Flood Risk Management Committee Handbook

A guide for committee members

Published by:

Department of Planning Industry and Environment
59 Goulburn Street, Sydney NSW 2000
PO Box A290, Sydney South NSW 1232
Phone: +61 2 9995 5000 (switchboard)
Phone: 1300 361 967 (DPIE and national parks enquiries)
TTY users: phone 133 677, then ask for 1300 361 967
Speak and listen users: phone 1300 555 727, then ask for 1300 361 967
Email: info@environment.nsw.gov.au
Website: www.environment.nsw.gov.au

Report pollution and environmental incidents
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Contents

List of tables

List of figures

1. WELCOME

Enjoy being part of your flood risk management committee. Your input into the flood risk management process is valuable, and it is hoped that it will also be a rewarding personal experience.

This handbook has been prepared by the NSW Department of Planning, Industry and Environment (DPIE)[1] to provide committee members with a basic understanding of flood risk management in NSW.

The handbook explains some of the key areas of flood risk management, such as:

- what is flood risk and what is involved in managing flood risk (Section 2)
- the flood risk management framework, principles, aims and the various responsibilities (Section 3)
- some of the technical procedures (Section 4), and
- some of the key options in managing flood risk and how they are evaluated (Section 5).

The handbook can be used as a quick reference guide to the issues that may arise during committee meetings.

Should you have any questions about flood risk management, do not hesitate to ask the relevant Council staff, DPIE or other State Government representatives.

The NSW Government's Floodplain Development Manual and supporting publications provide advice to local councils on how to most effectively understand and manage their flood risk. These can be viewed and/or downloaded from https://www.environment.nsw.gov.au/topics/water/floodplains/floodplain-manual and https://www.environment.nsw.gov.au/topics/water/floodplains/floodplain-guidelines.

Definitions and abbreviations used in this guide have the same meaning as those in the NSW Government's Floodplain Development Manual.

Note

[1] The Department of Planning Industry and Environment (DPIE) was formerly the Office of Environment and Heritage (OEH) up until 30 June 2019. References to DPIE documents may relate to documents labelled OEH.

2. MANAGING FLOOD RISK IN NSW

2.1 What is flooding and what causes it?

Flooding is a natural phenomenon that occurs when water covers land which would normally be dry. Floods generally come from catchment flooding due to prolonged or heavy rainfall (severe thunderstorms, tropical cyclones, monsoonal rains in the tropics and east coast lows) or coastal inundation or a combination of these. Catchment flooding may result in flooding from water leaving waterways (riverine flooding) or from water on the way to waterways (overland flooding). In coastal areas, flooding may also be influenced by water levels in the oceans, tides as well as the same rainfall events that result in flooding.

Floods vary greatly in size and frequency. Small floods may cause local nuisance flooding in an area each year, or more regularly. Larger floods causing significant community impacts may occur at the same location a few times in an average lifetime, or in some cases, not at all.

Studies under the Program generally look at larger floods. They will look at what happened in historical floods but also consider what may happen when floods larger than historical floods and outside the experience of the community occur. It is important to understand the potential impacts so that ways to manage these can be considered. Studies will also consider extreme floods to help understand the upper limit of potential impacts as this is important to understand in emergency management.

2.2 What is Flood Risk?

A flood event can create dangerous or damaging conditions on the floodplain. These hazardous conditions can exist whether or not there are people, infrastructure or assets in the floodplain.

It is the human interaction with a flood that results in a flood risk to the community. Flooding can affect the health and safety of individuals and communities living in the floodplain. It can also affect the built environment and other interests that support them.

Floods can be fatal, cause significant damage to public and private infrastructure and utilities, and have devastating impacts on communities that can require extended recovery time. They can cause considerable stress and concern in the community and on average, floods in New South Wales cause damage well in excess of $150 million a year.

Flood risk involves a combination of both the likelihood that a flood event causes a consequence to the community and the scale of the consequences of that event when it occurs. 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 (Figure 1). For example, a frequent storm likely to flood an area but only results in minor consequences is of low risk, whereas a frequent storm likely to flood an area that results in significant consequences would be a high risk.

Figure 1 Risk Triangle

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

- Existing flood risk – risk associated with the existing development in the floodplain. This can be limited by mitigation actions
- Future flood risk – risk associated with the future development of the floodplain. This can be limited by considering flooding when deciding where and how to develop within the floodplain
- Continuing flood risk – the risk remaining in both existing and future development areas, after all practical and justifiable management measures such as works, land-use planning, and development controls are implemented.

2.3 What is Flood Risk Management?

Flood risk management (FRM) is the management of flood risk to both existing and future people and property in the floodplain.

Effective consideration of flood risk requires both an understanding of the impacts of floods and the ways that it can practically be managed at a local level.

Flood risk is managed in NSW through the development of a FRM framework and undertaking studies through the FRM process. These are discussed in Section 3.

For more information on the general benefits of undertaking FRM refer to videos developed by Gosford City Council, Part A (before FRM) and Part C (after FRM).

3. FLOOD RISK MANAGEMENT FRAMEWORK

3.1 Background

To address the community's concerns with flooding, the State Government released the Flood Prone Land Policy (the Policy) in 1984 with the primary objective of reducing the impact of flooding and flood liability on individual owners and occupiers, and to reduce private and public losses resulting from flooding. The Policy has since been updated but its primary objective remains the same.

To support delivery of the Policy, the State Government released the first NSW Government Floodplain Development Manual in 1986 which provides councils with advice on a recommended framework and approach to better understand and manage their flood risk.

The 1986 Manual and Policy have since been updated with the gazetted 2005 Floodplain Development Manual (the Manual) and incorporates the Policy. A suite of guidelines also support the implementation of the Policy and Manual.

Councils can apply for subsidised funding under the State Floodplain Management Program (the Program) managed by DPIE to develop and implement FRM plans to manage their flood risk in accordance with the Policy and Manual.

The Manual is currently being reviewed and updates are available from DPIE's representative on the committee. When complete, the updated Manual will be available on the relevant government website. Supporting publications are regularly reviewed and updated and made available through the relevant government web page. During the update of the Manual some of the information or diagrams provided in this document may be slightly different than in the Manual.

3.2 Responsibilities in Flood Risk Management

Managing flood risk to the community requires cooperation across all levels of government, and between the government and non-government sector. The National Strategy for Disaster Resilience outlines that flood resilience is a shared responsibility between government and the community.

FRM 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.

3.2.1 Government

In NSW, FRM is a partnership between all levels of government with local councils primarily responsible in their local government area (Table 1). Additional details on key local, state and federal government roles are provided below.

All councils are strongly encouraged to call on the local community and state government agencies to assist them with this responsibility. This is best achieved by the establishment of a management committee and technical working group (Section 3.3).

Table 1 Government Roles and Responsibilities

Local Government	State Government	Federal Government
Flood risk management, land-use planning, development and infrastructure provision and maintenance	Leading, monitoring and maintaining legislative, policy and administrative framework for flood risk management.	
	Supporting management of flood risk by councils.	
	Supporting effective land-use planning, and development and building controls.	
	Technical and financial support to councils for studies and infrastructure under the management process	Financial support to councils under the management process (via the state government)
Supporting flood emergency management	Lead flood emergency management planning	
Local flood recovery	Leadership of regional and statewide disaster recovery and support for local disaster recovery	Support for disaster recovery
Providing information on flood risk to the community and to support local decision making	Information systems to support state government decision making	
Considering flood risk in decision making	Considering flood risk in decision making	Considering flood risk in decision making
		Conservation of natural resources and environmental values of national significance.

Roles and Responsibilities Shared across all Government levels
Flood prediction and warning
Managing gauges and supporting infrastructure to inform flood warning
Funding coordination and management
Recovery after a flood
Research and training
National coordination and cooperation in best practice

Local Government

The Policy outlines that the management of flood prone land is primarily the responsibility of local government. Managing flood risk at a local level involves understanding flood risk and supporting practical management options across the local government service area (LGA).

Local responsibilities include:

- FRM – establishing a local FRM framework and developing and implementing FRM plans to understand and manage flood risk
- providing information on flood risk to the community and government
- considering flood risk in land use planning decisions
- developing, operating, maintaining and asset management for FRM infrastructure
- leading the local emergency management committee and support for flood emergency management planning

- local flood recovery

Many decisions are made at a local government level. These may involve prioritising efforts to understand and manage flood risk across different catchments within the LGA, including catchments shared with other LGAs. These decisions may be informed by flood studies, management studies and management plans in different catchments within the LGA, including those derived from studies undertaken in partnership with other LGAs in the same catchment.

State Government

The State Government provides local councils with technical and financial assistance to undertake studies to understand their flood risk, examine options to manage this risk, and to decide on and implement plans to manage this risk through the Program managed by DPIE. Under the Program funding may be available for the preparation of the various studies, and the implementation of FRM plans including the construction of mitigation works.

Funding under the Program (State and sometimes Federal Government funding) is provided on a priority basis considering annual applications from local councils across NSW for all stages of the FRM process. The priorities are determined by the relevant Minister considering the advice of the State Floodplain Management Assessment Committee led by DPIE.

Local government usually contribute its share (generally 1/3rd) of funding through its budgetary processes. However, low financial capacity councils can access better funding ratios requiring lower local contribution for some projects. In some cases, a council may seek to raise a specific levy to support implementation of major works.

DPIE technical staff assist councils with managing their flood risk and developing and implementing FRM plans.

The NSW State Emergency Service (SES) also has a key role in emergency management of flooding including:

- establishing, maintaining local flood plans and activating these plans in response to a flood threat.
- educating the community on response to flood threats and advising them of how to respond to an imminent flood threat.

3.3 The Flood Risk Management Committee

The formation of a FRM Committee is a key step in the management process to develop and implement management plans.

3.3.1 The Role of the Committee

The Committee assists Council in developing and implementing a FRM plan by contributing ideas, professional expertise, experience, and local knowledge.

Community members contribute their knowledge of historical information, local problems, and possible solutions. They also channel input from the wider community.

While it is important that key aspects of the FRM process are addressed, members are encouraged to contribute widely to the Committee’s deliberations to produce the best possible outcomes for managing the flood problem. This involves seeking solutions to the existing, future and continuing flood risk issues, not solely on addressing the past.

The Committee should operate as a team with the community’s interests being foremost.

Committee members may be required to vote to determine the majority opinion on different issues. Because the FRM plan should be a local based process, State Government representatives abstain from voting.

It is crucial that the Committee actively directs the course of the studies to ensures studies represent the views of the Committee, not only those of the consultant and Council.

3.3.2 Membership of the Committee

The FRM committee may be stand alone or the role of the committee may be given to a broader council committee which may already exist.

If flood risk is to be considered as part of a broader committee, both a technical working group (to facilitate agency input) and a community reference group (to support community input) should be established to ensure the community is included in the FRM process. FRM issues should also be a clear part of meeting agendas.

Committee (including technical working and community reference group) members are generally a mix of elected, community, and professional members, whose collective skills and interests are suited to addressing the flooding problem of a particular catchment. Typically, membership is:

- elected members of council;
- council staff from engineering, planning and environmental disciplines;
- an appropriate number of representatives of the local community (for example, local flood affected landholders (residential and business), relevant industry bodies (e.g. the chamber of commerce), and environmental groups);
- officers from the DPIE; and
- representative(s) from the State Emergency Service (SES).

Depending on the nature of the flooding problem at hand, the Committee may choose to co-opt other individuals or agencies as required.

3.3.3 What is expected of Committee Members

The FRM process is neither short nor simple, nor is it the singular responsibility of council officers, consultants or government officers to have input to the process.

The FRM Committee must comprise members who are committed to and actively involved in the preparation and implementation of the FRM plan. It may take 2 to 5 years from the start of a flood study to the development of the FRM plan and the implementation of all recommendations may take much longer (typical lengths of time are shown in Table 2). Local community members who are enthusiastic and energetic are more likely to ‘see the distance’ to complete the FRM plan.

Committee members are expected to attend meetings at critical points in the project stages, on average this is every 3 months. Meetings are generally held at a convenient time for all committee members, most likely at night to accommodate work schedules. Committee members are expected to read and review the documents provided prior to meetings. This guide can be referred to in order to get an overview of the relevant stage in the project and a background on what may be discussed in the meetings.

In view of the length of time involved, the turnover of committee members, including both council staff and elected representatives, can be a problem. Whilst little can be done with respect to the potential turnover of council and government officers, the structure of the committee should be decided with consideration of its long-term viability and relationship with other committees in operation in the local area.

