Australian Disaster Resilience Handbook Collection

GUIDELINE 7-6

Assessing options and service levels for treating existing risk

Australian Institute for Disaster Resilience

AUSTRALIAN DISASTER RESILIENCE HANDBOOK COLLECTION

Assessing Options and Service Levels for Treating Existing Risk

Guideline 7-6

Supporting document for the implementation of *Australian Disaster Resilience Handbook 7 Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia* (AIDR 2017)

Australian Government
Attorney-General's Department

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Handbook 7 Collection

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

For use with 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

For use with 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

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1 Introduction

Flood risk is created when the community and the built environment are exposed to hazardous flood conditions.

Risk can be measured in terms of the likelihood and scale of consequences to people, the economy, the environment, public administration and the social setting (see *Australian Disaster Resilience Handbook 10, National Emergency Risk Assessment Guidelines* (ADR Handbook 10) (AIDR 2015).

Understanding existing risk provides an important baseline for identifying whether treatment of flood risk warrants consideration. *Australian Disaster Resilience Handbook 7 Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia* (ADR Handbook 7) (AIDR 2017) provides a sound basis for understanding flood risk.

Managing flood risk to the community generally involves a mix of treatment measures, including land-use planning activities, mitigation works and emergency management, as shown in ADR Handbook 7. The handbook provides information on the options available for treating flood risk, and the associated limitations in managing risk to the community.

The selection of different treatment measures and the level of service they provide to the community is influenced by:

- the physical characteristics of the location
- economic, social and environmental benefits and costs
- the technical feasibility
- local factors, including community attitudes, support and affordability.

A significant challenge is to evaluate and optimise options robustly.

This guideline outlines a methodology and criteria to consider when selecting and optimising both treatment options and packages, and the design flood level for a mitigation work for a local community. The information in this guideline should be considered when developing fit-for-purpose assessment processes.

1.1 Outline of this guideline

This guideline is divided into three sections:

- Section 1 outlines the guideline, and its relationship to other handbooks and documents.
- Section 2 outlines typical stages and issues to consider when assessing flood risk.
- Section 3 provides case studies of how to use this guide to select a treatment option and level of service for a mitigation work.

In addition, an appendix provides some issues to consider in developing cost estimates.

1.2 Use with other guidelines

This guideline is to be read in conjunction with ADR Handbook 7. Many of the terms used in this guideline are defined in the handbook and a range of other relevant guides. Specifications for studies using the *Australian Disaster Resilience Guideline Template 7-4 Technical Project Brief Template* (AIDR 2017), and the associated guideline *ADR Guideline 7-1 Using the National Generic Brief for Flood Investigations to Develop Project Specific Specifications* (AIDR 2017) can be extended to include the requirements of this guide.

The guideline was developed considering ADR Handbook 10 and *A framework for natural disaster mitigation decision-making* (Risk Frontiers 2016a).

ADR Handbook 7, the associated guidelines and the national generic brief for flood investigations are available for free download at **www.knowledge.aidr.org.au**.

2 Assessing and optimising treatment options

Option assessment and optimisation aim to provide decision makers with robust advice to inform their decisions about treatment options and packages.

Developing this advice starts with an understanding of existing flood risks, and then progressing through option identification and preliminary assessment. The most promising treatment options and packages would then progress to more detailed assessment and optimisation.

2.1 Identification of existing risks

Understanding of the full range of flood behaviour with existing treatment measures in place, and the consequences of flooding on the community provides a basis for understanding existing risk. This understanding can be developed through the floodplain-specific management process outlined in ADR Handbook 7. This information can be used to assess the existing risks based on the likelihood and consequences to:

- **people**—threat to human life as measured by the number of fatalities and injuries, and risk perception
- **economy**—effects on economic activity and or asset losses
- **environment**—effects on flora and fauna communities and ecosystems
- **public administration**—effects on the ability to govern, and short- and long-term impacts on services, including health, communications, water and sewerage systems, electricity and gas, transport services, and waste removal services
- **social settings**—loss of community wellbeing, including community amenity, loss of culturally important objects and activities such as community connectedness, aesthetic values, landscapes and recreational facilities. It also considers any implications on the ability of the community to grow.

Risk analyses may be quantitative or qualitative.

A quantitative analysis is often used where both the probability and the consequences can be measured. For example, when examining flood damage, a damage model may be established to assess the financial effects from floods on the community for the full range of flood events. Consequences may be estimated by determining tangible direct or indirect flood damages to the community for flood events of different annual exceedance probabilities (AEPs). This information can provide an understanding of the scale of effects, and the frequency of the flood event in which these effects start to occur or may change significantly. It can also indicate the potential scale of benefits from treatment packages and mitigation works with different service levels.

Qualitative estimates are generally undertaken where consequences cannot be quantitatively measured. For example, social and environmental effects are often difficult to quantify. Figure 1 provides an example qualitative risk assessment matrix that could be used to indicate the magnitude of risks to the different elements at risk. Tables 3–8 of ADR Handbook 10 provide information on relative scales of consequences. Risk Frontiers (2016b) provides an example of combining qualitative with quantitative estimates to assess a levee system in Carnarvon in Western Australia.

Estimates of current risk to different elements can provide a baseline to inform decisions about the effectiveness of existing treatment measures, and to identify whether further risk mitigation may warrant consideration.

The variation in risk can be analysed in more detail. As shown in this example, the community is most affected by flooding of moderate to major consequence. This results in medium to high flood risks to people, public administration, social setting, people and the economy. The risks to the environment are less significant.

2.2 Identification of treatment options

Option identification should be an inclusive process to gather a wide range of ideas. It may involve those contributing to, or affected by, flooding or its treatment, such as the floodplain management entity, the community, government agencies or other stakeholders.

Appropriate measures to treat the existing risk to a community or location will vary depending on the flood risk exposure of existing development, and the practicality and feasibility of the options to mitigate this risk. A combination or package of treatment measures is often used to manage the risk profile, as discussed in Chapters 7 and 9 of ADR Handbook 7.

Likelihood 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

Figure 1: Example qualitative risk matrix

2.3 Preliminary assessment of treatment options

After a range of flood risk management options appropriate for treatment of the existing flood risk are identified, the next step may involve a preliminary or screening assessment to determine which treatment options and packages may be worth further consideration. Preliminary assessment examines whether solutions are practical and feasible, and if they would warrant a more detailed assessment. This process can filter out projects that are:

- not physically and technically feasible for the location
- not likely to be supported by the community
- not likely to be compatible with the management of other hazards and issues
- not likely to reduce the risk
- likely to involve substantial costs and disbenefits relative to their likely benefits on preliminary examination.

Assessing the treatment options can also identify a range of similar packages, and recommend more detailed assessment of the most viable of these packages rather than using time and resources to assess them all.

2.4 Detailed assessment of treatment options

A detailed assessment of options, packages and different levels of service for mitigation works can determine their effectiveness and efficiency in treating risk. Detailed assessment of treatment options may involve:

- assessing the capability to treat risk (Section 2.4.1)
- assessing multiple criteria (Section 2.4.2)
- scoring against a range of assessment criteria (Section 2.4.4)
- reporting on a treatment package (Section 2.4.4).

The floodplain-specific management process outlined in ADR Handbook 7 can provide the basis for gathering the information necessary to understand specific flood problems and testing the effectiveness of different options to reduce risk. Assessing the functionality and benefits of different options and service levels may use information from a range of design floods, such as the 0.5 per cent, 0.2 per cent, 1 per cent, 2 per cent, 5 per cent and 10 per cent AEP floods.

2.4.1 Assessing the capability to treat risk

Assessing the relative effectiveness of options to treat different risk factors at a location is an important step in developing an effective treatment package. This assessment is usually done using a combination of qualitative and quantitative approaches that consider any changes to the likelihood or consequences, and therefore to risks, because of the implementation of measures.

The example discussed in Section 2.1 (with existing risks shown in Figure 2) is now used as an example of

Likelihood of consequence	AEP range (%)	Level of consequence				
		Insignificant	Minor	Moderate	Major	Catastrophic
Likely	>10	Environment	People Public admin Social setting	Economy		
Unlikely	1 to 10	Environment		People Public admin Social setting	Economy	
Rare to very rare	0.01 to 1		Environment	Public admin Social setting	People Economy	
Extremely rare	<0.01		Environment	Public admin Social setting	People Economy	

Risk: Very low Low Medium High Extreme

AEP = annual exceedance probability

Figure 2: Example of flood risk to an existing community

assessing the capability of a mitigation work to treat risk. In this example, the mitigation work proposed is a levee built to protect the community from the 1 per cent AEP flood. By setting this service level, the community is accepting that—even with the levee in place—there is a 1 per cent (or 1 in 100) chance that the protected area will be flooded in any given year, although the consequences of flooding when a flood of this magnitude or greater occurs may be reduced.

