SYNTHESIS SUMMARY 2

Floods

Floods are costly and devastating. Many parts of Australia are exposed to flooding but are poorly adapted to withstand the associated impacts. Climate change will increase the risks in some areas through higher rainfall totals, more intense rainfall and/or increased risk of inundation from the sea due to sea-level rise.

NCCARF
National
Climate Change Adaptation
Research Facility

About this series

Between 2008 and 2013, the Australian Government funded a large nationwide Adaptation Research Grant Program (the ARG Program) in climate change adaptation. The Program was managed by the National Climate Change Adaptation Research Facility (NCCARF). It resulted in over 100 research reports that delivered new knowledge on every aspect of adaptation. The aim of the Program was to help build a nation more resilient to the effects of climate change and better placed to take advantage of the opportunities.

This series of Synthesis Summaries is based on research findings from the ARG Program, augmented by relevant new literature and evidence from practitioners. The series seeks to deliver some of the policy-relevant research evidence to support decision-making for climate change adaptation in Australia in a short summary. It takes an approach identified through consultation with relevant stakeholders about the needs of the intended audience of policymakers, decision-makers and managers in the public and private sectors.

About this summary

This summary deals with floods and flooding. The opening pages provide the context, including the nature and impacts of floods ('Why we need to adapt'), followed by a synthesis of research findings around the impacts and adaptation response to floods and flooding ('The research base …'). It concludes with a summary of how this new research knowledge might help address key adaptation policy challenges. This final section is informed by a workshop held with practitioners ('Evidence-based adaptation challenges').

This brief was developed by NCCARF staff, with input on policy challenges developed in workshops held in Mackay (Queensland), Adelaide (South Australia) and Cardinia Shire (Victoria) in December 2015. The workshops were attended by practitioners, policymakers and managers from within local, state and federal government organisations, community service organisations, not-for-profit organisations and universities.

The key research reports used to develop this summary are highlighted in Section 4. To see all reports from the ARG Program, please visit **www.nccarf.edu.au/adaptation-library**.

Key findings

Flooding may continue to be a problem for areas already prone to flooding, with an increased risk of inundation for coastal areas exposed to rising sea levels. Five principal adaptation challenges emerge from the research evidence:

1. **Understand and communicate risk:** How risk is communicated affects the outcome of discussions between policymakers and their affected communities around planning for future flood risk. Risk communication that is two-way, seeking to gather local information from the communities involved, is likely to build understanding of flood risk and to foster open discussion around potential responses.

2. **Reduce risk through planning and building design:** Development and planning guidelines that address existing and future risks through appropriate design are likely to be an important tool in reducing flood risk. Measures might include consideration of building and land use to minimise flood risk and strategies to manage this risk, including provision of evacuation routes.

3. **Find the right policy levers and know when to act:** Approaches to increasing resilience and reducing flood risk are likely to be able to build on the community's desire for reduced risk. Appropriate strategies include market mechanisms that encourage understanding and consideration of flood risk in decision-making around property purchase and development.

4. **Be prepared:** Preparation for major flooding events will remain important, and approaches to enhance preparedness might include use of technology for warnings, investment in flood mapping and changes to infrastructure.

5. **Match policy, advice and resourcing:** Building resilience in the community and its settlements is an important part of future directions in managing flood risk. Care should be taken to support these policies (e.g. by investing in knowledge needs, communication and capacity building) and to avoid contradicting them in responding to flood events.


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1. Why we need to adapt

1.1 The climate context

Climate change influences floods and flooding in two ways. First, the changing incidence of intense rainfall events during storms and cyclones can lead to increased occurrence of riverine flooding and overland flow. Second, rising sea levels together with storm surge that coincides with high tides can increase coastal inundation.[12] These two can also combine: higher sea levels can exacerbate flooding in coastal rivers and estuaries. Although both types of flood are existing risks, climate change means that future risk will change.[12]

Climate models vary considerably in their projections for future annual average rainfall in Australia. There is high confidence of winter drying in southern Australia, and natural variability will continue to dominate average rainfall patterns in the near future (to 2030) in eastern and northern Australia. There is high confidence in projections that extreme rainfall events (wettest day of the year and wettest day in 20 years) will become wetter across most of Australia with the exception of south-west Western Australia. The trend of reducing mean rainfall in south-west Western Australia may be so strong as to mitigate any increased extreme rainfall trend.[12]

The likely range of future sea-level rise is shown in Table 1.