Table 2 Flood Risk Management Process Time Frames

Stage	Typical timeframe	Typical steps
Flood Study	1-1½ yrs.	Data collection. Engage consultant/s. Study very complex.
Flood Risk Management Study	1-2 yrs.	Committee/consultant examines management options. Involves widespread community consultation.
Flood Risk Management Plan	½ - 1 yrs.	Finalise options. Committee plans implementation.
Plan Implementation	1-15 yrs.	Flood warning systems, development controls, rezoning, levee construction, voluntary purchase etc.

3.3.4 The Role of the Consultant

In most cases, consultants will be engaged to prepare the necessary studies and reports in accordance with Council's study briefs. The Committee should contribute to the development of these briefs.

Consultants will undertake a range of investigations to enable Council to make management decisions with the Committee's assistance. The consultant will often be required to make presentations to the Committee to help with their deliberations.

Whilst it is expected the consultant will contribute initiative to the study, it is important that the Committee direct the consultant so that local issues are considered.

3.3.5 Community Involvement

If FRM is to be successful, it is important that the local community accepts the need for effective management practices, recognises that the finalised FRM plan has considered all factors of concern to the community, and that flood prone members of the community accept their individual responsibilities to reduce flood risk.

This requires the support of the community covered by the plan. Community involvement is a key component of the development of the plan through both membership of the Committee and through consultation at key points during studies. The Committee should represent the wider community and ensure that it acts in the interests of the whole community.

An important role of the management committee will be to assist in the presentation and resolution of conflicting desires and requirements on the part of various community groups and individuals. Public meetings, often spirited, are an important part of this process.

The community can be actively involved in the process by engaging in the community consultation activities and providing information on their local experiences with flooding.

The FRM plan will be a compromise involving trade-offs. Certain individuals may be disadvantaged, others advantaged, but the community will be better off.

3.4 The Flood Risk Management Framework

The FRM framework in NSW is outlined in Figure 2. It sets out a series of logical steps that if followed are likely to produce the best possible FRM outcomes for the community, allowing for variation in flood behaviour and impacts. Councils can provide local advice on the way in which they manage flood risk within their organisation. The keys steps in flood studies and FRM study and plan projects are described in Section 3.4.1 to 3.4.5.

FRM plans comprehensively consider flood risk and outline practical measures that can address the flood problems in the area covered by the plan. The area covered by a plan may be a town or locality or specific river catchment. The development of the FRM plan involves the application of a merit-based approach to management options that considers the variation in flood behaviour and impacts on the community rather than the application of a blanket rule.

For FRM to be successful, it is important that the local community accepts the need for effective FRM practices, recognises that the effective management plan has taken into account all factors of concern to the community, and that flood prone members of the community accept their individual responsibilities to reduce hazard. Community consultation and input is a major component of the development of the plan.

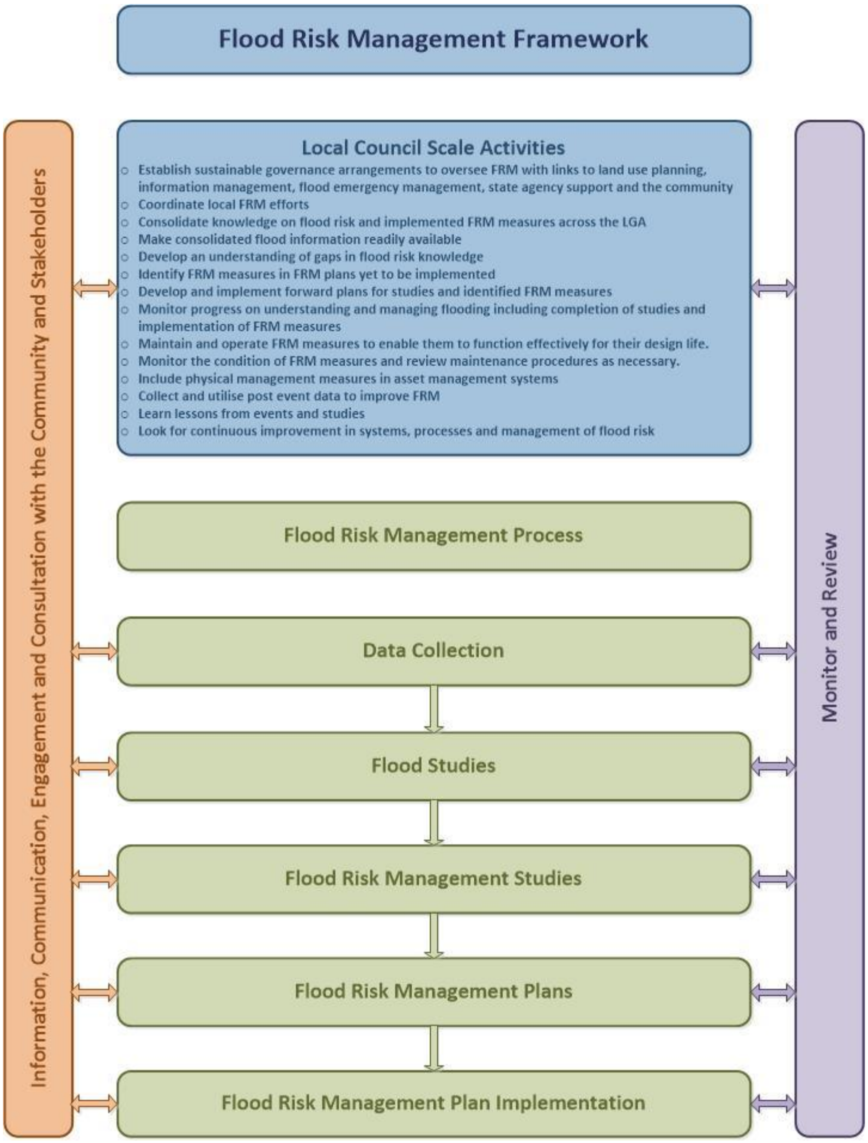


Figure 2 Flood Risk Management Framework

3.4.1 Flood Study

The flood study is generally the first stage of the FRM process as it involves defining flood behaviour and provides the main foundation of a robust management plan. It aims to improve the current understanding of the full range of flood behaviour and consequences.

Typically, a flood study considers the local flood history and available collected data, to develop flood models that are calibrated and verified, where possible, against significant historic flood events. These models are then used to determine the full range of potential flood behaviour and impacts. The community is to be consulted at key milestones throughout the development of the flood study.

Study outputs can include:

- a description of the historic floods,
- a description of existing flood mitigation measures,
- hydrologic and hydraulic models that are calibrated and validated considering historic flood events where possible,
- a description of the existing flood situation, and flood extent and level, depth, velocity information,
- the scale and variation in flood impacts, which can include the number of properties affected and the potential flood damages,
- breakdown of the floodplain considering:
    - variations in flood functions of flow conveyance and flood storage in the floodplain
    - variation in flood hazard (based on velocity and depth) across the floodplain
    - emergency response management limitations, including a breakdown of the floodplain to identify areas with different types and severities of response limitations
    - development of mapping to identify how flood related constraints on land vary across the floodplain for consideration in land use planning
- updated and consolidated information on flooding and its management, including the report, updated flood mapping, emergency management and land-use planning information, and community flood awareness information,
- an explanation of the degree of uncertainty in flood estimates.

The study, developed with Committee input, is provided to Council for consideration and adoption. Information in the study should be considered in FRM, land use planning activities and emergency management planning and associated decisions.

3.4.2 Flood Risk Management Study

The FRM study extends the flood study to increase understanding of the flood risk to the existing and future community and test management options. It provides a basis for developing the FRM plan.

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 options to be considered. Study outputs include:

- a description of existing flood mitigation measures
- the scale and variation in flood impacts, including the number and types of properties affected, and the potential flood damages
- An understanding of future development directions and consideration of the cumulative impacts of future development on flooding
- An assessment of FRM options to address risks to the existing and future community

- the outcomes of community consultation
- recommendations on options
- updated information and consolidated information on flooding and its management – this should include the report, flood mapping, 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 options to provide an understanding of their capabilities, limitations, interdependencies, costs and practical feasibility to inform implementation or further investigation.

Information in the study should be considered in FRM, land use planning activities and emergency management planning and associated decisions.

3.4.3 Flood Risk Management Plan

The FRM plan forms the basis of FRM in the study area into the future and details the final management options that have been agreed upon. 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 continuing 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.

Management plans need to consider the cumulative impact of changes in the catchment on flooding behaviour due to both incremental development of the floodplain and a changing climate.

The plan developed by the committee is provided to the Council for consideration and adoption. Once a plan has been finalised and adopted by the council, it should be used to update and consolidate information on flooding and its management and communicate to relevant agencies and the community to update them on the flood risk.

3.4.4 Flood Risk Management Plan Implementation

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.

The recommendations from the FRM plan would generally feed into the broader consideration and prioritisation of recommendation from FRM management plans from across the whole LGA. It should be reviewed every 5 years, if possible, or after a significant event has occurred.

Implementation of major mitigation works that significantly changes flood behaviour or the response of the community to a flood event can lead to a need to review the management study and plan to ensure that information is up to date and available to the community. It can also involve education of the community of how flood impacts or community response has changed.

Implementation is generally led by council and overseen by the Technical Working Group, led by the Council and involving relevant agencies.

3.4.5 Key Steps in Projects under the Process

Although there may be some variations, typically the major steps involved in producing these reports and who is involved in these steps are outlined in Table 3.

Table 3 Flood Study Key Steps Example

Step	Council	DPIE	Consultant	FRM Committee	Council decision making Committee
All projects					
Application for funding	x	x			
Scoping	x	x		x	
Prepare Brief	x	x			
Call for Proposals	x				
Review Proposals	x	x			
Engage Consultant	x				
Inception Meeting	x	x	x		
Data collection and review	x		x	x	
Model setup or review, calibration and validations	x		x	x	
Design results and mapping	x		x	x	
Draft flood study report	x		x	x	
Final flood study report			x		
Adoption of flood study					x
Update and consolidate information on flooding and its management	x				x
Updated information available to the community	x				x
Incorporation into decisions (FRM and land use planning)	x				
Incorporation into Emergency Management planning	x				x

4. UNDERSTANDING FLOOD BEHAVIOUR

4.1 Introduction

Councils may use in-house or consultancy hydrology and hydraulics skills to provide information on flood behaviour. This information is used to:

- understand the impacts of floods on the community
- analyse mitigation and management options
- investigate, design, construct and maintain mitigation works
- facilitate informed decisions on treating flood risk
- consider constraints on land use planning to facilitate informed decisions for floodplain development
- improve flood predictions and warnings
- support updated emergency management planning
- provide information to the community on flood risk and emergency response.

4.2 Flood Modelling

Flood modelling allows the computation of complex mathematical equations and procedures to provide simulations of river and flood behaviour and are most commonly performed by computers. Computer models can be developed to represent the whole or part of the catchment. There are two main types of computer models used in flood studies; hydrologic models convert rainfall to flows and hydraulic models route flows across the catchment. More recently, direct rainfall models allow for rainfall to be directly input onto the hydraulic model (i.e. bypassing the hydrologic model). There are various benefits and limitations to these models, some of which are discussed in the following sections.

4.2.1 Hydrological Models

Hydrological models convert rainfall over catchments into flow(s), see Figure 3.

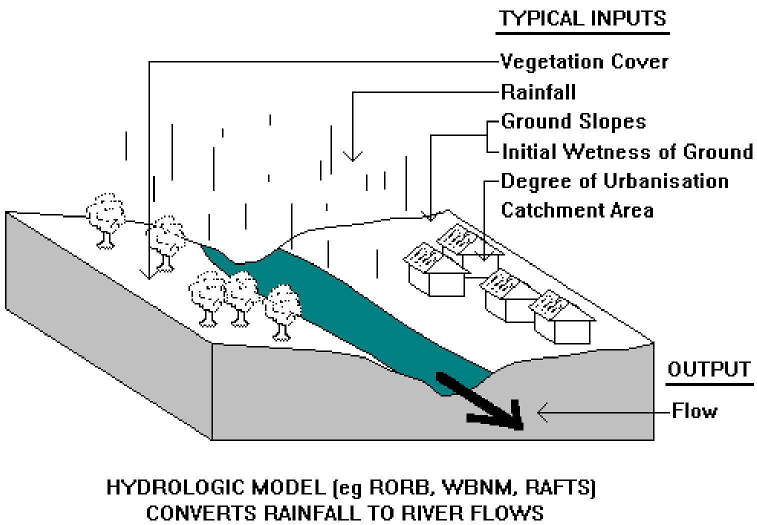


Figure 3 Hydrologic Computer Model

Typical examples of hydrologic model setups are shown in Figure 4.

