Australia's National
Science Agency

Climate and Disaster Resilience

30 June 2020

Citation

CSIRO (2020) Climate and Disaster Resilience

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30 June 2020

The Hon Scott Morrison, MP
Prime Minister of Australia
By email to: COAGCommonwealth@pmc.gov.au

Dear Prime Minister,

CSIRO Report on Climate and Disaster Resilience

We are very pleased to provide CSIRO's Report on Climate and Disaster Resilience, as requested by you on 29 January 2020, to inform Australia's response to future disasters.

This report draws on almost a century of expertise from the national science agency, CSIRO, encompassing research across multiple fields of science including resilience, land management, building and materials design, fire protection and testing, and biodiversity management.

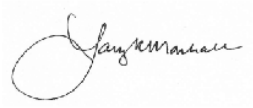
The broad scientific expertise in this report is grounded in the lived experiences from across Australian communities provided by the National Bushfire Recovery Agency, and the National Drought and North Queensland Flood Response and Recovery Agency, who continued to engage communities during the COVID-19 period.

Throughout the development of the report, the Expert Advisory Panel you appointed has provided input and advice, including engagement with Premiers or Ministers of each state and territory.

The team has also consulted widely with the Australian research community, the multi-departmental Australian Government Disaster and Climate Resilience Reference Group, with the Commonwealth, State and Territory Adaptation Working Group and with member agencies of the National Council of the Australasian Fire and Emergency Service Authorities Council (AFAC).

We look forward to briefing National Cabinet on the report at the appropriate juncture and commend this report to you.

Yours faithfully,



Dr Larry Marshall
Chief Executive CSIRO

Dr Alan Finkel
Australian Chief Scientist
Chair, Expert Advisory Panel

Executive Summary

The summer of 2019-20 was defined by a series of consecutive and at times coincident natural events involving a confluence of bushfires, floods, drought and heat extremes. Their cascading effects have impacted Australian communities and industries. Apart from loss of life, the cost to the community and government of these events is significant. For example, insurance losses for this year's bushfires already exceed A$2.3 billion[1], and for the 2019 North Queensland floods social and economic costs exceed A$5.6 billion[2].

Climate change influences the frequency and severity of these events and will be a factor into the foreseeable future, given the long timeframes associated with current climate trajectories. It is important to better understand and predict the interplay of these natural events and the challenges, risks and impacts they present over different timescales with an increasing population and changing human footprint. This is a complex undertaking. Much has already been done and achieved by all levels of government, response agencies and the community to increase Australia's resilience. However, there is both a need and an opportunity to take this to the next level as we face increasing climate variability and hazard exposure, and drive a truly national response to further build the resilience of our infrastructure, our land use practices, our communities, our industries and our environment.

In response to the recent bushfires, CSIRO was tasked in January 2020 by the Prime Minister to deliver an independent study recommending ways in which Australia can increase its climate and disaster resilience, supported by an Expert Advisory Panel chaired by Australia's Chief Scientist, Dr Alan Finkel. This work has been guided by the following principles:

- Evidence-based analysis informed by literature, lived experience and expert inputs
- A focus on where research, science and technology can contribute to building resilience
- Acknowledgement of past improvements and the importance of complementarity, with a number of related reviews, reports and inquiries currently underway including the Royal Commission into National Natural Disaster Arrangements
- CSIRO's role in providing relevant insights to inform policy makers but not policy advice.

Given the breadth of this topic, and the timeframe available, this Report (and accompanying Technical Report) is not intended be a comprehensive and definitive treatment of climate and disaster resilience. Compromises in scope have been made, with a focus on acute events, and limitations in the depth of exploration possible on some topics.

The opportunities to take Australia to the next level of building resilience broadly fall under the following six actionable themes outlined below. To realise these opportunities, this study makes a detailed series of findings and recommendations which form the basis for a forward plan of action. The themes of these are:

1. A harmonised and collaborative national approach is required to achieve global best practice
2. The national approach requires systems thinking and solutions to deal with complexity – including foresighting, management of risk and learning and education for all stakeholders
3. Availability of data is a key enabler – there is a compelling case to shift to common approaches and platforms for both resilience planning frameworks and operational management systems
4. The community plays an essential role in all phases of resilience building and must be appropriately included and engaged
5. Investment in targeted research, science and technology remains a key enabler of many of the improvements required to build resilience
6. We need to build back better. Resilience needs to be embedded as an explicit consideration in all future planning, agricultural and urban land use and zoning and investment decisions.

[1] Insurance Council of Australia figures May 2020

[2] Commonwealth of Australia, North Queensland Livestock Industry Recovery Agency, Annual Report 2018–19

The United Nations defines resilience as the ability of a system, community or society exposed to hazards to resist, absorb, accommodate and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions. Natural disasters and their impacts are extremely contextual and influenced by factors such as timing, intensity, geographic location and associated level of development, infrastructure and community preparedness. Preparing for and responding to these events demands a multidisciplinary, risk-based systems thinking approach. In addition, disaster risk and response management and resilience building are a distributed responsibility, shared by all levels of government, with critical involvement of and ownership by individuals, communities and the private sector

There has already been strong progress on increased adaptation and resilience measures for events such as tropical cyclones, as evidenced by decreases in the impacts on life and property. While Cyclone Tracy caused 65 deaths and damaged 70 percent of Darwin homes in 1974, analysis after cyclones Vance (1999), Larry (2006) and Yasi (2011) showed that updated regulations and standards have resulted in much less building damage and consequent loss of life. During Cyclone Yasi, for example, 12 per cent of older homes suffered severe roof damage, but only three per cent of newer homes. [3] In Innisfail, which was rebuilt after Cyclone Larry, insurance claims were half the cost of those nearby towns that did not experience the post Cyclone Larry rebuild.

Similarly, learnings from past events meant the lives lost in the 2019-20 bushfire season were markedly lower than in previous events as illustrated by the comparison in Figure 1.

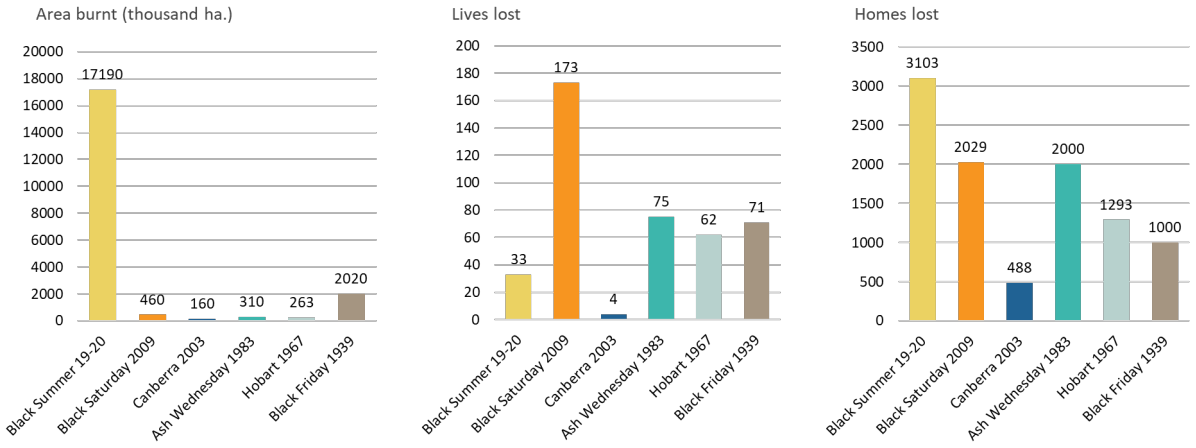


Figure 1 Areas burnt (thousands of hectares), number of lives lost, and number of homes lost in some significant fires between 1939 and 2019-20. Source Australasian Fire and Emergency Services Authorities Council (AFAC)

Much has already been learned and applied from previous experiences, and improvements adopted to date are to be commended. However, there is clearly much more work to do to fully understand the future risks and put in place the appropriate and proportional actions and accountability necessary to further build climate and disaster resilience across the country to the next level.

The lifecycle of managing climate and disaster resilience can be characterised as (i) planning and preparation, (ii) response, (iii) recovery and (iv) learning and improvement to build further resilience. Through improvement and resilience building, future events may be prevented from becoming disasters.

Effective planning and preparation require a better understanding of the future we face, and this understanding must be broadly shared and understood by all stakeholders. This includes acknowledging unknowns that shape our perceptions of the future. To achieve this there is a need for an inclusive national discussion about climate change and disasters, and how we best address them. This discussion needs to articulate: the many things we value and will work to protect; a shared vision for what a climate and disaster resilient Australia looks like; principles for determining how responsibilities for preventing and mitigating risks are to be negotiated and capabilities resourced; the uncertain nature of the causes and effects of future

[3] ACCC 2018 Northern Australia Insurance Inquiry First Interim Report https://www.accc.gov.au/focus-areas/inquiries-ongoing/northern-australia-insurance-inquiry/first-interim-report

risks; and the need for an adaptive, values-based, and whole-of-society approach to address the system-wide causes of exposure and vulnerability to natural hazards.

This in turn forms the basis of a national and integrated systems approach. Such an approach will bring efficiencies and agility through common tools, increased interoperability, education and training, sharing of resources, scenario planning approaches and data and decision platforms. Australia currently has no standard approach to scenario planning, risk and vulnerability assessment, prevention or progress measurement; all of which are essential elements for better co-ordinated and effective national action.

The recently adopted National Disaster Risk Reduction Framework[4] provides a foundation point but more can be done, and it is important that this is implemented in a harmonised way with appropriate local customisation. There is appetite for increased levels of harmonisation, but it is not without challenge and to date has not been achieved across many sectors. There is opportunity to learn from other countries such as New Zealand and Canada where, most importantly, they have a common governance mechanism to actioning resilience measures.

It is also important to recognise that individuals and communities, with their intrinsic and planned resilience also play a critical role in effective preparation and subsequent recovery. They need to be well supported with regular engagement, trusted information and education, particularly on understanding and managing risk. This is a key factor in further building resilience.

Prior to, and at commencement of an event, there is no substitute for good situational awareness delivered through state-of-the-art operational management systems to inform response agencies and the community, to ensure as safe, effective and co-ordinated a response as possible. This is dependent on a range of effective and robust sensing, communication, data and visualisation systems. Operating agencies have a strong awareness of this importance and invest in various technological innovations. However, there is scope for more targeted and collective investment.

Successful recovery is responsive to the complex and dynamic nature of both the event and the community. While short-term recovery responses are vital, there is also a need to foster longer-term resilience, and reduce industry, community and environmental exposure to natural disasters. The current experiences of the National Bushfire Recovery Agency and the National Drought and North Queensland Flood Response and Recovery Agency reinforce previous experiences that recovery is enacted at the local and community levels. Therefore, to achieve faster and more effective recovery we need to understand not only national and state or territory drivers, but also local government and community perspectives and aspirations, in order to facilitate a coordinated disaster response across suppliers, industry, government and senior community leaders. This ensures the timely, efficient and cost-effective delivery of critically needed goods and services to affected communities across urban, regional and remote Australia.

It is important to drive continual improvement in resilience as experience grows and the nature of threats also evolves or becomes better understood. Ongoing regular review and update of risks and short-term and longer-term risk reduction measures is essential and can be conducted by both scenario planning and post-event assessments that capture new experiences. Most importantly, the concept of resilience must be incorporated into planning, land use and investment decision processes, including critical infrastructure and capability investment, to influence how and where we build and drive ongoing improvements in the standard and design of the built environment and critical infrastructure. This essentially forms the foundation of the next cycle of planning and preparation on which future resilience can be built.

The work conducted in this study is based on our current understanding of the relevant science, research and practical inputs from a broad range of stakeholders consulted from many sectors, including industry, government and community. There is a clear opportunity for further improvement and to take Australia's approach to climate and disaster resilience to the next level alongside global best practice.

[4] Department of Home Affairs (2018) National Disaster Risk Reduction Framework https://www.homeaffairs.gov.au/emergency/files/national-disaster-risk-reduction-framework.pdf

Findings and recommendations

Planning and Preparation

National approach required

The current approach to building resilience is at a relatively formative stage and is more complex and less coherent than is appropriate. This is evidenced by the numerous stakeholders and mechanisms, some ambiguity in roles and leadership, and differing approaches across jurisdictions. An inclusive, evidence-based, national climate change and disaster discussion is needed among governments at all levels, across all sectors and in the community to raise awareness of the benefits of an inclusive, integrated, risk-based national approach to managing disasters.

