood durations, the potential for a separate wind event to the flood event resulting in wind waves is increased. Open coastal waterways with broad, deep entrances can also allow a high degree of coastal wave penetration.
- the cumulative effect of subsequent infill development of existing zoned land.
- where the future climate has the potential to significantly increase risk.

In effect, freeboard acts as a factor of safety. However, it should not be considered as giving additional protection beyond the DFE to which it is applied. A flood planning area is the extent of area below an FPL.

There are many circumstances in which a freeboard of 0.3–0.6 m may be considered acceptable. The lower freeboard is generally only considered acceptable for use in very shallow water where the potential for other effects is limited. A freeboard higher than 0.6 m may be necessary due to particular local circumstances, such as where estimated design flood levels are particularly sensitive to modelling assumptions.

Flood mitigation works – such as levees, and retarding and detention basins (see Chapter 9) – may also require higher freeboards to offset additional uncertainties due to their nature and construction. For example earthen mitigation works also need to consider:

- post-construction settlement, which reduces the long-term level of the embankment
- surface erosion due to vehicles, animals or pedestrians crossing, reducing the level of the embankment
- the potential for significant surface shrinkage, cracking and associated additional risk of failure where good grass cover and appropriate moisture content cannot be maintained
- the additional erosion caused by the overtopping of earthen structures, which can lead to embankment breaches. This can result in fast-rising flooding and difficult evacuation, which is exacerbated when there is no vehicular access to flood-free land.

Table 7.1: Treatment measures for existing development

Development scale	Type of flood risk	Treatment measures
Community or a specific area	Existing	Flood mitigation dams Retarding and detention basins Permanent levees Flow conveyance improvements Flood gates Temporary barriers Change in property zoning
	Residual	Flood prediction and warning Community-scale emergency response plans Evacuation arrangements Evacuation route upgrade Community flood readiness Community recovery plans
Property	Existing	House raising House purchase Relocation of development Flood proofing of buildings Temporary measures
	Residual	Residual risk management options listed above augmented by appropriate property based emergency management plans

Table 7.2: Treatment measures for future development

Development scale	Type of flood risk	Treatment measures
New development and redevelopment areas	Future	Zoning Development controls Building controls
	Residual	Flood prediction and warning Flood access and evacuation routes Emergency response arrangement for new areas Update of community-scale emergency management plans Development-scale flood awareness and readiness
Infill development within existing zoned areas	Future	Development controls Building controls
	Residual	Residual risk management options listed above augmented by appropriate property based emergency management plans

7.3 Selecting treatment options

Tables 7.1 and 7.2 outline a range of treatment options suitable for managing risk to existing and future development respectively. The identification and assessment of treatment options for a specific floodplain is generally undertaken in the management study (Chapter 12). The management plan (Chapter 13) outlines the proposed method of treatment of risk on a prioritised basis across the catchment. The selection of suitable options requires the consideration of community aspirations and what can be done to reduce the flood risk.

Treatments may be developed at the regional, community or individual property level. Suitable treatment measures may include better land-use planning and development controls, improved information to inform emergency management planning, improved flood warning systems, more infrastructure to protect areas from flooding and better communication of flood risk to the community. Treatment options and their cumulative effects, both positive and negative, need to be considered strategically, which involves:

- considering the limitations that flood behaviour, hazard and impacts place on the capability of land to support community growth (Section 8.2)

- accounting for future growth in the numbers of occupants in the floodplain – such growth increases the pressure on response and recovery agencies when flooding occurs and may impact upon community-scale emergency management plans
- assessing decisions on mitigation works and measures, future development and infrastructure, and environmental consequences on a long-term strategic basis
- considering costs on a life-cycle basis. All treatment options come with up-front, ongoing (operation and maintenance) and complementary costs, and may depend upon other measures (see Tables 8.1, 9.1 and 9.2)
- considering interactions and interdependence with other options
- considering the effects of a changing climate on flood behaviour, flood hazards and the associated impacts upon the community.

Tables 7.1 and 7.2 outline treatment measures for different types of flood risk.

It is important to consider how effective each option is for managing risk and how important that issue is for the specific community when assessing options. Table 7.3 provides a summary of the general benefits of a range of different types of options in managing flood risk. Some may have localised benefits, while others may have broader community benefit. Assessment should consider:

- the full range of flood events
- the limitations, and social, economic and environmental benefits and costs of options
- existing development and infrastructure
- future development needs and opportunities that cater for a growing community and how this may influence flood behaviour
- any impacts on emergency management infrastructure – for example, existing or proposed flood warning systems, evacuation routes and response strategies
- any impacts of the option on flood risk elsewhere in the floodplain.

7.4 Prioritising treatment options across a floodplain management entity service area

Floodplain management plans provide a way to prioritise treatment options across a study area. A floodplain management entity (FME) service area will generally contain a number of floodplains and therefore may have a number of plans. Plans generally involve a range of measures, such as updating strategic planning instruments that are complementary across plans and generally require limited resources. These types of measures should be implemented without prioritisation across the FME service area.

There are other management measures, such as works projects, that require significant investment. It is recommended that all projects requiring significant financial and resource investment identified in management plans be compared to develop an overall priority list that considers benefits, costs and feasibility. This provides a basis for prioritisation considering the most effective and efficient use of the available resources across the entire FME service area.

7.5 Managing the flood risk to, and resulting from, infrastructure

A community's ability to respond to and recover from the impacts of flooding relies upon the availability of community infrastructure such as emergency response hospitals, emergency management headquarters, evacuation routes and centres, and communications infrastructure. The location and level of protection provided to this infrastructure needs to allow it to perform its function during and after a flood event, where practical. Utility services essential to recovery from a flood and in response to long-duration floods include water supply and reticulation, sewerage reticulation and sewage treatment, electricity and communications, and road and rail networks.

Infrastructure providers need to consider design standards that enable continuity of use or ready re-establishment of services after a flood, as appropriate. These standards may involve reducing the likelihood of infrastructure flooding or the vulnerability of the infrastructure to the impacts of flooding when it occurs, and using readily available components to re-establish services easily after a flood.

Design standards should also consider the potential impacts of new, upgraded or refurbished infrastructure in the floodplain on flood risk to the community. Elements such as roads and railway lines that cross the floodplain or otherwise interact with flooding can alter flood behaviour with adverse consequences to the community. Their design should also consider their role in response and recovery to ensure they are fit for purpose for this role.

Table 7.3: Typical ability of management options to address flood risks

Option type	Existing developed areas			Future development areas		
	Existing risk		Residual risk	Future risk		Residual risk
	Safety	Damage	Safety	Safety	Damage	Safety
Measures to modify property						
Zoning and development control				High	High	Low[a]
Voluntary purchase	High	High	High			
Voluntary house raising	Low	Medium	Negative[c]			
Flood proofing of buildings	Low	Low				
Access during flood events	High	Low[e]	High	High	Low[e]	High
Measures to modify response						
Community flood awareness & readiness[b,d]	Low[b]	Low[b]	Low[b]	Low[b]	Lowb	Low[b]
Flood predictions and warnings[b]	Medium[b]	Low[b]	Medium[b]	Medium[b]	Low[b]	Medium[b]
Emergency response planning for floods[b]	Medium[b]	Low[e]	High[b]	Medium[b]	Low[e]	High[b]
Measures to modify flood behaviour						
Levees	High	High	Negative[c]	High	High	Negative[c]
Detention/retarding basins	Medium	Medium	Negative[c]	Medium	Medium	Negative[c]
Flood mitigation dams	Medium	Medium		Medium	Medium	
Bypass flow conveyance	Medium	Medium		Medium	Medium	
Channel improvements	Medium	Medium		Medium	Medium	
Enhance environment						

a. Depends on consideration of emergency management issues and vulnerable development in land-use planning activities.

b. These options all rely on each other to be effective.

c. Measures such as house raising and levees reduce risk to property but are known to have an adverse impact on perceived risk to life because people incorrectly assume that property protection measures have eliminated flood risk.

d. There is little qualitative evidence showing community awareness and education campaigns are effective to reliably and perpetually reduce risk.

e. Have no impact on structural damage. However, in some cases, where response times and conditions allow may permit some reduction in contents damage.

Notes: Existing risk: events up to the design flood for mitigation works or the main defined flood event (DFE) for land-use planning

Residual risk: events rarer than the design flood for mitigation works or the main DFE for land-use planning. Future risk: events up to the design flood for mitigation works or the main DFE for land-use planning.

The ratings in this table are a guide only as the effectiveness will vary dependent upon the individual situation and should be assessed accordingly.

Blank squares may be not applicable or options have nil affect. High/medium/low relate to positive effects.

Negative relates to potential adverse impacts.

CHAPTER 8

Treating flood risk to future development

In a nutshell…

There are areas of the floodplain that may be either too hazardous to develop or where development may have a significant impact on existing flood function that can result in adverse impacts on the existing community or environment. Managing flood risk to new development is essential to limiting the growth of flood risk. This can be achieved most effectively by strategic and development-scale land-use planning cognisant of the need to maintain flood function, consider flood hazard and develop sustainable emergency response arrangements. Best practice encourages the setting of 'flood risk' informed strategic land-use planning directions, and supporting zonings and development and building controls that:

- limit the impacts of new development and the intensification of development on the flood risk of the existing community
- limit the exposure of the new community to flood hazard
- limit damage to new property and infrastructure to acceptable levels
- consider public safety and the associated needs of emergency response management.

Managing the growth in risk resulting from urban expansion and consolidation within floodplains provides the opportunity to manage this risk **from the outset** by reducing risk to an acceptable level. This may involve:

- limiting the impacts of new development and intensification of development on the flood risk to the existing community and its emergency response capability through zonings
- limiting development to be compatible with flood function and hazard (including hazard resulting from 'islands' of land isolated from flood-free land) through zonings
- limiting where different types of development can occur, through zonings, to encourage developments that locate people who are more vulnerable in less-exposed areas
- having appropriate development controls in place to support zonings to limit the vulnerability of development to flooding
- designing infrastructure considering its potential impacts on flood behaviour and making it fit for purpose when needed in response to and recovery from floods.

Land-use planning measures informed by a good understanding of flood behaviour provide the most effective means to address future flood risk. The earlier flood risk is considered in the planning process, the more effectively flood risk can be addressed. For example, considering the full range of flood risk in zonings can encourage development in locations where it is compatible with flood function and flood hazard, and where emergency response arrangements are sustainable.

Table 8.1 outlines some of the key complementary options for treating risk to future property. The following issues need to be considered when managing risk for new or future development:

- flood risk when assessing the development capability of land (Section 8.1)
- flood risk when planning strategically, using zonings, and development and building controls (sections 8.2 and 8.3)
- emergency management arrangements for new development (Table 8.1)
- climate change impacts on flood risk for new development (Section 8.4)
- impacts on community-scale emergency response plans (Section 8.5).

8.1 Understanding development capability of land considering flooding

The floodplain-specific management process (Chapters 10–13) provides information to better understand the full range of flood behaviour (Chapter 5), such as the varying flood function of areas within the floodplain, the variation in flood hazard and its drivers (including isolation) and the impacts of flooding on the existing community. This information can be used to assess land capability for development in relation to flooding and:

- steer development away from areas where it may adversely affect flood behaviour, where the hazard is too high or emergency response is too difficult, or where development may impact adversely on the hazard or emergency response of the existing community
- steer development towards areas where it would have limited impact upon flood behaviour, where the hazard is relatively low and can be managed, and where emergency management can be effectively achieved
- steer development types to areas that consider people's specific vulnerabilities – for instance, developments whose occupants are vulnerable in terms of their independence of action may be directed towards areas where evacuation is more readily achievable.

To assist in informing strategic land-use planning and associated development conditions, it is important to understand the potential impacts of the full range of floods on future development. It is possible to do this by estimating flood damages to, and assessing the emergency response capacity of, new development areas, based upon general development standards. This can help in assessing whether general development standards can reduce residual risk to an acceptable level in these areas or whether additional controls need to be considered. This can then feed into strategic land-use planning considerations (Section 8.2).

Table 8.1: Up-front, ongoing and complementary options to treat future risk

Option	Up-front work	Ongoing work	Complementary work
Zoning	Inform zonings with an understanding of flood function, hazard and emergency response limitation, and vulnerability of different development types to flooding.	Ensure intent of zonings is maintained, and development controls are reducing risk to an acceptable level. Monitor effectiveness and revisit if outcomes unsatisfactory.	Incorporate zonings intent into statutory plans. Reduce residual risk to an acceptable level with complementary development controls. Interact with flood warning and emergency response management, and ensure community awareness.
Emergency response arrangement from new development	Examine evacuation needs of new development, including flood access to site and evacuation capacity from site.	Monitor effectiveness versus expectations to inform future work.	Ensure arrangements are complementary with zonings; may require specific development controls. Interact with flood warning and emergency response management, and ensure community awareness.
Impacts on community-scale emergency response plans	Examine the impacts of development on community emergency response plans and evacuation capacity of relevant roads, etc.	Monitor effectiveness versus expectations to inform future work.	Ensure arrangements are complementary with zonings; may require specific development controls. Interact with flood warning and emergency response management, and ensure community awareness.
Flood access to site	Examine appropriateness of access point to development given flood behaviour and risks.	Monitor maintenance of any special (non-road or not in public ownership) evacuation paths so these are maintained and available as necessary.	Ensure arrangements are complementary with zonings; may require specific development controls. Interact with flood warning and emergency response management, and ensure community awareness.
Development and building controls	Understand purpose and desired outcome in supporting zonings.	Ensure intent of zonings is maintained and development controls are reducing risk to an acceptable level. Monitor effectiveness and adjust if outcomes unsatisfactory.	Ensure arrangements are complementary with zonings. Place development controls into statutory planning instruments and development control plans and/or policies. Interact with flood warning, emergency response management, and ensure community awareness.

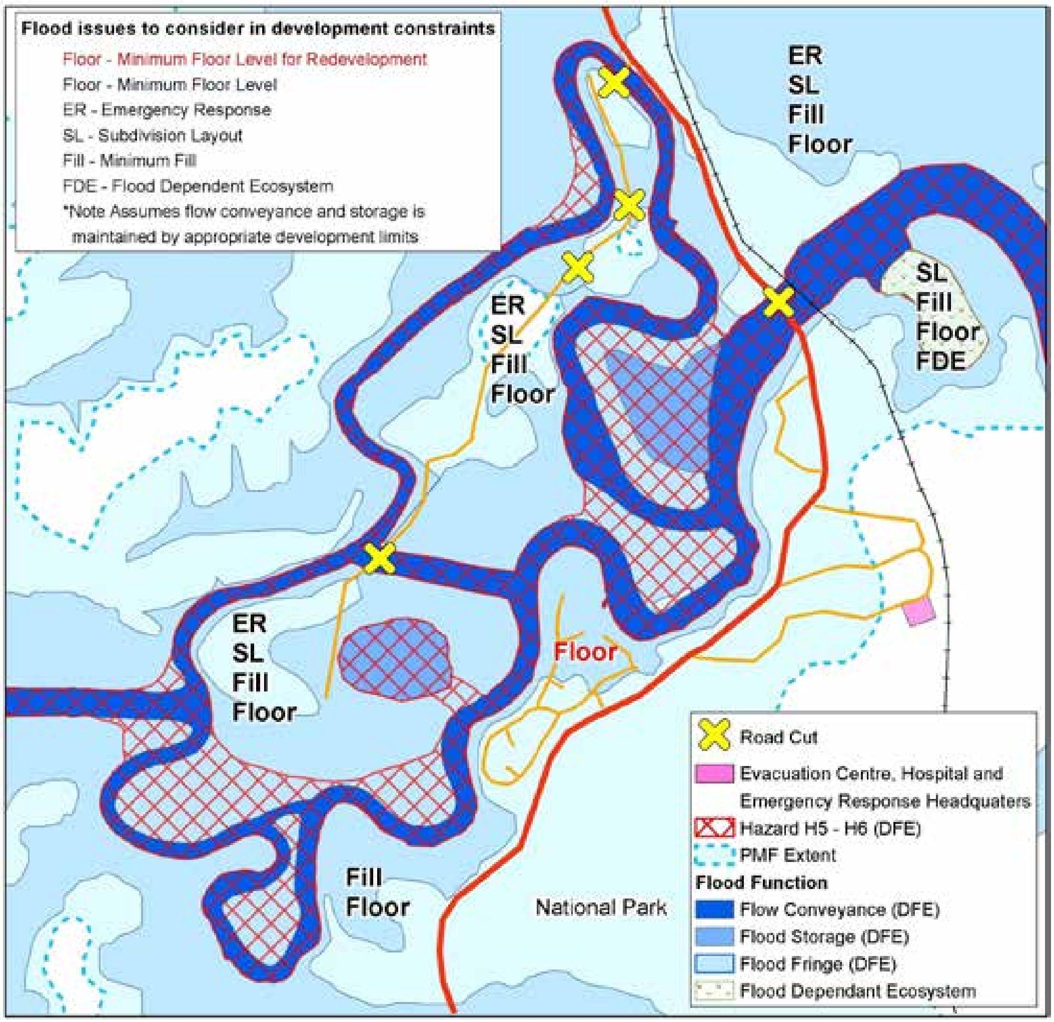


Figure 8.1 provides an overlay of the constraints shown in figures 5.1–5.3 as they differ with relevance depending upon location within the floodplain. These constraints assume that the flood function (conveyance and storage) have been considered in setting limits on intensification of development as changes to these parameters can have a significant impact upon flood behaviour elsewhere in the floodplain.