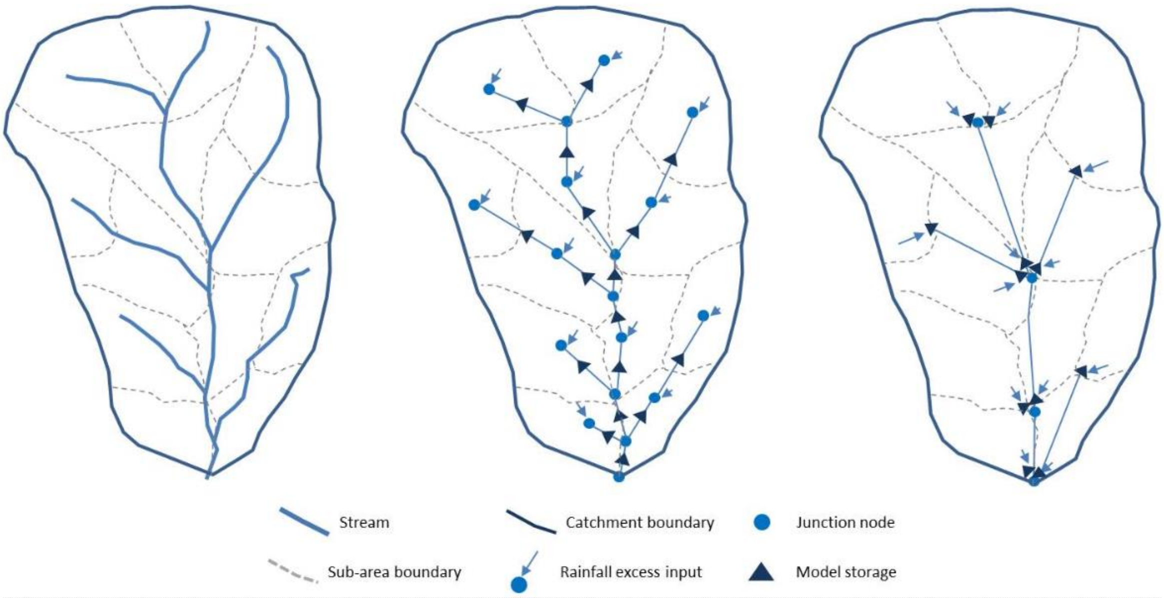


Figure 4 Examples of hydrologic runoff-routing models (ARR 2019)

The output from hydrologic models is normally in the form of flow hydrographs. As storm duration and patterns vary, hydrologic computer models run a range of different storm patterns for the same storm duration (see Figure 5) and compare representative patterns for different storm durations in selecting a design hydrograph(s) (see Figure 6) that are used in hydraulic modelling.

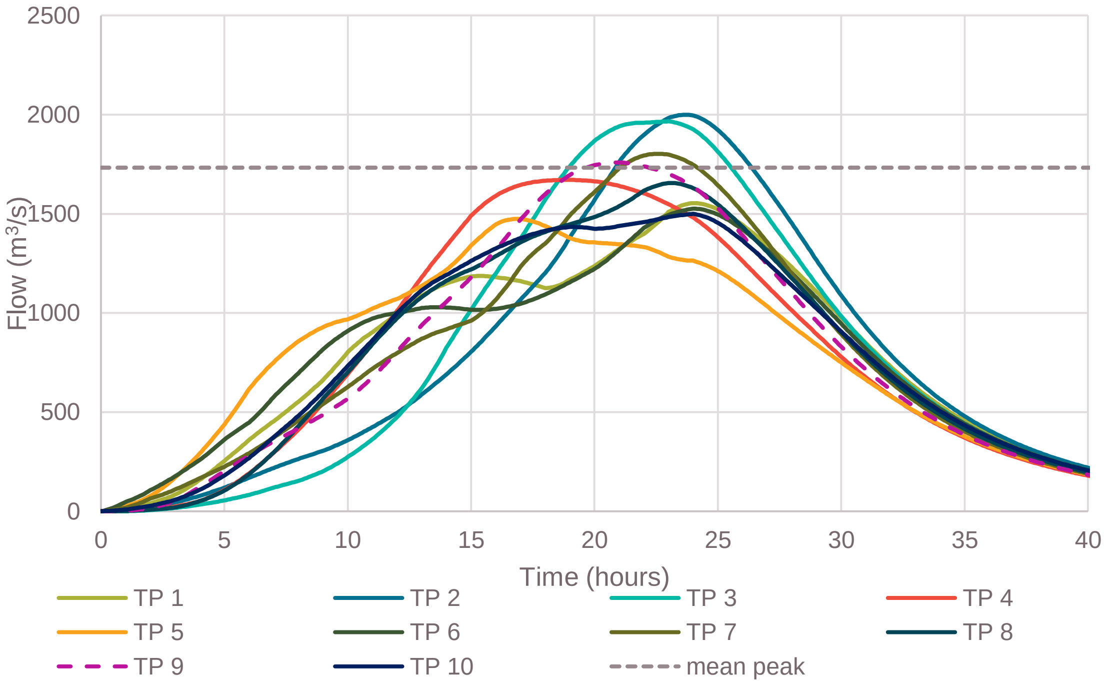


Figure 5 Sample of variations in Flow Hydrograph for different storm patterns (DPIE 2019)

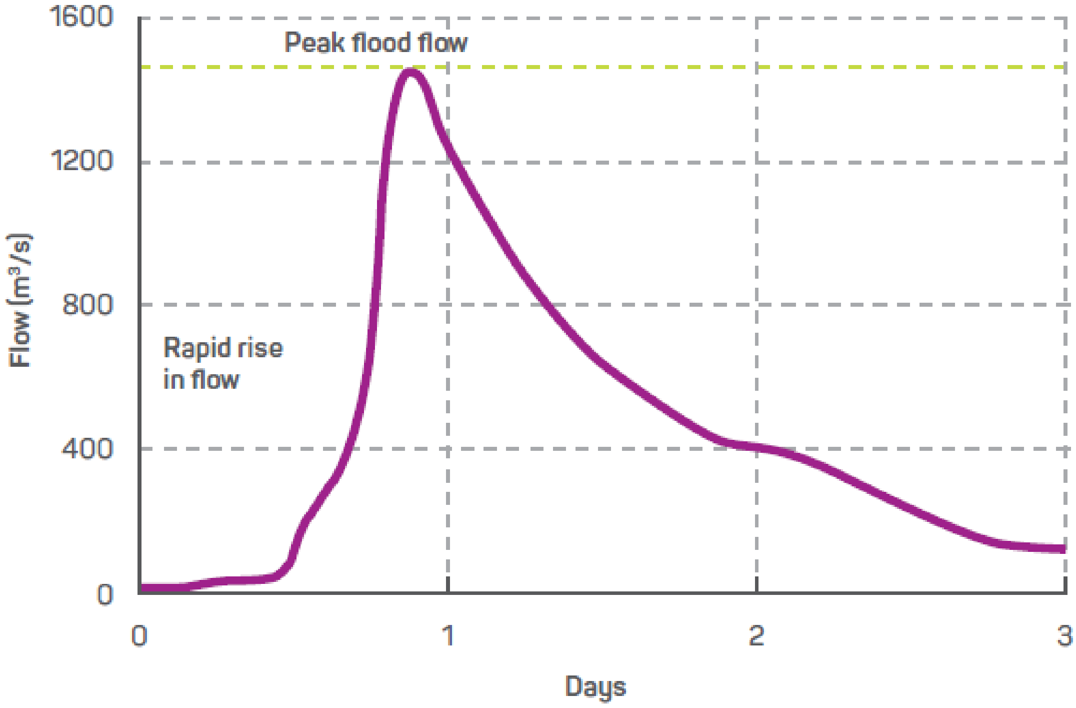


Figure 6 **Sample Selected Design Flow Hydrograph (AIDR 2017a)**

4.2.2 Hydraulic Models

Hydraulic models take the flow produced from hydrologic models and produce outputs such as flood levels, depths and velocities (see Figure 7).

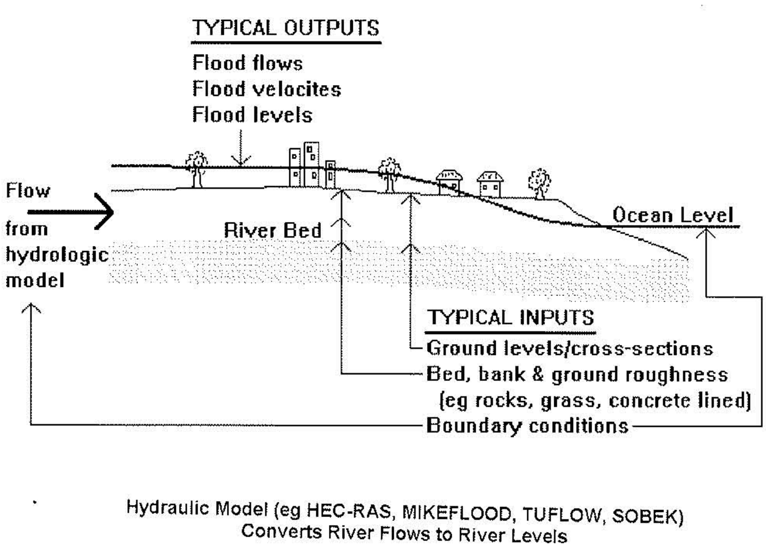


Figure 7 **Hydraulic Computer Model**

1D Hydraulic Model Examples

Hydraulic models can be 1D (see Figure 8 and Figure 9) to allow analysis of flooding in a channel, for example a river.

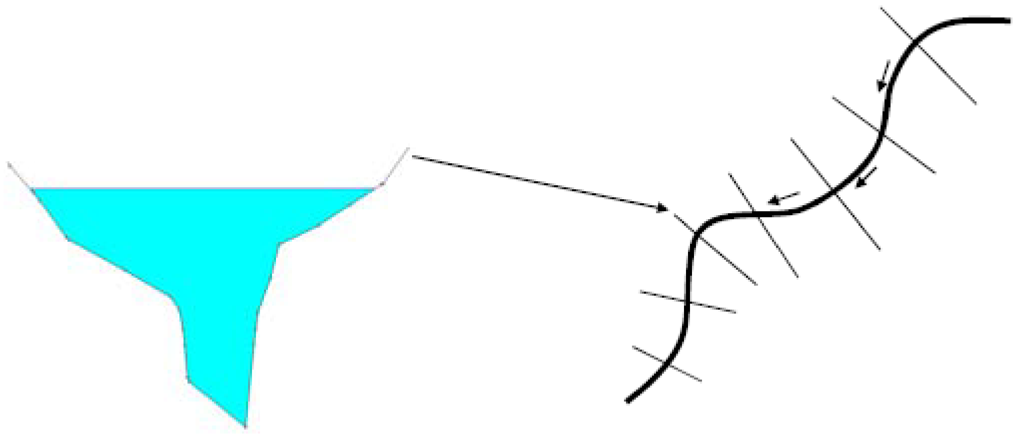


Figure 8 1D hydraulic model typical cross-section

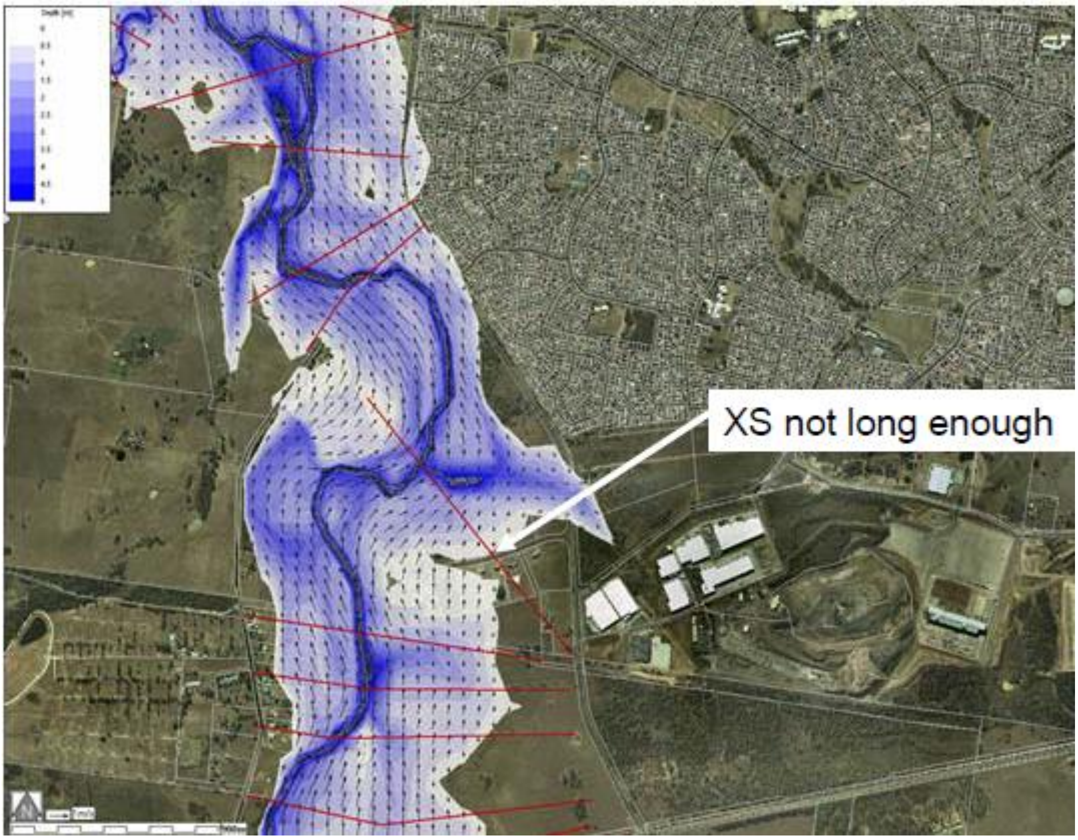


Figure 9 Example 1D hydraulic model results

2D Hydraulic Model Examples

Hydraulic models can be a 2D grid or mesh (see Figure 10) to analyse flooding from channels that extends into the floodplain and overland flows from catchment flooding.