In this example, the levee will reduce the likelihood that the existing community will be exposed to flooding and its consequences in events up to the design flood. As shown in Figure 3, the level of consequence for an unlikely flood reduces from major and moderate to minor.

However, floods larger than the 1 per cent AEP flood (rare to extremely rare floods) will exceed the design capacity of the levee and can flood the protected area, which will affect the community. Unless this risk to people is addressed, the consequences to people from these rare events are unlikely to decrease and may in fact increase. This may warrant additional measures, such as:

- a flood gauging network to facilitate flood predictions
- flood warnings to the community based on flood predictions
- changes to emergency management planning considering the levee
- work to improve and maintain community flood awareness.

For example, improvements in emergency response planning may rely on a particular evacuation route that is vulnerable to flooding. It may be necessary to make improvements aimed at reducing the vulnerability of this evacuation route to flooding, to facilitate effective emergency response. With these additional treatments in place, the consequences to people in extremely rare events are reduced from major to moderate, and the risk to people is now relatively low. These additional treatments do not necessarily significantly influence risks to the economy or public administration. In some cases, improved warning time can enable some minor flood damage reduction, but not in this example.

In some cases, plans to protect objects of cultural significance during a flood emergency can reduce the effects on social settings. However, this reduction is not significant in this example. Figure 4 shows the additional modifications in risks to the community because of these extra treatments.

Figure 5 shows the overall risks with the whole package of treatment measures in place. This example shows how a combination of treatment measures may be necessary to effectively manage the different elements of flood risk identified in Figure 2.

Likelihood of consequence	AEP range (%)	Level of consequence				
		Insignificant	Minor	Moderate	Major	Catastrophic
Likely	>10	Environment People Public admin Social setting Economy	People Public admin Social setting	Economy		
Unlikely	1 to 10	Environment	People Public admin Social setting Economy	People Public admin Social setting	Economy	
Rare to very rare	0.01 to 1		Environment Social setting	Public admin Social setting Economy	People Economy	
Extremely rare	<0.01		Environment Social setting	Public admin Social setting	People Economy	

Risk: Very low Low Medium High Extreme

AEP = annual exceedance probability

Figure 3: Example of transformation of existing risk to the community with a 1% AEP levee

Likelihood of consequence	AEP range (%)	Level of consequence				
		Insignificant	Minor	Moderate	Major	Catastrophic
Likely	>10	Environment People Public admin Social setting Economy				
Unlikely	1 to 10	Environment	People Public admin Social setting Economy			
Rare to very rare	0.01 to 1		Environment Social setting	People Public admin Economy	People	
Extremely rare	<0.01		Environment Social setting	People Public admin	People Economy	

Risk: Very low Low Medium High Extreme

AEP = annual exceedance probability

Figure 4: Example of transformation of risk to the existing community with additional mitigation

Likelihood of consequence	AEP range (%)	Level of consequence				
		Insignificant	Minor	Moderate	Major	Catastrophic
Likely	>10	Environment People Public admin Social setting Economy	People Public admin Social setting	Economy		
Unlikely	1 to 10	Environment	People Public admin Social setting Economy	People Public admin Social setting	Economy	
Rare to very rare	0.01 to 1		Environment Social setting	People Public admin Social setting Economy	People Economy	
Extremely rare	<0.01		Environment Social setting	People Public admin Social setting	People Economy	

Risk: Very low Low Medium High Extreme

AEP = annual exceedance probability

Figure 5: Reduced risks with all treatment measures in place

2.4.2 Assessing multiple criteria

A multicriteria assessment can provide a sound basis for determining the relative benefits, disbenefits and costs of different treatment options, treatment packages and design service levels. It can be used to inform decision-makers when they are considering how to manage flood risk within their floodplain. It can assist in deriving and choosing between treatment options and packages, optimising the design flood for a mitigation work, and prioritising between different elements of an agreed management program.

In Sections 9.4 and 12.3, and Table 9.3 of ADR Handbook 7, and Risk Frontiers (2016a) provide information on multicriteria assessment, including scoring and weightings of options and issues. The issues considered during this type of assessment will vary with the specifics of the location, flood behaviour and community flood exposure, and with jurisdictional requirements.

The components of a detailed multicriteria assessment may include the criteria outlined in Section 2.1 and other criteria that may influence decision making. A range of criteria that may be considered are outlined below.

People

The effects of flooding on people can include fatalities and negative health outcomes, which can vary across the range of design events.

Structural mitigation works can alter exposure of the community or parts thereof to flood behaviour. This can provide benefits to those whose exposure is reduced. It may also alleviate some of the fear or dread of flooding in the community.

Mitigation works may also have disbenefits. Some areas of the community may have increased flood risk, posing a social equity issue. In addition, a large mitigation work may give the false sense of security that flooding is no longer a risk, and the community may become complacent or less aware of the need to be alert for, and respond to, a flood threat. An ongoing program to increase and maintain community awareness of the flood threat and how to respond to this threat may need to be considered.

Economy, financial efficiency and affordability

Economy

Floods can have a significant effect on local, regional, state and even national economic activity, and result in significant asset losses. An estimate of asset losses can be derived using a flood damage model that compares flood modelling results with information about the assets at risk in the floodplain (e.g. ground levels, floor levels to structures, and estimates of damage to structures and contents).

Financial efficiency

The relative financial efficiency of different treatment options, packages and levels of service for works can be assessed by comparing the costs of the works with the benefits they may produce through a cost–benefit analysis.

Measuring benefits

Mitigation works can reduce the effects of floods on economic activities, alter the scale of damage to assets and reduce other financially quantifiable damages, as well as having non-financial benefits.

Understanding the flood damages for the existing situation provides a base case for assessing the reduction in damages as a result of applying different treatment options, packages and service levels.

Assessing the reduction in flood damages from existing circumstances to those with the mitigation work in place outlines the benefits for different design events. This can be used to derive average annual benefits and the net present value (NPV) of benefits for the option (see the example in McLuckie et al. 2016).

Assessing costs

The cost of the works should be initially assessed with sufficient accuracy so that it can be compared with other factors in the assessment. Cost estimates should be based on life-cycle costs, and include:

- upfront costs such as investigation, design and construction, which should
  - include all work integral to the project, such as compensatory works to offset impacts
  - include any land acquisition costs
  - consider the need for relocation of services
  - consider the requirements of construction
- ongoing operation and maintenance costs, which should be separately identified from upfront costs. Depending on the type of work, these ongoing costs can be prohibitive or can influence the design of the project (e.g. a lower life-cycle cost may result from a higher investment in construction, which leads to lower maintenance costs).

This information can be used to derive an NPV of costs for an option.

Estimates can be developed for different treatment options, packages and design service levels. In general, costs will follow an identifiable trend when comparing option cost and design event. This trend can be used to interpolate the cost of a particular level of service. Three events—for example, a 'high', 'medium' and 'low' event—will generally be enough to establish a relationship between option cost and design event.

Additional advice on developing cost estimates is provided in the appendix.

Cost–benefit ratios

As the cost of flooding to the community increases with larger floods, a structural work designed to provide protection from a larger flood will almost always give a higher financial benefit. However, this higher benefit needs to be considered in light of both the increased costs and disbenefits that may be associated with the larger works, and the physical constraints that the built and natural environment may place upon the works.

Cost–benefit ratios provide a basis for assessing relative financial efficiency. They are derived by comparing NPV of benefits relative to the NPV of costs (see McLuckie et al. 2016 for an example).

The higher the cost–benefit ratio, the more financially efficient the project. Any project with a cost–benefit ratio >1 has a positive financial return on the project. Relative financial efficiency can be assessed by comparing cost–benefit ratios for different options, packagers and service levels. Further benefits, costs and disbenefits relate to other factors outlined in this section.