Figure 8.1: Variation in development considerations within a floodplain

8.2 Considering flood risk in land-use planning activities

Land-use planning activities often involve striking a balance between competing objectives. The management of flood risk is just one of these objectives. However, it is important to understand that it can be impossible, impractical or very expensive to rectify a decision to place development in a location where the flood risk is unacceptable or the development's impact on flood behaviour significant. The initial decision to allow intensification of development, and the type of development to permit in specific locations, needs to be an informed one that considers the implications for emergency management and the risk to the community.

Figure 8.1 provides an example of flood issues that may impact upon strategic land-use planning and how these may vary with location within a floodplain. *Australian Disaster Resilience Guideline 7-5 Flood Information to Support Land-use Planning* (ADR 2017) outlines how information on flood extents for varying scales of floods, varying flood function, varying flood hazard, and varying flood range (including isolation) can all be bought together to develop flood planning constraint categories that can provide information on the varying types and severities of flood issues on land within the floodplain. This guideline also outlines how this information can assist in land-use planning activities.

The early consideration of flood risk in strategic land-use planning can result in zonings that steer development away from areas where intensification of development is not sustainable due to its impacts on flood behaviour or flood risk to the existing community or the degree of residual risk the new community will face. It can also result in zonings and development controls that support sustainable development of the floodplain in consideration of flood risk.

Considering this information in developing strategic planning instruments and associated development control plans provides the opportunity to manage land use and development within floodplains. Although the requirements will vary between States and Territories, collectively, they can address the way land use and development have regard for the flood function within the floodplain, the varying degrees and drivers of flood hazard, and the varying vulnerability of buildings and their occupants.

Zonings can support land uses that can limit the impact of intensification of development on the flooding of other property and limit the impact of flooding on the new development itself. Therefore, it is important that the best available information is considered in limiting risk to new development. Where there is insufficient information to inform decisions then undertaking flood investigations to inform decisions may be warranted. If strategic land-use planning decisions are required before flood investigations are complete, then these should be made in a precautionary way using the best available information in a conservative manner. These decisions may need to be revisited when improved information becomes available.

Zonings can be used to restrict activities within areas of the floodplain needed to perform their natural flood function (see Section 5.2) to uses compatible with this function. This will limit impacts of activities in these areas upon existing flood behaviour.

Zoning can also be used to discourage development incompatible with flood hazard in areas where the flood hazard is too high and cannot be effectively managed. This can limit exposure to excessive hazard or may limit the type of development permissible due to a particular driver for hazard. For example, developments expected to have inhabitants who are more vulnerable in terms of their independence of action (such as aged care homes and hospitals) should be placed in areas where evacuation is not necessary, or can be more readily achieved. Other types of development housing inhabitants who are more agile may be better suited to these locations.

Zonings can also curb the scale of intensification of development by limiting development type or density. This can help control the scale of development in evacuation-constrained areas, unless constraints such as road capacity are increased to allow for further development.

Effective zonings are critical because poor locations of development cannot be overcome by development controls (such as minimum floor levels). Moreover, inappropriately located new development adds to the potential damage, creates later demand for mitigation expenditure and increases the scale and difficulty of the emergency management task.

It is important that zonings are accompanied by development controls to reduce residual risks to acceptable levels. These can be expected to vary between development types and across the floodplain, due to the variation in the drivers for, and degree of, flood hazard present. Some controls are related to a particular flood event – for example, minimum fill levels generally relate to the DFE. However, other controls may relate to a specific area, such as providing adequate infrastructure to facilitate effective emergency management.

8.3 Planning and development controls

The planning and development controls necessary to manage risk will vary depending upon the drivers for, and scale of, flood hazard in a particular area for the full range of flooding and the cumulative impacts of development. They may also be different for infill development and new development areas.

Development controls may be needed to reduce vulnerability even further for a particular development type. For example, emergency response hospitals may be located outside the floodplain or be designed to be protected from rarer floods than the DFE. Caravan and mobile-home parks may be required to have detailed site-evacuation plans, awareness documents and signage.

8.3.1 Impact of development on flood behaviour

Development may alter flood behaviour by diverting or altering flow paths due to changes to topography within the floodplain. Filling, reshaping or placing infrastructure can alter flow paths or result in a loss of flood storage. Land clearing may increase flow off the land, which may have downstream impacts that need to be considered and managed.

Zonings that maintain flood function can manage these changes by setting limits on development not compatible with these functions. Cumulative impacts of changes should be considered and are best addressed in broader or strategic (rather than site-specific or development-scale) studies.

8.3.2 Excavation and compensatory fill

Some development projects will seek to be based upon a balance of fill and compensatory excavation. It should be noted, however, that excavation and filling are not comparable, as excavation is more likely to take place on the lower part of the floodplain, while fill will take place on the higher parts. The net effect will be that any additional storage created through excavation will be lost if the excavated area fills with floodwater before the flood peak arrives. Any fill on the floodplain will have a greater impact when major floods occur. Fill should be excluded from flow conveyance areas because of the effect on flow conveyance. In flood storage areas, there will often be a need to place limits on the location, level and quantity of fill and excavation in consideration of the cumulative effect of potential excavation or filling projects across the whole floodplain.

8.3.3 Minimum fill levels

Filling of the floodplain can have a detrimental impact on flood behaviour, which should be assessed. Limiting filling to areas outside flow conveyance and flood storage areas can limit the potential impacts. It is common practice to set minimum fill levels to reduce the frequency of exposure of developed land and its occupants to a flood threat. Minimum fill levels are generally directly related to development standards, such as the DFE.

8.3.4 Minimum floor levels

It is also common practice to set minimum floor levels, particularly for habitable rooms in residential buildings and other structures. Setting minimum floor levels can reduce the frequency and extent of flood damage. These are generally derived from development standards, such as the FPL. A different FPL may be used for residential and commercial development, and a higher FPL adopted to reduce the risk exposure of more vulnerable or emergency response development (e.g. hospitals).

8.3.5 Fencing

Fences, whether solid or open, can affect flood behaviour by altering flow paths. The impact will depend upon the type of fence and its location relative to the flow path. Where a significant impact is expected in an area, controls should be considered in relation to type of fencing permitted, or to limit its location or height. In general, solid fencing, especially to ground level, should not be erected across flow paths where it might act as a dam. Open fencing is preferable.

8.3.6 Structural requirements for building

Flow velocities, flow depths and associated debris loads can affect the structural soundness of buildings in a number of ways. Structural soundness of buildings can be tested by the resultant impacts, including buoyancy. Certification of the soundness of structures (including use of appropriate materials able to maintain their structural soundness once inundated) for the local hydraulic conditions should be considered in flood-affected areas.

8.3.7 Provision of essential services

Services might be disrupted at key infrastructure plants (water treatment, sewerage treatment, power generation and communication exchanges) or along distribution networks. To reduce interruption caused by floodwaters, service location or vulnerability to flooding should be limited. Service providers should also consider emergency response and recovery planning for floods for key assets.

8.3.8 Using building controls

Building controls are not stand-alone solutions to mitigating flood risk. They need to be used in conjunction with strategic land-use planning, flood mitigation measures and emergency management planning. Building controls are important to reduce damage to buildings and their contents, and to ensure the building does not collapse in events up to the structure's design flood event. The standard *Construction of Buildings in Flood Hazard Areas* (ABCB 2012a) and associated handbook released by the Building Code of Australia provide guidance (ABCB 2012b). State and Territory, and local government requirements also need to be considered.

8.4 Climate change

Managing the potential impacts of climate change on flood behaviour needs to consider the policy advice and guidance material relevant to the State or Territory. Building the resilience of the community to the impacts of climate change should consider adaptive decision making. The options relevant will vary depending upon the location and its vulnerability to climate change impacts. Some examples of adaptive solutions include:

- strategic land-use planning that builds consideration of climate change into decisions to rezone land to allow for more intense development
- land-use strategies that may encourage consolidated urban development on less-vulnerable land with surrounding more-vulnerable land used for communal purposes
- designs that are adaptable – for example, levees or houses that are designed to be able to be readily raised in the future if necessary
- designs that consider the proposed life of structures, particularly those meant to be short term (note that design life and the actual working life of the structure may bear little resemblance).

8.5 Management measures to reduce residual risk to new development

New developments also need to consider managing residual flood risks. Whether infill within existing areas or in new development areas, new development may affect existing emergency management arrangements, such as flood warning systems, evacuation routes and arrangements, and community-scale emergency management planning. Any adverse consequences need to be considered and managed – ideally through strategic planning (Section 8.2) – so the broader community is not affected by intensification of development. If this is not possible, then it should be considered when developing the area – it may influence the scale of development, or the external and internal infrastructure needed to support development.

Master planning of new development areas can also inadvertently add to the flood risk of occupants if emergency management is not considered effectively. For example, if the only access to an area is cut-off before the area is flooded, evacuation problems can be exacerbated. Suitable access to facilitate emergency management is recommended.

An important consideration is the ability to assess the cumulative impacts of changes in development on flood behaviour and its impacts. Cumulative impact assessment enables more informed understanding on the broad effects of changing development patterns.

Section 9.3 discusses treating residual risk at a community scale.

CHAPTER 9

Treating flood risk to existing development

In a nutshell…

Strategic management of flood risk to the existing community requires an understanding of the flood risk they face and a prioritised plan for reducing intolerable risks where practical and feasible, and in light of resource issues. Generally, consequences of flooding to existing buildings and infrastructure cannot be reduced in the short term through land-use planning and development controls. Strategic management of flood risk requires intervention through management and mitigation measures as discussed in this chapter. Options to reduce risk to the existing community aim to reduce vulnerability or exposure of the community to flood impacts, or improve the community's resilience to respond to floods.

Mitigating flood risk to existing development involves lowering flood impacts retrospectively by reducing the frequency and/or the consequences of flooding by:

- modifying flood behaviour
- improving flood warning and emergency response
- altering the community's behaviour during floods (e.g. changing attitudes to entering or driving through flood waters) or their response to floods
- reducing the effects of flooding on vulnerable sectors of the community
- reducing the vulnerability of the built environment to flooding.

An effective risk reduction strategy for existing development encompasses a suite of often interdependent measures to deal with existing and residual risk (Tables 9.1 and 9.2). These may be developed at a community-wide or regional scale (Section 9.1), or on an individual property basis (Section 9.2). The management of the resulting residual risk is discussed in Section 9.3; the assessment of mitigation options is discussed in Section 9.4. Sections 7.3 and 7.4 are also relevant to reducing existing risk.

Treating risk to existing development is constrained by current circumstances, which limit the risk reduction that can be practically achieved through mitigation. Although implementation of mitigation measures might present challenges, decision making is generally based upon an assessment that considers the economic, social and environmental benefits and costs. The assessment generally involves calculating the potential damage reduction and comparing it against the cost of the required works. If considered worthwhile economically or socially, the works are then put forward for consideration. Social benefits from works may include reducing the exposure of people to the flood threat, and enabling the community to function and support surrounding rural areas during an event, particularly in areas affected by long-duration flood events lasting weeks to months.

Treating risk to existing properties cannot generally be achieved in the short term through land-use planning and development controls, unless supported by a legislative and policy framework and a coordinated and funded relocation program. Large scale changes to existing settlement patterns or the built form through relocation or other land use changes requires careful consideration and analysis of the social, economic and environmental consequences of taking such action. Broad agreement of the affected and wider community is critical for such actions to be successful.

Table 9.1: Different management options for existing risk and associated works

Option	Up-front work	Ongoing work	Complementary work
Permanent levees and associated works	Analyse impacts, investigate, design and construct. Develop operation and maintenance manuals.	Perform maintenance and operate, and monitor during floods. Regularly monitor condition and rectify issues. Regularly trial and test operational procedures.	Manage the drainage and local flooding behind the levee (e.g. upgrade, flood gates, detention and/or pumping) and have development controls in place. Interact with flood warning and emergency response management, and planning and community awareness.
Temporary barriers	Analyse impacts, investigate, design and construct. Develop operation and maintenance manuals.	Perform maintenance and operate, and monitor during floods. Regularly monitor condition and rectify issues. Regularly trial and test operational procedures.	Manage the drainage from behind the structure and associated local flooding. Consider access across the structure for evacuation/rescue. Interact with flood warning and emergency response management, and planning and community awareness.
Flood gates	Investigate, design and construct. Develop operation and maintenance manuals.	Perform maintenance and operation, and monitoring during flood. Regularly monitor condition and rectify issues. Regularly trial and test operational procedures.	Ensure timely gate closure and that closure occurs in automated systems. Help with community awareness.
Flood mitigation dams	Analyse impacts, investigate, design and construct. Develop operation and maintenance manuals. Meet dam safety requirements where relevant.	Perform maintenance and operate, and monitor during flood. Regularly monitor condition and rectify issues. Regularly trial and test operational procedures.	Manage dam gate operation. Interact with flood warning and emergency response management and planning, and community awareness.
Detention and retardation basins	Analyse impacts, investigate, design and construct. Develop operation and maintenance manuals. Meet dam safety requirements where relevant.	Perform maintenance and operate, and monitor during flood. Regularly monitor condition and rectify issues. Regularly trial and test operational procedures.	Interact with flood warning and emergency response management, and planning and community awareness. Manage downstream zonings and development controls to limit impacts on development.
Improved flow conveyance (i.e. channel widening, bypass flow conveyance)	Investigate, design and construct considering environmental issues such as riparian vegetation and environmental flows.	Rectify issues; perform ongoing maintenance.	Interact with flood warning and emergency response management, and planning and community awareness.
Evacuation route improvement	Investigate, design and construct (e.g. raise low points on roads to improve emergency response capacity). Consider potential growth in risk due to development.	Rectify issues; perform ongoing maintenance.	Interact with flood warning and emergency response management and planning, and community awareness.
Relocate development and rezoning to more flood-compatible purposes	Investigate and justify. Remove existing development. Rezone for flood-compatible purposes. Relocate development or build new.	Ensure land remains appropriately zoned.	Investigate availability of suitable areas of correct zoning and appropriate risk. Restrict development of original site to be compatible with flood hazard.
House purchase	Investigate and justify. Remove existing development. Rezone for flood-compatible purposes.	Ensure land remains appropriately zoned.	Ensure knowledge of purpose of zoning remains.

Option	Up-front work	Ongoing work	Complementary work
Rezoning property for reduced use	Reduce potential to develop or redevelop existing development areas.	Ensure land remains appropriately zoned.	Ensure knowledge of purpose of zoning remains.
House raising	Investigate and justify. Gain building approvals.	Monitor to ensure no development below raised floor level. Notify future purchasers.	Ensure infill with an appropriate system, and notify future purchases of risk and limitations. Interact with flood warning and emergency response management, and planning and community awareness.
Flood proofing of buildings	Investigate, justify and understand limitations and operation.	Perform operation and maintenance; rectify issues.	Ensure owner is aware of the system's limitations.

Table 9.2: Different management options for residual risk, and associated works

Option	Up-front work	Ongoing work	Complementary work
Flood prediction and warning	Investigate, design and construct. Develop operation and maintenance manuals for gauges and associated information systems or networks.	Perform maintenance and operation. Monitor during flood. Regularly monitor condition, and rectify and upgrade as necessary as technology and requirements change.	Gauge flows at key locations during a flood. Interact with flood emergency response management and planning, and community awareness.
Community-scale emergency response plans	Gather information, investigate, analyse, develop strategy, formalise and communicate.	Operational use during flood. Collect extra flood intelligence. Maintain plans to allow for knowledge changes or mitigation measures, or new emergency response procedures implemented (includes new development impacts).	Implement management plans and monitor impacts of these and new development on emergency response management plans. Interact with flood warning and emergency response, and community awareness.
Community awareness and flood readiness	Understand flood behaviour, impacts and evacuation limitations. Make flood risk information available. Understand community exposure. Make clear advice available to community on how to respond to a flood threat.	Maintain up-to-date advice with changes in knowledge and the implementation of management measures. Provide regular advice to the community to maintain knowledge of flood threat and necessary response.	Interact with flood warning and emergency response, and community awareness. Implement floodplain management plans and improve flood risk knowledge through data collection or studies.
Residential or commercial emergency response plans	Provide templates and promotion. Assist with understanding flood issue and completion.	Operational use during flooding. Provide training and ongoing reminders and assistance.	Provide flood information for the community, including warnings and time for action.
Recovery plans	Understand scale of potential flood impacts and emergency response planning. Ensure flood recovery planning is in place.	Ensure advice is up to date with changes in knowledge and management measures.	Interact with flood warning and emergency response, and community awareness. Implement floodplain management plans and improve knowledge of flood risk.