Storm surge is associated with cyclones, East Coast Low pressure systems and other severe storms. The combination of high astronomical tides, storm surge and sea-level rise can increase the height and penetration of flooding along the coast. While the frequency of tropical cyclone activity is expected to decrease, the intensity of those cyclones that do occur is expected to increase[16], and systems may track further south. An increased intensity of cyclones (i.e. those with a lower atmospheric pressure) would increase wave height and storm surge.

1.2 Key risks: Flooding impacts on infrastructure, people and ecosystems

Exposure to flooding as a result of increasing development in flood-prone areas, as well as increase in the value of assets at risk, is increasing regardless of climate change, and this in itself calls for adaptation. Climate change may increase the risk of flooding in some of these areas.

Business and infrastructure

During floods, buildings (i.e. residential and commercial structures, public infrastructure) are at risk of structural damage from pressure forces and floodwater. Pressure can come from (i) internal and external differences in pressure in still water, (ii) flowing water and wave action, and (iii) buoyancy, in which a lightweight watertight building can float and detach from anchors. Most building materials will decay on contact with floodwaters, with water contaminants (e.g. sewage, petrol and chemicals) accelerating damage. Floating debris can also cause additional damage or pressure, and the force of floodwaters can cause erosion and collapse of soils supporting a structure.[20] Infrastructure such as roads, culverts and bridges can also be severely impacted by floodwaters. Beach erosion caused by storm surge or extreme high tides can undermine foundations and impact infrastructure on coastal and estuarine foreshores.[29]

Damage repair and recovery can extend over long periods of time and can be very costly. Following extensive flooding in Central Queensland in January 2008, the Ensham coal mine did not return

Table 1 Projected change in global mean sea-level rise (SLR) for the mid- and late 21st century relative to the reference period 1986–2005.[16]

	2046–2065		2081–2100	
Scenario	**Mean SLR (m)**	**Likely range of SLR (m)**	**Mean SLR (m)**	**Likely range of SLR (m)**
RCP2.6	0.24	0.17–0.32	0.40	0.26–0.55
RCP4.5	0.26	0.19–0.33	0.47	0.32–0.63
RCP6.0	0.25	0.18–0.32	0.48	0.33–0.63
RCP8.5	0.30	0.22–0.38	0.63	0.45–0.82

to 100% operational capacity until a year later. Contaminated mine waters were pumped into local rivers to empty the mine pits, affecting downstream towns and farms. Clean-up and lost production of that mine alone cost AUD 270–300 million.[25]

The Queensland Chamber of Commerce and Industry reported that following the 2011 Queensland floods, 80 000 businesses were forced to close, of which 5% never reopened.[24]

People

The most immediate threat of flooding to people is the threat to their personal safety. Beyond that is the loss of property and assets; interruptions to travel and transport, including short-term interruption to employment and education; and disruption to food supplies, emergency services, essential services (e.g. electricity, water supply) and health services. Psychological impacts can affect both adults and children, particularly those with no prior experience of floods. These impacts can cause people to move away from the flood area.[1]

In the longer term, increased frequency of flood damage can affect the cost of insurance premiums and the willingness of governments to provide support for flood-affected residents. Considerable economic implications arise from this.

Ecosystems

Flooding of ecosystems can impact negatively on the health of individual species or positively by recharging groundwater and restoring ecosystems. Large inland wetlands in Australia rely on floodwaters to sustain the life cycles of plants and animals.[4,19] Changes in freshwater and saltwater inputs can alter the mix of saline and freshwater in estuarine habitats. The flow of freshwater into these habitats is important to sustain life: freshwater brings with it nutrients that are essential for coastal productivity but can also lead to poor water quality. Run-off from coastal catchments contaminated by sediment and agricultural chemicals has led to significant degradation of many areas of the Great Barrier Reef.[27]

Ecosystems have an important role to play in flood mitigation, for example by slowing flow rates and by flood buffering.[19]