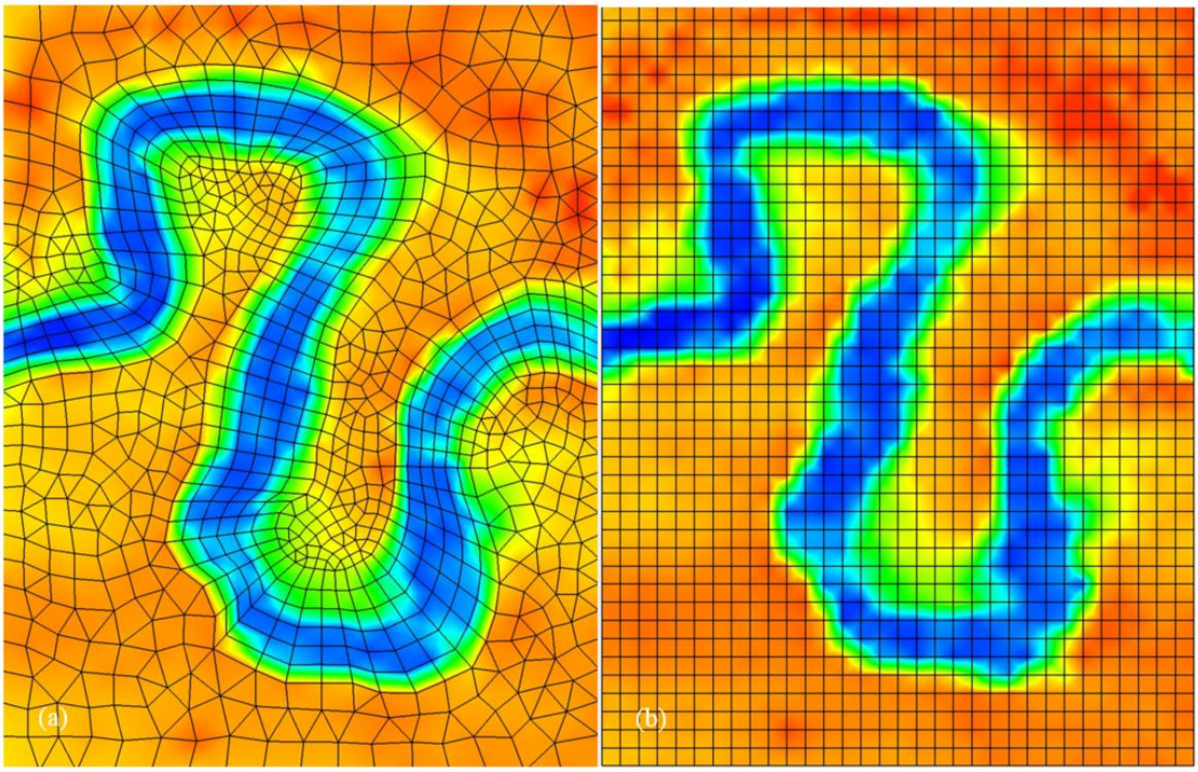


Figure 10 2D hydraulic model examples (a) is a flexible mesh (b) is a grid (ARR 2019)

1D/2D Hydraulic Model Examples

Hydraulic models can be a combination of 1D and 2D to allow the combination of riverine and overland flows to be modelled at the same time (Figure 11 and Figure 12).

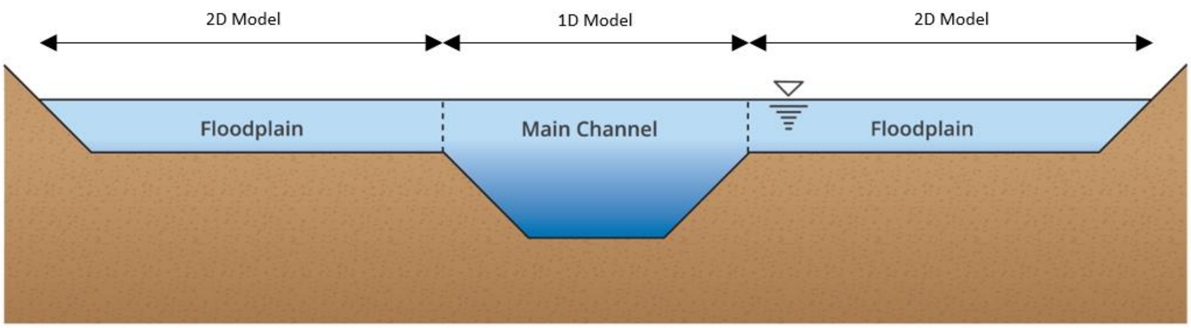


Figure 11 Cross-section of 1D/2D interface

Figure 12 1D/2D Hydraulic Model results showing flow patterns

The output from hydraulic models comes in a number of forms e.g. stage hydrographs, flood profiles, flood contours (Figure 13).

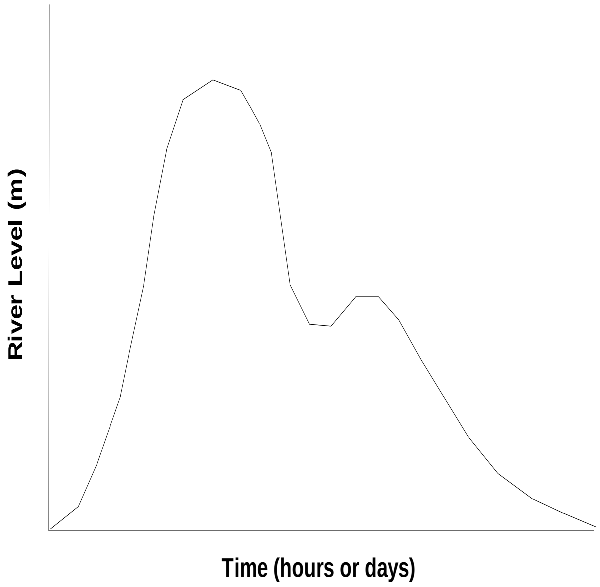


Figure 13 Sample Stage Hydrograph at a Particular Site

The output at different locations can then be used to produce flood profiles or contours along the river showing the maximum water level, depth and velocity at each location for either an actual or design flood (Figure 14 and Figure 15).

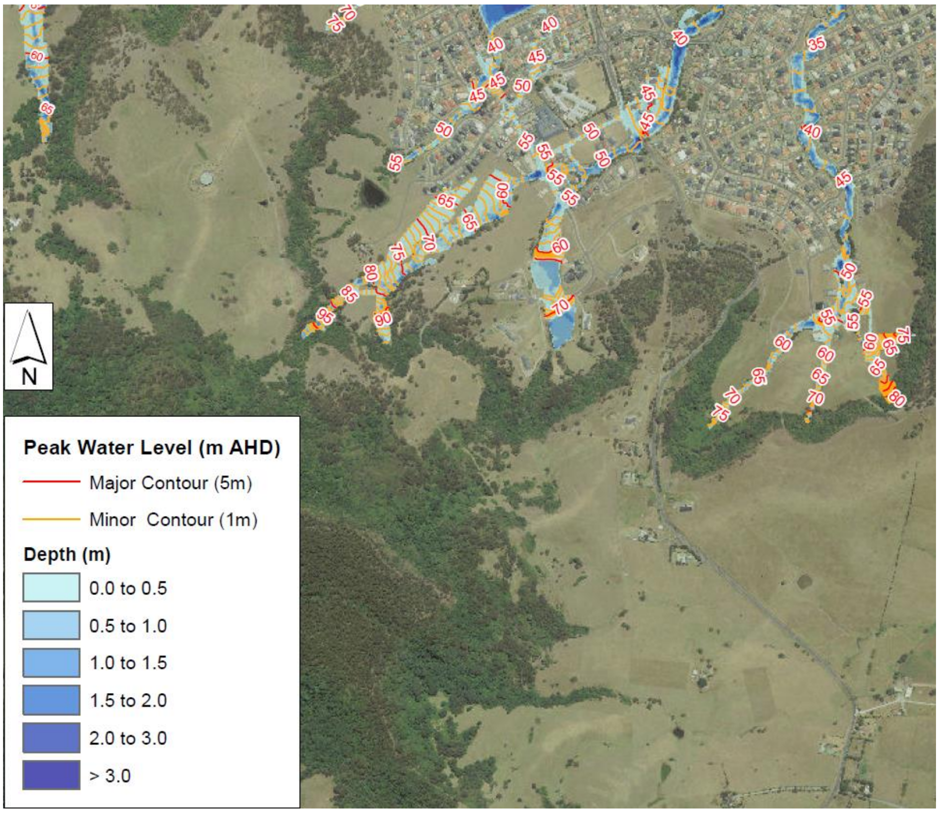


Figure 14 Flood Depths and Flood Level Contours (WMAwater 2017)

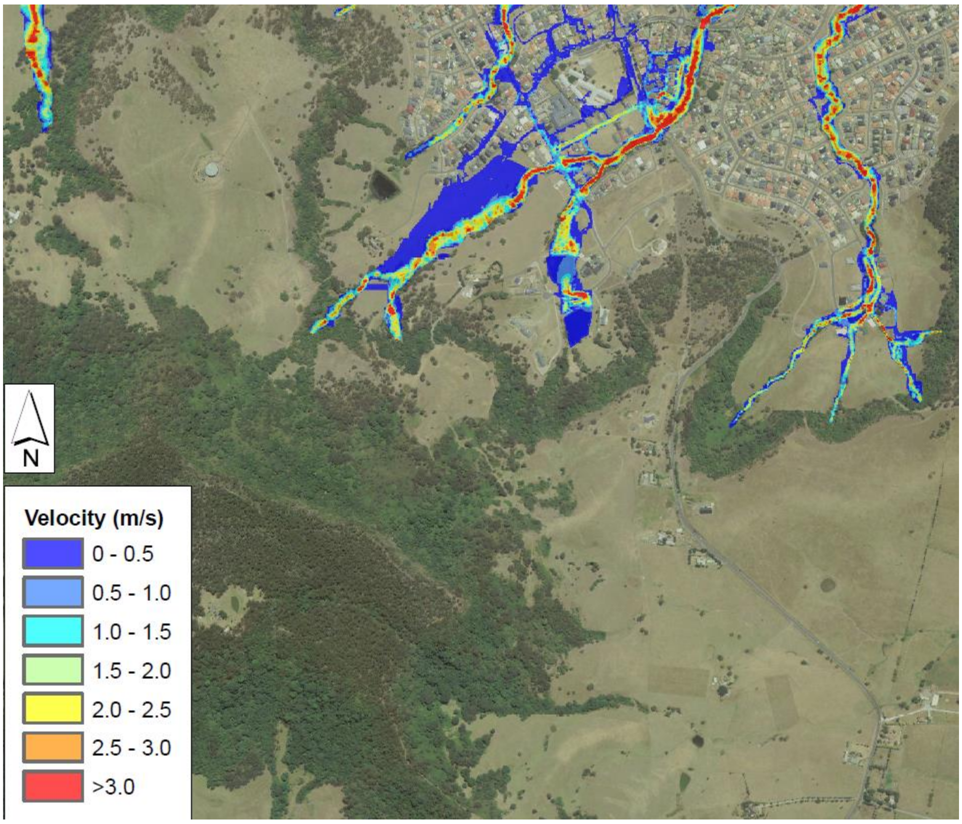


Figure 15 Flood Velocities (WMAwater 2017)

4.2.3 Direct Rainfall Models

Direct rainfall models, known as "rainfall on the grid" take rainfall directly onto the hydraulic model (Figure 16) to generate flow and produce outputs such as flood levels, depths (Figure 14) and velocities (Figure 15).