9.1 Reducing flood risk at a community scale with structural works

Structural mitigation options are generally used to reduce the exposure of the existing community to flood risk. Current circumstances can limit the level of service that can be practically and cost-effectively achieved through mitigation works. This may result in a level of service below the standards for new development; however, it might still significantly reduce current risk exposure. This section discusses community-scale options from Table 9.1 with option assessment discussed in Section 9.4.

9.1.1 Permanent levees

Traditionally, levees have been used to reduce the frequency of riverine flooding in towns as they are often the most economically attractive measure. For events up to their design flood, levees can provide significant reductions in damage and allow communities to function during long-duration floods, provided the structural integrity of the levee is not compromised.

Levees generally have a finite design limit and freeboard (Section 7.2.2) on top of this. They are almost never designed to exclude the PMF and, as such, will be overtopped at some stage. Levees are only as good as their weakest link, which is often the lowest crest level. However, they may also fail through mechanisms, such as piping, if they are not adequately maintained. They should be designed to ensure that overtopping floods can enter the protected area in a manner that reduces the associated consequences. A purpose-built spillway may direct overflows to the most manageable location in the protected area.

Levees can have a significant effect on flood behaviour, particularly if located in a flow conveyance area. Investigations should consider the potential to offset impacts where necessary. Current development and infrastructure may limit the levee alignment, and the levee may cut local drainage paths, which may result in flooding inside the levee that needs to be managed. Legal arrangements are generally necessary to gain permanent access to the levee and prohibit land-use practices that may reduce its ability to perform its design function.

Levees require large capital investments to construct. They also require an ongoing financial and resource commitment to operate the levee, monitor its condition, and maintain it so it can fulfil its design function for its design life. Without this long-term commitment, levees may not be sound when a flood occurs and the value of the initial capital investment will be significantly reduced. Therefore, life-cycle costs should be considered when assessing levee options.

A fully documented and implemented operational, maintenance, monitoring and asset management plan can help ensure the levee can perform its design function when required. Operation may involve placing temporary components across areas where road or rail access is maintained when there is no flood threat. These elements need to be able to be installed within the effective warning time available for the location.

Land-use planning controls may be needed inside the levee to limit development near any spillway and to limit the impacts of local flooding from internal drainage issues to development within the protected area.

Emergency management planning should consider the ability to maintain the community behind the levee during an event. This may depend upon the residual risk, the safety of occupying the area, the rate at which the protected area would fill if the levee overtopped, the ability to evacuate if the levee overtops and the availability of essential community services.

Ongoing community education is required to ensure that the population is aware of the risk of overtopping and associated emergency management plans, and does not lapse into the common belief that a levee provides protection against all floods.

9.1.2 Temporary barriers as part of a long-term management strategy

Temporary barriers are relocatable systems erected in response to a flood threat. They can be considered as part of a long-term strategy to manage flood risk if designed to be erected each time a flood occurs that threatens the area. Temporary barriers are like all barrier-style systems, including permanent levees. If placed in the wrong location, they can have a significant negative effect upon flood behaviour, which may adversely affect other development. Their location needs to consider potential impact on flood behaviour, local drainage, emergency management planning – and when considered as part of a long-term strategy – they need to consider the full range of issues identified for permanent levees (Section 9.1.1) and the service life of the product and its components.

The suitability of temporary barriers as part of a permanent management approach will also depend upon the ability to have the system in place and operational within the effective warning time (i.e. before the flood arrives). This is a matter of operational logistics. Additional issues to consider include the risk of the location (i.e. proximity to riverbank); the stability of the foundation; the ability to manage seepage; the security of storage; the logistics of collection, handling, transport, and erection in the available time; any workplace health and safety issues in erection; service life of the product and ongoing training needs of staff. The need for emergency service and public access across the barrier, particularly in longer duration floods where a town may support surrounding rural areas, should also be considered. Logistical issues mean that temporary barriers are unlikely to be feasible for flash-flood environments.

9.1.3 Temporary barriers as part of a short-term management strategy

Temporary barriers, like levees, can significantly affect flooding. Ideally, they are used where hydraulic investigations into their impacts have been completed through studies outlined in this handbook or equivalent. Unless these detailed investigations are undertaken and indicate their use in the location is appropriate, it would not be recommended that they be located in any of the following locations:

- On the spillway of an existing levee. Spillways are designed to direct overtopping flows to areas that minimise their impacts. Blocking spillways may cause the levee to overtop at another location with additional community impacts and potential risk of levee failure.
- On top of an existing levee. This may place more hydraulic load on the levee than it is designed to manage, and increase the potential for seepage or piping failures.
- In flow conveyance or active flow areas. Use in these areas may have a significant impact upon flood behaviour and may increase flood risk in unprotected areas.

However, there may be situations or areas where a FME, with advice from suitably qualified technical staff, may consider that a temporary system will not adversely affect flood behaviour and may be a viable short-term emergency option, without the need for significant additional investigation. These may include being a temporary solution:

- to fill a gap in a partially constructed levee, thus providing the town with flood protection while the remainder of the levee is being constructed
- where a permanent levee has been designed but is yet to be constructed – the alignment should stay within the design limits of the permanent levee, and local catchment flooding, overtopping and access over the levee need consideration
- in areas such as inactive or backwater areas where the FME considers they will not adversely affect flood behaviour. Issues such as local catchment drainage, overtopping and access across the barrier need to be considered.

9.1.4 Floodgates

Floodgates may be designed to prevent backflow from rivers into town drainage systems during floods. They can allow regular tidal inundation of areas behind structures between floods, facilitate environmental flows into protected areas, control flow into a bypass flow system until design conditions are reached and control minor flows in spillways on major dams. Their operation may be automatic or manual. In either case, they require regular maintenance and operation because they may readily become stuck open or blocked closed when fouled by debris. The appropriateness and feasibility of floodgates need to consider benefits relative to costs from social, economic and environmental perspectives. Environmental implications can include:

- changed aquatic ecology
- exposed acid sulfate soils
- changed water quality
- dried out wetlands and change in function
- potentially altered hydrological regimes resulting in changed vegetation species composition
- restricted fish passage and lost nursery habitat.

9.1.5 Dams

The primary purpose of most dams in Australia is to provide a secure water supply. They are, therefore, generally kept as full as possible and cannot be relied upon to provide significant volume capacity to mitigate a flood threat, as this is not their design purpose. Major storage dams, whether they have a designed flood mitigation capacity or not, may have some flood mitigation impact. This is often small and depends upon the dam surface area, the size of the spillway and the available capacity relative to the size of the flood. Where a major dam exists in the catchment of interest, it may be prudent to test its potential to reduce downstream flood flows whether or not it has a specific flood mitigation capacity.

There are, however, a number of dams in Australia that are designed with some flood mitigation component. They mitigate flooding by absorbing some of the flood volume in 'air space' kept free from water supply needs. This usually has more impact on peak flows in minor or moderate floods – the benefits diminish as the scale of the flood increases. Dams with gated spillways have a greater potential to be operated to reduce the impacts of flooding on downstream areas. For flood mitigation dams to be effective, they generally need to be located near the area of interest; otherwise, there may be significant catchment area downstream of the dam and tributaries that bypass a dam and reduce its effectiveness.

9.1.6 Retarding and detention basins

Basins provide temporary storage for floodwaters as a means of reducing peak downstream flows, often to offset the impact of land-use changes on flows. Basins can be large and may, in some cases, be regarded as small dams and need to meet dam safety requirements. They behave in a similar manner to flood mitigation dams, but on a smaller scale. In urban areas, basins are most suitable for small streams that respond quickly to rapidly rising floods. They may require a substantial area and reasonable depth to achieve the necessary storage and sufficient differential ground level to limit upstream impacts. Long-duration or multi-peak storms can increase the likelihood of overtopping or failure. They often have little attenuating effect on larger events than the design storm and, once overtopping occurs, downstream flows can rise quickly. These factors require careful consideration in urban design, emergency management planning and community education programs. They are often sited in areas with multipurpose use (e.g. playgrounds), so safety aspects need to be considered. Consequently, it is important that basins are properly designed (including consideration of alternative storm patterns), constructed and maintained. Risk is reduced by complementary works (bywash spillways) or specific land-use planning measures (to keep incompatible development clear of downstream flow paths and facilitate emergency response).

Well-designed retarding and detention basins may also be utilised to achieve water- sensitive urban design principles, such as stormwater treatment and stormwater capture and harvesting.

9.1.7 Improved flow conveyance

Improved flow conveyance can reduce peak flood levels upstream of locations where additional capacity is provided by improving channel capacity or bypass flow conveyance.

Channel capacity improvements

The hydraulic capacity of a river channel to convey floodwater can be increased by widening, deepening or re-aligning the channel, and by clearing the channel banks and bed of obstructions to flow. The effectiveness of channel modifications depends upon the characteristics of the river channel and the river valley. In urban situations, channel modifications can also provide the community with additional positive benefits such as visual aesthetics by landscaping with vegetated riparian corridors and recreation facilities, such as linear parks, and provide for a more water sensitive.

Channel modifications are likely to be most effective on steep, small streams with overgrown banks and narrow floodplains. They are unlikely to have a significant effect in flood situations where there are extensive areas of overbank flooding or where flood effects are dominated by downstream effects.

If carefully designed to maintain a natural stream length – with appropriate riparian and floodplain vegetation, but with increased waterway area – the impact of channel modification on downstream flood flows, bank and bed stability, and maintenance costs can be reduced. The use of concrete-lined channels to replace natural streams is particularly undesirable from an environmental standpoint and should be avoided where possible. Where modifications to natural streams are proposed, these should be designed considering guidelines for the rehabilitation and restoration of streams.

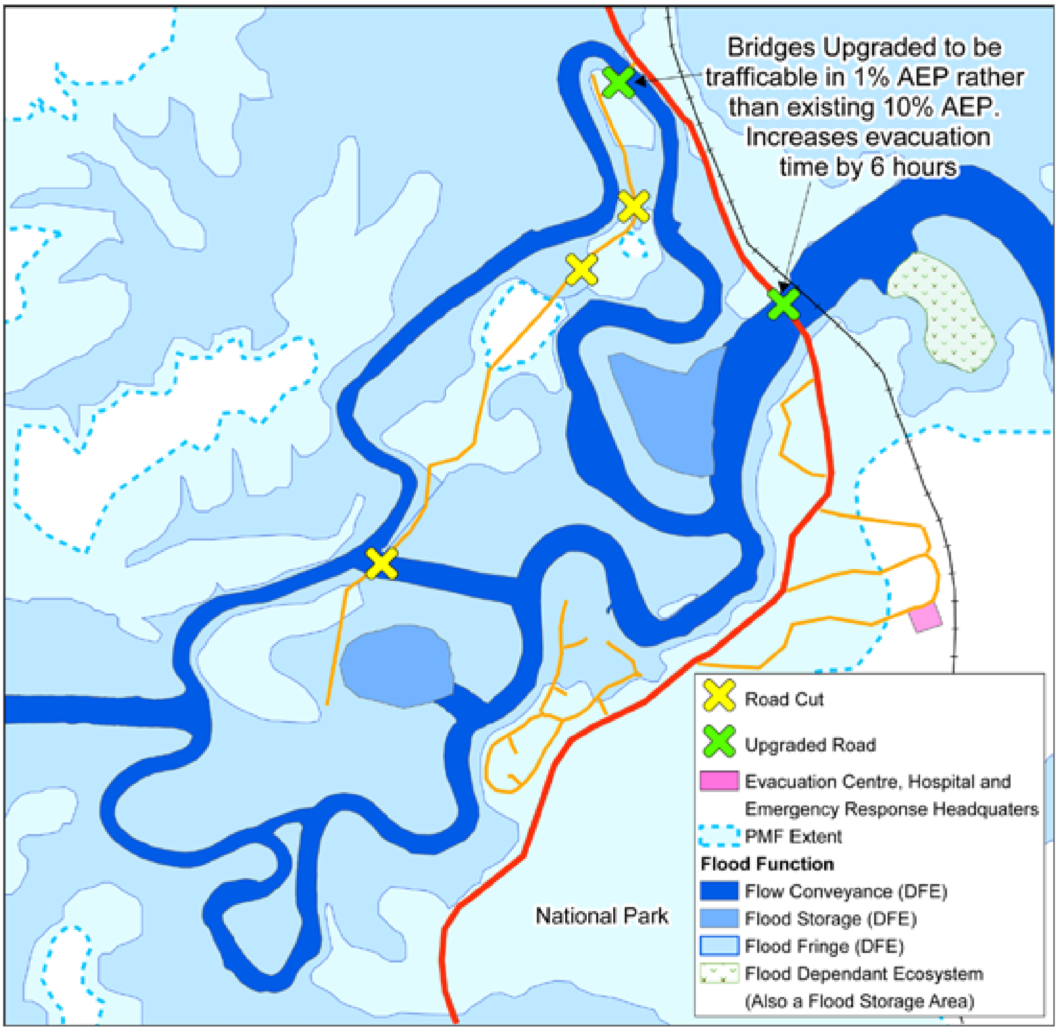
Bypass flow conveyance

Bypass flow conveyance redirects a portion of the floodwaters away from threatened areas, and so reduces flood levels along the channel downstream of the diversion. Opportunities for construction of bypass flow paths are limited by the area's topography, environmental considerations and land availability. Bypass measures may exacerbate downstream flood problems and, as they direct flows away from natural paths, and may affect channel form both upstream and downstream of the site of the works. Despite these shortcomings, bypass flow conveyance can, on occasions, provide a useful risk management option.

9.1.8 Evacuation route improvement

Evacuation relies upon having an available route of sufficient capacity to enable the community to self-evacuate to evacuation centres within the time available. Routes can be upgraded (Figure 9.1) to improve their carrying capacity for the available evacuation window by adding trafficable lanes (contra-flow is not generally recommended, as emergency management vehicles may need to enter evacuated areas), the time available to evacuate the community (by raising the evacuation route, but maintaining evacuation procedures) or by increasing certainty of knowledge of the eventuality of a flood (i.e. reducing reliance on forecast rainfall or early predictions in deciding when to enact an emergency management plan).

The upgrade of evacuation routes needs to balance the relative benefits of improved safety with the costs. It may be possible for such works to be incorporated as part of upgrades of existing roads, or by upgrading road shoulders and bike lanes to enable vehicular traffic.



AEP = annual exceedance probability;
DFE = defined flood event

Figure 9.1: Upgrade to improve evacuation routes

9.1.9 Relocation of urban development and rezoning of existing location

Where the impacts of flooding are significant and not able to be feasibly or cost- effectively managed by mitigation works, relocation of urban development to a less hazardous situation or rezoning of land to limit its development potential may be alternatives. It was found to be the most appropriate response in Grantham, Queensland, after flooding in 2011. Relocation can remove urban development from flow conveyance areas and improve flood flow, remove people and property from hazardous areas where they and their potential rescuers are at significant danger during flood events, and limit future development to purposes compatible with flow conveyance and flood hazard.

Relocation would generally involve the establishment or identification of appropriately zoned development sites in areas where flood risk is limited to more acceptable levels. It may involve a land swap with the existing site being transferred to government and rezoned for flood-compatible purposes. It may involve either relocating the existing structure to the alternate site, or constructing new buildings on the alternate site and demolishing the existing structure. Such change cannot generally be achieved in the short term through land-use planning and development controls, unless supported by a legislative and policy framework; a coordinated and funded program of relocation and the affected and wider community.

9.2 Mitigation works to reduce existing flood risk at the property scale

A house and associated property is often an individual's largest capital investment, and they can have strong sentimental and emotional attachment to it. Once a structure is built, the potential to reduce flood damage substantially at the property scale is limited. Table 9.1 outlines some of these options and the up-front, ongoing and complementary effort required for implementation. These options may be used as part of broader schemes. Their effectiveness should be tested against other options considering their social, economic, environmental and cultural costs and benefits, and considering their limitations.

9.2.1 House raising

The damage to a structure due to flooding generally increases significantly once its habitable floor level overtops. In some cases, the floor level can be raised to reduce the frequency of above-floor flooding, the scale of losses and clean-up required, and the post-flood trauma and stresses on individuals. House raising is generally best suited to timber-framed and clad structures; single or double brick, or slab-on-ground structures are often impractical or cost-prohibitive to raise. To achieve this benefit, the structural elements of a building need to be designed to cater for the potential flood forces possible at the location for the design event. This can reduce the frequency of over-floor flooding – but, unless the PMF is used for the floor event – the floor will still be inundated in rarer floods.

Therefore, house raising does not remove the need for the occupants to respond appropriately to a flood threat. Experience has shown that it is poor emergency management practice, particularly in urban areas, to leave people isolated in houses surrounded by floodwaters. This may mean that emergency management planning may identify the need to evacuate a house even though it may not be at-risk of above-floor flooding in the particular event. If evacuation is not undertaken in a timely manner, the occupants may have to traverse significant depths of water to flood-free areas and the potential need for rescue increases, particularly where flood levels exceed earlier predictions.

It is essential that both the benefits and the problems associated with house raising be examined if it is to be considered as a management option.

9.2.2 Shelter in place

There are some limited instances where an individual house or commercial development may be designed as a shelter during a flood event. This would generally only be considered appropriate in existing developed areas:

- that have no other practical management options available
- where evacuation is not possible due to lack of flood warning
- the development is outside flow conveyance areas
- it is likely to be safer to shelter in place than to try and evacuate at the wrong time.