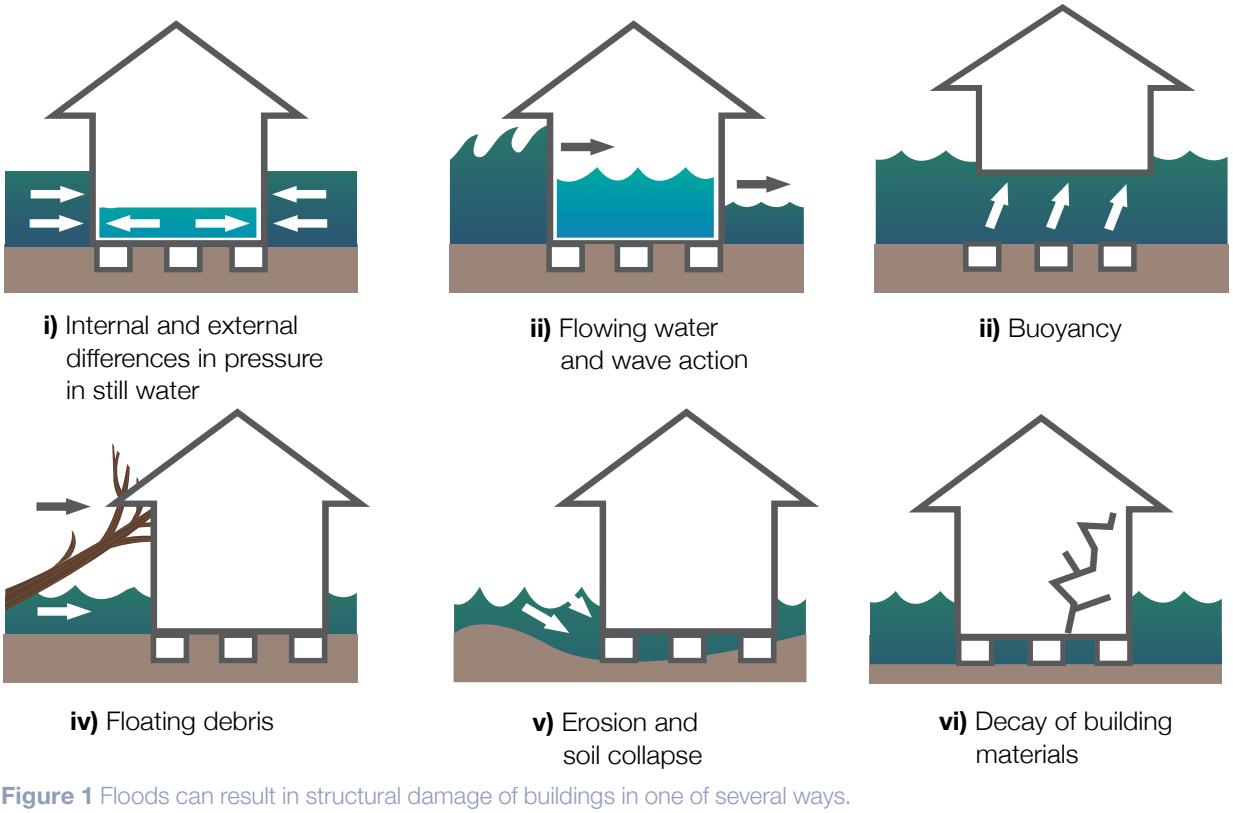


Figure 1 Floods can result in structural damage of buildings in one of several ways.

2. The research base informing adaptation to floods and flooding

2.1 Designing for the future

Adaptation options for floods can be categorised as retreat, protect and accommodate. For most residents already living in a flood zone, retreat or moving out of the flood risk area is not a desirable option.[17]

Building design

New builds can accommodate flood risk. If the flood risk is understood and quantified, then a suitable floor height can be chosen, the size and placement of utilities can be chosen to avoid flood damage, and supporting structures can be designed to cope with inundation. Enclosed structures should allow floodwaters to enter and exit (to reduce pressure on the structure), and structural attachments (i.e. footings and foundations) should be able to resist floodwater pressure. The foundations need to be secure in order to prevent flotation, and building materials must be resistant to floodwater damage and deterioration.[20]

For existing houses and structures, there are a number of retrofit options, including elevation or relocation of houses and the construction of barriers (e.g. freestanding structures such as berms, levees or floodwalls or structures that seal the building). Modifications can be made that allow floodwaters to flow freely through the building, to prevent pressure build-up, with electrical services and equipment placed above flood levels. Where flood levels greater than 0.7–1.0 m are expected, this last option is likely to be the most effective and safest to protect housing.[20]

Clearly, improved design is an essential tool in building resilience and adapting to increased flooding impacts. Following flood damage, there is an opportunity to repair and improve buildings to better withstand flood damage in the future. Policy mechanisms to facilitate infrastructure improvements exist, but have had only limited take-up, due to factors such as cost and pressures to rapidly restore infrastructure following flood damage. Government policy to encourage buildings to be built back to a higher standard may need to be accompanied by regulation and/or by financial support, especially since at present insurance tends only to finance rebuilding to the original standard.[19]