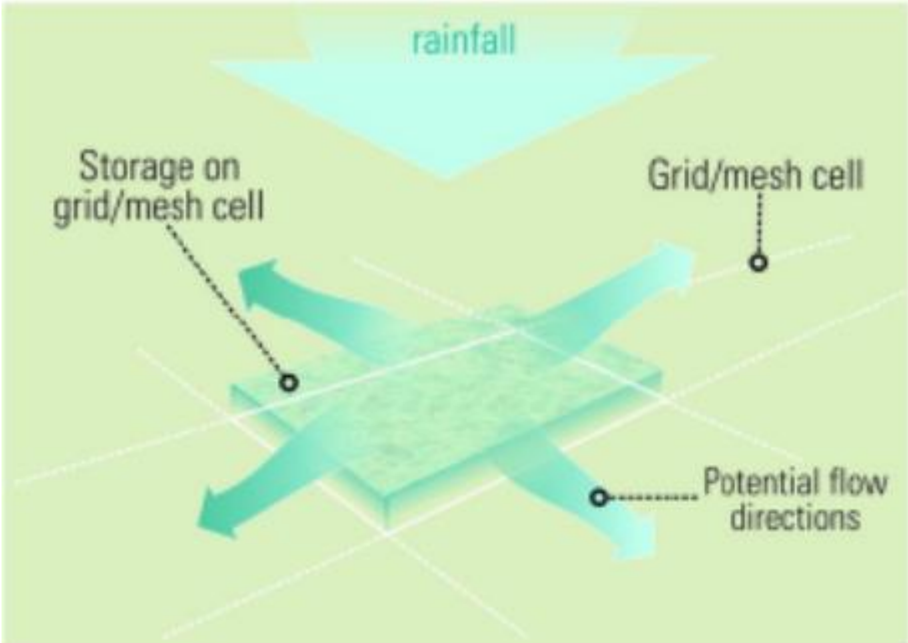


Figure 16 Conceptualisation of Direct Rainfall

4.2.4 Modelling Process

Modelling usually follows the process below, including:

- Calibration – Local historical data recorded during an actual flood event is used in the models to calculate river flows and levels and compare these to recorded levels. These are then compared with the recorded river flows, levels and extents for that flood event. It is normal to have to adjust some of the catchment characteristics to get a match between actual and modelled flows and levels.
- Validation – After calibration of the model is achieved, a check of the ability of the model to predict flood behaviour is carried out. Here the models are run for perhaps 2 or 3 other known flood events to ensure that the model results compare with the recorded flood levels from those events within an acceptable degree of accuracy.
- Design Modelling – After the models demonstrate they can satisfactorily represent actual flood events via calibration and validation, design rainfall data are used to enable the models to produce design flood flows and levels, depths and velocities along the river or floodplain. This is used as a baseline for looking at management options in the management study phase.
- Models are then used to develop the information required from design floods which can vary between studies. This information is then used to derive information to assist in future flood risk management, emergency management and land use planning.

In the FRM study phase, the model is run to assess:

- Development impacts – the effect that development has on flood behaviour and impacts can be assessed.
- Management options – to examine the effect flood mitigation works can have flood behaviour and impacts.

4.2.5 Accuracy of Computer Modelling

Even with powerful computers and programs, flood modelling still needs to be based on a number of assumptions. Accordingly, it would be unrealistic to believe that modelling can exactly replicate the river behaviour at every location.

However, with experienced operators, using proven modelling software to develop the models, reliable estimation of flood behaviour can be provided. This reliability is improved by the calibration and validation of model results (discussed above) with the information available in historical floods and the communities experience of these floods.

It is important to remember that the calibration and validation process demonstrates that the models can satisfactorily predict flood levels within acceptable limits of accuracy. Models can also predict the impact of floodplain changes such as development or mitigation works.

4.3 Design Floods

4.3.1 What Are Design Floods?

To fully appreciate the flood hazard, it is desirable to have a consistent procedure to assess how often floods will reach different levels. The concept of design flood levels achieves this. For example, a 1% AEP (annual exceedance probability) design flood level has a 1% (or 1 in 100) chance of being reached or exceeded in any one year. Historically, this flood was referred to as the 100 year ARI (Average Recurrence Interval) flood as it can be expected to occur, on average, once every 100 years over a very long period, say 10,000 years. Common design floods used in flood risk management shown in Table 4.

Table 4 Common design floods used in flood risk management

PMF	PMF
0.2% AEP	500 year ARI
0.5% AEP	200 year ARI
1% AEP	100 year ARI
2% AEP	50 year ARI
5% AEP	20 year ARI
10% AEP	10 year ARI
20% AEP	5 year ARI

Although a 10% AEP flood is likely to occur once every 10 years on average, it is important to note that there is nothing preventing two 10% floods (or even 1% floods) from occurring only weeks or months apart. This is similar to a lottery where the odds suggest you have a chance of winning a prize say once every 50 tickets you buy, but there is nothing stopping you winning a prize twice in a row or purchasing 200 tickets without a win. Figure 17 shows how likely you are to experience a given size flood at a location in an average person's life time.

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

Figure 17 Probability of experiencing a given-sized flood one or more times in 80 years (AIDR 2017a)

4.3.2 Estimating Design Flood Levels

There are three accepted methods of estimating design flood levels:

- Physical Modelling: A scale model of the catchment is built, flooded, and water levels measured. Whilst they have some benefits, physical models are expensive and, as they occupy large amounts of space, are normally dismantled after use making unplanned subsequent studies costly. These are rarely undertaken today.
- Computer Modelling: This is the most common method (see Section 4.2 for explanation). It is used in conjunction with other techniques, such as flood frequency analysis, to determine design flood levels.
- Flood Frequency Analysis (FFA): This method involves performing a statistical analysis on known historic flood flows to draw a graph of flood flows against probability of occurrence, see Figure 18. Generally, creek and river flows are not measured directly. They are estimated from water levels using rating curves that relate water level to estimated flow based upon gauge measurements and hydraulic analysis, see Figure 19. FFA is often used as a check of the computer modelling results at sites where a sufficient length of record exists. FFA is site specific and can only be applied at the gauge location.

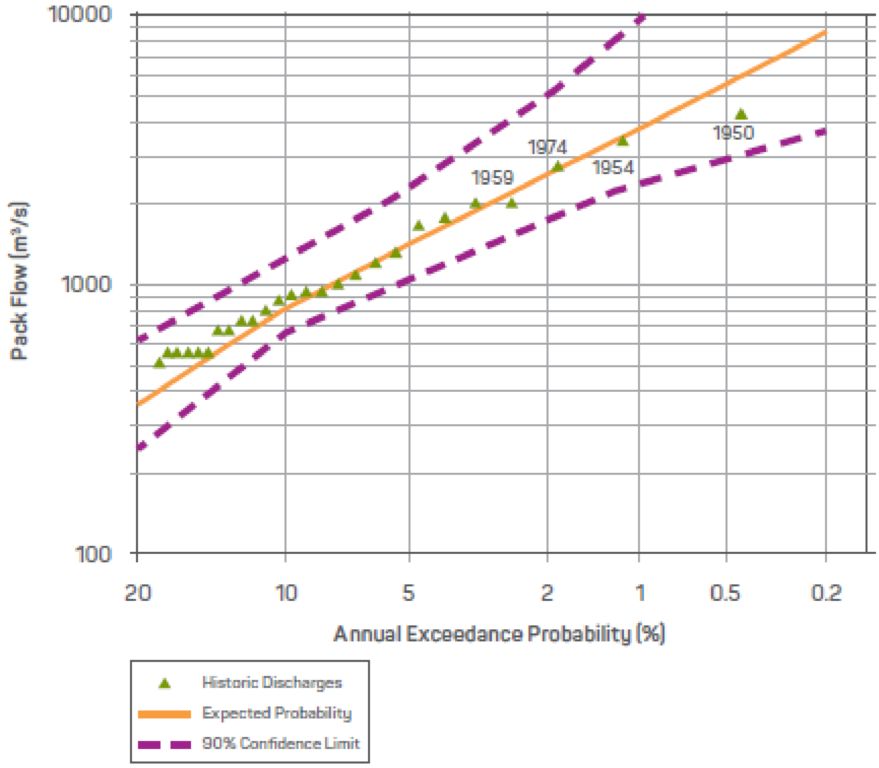


Figure 18 Sample frequency distribution for a stream gauging station (AIDR 2017a)

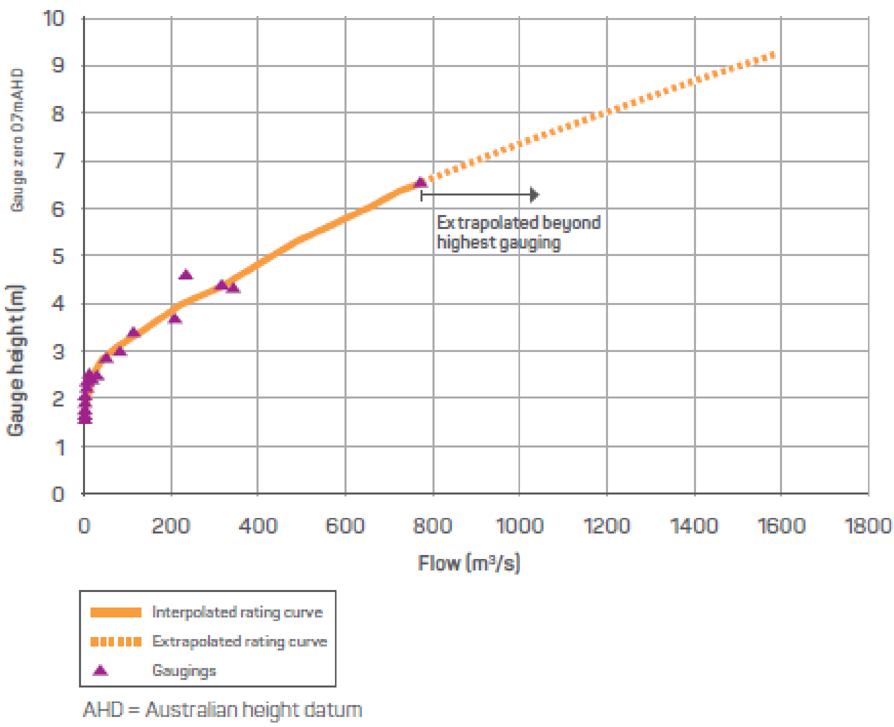


Figure 19 Example rating curve for a stream gauging station (AIDR 2017a)

4.3.3 Defined flood event or planning flood

The defined flood event (DFE) or planning flood is a large flood that is selected and used to determine where to apply minimum development standards, see Figure 20.

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. DFEs are the key floods used to derive information to inform management and land-use planning.

In NSW the 1% AEP flood is often used to define the DFE, a freeboard is then added to the DFE to determine the Flood Planning Level (FPL) (see Section 4.4.2) in which general development controls are applied to new standard residential and commercial development to limit growth in risk.

DFEs are initially determined in flood studies and may be refined in management studies, they are then incorporated in management plans.

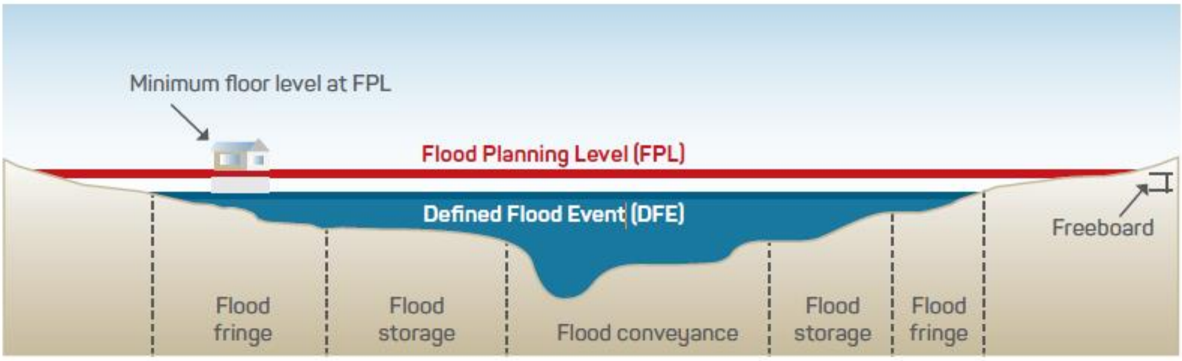


Figure 20 Defined flood event and other key terms (AIDR 2017a)

4.3.4 Probable Maximum Flood

The probable maximum flood (PMF) as defined in the Floodplain Development Manual provides the upper limit of flooding to inform flood risk management for communities. Estimation of the PMF provides a basis for understanding the extent of the floodplain and the upper scale of the flood problem faced by communities.