This approach generally involves risk reduction by replacing existing flood-affected development with less-vulnerable development of the same density.

The structure should be designed for flood impacts with suitable water-resistant structural materials, and be designed to have some habitable floor area above, and to withstand the forces of, the PMF. Even in the case of shelter in place, occupation during a flood may be without water, sewerage, electricity, communications and other services, and the house will be isolated (and there is no safe duration of isolation). These factors all increase the risk of a need for rescue or on-site assistance due to, for example, the need for medical attention, on-site risks such as house fire (exacerbated by lack of electricity and difficult to extinguish due to isolation) and the need for basic supplies.

These factors can impose additional loads on emergency services during floods. For these reasons, shelter in place is a last resort option, normally only appropriate for existing flash-flood environments.

9.2.3 Government house buyback

There are areas of floodplains where hazards are extremely high and the danger to people during flood events can be significant, but where it may not be feasible or economic to mitigate the effects of flooding by any of the means discussed above. In these cases, it may be appropriate for an FME to consider house buyback as an alternative, to give the property owner the opportunity to relocate away from the danger associated with flooding at the specific location. House buyback aims to remove the people and the structure from the floodplain, and involves either removing or demolishing the house, and rezoning the land to a more flood-compatible purpose. It is generally an expensive option and, as such, is generally targeted to specific locations and scales of problems. Properties may be purchased to remove urban development from flow conveyance areas to improve flood flows, and remove people and property from hazardous areas where they and their potential rescuers are at significant danger during flood events. However, it may also be done to enable the construction of flood mitigation works, such as levees. This may be due to the location of the structure in relation to the works or the inability to manage the impact of works on flood behaviour at the structure.

9.2.4 Flood proofing of buildings

Flood proofing of buildings may involve using materials that are flood compatible (i.e. are resistant to damage by floodwaters) or temporary measures. They may include a range of built-in automatic and manual barrier systems that aim to prevent water penetration into the building during a design flood. These measures need to consider the overall design of the building, the potential for alternative ways for water to penetrate the building and the potential flood forces that may need to be managed. These systems are likely to have design limitations (i.e. maximum depths of water that they can withstand before failure) that need to be considered. They may facilitate ground-level access to a building when no flooding is occurring along with offering the ability to reduce damages during a flood. In cases where there is a need to reduce the differential in water levels between the exterior and interior of the building to minimise the potential for structural failure of building components, permanent measures allowing water penetration into the structure may be used.

9.3 Treating residual risk at a community scale

Rare floods may result in buildings with minimum floor levels based upon the DFE or protected by works such as levees being flooded. This may expose people to hazardous flood situations requiring emergency response, which could result in damage to infrastructure, and both public and private property. Informed flood emergency management planning and associated support systems (flood warning systems) and infrastructure (evacuation routes and centres) can facilitate the development of effective emergency management plans for the community to reduce the risk to life and enable some damage reduction. Table 9.2 outlines a range of measures to reduce residual flood risk at a community scale. These include flood prediction and warning, community-scale emergency response, and community preparedness and recovery. These are discussed in Sections 9.3.1–9.3.4. Treating residual risk to new development at a property scale is discussed in Section 8.5.

9.3.1 Flood forecasting and warning systems

Flood forecasting and warning systems, and emergency response arrangements that help communities cope with the impacts of flooding are essential in managing flood risk. They need to be buttressed by appropriate flood intelligence, which can be used by those who are responsible for warning and response activities. Flood warning is discussed in detail in *Australian Disaster Resilience Manual 21 Flood Warning* (AIDR 2009).

A flood warning system is an important element of flood response arrangements for any community. It may be technically simple or complex, and needs to consider the local flood situation, the needs of the emergency response agencies and the community.

Effective flood warning messages communicate to the public the threat posed by a flood event, the action they should take in response to the threat and the assistance that may be available to them. The careful use of language in flood warnings is critical to help people understand the flood threat and encourage them to act appropriately. The floodplain-specific management process can provide data, and hydrologic and hydraulic tools to assist in flood forecasting (Section C). It may also identify the need to develop or upgrade the flood warning system for a specific location to improve emergency response or community resilience.

9.3.2 Community-scale emergency response plans

A high standard of flood emergency management planning based on national, State and Territory guidelines is fundamental to flood risk management. Detailed advice on flood emergency response planning is provided in the *Australian Disaster Resilience Manual 43 - Emergency Planning* (AIDR 2004). Planning should:

- be based on flood intelligence from all credible sources, and be improved through data collection after flood events and using information from flood investigations
- include detailed evacuation planning where human populations are threatened; this requires identifying constraints to evacuation (e.g. lack of effective flood warning or time to act), lack of evacuation access and the scale of impact upon the area. Special consideration is usually necessary for more severe floods
- link with community flood awareness, education and advice (e.g. brochures about flood safety)
- identify infrastructure, such as emergency hospitals and evacuation centres, and routes and services to them, including emergency water, sewerage and power supplies. These are essential to emergency response and recovery, and it is important to understand the limitations that flooding may place upon their use during and after an event
- be subject to regular audits after flood events.

The floodplain-specific management process (Section C) is a valuable source of information for the development, maintenance and upgrade of community-scale emergency management plans. The process provides the opportunity to improve the knowledge of emergency managers about the full range and scope of the flood threat, and the varied types and severities of issues that need to be considered in emergency management planning.

Table 9.3: Example floodplain management option assessment matrix

CATEGORY	ISSUE	OPTION – RAW SCORES					OPTION – WEIGHTED SCORES			
		Weighting 5 highest, 1 lowest	Continue current practice or no change	DFE Levee	Flood Warning & Evacuation	Development Control	Continue Current Practice or no change	DFE Levee	Flood Warning & Evacuation	Development Control
SAFETY OF PEOPLE:	Reduce hazards in event deriving flood planning levels	4	2.5	4.5	3.5	3.5	10	18	14	14
	Reduce hazards extreme event	3	2.5	3.5	3.5	3	7.5	10.5	10.5	9
	Improve evacuation extreme event	4	2.5	3	3.5	2.5	10	12	14	10
SOCIAL:	Increase community growth									
	Disruption/ relocation due to measure									
	Improve property values									
	Minimise social disruption during flooding									
ECONOMIC:	Life cycle cost of management measures									
	Reduce flood damage									
ENVIRONMENTAL:	Flora/fauna impact									
	Enhance environment									
FLOOD BEHAVIOUR/ IMPACTS:	Negative or positive impacts of change in hydraulic behaviour									
	Reduce number of houses impacted									
FEASIBILITY:	Physical/ technical									
	Financial council									
	Potential for Australian, State or Territory funding									
ATTITUDE:	Decision makers									
	Community									

CATEGORY	ISSUE	OPTION – RAW SCORES					OPTION – WEIGHTED SCORES			
		Weighting 5 highest, 1 lowest	**Continue current practice or no change**	**DFE Levee**	**Flood Warning & Evacuation**	**Development Control**	**Continue Current Practice or no change**	**DFE Levee**	**Flood Warning & Evacuation**	**Development Control**
COMPATIBILITY:	Other hazards & urban drainage									
	Environmental management measures									
KEY INFRASTRUCTURE:	Improve availability and function									
TOTAL										

DFE= defined flood event

Notes: Issues considered, their weighting and score vary between committees and location depending on their effectiveness. Example calculations shown (including item weighting and scores). These can be extended to other items and totalled.

Weighting is from 1 to 5, with 5 the highest rating. These may be derived from committee discussions.

Options have been rated on a scale of 1 to 5, with 5 the highest score. The 'continue current practice' or 'no change' option is weighted at 2.5 for each issue, as it does not have a cost or benefit to the community. This provides a basis for ranking other options based upon their relative benefit or cost. Options with positive benefits are scored from 2.5 to 5. Options with negative impacts are scored from 0 to 2.5. Scores may be derived from committee discussions.

It also provides the opportunity to develop or review community- scale emergency management plans as it may:

- provide improved information on the flood threat, and its impacts upon the community and key emergency response infrastructure
- identify and lead to the implementation of treatments that may improve flood warning, significantly alter the flood threat and the scale of impacts on the community, or alter the viability or relevance of current emergency response plans.

It is important that the best available information is used for emergency management planning. This requires regular contact between the FME and those undertaking emergency management planning.

9.3.3 Community preparedness

Community engagement, education and communication provide advice on flood risk to make the community aware of the flood threat they face and how to respond to it appropriately. However, just because the community is made aware of this risk, it does not mean that they are prepared for all floods. Advice on preparation should not be solely for the more common or less severe floods. The community also needs to be prepared for floods that are outside of their experience, as there will eventually be a flood that overwhelms access routes used during more frequent floods, overtops levees, and inundates rural or urban areas that have not been previously affected. The key message is that for these rare floods, different actions must often be taken from those appropriate in the smaller event, which some community members may have experienced.

The first step in creating readiness is creating awareness of the potential for flooding. Other steps will follow that may be specific to particular areas, and will seek to create learning about particular issues, such as how to use warnings, means of protecting property, what to do before and while evacuating, and how to manage household recovery from flooding. Like all flood risk management measures, flood readiness needs to be developed and maintained to be effective. The development of community preparedness for floods is discussed in detail in the *Australian Disaster Resilience Manual 20 - Flood Preparedness* (AIDR 2009) and *Australian Disaster Resilience Manual 45 - Guidelines for the Development of Community Education, Awareness and Engagement Programs* (AIDR 2010).

9.3.4 Community recovery plans

Floods can have devastating impacts upon the community and the built environment, and require significant effort from the community, government, utility service providers and industry to recover. *Australian Disaster Resilience Handbook 2 - Community Recovery* (AIDR 2011) discusses recovery from flood events that should be considered in recovery planning.

9.4 Assessment of treatment options to reduce existing risk

Existing development is constrained by current circumstances, limiting the risk reduction that may be able to be practically achieved through mitigation. Decisions on treatments are generally based on an assessment of economic, social and environmental benefits and impacts, which generally involves calculating the potential damage reduction and comparing it against the cost of the required works. If considered worthwhile economically or socially, the works are then considered for implementation. Social benefits from works may include reducing the exposure of people to the flood threat, enabling the community to function during a flood, and enabling towns to support surrounding rural areas during an event, particularly in areas affected by flood events lasting weeks to months.

The assessment may consider different levels of service to the community, such as protection for the 5%, 2%, 1% and 0.5% annual exceedance probability floods, to determine which one is most practical, feasible and beneficial to the community relative to the cost. Some treatments have relatively high social or environmental costs – for example, the relocation or disruption of a community, the construction of a levee, the clearing of vegetation, or the reshaping of a waterway to improve hydraulic efficiency and lower flood levels. In addition, the implementation of risk management measures may benefit some groups in the community while disadvantaging – or at least not benefiting – others (e.g. protecting those inside the levee, but potentially impacting on those outside of the levee).

To compare issues and management measures objectively, it is necessary to gather a variety of socio-economic data. An economic appraisal of proposed management measures would generally need to be undertaken to ensure that costs are at least balanced by the benefits derived. This economic analysis principally deals with tangible costs, but also needs to consider:

- the flood damage assessment, to determine the reduction in damages due to mitigation. Although direct economic benefit is important, it is not unusual to proceed with mitigation schemes on largely social grounds – that is, on the basis of the reduction in intangible costs, and social and community disruption. In fact, on a global basis, it is often the experience that many mitigation schemes are often only marginally economical in strict tangible cost-benefit terms
- any social costs and benefits. The social impact of flooding on the community – in general and on specific community groups – needs to be assessed, and the benefits of mitigation understood. For example,
    - do flood-prone residents have certain characteristics or disadvantages that will make them less resilient in dealing with the occurrence and aftermath of a flood?
    - does regular flooding occur and is the community flood aware?
    - are floods highly disruptive to the community and could strategies address this disruption to the social fabric of the community?
    - is the community mobile and is there a high turnover of people?
    - what is the benefit of mitigation to public safety and to reducing community disruption?
- the environmental costs, considering the principles of environmentally sustainable development. Valuation of environmental assets and services should be included.

It is possible that public safety management measures are not properly assessed solely using traditional cost–benefit methodologies – they should consider broader assessment criteria. Table 9.3 shows a typical option assessment matrix, which identifies issues and enables their importance to be considered. The outcomes provide advice that can be used to inform decision making. The matrix considers the benefit of the option and multiplies this by the importance to develop a weighted score, and assessment criteria apply across a range of economic, social and environmental categories. An understanding of how risk is currently managed provides a continuing current practice or 'no change' option to compare with options to change practice. Assessments provide an understanding of the effectiveness of options and in optimising the mixture of measures needed to treat risk.

Effective risk management generally involves a mix of management options. It is unusual for a single management option to manage the full range of flood risk to existing and future development. Recommendations may involve:

- options to treat flood risk to the existing community, which may vary from options with localised benefits to those with broad community benefit
- strategies to reduce the risk to public infrastructure, which may involve reducing or limiting the vulnerability of infrastructure to flooding, or improving its ability to perform its function during a flood event
- strategies to manage risk to future development, and ensure it does not adversely affect the current flood regime and existing development, and has acceptable residual risks.

Guideline 7-6 Assessing Options and Service Levels for Treating Existing Risk provides advice on multi-criteria assessment of selecting options and combinations of options for treating existing risk and optimising these options.

SECTION C

Floodplain-specific management process

The floodplain-specific management process, as shown on Figure 10.1, is a risk-based process that involves steps that support understanding and management of flood risk for a specific geographic area. This is generally part or all of the floodplain of a single waterway (and may include its tributaries) or a combination of the floodplains of several waterways, where flood behaviour may interact. This understanding begins with knowledge of local flood history, evidence of the types and scales of storms that have previously caused problems, and indications of what landforms or human-made structures may influence flooding.

Data collection (Chapter 10) provides a starting point for understanding flood behaviour. However, catchments and floodplains are not static and, therefore, changes in vegetation, topography, density of development and infrastructure since key historic events need to be understood to derive current flood behaviour. The flood study (Chapter 11) provides a sound technical foundation for calibrating and verifying models against historic floods, and updating and extrapolating these models to understand the full range of flood behaviour for the current conditions. This can inform strategic land-use planning and emergency management, and provides the technical basis for the assessment of management options and more detailed consideration of future development in a floodplain management study (Chapter 12). This in turn supports informed management of flood risk through the development and implementation of a management plan (Chapter 13).

CHAPTER 10

Data collection

In a nutshell...

Data that is key to understanding and managing floods includes information on the community, the floodplain and its catchment and historic flood events. There are many sources of data to be tapped to support a more complete and credible floodplain-specific management plan. An important source is post-event data collection, because it provides clear evidence of the scope, scale and impacts of floods. The value in collecting this information and the associated lessons learnt cannot be underestimated.

Data accessibility is important. Systems to store data in consistent formats are important to making information readily available and usable. A flood risk knowledge hub may assist.

Flood data can come from many sources and should be collected when opportunities arise (i.e. immediately after a flood event when it is readily available and memorable). Data is essential for providing a robust basis for understanding flood behaviour and impacts and making decisions on its management. Data collection should not be seen as an end in itself, but rather as an input to help prepare properly informed studies than can facilitate informed decision making.

At the start of the floodplain-specific management process, it is unlikely there will be sufficient data to complete flood investigations; gaps will exist. The relevant floodplain management entities and government and non-government agencies will have some information. Relevant data types may include historic, topographic, social, economic, flood, ecological, land-use, cultural and emergency management data.

The data collection phase of the process involves gathering current knowledge on floods and extending it to facilitate management. Before collecting data, it is important to consider the types of information that may assist with scoping and undertaking investigations, and the preferred format of these data, which may include:

- flood risk management standards, manuals, guidelines and other material that provide guidance on data collection and preferred data format
- records of previous flood investigations
- records of historic events including information on the weather systems that have produced flooding and flood behaviour, such as peak flood flow measurements, aerial flood photography, satellite imagery and flood levels
- data from rain and river gauges, and dams
- survey information (both ground level survey and feature survey)
- details of catchment conditions, infrastructure, and areas of interest from a culture and heritage perspective
- information on flood vulnerability and damage to structures and infrastructure
- land use information.

Data from sources such as light detecting and ranging (lidar) survey, sometimes called aerial laser survey (ALS), has many uses across the government. Appropriate licensing can facilitate availability and avoid duplication of effort. The specification should ensure the data meet the high degree of accuracy in height and location (coordinates) required for flood risk management purposes.

Data collection should be encouraged after significant floods to provide a record of historic floods and their impacts, and inform future studies. This data is invaluable for informing decision making, and calibrating and validating flood models. The data is also evidence when disputes arise over the accuracy of flood information.

Information needs will vary with the type of study, its scale and complexity, and the output needs. However, Table 10.1 outlines some of the key data that can inform management efforts.