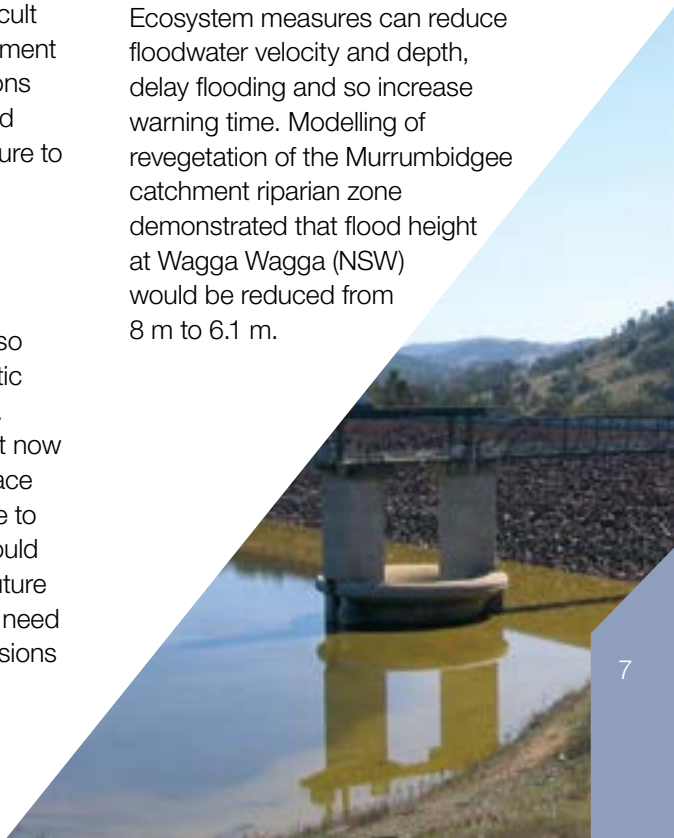
Development controls

Decisions taken now to allow development in areas that are at risk of future flooding can create path dependency: they lock councils and residents into future vulnerability and can be difficult to reverse. Allowing development in these areas raises questions for local governments around legal liability and their exposure to compensation claims.[3]

Development controls and planning are potentially the most effective tools against future flood risk. They are also some of the most problematic areas for local governments. Restrictions on development now based on future risk could face legal challenges, while failure to account for future hazard could leave councils exposed to future liability. Local authorities will need to ensure development decisions are reasonable, that appropriate decision-making procedures are followed, and that all relevant considerations are taken into account, including up-to-date scientific knowledge. Accurate flood mapping, accompanied by guidance and explanation of the limitations, is a useful tool to support development controls and planning.[17,20]

There is potential for tension between planning controls and policy and the preferences of local residents. Recently flood-affected residents of Brisbane expressed a preference for protection (e.g. levees) over relocation or retreat.[18] While there was support for adaptation actions (e.g. raising floor levels, etc.) it was clear they would do nothing without mandatory regulation. Cost was a driving factor. Planners, on the other hand, are more likely to consider flood adaptation options such as flood-proofing buildings and infrastructure.

Ecosystem measures can reduce floodwater velocity and depth, delay flooding and so increase warning time. Modelling of revegetation of the Murrumbidgee catchment riparian zone demonstrated that flood height at Wagga Wagga (NSW) would be reduced from 8 m to 6.1 m.



The effect is more pronounced for small to medium floods than larger floods.[24] Ecosystem measures can also help protect water supplies and water quality, and the multiple benefits of ecosystems should be considered in adaptation options.[14]

2.2 Understanding and communicating risk to change behaviour

Human behaviour and response to flooding are important determinants of damage and risk to lives. Information can be made available before events to encourage preparedness, during events to ensure safety and emergency response and afterwards to assist in recovery. The use that people make of that information is critical in minimising the impact of flooding.

Surveys of flood-affected residents show there is a clear sense that more information is needed both before and after floods and from a variety of sources, including insurance companies, government at all levels and non-government organisations.[6] A study has shown that, where warnings had been received during flooding, many people were unsure what action to take; residents wanted more detailed and specific local warnings as well as information on what to do after floods.[6] The study found there was a willingness to respond to an immediate threat, but less willingness to undertake actions that will help people adapt to future risks and so reduce future personal impacts. [6]

Accurate and trusted communications are important in assisting preparedness. Trusted communicators include neighbours, family, local community and local community service organisations such as the Country Fire Service and State Emergency Service.[8] Local champions are important in leading the learning process,[7] and positive role models are valuable for disaster preparedness. It is important that information is understood; for example, few people understand what a '1-in-100-year flood' actually means[17], yet this is often how risk is expressed to the general public.