Depending on a number of factors, the PMF or an equivalent extreme flood can range from less than 1 metre to more than 10 metres higher than the 1% AEP flood levels (Figure 21). The PMF is likely to be higher than levels considered for minimum floor levels or for the crest of a levee.

It is a key event to consider in emergency management and should be considered with regard to the location of resources critical during floods such as evacuation centres and, hospitals with an emergency response function, disaster management centres and those whose occupants may be placed at more risk in evacuation (i.e. critical care patients in hospitals).

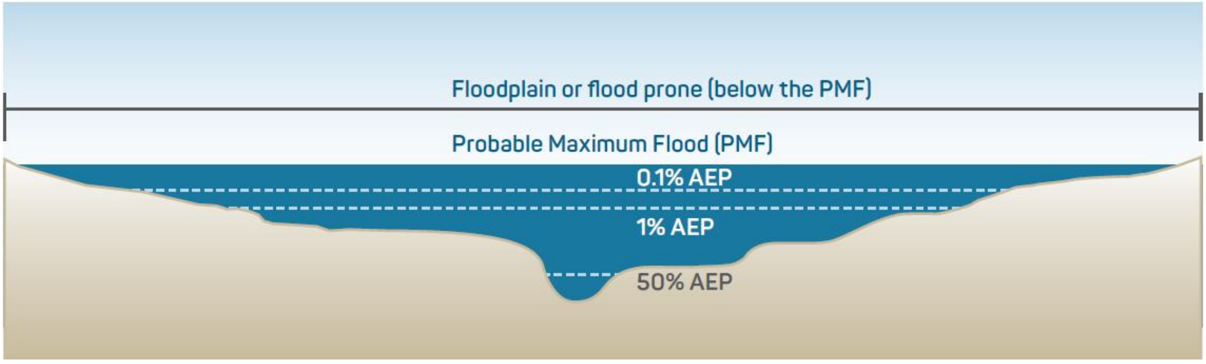


Figure 21 Floodplain and probable maximum flood (PMF) (AIDR 2017a)

4.3.5 Consideration of Climate Change

Consideration of climate change in flood studies is important as it can lead to altered flood behaviour and increased community exposure to flood risks and impacts. Climate change is expected to have adverse impacts upon sea levels (relevant in the lower portion of coastal waterways) and flood producing rainfall events (relevant across NSW).

Depending on the local flood situation both can have significant impacts on flood behaviour that is assessed as part of the studies.

Guidance on how to assess climate change impacts on flood behaviour and its impacts on the community is available within NSW Government FRM Guidance.

4.4 Categorisation of the Floodplain

The area flooded during a flood event (or events) can be further categorised based on different criteria depending on what information is required. These include the flood planning area, flood function (also call hydraulic categorisation), flood hazard, flood emergency response classifications and flood planning constraint categorisation. The categorisation of the flood behaviour in these ways can better inform processes such as land use planning and emergency planning, discussed in the sections below.

4.4.1 The Floodplain or Flood Prone Land

The floodplain or flood prone land is the area that is inundated by the PMF. Land above the PMF level may sometimes be referred to as flood-free although it should be remembered that some land above the PMF level could still experience local drainage problems or water flow across the ground or may be indirectly affected by flooding due to loss of services or power from facilities that are inundated.

4.4.2 Flood Planning Areas (FPAs) and the Flood Planning Levels (FPLs)

Flood planning areas are a type of flood planning constraint category. They are areas where councils apply flood planning controls for all types of development. The FPA is generally determined based on the areas inundated by the DFE or planning flood and includes a freeboard and therefore below the flood planning level (FPL) (Figure 20). Freeboards can vary depending on the type of flooding and the certainty of the modelling process, typical freeboards for riverine flooding are generally 0.5m and for overland flow flooding are generally 0.3m.

FPAs should be based on an understanding of flood behaviour and the associated hazards and risks. Choosing an FPL is a matter of assessing and balancing the social, environmental and economic consequences of adopting that FPL.

4.4.3 Flood Function (Hydraulic Categorisation)

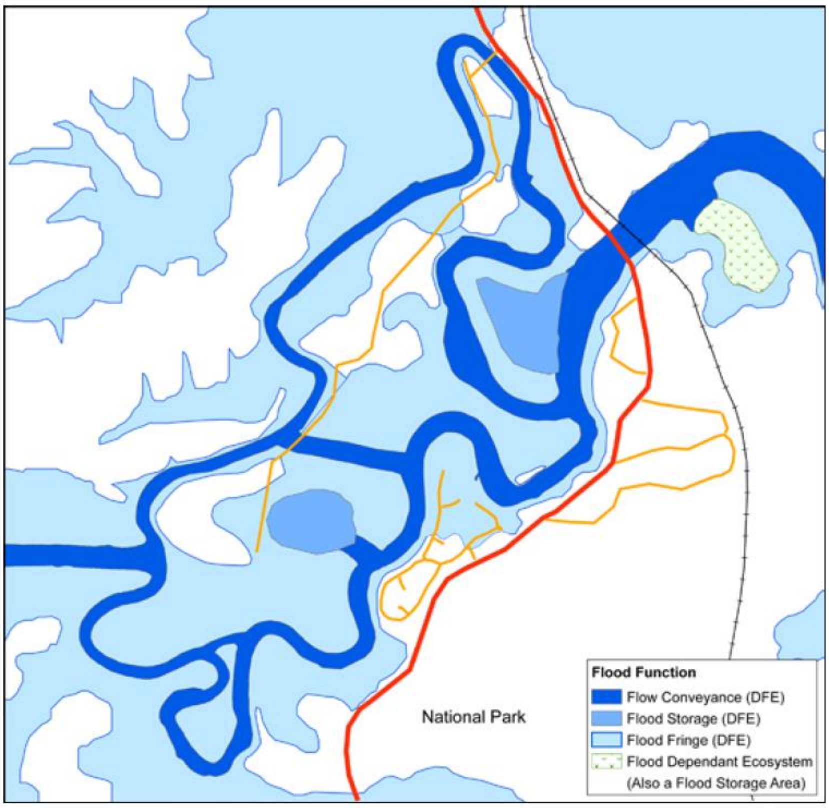
The determination of flood function (hydraulic categorisation) of flood prone land is an essential element of flood studies and management studies as it assists in determining appropriate flood risk management strategies for both existing and future development.

To identify areas that perform an essential flood function it is necessary to divide the floodplain into areas that reflect different flood functions or hydraulic categories. These are:

- Floodway - areas where a significant volume of water flows during flood and are often aligned with obvious natural channels. They are areas which, if only partially blocked, would cause a significant increase in flood levels and/or a significant redistribution of flood flow.
- Flood Storage - areas are those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood.
- Flood Fringe - is the remaining area of land affected by flooding, after the floodway and flood storage have been derived.

The extent of flooding and floodways and flood storage areas will generally increase as the scale of flood increases. They are usually mapped for a minimum of the DFE (see Figure 20 and Figure 22), plus a smaller and larger event, and the PMF. This enables an understanding of how the flood function varies to be considered in management decisions.

Floodways and flood storage areas would have additional development controls that aim to support the flood function of the floodplain.



DFE = defined flood event

Figure 22 Breakdown of the DFE flood into flood functions (AIDR 2017a)

4.4.4 Flood Hazard

The extent of flooding in an event can be categorised based on the varying degree of hazard that flood poses to the land.

Hazard vulnerability curves (Figure 23) classify hazard based on the consequences of the flood hazard on people, vehicles and buildings. This information can be used to highlight where the flood is hazardous to these different elements (Figure 24).

This provides important information for FRM, emergency management planning and land use planning

Hazard Categories

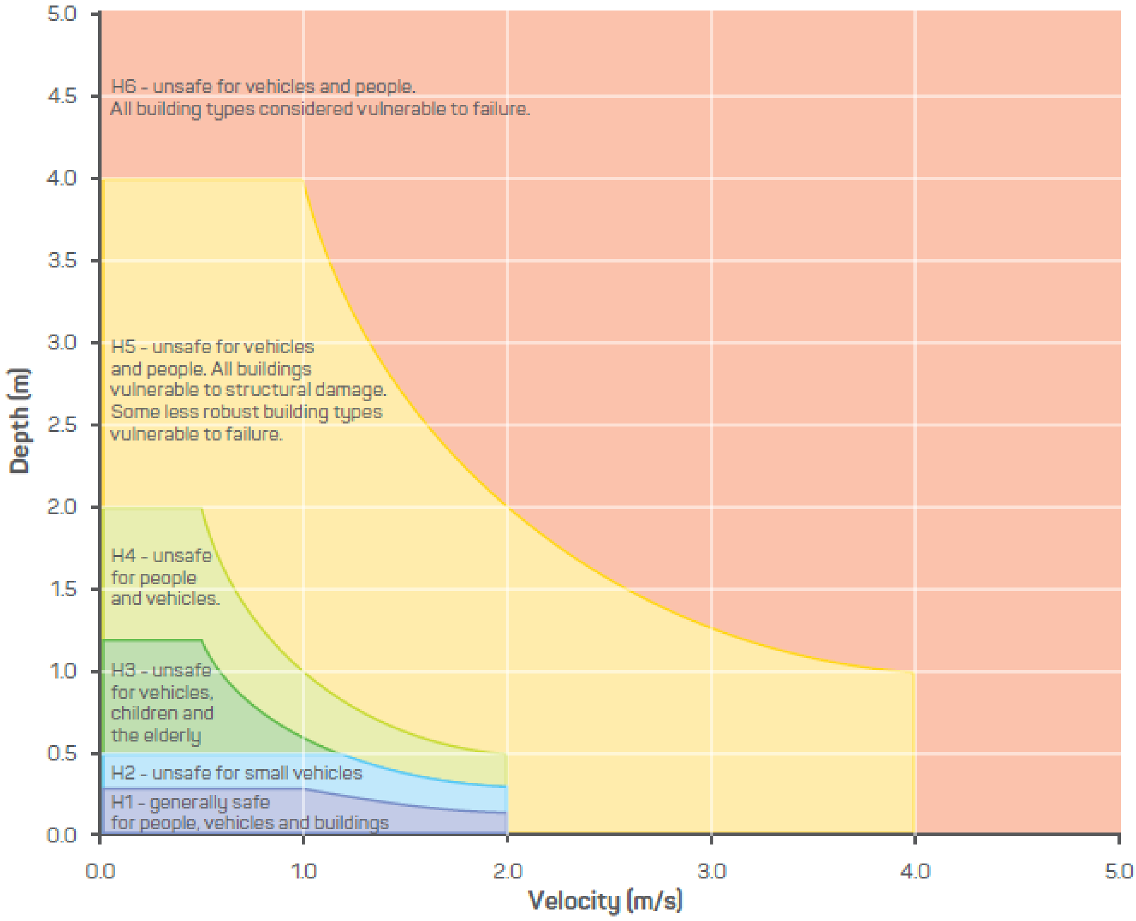


Figure 23 General flood hazard vulnerability curves

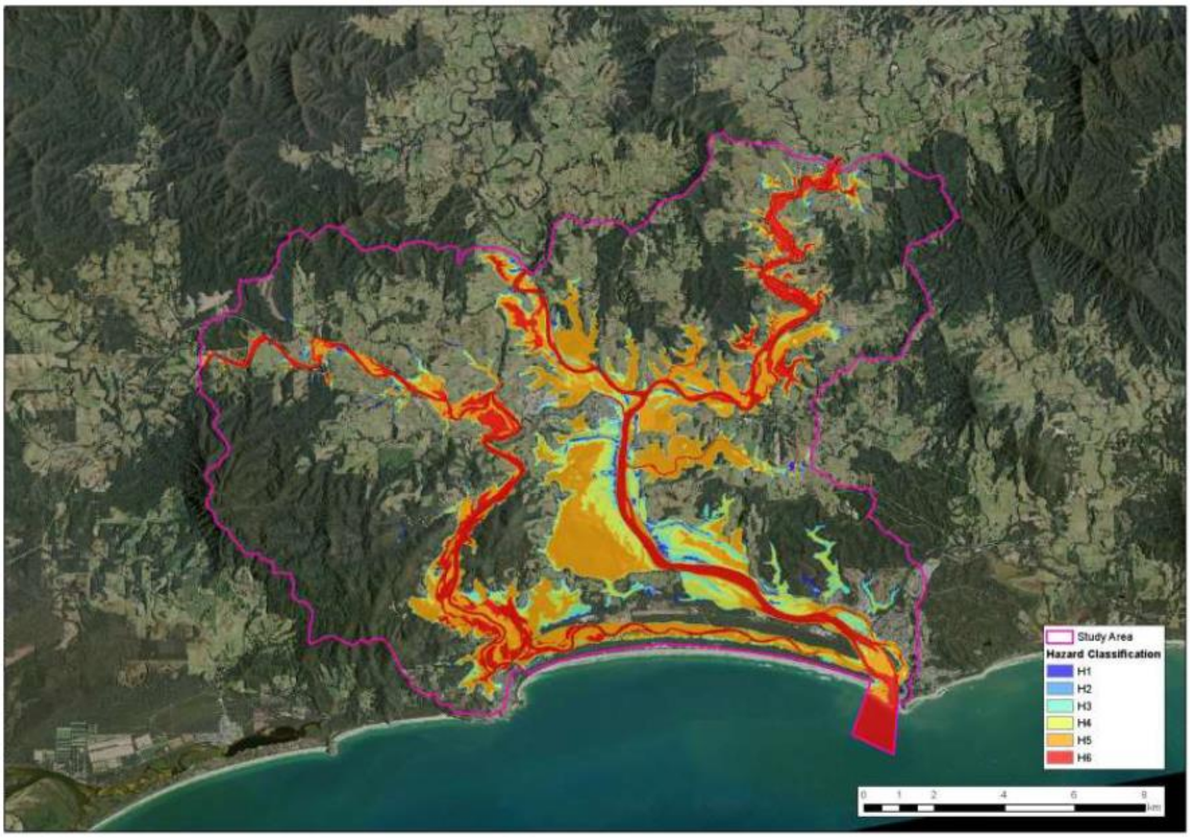


Figure 24 Example breakdown of the floodplain into hazard categories (AIDR 2017b)

4.4.5 Flood 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. Any situation that increases people's need to cross floodwaters increases the likelihood of an injury or fatality.