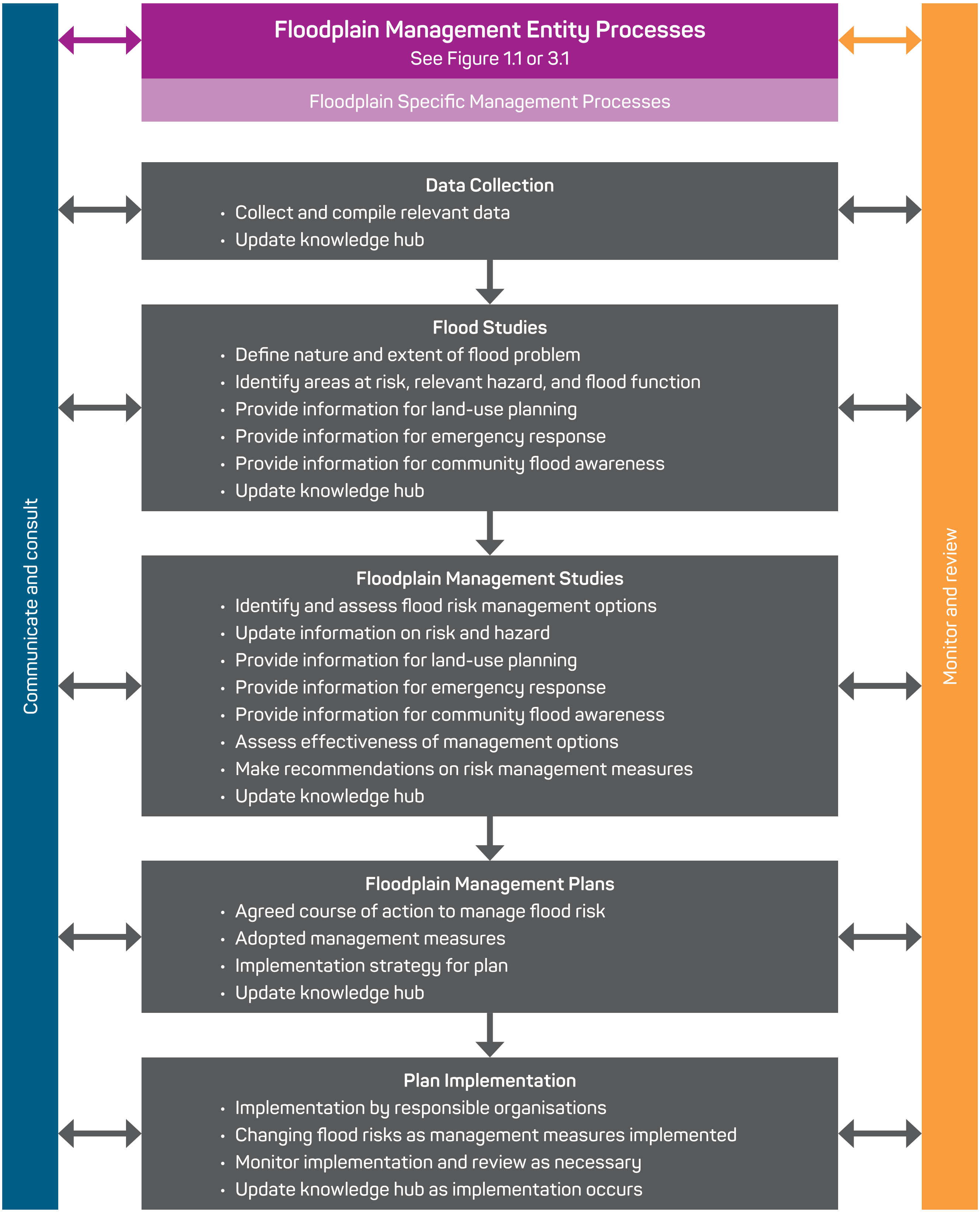


Figure 10.1 Floodplain-specific management process

10.1 Reporting on data collection

Data collection, as part of the management process, should be summarised and documented in a report that could either form part of a study report or (where substantial) be a stand-alone report. The report should provide information about the original source of all data, their quality and any assumptions used to adjust them to current conditions. For key historical information, such as flood levels, it is worth recording the primary source of information, such as newspaper stories, and the source document that describes how the flood level was converted to current datum. Any license limitations on the use of the data should be clearly outlined.

All the data collected should, wherever possible, be appropriately licensed and supplied with the report in standard digital formats to enable aggregation into data management systems and broader use.

Table 10.1: Key data for specifying and undertaking flood investigations

Information category	Information subcategory	Type of information
Available guidance at national, State, Territory or local level	Context	Relevant legislation, policies, administrative guidance.
	Floodplain management guidance	Relevant standards, manuals and guidelines from government and industry to consider. Relevant specifications for studies. Relevant specifications for data collection (e.g. lidar). Relevant information sources. Requirements for outputs from studies (e.g. compatibility with databases).
	Climate change guidance	Projections of changes to relevant sea level. Projections of changes to antecedent catchment conditions. Projections of changes to flood-producing rainfall events.
Existing and historical information	Existing flood investigations	Existing flood investigations in the area, and their extent, scope, availability, relevance and limitations.
	Historical records on significant flood events and their impacts	Rainfall from historic events, including preceding rainfall. Flood behaviour in general, major flow paths, peak flood levels, flow velocities, rate of rise of floodwaters, travel time between points. Information on the impacts of flooding on the community from sources. Flood photography and satellite imagery of flood events.
	Significant changes in the floodplain and catchment	Information on significant changes that may influence flood behaviour and their timing relative to historic events, such as: · changes to major infrastructure crossing the floodplain or key waterways · changes to the scale of development in flow conveyance and flood storage areas, on the floodplain and in the catchment · implementation of significant flood mitigation measures.
Long-term datasets	Long-term datasets	Historic data from rainfall and river flow and level gauges. Historic records of flood warnings. Data on conditions in the waterway and catchment, and downstream areas receiving water (i.e. the ocean, estuaries or downstream waterways). Data on the condition in flood mitigation dams in the catchment. Available survey data including that from lidar. Information on watertable levels where these may influence surface flooding. Long-term surveys of coastal entrances. Records of coastal entrance works (training walls and bypass systems).

Information category	Information subcategory	Type of information
Current floodplain and catchment conditions	Current catchment and floodplain	Topography of the area from ground, ALS, lidar survey, maps, etc. Information on the geology of area, including soil types, and rates of erosion and deposition. Information on land use and vegetation, and changes over time. Information on groundwater and local recharge areas. Detailed survey of natural and artificial features likely to influence flood behaviour.
	Infrastructure	Details on infrastructure that may control flood behaviour. Details on key infrastructure used in supporting a community in emergency response and recovery.
	Flood controls and management measures	Details on human-made flood-control structures such as levees, retarding basins, bridges and culverts. Details of current flood risk management measures, their effectiveness and deficiencies, including environmental disturbance and impacts on water quality. Details on current flood warning systems, emergency response plans and community flood readiness. Operating plans for flood control structures such as dams.
	Land-use and building information	Information on current flood-related zonings and development controls. Information on developed and vacant lots. Ground- and flood-level information for buildings.
	Environmental and cultural information	Areas of Indigenous and historical cultural significance. Aquatic and terrestrial flora and fauna surveys and habitat information, especially on threatened species, endangered populations and ecological communities.
	Emergency response, and recovery management limitations and planning	Information on likely evacuation routes. Information on the effects on the community of flooding to different heights, including road closures, isolation and the need to evacuate, etc. Likely community disruption caused by flooding. Planning in place for emergency response and recovery from floods. Information on the flood risk exposure of key infrastructure in response and recovery including evacuation routes and emergency response operational headquarters; potential evacuation centres; and key utility services, such as water supply, sewage treatment, electricity substations and communications.
Future floodplain and catchment conditions	Flood controls and management measures	Details on proposed management measures and their limitations.
	Land-use and building information	Current and projected future land-use and development trends within the catchment, including available land and demand for future development.
	Infrastructure	Details on proposed upgrades to infrastructure that may control flood behaviour. Details on proposed future infrastructure that may control flood behaviour. Details on proposed changes or replacement of key infrastructure for emergency response and recovery.
	Climate change	Projections of changes to relevant sea level rise. Projections of changes to antecedent catchment conditions. Projections of changes to flood-producing rainfall events.

ALS = aerial laser survey; lidar = light detecting and ranging

CHAPTER 11

Flood study

In a nutshell…

The flood study is a comprehensive technical investigation of flood behaviour that provides the main technical foundation of a robust management plan. It aims to provide a better understanding of the full range of flood behaviour (Chapter 5) and consequences (Section 6.1). It involves consideration of the local flood history, available collected data, and the development of models that are calibrated and verified, where possible, against significant historic flood events and extended to determine the full range of flood behaviour.

The flood study provides information to update the knowledge hub, inform the community, update emergency management planning, and limit growth in risk by informing land-use planning measures to control new development. The degree of sophistication of the flood study should be commensurate with the outcomes and outputs required from the study and the complexity of the flood situation (Section 3.3.3).

Flood risk management involves the extension of our current knowledge on flood behaviour to understand better the full range of potential impacts of flooding to the community. This can be in response to gaps in current knowledge, as discussed in Section 3.3.3, where the suitability of simplified methods is discussed.

A flood study can be used to fill gaps in knowledge and may also provide a platform for considering options to manage flood impacts. It needs to be undertaken with sufficient technical rigour to meet the needs of the FME and the other agencies with key roles in managing flooding. It can be undertaken to different degrees of complexity, depending upon the outcomes required, the complexity of the flood situation, the exposure to risk and the potential growth in risk exposure. The study should consider the implications and interaction of different sources of flooding in the study area (Chapter 1). The main components of a study involve the consideration of the following elements over the full range of floods:

- determining hydrologic aspects and varying flow over time
- determining hydraulic aspects, including water levels, velocities as they vary with time
- understanding varying flood (or hydraulic) function within the floodplain
- understanding varying flood hazard within the floodplain
- assessing the scale of potential impacts of floods on the existing community
- assessing the potential impacts of floods on areas of the floodplain that may be considered for future development
- understanding the potential impacts of climate change on flooding and the community.

The outputs of the study should be produced so they can be integrated into the knowledge hub, and can inform the community and stakeholders of flood risk.

11.1 Scoping

A flood study generally identifies the degree and scale of existing flood inundation and impacts on the community within a study area. It should be developed cooperatively with relevant agencies to ensure best value for money within financial and any other constraints.

Hydrological modelling is undertaken, considering the whole catchment to the location of interest. Hydraulic modelling is normally based around the study area that has a more limited areal basis than the catchment. This is generally determined by where management efforts need to concentrate – that is, where it is warranted by the scale of existing risk (due to development, population or investment) and the potential for growth of risk are highest. Thus, the usual focus will be on existing development and areas that may, over a reasonable planning horizon, be considered for development. It may be undertaken at a catchment scale where warranted by the risk (e.g. small urban catchments).

To reduce uncertainties in flood behaviour in the study area and for model calibration purposes, the hydraulic model often extends beyond the study area. This may result in less accurate flood estimates being available outside the study area. These estimates have greater uncertainty and should only be used in decision making with caution and with accommodation of this increased uncertainty.

11.1.1 Study outcomes

A flood study should aim to:

- gain an understanding of the flood behaviour and impacts upon the community for the full range of floods – this can inform decisions on the adequacy of current management regimes and identify whether additional management measures may need consideration
- make updated information available through the knowledge hub
- inform land-use planning decisions by providing
  - an understanding of the flood constraints and management considerations for future development of undeveloped areas
  - information to support development controls to reduce risk in areas already identified for development in statutory planning instruments
- allow emergency managers to be better informed when planning for emergency response. This provides an essential understanding of the implications of flooding on the community (including isolation and flooding of areas and the flooding of transport links that could be used for evacuation) for a range of flood scenarios, up to and including the PMF. This information should be able to be related to flood predictions, and as such, should be related to relevant flood gauges where practical
- facilitate flood insurance availability by providing information that allows insurers to make informed decisions on insurance pricing
- understand the potential impacts and implications of climate change on flood behaviour
- account for uncertainty. Every step in hydrologic and hydraulic assessment reduces the uncertainty associated with estimated flood levels, velocities and extents. Uncertainty needs to be identified and its implications, in terms of study objectives and desired outcomes, quantified for decision makers. In general, the greater the quantity and quality of data, the greater the confidence in design estimates. Using experienced practitioners to undertake the hydrologic and hydraulic components will minimise systematic errors and facilitate an assessment of overall uncertainty. Sensitivity analyses to key input variables can indicate the risk associated with errors in adopted criteria, coefficients or assumptions, so that these can be considered in management decisions, such as the freeboard selected.

11.1.2 Study outputs

Generally, and as a minimum, the events for which information is provided should include the defined flood event, several more frequent and a slightly rarer flood, and the PMF. As the cost to develop and produce outputs for extra flood scenarios is small compared to the cost of setting up the model, a wider range of events should be considered to provide additional information to inform end users. The information should be produced in digital format and include:

- a description of existing flood mitigation measures
- a description of the historic floods, and calibration and verification of models
- a description of the existing flood situation, and flood extent and level information
- the scale and variation in flood impacts, which can include the number of properties affected and the potential flood damages
- variations in flood functions (i.e. flow conveyance, flood storage and flood fringe) in the floodplain
- breakdown of the floodplain considering the drivers for hazard (e.g. depth, velocity, velocity and depth, isolation) and their relative severity
- emergency response management limitations, including a breakdown of the floodplain to identify areas with different types and severities of response limitations
- updated details for the knowledge hub, including on emergency management and land-use planning, and community flood awareness
- information to facilitate understanding of the degree of uncertainty in flood estimates.

11.2 Analytical tools for understanding flood behaviour

A variety of analytical tools can be used in flood studies. The tools selected need to be fit for purpose, and will depend upon the data available, the flow situation, the nature and extent of development, the level of detail required, the end use of the information, and the specification of required outputs. The use of these tools to develop effective models that reasonably reflect flood behaviour and the interpretation of their results can be extremely complex. This is a specialist area, and it is strongly recommended that the tools be used and results reviewed by suitably qualified and experienced flood risk management professionals.

In most cases, the analytical tool used will be one or more computer models. The degree of sophistication of the model and its appropriateness for the assessment of the flood behaviour for a particular situation will vary dependent upon the:

- need to calibrate and verify the model against historical flood events, which may involve modelling historic catchment development, and floodplain infrastructure and topography

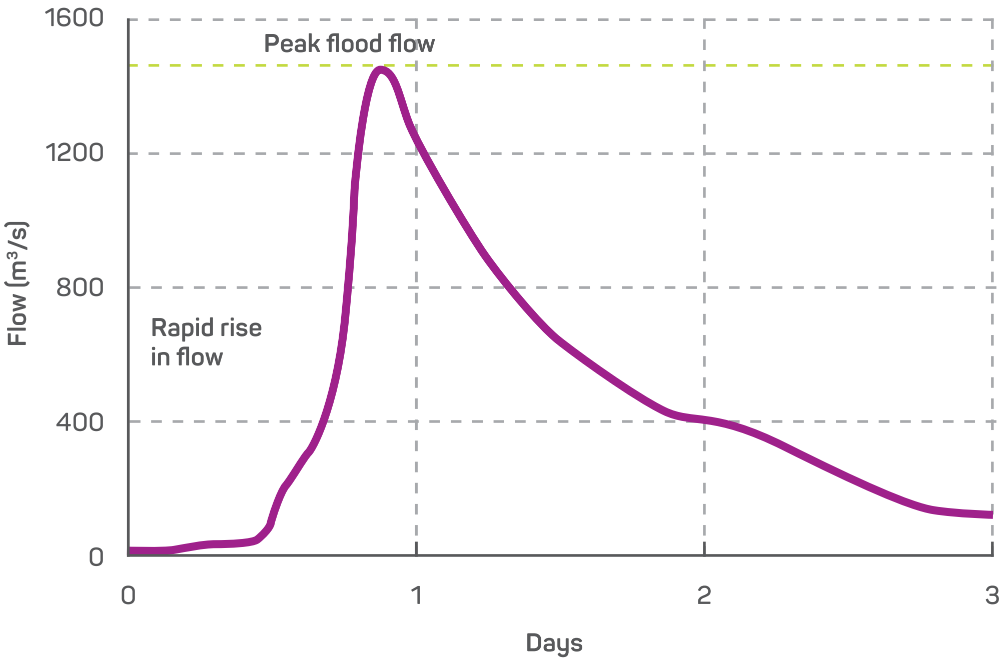


Figure 11.1 Typical coastal river flow hydrograph

- scale of the study; the larger the study area the coarser the scale of a model necessary to be able to model flood behaviour within reasonable costs and timeframes
- flood situation – if it is complex then models generally need to reflect the complexity
- ability for the model to reflect historic conditions for calibration and verification purposes
- available information and cost of collecting base information, particularly survey data
- scale of the catchment and the relevance of catchment models in determining flood flow; in very large catchments, flood frequency analyses are often used rather than detailed hydrological modelling where appropriate data is available and large hydrological models are impractical
- ability to make changes to reflect likely future development of the catchment
- likely variety of flood modification options affecting flood behaviour that may need to be assessed; it is generally more efficient to develop a model capable of assessing options rather than having to develop and calibrate a separate model
- logistical information needs of emergency management; managing floods in real time requires an understanding of issues relating to the initial flooding of areas, the overtopping of structures such as levees, timing of loss of evacuation routes and ramifications to community infrastructure
- need to provide information in a form suitable for FME and government end users.