Affordability

Treatment measures may involve financial contributions from a range of parties, including the local community, often through the floodplain management entity or other local government body. Financial contributions from higher levels of government are often limited to funding for investigation, design and construction, with ongoing operation and maintenance costs solely funded at a local level. Affordability for the local community can be a key issue and needs to be considered across the life cycle of the project.

Financial feasibility should consider the availability of financial assistance from higher levels of government, and how the local community would contribute to or pay for these works, such as through broad or targeted (raising from benefitting properties) revenue sources.

Environment

The main purpose of mitigation works is to reduce flood risk in certain areas of the floodplain. This can alter flood behaviour, which can affect the environment. When considering flood mitigation works, it is important to understand the environmental issues they may influence.

Environmental effects generally depend on whether a work is likely to impact on areas of environmental significance, or whether it is bringing the catchment closer to its pre-developed state or modifying it further from the existing state. Where an area of environmental significance will be affected, a specific assessment of these impacts will generally be required. Where modifications move the floodplain closer to the pre-developed state (which may include clearing non-native vegetation, and reinstating or rehabilitating watercourses in urbanised areas), these changes are generally beneficial to the local environment.

In contrast, modifying away from pre-developed catchment conditions (by using channel straightening, dams, retarding basins and levees) can have both positive and negative effects on the environment. The effect largely depends on the sensitivity of the affected area to decreased or increased inundation, as well as the effect during relatively frequent floods.

Mitigation works also have the potential to isolate flood-dependent ecosystems from flooding. Where this is the case, complementary measures may be necessary to enable floodwaters to reach the ecosystem while still managing the flood risk.

Public administration

Floods can affect the ability of government to function. Services such as health, communications, water and sewerage systems, electricity and gas, transport services and waste removal services can be affected by flooding in the short or long term.

Mitigation works can reduce the effects on public administration, and the associated benefits should be considered in assessing options. For example, extending a levee around a town to protect the sewage treatment works may enable sewage to be treated during a flood. In addition, having in place an emergency response plan for the sewage treatment plant that addresses the flood impacts to critical plant (such as key pumps and electrics) for floods that will overtop the levee, can facilitate return to operation. This would reduce the adverse health and environmental effects, and improve the potential for the community to be able to operate effectively during, and while recovering from, a flood event.

Standards, physical and technical constraints

Jurisdictional or local policies that set standards for new development can influence the level of service that the existing community prefers. Physical constraints can affect the feasibility of mitigation, the type of mitigation works suited to a location, the area that can be protected, the service level the work can achieve and the complementary measures needed to support a mitigation work. The limitations include the following factors:

- The location of the mitigation works. For example, if flood mitigation works, such as a levee, cannot be constructed and operated on public land, land may need to be acquired or access to private land (such as through easements) gained. Alternatively, the design may need to be changed to go through public land, which may reduce the area protected and may influence the level of service.
- The effect on flood behaviour. Construction of a levee, detention basin or other form of flood mitigation works could change flood levels, flow velocities and drainage paths. Although the mitigation works may protect some in the community, it may have negative impacts on others in the community. This can cause social equity issues, as discussed in a later section.
- The design height of a structure, such as the crest level for levees, dams and detention basin embankments and similar structures. This affects the amenity of the surrounding land and is often a key issue for those living nearby. The design height needs to include freeboard (see ADR Handbook 7), which should not be treated as a flexible quantity that can be lowered to misrepresent the advantages and disadvantages of a particular design flood.
- The level of flood protection that is feasible. For example, the natural high points in a town can be used to limit the length of levee needed to provide a certain level of protection for a community. This has cost advantages. However, the height of these high points may limit the service level that is able to be provided without raising and extending the levee. This can have practical and financial implications.

In addition, the non-stationary nature of hydrology, the floodplain and the catchment means that the flood behaviour for a particular design event may change within the design life of a mitigation work. Designs that enable adaptive management can support modification over time to address change where warranted.

Climate change is a well-known factor contributing to changes in flood behaviour. Bates et al. (2016) and McLuckie et al. (2016) discuss how to consider climate change. Testing the sensitivity of the design flood to change can inform the potential need to alter mitigation works to adapt to changes in climate within its design life. The need for adaptive management can then be considered, where relevant, in design. Adaptive management, for example, can involve designing a levee so that it can be practically and cost-effectively raised in the future. In the case of an earthen levee, this can affect the design of the structure and area of land acquisition—and therefore costs.

Social setting

Floods can disrupt important community social and cultural events, destroy or damage culturally important artefacts and recreational facilities, affect the social wellbeing of the community and affect the ability of the community to grow. Mitigation works can change the scale or frequency of these effects.

The location or scale of mitigation works may also affect culturally important artefacts and recreational facilities. They can also have an effect on community connectedness to the river, and the aesthetics and enjoyment of the area by reducing visibility of, and access to, the watercourse (by foot or perhaps boat), or temporarily or permanently losing vegetation. These aspects need to be considered, and effects minimised in the investigation, design and construction of works. These may be broad effects on the community, or there may be more localised effects for a particular area or number of properties.

Community issues

The acceptability of treatment packages by the community can depend on community issues such as social equity and support for the package.

Social equity

Mitigation works can change flood behaviour, which may influence the degree that floods affect certain properties, property values or flood insurance premiums. As outlined previously, they can also adversely impact on the enjoyment and use of some properties or amenities.

Considering social equity can identify whether the mitigation works result in winners or losers. It also looks at opportunities to consider whether such inequities can or should be addressed.

Where measures to address inequities are warranted, these may include identifying the need for compensatory measures to offset or reduce negative effects. Where appropriate, they should form part of an overall treatment package for the community or location, and be included in any associated cost estimates.

Community support

It is important to consider the community's attitude to the works, because this is likely to influence whether the community will support their implementation. There can be widespread or localised community support or opposition to a mitigation work or package. It is important to understand the associated reasons so they can be considered during decision-making processes.

The alignment of proposed treatment works with other community goals can be important for this support. For instance, removal of exotic riparian or floodplain vegetation and replacement with appropriate native vegetation, combined with a plan to manage vegetation, may be compatible with the community's environmental goals while improving and maintaining flow conveyance. However, removal of native vegetation to improve conveyance may come at an environmental cost and not be compatible with other community goals.

Community expectations

The choice of treatment options, packages or the service level for a structural work often depends on the level of flood risk the community is willing to accept, and the associated cost. The willingness to pay for protection can vary across a community and should be examined during community consultation as part of a study.

Communities that have experienced flooding are likely to have their own perception of the causes and effects of flooding, and may have their own way of responding to a flood. For example, residents of flood-prone properties may be willing to accept their flood risk and have their own systems in place to manage flooding when it occurs. On the other hand, others in the community may strongly advocate for mitigation works that improve their flood protection.

A community will typically consider several factors when examining the service level provided by a mitigation work, such as:

- the service level provided to new development in the community. Some members of the community may see the minimum standards for new development as the least that should be achieved. Others may see this as an upper limit on the level of protection that can be provided to an existing community
- the cost of works to the community and individuals, and their ability to pay for them
- the costs of flood insurance now and how this will change with the works in place
- any negative effects of the works on existing flood immunity.

Where mitigation works are hidden, such as upgrading pipe systems, or further away, such as basins well upstream of the location, the community is less likely to be concerned about amenity or land issues, and more interested in the protection provided and its costs. When strong expectations do exist, a more involved community and stakeholder consultation process will generally be required, and may require examination of a range of options.

Optimisation

Optimisation generally involves reviewing a package of options to examine the potential to improve its benefits, and reduce its costs and disbenefits through a multicriteria assessment. Those options might have different service levels, and require balancing the benefits, costs and disbenefits to achieve the most effective solution.

In many cases, the initial examination of the structural mitigation work is based on the service level for a specific design flood. The defined flood event used to manage new development is often used for this initial assessment, because it would provide protection to the existing community in line with the protection provided to new development. However, constructing, operating and maintaining structural mitigation works within the constraints of the built and natural environments can be challenging, and it may not be feasible to achieve this service level.

Therefore, other service levels should be tested in terms of their capability to manage risk with the aim to optimise relative benefits, costs and disbenefits of the works.

A package will often contain complementary measures, such as flood warning systems, that do not relate to a specific service level. Therefore, the benefits they provide are unlikely to be affected by a change in service level of the mitigation work.