There is clear evidence that communities experiencing regular and seasonal risks (e.g. cyclones) have routine behaviours in response to warnings. They are good at preparing, staying safe during events and recovering, especially long-term residents.[6,8] Personal and recent experience of previous disasters helps enable response, recovery and adaptation actions.[5] There is some evidence that resilience comes from a sense of community or community connectedness and is related to the size of a town (i.e. the smaller the town, the greater the social connectedness).[8] While it is not possible to alter town size or time of residency, there is some evidence that well-publicised warnings and building community connectedness could work to reduce risks associated with severe floods.

2.3 Understanding resilience and building adaptive capacity

The motivation to adapt and reduce vulnerability to future floods is driven by the stress, cost and inconvenience of being flooded; the need to protect children, belongings and assets; and a desire for peace of mind. Barriers to action include the cost, the design and construction of existing homes, insurance limitations, government restrictions on levee building on private property and being a renter.

A study in 2013 has shown that, while three-quarters of surveyed flood-prone Brisbane residents know their home is subject to flooding, only a quarter carry insurance for all types of floods.[5]

Private industries also face barriers to adaptation. In the case of flooded mines in Central Queensland, identified barriers include short-term planning cycles, poor communication within an organisation and with external stakeholders, limited local and medium-term climate forecasting, the local context of individual mine sites, loss of corporate memory and community perceptions (both positive and negative).[25] In an industry that is important for the economic prosperity of local communities yet is being perceived by them as controversial, adaptation will only succeed if there is longer term planning and if it is sensitive to the local social context, flexible in its management and ensures collective knowledge transfer.[25] Many of these attributes in thinking and practice to ensure effective adaptation are common to other sectors.[25]

2.4 Governance, building resilience, and insurance

The experience of flooding in Queensland in 2011, following almost a decade of drought, highlighted the difficulty of balancing water management for drought versus water management for flooding[14], which has been a major adaptation challenge for governments and communities in Australia.[15] In Queensland, while each crisis created new management options and highlighted flaws in old systems, it did not necessarily 'generate … [or] consolidate institutional capacity to plan collaboratively for the future'.[14]

The current approach to flood management in Australia is a 'resilience' approach that shifts the emphasis onto building household and community capacity before disaster strikes and shares responsibility between private and public sectors. It has fostered some innovative programs and products (e.g. Enhancing Disaster Resilience in the Built Environment Roadmap;[2] National Flood Risk Information Project – Geoscience Australia.[13]

As yet, it is unclear if this resilience approach will help to improve adaptation to future flooding.[28] Policy levers that would promote climate change adaptation have not been activated, for example, incorporating climate change risks into planning controls through the Building Code of Australia. Interviews with local councils, the insurance industry, the State Emergency Services and local residents have demonstrated that, in order to develop a resilience approach, each stakeholder must better understand their roles and responsibilities – for residents this includes personal protection – and the roles and responsibilities of others.[9]

Resilience in the community is related to financial capacity, support networks (friends and family) and effective communication from trusted sources about the weather events and climate change.[8]

Efforts to improve resilience will need to understand how to build and support these characteristics. However, there is a clear expectation from flood victims that government should do more to protect residents' properties, be that through management of dams, drainage and creeks, construction of dams, levees and protective barriers or permitting residents to build their own walls or drains.[5]

The Productivity Commission highlighted the potential for government intervention to lead to negative outcomes and emphasised the benefits of allowing market mechanisms to manage risk wherever possible.[21] For example, by pricing risks through insurance, households, business and governments have an incentive to reduce risk.[21] Both the Productivity Commission recommendations and the *National Strategy for Disaster Resilience*[11] point to a clear policy intention that seeks to avoid government taking a role in insurance (e.g. through taxes and levies on insurance, compulsory

flood cover requirements or insurance subsidies). The role for government is seen as most effective in hazard mapping and data provision, community awareness raising and education, building preparedness and supporting emergency services and volunteers.

Pursuing such a course can leave residents of flood-vulnerable properties exposed, particularly where insurance is either unavailable (e.g. no storm surge or coastal flooding cover in some policies, and no sea-level rise cover in any Australian insurance product) or prohibitively expensive. In such cases, government will be called upon to provide financial assistance following a disaster. The adaptation challenge is how to avoid this outcome.