Analytical tools will usually involve models to undertake hydrologic and hydraulic analysis as discussed below. More detailed advice on hydrologic and hydraulic analyses and on the use of associated models is given in the latest version of Australian Rainfall & Runoff (Engineers Australia 2009).

11.3 Hydrologic analysis

The flow of floodwaters past a given point on a river system is measured in volumetric terms (e.g. cubic metres per second [m3/s] or megalitres per day [ML/day]) and varies throughout the course of a flood event. Figure 11.1 shows a hydrograph indicating variation of flow with time. This is characterised by a relatively rapid rate of increase in flow on the rising limb, followed by a slower decline in flow on the falling limb.

Peak flow information is of limited use. It does not provide information on how quickly floods may reach critical levels, which is essential to time-constrained emergency management activities like asset protection or evacuation. It may need to be used in conjunction with knowledge of rates of rise and timings from large-scale historic events.

Flood frequency analyses (based upon available recorded rainfall and/or flood data near the point of interest or in the upstream catchment) and rainfall-runoff routing modelling (which uses regional or design rainfall methods recommended in the latest version of Australian Rainfall & Runoff [Engineers Australia 2009]) are the two techniques commonly used to estimate peak flood flows and hydrographs.

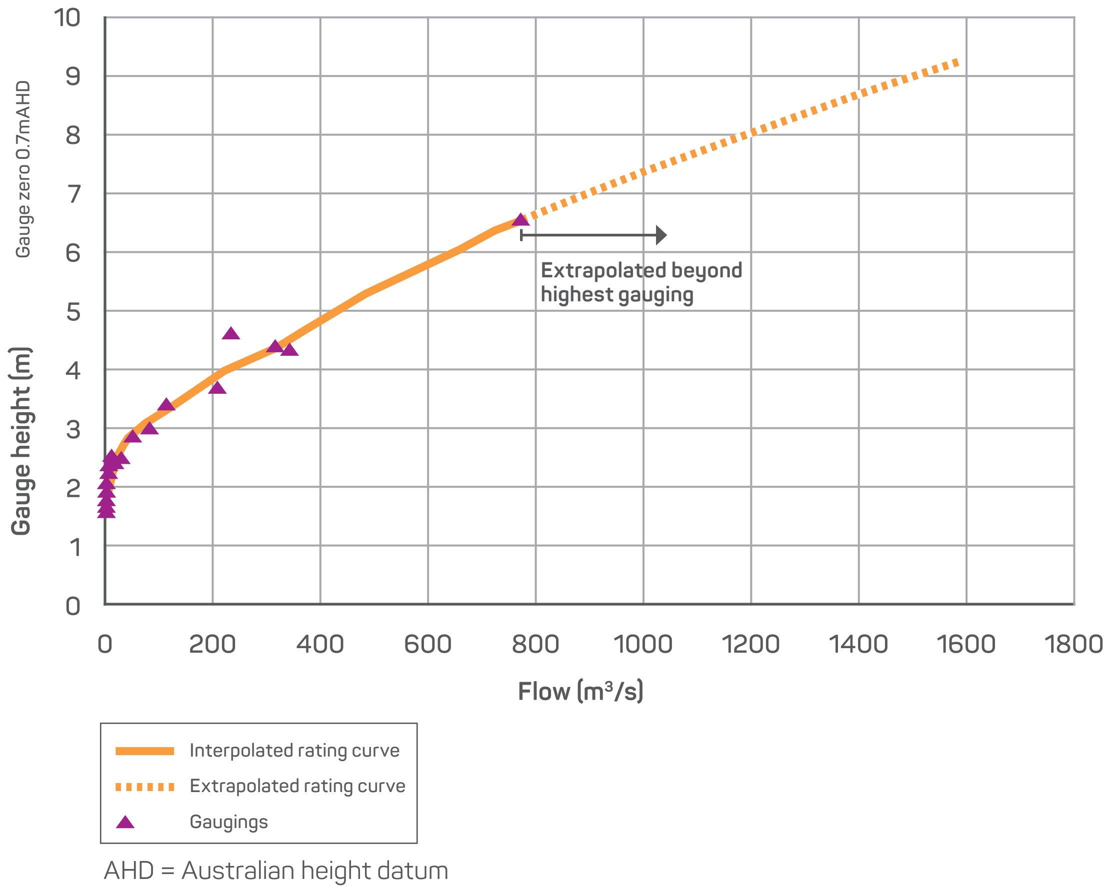


Figure 11.2 Typical rating curve for a stream gauging station

There is a common misconception that flood frequency analysis is less accurate than rainfall-based methods because it involves uncertainty bounds. However, many of the parameters used in rainfall-based methods were validated with flood frequency analysis and, therefore, most of the uncertainties in flood frequency analyses are also inherent in rainfall-based methods.

Hydrologic data are key to a reliable hydraulic analysis. Therefore, it is essential that experienced practitioners undertake the calibration, validation and design application of any numerical methods or models.

11.3.1 Flood-frequency studies

A flood-frequency study is a relatively rapid means of determining the relationship between peak flood flow at a location of interest and the likelihood of occurrence of a flood event of that size or greater. They are generally based on the annual (or water year) flood series, which comprises the highest or peak instantaneous rate of flow at a stream gauging station close to the location of interest in each year of record.

In general, creek and river flows are not measured directly. Rather, flows are estimated from water levels using rating curves that relate water level to estimated flow based upon gauge measurements and on hydraulic analyses. Due to the relative infrequency of high (flood) flows, most flow measurements are taken in the low-flow range. Thus, a rating curve may be reliable for low flows, but usually becomes increasingly inaccurate for higher flows, such as larger floods. Hydraulic analysis is used to extend the rating curve to cover larger floods, an approach that is approximate rather than exact. As a consequence, flow estimates obtained from recorded water levels at a gauging station are probably at best only accurate to within ±20%, even when made by an experienced hydraulic engineer.

Because of the generally short periods of record at gauging stations (30–60 years), there is an added degree of uncertainty in the estimates of peak flow obtained from a flood- frequency study, particularly in the medium- to large-flood range. These uncertainties are a statistical characteristic of the method of analysis or the short period of record, and are additional to inaccuracies arising from rating curves. Long periods of continuous stream flow monitoring can reduce the uncertainty of flood frequency analyses and enable these to be updated over time as more information becomes available. The implications of the uncertainty in design flood estimates need to be assessed in the flood study.

Figure 11.2 shows the rating curve for a stream gauging station. Once a rating curve has been defined, the peak annual (or water year) flood levels recorded at a gauging station can be converted to peak annual flows and a frequency analysis of the flows can be undertaken.

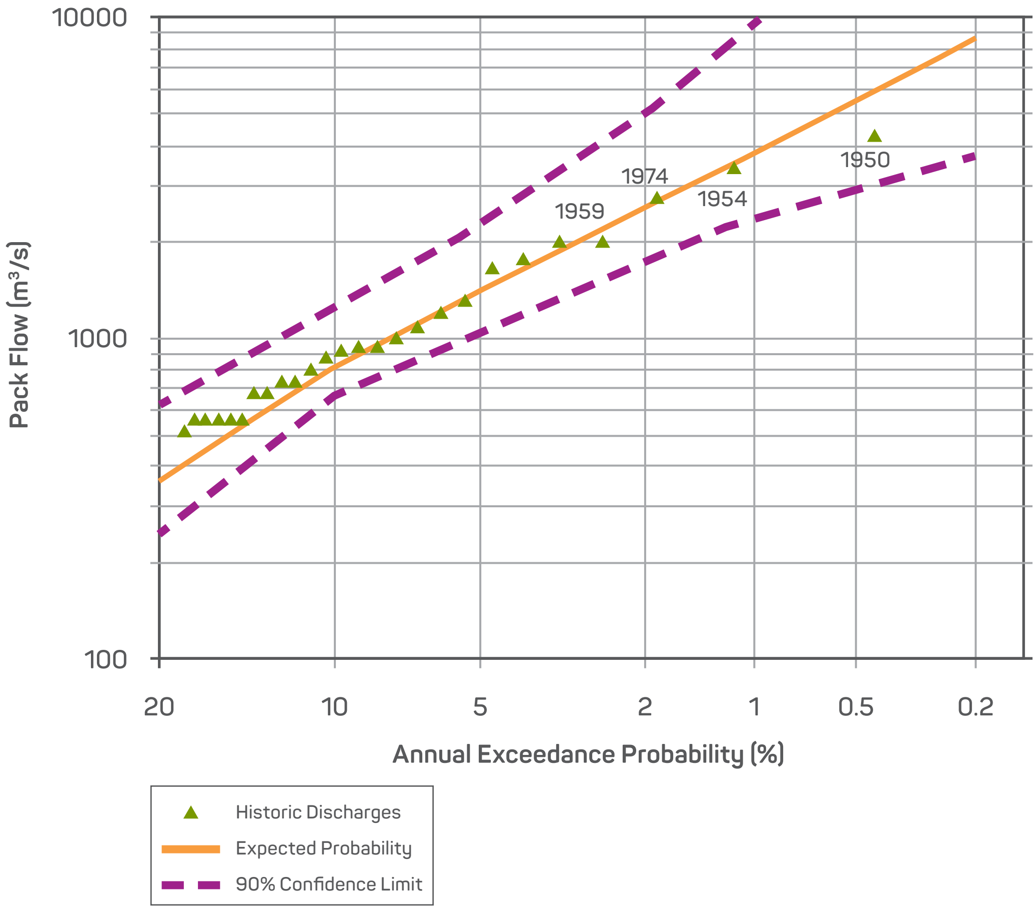


Figure 11.3 Typical frequency distribution for a stream gauging station

Figure 11.3 shows a frequency distribution and 90% confidence limits for a stream gauging station. Based on statistical theory, these limits define the range in which the actual frequency curve is expected to lie for a selected level of probability. In this case, there is a 90% chance that the actual flood frequency curve lies within the range defined by the confidence limits. The range is narrowest about the mean annual peak flow (approximately 40% AEP), and increases in width with increasing flow and decreasing frequency of occurrence. Confidence limits will be wider where less information is available. The implications of this increase in uncertainty in estimates of peak flows, particularly events used in a flood study, needs to be considered.

In the absence of recorded peak flood flow estimates at a stream gauging station close to the point of interest, regional methods of flood frequency analysis are generally followed. The latest version of Australian Rainfall & Runoff (Engineers Australia) recommends a range of methods that vary with location and catchment size. The uncertainty of design estimates based on regional methods is generally greater than those based on recorded flood data and the implications of this uncertainty need to be assessed in the flood study.

Additional studies enable the hydrographs associated with these peak flows to be estimated.

11.3.2 Rainfall-runoff routing models

A rainfall-runoff routing model is a mathematical representation of the various catchment processes that transform rainfall into runoff. With these models, a rainfall event defined in space and time is used as input data for the model, which then simulates the associated flow hydrograph at locations of interest in the catchment. There are generally two methods of applying rainfall-runoff routing models. The first uses recorded flood and rainfall event data, and is generally used in flood forecasting and in calibrating and validating rainfall-runoff routing models for use in probabilistic applications. The second application is used to determine flood hydrographs for different AEPs. It involves the use of probabilistic design model parameters and design rainfall (spatially and temporally) to simulate a design flood hydrograph at the catchment outlet or at nominated locations on the catchment.

The two main catchment processes that affect the size and shape of the flow hydrograph are rainfall losses and storage routing effects as runoff travels down the catchment. Rainfall-runoff models can only represent these processes approximately. To obtain reliable estimates of flow hydrographs, it is necessary to calibrate the model parameters to a large flood event with available recorded rainfall and flow data.

The data requirements for calibrating rainfall-runoff routing models are considerably more intensive than for flood-frequency analyses. Total flow hydrographs at the catchment outlet, and data for the corresponding rainfall event defined spatially and temporally across the catchment, are required. In the absence of these data, regional parameters for the rainfall-runoff routing models are generally followed.

The calibration process consists of adjusting rainfall loss rates and routing parameters to obtain agreement between the recorded and simulated hydrographs. This can be a lengthy and difficult process, and should be undertaken for a number of large flood events. The calibrated model should be validated against several other recorded flood events to ensure that the model acceptably reproduces recorded results. The calibrated model parameters will vary with the flood event being assessed, so some form of weighting process is required to estimate model parameters for use in design flood estimation applications. The uncertainty associated with this procedure needs to be recognised and any implications assessed as part of the study. Once calibrated and verified, the rainfall-runoff routing model and adopted parameters can be used to predict the design flow hydrographs associated with the design rainfall events of known AEPs.

Design rainfall data throughout Australia are available in the form of intensity– frequency–duration data (spatial) and design temporal patterns (time). With these data, it is possible to estimate the time-varying intensity of rainfall (in millimetres/hour [mm/h]) for a given duration of storm (in hours) with a specified AEP for any given location in Australia, using the latest version of Australian Rainfall & Runoff (Engineers Australia). Design rainfall data are fed into the rainfall-runoff model, rainfall losses are abstracted and the associated design flow hydrograph is simulated. The use of these models in estimating design flood hydrographs involves a number of assumptions and a relatively large degree of uncertainty. The implications of this uncertainty need to be assessed by an experienced practitioner. Once calibrated, rainfall-runoff routing models also provide a convenient way of simulating the effects of dams, retarding basins and reservoirs within catchments. They can also provide advice on the propagation and timing of events.

11.3.3 Comparison of methods

The overall objectives set for the flood study, the size and nature of the catchment being investigated, and the availability of recorded flood and rainfall data on the catchment will determine which method or combination of methods (e.g. flood frequency or rainfall- runoff models) will provide the desired outcomes.

In general, rainfall records are longer, more extensive and more accurate than stream flow records. Hence, rainfall data have a greater degree of statistical reliability than flow data. Consequently, it is usual to use rainfall-based techniques, such as rainfall-runoff routing models, to estimate design peak flows and flood hydrographs for less-frequent events. On the other hand, as long as recorded flood data are available at a representative stream gauging station and that the period of record is sufficiently long, a flood frequency analysis generally provides a more accurate estimate of design peak flows for the more frequent events. As the flood study requires design flood estimates for the full range of flood events, up to and including the PMF, a combination of methods generally provides estimates of both design peak flow and flood hydrographs. These procedures are presented in the latest version of Australian Rainfall & Runoff (Engineers Australia).

For the larger catchments, where sufficient data exist to carry out a flood-frequency analysis or use a regional flood-frequency method, and the use of rainfall-runoff routing models is not practicable, recorded flood hydrographs are generally used to estimate design flood hydrographs at points of interest. This involves scaling recorded flood hydrographs until the resulting peak flow and – occasionally, the flood volume – are equal to the corresponding estimates from the frequency analysis.

Irrespective of the method or combination of methods used to estimate design peak flows or hydrographs, the implications of the uncertainty of the methods and estimates need to be assessed as part of the study. These can be tested by undertaking and reporting on sensitivity analysis of key parameters.

11.4 Hydraulic analysis

Once the design flow hydrograph or design peak flows for the flood events of interest are determined, variations in water levels, velocities, depths and the extent of flooding can be determined for the study area. This requires a hydraulic model.

Hydraulic models are of two main types – numerical and physical. In numerical models, a computer is used to solve equations representing the flow of water down a river system, and to predict water levels and velocities. Numerical models do this by solving fundamental equations based on conservation of mass, and momentum or energy. A physical model is a scaled version of the floodplain being studied. Before describing numerical and physical models, the various factors that affect water levels and velocities are briefly discussed.

11.4.1 Water levels and velocities

The water level and velocity associated with a flow of water past a given point on a river system depends upon a range of factors. Water flows from one place to another because of a difference in energy levels. In broad terms, the slope of the river channel defines the available energy. A greater slope results in more available gravitational energy to cause water to flow faster downstream. Energy is used to overcome frictional resistance from the river channel and floodplain. Smooth surfaces have less frictional resistance, which results in faster and shallower flows compared to rough surfaces. The effects of frictional resistance are also reduced as flow depths increases.

Water level and velocity are not constant. The slope of the river channel changes along its length. Frictional resistance will generally vary across the river and floodplain, and along the river reach. The shape of the channel and floodplain also changes along the length of a river. Because of these variations, the factors that affect water levels and velocities interact in a complicated way. It is further complicated by infrastructure, such as road embankments or bridges, rural and urban development, and any major constrictions along the river system. In the lower reaches of tidal rivers, and in estuaries, the ocean tide level can be of great significance in overall water level estimation. Any rise in sea level will impact upon flooding in lower coastal waterways, because it reduces the available 'air space' for flood storage in waterways and increases downstream levels, whether ocean level or outlet berm height.

11.4.2 Developing numerical hydraulic models

In a numerical hydraulic model, the equations that relate available energy to friction losses and the area and depth of flow are solved on a computer. This process provides estimates of the variations over time in water levels, velocities and extent of flooding. Numerical models vary greatly, from simple backwater flow models to complex two- dimensional (2D) models. Developing an effective model relies on understanding the available topographic data, and how the catchment and floodplain may have changed over time (particularly for calibration and verification against historic events), and information on likely controls on flood behaviour. Model development can also be informed by aerial photography and survey, historical information and field inspections to obtain a general understanding of the expected flood behaviour and model parameters, including loss factors such as spatial variations in frictional resistance or roughness. Published typical values of resistance for different conditions and materials should only be used as a guide, because different models treat resistance slightly differently. Values tend to change between models and even with different grid size.