However, the effectiveness of a treatment measure may be reduced if it relies on the service level of the mitigation work. For example, a levee upgrade may not only reduce flood damage but may also protect the evacuation route. This protection to the evacuation route may provide more time for the community to evacuate safely in accordance with local emergency management arrangements. Lowering the service level for the levee may reduce these benefits and, therefore, should be considered when optimising the service level.

2.4.3 Scoring projects to inform decisions

Translating an understanding of the relative benefits, costs and disbenefits can involve scoring the relative effectiveness of treatment options or packages in addressing risk. Table 9.3 of ADR Handbook 7 provides an example of a weighted assessment, and Risk Frontiers (2016a) outlines several such approaches.

Scoring against each criteria

The relative effectiveness of an option to address an issue can be assessed using a scoring system. For example, for the effects of a mitigation work in addressing a particular criterion:

- highly effective could be 5 or 10
- no change could be 2.5 or 5
- significant negative impacts could be 0.

Therefore, using the larger range, positive benefits range from 5.1 to 10, negative benefits from 0 to 4.9 and no change is 5. This raw scoring can then be used with weightings to translate relative qualitative benefits and disbenefits of different options into a quantitative score to inform decision making.

Weighting criteria

Different communities, decision makers and groups may consider different criteria to be more or less important. Weighing the relative importance of these criteria can provide a basis for enabling these differences to be effectively included into the assessment. For example, weightings could go from highly important (5 or 10) to relatively unimportant (1).

Weighted scores

Where weightings are being used, raw scores are translated by multiplying these by the weightings to create weighted scores for each factor. An overall score can then be derived for each option presented in a matrix style, with scoring against each factor for simplification.

This information may be used to compare different treatment options, packages and service levels, to help select a preferred package.

Weighted scores can also be used to help prioritise the order of works within an individual package. However, prioritisation also needs to consider the resources needed and the ease of undertaking the measures. For example, altering land-use planning controls could be well within the resources of the local floodplain management entity and, therefore, be more readily able to be implemented. On the other hand, construction of a levee may rely on financial assistance from external sources.

2.4.4 Reporting

The assessment and scoring process cannot make the decision for decision makers. However, it can provide guidance that is based on the relative effectiveness and efficiency of options in addressing a wide range of concerns of varying relative importance.

Reporting should include the assessment's findings, cover the full range of relevant issues outlined in this section, document community consultation and outline the outcomes. Reporting may include advice on:

- the options identified
- the options excluded after preliminary assessment and associated reasoning
- the options and packages that underwent detailed assessment, including complementary and compensatory measures to provide the desired level of service and address adverse impacts
- the results of a multicriteria assessment, including reporting on scoring (weighted and raw) and sensitivity to weightings, scoring and assumptions
- the ability of treatment packages and works to adapt to catchment and climate changes
- where improved knowledge would warrant reconsideration of packages.

For the recommended treatment package, the following advice should be included:

- the make-up of the package, including complementary and compensatory works
- the effectiveness of this package to treat risk
- any practical or feasibility issues identified with the package
- where relevant, the freeboard suitable for the type of mitigation work at the location
- ongoing maintenance and operational costs and resourcing needs
- any known issues, and recommendations for further investigations that should be considered during the preliminary design, and any environmental assessment
- any residual risks that remain.

Section 9.4 of ADR Handbook 7 provides further advice about assessing options.

3 Case studies

This chapter outlines four case studies on option- and service-level assessment that cover a range of different flood issues and types of works.

The case studies help to illustrate the factors that can influence decisions. Examples 1 and 3 consider a number of options. Examples 2 and 4 concentrate on different levels of service.

3.1 Example 1—levee for a medium-sized rural town

3.1.1 Identification of existing risks

A medium-sized rural town is located on the north and south banks of a major river. The town experiences out-of-bank flooding in floods greater than and including the 10 per cent annual exceedance probability (AEP) event. The major commercial centre is on the southern bank, which is protected by an existing levee and excludes inundation from floods up to a 1 per cent AEP event.

The community on the unprotected northern bank is well established and enjoys the amenity of the location. During a 1 per cent AEP flood event, approximately 500 properties on the northern bank are affected by above-floor flooding.

Fewer than 10 agricultural properties are on the rural floodplain. Flood events occur with a long warning time (>1 week) and typically last for multiple weeks. There is little difference in level (approximately 0.1–0.3 m) between the 2 per cent and 0.5 per cent AEP events. An extensive flood warning system and effective emergency response planning are in place.

The frequency of flood impacts on the northern bank can result in medium risks to the community, even in minor events. Consequences increase to moderate to major levels in rarer floods, as the levee protecting the southern area of town is overtopped in rare to very rare events. This results in the risks to people, the economy and public administration increasing to high, whereas

Likelihood of consequence	AEP range (%)	Level of consequence				
		Insignificant	Minor	Moderate	Major	Catastrophic
Likely	>10	Environment	People Public admin Social setting Economy			
Unlikely	1 to 10	Environment	Social setting	People Public admin Economy		
Rare to very rare	0.01 to 1		Environment	Social setting	People Public admin Economy	
Extremely rare	<0.01		Environment	Social setting	People Public admin Economy	

Risk: Very low Low Medium High Extreme

AEP = annual exceedance probability

Figure 6: Example 1—flood risk to the existing community

risks to the social setting remain at medium. The risks to the environment are less significant.

The consequences and risk to people, the economy and public administration would be higher without the existing levee protecting the southern bank. Considering the relative risk exposure of the existing community, a decision has been made for the potential treatment measures to aim to reduce the medium and high risks experienced by people, the economy, public administration and the social setting.

3.1.2 Identification of treatment options

Potential treatment measures identified include:

- protecting residential properties by a levee in a design event
- minimising property damage by raising the houses that are affected
- reducing property damage by acquiring the affected properties
- improving the road access between the north and south banks
- flood-proofing the infrastructure services that are affected during a flood event.

3.1.3 Preliminary assessment of treatment options

A preliminary review of these measures identified that a levee and flood-proofing infrastructure services were practical and feasible to reduce the flood risk profile for the community.

House-raising was not considered practical, because it would only reduce the property damage and not the associated risks to residents. Property purchase would involve substantial costs and would be unlikely to be supported by the community. Improved road connectivity in the form of an upgraded bridge between the north and south banks was also not further considered, because of the likely high costs and the current alternative (less convenient) routes that can be used during floods.

3.1.4 Detailed assessment of treatment options

As part of the detailed assessment of a levee, a number of different design heights were assessed to ensure that the efficiency of the measure's treatment of flood risk was optimised. The following sections explain the factors that were considered during the detailed assessment.

People

In this case, a levee has to provide in excess of 2 per cent AEP protection to advantage the community.

Levee construction may create a false sense of security in the community, regardless of the design height. A targeted community consultation strategy would be needed to advise and maintain awareness of flood risk in the community.

Economics, financial efficiency and affordability

The area to be protected by the levee has an average annual damage (AAD) estimate of $530,000, with virtually all of the damage occurring in the 1 per cent AEP and rarer events. Table 1 shows the reduction in AAD, total cost saving over a design life of 50 years (assuming a 7 per cent discount rate), the life-cycle costs of construction and maintenance (including complementary and compensatory measures), and cost–benefit ratios for a 1 per cent AEP and 0.5 per cent AEP levels of service. Returns on investment and other benefits mean that there is the potential to access funding from higher levels of government.

Table 1: Example 1—financial benefits relative to costs of mitigation works

Levee design event	AAD reduction ($ million)	Reduction in damage (benefit) ($ million)	Cost of levee ($ million)	Cost–benefit ratio
1% AEP	0.17	2.5	2.8	0.9
0.5% AEP	0.34	5.0	3.1	1.4

AAD = average annual damage; AEP = annual exceedance probability

Environment

The levee would have very minor effects on the local environment, mainly limited to single trees or other vegetation that would be removed as part of levee construction. The alignment of the levee and the protected area are fully developed and do not contain flood-dependent flora or fauna that would be affected by a change in flood behaviour in a 1 per cent AEP or a 0.5 per cent AEP flood.

Public administration

Flood-proofing the community services that are affected during the design flood event is proposed to improve the services available during a flood and the ability to recover from a flood event.

Standards, and physical and technical constraints

Development controls for new residential development are generally managed based on the 1 per cent AEP flood event. The proposed levee is generally less than 1 metre high (slightly higher or lower depending on the level of service chosen) and there is ample open space for its construction. There may be constraints around purchasing land upon which to build the levee or negotiating easements to allow the levee to be built on private property but—given the small height variation—they are not likely to vary significantly with the level of service selected. There are no other physical features that might constrain levee height.