There is acknowledgement of the value and demand for more consistent approaches to enhancing climate and disaster resilience by a growing number of government and private sector organisations but achieving this is not without challenge and progress in harmonisation has not been sufficient to date.

The National Disaster Risk Reduction Framework (NDRRF) can be used to unite stakeholders from across governments, private sector and communities and facilitate discussions needed to underpin a national approach to building resilience.

Recommendation 1: The Prime Minister, Premiers and Chief Ministers through National Cabinet should consider this Report, task reform committees to implement its recommendations and regularly update leaders on progress and outcomes.

Continue learning from global best practice

There is a pro-active approach by Australian governments to continue to learn from and share with global leading practice in the implementation of disaster risk reduction. Specifically, this study has identified New Zealand, Canada, the UK and California as exemplifying best practice with respect to governance of actions delivering disaster risk reduction and resilience outcomes.

Recommendation 2: Commonwealth, state and territory governments should continue to actively engage with Canada, the UK, California and in particular New Zealand (e.g. via ANZEMC) to learn how their experiences and approach to governance can inform and guide the development and delivery of our national approach. To ensure learning and sharing is sustained, monitoring and review of the adoption and effectiveness of best practice learnings and regular benchmarking against global best practice should occur at least every two years.

A systems approach is critical to dealing with complexity

As identified in the NDRRF, understanding and managing risk is essential to building resilience. Effective foresighting and education for all stakeholders are also required. A coordinated and holistic approach to bringing disciplines and systems together to manage risk is essential due to the complexity and highly contextual nature of the possible events the nation is exposed to, the range of timeframes in which these could occur, and the geographic breadth and diversity of jurisdictions involved.

Effective planning, preparation and development of resilience strategies requires a robust understanding of the types and severity of events that could occur and the potential impacts they can cause under different scenarios. These need to be characterised and presented in a form which can be understood by governments, agencies, communities and individuals alike.

Recommendation 3: The Bureau of Meteorology (BoM) and CSIRO be tasked with developing nationally consistent risk projections, involving the specification of integrated climate and disaster risk scenarios, underpinned by an agreed common core set of climate trajectories and timelines. These Risk projections should be used to understand potential impacts and inform development of resilience strategies and actions to reduce risk in the public and private sector. These strategies can be regularly evaluated using stress-testing methodologies at a range of scales from regional to national by all three tiers of government.

Data is a key enabler

Reliable access to information, data and knowledge about climate and disaster risks and their impacts is essential for effective planning and improvement. Data and knowledge are currently spread across many platforms with limited opportunity for sharing of technology or approaches. There is a compelling case to shift to a common approach and platforms.

Recommendation 4: The Prime Minister, Premiers and Chief Ministers should ensure all jurisdictions work together, with local government and industry, to deliver climate and disaster risk information to all sectors. This includes accelerated implementation of harmonised data governance and sharing common technologies to enable collaboration in the production, analysis, access, and exchange of information, data and knowledge about climate and disaster risks, including a national risk map. The National Disaster Risk Information Services Capability (NDRISC) and aligned adaptation initiatives provide opportunities to build national and thematic platforms to support coproduction of information, linked expertise, decision science support and action.

Community plays an essential role in all phases of resilience building

Governments, businesses and communities need to understand and reduce risks within their influence and control and develop on appropriate responses to build resilience. Individuals also play a critical role in building resilience through effective preparation and their involvement in subsequent recovery and need to be well informed on vulnerability to potential events, and measures to reduce risks that are within their control.

Community education is an important part of many response agencies' current practices, especially the sharing of locally relevant advice. However, there is an opportunity for a more holistic and consistent approach.

Recommendation 5: Response agencies should further collaborate with research agencies to develop additional community education, engagement and training programs informed by science. These programs should be, updated and delivered regularly, to address the nationally shared and locally specific threats presented by climate and disaster risk.

There is scope to further empower Indigenous fire knowledge and land management practices

There is existing and growing support for Indigenous leadership in the incorporation and implementation of cultural burning and land management practices across more of Australia's landscape. Many land management and fire response agencies have engaged with Indigenous groups, both within and external to their organisations. Existing partnerships provide important lessons on how to empower and give authority to Indigenous fire practitioners and cultural burning.

Recommendation 6: Fire response and land management agencies should further support successful partnerships that recognise the complexity of cross-cultural engagement and interactions, respect Indigenous knowledge and cultural protocols, and create the necessary two-way knowledge exchange needed to understand fire impacts and behaviour.

Recommendation 7: Recovery agencies, state and territory and local governments should ensure local Indigenous leaders are empowered to contribute to the design of health and recovery business recovery programs, as well as develop collaborative frameworks involving emergency services organisations and Indigenous communities to mitigate, manage and recover from the impacts of natural disasters in regional and remote communities.

Bushfire Hazard reduction is complex

Australia's extraordinary range of fuel types and structures, climatic conditions, and topographic influences reduce our ability to reliably extrapolate and apply knowledge from one locality to another. However, hazard reduction burning remains an important tool for fire management to be used well before the onset of bushfire threat. The recent publication on prescribed burning by the Australasian Fire and Emergency Services Authorities Council (AFAC) captures current understanding and practice on this complex topic[5]. Its application and effectiveness are complex, highly contextual and resource intensive. More research and learning from experience are required to refine how and where it can bring best value and protection.

Recommendation 8: Improved understanding of hazard reduction burning effects on fuels and subsequent fire behaviour is required to inform a national risk map. This needs to draw on Commonwealth, state and territory agencies, researcher and practitioner experiences for the full range of vegetation and climatic types, in the face of a changing climate. Improved tools for better quantifying risk and risk reduction under a range of scenarios and for maximising opportunities for effective hazard reduction are required. Monitoring of both risk reduction and the effectiveness of hazard reduction burns is also required in current and changing contexts.

Recommendation 9: Improved understanding of best practice fire clearance zones around residential, commercial, industrial and service infrastructure, across jurisdictions is also required. The impact of fuel items in the clearance zone, e.g. outdoor furniture etc, should be quantified. Tests could be run at fire simulation facilities such as CSIRO's burn-over facility at the NSW RFS Hot Fire Training Facility near Mogo. Use of app-based post fire asset and infrastructure damage surveys can provide comparable, reliable and readily available data to support such investigations and recovery efforts.

[5] Leavesley, A, Wouters M and Thornton R (2019) Prescribed Burning in Australasia: The science practice and politics of burning the bush, Australasian Fire and Emergency Service Authorities Council Limited

Continue to embrace and invest in science and technology

Fire behaviour knowledge is also captured in modelling platforms such as Phoenix, Aurora and Spark. Ongoing research is adding to our understanding of fuel management in natural and managed landscapes.

Recommendation 10: Spark has been identified as the most future-proof next generation fire behaviour modelling platform and is supported by the AFAC National Council. Commonwealth, state and territory governments need to centrally resource its development and application and ensure it can embrace new technologies such as Artificial Intelligence to enable near-real-time prediction as well as incorporate national mapping of fuel load, condition, state and distribution.

There has been an increased use of, and dependence on, technology such as aerial assets and chemical fire retardants in fire management strategies. Australia is largely dependent on importation of firefighting chemicals from a very small numbers of suppliers accredited under USDA regulation, and purchase, stockpiling and inventory is managed separately by state and territory agencies.

Recommendation 11: Commonwealth, state and territory governments should work together to investigate the accreditation and environmental assessment required to enable domestic production of appropriate fire retardants, water enhancers, foams and gels. National coordination of product inventory should also improve security of supply.

Bushfire agencies have a long history and culture of identifying and embracing science and technology to improve preparedness and response. There are a number of key challenges that science and technology can help solve.

Recommendation 12: Investment in collaborative, impact-driven research that brings together universities, Commonwealth agencies and delivery partners is necessary to realise opportunities that require new science and technology to be developed and adopted. This should include:

12.1 A national approach to air quality measurement and prediction including the roll-out to all states and territories of smoke plume forecasting. This is currently deployed across NSW and Victoria by CSIRO and BoM to anticipate hazards to health, aviation and Australian Defence Force operations. There is also potential to apply smoke forecasting approaches to other airborne particulates such as dust and pollen, and to predict smoke plume behaviour from other planned and unplanned fires, and industrial activities.

12.2 Work by the BoM and AFAC on a multiple hazard early warning system for use in bushfire, flood, cyclone, heatwave and extreme weather situations is well advanced. This is currently being developed in conjunction with the Australian Fire Danger Rating System (AFDRS). It is recommended that implementation of the warning system is brought forward using existing fire danger rating approaches to enable delivery in 2020/21. The development of the new AFDRS, which needs to be tested during the next two fire seasons, should continue and be integrated into the warning system when verification is complete.

12.3 Further develop, adopt and integrate Earth observation technologies into operational management and risk reduction systems to improve disaster preparedness and situational awareness through more timely and accurate intelligence. This should include both satellite and high resolution aircraft-mounted camera technologies to provide greater detail and improve the ability to see through smoke and cloud, as recommended by the Earth Observation Taskforce facilitated by the Australian Space Agency. This should be phased, with initial implementation into existing state-based systems followed by a fully integrated national platform.

12.4 Continue investment in the development and assessment of new materials for construction, personal protective equipment and, where applicable, affordable retrofitting of older buildings by government agencies, industry and researchers working together, overseen by national standards authorities.

Response

Reliable communications are critical to good situational awareness

For acute events such as bushfires, good situational awareness for first responders and in co-ordination centres is a critical aspect of safe and effective response. This requires reliable communication with responders and communities and access to data and information from the operational management system both in real time and from planning and historical databases. Best practice in operational management systems demands the availability and integration of data, good visualisation and modelling tools, effective resource management and accessible decision support platforms and must be supported by robust communications and data infrastructure

Recommendation 13: State and territory response, data and digital agencies and the Commonwealth, should characterise and learn from the approaches currently used by response agencies in different jurisdictions, in Australia and internationally. This should enable evolution of decision-making platforms and other common tools and ensure that future common data platforms are designed to accommodate the applications critical to good situational awareness. Consultation with end users and capacity to broaden applications beyond bushfires and to respond to all types of events are also required.

Recommendation 14: Ongoing improvements in communication technology for emergency response agencies requires coordinated action and investment from Commonwealth and state and territory governments. This includes availability of sufficient bandwidth and dedicated frequencies for response agencies. In addition, the provision of mobile broadcasting units for deployment in mobile phone blackspots or areas where telecommunications are lost, dedicated satellite channels for exclusive use of emergency services, and renewed consideration of appropriate levels of redundancy and backup are recommended.

Recommendation 15: Increasingly robust communications infrastructure to support communities is also required, particularly in bushfire and cyclone-prone zones. The Commonwealth, states and territories, with industry, should investigate ways to improve robustness including developing enhanced standards of heat protection and shielding of mobile phone towers and other communication infrastructure, minimum specifications for storm and wind strength resistance as well as required levels of design redundancy and duration of backup power considerations.

Greater interoperability should be a guiding principle for more effective use of resources

Increased inter-operability and deployment of equipment and assets is one way to increase the agility of responses nationally and beyond. Much of the equipment deployed (and to some extent the protocols used) is currently developed and built to specifications bespoke to specific jurisdictions, limiting flexibility for sharing.

Recommendation 16: It is recommended that increased inter-operability between jurisdictions is considered for all future operational asset purchases, building on existing collaborative procurement approaches. To achieve this a national working group, with industry and state and territory agency representation to identify the minimum critical specifications of each class of asset, should be established, which may also coordinate further shared or group purchase arrangements.

Recommendation 17: Commonwealth, state and territory governments should upgrade and integrate existing operational management systems to ensure more effective deployment and use of limited personnel and equipment within and between states, better asset-tracking and monitoring of status of deployed resources and fatigue management.

Brisbane City Floods. Photo Andrew Kesper / CC BY (https://creativecommons.org/licenses/by/2.0)

Recovery

The timely, efficient and cost-effective delivery of critically needed goods and services to affected communities across urban, regional and remote Australia is critical to effective recovery. The current experience of the National Bushfire Recovery Agency and the National Drought and North Queensland Flood Response and Recovery Agency demonstrates that recovery enabled by Commonwealth and state governments is enacted at the local community level. To achieve effective recovery there is a need to understand not only national and state or territory drivers, but also local government and community aspirations in order to facilitate a coordinated disaster response across suppliers, industry, government and senior community leaders.