All of these data are input into the model, which is then ready for calibration. If the downstream end of the model is non-tidal, then a rating curve is used to determine the downstream water level. If the downstream end of the model is a tidal river reach or the sea, it is necessary to incorporate the tidal fluctuations in downstream water levels in the model.

11.4.3 Calibrating and validating numerical hydraulic models

The most common calibration parameter for hydraulic models is surface roughness. The calibration process consists of adjusting model parameters to obtain agreement between simulated flood behaviour and that which has been recorded or observed. First, a flood suitable for calibration purposes is selected. Next, the flood flow is estimated (Section 11.3). Information on flood behaviour and peak levels is sought from long-term residents, newspapers, FME records and other sources, all of which is used as a basis for adjusting parameters to achieve agreement between recorded and simulated water levels in calibration. Once the model is calibrated, it should be validated against several other recorded flood events to ensure that the model acceptably reproduces recorded results.

There are uncertainties in the calibration and validation process. First, the most recent large flood suitable for calibration purposes may have occurred many years ago and catchment conditions may have changed. The number of long-term residents still living in the area will be fewer and time may have clouded their memories of the flood. Calibrating hydraulic models requires both detective work and judgement to uncover facts. Inconsistent information must be identified and discarded, and discrepancies studied and explained. It is essential that the work is undertaken by experienced practitioners. For some floodplains, the lack of calibration data may mean that published parameter values may need to be used.

The latest version of Australian Rainfall & Runoff (Engineers Australia) provides details on the available numerical models, and their applications and limitations. These include one-dimensional (1D), quasi-2D, 2D and three-dimensional (3D) models. In general, 1D and quasi-2D models require the user to define the flow paths that are modelled as a 1D system, with flow paths fixed during computation. In the quasi-2D model, the 1D flow paths are connected by a series of weir or fluvial links to enable the complex nature of flood behaviour to be modelled. In 2D and 3D models, the user does not need to define flow paths, but the data requirements, particularly topographic survey and calibration data, are far greater than for 1D and quasi-2D models. In combination, 1D, quasi-2D and 2D models can provide varying degrees of hydraulic detail, with the 1D or quasi-2D model generally used to model large reaches of the floodplain (particularly if flow is generally linear and the floodplain narrow). They may also be used to coarsely model a larger area than the study area to set boundary conditions for a 2D model, which models the study area in more detail.

CHAPTER 12

Floodplain management study

In a nutshell...

The floodplain management study extends the flood study to increase understanding of the impacts of floods on the existing and future community, and test management options. It provides a basis for informing the development of a management plan to increase community safety through the treatment of existing, future and residual risk. Community engagement is vital to the successful development of the management study. The community should be consulted to allow their concerns, suggestions and comments about management and options to be considered.

The floodplain management study increases the understanding of the impacts of floods on the existing and future community from the flood study. It also provides a basis for the assessment of management options. It needs to be undertaken with the technical rigour to meet the requirements of the floodplain management entity and other agencies with flood risk management roles, and support the development of the management plan. The study may provide improved information on flood risk and its management in its area of interest that can feed into the knowledge hub in a consistent format to facilitate data sharing.

A management study aims to identify, quantify and weigh all relevant issues so that these can be considered in developing a management plan by which the community, as a whole, is better off. A successful management study requires a comprehensive multidisciplinary approach and active public consultation. The study should provide advice on the mix of practical, feasible and economic measures necessary to manage the varying flood hazard to the existing and future community to limit the resultant residual risk to a level acceptable to the community. This advice should be considered in the development of a management plan (Chapter 13).

A management study may be undertaken over the same area of interest as the flood study that precedes it. Alternatively, it may concentrate on one or a number of key locations of interest – for example, individual towns or other areas with significant local risks that need to be addressed by local measures. This may result in one or more narrowly focused management studies done within the overall area of the flood study.

12.1 Study outcomes

A management study needs to:

- review the flood study and other relevant data to understand the current flood risk and consider whether treatment is necessary to reduce this risk
- compile relevant background information on flood impacts, the environment, land use, emergency management planning and socioeconomic matters, and – where relevant – build associated vulnerability models to inform decision making. The methods used for analysis should be justified based upon their reliability and validity to the situation
- review the information in the knowledge hub and the adequacies of management strategies to identify areas where improvements may be necessary in managing risk
- engage with the community to identify options, provide opinions and raise concerns about options so that people's views can be considered in decision making
- identify, assess, compare, make recommendations and report on options to improve risk management for the community. Options should be tested against the current management practice and existing community exposure, which requires an understanding of the social, economic and environmental benefits and costs of options, and their relative benefit and effectiveness in managing risk. The assessment provides a basis for understanding the level of service provided; the feasibility, practicality and cost-effectiveness of different options; and constraints that may inhibit implementation. It also involves understanding where the benefits accrue, the work required to achieve these benefits and the residual risks that remain with options in place

- consider the adaptability of options to the potential impacts of climate change, and advice on adaptability and suitability to any associated changing risk profile
- assess the cumulative impacts of potential future development on flood behaviour, emergency management and associated risk to the existing community.

Undeveloped zonings within statutory planning instrument and specific development proposals can provide a basis for this assessment. Where relevant, strategies to manage cumulative impacts should be assessed

- inform strategic land-use planning on the capability of land to support future development, and the limitations, controls and infrastructure necessary to support the development at an acceptable level of risk, and without exacerbating the flood risk of the existing community
- inform emergency management planning on the limitations to, and constraints on, emergency response and their implications for the capability of undeveloped land to support future development
- make updated information available through the knowledge hub
- make recommendations to consider when developing a floodplain management plan.

12.2 Study outputs

To support these outcomes in Section 12.1, the management study should produce information in digital format. As a minimum, the events for which information is provided should include the defined flood event, several more frequent and a slightly rarer flood, and the probable maximum flood. The information should include:

- a description of existing flood mitigation measures
- flood extent, and flood level information and maps for a range of floods, preferably linked to a relevant flood gauge
- the scale and variation in flood impacts, including the number and types of properties affected, and the potential flood damages
- areas of different flood function (flow conveyance, flood storage, flood fringe)
- breakdown of the floodplain, considering the drivers for hazard (e.g. depth, velocity, velocity and depth, isolation) and their relative severity
- emergency response management limitations, including a breakdown of the floodplain to identify areas with different types and severities of response limitations
- updated information for the knowledge hub – this should include information to assist with emergency management planning, land-use planning, and understanding the climate change impacts and the degree of uncertainty in flood estimates
- sufficient information on viable options to provide an understanding of their capabilities, limitations and interdependencies, costs and feasibility to inform implementation or further investigation.

12.3 Detail of assessment needed

A management study provides a robust basis to assess and compare individual and combinations of treatment options in terms of their effectiveness in managing the flood risk. The development and assessment of treatment options relies upon a detailed understanding of flood behaviour and its impacts, and understanding the benefits, costs and limitations of various management measures. As such, the management study draws together the results of the flood study and data collection to provide a basis for examining the feasibility, effectiveness and limitations of options. It also provides information and tools to inform the robust decision making required to develop a plan.

Detailed management studies are generally undertaken in areas where current management strategies are insufficient to manage flood risk into the future, and investigations are necessary to identify and assess treatment options for risk management. Where there is a community at risk and a management study does not exist, the need for a detailed management study may be due to one or a combination of the following factors:

- the current level of flood risk exposure is considered intolerable and management is necessary to reduce risk to a more tolerable level
- the current level of flood risk may be expected to change significantly due to alteration to land use in the floodplain or catchment, or the impacts of climate change
- where significant demand is anticipated for new development in the floodplain outside existing areas zoned for development within a reasonable planning horizon. The study provides an opportunity to determine flood-related constraints to inform statutory planning to manage the risk to new development areas to within acceptable levels.

A detailed management study may not be necessary if the risk to the existing community is acceptable, the growth in development is limited to within the boundaries of the existing zoned land and the flood risk exposure of new development is being managed by effective development controls. A simple management study could be undertaken to update information for the community, improve the information available for relevant management agencies and inform the development of a management plan.

CHAPTER 13

The floodplain management plan

In a nutshell...

The management plan forms the heart of the study area's flood risk management into the future. The management plans is where decisions are made on how to manage flood risk into the future. It should be developed in consultation with the community and in consideration of relevant legislation, policies and guidance that may influence its implementation and the viability of the various management measures.

The plan generally involves a range of measures to manage existing, future and residual risk, which will vary between different locations in the floodplain. It needs a prioritised implementation strategy, which outlines the commitment to implement, its staging and provides sufficient detail to facilitate implementation. Once a plan has been finalised and adopted, it should be used to update the knowledge hub, and communicated to relevant agencies and the community to update them on the flood threat. The plan needs to be implemented to manage risk, and this implementation monitored. This requires commitment, coordination and communication within government and with the community. This may best be achieved by having a group overseeing implementation, led by the floodplain management entity (FME) and involving relevant agencies.

The management plan should feed into the broader consideration and prioritisation of management options across the whole FME service area.

A management plan provides the vehicle for the FME to make and convey decisions on how it and any partner agencies intend to manage flood risk for the study area. It is prepared in consideration of the investigations and consultation undertaken in the management study. The plan can be relatively simple, depending upon the degree of change necessary to existing management practices to manage flood risk to an acceptable level.

The management plan needs to outline not only what measures are proposed to manage flood risk, but also how they will be implemented. This involves the development of a prioritised implementation strategy, which outlines the commitment necessary to implement the plan, stages implementation and describes measures in sufficient detail to enable them to be taken forward to implementation. The plan should also identify the residual risk remaining after options are implemented and indicate how it will be managed.

A management plan is not a static document but should be kept up to date and implementation monitored by the FME who can in turn use it to update the knowledge hub and inform relevant agencies and the community.

13.1 Developing a successful plan

For a management plan to be fit for purpose, it needs to:

- be consistent with any relevant legislation, policies and guidance material developed by the local, State or Territory, or Australian government
- be effective and efficient in addressing the full range of flood risk to both existing and future development by limiting growth in risk to future development, and outlining practical, feasible and cost-effective measures to reduce risk to existing development to more tolerable levels
- have prioritised actions that can feed into other FME processes – for example, treatment options requiring significant investment should be considered in forward-planning processes for relative priority against other such measures across the FME service area
- be supported, on balance, by the community, which can be facilitated by an inclusive consultation approach that provides the community with an opportunity to provide input. The plan should indicate how the community has been consulted and how community members' concerns were addressed

- have actions that are practical and sustainable in social, economic, environmental and cultural terms in the short and long term. These need to be able to be implemented, operated and maintained considering available resources and support available from government and industry. It is important to identify any significant obstacles to feasible implementation – for example, levees are costly to build, and a long-term operational and maintenance commitment is required to ensure that their design capability is maintained; flood gauges are relatively inexpensive to install, but have a high maintenance-to-capital cost ratio; and community education programs require regular ongoing effort to remind people of the risks they face and the actions they can take to manage them, and to related these issues to new individuals in the community
- have the commitment of the FME and other agencies that may be requested to undertake or assist with plan implementation
- be fully integrated with the mechanisms that will be used in delivery (e.g. statutory planning instruments, development control plans and policies, and forward plans)
- include base information necessary to support funding applications
- consider the need for interim measures while awaiting implementation of the plan, which may include interim development controls while statutory planning instruments are updated or mitigation works are implemented
- outline how implementation of the plan should be monitored and under what guidance
- update the knowledge hub, and use this to make information available to the community and relevant agencies when actions are implemented.

13.2 Developing an implementation strategy

Generally, an entire management plan cannot be implemented immediately. Certain components of the plan can be implemented relatively quickly, such as incorporating flood-related development controls into statutory planning instruments or development control plans or policies. Others are likely to require development approvals, environmental assessments, investigations and designs, and successful funding applications. In cases where implementation is likely to be a drawn-out process, interim measures may need to be instigated before long-term strategies are implemented. These should be incorporated in the management plan.

Consequently, a management plan should include an implementation strategy to outline how it will be delivered. This strategy should outline:

- the relative priority of measures, which should consider their relative benefits and costs, and ease of implementation. Generally, land-use planning changes are low cost and can be relatively straightforward to implement
- the organisation responsible for implementation and their agreement to implement
- the timeframe for delivery (including any associated staging)
- potential funding sourced
- the way in which options can be delivered, the limitations or inhibitors that may exist to delivery, and how these constraints are to be addressed – for instance, how options will be funded and any associated assumptions, the approvals necessary to enable implementation (development, environmental and cultural assessments and approvals) and relevant legislation and policies that must be considered in implementing the option
- the social, economic and environmental benefits and costs of implementation to the community
- any specific ramifications to the community if these measures are not delivered
- any interdependence between options (e.g. works to offset any adverse impacts of other works instituted to benefit a portion of the community)
- any interim measures necessary before implementing a portion of, or the entire, management plan
- whether individual options trigger the need to update the knowledge hub, and to activate the communication plan or any other portion of it.

13.3 Implementing the plan

The process of reducing flood risk begins with implementing the management plan. The plan is not static, but will change as the project is implemented, and will therefore need to be reviewed and updated. Implementation is generally undertaken during an extended period through a series of stages.

Implementation of flood mitigation works or flood warning system upgrades will often involve several partners, and require agreement to be reached on who owns, operates and maintains the assets (e.g. levees or river level gauges). Processes need to be completed to acquire land, undertake cultural and heritage surveys and environmental assessments, obtain any necessary permits, and consult the community.

Project management tasks associated with design and construction of the works also need to be undertaken. Implementation of the plan may be assisted by:

- the knowledge hub, and updating it with current information on flood risk exposure and its management across the FME (these should be updated when the plan is completed, and at stages during implementation when risks or response change significantly)
- communication plans to ensure the community and agencies are kept up to date on the flood threat and how to respond to it. It is particularly important that government and the community know when measures are implemented that may change how they need to manage or react to a flood threat
- community education programs to inform and remind the community of the flood threat and actions they can undertake in preparing for and responding to floods. These programs should aim to improve community resilience to flood risk and the ability of community members to properly fulfil their roles in emergency preparation and response
- strategic land-use planning, and supporting development and building controls that are based on the best available information. These may need to be updated with plan implementation, and amendment processes should be done according to relevant legislation, and State or Territory direction and policy guidance
- mitigation and forward-works programs that facilitate implementation of works to reduce the flood risk to the portion of the community who are benefiting from the works
- acquisition plans to purchase properties or attain easements for mitigation works, or as part of flow conveyance path clearance or other mitigation schemes
- flood emergency management plans developed by the responsible agency in accordance with relevant legislation, policy guidance and direction of government; such plans need to consider the flood threat, community exposure, and any constraints on warning or evacuation
- recovery plans developed by the responsible agency; such plans need to outline actions that aid the community recover from a flood event.

13.4 Updating and reviewing the floodplain management plan

A plan is never truly finished. It may be adopted by the relevant committee of decision makers at a point in time as the agreed way forward to manage risk, but social and economic circumstances and flood conditions can all change. Therefore, implementation needs to be monitored, and plans and implementation strategies reviewed every five years to ensure that they remain appropriate. Where necessary, a plan should be revised to reflect changes or updates, and deficiencies, because the situation may change with recent flood events. A range of circumstances may trigger the need to review a management plan sooner:

- if the needs of the community change significantly
- when impediments to implementation exist that may warrant a review
- when significant changes in future land-use trends, outside those considered in the plan, are proposed
- after significant flood events, which provide lessons to consider in management
- where new technologies change the utility of different management options or produce new ones
- where options previously thought to be viable may prove not to be after more detailed investigation
- where management options, such as mitigation works, are implemented
- where there are significant changes to the relevant emergency management plan.

Each management review should account for changes across the full range of issues originally addressed and consider any associated emergent issues.

SECTION D

ADDITIONAL MATERIALS

CHAPTER 14

Terminology

In a nutshell

The acronyms and glossary of relevant terms is provided below. If using this handbook within their jurisdiction, States and Territories may wish to provide a list of jurisdictional terms where they differ from this handbook.

14.1 Acronyms

AAD	average annual damage
AEP	annual exceedance probability
AHD	Australian height datum
ARI	average recurrence interval
DFE	defined flood event
FME	floodplain management entity
FPL	flood planning level
KPI	key performance indicator
PMF	probable maximum flood
PMP	Probable maximum precipitation

14.2 Glossary

Annual exceedance probability (AEP)

The likelihood of the occurrence of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood flow of 500 m3/s has an AEP of 5%, it means that there is a 5% chance (that is, a one-in-20 chance) of a flow of 500 m^3/s or larger occurring in any one year (see also *average recurrence interval, flood risk, likelihood of occurrence, probability*).

Astronomical tide

The variation in sea level caused by the gravitational effects of (principally) the moon and sun. It includes highest and lowest astronomical tides (HAT and LAT) occur when relative alignment and distance of the sun and moon from the earth are 'optimal'. Water levels approach to within 20 cm of HAT and LAT twice per year around mid-summer and mid-winter 'king tides'.