Changes to flood behaviour as a result of the proposed levee are generally minimal except for three of the ten dwellings on agricultural properties that experience an increase in flood level. The number of affected dwellings increases to five for the 0.5 per cent AEP. Compensatory works are required, and house-raising and stock mounds are practical and feasible solutions.

Climate change effects on design flood levels have been shown to be minimal at this location, and the need for adaptive management is similar across the range of different service levels being considered.

Social setting and community issues

For events up to the design event, the levee reduces the effects of flooding on cultural and social events in the town and on cultural artefacts. This benefit is similar across the range of design heights being considered. Levee construction and operation do not affect any cultural or historic artefacts. The levee location does not impact on the ability of the community to grow and may encourage development in protected areas.

There is general community sentiment that a levee is required to protect the area. However, there are mixed opinions about the required height. Some of those within the protected area want the same level of protection that occurs with new development (1 per cent AEP). These concerns also relate to flood insurance, because this can change substantially depending on exposure to a 1 per cent AEP flood event. There is a general awareness of the risk of larger floods, as a 2 per cent AEP flood was experienced around ten years ago.

However, there is not the same sense of urgency in the community that typically occurs after a larger flood. No current residents have experienced a 1 per cent AEP flood, and so some knowledge gaps exist about the impacts the levee will mitigate. Large areas of the town are outside the levee, which do not benefit from, and are not impacted by, construction of a levee. They are either supportive of a high standard (i.e. protection for a 1 per cent AEP) or are not actively engaged in discussions.

Approximately 50 properties situated next to the river will have impaired waterfront access and minor visual impacts. Both the positive and negative effects increase if the levee is higher (i.e. designed for a 0.5 per cent AEP). These residents are generally against a higher levee and are strongly advocating for a lower levee (i.e. 2 per cent AEP) or no levee at all. Figure 7 shows an example of how a levee might affect visual amenity and waterway access.

There are minor impacts on three of the ten agricultural properties as a result of the levee construction, at all levels of service being assessed. Compensatory works are required, and house-raising and stock mounds are practical and feasible solutions.

The proposed works have no impact on other community goals.

Residual risk

Choice of the 2 per cent AEP design event will leave significant residual risk, while the 1 per cent AEP or 0.5 per cent AEP design will lower residual risk substantially. Given that there is greater than 50 per cent chance that an area will experience a 1 per cent AEP flood during an 80-year period, then choice of the 2 per cent AEP event will mean the area is more likely to be flooded during an individual's lifetime. In contrast, there is around 30 per cent chance of experiencing a 0.5 per cent AEP event during an 80-year period. In this case, the broader community considers this a more acceptable level of residual risk.

Figure 7 Example of visual impact of a levee

Likelihood of consequence	AEP range (%)	Level of consequence: Insignificant	Minor	Moderate	Major	Catastrophic
Likely	>10	Environment	People Public admin Social setting Economy			
Unlikely	1 to 10	Environment	People Public admin Social setting Economy	People Public admin Economy		
Rare to very rare	0.01 to 1		Environment Public admin	People Social setting Economy	People Public admin Economy	
Extremely rare	<0.01		Environment	People Public admin Social setting Economy	People Public admin Economy	

Risk: Very low, Low, Medium, High, Extreme

AEP = annual exceedance probability

Figure 8: Example 1—reduced risks with all treatment measures in place

3.1.5 Conclusions

The dominant considerations in this case are the consequences to people and the economy, and financial feasibility and community expectations. The community expectations suggest that a 1 per cent AEP levee or higher is favoured by the majority of the community, because this provides the same level of protection as would be required for new development. The financial feasibility and consequences for people suggest that a rarer event (i.e. 0.5 per cent AEP) would have greater benefit, even considering the additional compensatory works. However, it would also negatively affect the riverfront properties and residents, and consequences to social equity slightly more than a 1 per cent AEP levee. The 1 per cent AEP would have significant benefits but slightly fewer impacts on riverfront properties. The 2 per cent AEP has limited benefit and is therefore not considered viable. Based on these factors, a decision was made to set the level of service for the levee based on the 0.5 per cent AEP flood event, given the overall benefit to the broader community.

A levee is capable of effectively treating the high flood risks experienced by the community. This is achieved by reducing the consequences to people and the economy during the design event by reducing the effects of a flood on the community and associated asset losses.

It is accepted that flooding will still occur in rarer events that exceed the service level of the levee, but it is probable that the consequences will be reduced with the levee in place. To reduce the risk across the community's risk profile, the levee construction would be supported by flood-proofing some community and utility services, community awareness programs targeting the ongoing flood risk, and compensatory measures for agricultural properties (house raising and stock mounds). Figure 8 shows the reduced risk with the treatment measures in place.

3.2 Example 2—levee upgrade for a large coastal town

3.2.1 Identification of existing risks

A large coastal town experiences significant riverine flooding (Figure 9). Approximately 4,000 properties on both sides of the river, including the town's commercial centre, experience inundation. An existing levee protects against flood events up to a 20 per cent AEP event, above which the levee is overtopped, and the roads and properties become inundated. There is ongoing development in the area, including new infill development behind the existing levee. Flood events occur with short warning time and will typically last for around 24 hours. An established warning system and evacuation arrangements are both in place.

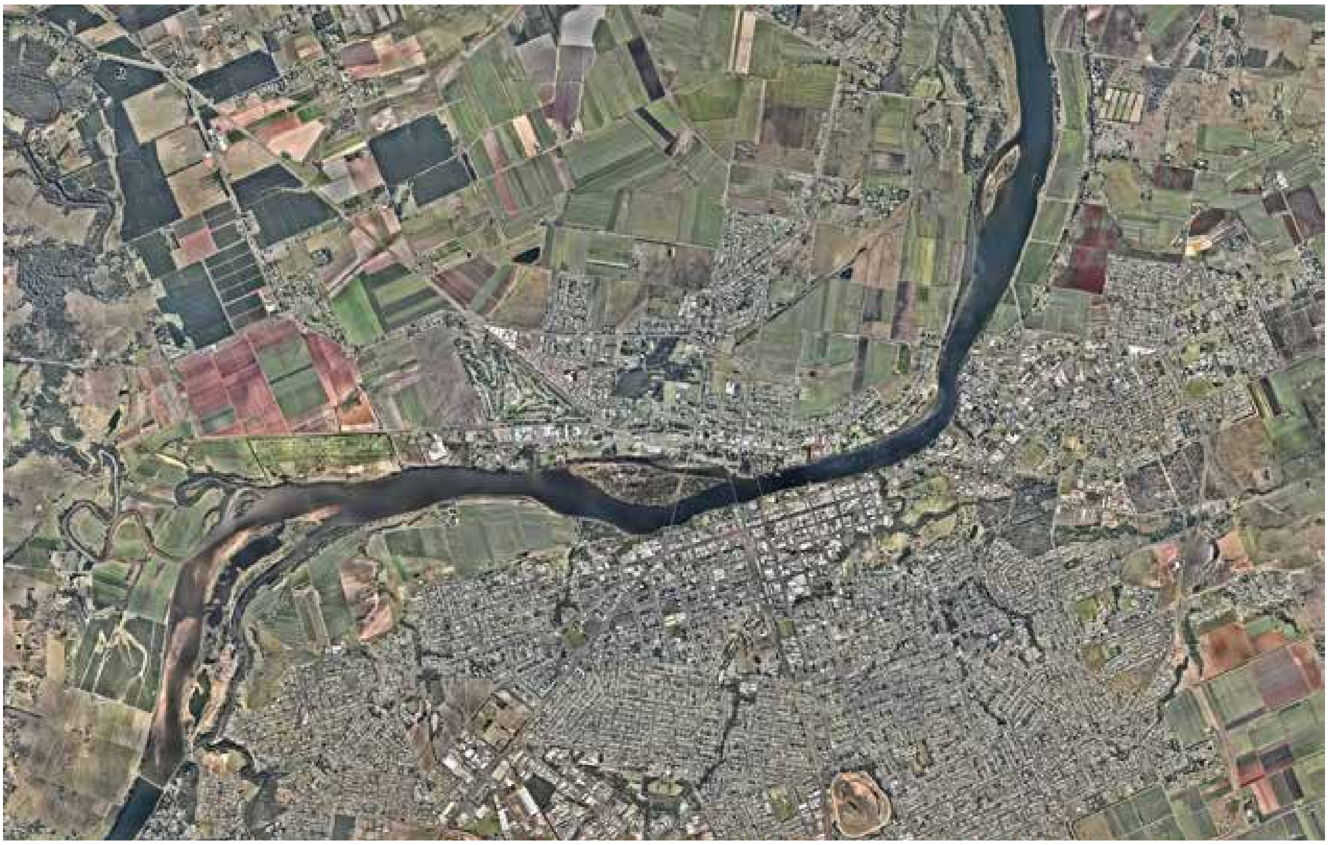

Figure 9: Example 2—large coastal town with riverine flooding

Likelihood of consequence	AEP range (%)	Level of consequence				
		Insignificant	Minor	Moderate	Major	Catastrophic
Likely	>10	Environment	Social setting	People Public admin Economy		
Unlikely	1 to 10	Environment	Social setting	People Public admin	Economy	
Rare to very rare	0.01 to 1		Environment	Social setting	People Public admin Economy	
Extremely rare	<0.01		Environment	Social setting	People Public admin Economy	