Successful recovery depends on the complex and dynamic nature of both the disaster event and the needs of the community. While short-term recovery responses are vital, there is also a need to foster longer-term resilience and reduce industry and community exposure to hazards. Foresighting exercises involving local government could support cross-sectoral learning in the development of tailored responses and also address longer term impacts such as those to health and welfare.

Emergency response and recovery management is delivered through a range of government, volunteer and community resources. The sustainability of this approach is increasingly challenged by the frequency and, at times, longer duration of events. Many of these resources must deal with both preparation and planning and the operational and recovery phases which can last for extended periods causing fatigue and potentially impacting livelihoods.

Recommendation 18: Commonwealth, state and territory governments should review the human resourcing of emergency management to understand how it is being delivered on the ground, including consideration of the role of community and volunteers, and paid workers. For example, increased hazard reduction burning is likely to call heavily on volunteer firefighters, who are also increasingly called upon during the main fire seasons.

Recommendation 19: Disaster-affected communities are a central part of the recovery process. It is recommended that recovery planning empowers communities and engages with all levels of government, businesses and not-for-profits through engagement pathways such as those established by the National Bushfire Recovery Agency.

Recommendation 20: Commonwealth, state and territory health and research agencies should ensure that appropriate longitudinal studies are conducted during and after events on the health and welfare of people and communities directly and indirectly affected by natural disasters and use this evidence to provide targeted mental and physical support for future concurrent or consecutive natural disasters. These studies could inform NDRISC deliberations, and the development of climate adaptation approaches, and build on existing studies targeted at specific sectors, such as the long-term consequences of the 2011 Queensland floods.

Recommendation 21: The natural environment is impacted, in addition to communities and infrastructure. Commonwealth, state and territory environment agencies should collaboratively build national information resources to more effectively manage Australia's unique natural assets, including nationally agreed data standards, distribution mapping protocols, threat identification and management approaches, and the integration of ecological and cultural values into natural disaster response planning. These resources could inform NDRISC deliberations, and the development of climate adaptation approaches.

Building Further Resilience

Learning from each event and regular review of risks drives continual improvement

Vulnerability and exposure to climate and disaster risk is continually changing as the nature of events, our population and the footprint and nature of our land use, built environment and infrastructure change. Building resilience in communities, infrastructure and the natural environment requires an ongoing up-to-date and informed understanding of hazard, vulnerability and exposure to drive continual improvement, and needs to be strongly linked to land use planning and zoning to avoid unnecessary exposure to new hazards e.g. flooding and inundation associated with sea-level rise; or tropical cyclones tracking further south.

Recommendation 22: Commonwealth and state and territory agencies should regularly re-evaluate the risk profile and measures after events to test the effectiveness of adaptation and resilience-building measures and learn from them. This includes conducting timely post-event impact assessments to provide the necessary evidence-base for evaluation and learning. Recommendations 1, 3 and 4 provide a process to inform policy and investment decisions to reduce risk before an event occurs.

Recommendation 23: Review processes should involve all key stakeholders including three tiers of government, especially local government where planning and zoning controls are primarily managed, along with communities and businesses. There is also opportunity to learn from the insurance industry which has well developed risk methodologies that can provide important insights into the vulnerability of locations.

Cyclone Damage to a banana plantation at Liverpool Creek. Photo Dan Metcalfe

Resilience needs to be embedded in key investment decisions

'Building back better' is an important aspiration in resilience frameworks and approaches. This includes consideration of where we should build, not just how. The insurance industry has a sophisticated understanding and approach to risk management relating to the built environment and infrastructure and could make a significant contribution to incorporating resilience innovations in this area.

Recommendation 24: Given the benefits of 'building back better', governments, regulators businesses and communities should work together to agree on methods to explicitly embed resilience and review cycles into planning and investment frameworks, including those for land use, utilities and infrastructure, zoning and development, to progressively drive resilience in the long-term. This will lift the standard and robustness of both

- Critical infrastructure, especially power networks and communications assets and
- The built environment including community facilities, other social infrastructure and housing, with consideration of the standard and location of new developments and the appropriate standards and suitability of re-building post-disaster. The latter should also consider options for affordable retrospective applications.

Recommendation 25: Commonwealth, state and territory governments and regulators together with critical infrastructure owners and operators, should review the appropriate level of protection, backup and redundancy for existing critical infrastructure, including power supply, communications, major roads, transport corridors and facilities, fuel storage and distribution facilities, water and waste-water services, for the anticipated life of that infrastructure, taking into account

- Existing risks and vulnerabilities
- Predicted future conditions
- Impacts of consecutive, concurrent or compounding events and
- The rapid rate of change of technology which offers opportunities to continuously improve infrastructure in a dynamic way.

1. Scope & Context

SUMMARY:

The 2019-20 bushfires have placed a renewed focus on building resilience to better equip Australia for the future. The impacts of natural hazards are contextual, and disaster prevention, risk and response management are distributed responsibilities, with the community playing a critical role. Currently no single standard approach exists to scenario planning, risk and vulnerability assessment, or measurement of resilience and progress in building it. Given the limited timeframe to undertake the analysis, this Report is not a intended to be comprehensive or definitive treatment of Climate and Disaster Resilience, or on how each type of natural hazard should be addressed. Rather it has used experiences from recent events and expert scientific evidence and opinion to highlight key concepts and learnings relevant to building on the systems approach required for increasing resilience, as well as provide insights into future climate challenges we collectively face. It also aims to be complementary to a number of other related inquiries and reports currently underway.

During 2019-20, many parts of Australia experienced one or more major events caused by natural hazards. These events included bushfires, floods, drought and heat extremes and significantly impacted Australian communities and industries. In doing so they reinforced the case for increased focus and action on climate adaptation and resilience. As part of the response to these events the CSIRO was tasked by the Prime Minister in January 2020 to deliver an independent study recommending ways Australia can increase its climate and disaster resilience. The Terms of Reference can be found in Section 9.5.

This Report is underpinned by a detailed Technical Report and has been guided by principles of:

- Evidence based analysis informed by literature, lived experience and expert inputs
- A focus on where research, science and technology can contribute to building resilience in the short and longer-term
- Acknowledgment of past improvements and the importance of complementarity, with a number of related reviews, reports and inquiries currently underway including the Royal Commission into National Natural Disaster Arrangements and
- Maintaining CSIRO's trusted advisor role and providing relevant insights but no policy advice

There is significant breadth, complexity and inter-dependency of numerous aspects relevant to the subject of resilience and initial investigation identified eleven topics for more detailed exploration and analysis, namely:

- Improved scenarios and models for disaster prediction, and early warning
- Harmonisation of approaches and frameworks including terminology, standards and protocols
- Adoption of Indigenous knowledge and practice into land and bushfire management
- Understanding fuel reduction efficacy and capturing learnings in models and approaches
- Reviewing knowledge platforms and tools for emergency services and others to identify gaps
- Understanding experiences to inform management of recovery and relief phase
- Infrastructure resilience and improvement needs
- Vulnerabilities and interconnectedness of critical infrastructure
- Integrating climate and disaster resilience into agricultural and environmental management
- National and international benchmarking and best practice
- Learnings from previous events, reviews and inquiries.

This deeper analysis has been conducted recognising that enhanced resilience will require improvements in:

- The capacity to project the likelihood, occurrence and consequences of extreme weather events and the locations that they impact

- Education, training and engagement of the community and individuals with respect to preparation and response to disaster events
- Reliability or alternative provision of critical infrastructure, including communications and energy
- Building standards and codes to reflect increasing severity of the events for which they are designed, based on research, testing and innovation, and
- Decision support tools for short-term operational and tactical decisions and longer-term strategic planning and investment decisions.

There has been strong progress on adaptation and increased resilience to climate risks by individuals, communities, all levels of government, and in the private sector, but improvement is still needed. To achieve this, more work is needed to fully understand and put in place the appropriate and proportional actions required to further build climate and disaster resilience across the country.

The United Nations defines resilience as the ability of a system, community or society exposed to hazards to resist, absorb, accommodate and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions.

Australia is guided by the United Nations Sendai Framework[6] in its approach to risk and disaster resilience. The framework includes four priorities for actions.

1. Understanding disaster risk
2. Strengthening disaster risk governance to manage disaster risk
3. Investing in disaster risk reduction for resilience
4. Enhancing disaster preparedness for effective response, and to "Build Back Better" in recovery, rehabilitation and reconstruction.

Apart from the nature and severity of an event, its impact depends on a range of factors including geographic location, landscape, level of development and type of infrastructure present, population size and density, and community preparedness and socio-economic standing.

Dealing with this contextual complexity requires a risk-based approach that takes account of location and enables scenarios to be generated for future timeframes aligned to planning horizons (for example 2030, 2050, 2070) so that resilience measures can be tested and prioritised. The need for ongoing co-design, development and application of these approaches is a recurrent theme and is critical to address short, medium and long-term planning horizons. Fundamental to this is the ability to:

- Leverage science and research to forecast and project the scale, severity and frequency of future natural events
- Understand exposure and vulnerability of communities, natural assets and infrastructure
- Undertake inclusive community-involved development of goals and objectives for interventions.

Australia currently has no standard approach to scenario planning, risk and vulnerability assessment, or measurement of resilience and progress in building it – all essential elements for better co-ordinated and effective national action. However, the agreement by the former COAG in March 2020 to adopt the National Disaster Risk Reduction Framework provides an excellent starting point for further building disaster resilience. This is now being progressed through development of an action plan under the stewardship of the Ministerial Council for Police and Emergency Management, led by Emergency Management Australia in the Department of Home Affairs. Additionally, the 2015 National Climate Resilience and Adaptation Strategy provides framing in terms of climate resilience beyond disasters, which could be built upon to achieve a standard approach to these elements. The elements of systemic risk-informed sustainable development as intended by the NDRRF and NCRAS is illustrated in Figure 2 overleaf.

[6] UNDRR (2015) Sendai Framework for Disaster Risk Reduction 2015-2030 https://www.undrr.org/implementing-sendai-framework/what-sf

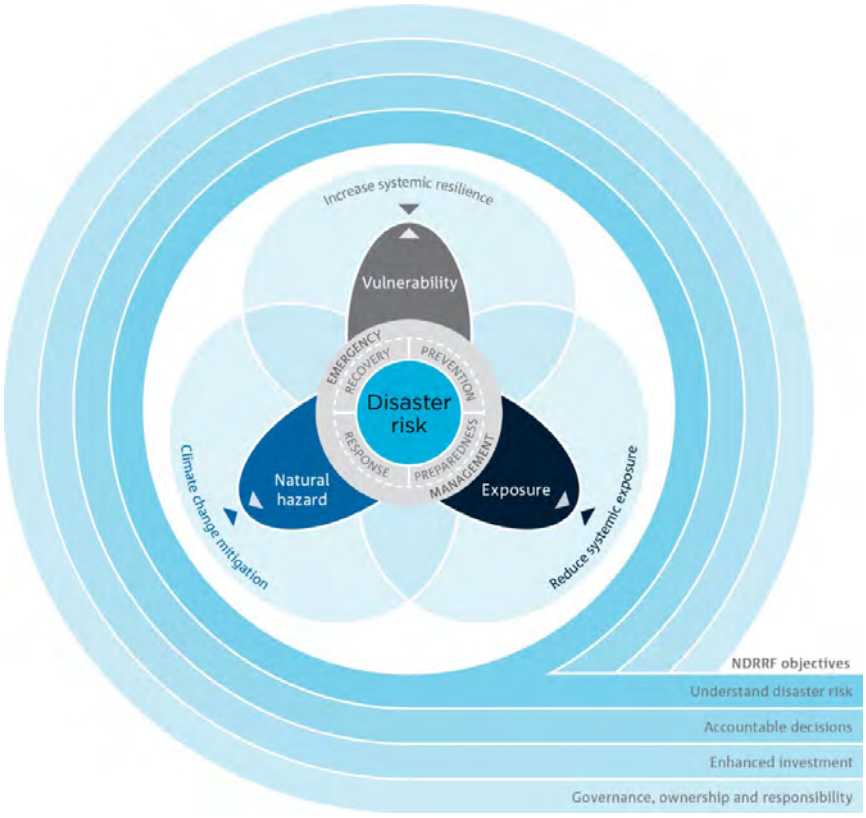


Figure 2 Illustration of a system-wide approach to disaster risk reduction that delivers on the NDRRF objectives of systemic-risk informed sustainable development. This is achieved through coordinated and targeted efforts that increase systemic resilience, reduce systemic causes of exposure and vulnerability, and integrate the strategic and operational dimensions of emergency and disaster management.