Australian height datum (AHD)

A common national survey height datum as a reference level for defining reduced levels; 0.0 m AHD corresponds approximately to sea level.

Average annual damage (AAD)

Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood-prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time. If the damage associated with various annual events is plotted against their probability of occurrence, the AAD is equal to the area under the consequence–probability curve. AAD provides a basis for comparing the economic effectiveness of different management measures (i.e. their ability to reduce the AAD).

Average recurrence interval (ARI)

A statistical estimate of the average number of years between the occurrence of a flood of a given size or larger than the selected event. For example, floods with a flow as great as or greater than the 20-year ARI (5% AEP) flood event will occur, on average, once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event (see also *annual exceedance probability*).

Catchment

The area of land draining to a particular site. It is related to a specific location, and includes the catchment of the main waterway as well as any tributary streams.

Catchment flooding

Flooding due to prolonged or intense rainfall (e.g. severe thunderstorms, monsoonal rains in the tropics, tropical cyclones). Types of catchment flooding include riverine, local overland and groundwater flooding.

Chance

The likelihood of something happening that will have beneficial consequences (e.g. the chance of a win in a lottery). Chance is often thought of as the 'upside of a gamble' (Rowe 1990) (see also *risk*).

Coastal flooding

Flooding due to tidal or storm-driven coastal events, including storm surges in lower coastal waterways. This can be exacerbated by wind-wave generation from storm events.

Consent authority

The authority or agency with the legislative power to determine the outcome of development and building applications.

Consequence

The outcome of an event or situation affecting objectives, expressed qualitatively or quantitatively. Consequences can be adverse (e.g. death or injury to people, damage to property and disruption of the community) or beneficial.

Defined flood event (DFE)

The flood event selected for the management of flood hazard to new development. This is generally determined in floodplain management studies and incorporated in floodplain management plans. Selection of DFEs should be based on an understanding of flood behaviour, and the associated likelihood and consequences of flooding. It should also take into account the social, economic, environmental and cultural consequences associated with floods of different severities. Different DFEs may be chosen for the basis for reducing flood risk to different types of development. DFEs do not define the extent of the floodplain, which is defined by the PMF (see also *design flood*, *floodplain* and *probable maximum flood*).

Design flood

The flood event selected for the treatment of existing risk through the implementation of structural mitigation works such as levees. It is the flood event for which the impacts on the community are designed to be limited by the mitigation work. For example, a levee may be designed to exclude a 2% AEP flood, which means that floods rarer than this may breech the structure and impact upon the protected area. In this case, the 2% AEP flood would not equate to the crest level of the levee, because this generally has a freeboard allowance, but it may be the level of the spillway to allow for controlled levee overtopping (see also *annual exceedance probability*, *defined flood event*, *floodplain*, *freeboard* and *probable maximum flood*).

Development

Development may be defined in jurisdictional legislation or regulation. This may include erecting a building or carrying out of work, including the placement of fill; the use of land, or a building or work; or the subdivision of land.

Infill development refers to the development of vacant blocks of land within an existing subdivision that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development.

New development is intensification of use with development of a completely different nature to that associated with the former land use or zoning (e.g. the urban subdivision of an area previously used for rural purposes). New developments generally involve rezoning, and associated consents and approvals. It may require major extensions of existing urban services, such as roads, water supply, sewerage and electric power.

Redevelopment refers to rebuilding in an existing developed area. For example, as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either rezoning or major extensions to urban services.

Ecologically sustainable development

Using, conserving and improving natural resources so that ecological processes on which life depends are maintained, and the total quality of life – now and in the future – can be maintained or increased.

Effective warning time

The effective warning time available to a flood-prone community is equal to the time between the delivery of an official warning to prepare for imminent flooding and the loss of evacuation routes due to flooding. The effective warning time is typically used for people to self-evacuate, to move farm equipment, move stock, raise furniture, and transport their possessions.

Existing flood risk

The risk a community is exposed to as a result of its location on the floodplain.

Flash flood

Flood that is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. It is generally not possible to issue detailed flood warnings for flash flooding. However, generalised warnings may be possible. It is often defined as flooding that peaks within six hours of the causative rain.

Flood

Flooding is a natural phenomenon that occurs when water covers land that is normally dry. It may result from coastal or catchment flooding, or a combination of both (see also *catchment flooding* and *coastal flooding*).

Flood awareness

An appreciation of the likely effects of flooding, and a knowledge of the relevant flood warning, response and evacuation procedures. In communities with a high degree of flood awareness, the response to flood warnings is prompt and effective. In communities with a low degree of flood awareness, flood warnings are liable to be ignored or misunderstood, and residents are often confused about what they should do, when to evacuate, what to take with them and where it should be taken.

Flood damage

The tangible (direct and indirect) and intangible costs (financial, opportunity costs, clean-up) of flooding. Tangible costs are quantified in monetary terms (e.g. damage to goods and possessions, loss of income or services in the flood aftermath). Intangible damages are difficult to quantify in monetary terms and include the increased levels of physical, emotional and psychological health problems suffered by flood-affected people that are attributed to a flooding episode.

Flood education

Education that raises awareness of the flood problem, to help individuals understand how to manage themselves and their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.

Flood emergency management plan

A step-by-step sequence of previously agreed roles, responsibilities, functions, actions and management arrangements for the conduct of a single or series of connected emergency operations. The objective is to ensure a coordinated response by all agencies having responsibilities and functions in emergencies.

Flood emergency management

Emergency management is a range of measures to manage risks to communities and the environment. In the flood context, it may include measures to prevent, prepare for, respond to and recover from flooding.

Flood fringe areas

The part of the floodplain where development could be permitted, provided the development is compatible with flood hazard and appropriate building measures to provide an adequate level of flood protection to the development. This is the remaining area affected by flooding after flow conveyance paths and flood storage areas have been defined for a particular event (see also *flow conveyance areas* and *flood storage areas*).

Flood hazard

Potential loss of life, injury and economic loss caused by future flood events. The degree of hazard varies with the severity of flooding and is affected by flood behaviour (extent, depth, velocity, isolation, rate of rise of floodwaters, duration), topography and emergency management.

Floodplain

An area of land that is subject to inundation by floods up to and including the probable maximum flood event – that is, flood-prone land.

Floodplain management entity (FME)

The authority or agency with the primary responsibility for directly managing flood risk at a local level.

Floodplain management plan

A management plan developed in accordance with the principles and guidelines in this handbook, usually includes both written and diagrammatic information describing how particular areas of flood-prone land are to be used and managed to achieve defined objectives. It outlines the recommended ways to manage the flood risk associated with the use of the floodplain for various purposes. It represents the considered opinion of the local community and the floodplain management entity on how best to manage the floodplain, including consideration of flood risk in strategic land-use planning to facilitate development of the community.

It fosters flood warning, response, evacuation, clean-up and recovery in the onset and aftermath of a flood, and suggests an organisational structure for the integrated management for existing, future and residual flood risks. Plans need to be reviewed regularly to assess progress and to consider the consequences of any changed circumstances that have arisen since the last review.

Flood planning area

The area of land below the flood planning level, and is thus subject to flood-related development controls.

Flood planning level (FPL)

The FPL is a combination of the defined flood levels (derived from significant historical flood events or floods of specific annual exceedance probabilities) and freeboards selected for floodplain management purposes, as determined in management studies and incorporated in management plans.

Flood-prone land

Land susceptible to flooding by the probably maximum flood event. Flood-prone land is synonymous with the floodplain. Floodplain management plans should encompass all flood-prone land rather than being restricted to areas affected by defined flood events.

Flood proofing of buildings

A combination of measures incorporated in the design, construction and alteration of individual buildings or structures that are subject to flooding, to reduce structural damage and potentially, in some cases, reduce contents damage.

Flood readiness

An ability to react within the effective warning time (see also *flood awareness* and *flood education*).

Flood risk

The potential risk of flooding to people, their social setting, and their built and natural environment. The degree of risk varies with circumstances across the full range of floods. Flood risk is divided into three types – existing, future and residual.

Flood severity

A qualitative indication of the 'size' of a flood and its hazard potential. Severity varies inversely with likelihood of occurrence (i.e. the greater the likelihood of occurrence, the more frequently an event will occur, but the less severe it will be). Reference is often made to major, moderate and minor flooding (see also *minor, moderate and major flooding*).

Flood storage areas

The parts of the floodplain that are important for temporary storage of floodwaters during a flood passage. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas (see also *flow conveyance areas* and *flood fringe areas*).

Flood study

A comprehensive technical investigation of flood behaviour. It defines the nature of flood hazard across the floodplain by providing information on the extent, level and velocity of floodwaters, and on the distribution of flood flows. The flood study forms the basis for subsequent management studies and needs to take into account a full range of flood events up to and including the probable maximum flood.

Flow

The rate of flow of water measured in volume per unit time – for example, cubic metres per second (m^3/s). Flow is different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).

Flow conveyance areas

Those areas of the floodplain where a significant flow of water occurs during floods. They are often aligned with naturally defined channels. Flow conveyance paths are areas that, even if only partially blocked, would cause a significant redistribution of flood flow or a significant increase in flood levels. They are often, but not necessarily, areas of deeper flow or areas where higher velocities occur, and can also include areas where significant storage of floodwater occurs.

Each flood has a flow conveyance area, and the extent and flood behaviour within flow conveyance areas may change with flood severity. This is because areas that are benign for small floods may experience much greater and more hazardous flows during larger floods (see also *flood fringe areas* and *flood storage areas*).

Freeboard

The height above the DFE or design flood used, in consideration of local and design factors, to provide reasonable certainty that the risk exposure selected in deciding on a particular DFE or design flood is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels and so on. Freeboard compensates for a range of factors, including wave action, localised hydraulic behaviour and levee settlement, all of which increase water levels or reduce the level of protection provided by levees. Freeboard should not be relied upon to provide protection for flood events larger than the relevant defined flood event of a design flood.

Freeboard is included in the flood planning level and therefore used in the derivation of the flood planning area (see also *defined flood event, design flood, flood planning area* and *flood planning level*).

Frequency

The measure of likelihood expressed as the number of occurrences of a specified event in a given time. For example, the frequency of occurrence of a 20% annual exceedance probability or five-year average recurrence interval flood event is once every five years on average (see also *annual exceedance probability, annual recurrence interval, likelihood* and *probability*).

Future flood risk

The risk that new development within a community is exposed to as a result of developing on the floodplain.

Gauge height

The height of a flood level at a particular gauge site related to a specified datum. The datum may or may not be the AHD (see also *Australian height datum*).

Habitable room

In a residential situation, a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom. In an industrial or commercial situation, it refers to an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.

Hazard

A source of potential harm or a situation with a potential to cause loss. In relation to this handbook, the hazard is flooding, which has the potential to cause damage to the community.

Hydraulics

The study of water flow in waterways; in particular, the evaluation of flow parameters such as water level, extent and velocity.

Hydrograph

A graph that shows how the flow or stage (flood level) at any particular location varies with time during a flood.

Hydrologic analysis

The study of the rainfall and runoff process, including the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.

Intolerable risk

A risk that, following understanding of the likelihood and consequences of flooding, is so high that it requires consideration of implementation of treatments or actions to improve understanding, avoid, transfer or reduce the risk.

Life-cycle costing

All of the costs associated with the project from the cradle to the grave. This usually includes investigation, design, construction, monitoring, maintenance, asset and performance management and, in some cases, decommissioning of a management measure.

Likelihood

A qualitative description of probability and frequency (see also *frequency* and *probability*).

Likelihood of occurrence

The likelihood that a specified event will occur. (With respect to flooding, see also *annual exceedance probability* and *average recurrence interval*).

Local overland flooding

Inundation by local runoff on its way to a waterway, rather than overbank flow from a stream, river, estuary, lake or dam. Can be considered synonymous with stormwater flooding.

Loss

Any negative consequence or adverse effect, financial or otherwise.

Mathematical and computer models

The mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.

Merit approach

The merit approach weighs social, economic, ecological and cultural impacts of land-use options for different flood-prone areas, together with flood damage, hazard and behaviour implications, and environmental protection and wellbeing of rivers and floodplains. This approach operates at two levels. At the strategic level, it allows for the consideration of flood hazard and associated social, economic, ecological and cultural issues in formulating statutory planning instruments, and development control plans and policies. At a site-specific level, it involves consideration of the best way of developing land in consideration of the zonings in a statutory planning instruments, and development control plans and policies.

Minor, moderate and major flooding

These terms are often used in flood warnings to give a general indication of the types of problems expected with a flood:

Probability

A statistical measure of the expected chance of flooding. It is the likelihood of a specific outcome, as measured by the ratio of specific outcomes to the total number of possible outcomes.

Probability is expressed as a number between zero and unity, zero indicating an impossible outcome and unity indicating an outcome that is certain. Probabilities are commonly expressed in terms of percentage. For example, the probability of 'throwing a six' on a single roll of a die is one in six, or 0.167 or 16.7% (see also *annual exceedance probability*).

Probable maximum flood (PMF)

The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from PMP and, where applicable, snow melt, coupled with the worst flood-producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood-prone land – that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event, should be addressed in a floodplain risk management study.

Probable maximum precipitation (PMP)

The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given-size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (WMO 1986). It is the primary input to probable maximum flood estimation.

Rainfall intensity

The rate at which rain falls, typically measured in millimetres per hour (mm/h). Rainfall intensity varies throughout a storm in accordance with the temporal pattern of the storm (see also *temporal pattern*).

Residual flood risk

The risk a community is exposed to that is not being remedied through established risk treatment processes. In simple terms, for a community, it is the total risk to that community, less any measure in place to reduce that risk.

The risk a community is exposed to after treatment measures have been implemented. For a town protected by a levee, the residual flood risk is the consequences of the levee being overtopped by floods larger than the design flood. For an area where flood risk is managed by land-use planning controls, the residual flood risk is the risk associated with the consequences of floods larger than the DFE on the community.

Risk

'The effect of uncertainty on objectives' (ISO31000:2009). NOTE 4 of the definition in ISO31000:2009 also states that 'risk is often expressed in terms of a combination of the consequences of an event (including changes in circumstances) and the associated likelihood of occurrence'. Risk is based upon the consideration of the consequences of the full range of flood behaviour on communities and their social settings, and the natural and built environment (see also *likelihood* and *consequence*).

Risk analysis

The systematic use of available information to determine how often specified (flood) events occur and the magnitude of their likely consequences. Flood risk analysis is normally undertaken as part of a floodplain management study, and involves an assessment of flood levels and hazard associated with a range of flood events (see also *flood study*).

Risk management

The systematic application of management policies, procedures and practices to the tasks of identifying, analysing, assessing, treating and monitoring flood risk. Flood risk management is undertaken as part of a floodplain management plan. The floodplain management plan reflects the adopted means of managing flood risk (see also *floodplain management plan*).

Riverine flooding

Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam. Riverine flooding generally excludes watercourses constructed with pipes or artificial channels considered as stormwater channels.

Runoff

The amount of rainfall that drains into the surface drainage network to become stream flow; also known as rainfall excess.

Stage

Equivalent to water level. Both stage and water level are measured with reference to a specified datum (e.g. the Australian height datum).

Storm surge

The increases in coastal water levels above predicted astronomical tide level (i.e. tidal anomaly) resulting from a range of location dependent factors including the inverted barometer effect, wind and wave set-up and astronomical tidal waves, together with any other factors that increase tidal water level (see also *astronomical tide, wind set-up* and *wave set-up*).

Stormwater flooding

Is inundation by local runoff caused by heavier than usual rainfall. It can be caused by local runoff exceeding the capacity of an urban stormwater drainage systems, flow overland on the way to waterways or by the backwater effects of mainstream flooding causing urban stormwater drainage systems to overflow (see also *local overland flooding*).

Temporal pattern

The variation of rainfall intensity with time during a rainfall event.

Tidal anomaly

The difference between recorded storm surge levels and predicted astronomical tide level.

Treatment options

The measures that might be feasible for the treatment of existing, future and residual flood risk at particular locations within the floodplain. Preparation of a treatment plan requires a detailed evaluation of floodplain management options (see also *floodplain management plan*).

Velocity of floodwater

The speed of floodwaters, measured in metres per second (m/s).

Vulnerability

The degree of susceptibility and resilience of a community, its social setting, and the natural and built environments to flood hazards. Vulnerability is assessed in terms of ability of the community and environment to anticipate, cope and recover from flood events. Flood awareness is an important indicator of vulnerability (see also *flood awareness*).

Wave set-up

The increase in water levels in coastal waters (within the breaker zone) caused by waves transporting water shorewards. The zone of wave set-up against the shore is balanced by a zone of wave 'set-down' (i.e. reduced water levels) seawards of the breaker zone. Wave set-ups of 2–4 m could occur during tropical cyclones.

Wind set-up

The increase in water levels in coastal waters caused by the wind driving the water shorewards and 'piling it up' against the shore. Wind set-up can be as high as 10 m in an extreme case, and often exceeds 2–3 m in typical tropical cyclones.

CHAPTER 15

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