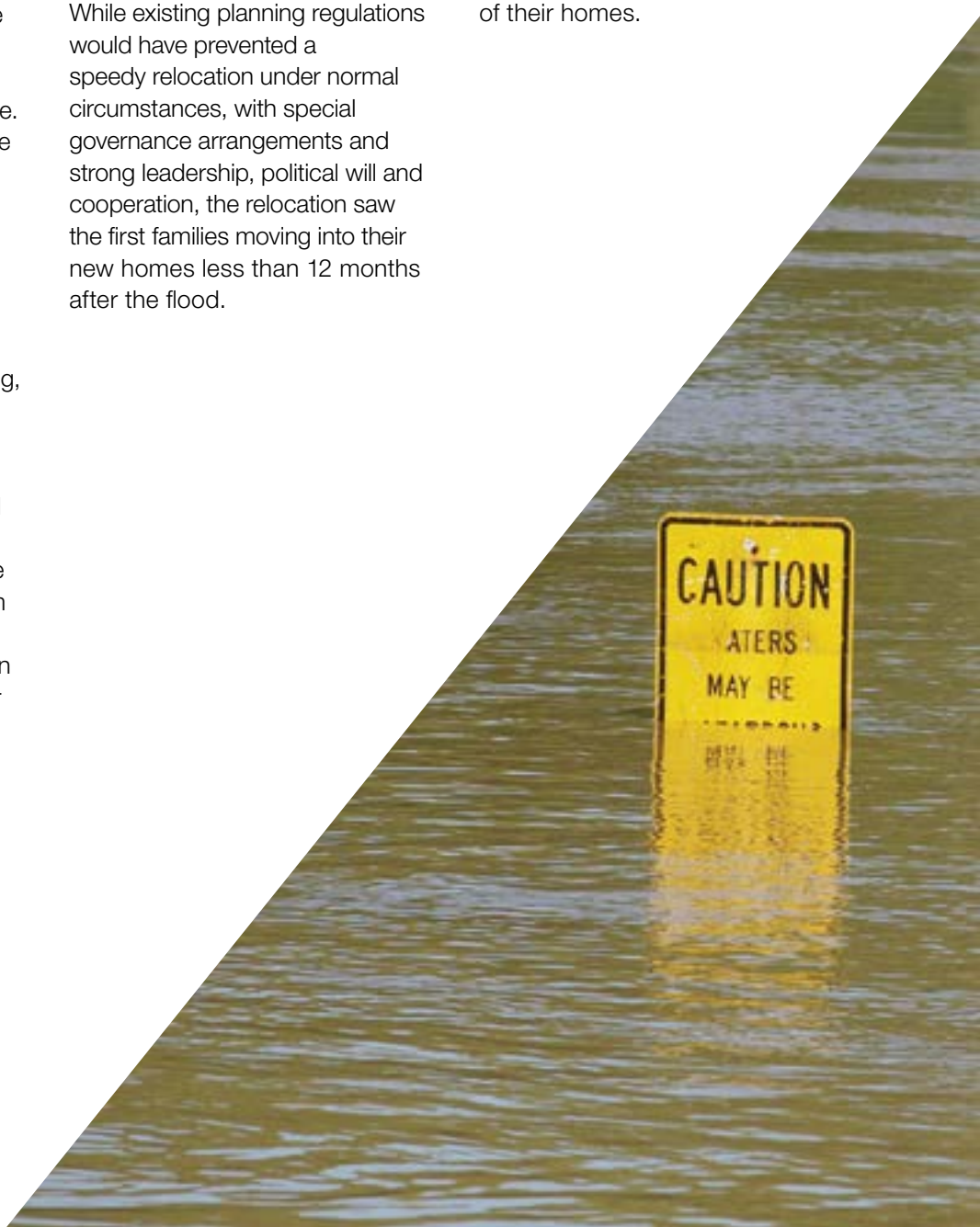
Disasters can lead to migration. Residents may be more likely to relocate within a town than leaving, particularly if they are long-term residents.[18] A desire to leave a community is seen in those with very low resilience, characterised by poor health, a lack of social connectedness or sense of place and lack of financial support from governments and charities.[8] So while out-migration might be seen as 'adaptive', it is not an indicator of a resilient community.

Government-facilitated relocation of communities is an adaptation option considered for areas that are subject to frequent and increasing flooding (e.g. coastal communities). There are few examples, but following a catastrophic flash flood of the small town of Grantham, Queensland, in 2011, in which 12 of the town's residents died, swift action allowed a relocation of flood-affected properties in a voluntary land swap.