The management of disaster risk and response will always be a distributed responsibility, shared by all levels of government with critical involvement of individuals and communities. It is observed that there is a strong emphasis at the state level. However, the more consistent the underlying principles, frameworks, tools, supporting information and approaches can be, the greater the benefits that can be realised in terms of flexibility and sharing of resources across jurisdictions, scalability of response and systems, shared learning, common language and clarity of communications to community and stakeholders.

Individuals and communities are key to determining levels of acceptable risk and enabling the uptake of prevention and risk reducing resilience measures within their control. Hence capacity building, education and learning must be factored into the design and implementation of resilience frameworks and measures at all levels.

The immediate urgency of recent natural events has abated, and the focus has shifted to recovery. However, it is critical to plan and prepare for potential future events and where possible influence recovery actions to improve resilience. This will require ongoing commitment and progress to put in place the necessary systems' approaches to drive resilience at all levels of government, business and community.

1.1. Scope of this Report

At the time of writing, several other reports are being written and there are concurrent inquiries on topics related to Climate and Disaster Resilience. While a number of the efforts underway are listed in section 9.2, the most relevant to this Report are work being conducted by the:

- Royal Commission into National Natural Disaster Arrangements
- Independent NSW Bushfire Inquiry
- National Bushfire Recovery Agency
- National Drought and North Queensland Flood Response and Recovery Agency
- Australian Institute of Health and Welfare
- Australian Competition and Consumer Commission

To avoid duplication, this Report aims to complement these other activities, and as the national science agency and where appropriate, bring to bear a research and development lens. Relevant insights, case studies and findings arising from other work are also referenced.

Given the breadth and complexity of the topic, and the timeframe available, this Report is neither intended nor able to be a comprehensive and definitive treatment of Climate and Disaster Resilience and how it should be specifically addressed for each type of natural hazard. Compromises have been made in the breadth of event types considered, with scope limited to more acute events, and prolonged events such as drought and coastal erosion are out of the scope for consideration. In some cases, the depth of exploration and consultation possible has also been limited by time.

This Report is intended to highlight the key concepts and approaches relating to building resilience and the systems approach that is required to achieve it. It provides some insight into future climate hazards we expect to face and suggests initial priorities and common pathways that can be collectively advanced, supported by scientific advice and research. The ongoing involvement of the relevant stakeholders and agencies at all levels of government, industry and the community who have shared responsibility for land use, transport, planning, zoning, infrastructure, environmental management and disaster planning, response and recovery in the co-design and ultimate customised implementation of these approaches is essential.

Insights have been gathered from a review of the relevant science, consultation with key organisations who deal with prevention, preparedness, planning and disaster response and recovery, and benchmarking against leading international approaches.

This Report is structured to mirror the key phases of the disaster management lifecycle:

- Planning and Preparation
- Response
- Recovery
- Learning and improvement to build further resilience.

It is supported by a comprehensive Technical Report that captures detailed information, observations and practices identified during development of these reports. The Technical Report provides further underpinning of the high-level findings in this Report and provides an excellent reference resource for those charged with progressing the implementation of the Key Findings and Recommendations made in this Report.

2. Scenarios, models, warning systems and frameworks for building resilience

SUMMARY:

The foundation to building resilience is preparation and planning. This should be undertaken well before an event occurs. The potential for future disasters needs to be better understood and incorporated into decisions about infrastructure and where and how people live. This must be underpinned by an understanding of historical and future climate, population and development trends and the types of hazards and events to be anticipated. There is clear scientific evidence of climate change, and an associated increase in climate variability and occurrence of natural hazards. Australia is at increased risk from the impacts of disasters. A number of factors influence the extent of these impacts, for example whenever events occur simultaneously or consecutively, resulting in consequences potentially catastrophic to lives, infrastructure, economies and ecosystems. When events occur, robust platforms to warn and communicate with communities and between response agencies are needed and this is an area for ongoing improvement and innovation. There is an opportunity to harmonise how jurisdictions and sectors consider climate and disaster risks and resilience in their planning, land use, risk and investment frameworks and plans, recognising the importance of appropriately tailored regional and local responses, products and services.

2.1. What do we need to prepare for?

The combined effects of climate change and other factors including population growth and footprint, land use and the design and interconnectedness of infrastructure are continually changing our exposure and vulnerability to natural hazard events, as illustrated in Figure 3. Good preparation and planning effected through land-use planning and zoning, development approvals, building design and construction, infrastructure planning, community awareness and management of risk provide the foundation for preventing or minimising these impacts and building resilience. As part of this approach the levels of exposure and vulnerability need to be understood and considered in a way that is inclusive of all relevant stakeholders. It is also critical that there is clarity on the type and magnitude of natural hazard events that are being prepared for including the requirement to be prepared for events beyond our current experience.

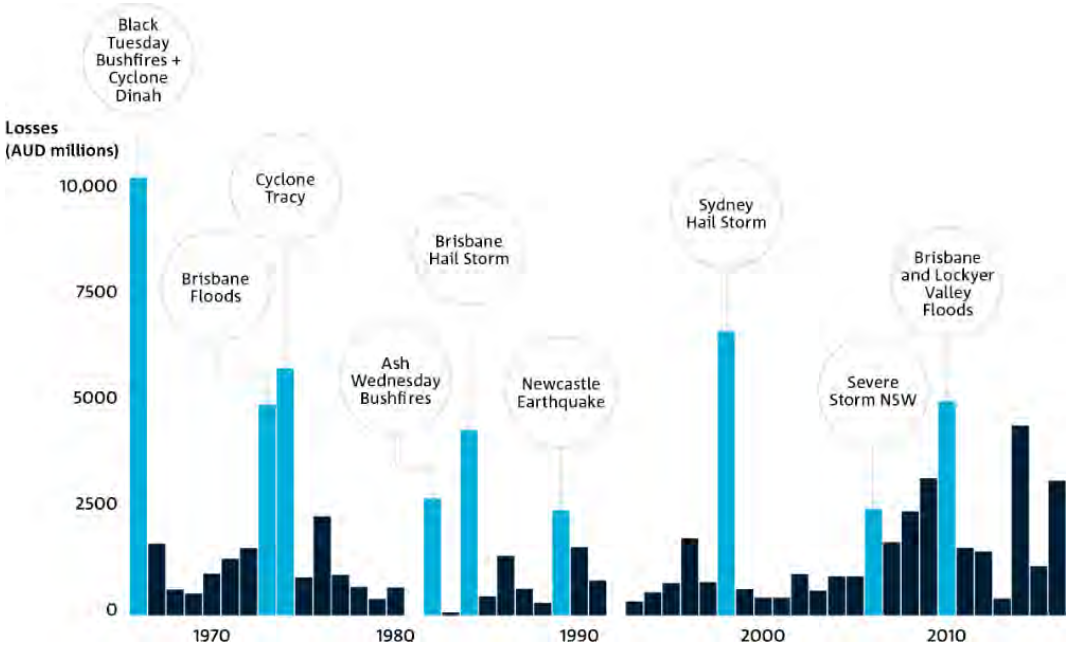


Figure 3: Normalised insurance losses 1966 – 2016 redrawn from *McAneney J, Sandercock B, Crompton R, Mortlock T, Musulin R, Pielke R Jr & Gissing A (2019) Normalised insurance losses from Australian natural disasters: 1966–2017, Environmental Hazards, 18:5*, with major disaster events superimposed.

To do this it is important to understand key climate related variables and trends, and their relevance to natural hazard events or disasters. Firstly, it is important to define and understand the differences between 'weather', 'climate' and 'climate change'. Weather is the day-to-day conditions (see Figure 4). Climate is the prevailing weather conditions of a region throughout the year, averaged over years. Climate change describes the persistent trends in the underlying climate and prevailing weather, either by reference to the average or other statistics such as variability or the incidence of extremes. Natural climate variability refers to the variations in our climate at all timescales due to processes within the system or variations in natural external factors such as solar cycles and large volcanic eruptions. Anthropogenic climate change is a change in climate attributed directly or indirectly attributed to human activity (often referred to as simply 'climate change'). An understanding of historical and future climate trends is essential in forecasting and calibrating the types of events and scenarios that should be envisioned for planning and preparation purposes. Also, as per more recent experience, the increasing variability in climate means that consecutive or possibly co-incident events need to be increasingly considered.

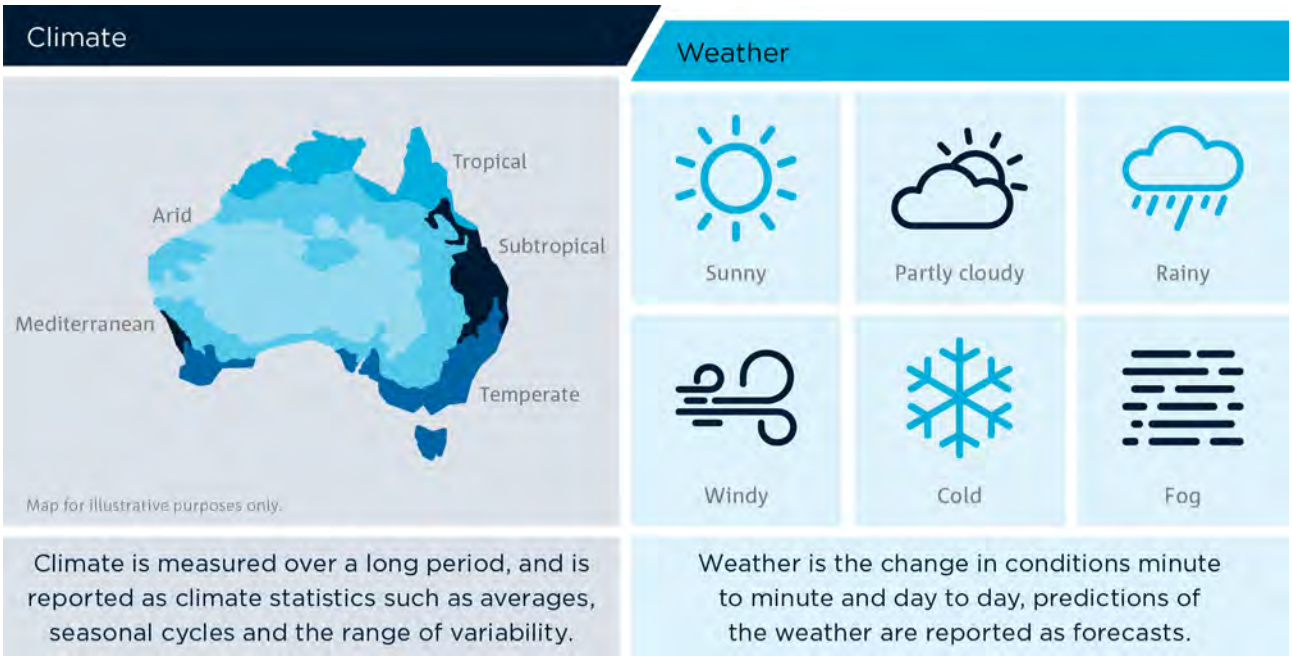


Figure 4 The difference between climate and weather

2.2. Climate trends

Australia has seen:

- An increase in average annual temperature of around 1.5°C since 1850
- Increased extreme heat events
- Warmer sea temperatures
- Higher sea levels
- Reduced rainfall in southeast and southwest Australia
- An increase in some rainfall extremes.

Studies of fire conditions, temperature and rainfall prior to recent fire events in Australia indicate human induced climate change has increased the fire risk. Similarly, climate can influence the level of risk associated with other types of natural events. While climate change projections should not be viewed as a prediction or forecast of upcoming events, simulation of the climate and earth system can provide comprehensive and consistent information on future climate risk and possible impacts.