The floodplain can be classified in relation to isolation and access considerations in a way that informs emergency response management (Figure 25). This classification provides the basis for understanding the nature, seriousness and scale of isolation problems.

It provides important information for emergency management planning, FRM and land use planning

Further information can be found in the Guide on Flood Emergency Response Planning Classification of Communities.

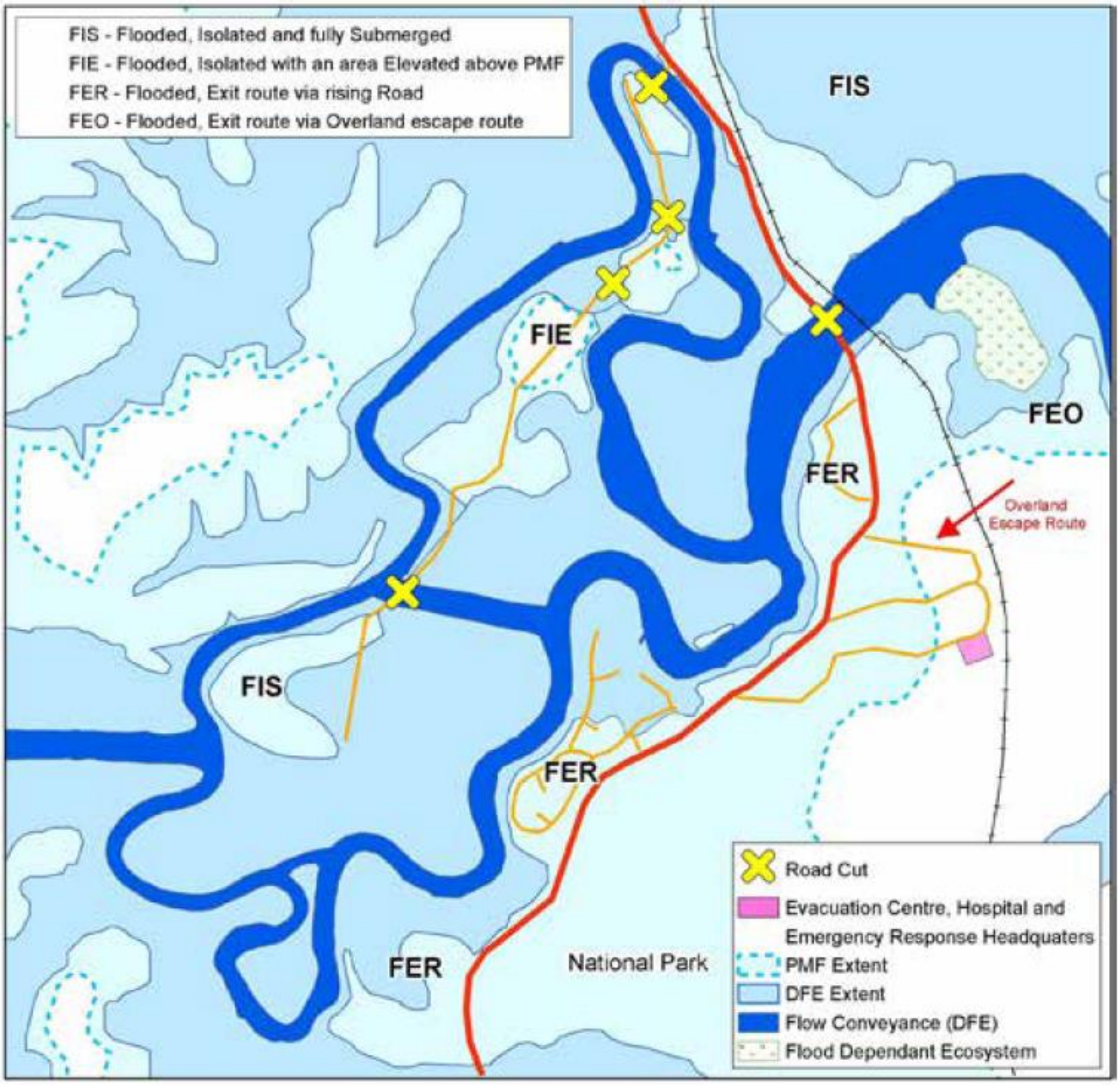


Figure 25 Example of flood emergency response classification of the floodplain (AIDR 2017c)

4.4.6 Flood Planning Constraint Categories

Flood studies typically produce many maps, each focusing on a particular design event and element of flood behaviour. Collectively, they provide a very detailed description of flood behaviour and the issues that are important in different areas of the floodplain.

Combining all elements of flood behaviour can produce a succinct set of information that breaks the floodplain down into areas with similar degrees of constraint – Flood Planning Constraint Categories (FPCC). FPCCs can better inform and support land-use planning activities by identifying where flood-related constraints can be treated similarly.

Deriving flood planning constraint categories involves using information derived from modelling including varied flood function (see section 4.4.3), flood hazard (section 4.4.4), flood emergency response classification (section 4.4.5) and considering the range of flood events. An example of FPCCs is shown in Figure 26, for further detail of the mapping components used to develop this example refer to Australian Disaster Resilience Guideline 7-5 Flood Information to Support Land-use Planning (AIDR 2017), Appendix A.

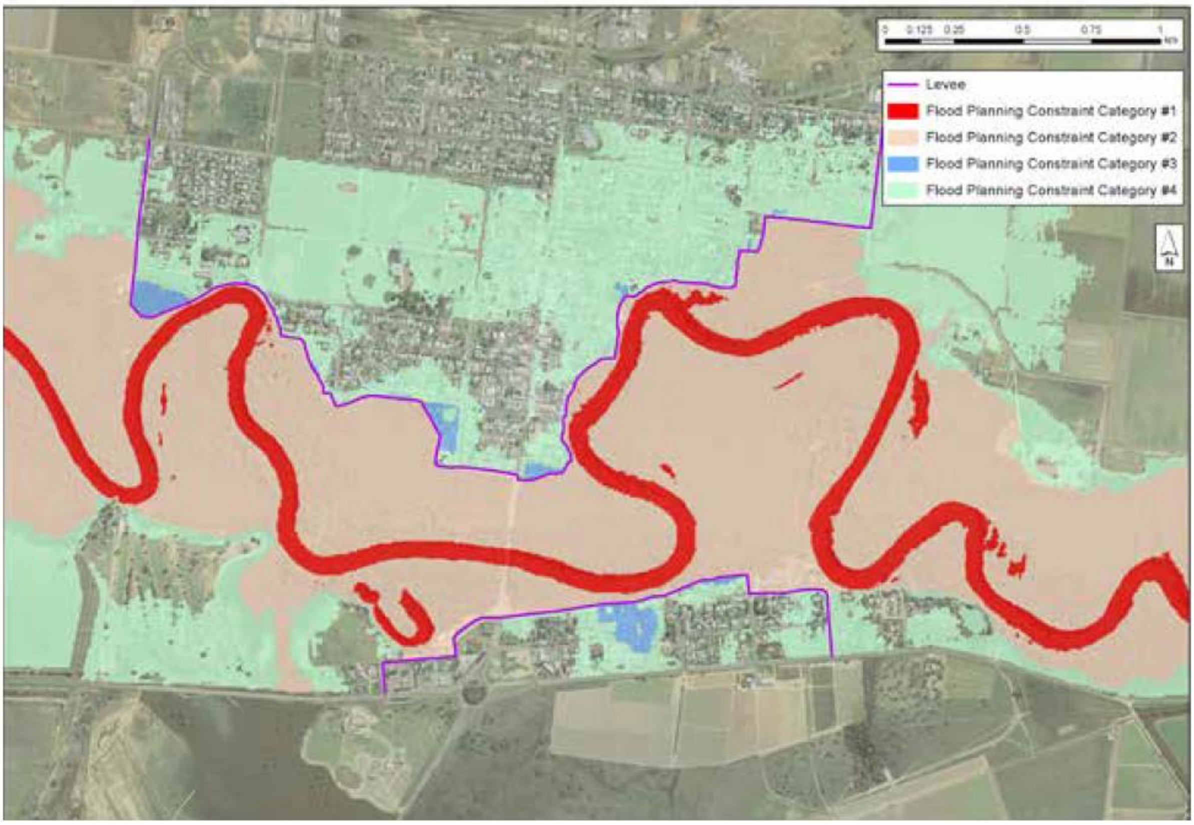


Figure 26 Example flood planning constraint categories (AIDR 2017c)

FPCCs can come in different forms. For example, Table 5 shows four FPCCs that have been developed to separate areas of the floodplain from the most constrained and least suitable for intensification of land use or development (FPCC1) to the least constrained and more suitable for intensification of land use or development (FPCC4). Other examples of FPCCs include flood risk precincts where the floodplain is broken down into areas of low, medium and high risk and the breakdown of the floodplain into floodway areas, the flood planning area and the flood risk management area.

Table 5 Flood Planning Constraint Categories – Implications and Key Considerations

FPCC	Level of constraints
1	Severe limitations on usage due to impacts on flood behaviour and hazard
2	Significant controls on development due to emergency response limitations, flood behaviour in rare events and the level of flood hazard
3	Standard land-use and development controls aimed at reducing damage and the exposure of the development to flooding in the DFE are likely to be suitable. Consider the need for additional conditions for emergency response facilities, key community infrastructure and vulnerable users.
4	Consider the need for conditions for emergency response facilities, key community infrastructure and land uses with vulnerable users.

5. MANAGEMENT MEASURES

5.1 Types of Measures

There are various ways of managing floodplains to reduce flood losses which include:

- modifying the response of the population at risk
- imposing controls on property and infrastructure development
- modifying the behaviour of the flood itself

The first two measures can be referred to as non-structural options or measures (Table 6). The third measure is often referred to as a structural option (those measures which modify flood behaviour by reducing flood levels or excluding floodwaters from areas at risk).

Table 6 Types of Modification Measures

Property Modification Measures	Response Modification Measures	Flood Modification Measures
Zoning	Community Awareness	Flood Control Dams
Voluntary Purchase	Community Readiness	Retarding Basins
Voluntary House Raising	Flood Prediction and Warning	Levees
Building and Development Controls	Local Flood Plans	Bypass Floodways
Flood Proofing Buildings	Evacuation Arrangements	Channel Improvements
Flood Access	Recovery Plans	Flood Gates

A FRM study will examine a wide range of management options for selection in the management plan and may include measures which:

- change the community's response to the next flood event;
- change the impact of floodwaters on development;
- change where the floodwaters go; and
- change the way we currently plan for future development and apply controls to current development.

5.2 Evaluation of Measures

The implementation of management measures is likely to have economic, social and environmental implications. The benefits of each measure need to be weighed up against their costs to justify their implementation.

When examining management options, the focus of looking at benefits and costs should be on aspects that will change due to the management option and effort should not be wasted on aspects that do not change.

Management option, especially structural options, need to consider whether the option impacts on the environment. For example, the construction of levees and floodgates may impact on wetlands which require tidal flows for efficient operation. Whilst such as examination should be sufficiently thorough to determine whether the option is environmentally viable, it does not extend to undertaking an environmental impact assessment. These more detailed assessments which will if needed be undertaken as part of detailed investigation and design before construction commencing. Where possible, opportunities for enhancement of the environment via the implementation of FRM measures should also be investigated and promoted.