While existing planning regulations would have prevented a speedy relocation under normal circumstances, with special governance arrangements and strong leadership, political will and cooperation, the relocation saw the first families moving into their new homes less than 12 months after the flood.

The success of the relocation was attributed to involvement of and collaboration with the community in decision-making, appropriateness of the new location, provision of basic infrastructure and the speedy commitment to relocation by all levels of government.[26]

The outcome has been of benefit to the residents, who no longer live in a floodplain. Combined with new improved infrastructure, it has increased the market value of their homes.



3. Evidence-based policy implications

ADAPTATION CHALLENGE 1:
Understanding and communicating the risk

How risk is communicated affects the outcome of discussions between policymakers and their affected communities around planning for future flood risk. Risk communication that is two-way, seeking to gather local information from the communities involved, is likely to build understanding of flood risk and to foster open discussion around potential responses.

There is greater certainty about some aspects of how the climate is going to change in the future as a result of anthropogenic warming than there is about others. For example, we know there is a very strong likelihood, even certainty, that our weather will become hotter, with more severe and longer heatwaves, and that sea levels will rise. The principal questions are around 'by how much?' There is much less certainty around what will happen to rainfall, especially at the local scale.

In Australia, there is an expectation from models that the north will become wetter and southern regions drier, although extremes such as rainstorms and droughts are expected to be more common. Under this uncertainty, it is important when undertaking adaptation activities to identify and implement low regrets actions that address present-day climate variability and help to deliver sustainability goals and economic development, while bearing in mind the precautionary principle.

Communities and stakeholders need to be aware of their flood risk if they are to take on shared responsibility for disaster management. In expressing flood risk, probability descriptions such as '1-in-100-year flood risk' are not well understood by the community. Probability statements are understood by the general public, largely due to their use in weather forecasting by the Bureau of Meteorology (e.g. 50% chance of rain). However, statements of flood risk need to be couched in terms that can be understood by the layperson, and it is likely that research is required to identify how this can be achieved.

To improve adaptation to existing and future flood risks, it is important that the provision of more detailed and specific local warnings is supported by information on what to do after floods to reduce current and future risks. Communication is best focused on understanding and accepting risk and on building resilience and adaptive strategies for the future. It is clear that there is a small window following a flood in which the public can be fully engaged and adaptive changes can be implemented.

In many coastal areas, predictions of flood risk and extent in the face of sea-level rise can be done quite accurately, and future flood mapping can help communicate risk to residents. However, there can be considerable pushback from affected residents over concerns about the effects of making public such data on property values and the cost of insurance. Coastal decision-makers, for example local governments, need to consider the most appropriate way to introduce discussions around future flood risk. This may be through future flood mapping, through gathering local information from the communities involved, or some combination of the two. Involving the community through citizen science can generate useful information and can be helpful in sensitive discussions, such as those around the introduction of planning restrictions on land identified as vulnerable to future flooding.

ADAPTATION CHALLENGE 2:
Reduce risk through planning and building design

Development and planning guidelines that address existing and future risks through appropriate design are likely to be an important tool in reducing flood risk. Measures might include consideration of building form and land use to minimise risk, and strategies to manage risk, including provision of evacuation routes.

New and existing developments may face an increased flood risk under climate change, from both increased rainfall intensity and a growing or emerging risk of storm surge inundation exacerbated by sea-level rise.[10] Planning and development approvals must find a way to reduce risk and support community preferences for development.

Reducing exposure to flood risk of any new or proposed developments can be achieved by ensuring development is not permitted in areas identified as at risk of flooding in a climate-

affected future. However, this may not always be practical nor match the risk appetite of the community. Where development does go ahead in areas of flood risk, then design provisions might be considered that reduce the risk of damage from flooding, for example by requiring floor heights to be raised above projected future flood risk levels and for structures to accommodate the passage of water. Planning might also need to look at ensuring access to and from at-risk areas, to ensure evacuation routes are available.

Options for reducing exposure of existing developments are more complex. Poorly situated developments may have always been subject to a flood risk, while others are likely to be exposed to an increasing risk as a result of sea-level rise or changes to rainfall. Policies to ensure communities are aware of their own risk may be necessary. This may include education and publicity, easy access to information and listing risks on property title deeds. For example, governments may find mandatory disclosure of flood risk as a component of property titles a useful mechanism to facilitate awareness and acceptance of risk by property owners (e.g. Flood Certificates are issued by the Yarra Ranges Shire Council).