2.3. Future projections

The observed climate over much of the last decade is consistent with many of the changes described in the climate projections since the late 1980s. Significant further climate changes are expected in the future under any scenario of human development. Along with further warming, projections for Australia indicate ongoing trends of further drying of southern and eastern Australia in some seasons. This will include reduced average rainfall, greater evaporation, lower humidity, lower soil moisture and less runoff on average. These long-term trends are expected to emerge amid high variability, with ongoing wet and dry years and seasons. Projections also indicate additional sea level rise, more intense rainfall extremes at hourly and daily timescales, decreased snow cover on mountains, ocean acidification and effects on vegetation from higher carbon dioxide concentrations over the next 20 years and beyond.

2.4. Impacts of climate change on hazard events

Impacts from climate change occur through changes in the underlying climate averages (sometimes called 'chronic' or 'slow burn' aspects), together with an increase in the frequency or intensity of some types of climate extremes (also called the 'acute' aspects). In terms of natural systems, these two aspects have been described as the 'press and pulse' of climate change impacts. An example is the alpine ash forests in the Australian Alps, where rising temperatures provide a background chronic 'pressure', then multiple fires in short succession acted as the 'pulse' to reduce tree growth, seed production and seedling establishment. There are analogous impacts from mean and extreme changes working together to increase the risks or impact of disasters in Australia. For example, a rise in the average sea level accompanied by extreme sea level events that erode shorelines create increase risk from coastal inundation. A hotter, drier average climate together with a greater chance of the worst fire weather events creates greater impact from bushfires.

Due to changes in the average climate and climate extremes described above, Australia is at increased risk of impacts from natural disasters, noting the confidence levels in relation to the increased risk of each type of event varies.

2.4.1. Drought

Increased impact from prolonged dry spells. This includes an increase in the impacts from multi-year droughts and short but intense 'flash droughts', caused by both decreased rainfall and high temperatures. Droughts are a natural part of Australia's climate, although they may be exacerbated by climate change. Confidence in relation to increased risk of drought varies, with higher confidence for increased impacts through hotter droughts, and for an increase in shorter duration droughts in southern and eastern Australia. Projections of multi-year droughts remain of lower confidence.

2.4.2. Bushfire weather

Dangerous bushfire weather has approximately doubled as predicted over the past decade and this trend is projected to continue in southern and eastern Australia. This includes the risk described by indices such as the McArthur Forest Fire Danger Index (FFDI). The FFDI combines measures of air temperature, relative humidity, wind speed, recent rainfall and long-term dryness. Fire risk is also increased through a background warmer and drier climate, plus possible climate impacts on ignitions through lightning strikes. The change in climate will also likely result in changes to bushfire fuel amount, structure and type.

2.4.3. Heat extremes

Continuing current trends, heat extremes of all kinds including hot days, warm nights and heatwaves are projected to increase. For both northern and southern Australia, in many places what are now 1-in-20-year extreme hot days are expected to occur every two to five years by the middle of the century. There is a very high confidence in these projections, which have implications for human health and operational of critical infrastructure under hot conditions.

2.4.4. Marine heatwaves

Following 100 years of increases in frequency and duration, more frequent, extensive, intense and longer-lasting marine heatwaves are projected which suggest more frequent and severe coral bleaching and significant impact on Australia's fisheries. The East Australia Current region is projected to continue to warm faster than the global average, which is linked to an increase in marine heatwaves and their impact. There is very high confidence in this projection.

2.4.5. Floods, flash floods

Greater short duration rain extremes associated with flash flooding are projected. As the climate warms, heavy rainfall is expected to become more intense, based on the physical relationship between temperature and the water-holding capacity of the atmosphere. For heavy rain days, total rainfall is expected to increase by around seven per cent per degree of warming, as a general rule. For short-duration, hourly, extreme rainfall events, observations in Australia generally show a larger than seven per cent increase and this is projected to continue.

2.4.6. Sea level rise and extreme sea level events

In Australia the consequences of sea level rise will include increased flooding of low-lying coastal, including tidal, areas and is likely to result in coastal erosion, loss of beaches, and higher storm surges that will affect coastal communities, infrastructure, industries and the environment. There is very high confidence in this projection. Averaged around Australia, sea level is projected to rise by 26-55 cm by 2090 relative to 1986-2005, under a very low emissions scenario. Under a very high emissions scenario sea level is projected to rise by 45-82 cm in this timeframe. However, any rise will vary by region. It should also be noted that a greater sea level rise is possible depending on the collapse of the Antarctic ice sheet.

2.4.7. Hail and damaging storms

An increased risk from large hail is possible, but currently uncertain due to the limited period of consistent observations as needed for historical trend analysis studies, as well as due to the limited ability of models to accurately represent the physical processes required for simulating future hail events. However, there is some indication of potential increases in severe thunderstorm events for parts of eastern Australia, noting a wide range of uncertainty. This represents a major gap in knowledge.

Some types of damaging storms are projected to change in frequency, severity or other characteristics (e.g. speed, size) due to a warming climate. For example, East Coast Lows are projected to decrease in number in winter, however the impact from each resulting storm may increase due to higher sea levels as well as changes to extreme winds, rain and waves.

2.4.8. Tropical cyclones

Climate change may mean fewer total cyclones but an increase in the number of more intense cyclones. However, it is not currently possible to quantify cyclone trends with a substantial degree of confidence. This is because tropical cyclone activity in the Australian region, which is specified as the ocean and land areas from 90° E to 160° E in the southern hemisphere, has large variability from year-to-year, due to the influence of naturally occurring climate drivers. The number of tropical cyclones in the Australian region generally declines with El Niño and increases with La Niña. Observations since 1982 indicate a downward trend in the number of tropical cyclones in the Australian region. Tropical cyclones are categorised by their wind speed, but the impact from tropical cyclones come not just from the winds but also from heavy rains and contribution to storm surge. For a given cyclone, the increased rainfall due to warmer oceans and atmosphere and higher storm surge due to sea level rise are projected to increase the overall impact.
A summary of the types of natural hazards and their potential impacts is provided in Table 1.

2.4.9. Compounding factors

While there is a link between climate variables and disasters, there are other factors that contribute to the occurrence and the magnitude of disaster impacts. These include the element of chance as to whether compounding or mitigating factors are present, the location in which the primary events occur, and the high variability of climate and the underlying vulnerability of the affected locations. For example:

- In the more populated area of southern and eastern Australia, fires involving major losses are almost always associated with fire weather represented by FFDI values that are extreme (75-99) or catastrophic or code red (>100). However, FFDI values that are 'severe' (50-74) or 'very high' (25-49) or lower can also lead to significant losses due to other factors such as hilly terrain, low separation distances, or preceding seasonal drying effect on vegetation. For example, losses in the hundreds of houses for FFDI < 75 are almost exclusively located in hilly terrain. Further, the severe dryness in Tasmanian highlands in early 2016 led to a greater loss of World Heritage Area vegetation.
- Conversely relatively high FFDI values do not always lead to high impact fires that cause losses of built assets and lives due to:
  - No ignition occurring (including through implementation of total fire bans)
  - Ignition occurring in areas where fire response is rapid and effective, either from the ground of the air maximising opportunities for early containment
  - Effective fire prevention works immediately adjacent to buildings and assets through fuel reduction
  - Built infrastructure having a lower vulnerability to fire.
- The local impact of storm surges is subject not just to underlying sea level rise but also depends on the local regime of tides and waves, the nature of the coastline (slope, landform and processes) and local geology (hard rock, or soft, unconsolidated sediments), and what is exposed to the surge (what is built and how it is built)
- Tropical cyclone tracks – whether they make landfall, where they make landfall – and building codes make a big difference to impacts of tropical cyclones
- The impact of floods not only depends on the rainfall but also the antecedent conditions such as soil moisture, the vulnerability of assets to floods and flood protection measures.

Table 1. Summary of climate related threats and their consequences

Threats	Impact areas	Examples of Consequences
Bushfires	Health & well-being	loss of life; injury; illness or mortality due to smoke exposure; increased mental health problems
	Environment	Ecosystem damage; loss of wildlife and biodiversity
	Agriculture &Water	Loss of crops, reduced productivity; tainted grapes; decreased water quality; impacts on and loss of livestock; damage to fencing and livestock
	Infrastructure	Loss of property; damaged infrastructure; road closures; impacts on aviation; impact on energy infrastructure
	Economy	Impacts on tourism and other businesses including supply chain, productivity, agriculture, forestry etc
Droughts	Health & well-being	Increased mental health problems
	Environment	Impact on biodiversity; ecosystem damage
	Agriculture & Food security & water	Decreased productivity; soil and nutrient loss; crop damage; Impacts on and loss of livestock; constraints on water resources
	Economy	Loss of livelihoods; decline in agricultural yields
Heat waves	Health & well-being	Greater risk of injury, disease and death; increased demands on hospitals, aged care facilities and service providers; reduced labour force productivity; poor air quality; increase in pollen
	Environment	Ecosystem damage; heat stress on wildlife
	Agriculture &water	Crop damage; impacts on livestock
	Infrastructure	Strain on rail transport and energy infrastructure; damage to infrastructure
	Economy	Cost, particularly on cities and agricultural sector
Dust storms	Health & well-being	Illness due to exposure and poor air quality
	Environment	Soil loss through wind erosion
	Agriculture &water	soil and nutrient loss, crop damage
	Economy	Disruption of transport services, especially air
Floods	Health & well-being	Loss of life; injury; Infectious diseases
	Environment	Ecosystem damage; impact on biodiversity
	Agriculture & Food security & water	Damage to or loss of crops; impacts on and loss of livestock; poor water quality
	Infrastructure	Damage to houses, roads and other infrastructure
	Economy	Impact on tourism and other businesses, including from damage and loss of buildings etc
Storms and cyclones	Health & well-being	Loss of life; injury
	Environment	Ecosystem damage; disruption of environmental processes
	Agriculture & Water	Damage to or loss of crops and livestock
	Infrastructure	Loss of property; damage to infrastructure
	Economy	Impact on tourism and other businesses, including from damage and loss of buildings etc
Sea level rise and storm surge	Environment	Coastal erosion; loss of coastal ecosystems; impact on biodiversity
	Infrastructure	Damage to buildings, roads, coastal infrastructure
	Economy	Reduced access to coastal environments
Marine heat waves	Environment	Damage to marine ecosystems; new pest species
	Economy	Impact on fisheries; tourism

2.5. How should we plan and prepare?

There is an opportunity for research to be integrated into decision-making and delivered in a form that is accessible and useful.

In Australia, responsibilities relating to disaster events start with the individual in a community, and span from local to Commonwealth levels of government, in the context of international frameworks. State and territory governments have primary responsibility for protecting life, property and environment within their borders and they have established plans in place to respond to, and recover from, emergencies. The Commonwealth Government can also provide physical and financial assistance, with Emergency Management Australia (EMA) coordinating Commonwealth Government disaster assistance to states and territories. The Australia-New Zealand Emergency Management Committee (ANZEMC) comprises senior officials from the Commonwealth and each state and territory government, plus a member from New Zealand and the Australian Local Government Association, and reports to the Ministerial Council for Police and Emergency Management. The Australasian Fire and Emergency Services Authorities Council (AFAC) also operates at a national level as the peak body representing 31 fire, emergency services and land management agencies in the Australasian region, coordinating interstate responses that do not require Commonwealth Government support.

Decisions made by agencies outside the emergency management sector over a range of different time scales can also impact a communities' experience of disaster. For example, decisions about land-use planning, zoning, development, infrastructure, construction and environmental management have the potential to influence a community's exposure or vulnerability to hazards, and the magnitude of impacts on the community.

Figure 5 Frameworks for natural disaster management at different geographic scales

In each state and territory, the roles, responsibilities and relationships between emergency services, metropolitan and rural fire authorities, volunteers, land management agencies and local government varies as illustrated in the example for Queensland at Appendix 1.

Jurisdictions have responsibility for building resilience and in some cases, states are increasing their focus on prevention, preparation and recovery from crisis in the longer term through such as existing agencies such as the Department of Fire and Emergency Services WA and the establishment of new agencies like Resilience NSW. Irrespective of jurisdiction, the following common elements must be in place to ensure good preparedness:

- A well-defined understanding of the types of likely scenarios, their timeframe and their potential impacts
- Clear expectations around roles, responsibilities, accountabilities of government and communities
- Co-ordination of the relevant agencies at all levels including those that deal with short term response, medium and long-term planning and development
- Regular assessments of climate and disaster resilience including infrastructure, population and demographic change and community vulnerability and exposure
- Common terminology, information and knowledge platforms and understanding of risk
- Use of scenarios and exercises to challenge and test planning standards, understand exposures and vulnerability of communities and train and equip response agencies
- Community education about risks and expected standards of preparation
- Robust mechanisms for the monitoring of threats and the provision of early warnings

There is an opportunity to map roles, responsibilities and initiatives across Commonwealth, state and local levels, the private sector and NGOs (building on the example provided at Appendix 1) to inform a coordinated approach.