Risk: Very low, Low, Medium, High, Extreme

AEP = annual exceedance probability

Figure 10: Example 2—flood risk to the existing community

Parts of the community are affected by medium to high flood risk, with moderate to major consequences to people, the economy and public administration as a result of property inundation and associated asset losses. Risk to the environment and social setting is low (Figure 10).

3.2.2 Identification and preliminary assessment of treatment options

In this case, with an existing levee in place, the obvious means of increasing the community's protection against flooding is to upgrade the current levee to a higher service level. This will also provide additional evacuation time to respond to a flood threat, as inundation will be delayed.

3.2.3 Detailed assessment of treatment options

The following sections discuss the factors that were considered for the choice of design event.

People

The proposed levee upgrade will alter the exposure of the community to flood risk and reduce community concerns about the consequences of flooding. It would also have significant benefit to the town's evacuation if the 5 per cent AEP event (or rarer) is chosen, because inundation of roads leading to the main evacuation route from the area would be delayed.

However, raising the levee can create a false sense of security among the community. Community members may believe that raising the levee will mean there is no longer a flood threat and therefore not be aware of the need to respond to a flood threat. This would exist for all levee design heights. An ongoing community awareness program would improve and maintain community awareness of ongoing flood risk.

Economy and financial feasibility

The area to be protected by the levee upgrade has an AAD estimate of $1.2 million. The first damage occurs at a 5 per cent AEP, with progressively higher damages for rarer events. Protecting against the 5 per cent AEP event will lower the AAD by $210,000. The total savings during the 50-year life of the levee will be approximately $3.1 million (assuming a 7 per cent discount rate).

This information, along with the life-cycle costs of construction and maintenance, and cost–benefit ratios for 5 per cent AEP, 2 per cent AEP and 1 per cent AEP levels of service are shown in Table 2. As space constraints limit the feasibility of earthen levees to provide protection from a 2 per cent or 1 per cent AEP event, the cost of the levee rises significantly for these events, reflecting a composite of part-earthen and part-concrete construction. There is sufficient financial capacity to undertake the works and the works have the potential to be subsidised by higher levels of government.

Environment

The levee would have minor effects on the local environment, mainly limited to two areas of vegetation that would be removed as part of the levee upgrade. This vegetation does not contain any threatened species. The change in flood behaviour because of the raised levee would not affect any of the natural environment. This would be similar for all options being considered.

Public administration

The impacts and benefits to public administration are similar across all design events assessed.

Standards, and physical and technical constraints

Development controls for new residential development are generally managed based on the 1 per cent AEP flood event. There are significant construction feasibility issues for upgrading the existing level to a 2 per cent AEP level of service or higher along the existing alignment, which follows property boundaries. There is insufficient space to increase its footprint in some areas to provide this additional protection.

Therefore, this or a larger level of service could only be achieved with alternative construction methods, which will affect the costs as discussed previously and shown in Table 2. In addition, a level of service of the 2 per cent AEP protection or higher would also require a far longer levee than one built to protect against the 5 per cent

Table 2: Example 2—financial benefits relative to costs of mitigation works

Levee design event	AAD reduction ($ million)	Reduction in damage (benefit) ($ million)	Life-cycle cost of levee ($ million)	Cost–benefit ratio
5% AEP	0.21	3.1	4.8	0.65
2% AEP	0.34	4.6	6.8	0.68
1% AEP	0.63	8.0	9.5	0.84

AAD = average annual damage; AEP = annual exceedance probability

AEP event. If built for a 2 per cent AEP or larger flood, the levee would adversely affect a number of properties upstream; this could be managed by extending the levee to protect these properties.

Providing protection for the 1 per cent AEP event would significantly reduce the available waterway area through the town, and would require a levee that is around 2.2 m higher than the current levee. An earthen levee would not be feasible given the limited construction space, so alternative construction options were considered. However, as shown in Table 2, these options reduce the cost–benefit ratio for the levee.

The levee is adaptable if alternative construction options are used that consider the limited construction space. The need for adaptive management because of changing climate is expected to be similar across the range of design flood options being considered.

Social setting and community issues

The levee would reduce the impacts of flooding on cultural and social events in the town, and on cultural artefacts. The construction and operation of the levee would not affect any cultural or historic artefacts. For the 2 per cent AEP level of service, the restriction of the floodplain because of the raised levee would cause some minor negative effects upstream from the levee that could be managed by extending the levee. For the 1 per cent AEP event, the floodplain through the town would be reduced more than for the 2 per cent AEP level, but there would be widespread impacts on flood levels to upstream properties. These upstream impacts cannot easily be managed by compensatory mitigation works.

Upgrading to a 5 per cent AEP level would have manageable visual impacts, because it is not more than 0.4 m higher than the existing levee. However, a service level based on a rarer flood would block off the river from the town at eye level. Negative effects also include impaired waterfront access for the 300 properties situated next to the river.

The community understands the benefits of a levee, as there is already a levee in place. The community would like to see flooding completely mitigated by human-made structures; however, it is not physically possible or affordable to protect the town against extreme floods. The community strongly expects the levee upgrade to protect against much larger floods than the existing levee. A 5 per cent AEP flood several years ago resulted in widespread inundation, property damage, indirect financial costs and other disruptions. An upgrade of the levee is seen to not only reduce flood risk, but to also reduce flood insurance costs.

The proposed works have no adverse impact on other community goals, but they do benefit the community goal of community growth.

Likelihood of consequence	AEP range (%)	Level of consequence Insignificant	Minor	Moderate	Major	Catastrophic
Likely	>10	Environment	People Public admin Social setting Economy	People Public admin Economy		
Unlikely	1 to 10	Environment	People Social setting	People Public admin Economy	Economy	
Rare to very rare	0.01 to 1		Environment	People Social setting	People Public admin Economy	
Extremely rare	<0.01		Environment	Social setting	People Public admin Economy	

Risk: Very low Low Medium High Extreme

AEP = annual exceedance probability

Figure 11: Example 2—reduced risks with all treatment measures in place

Residual risk

Choosing the 5 per cent AEP event will result in significant residual risks remaining, as the impacts of only relatively frequent flood events are mitigated. Events larger than the 5 per cent AEP event will continue to cause significant property damage and social disruption, and will require evacuation of the town. Community expectations are that a more acceptable level of residual risk would be to mitigate against the impacts of floods larger than the 5 per cent AEP event (e.g. to the 2 per cent or 1 per cent AEP). A levee built to the 5 per cent AEP will be just one of several measures aimed at managing the areas flooded.

3.2.4 Conclusions

The dominant considerations in this case are the financial costs, benefits and costs to people, physical limitations, environmental impacts and community expectations. The financial benefits and costs assessment suggests that a 1 per cent AEP flood event should be chosen, because it has the most favourable cost–benefit ratio and is the level of protection recommended in jurisdictional guidelines for new development.

However, the physical limitations and changing flood behaviour with a large design flood event rule out choosing the 1 per cent AEP event, and the 2 per cent AEP event is highly impractical. This is further supported by the environmental benefits and costs, which have significant adverse effects if a higher levee is chosen.