Adaptation measures are likely to focus on reducing risk and exposure to impacts, for example by raising floor levels, restricting room types in lower levels exposed to flood risk, and recommending designs that allow floodwaters to flow through buildings, reducing damage and facilitating easy clean-up. Success at instituting and implementing policies and incentives to encourage change is likely to be greatest in the aftermath of a flood when there is public will. A portion of flood recovery funds might be directed at enabling these changes at that time.

In the case of sea-level rise inundation risk for existing properties, policies may also need to include retreat options that enable properties with an unacceptable level of risk to be abandoned or relocated. The low-lying land can then be used as parkland or other uses that can cope with periodic flooding. Any policies of this nature will need careful consideration as to how they can be financed, and will need to be reinforced by significant community engagement and consultation.

Protecting property through construction of levees or sea walls is often the preferred option of affected communities. However, this option is expensive and may not be affordable in many areas. It also creates new hydrological effects downstream that may create other undesirable impacts or changes. Additionally, uncertainty about the magnitude of storm surge means there are situations where these options will not be sufficient to prevent flooding or overtopping as sea levels rise, potentially resulting in increased flood risk in the future. Hard structures such as sea walls have profound effects on the natural environment, causing beach loss and preventing the retreat of ecosystems such as wetlands. These options require considerable investigation and community consultation to properly assess their feasibility. Alternative resilience-building options to replace or complement more tradition 'bricks and mortar' infrastructure could include natural ecosystems, such as wetlands.

ADAPTATION CHALLENGE 3: Find the right policy levers and know when to act

Approaches to increasing resilience and reducing flood risk are likely to be able to build on the community's desire for reduced risk. Appropriate strategies include market mechanisms that encourage understanding and consideration of flood risk in decision-making around property purchase and development.

In seeking to build resilient communities that take some responsibility for their own risks, policymakers look to find the right balance between regulation and incentives, including market mechanisms.

In theory, including clear information about flood risk on property titles and rental documentation should encourage purchasers, owners and renters to understand and accept responsibility for risk and the associated cost of insurance, the purpose being to facilitate risk-driven decision-making. However, it is likely that attempts to implement such strategies will be highly unpopular, making them hard to implement if the community does not understand

and accept some responsibility for the risk.

Mitigation to limit the impact of natural disasters is likely to deliver long-term benefits and savings compared to post-disaster reconstruction.[22] However, investing in 'flood-proofing' can be hard to justify or afford immediately following a flood because of the additional expense at a time when all available resources are focused on recovery. The business case for adapting to flood risk should be well established in advance, so that the value of adaptation investment is clear at the time. For successful implementation of adaptation measures, information to support stakeholders to understand risk and the benefits of adaptation should be easily accessible and widely available.

ADAPTATION CHALLENGE 4: Be prepared

Preparation for major flooding events will remain important, and approaches to enhance preparedness might include use of technology for warnings, investment in flood mapping and changes to infrastructure.

Different floods require different preparation. Each type of flooding brings its own unique challenges, policy directions and responsibilities. Flash flooding can be hard to forecast and leaves little warning time, whereas riverine flooding is often well forecast, especially in large catchments, and warning times are longer. Australia already has an extensive operational system of flood gauges, and agencies increasingly make use of SMS messaging and social media to bring flood alerts to potentially affected residents and businesses. Changes to the geographical and seasonal incidence of flooding due to climate change may require adjustment to these networks.

Overland or flash flooding is increased by non-climatic factors such as replacement of soil-covered surfaces with impervious materials (e.g. concrete). Stormwater systems and their operation need to take into account this increased 'flashiness' of storm run-off to reduce flooding risk.

As our understanding of future climate change at local and regional levels improves, there is the possibility of improved flood management. Sensitivity studies (understanding where the vulnerabilities to climate change lie), probabilistic estimates of future rainfall climatology (based on historical data) and re-running hydrological models with climate model estimates of future rainfall can all help to identify where changes to infrastructure are required.

ADAPTATION CHALLENGE 5: Match policy, advice and resourcing

Building resilience in the community and its settlements is an important part of future directions in managing flood risk. Care should be taken to support these policies (e.g. by investing in knowledge needs, communication and capacity building) and to avoid contradicting them in responding to flood events.

In the face of a natural disaster, there are social pressures on and political currency for politicians to be seen to be providing funding and support. This can mean that disaster recovery takes place very quickly, and in piecemeal ways. Opportunities to 'build back better' may be lost under pressure for rapid response.

It is important to strive for policy that matches advice and resourcing. This might include ensuring that a policy to build resilience to disasters is well resourced, that plans to 'build back better' are in place, and that residents are supported to address their own risks through education and information.

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