2.5.1. Early warning mechanisms

Early warning is crucial to ensuring preparation measures are in place and active for both government and non-government response organisations and the community, but this needs to be addressed on multiple timeframes. Events such as inundation from sea level rise and drought typically need to be considered on seasonal through multi-decadal timescales while floods, fires, heat waves, storms and cyclones need to be addressed from minutes and hours to multi-day timescales.

The BoM is a critical operational component of the early warning mechanism in Australia across all timeframes, primarily through the provision of accurate forecasts and outlooks. This is done in close co-operation with relevant agencies and in the case of climate, CSIRO and universities. Weather forecasts and seasonal outlooks inform operational decision making by the community, disaster management agencies, agriculture, aviation, defence and other sectors. The BoM provides warnings for hazardous weather (heatwaves, floods, tropical cyclones, bushfire weather) communicated via the internet, mobile apps, traditional media, and text alerts.

For cyclones, severe storms, lightning, damaging winds and hail, public warnings are issued by the BoM. In the case of floods, the BoM works with local councils or emergency services to issue warnings which contain details of affected areas, road closures, etc. In the case of tsunami, the BoM works with Geoscience Australia, which monitors earthquake activity. In the case of bushfire, the BoM works with fire agencies to issue fire danger ratings. Work by the BoM and AFAC on a multiple hazard early warning system for use in bushfire, flood, cyclone, heatwave and extreme weather situations is well advanced. While this is currently being developed in conjunction with the Australian Fire Danger Rating System (AFDRS), its implementation of the warning system could be is brought forward using existing fire danger rating approaches to enable delivery in 2020/21. The development of the new AFDRS, which needs to be tested during the next two fire seasons, could continue and be integrated into the warning system when verification is complete.

Once an event appears likely, or commences, responsibility for warning advice typically shifts to the relevant emergency or response agency or a combination of agencies, and there is potential for improved clarity and

coordination during this transition process. Bushfire warnings are issued by states and territories and take into account BoM bushfire weather forecasts as well as other factors. Multiple platforms and agencies provide warnings and messaging to the community. There is an identified need for 'single point of truth' approach to avoid conflicting messaging. Apps such as 'Vic Emergency' and NSW 'Fires near Me' have proved to be valuable messaging platforms, however, the recent bushfire crisis demonstrated some issues with accuracy and reliability, and the need for a coordinated approach across jurisdictions.

Seasonal flood outlooks inform dam management, while seasonal bushfire weather outlooks inform movement of resources such as aerial fire-fighting assets. There is room to improve the integration of seasonal outlooks into disaster and climate risk management platforms such as National Disaster Risk Information Services Capability (NDRISC), and to learn from and expand on the climate services approaches used in the Agriculture sector through tools such as Yield Prophet® to provide guidance based on these outlooks. The Australian Fire Danger Rating System proposes to implement a new seasonal outlook capability in 2022, and this could follow roll out of the multiple hazards warning system as described above.

The provision of robust and reliable platforms to communicate and share early warnings to the community and response agencies remains an area for ongoing improvement and innovation. More acute challenges of communications during response to an event are discussed in more detail in Section 5.

2.5.2. Testing the approach – the case for stress testing

Coincident and consecutive climate extremes and disasters present new challenges, particularly when they cross jurisdictions. In 2019-20 some areas of Australia have seen drought followed by bushfires, then floods and pandemic. This has stretched response and recovery agencies and led to fatigue and resource constraints. While various emergency services organisations simulate their response to potential disasters within their jurisdictions (e.g. NSW SES conducted an exercise simulating a flood event in the Hawkesbury and Nepean floodplain), there is potential to extend such scenario testing and exercising to cross state and territory borders and simulate responses to coincident and consecutive events in terms of warnings, responses, deployment of resources and coordination of recovery efforts, and improve arrangements and plans before they are needed.

2.6. Scenario planning is a key tool

A $1 investment in climate adaptation or disaster risk reduction saves between $2 and $11 in post-disaster recovery and reconstruction[7]. This makes a compelling case to maximise prevention and preparation through scenario-based approaches.

The application of climate in scenario planning in the shorter term is relatively straight forward as climate trajectories over the next 20 years are reasonably well understood and the types of impact parameters are more tangible and can be better estimated. As the planning horizon is extended out beyond 2040, the global emissions pathway is uncertain, and the need to use a climate scenario approach becomes necessary. Consistency in the scenarios used enables physical projections and policy to be brought together to test different interventions and support decision-making. There are already some initiatives underway across the public and private sector to develop common scenarios, for example the value of a common scenario approach has been acknowledged in the finance sector's Climate Measurement Standards Initiative, which will build Australia's build first comprehensive set of common climate change risk disclosure standards.

Stakeholder engagement is required to interpret physical models. There are opportunities for provision of climate services that are customised to the specific stakeholders' situation and location but are based on a consistent suite of underlying climate assumptions and resultant impact scenarios. This type of approach provides the consistency and insight for decision makers to make and compare climate adaptation and resilience decisions across projects and sectors.

[7] Global Commission on Adaptation, 2019 Adapt Now: A global call for leadership on climate resilience, Global Centre on Adaptation and World Resources Institute https://cdn.gca.org/assets/2019-09/GlobalCommission_Report_FINAL.pdf

2.7. Harmonisation of approach can lead to greater effectiveness

There is support for a more harmonised approach to climate and disaster resilience across a wide range of government, industry and community stakeholders, yet it remains difficult to progress this goal in practical terms.

Harmonisation requires recognising and accommodating fit-for-purpose regional and location-based responses, within a nationally facilitated framework based on common platforms and approaches. This can increase efficiencies through greater cross-learning, less duplication of effort through common solutions, shared platforms and tools, lower transaction costs, and better alignment of policies and plans. It can also build capacity. This can in turn lead to reduced exposure and vulnerability, greater investment and return on investment in resilience and risk reduction connected communities that benefit from coordinated investment. The opportunity for engagement and co-design has been enhanced given the more integrated and successful approach demonstrated at senior levels during recent events including the COVID-19 pandemic.

Harmonisation of approaches to climate and disaster resilience across levels of government could be achieved by bringing together climate adaptation plans implemented by environment and land management agencies with risk reduction strategies developed and implemented by disaster management agencies. For instance, at the Commonwealth level, inclusion of the National Disaster Risk Reduction Framework alongside the National Climate Resilience and Adaptation Strategy within the remit of the Australian Government Disaster Climate Resilience Reference Group provides opportunity to bring adaptation and resilience building agendas together. Mainstreaming climate and disaster risk considerations into all policy, planning and investment frameworks across levels of government and sectors as intended by the NDRRF would also help to embed the approach.

Examples of success in harmonisation of frameworks include:

- The National Disaster Risk Reduction (NDRRF) Framework proposes an integrated approach to consideration of climate change and disaster risk
- Queensland state and local government planning provisions include local flexibility and support innovative planning that establishes resilient settlements, safeguards wellbeing and protects property, the environment and infrastructure
- The Australian Sustainable Finance Initiative (ASFI) recognises that finance has a fundamental role in all aspects of disaster. It identifies a range of challenges in adapting finance to climate risks
- Infrastructure Australia's Infrastructure Assessment Framework requires consideration of climate using scenarios from Climate Change in Australia (unless state climate risk scenarios are mandated) for initiatives and projects to be included on the national Infrastructure Priority List.

Harmonisation case study – National Bushfire Mapping

Various models, data sources and platforms are used by jurisdictions to map both bushfire risk and spread during an event. A possible mechanism being explored is a National Bushfire Intelligence Capability (NBIC) pilot project under the NRRF's National Disaster Risk Information Services Capability (NDRISC) which would initially focus on preparedness and prevention through development of a national bushfire hazard planning map. It is designed to build on existing systems, including the AFDRS and to take a federated rather than centralised approach. Complementary initiatives in earth observation may provide tools for dynamic situational awareness. Currently the Northern Australia and Rangelands Fire Information (NAFI) system provides an exemplar in the use of remote sensing for fire management and cross jurisdiction cooperation between WA and the NT. While end-user requirements such as active fire detection and burn severity mapping may simply involve integration of new Earth Observation data into existing frameworks, deeper understanding of bushfire behaviour and impacts may require a rethink of our understanding of vegetation communities, their structural form, microclimates and how they respond to weather, climate and disturbance. Without this ecological intelligence, realising the benefits of development in national bushfire information systems and modelling is likely to be limited.

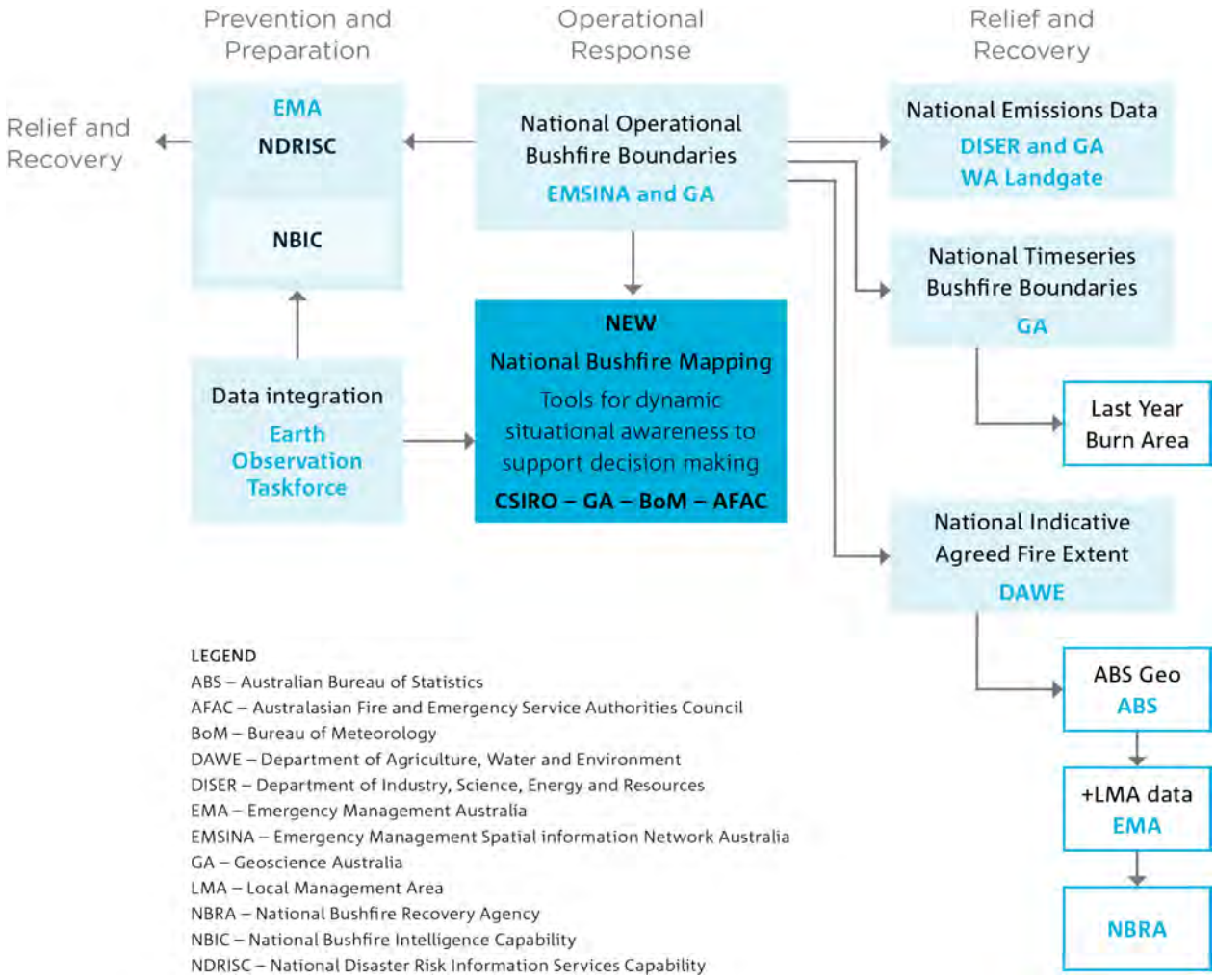


Figure 6 New opportunity to build on current data and platforms for mapping bushfire risk and spread

Internationally, work being implemented in New Zealand, Canada, UK and California is best practice with respect to governing and actioning disaster risk reduction and resilience measures. The New Zealand Disaster Resilience Strategy (NZDRS) provides an example of where mechanisms have been embedded in existing frameworks through harmonisation of culture and behaviour, institutional arrangements, knowledge use and capacity building.