Based on these factors, the 5 per cent AEP event should be chosen. Although the works have a cost–benefit ratio of less than 1, the additional benefits in improvements to evacuation time—and therefore emergency response—and lack of critical constraints mean it is preferred relative to other events. Alternate designs were considered in light of the critical constraints; however, these significantly increased the cost of the works (lowering their financial efficiency) and they are considered to be unviable.

Figure 11 outlines the altered risks with these additional mitigation works in place. This shows a reduction in risk to people and the economy in unlikely events because of the protection the levee provides to property and the evacuation route, and the benefits of improved community awareness. The risk to people is also reduced to medium in rare to likely events. Risks to the economy and public administration still peak at high in rare to very rare events.

Figure 12 Example of an access road (red) for a flood-affected town

Likelihood of consequence	AEP range (%)	Level of consequence: Insignificant	Minor	Moderate	Major	Catastrophic
Likely	>10	Environment (Low)	People, Public admin, Social setting, Economy (Medium)	(High)	(Extreme)	(Extreme)
Unlikely	1 to 10	Environment (Low)	People, Social setting (Low)	Public admin, Economy (Medium)	(High)	(Extreme)
Rare to very rare	0.01 to 1	(Very low)	Environment (Low)	People, Social setting (Medium)	Public admin, Economy (High)	(High)
Extremely rare	<0.01	(Very low)	Environment (Very low)	Social setting (Low)	People, Public admin, Economy (Medium)	(High)

Risk: Very low, Low, Medium, High, Extreme

AEP = annual exceedance probability

Figure 13: Example 3—flood risk to the existing community

3.3 Example 3—upgrade road access for a small town

3.3.1 Identification of existing risks

A small town is affected by riverine flooding. Evacuation orders are given if the forecast flood is expected to reach or exceed the 2 per cent AEP level. During events of this size, there is only one access route in and out of the town, as the other access road from town is cut during high river flow (Figure 12). The evacuation route consists of a single-lane road. Its capacity is exceeded during evacuations, causing significant delays and allowing only 60 per cent of the town to be evacuated within the available time frame. In addition, the access road is inundated in a rare to very rare flood event (approximately 0.75 per cent AEP). If evacuation fails, residents may become trapped in the flooded town, and require resupply and perhaps medical rescue. This places a significant burden on emergency services.

Under existing conditions, there are significant community issues once the evacuation route has been cut-off as reflected in Figure 13. For floods greater than 2 per cent AEP, there are moderate to major consequences to social setting, people, public administration and the economy, and minor consequences to the environment

3.3.2 Identification of treatment options

Considering the risk exposure of the existing community, potential treatment measures should aim to reduce the high risks experienced by people and the social setting (Figure 13). Potential treatment measures include:

- increasing the traffic capacity of the evacuation route
- raising the evacuation route to increase its flood immunity—this would mean that it is cut off less frequently, and, in events that cut off the levee, the evacuation route is likely to be available for longer
- improving flood warning and the community's understanding of how to respond to a flood warning
- reducing property damage by raising the affected houses.

3.3.3 Preliminary assessment of treatment options

A preliminary review of the measures in Section 3.3.2 has identified that improving the capacity and level of service of the existing evacuation route is feasible and practical to reduce the flood risk for the community. Raising homes was not considered practical, because it would not, in this case, be financially efficient or resolve the evacuation issues. Potential land-use planning measures, such as flood planning levels for future development, were also considered to manage the growth in flood damage because of new development. This would manage the damage to new development; however, new development would add traffic and demand on the evacuation route, which is already below capacity.

3.3.4 Detailed assessment of treatment options

Upgrading the road would reduce the risk to life posed by the existing evacuation constraints and could be done in a way that provides additional evacuation capacity to support community growth. Evacuation can be improved in two ways: raising the road or increasing its capacity. Increased capacity (which would take the form of an extra lane) does not pertain to a particular design event and would therefore have benefits in all events where evacuation was necessary. As the road is only cut off in floods rarer than the 0.75 per cent AEP flood, raising the road would only have benefit in floods rarer than this event.

People

The improved evacuation access would benefit people and has only negligible negative impacts. More people would be able to evacuate within the available warning time, meaning that people are less likely to be isolated, and therefore less likely to need resupply or rescue during an event as long as emergency management directions are followed.

Improving the evacuation access capacity could also enable the town's new residents (i.e. from new development) to evacuate. Positive effects are mainly in the form of reduced impact from large flood events because of the lower risk to life. Increasing the road's capacity provides more benefits than raising the road, because it serves a wider range of design events.

Economy, financial efficiency and affordability

An analysis has shown that raising the road or increasing its capacity will not modify the flood behaviour, and thus will not affect the flood risk to property and infrastructure in the town. It will not alter existing flood damages and therefore has no tangible economic benefit. The additional road capacity is not needed on a daily basis; therefore, there are no general financial benefits to the community whether the road is upgraded or raised. Sufficient financial capacity exists to undertake the works, and the works could potentially be subsidised by higher levels of government.

Environment

Both options (increased road capacity and a raised road) would have minor environmental impacts, including the removal of several trees adjacent to the road. There are no flood-dependent ecosystems that are impacted by the works.

Likelihood of consequence	AEP range (%)	Level of consequence				
		Insignificant	Minor	Moderate	Major	Catastrophic
Likely	>10	Environment	People Public admin Social setting Economy			
Unlikely	1 to 10	Environment	People Social setting	Public admin Economy		
Rare to very rare	0.01 to 1		Environment People Social setting	People Social setting	Public admin Economy	
Extremely rare	<0.01		Environment	People Social setting	People Public admin Economy	

Risk: Very low · Low · Medium · High · Extreme

AEP = annual exceedance probability

Figure 14: Example 3—reduced risks with all treatment measures in place

Public administration

The works do not reduce any impact on community services or infrastructure.

Standards, and physical and technical constraints

Development controls for new residential development are generally managed based on the 1 per cent AEP flood event. Available land on either side of the existing road means that there are no significant physical limitations. The existing road level is first inundated during a rare event (0.75 per cent AEP). The works are unlikely to result in large changes to flood behaviour. The need for adaptive management is similar across the range of different options being considered. An adaptive strategy based on raising the road in the future could be used to account for changes in flood behaviour.

Social setting and community issues

Increasing the road level or capacity would increase well-being in the community. Its construction and operation would not negatively affect any cultural or historic artefacts. No areas are significantly adversely affected by changes to the road; therefore, no social equity issues will be created by the works.

The current evacuation capacity limits the community's ability to grow without adding to the current evacuation problems. The addition of capacity across the wider range of events would benefit this aspect.

There is a strong expectation in the community that the evacuation issues will be resolved. The constraints associated with the existing single-lane access road are well known and the community expects a lane to be added. There is less knowledge of the possibility of larger floods that would overtop the road, as no such flood has occurred recently. The community also supports the capacity upgrade, because it will improve the condition of the road. The cost of the works does not appear to be of concern to any groups within the community and is outweighed by the increased benefits to evacuation.

The proposed works have no adverse effects on other community goals. Rather, they benefit the community, because an increased road capacity for evacuation supports a growing community.

Residual risk

The lowest residual risk is achieved by both raising the road and increasing its capacity. The former will increase the time available for evacuation, while the latter will increase the rate of evacuation.

3.3.5 Conclusions

The upgrade options for the road are not clearly tied to a particular design event, but both upgrading the capacity and elevating the road will provide more benefit in larger floods than the road currently provides. Beyond the cost of the works, no critical constraints exist that prevent both raising the road and adding one lane.

The community generally accepts the residual risk from not raising the road, and that raising the road will provide less benefit than increasing its capacity. Therefore, as the capacity upgrade has more support and benefit, it should be undertaken (see Figure 14).

If there is ever the opportunity to cost-effectively raise the road, perhaps as part of future upgrading, this can be done to further improve access. However, this additional upgrade would have a lower priority.

3.4 Example 4—expanding a proposed basin to reduce flood risk to existing development

3.4.1 Identification of existing risks

Urban expansion in this area has occurred for many decades. The town is adjacent to a moderately sized creek system. Properties are inundated in the 2 per cent AEP event and widespread overfloor inundation occurs in the 1 per cent AEP event. The catchment has a quick response time, with rainfall and inundation occurring within several hours.

A large subdivision is proposed adjacent to two tributaries in the upper catchment. There is community concern that the subdivision will increase the negative effects from a flood on the existing community.