While it is possible to identify tangible costs e.g. the financial costs of implementing structural works or development controls, it is not practical to ascribe a monetary value to intangible costs e.g. social dislocation caused by flooding. This does not mean, however, that intangible costs are any less important in considering whether management options are justifiable. They are generally examined in a qualitative way so that this can inform decisions.

When examining management measures and development proposals, it is very important that consideration be given to the impact of the development or measure on flood behaviour as well as the impact of flooding on the measure or development.

5.3 Flood Damage

The assessment of damages can help focus FRM efforts by providing important information on the severity and location of impacts. Any reduction in impacts resulting from the implementation of mitigation measures provides advice on their relative cost-efficiency through cost-benefit analyses including qualitative assessments of benefits and costs where relevant.

The severity of consequences of flooding on the community can be assessed based upon the frequency and scale of tangible and intangible impacts.

5.3.1 Types of Damage

Flood damages are traditionally divided into tangible and intangible damages. Tangible damages are also sub-divided into direct and indirect damages (Figure 27).

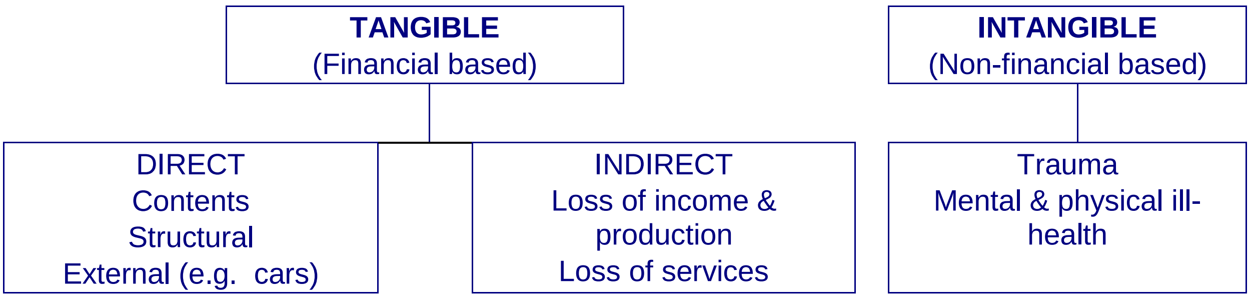


Figure 27 Types of Damage

5.3.2 Stage – Damage Curves

Direct damages are normally calculated using stage-damage curves. These curves show the damages that can be expected to occur for a range of depth of water over the floor. A sample stage-damage curve is shown in Figure 28.

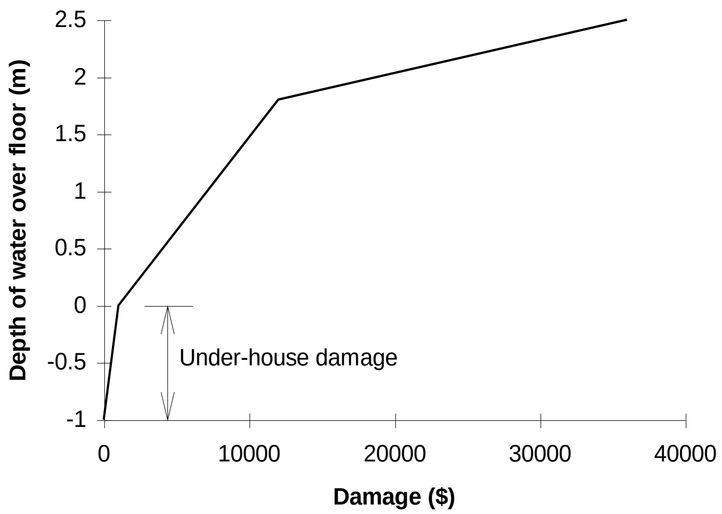


Figure 28 Sample Stage-Damage Curve

5.3.3 Average Annual Damage

The average annual damage (AAD) is the total damage caused by all floods over a long period of time divided by the number of years in that period. It represents the amount of damage that can be expected to occur every year on average. A sample curve relating damages to various design floods is shown in Figure 29. Such curves can be used to calculate the area under the curve to give AAD.

Examining the change in AAD is a convenient way to compare the economic benefits of various proposed mitigation measures.

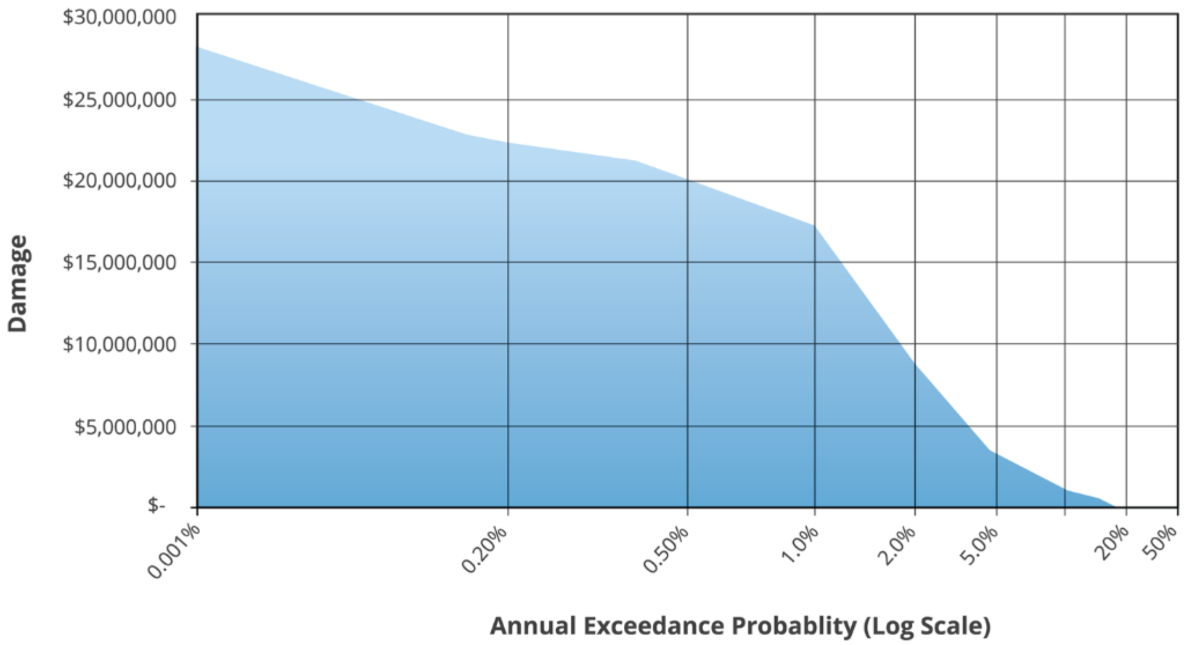


Figure 29 A Sample of a flood damage curve for a range of AEP events (ARR 2019)

5.3.4 Benefit/Cost Ratio

A convenient method of assessing the economic viability of proposed mitigation measures is the benefit/cost ratio. Here the net present worth of the benefits associated with the measure (e.g. the reduced AAD) (Figure 30) is divided by the cost of the measure (e.g. construction cost, on-going maintenance costs and financing costs). If the B/C ratio is greater than 1 this implies the works have more tangible benefits than cost, and vice versa for a B/C ratio less than 1. However, works with a lower B/C ratio may still be viable when social, environmental and similar benefits and costs considerations are also considered.

The level of economic appraisal of an option varies with cost, impacts etc. Economic appraisal can be an iterative approach with cursory analysis needed in the initial phases of a study to detailed analysis for final decisions.

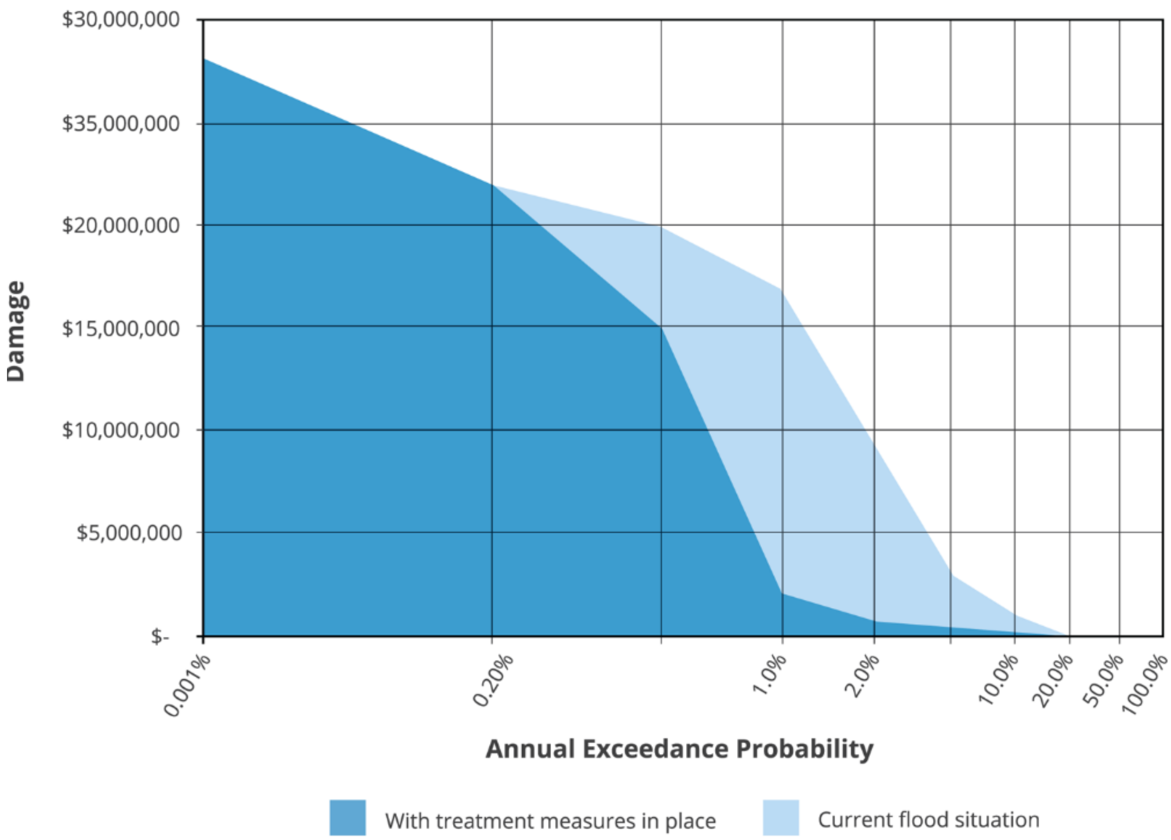


Figure 30 Sample Damage Curve with and without treatment options (ARR 2019)

6. REFERENCES

This handbook only provides basic information on flood risk management issues. The following publications and videos can assist in obtaining more comprehensive information.

AIDR 2017a, Australian Disaster Resilience Handbook 7 Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia, https://knowledge.aidr.org.au/media/3521/adr-handbook-7.pdf

AIDR 2017b, Australian Disaster Resilience Guideline 7-3 Flood Hazard, https://knowledge.aidr.org.au/media/3518/adr-guideline-7-3.pdf

AIDR 2017c, Australian Disaster Resilience Guideline 7-5 Flood Information to Support Land-use Planning, https://knowledge.aidr.org.au/media/3519/adr-guideline-7-5.pdf

ARR 2019, Australian Rainfall and Runoff: A Guide to Flood Estimation, Geoscience Australia, http://arr.ga.gov.au/arr-guideline

Managing Flood Risk (Video Series) Gosford City Council (2013), https://www.youtube.com/playlist?list=PLjDIzhwADz3YsX_Wb-B9JUsEI9PEiX0-Y

NSW Government (2005), *Floodplain Development Manual*, Department of Infrastructure Planning and Natural Resources, DIPNR 05_020, https://www.environment.nsw.gov.au/research-and-publications/publications-search/floodplain-development-manual

NSW Department of Planning Industry and Environment (DPIE), Floodplain Risk Management Guidelines, https://www.environment.nsw.gov.au/topics/water/floodplains/floodplain-guidelines

NSW Department of Planning Industry and Environment (DPIE), Floodplain Risk Management Guidelines, *Incorporating 2016 Australian Rainfall and Runoff in studies*, 2019, https://www.environment.nsw.gov.au/topics/water/floodplains/floodplain-guidelines

Shellharbour City Council, *Macquarie Rivulet Flood Study*, WMAwater, 2017

Note

[1] The Department of Planning Industry and Environment (DPIE) was formerly the Office of Environment and Heritage (OEH) up until 30 June 2019. References to DPIE documents may relate to documents labelled OEH.