In each case above, effective governance which ensures all parties are represented and engaged is key.

There is an opportunity to build on these examples and to embed requirements for considering risks in core central economic planning and investment frameworks. In particular there is scope for:

- Government to connect with the finance sector to build resilience (see example below)
- Applying lessons learned from exemplary approaches to harmonisation to support and enhance existing frameworks and approaches.

Case Study – Resilience Investment Vehicle

Insurance Australia Group, National Australia Bank and CSIRO are collaborating to develop a pilot project that will seek to fund built, social and natural infrastructure that builds community resilience to natural hazards. The Resilience Investment Vehicle pilot aims to direct public and private capital to finance new and/or adapt existing infrastructure that builds resilience, reduces disaster risk and that can derive a financial return for investors.

The Australian Government, through the Department of Home Affairs, is engaged through the pilot Steering Committee. As the pilot progresses, Home Affairs will look for opportunities to support and enable aspects of the pilot, such as fostering the provision of necessary data from the Commonwealth, sponsoring research activity as part of the pilot to determine processes needed to quantify benefits from resilient investment and assessing the governance arrangements needed between the public and private sector that promote resilience investment opportunities.

3. Indigenous cultural burning and land management

SUMMARY:

Australian Indigenous people have used fire to manage land for millennia. Fire is culturally significant, and its symbolic significance is passed from generation to generation. Recent bushfires have re-emphasised the need to empower Indigenous communities and landscape burning experts to engage in bushfire prevention, preparedness, response and recovery. To boost the capacity of Indigenous communities in future bushfire responses as well as build the capacity of non-Indigenous land managers, will require consideration of legal, policy and resourcing unique to state and territory jurisdictions. Cultural burning practices are deployed across Australia and these partnerships provide useful lessons to guide further support for Indigenous cultural burning and land management.

Fire has influenced how Australian Indigenous[8] people live on, with and through their land for millennia, with Aboriginal Australians skilfully using fire to adaptively manage their local environments. Aboriginal elders are aware of the significance of this, which underpins their advocacy to sustain, rejuvenate and support 'cultural burning' as a more holistic and Indigenous approach to fire knowledge and associated fire management practices.

Cultural burning involves manipulating fire to create a mosaic of burned patches across the landscape, with practices carefully tailored to protect designated features of the ecosystem. For Indigenous people, this physical impact is complemented by a cultural and symbolic significance that is passed from generation to generation. Knowledge about landscape burning is not only about where, when and how to burn – it is also about ensuring that those who light fires are acting under the appropriate authority of the Indigenous people of that country.

Cultural burning activities are now conducted by Indigenous Ranger groups (including in National Parks), Indigenous land and sea management organisations and Indigenous enterprises in many locations across Australia. Work is carried out on a mixture of land tenures and is developed via a suite of partnerships, including between Indigenous groups and with government agencies, scientists, non-governmental organisations and private landholders. Indigenous fire managers and their partners engage in a range of fire management activities, which taken together constitute their fire management work. These activities relate to different, sometimes concurrent stages of knowledge sharing and training, planning, site preparation, burning, monitoring, evaluating and reporting.

3.1. Recent bushfires and Indigenous community's policy considerations

Recent bushfires have re-emphasised the need to empower Indigenous communities and landscape burning experts to engage in bushfire prevention, preparedness, response and recovery. Legal and policy solutions to the challenges of enabling traditional owner groups access and input into decision making and management across tenures vary depending on the state or territory in which fire projects are located, affecting who manages landscape-scale fires, and how. There are also challenging issues around risk and liabilities, who is resourced to do this work, and an opportunity to prioritise engagement of Indigenous fire practitioners.

Policy and industry support for Indigenous leadership, cultural burning and land management practices is growing across the nation. A national bushfire management policy statement for forests and rangelands endorsed by COAG in 2014 provides explicit recognition of the need to promote and empower Indigenous fire practitioners, and AFAC acknowledges Traditional Owner use of fire in the landscape in its national position on prescribed burning. Fire authorities have established Indigenous inclusion plans, and government

[8] In this Report, the terms Aboriginal and Indigenous refer to Aboriginal and Torres Strait Islander and First Nation peoples of Australia

agencies across the country have developed a range of partnerships with Traditional Owners. Research programs have also supported collaborative work with Indigenous people and practitioners. However, better acknowledging and resourcing Indigenous cultural fire knowledge training and mentoring programs will increase the adaptive capacity of Indigenous leaders to respond to future bushfire events as well as building the capacity of non-Indigenous land managers to work with Indigenous communities and businesses.

One approach that warrants further development is support for successful partnerships that recognise the complexity of cross-cultural engagement and interactions, and respect Indigenous knowledge, know-how and protocols, and which create the necessary space for two-way knowledge exchange. This can empower Indigenous leadership to prevent, respond to and recover from bushfire events.

Building resilience in Indigenous communities to bushfires and other natural hazards is also dependent on building emergency risk management capacity and leadership in Indigenous communities. This can include empowering local leaders to contribute to the design of context-specific recovery health and well-being programs, as well as developing collaborative policy frameworks involving emergency services organisations and Indigenous communities to mitigate and manage incidents while following Indigenous cultural protocols. Improving transport, communications and local energy provision systems in remote areas reduces the impacts of natural disasters on remote communities by increasing self-sufficiency and thus the capacity to enact recovery plans and actions rapidly after an event.

Cultural burning activities are now conducted by Indigenous Ranger groups, including in National Parks, Indigenous land and sea management organisations and Indigenous enterprises in many locations across Australia. Work is carried out on a mixture of land tenures and is developed via a suite of partnerships, including between Indigenous groups and with government agencies, scientists, non-governmental organisations and private landholders. Indigenous communities and organisations across northern Australia have also seized opportunities to earn carbon credits through voluntary and Payment for Ecosystem Services Arrangements which recognise the emission mitigation effect of cultural burning practice.

Indigenous fire managers and their partners engage in a range of fire management activities, which taken together constitute their fire management work. These activities relate to different, sometimes concurrent stages of knowledge sharing and training, planning, site preparation, burning, monitoring, evaluating and reporting.

4. Fuel management including hazard reduction burning

SUMMARY:

Proactive management of vegetation by a range of means before the onset of bushfire threat can be an effective tool for fire management. However, effectiveness of hazard reduction burning as a management tool is beset by many complex factors. Debate persists about its effectiveness, the approaches required to achieve useful outcomes, and whether the costs and consequences associated outweigh the benefits. This is primarily due to the difficulty of quantifying both the effect of hazard reduction burning on fuels and the effect of hazard-reduced fuel on fire behaviour, particularly under the conditions associated with the occurrence of bushfires. Australia's landscape diversity makes it difficult to reliably extrapolate and apply knowledge gained in one locality to another. There are very few detailed peer-reviewed Australian bushfire case studies where the level of information about fuel state and condition and subsequent bushfire behaviour was obtained accurately enough in time and space that the effect of fuel treatment on fire behaviour is sufficiently clear to confidently inform hazard reduction strategies.

Bushfires are the result of the combination of weather conditions, combustible vegetation and ignition – most commonly due to a lightning strike and sometimes human influences. As outlined in Section 2.4.2 increasing frequency of fire weather presents an increased bushfire risk. Risk reduction and resilience building approaches in the longer term include land use and development planning, national construction code implementation, hardening and maintenance of infrastructure. In the short-term implementation of total fire bans, restricted access to fire prone areas and other local controls can be used.

Hazard reduction by individuals and communities in the immediate vicinity of homes and buildings can significantly reduce house and life loss. Hazard reduction on the property influences the impact when a fire arrives, and broadscale hazard reduction may affect the probability of fire arrival, but this is an area that requires ongoing investigation. It is complex and context dependent so there is no one right answer

4.1. Bushfire fuel – a factor we can directly control

Various elements contribute to the hazard of a bushfire, one we can directly attempt to modify, mitigate or remove is that of the vegetation and vegetation debris that burns during a bushfire – bushfire fuel. Bushfire fuel provides the energy for a fire and therefore contributes to its intensity, but also allows it to spread either through direct contact with continuous vegetation, or potentially over long distances via fire brands or embers.

Proactive management of fuel well before the onset of threat of bushfire is an effective tool for fire management as it can reduce propensity for firebrands and spotting, lower fire intensity and increase the range of conditions under which fire suppression is effective. Such fuel management may include physical removal via grazing, burning or mechanical means such as slashing and mulching or chipping and shredding, or chemical or biological treatment to reduce combustibility or presence. Cultural burns carried out by Australian Indigenous people can also achieve fuel reduction, but the reasons for cultural burns are more varied and complex, as described in Section 3. Prescribed burning is the most common approach to fuel reduction at the landscape scale and may also be carried out for other primary reasons, such as ecological, forest management or catchment management objectives, removal of post-harvest forestry debris, site preparation and seedling regeneration, or for biodiversity habitat management. Each of these will also have some impact on reducing bushfire hazard.

Once a fire is active, control may be attempted by reducing fuel flammability through use of retardants, or through reducing fuel availability in the form of firebreaks or backburning. Such actions efforts are most effective during mild to moderate fire weather, with fires being very difficult to control under severe, extreme or catastrophic weather conditions regardless of prior fuel management. as to best or most appropriate practice.

Case study: Fire retardants, foams and gels

A range of chemicals are used in modern bushfire firefighting, usually as enhancers to increase suppression effectiveness of water. These act to inhibit flaming combustion, reduce evaporative loss during delivery, restrict oxygen flow to fires or to reduce the combustibility of fuels. These may be delivered via aerial application (e.g. water bombers) or ground application (e.g. tankers or slip-on units). Most firefighting chemicals are sourced overseas from a small number of suppliers whose products have met the United States Department of Agriculture's wildland fire certification process. In Australia, fire authorities and land management agencies have agreed jointly through AFAC to the appropriateness of the USDA wildland fire testing standard for human and environmental safety, and for the safe use of such chemicals in firefighting appliances, especially aircraft in terms of corrosion risk. Some states, e.g. South Australia, apply an extra layer of approval over products deployed, or more widely, where they can be deployed.

Firefighting chemicals used in Australia are of two main types. These are flame retardants and fire suppressant enhancers. Retardants are comprised of inorganic salts in the form of powders which are mixed with water to aid delivery and a dye to aid visualisation. They can slow fire progression even after the water used to deliver it has evaporated. Retardants are typically used in indirect attack and delivered by aircraft where they coat unburnt fuels in the path of an active fire. Suppressant enhancers are added to water to improve the effectiveness of water as a fire suppressant by modifying its physical attributes. Two main classes of suppressant enhancers are foaming agents and gel additives. Foaming agents improve the ability of water to coat fuel particles and prolong its wetting effect, in addition to forming an insulative foam barrier between the fuel and the fire, restricting heat transfer and oxidation. Gels increase water viscosity, increase adherence to fuels, slow evaporation and minimise drift and dispersion when applied by aircraft. Suppressants are typically used in direct attack (i.e. directly on flames or burning material) and may be delivered via aerial or ground-based firefighting resources. Foam is often used to facilitate mop-up after a fire has been controlled, particularly of residual combustion in coarse fuels.

Fire retardants currently used in Australia are of relatively low toxicity to people (Gould et al. 2000). The toxicological assessments suggest low-level irritation is possible before chemicals are mixed with water and recommend normal protective equipment be worn for handling (State of Victoria 2020). There is also a low risk to anyone drinking rainwater contaminated with retardant (NSW Health 2019) but the water may taste and smell unpleasant and consumption should be avoided.