As shown in Figure 15, there is a medium flood risk to people and a high flood risk to the economy. Risks to the social setting and public administration are low in all but likely events, where they increase to medium. Risks to the environment are generally low.

3.4.2 Identification and preliminary assessment of treatment options

Council is concerned about managing the impacts of flooding to the new development and managing the impacts of new development on flooding to the existing community. It also wishes to consider whether the development of this site could provide the opportunity to reduce the flood risks to existing development below existing levels.

Option 1 involves development controls to reduce the effects of flooding on the new development and its occupants (noting that development controls for new residential development are generally managed based on the 1 per cent AEP flood event) in conjunction with construction of a detention basin. This would offset the impacts of new development on flooding of existing properties. This option would not reduce existing flood risk.

Table 3: Example 4—financial benefits relative to costs of mitigation works

Basin level of service	AAD reduction ($ million)	Reduction in damage (benefit) ($ million)	Life-cycle additional cost of basin ($ million)	Cost–benefit ratio
2% AEP	0.03	0.58	0.6	0.97
1% AEP	0.18	1.16	0.8	1.45

AAD = average annual damage; AEP = annual exceedance probability

Option 2 involves development controls to reduce the effects of flooding on the new development and its occupants, but in conjunction with the construction of a larger detention basin. This would not only offset the impacts of new development on flooding of existing properties, but also reduce the impacts of flooding on the existing community. This option manages risk to new development and reduces the flood risk to the existing community.

Preliminary assessment of these options, based on a 1 per cent AEP design flood, indicates that both are feasible, although the additional land and construction costs of option 2 compared with option 1 would need to be borne by the community, rather than the developer. The level of service, based upon the 1 per cent AEP flood, requires optimisation.

3.4.3 Detailed assessment of treatment options

The following sections consider the level of service for option 2 involving the expansion of the basin to reduce flood risk to existing development.

People

Expanding the basin has the potential to reduce the frequency and severity of consequences to people.

Economy, financial efficiency and affordability

The cost of providing additional risk reduction to the existing community was examined, finding relatively minor difference between the AAD for a 2 per cent AEP or a 1 per cent AEP level of service. However, more land was required to provide more storage for the 1 per cent AEP level of service. The life-cycle costs of construction and maintenance, and the cost–benefit ratio for a 2 per cent AEP and a 1 per cent AEP level of service are in Table 3. The expansion of the basin and the associated land costs would be funded through local revenue sources and is affordable.

Environment

The works would have very minor effects on the local environment, with impacts limited to the removal of several trees located at the potential site of the detention basin. There are no flood-dependent ecosystems that are affected by the works. These effects do not change significantly between options.

Public administration

The works would reduce some negative effects on community services and infrastructure.

Standards, and physical and technical constraints

As part of the new subdivision layout, there are space constraints that would limit the ability of the basin to offset the effect of development during the design event. Additional land would need to be set aside to reduce risk to the existing community, with more land required for larger proposed design floods. The need for adaptive management is similar across the range of different options being considered.

Social setting and community issues

The construction of a detention basin at the proposed location would not affect any cultural or historic artefacts. The works are designed to offset the impacts of proposed development and reduce existing flood risk in the community, and will therefore have some benefit in reducing the exposure of community services and cultural artefacts to flooding. The community has a strong expectation that the basin in the subdivision should be expanded to reduce flood risk to the existing community, which the proposal supports.

3.4.4 Conclusions

The dominant considerations in this case are the consequences to people, the economy, financial feasibility, community issues and physical constraints.

Community expectations are that any effects resulting from the development should be mitigated, and that the opportunity should be taken to reduce the flood risks to existing development. The financial feasibility and consequences for people suggest that a larger design event (i.e. 1 per cent AEP) for offsetting impacts would have greater benefit. The basin can be optimised to reduce the existing effects on the community for the 1 per cent AEP flood event, and offset the impacts of development.

Expanding the detention basin is shown to be capable of treating the high flood risks experienced by the existing community. This is achieved by minimising the consequences to people, public administration and the economy, and by reducing any increase in asset losses. To minimise risk across the risk profile for the community, the basin construction would be supported by appropriate development controls. Figure 16 shows the reduced risk with the treatment measures in place.

Likelihood of consequence	AEP range (%)	Level of consequence				
		Insignificant	Minor	Moderate	Major	Catastrophic
Likely	>10	Environment	People Public admin Social setting Economy			
Unlikely	1 to 10	Environment	Public admin Social setting	People Economy		
Rare to very rare	0.01 to 1		Environment Public admin Social setting	People	Economy	
Extremely rare	<0.01		Environment Public admin Social setting	People	Economy	

Risk: Very low Low Medium High Extreme

AEP = annual exceedance probability

Figure 15: Example 4—flood risk to the existing community

Likelihood of consequence	AEP range (%)	Level of consequence				
		Insignificant	Minor	Moderate	Major	Catastrophic
Likely	>10	Environment People Public admin Social setting Economy	People Public admin Social setting Economy			
Unlikely	1 to 10	Environment	People Public admin Social setting Economy	People Economy		
Rare to very rare	0.01 to 1		Environment Public admin Social setting	People Economy	Economy	
Extremely rare	<0.01		Environment Social setting	People Public admin	Economy	

Risk: Very low Low Medium High Extreme

AEP = annual exceedance probability

Figure 16: Example 4—reduced risks with all treatment measures in place

Appendix: Developing cost estimates

Cost estimates should be undertaken on a life-cycle basis, as discussed in Section 2.4.2.

Construction estimates are generally based on estimates from previous similar project or construction cost guides. In Australia, Rawlinson's *Construction cost guide* (Rawlinsons 2016) is used to estimate the cost of many construction works. However, as many structural flood mitigation works are unconventional in design, they are not fully covered by cost guides. Therefore, where possible, estimates should use construction costs from recently completed projects with a similar type and scale of work in the same location or in another area. It is recommended that, wherever feasible, a range of existing examples should be included to give information on the range of costs that may occur.

Costs from elsewhere need to be adjusted considering the location relative to the location for the previous estimate (e.g. close to a major city relative to regional location) and any associated relative difficulty (e.g. working close to structures rather than in open areas). Any comparison must also account for differences in size by converting both projects to unit amounts—for example:

- cost per metre length for an earth levee
- cost per cubic metre for a basin structure and earthworks
- cost per square metre for surface treatments.

They also need to be translated to the current time frame using relevant construction cost indices, to provide up-to-date unit costs for a variety of works, including earthworks, laying new drainage and building retaining walls. For such works, the floodplain management entity or other relevant authority may have experience with similar projects in the area that can be used to estimate a cost.

Costing must also include contingency factors calculated as a percentage of the construction cost. The percentage varies depending on the estimated magnitude of possible unforeseen complications. These may include compliance issues if the works affect a number of stakeholders, complications in construction because of an unusual or technically difficult design, or issues from infringing on existing features, such as environmental assets, buildings or services. The percentage is generally higher for a preliminary cost estimate than a more detailed cost estimate because of the higher uncertainties in the former.

An example of a straightforward project may be the construction of a levee across a cleared area, away from buildings and services. Geotechnical investigations have been done to identify the scope of work and appropriate earthen construction materials. This is likely to have relatively few unknown factors that will affect costs and, therefore, can have a relatively low contingency value at concept design phase. In contrast, large stormwater channels or pipes in a dense urban area will very likely encounter issues with existing services and may have a significantly higher contingency factor.

Although construction of a mitigation work is a major component of the cost, other costs are also important to consider, such as professional fees associated with feasibility, and design studies for project and construction management These can typically be estimated from experience and other project examples. Costs of land or easement acquisition can also be significant and should be included. These should be estimated based on experience, examples or appropriate guidelines. Depending on the type of work, these ongoing costs can be prohibitive or can influence the design of the project. For example, a lower life-cycle cost may result from a higher investment in construction, which leads to lower maintenance costs.

Finally, cost estimates should be checked by alternate methods to gain an understanding of their robustness, as well as testing for changes in assumptions and unit rates.

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Figures

The following reference provided the basis for the production of several of the figures throughout this document.

McLuckie D, Toniato A 2015, Planning for flood risk, Hydrology and Water Resources Symposium, Hobart, 7-10 December.

Background information

The following references provide an explanation around the development and interrelationship of ADR Handbook 7 and the associated suite of related guidelines and other documents that support ADR Handbook 7.

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