If not burned up by a bushfire, retardants are a direct source of nitrogen, phosphorus and sulphur and tend to be dispersed by the first rain, being washed into the soil or transported overland in run-off, with potential consequences for stream contamination. Most environmental ecotoxicological assessment is based on North American studies utilising US standards, though a small number of Australian studies have been conducted. Given the notably nutrient-poor ancient soils across much of Australia, plant communities have adapted to thrive in these contexts, so ammonium- and phosphate-based retardant additions can increase plant-available nutrients in soils, both inhibiting native plant growth and stimulating weed growth. Agency guidelines for the aerial application of suppression chemicals prohibit their use near water bodies and organic farms and in some critical habitat (in Tasmania). Further detailed assessment of the ecotoxicology of firefighting chemicals in the Australian context is required.

4.2. Hazard reduction is multifaceted

There are many factors that need to be taken into account to successfully conduct a hazard reduction burning program. These include the increased complexity of:

- Integrating fire management with public land uses including conservation and provision of ecosystem services
- Availability of personnel with operational experience and skill
- The need for appropriate weather conditions
- Increasing public concern about the effects of smoke on air quality
- Risk of fire escapes and resultant litigation.

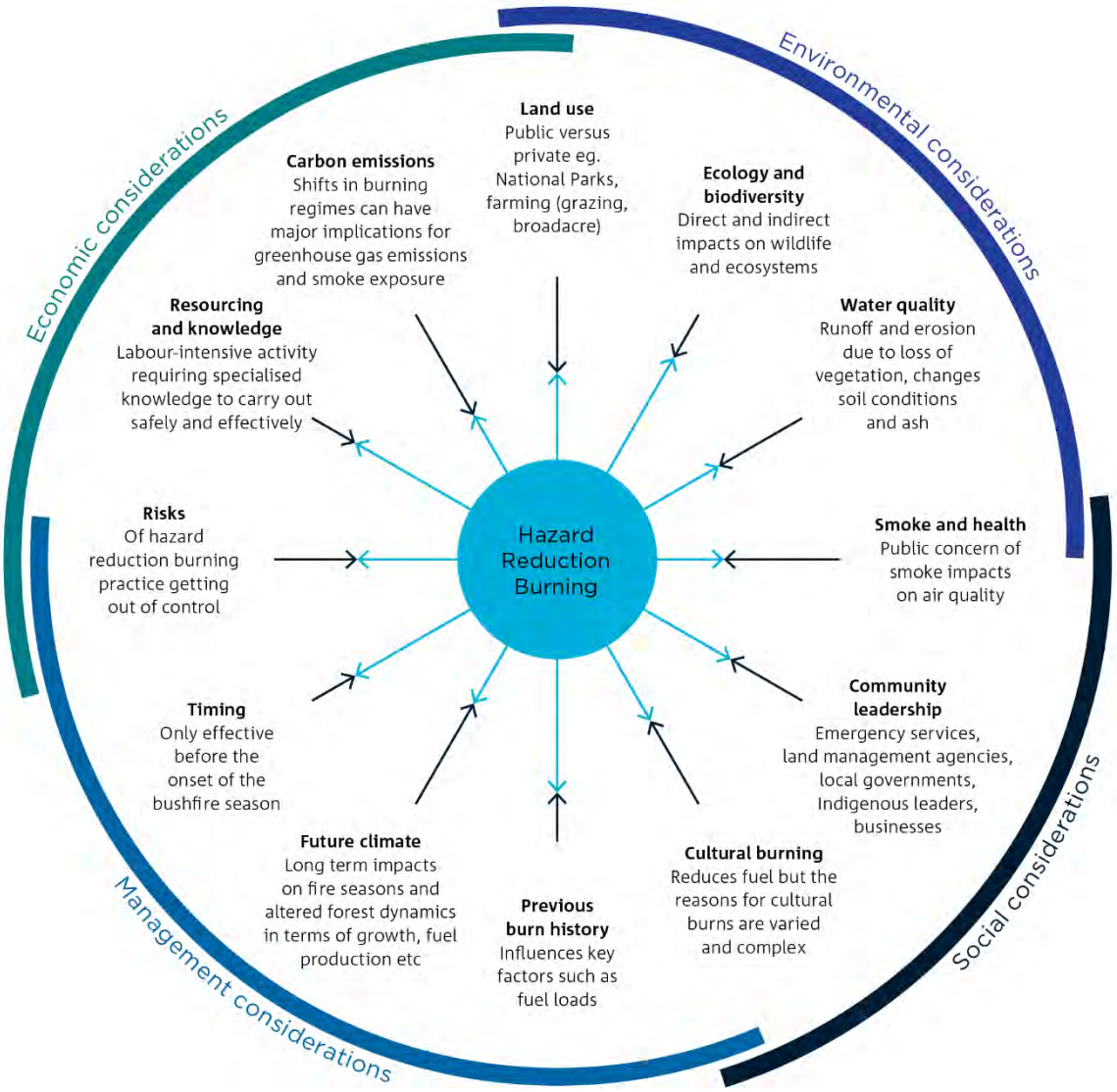


Figure 7 Hazard reduction burning remains an important tool for fire management to be used well before the onset of bushfire threat. Its application and effectiveness are complex, highly contextual and resource intensive. More research and learning from experience are required to refine how and where it can bring best value and protection.

The recently completed National Burning Project, jointly funded by member agencies of AFAC and the Commonwealth Attorney General's Department, has collated knowledge of prescribed burning from across Australasia to develop guiding principles, frameworks and processes to create a more holistic and consistent approach to prescribed burning for a wide range of purposes. This recently published knowledge provides essential context and information for understanding the operational use of prescribed fire, particularly for hazard reduction, including risk frameworks, best practice and training. The documents are underpinned by the National Position on Prescribed Burning, that identifies 10 key principles to be considered in any prescribed burn program. The Centre of Excellence for Prescribed Burning now has carriage of this.

Development and deployment of a nationally applicable decision support tool to integrate the impact of hazard reduction on reduced bushfire risk, while recognising the costs as well as the benefits, and enabling appropriate and informed decision-making, would go some way to addressing the challenges of hazard reduction planning and application.

Hazard reduction burning is an important tool to prepare for the bushfire, though debate persists in many fire-prone ecosystems around the world about the efficacy of hazard reduction burning and the magnitude and frequency required to achieve useful outcomes. There are unresolved questions about whether the costs and consequences in terms of economic, health, ecological and social factors are balanced or

outweighed by the benefits in hazard reduction. Such benefits are difficult to quantify in terms of the effect of hazard reduction burning on fuels and the effect of reduced fuel on resultant fire behaviour, particularly under the conditions associated with the occurrence of bushfires. In Australia, the broad range of fuel types and structures, fuel and climatic conditions, and topographic influences in which hazard reduction is undertaken makes it difficult to reliably extrapolate and apply knowledge gained in one locality to another.

4.3. More effort required to better understand fuel treatment on fire behaviour

While hazard reduction burning is not intended to stop the spread of bushfires, it can reduce the intensity of unplanned fires in less severe conditions and provide a firefighting advantage during fire events. Published and unpublished case studies provide useful information on the effect and duration of hazard reduction on fire behaviour in different environments. Hazard reduction burns reduce surface fuels, low-growing vegetation and the amount of loose bark which causes firebrands and spotting. Fuel reduction may also slow initial propagation of bushfires, increasing the time during which active suppression may bring a new fire under control.

The duration of reduced hazard is a concern in many ecosystems and is affected by previous burn history, conditions and effectiveness of the treatment, subsequent weather, site productivity, species type and specific species abundance. Climate change may alter forest dynamics in terms of growth, mortality, fuel production, etc, complicating the ability to determine likely changes in fuel attributes without direct measurements. In the longer term there are opportunities to take bushfire hazard into account when planting, replanting and managing the forestry estate and in land use planning. Post-event recovery in the ACT after the 2003 Canberra fires provides an example of this.

Finally, any consideration of prescribed burning and fuel management needs to consider other consequences. These include smoke hazard to communities both as a nuisance and a threat to human health, broader air quality and greenhouse gas emissions, impacts on water quality, and both direct and indirect effects on wildlife and ecosystem services provision. Hazard reduction burning can also be a labour-intensive activity that demands significant knowledge and experience to carry out safely and effectively. The capacity of fire managers either in the fire and emergency services, state land management agencies such as National Parks, local government or businesses including Indigenous fire management suppliers needs to be considered, as does the capacity of property owners and managers.

5. Operational responses to natural disasters

SUMMARY:

Disasters are complex and dynamic situations where emergency services depend heavily on robust communications, intelligence and technology. Emergency resource management and co-ordination is delivered using an operational management system, underpinned by access to appropriate intelligence and tools, and ensures limited resources are efficiently and strategically deployed. Lessons from past natural disaster events are key in driving continuous improvement of all facets of emergency management, including application of local knowledge and experience. Technological developments in Earth observation, including satellite and near-Earth aerial and remotely piloted aircraft systems, provide a real potential for an increasing role in emergency management and firefighting in an intelligence gathering role. These developments can support operational management systems and enhance situational awareness, from the location of human and technology assets in an event, to visualising the disaster front (fire, flood) in real time. As mapping and intelligence products become increasingly automated and digitised their accessibility is increasingly vulnerable to power failures and communication systems often under pressure during events. Community information and warnings are a key component in managing emergencies and are used to empower the public to make informed decisions about their safety prior to and during events.

Disasters are complex and dynamic environments that can have profound impacts on individuals, communities and the environment. While we may play a role in preventing, responding to and recovering from natural disasters through our individual and collective actions, we also cede much of the responsibility for response coordination and action, and subsequent relief and recovery, to agencies managed primarily at the state and territory level, but along with Commonwealth and local governments.

To deal with the complexity and dynamics of natural disasters, fire and emergency workers depend heavily on operational management systems which provide access to data, information and technology to assist in the preparation, planning and response to disaster events. Such tools are also important for strategic planning and decision making. It is critical that intelligence capabilities are current, robust, maintained, fully utilised, integrated and shared. It is important that innovation and adoption of new technologies occurs in concert with training and capability development for emergency workers in the effective use.

Lessons from past disaster events are key in driving continuous improvement of knowledge systems, tools and technology used in emergency management. Reviewing developments over the last ten years, there have been tangible improvements in knowledge systems, tools and technology and in the capacity of emergency workers s to use these during natural disaster events. However, there are areas where challenges and opportunities for innovation remain.

5.1. Timely and accurate information for effective disaster management

Timely and accurate data and information is the key input to operational management systems that enables situational awareness, resource management and tracking, and during an emergency response. Information available to emergency services provides the situational awareness required to properly assess current and forecast emergency incidents. This includes weather forecasts; mapping and monitoring using ground, aerial and satellite observations; predictive modelling; vehicle location information and early detection systems.

Availability of accurate, frequent and up-to-date weather forecasts provided by BoM are often the keystone in building an accurate intelligence picture around current and forecast weather conditions for bushfires, floods and cyclones, informing predictive models, operational decision making and community warnings/messaging. Post-event reviews and inquiries have generally found that weather forecasts are accurate and within bounds of reasonable expectation. BoM forecasts are a key trusted source of

information for first responders and the public during events and are accessed via various digital platforms (websites, apps) and the media especially via the ABC, an official emergency broadcaster. In terms of forecast inputs, BoM's access to data for forecasting can be limited by complex access arrangements as a result of multiplicity in data streams, ownership, and technology. Interagency collaboration to share information about weather impacts as disasters unfold is instrumental to their management. Embedded meteorologists within State Control Centres and Incident Management Teams provide weather briefings, interpretation of radar and satellite observations and timely relays of forecast uncertainty and warnings.

Maps and on-the-ground monitoring and intelligence combined with the information outlined above have long been a mainstay in coordinating first response. Accurate vegetation and fire scar mapping, up-to-date information on soil moisture and fuel loads combined with weather forecasts are powerful predictors of bushfire risk. Mapping and monitoring from ground-based, airborne, and more recently satellite platforms provide intelligence both for preparedness and response.

Accurate and clear mapping and timely, reliable ground-based and aerial intelligence are also instrumental for situational awareness needed to inform decision making. Availability of mapping with overlays that identify critical assets and infrastructure, vulnerable people and high-risk areas is critical to coordinated, targeted first response in many natural hazard events. In some cases, gaps remain about the location of critical infrastructure, and inconsistencies in mapping systems and mapping layers can make it challenging to use information effectively. GIS-based Common Operating Picture systems used across numerous agencies are a great step forward in integrating and visualising multiple data feeds, though maintaining these requires resources. More work is required to facilitate accurate transfer of information between mapping products and more effective information sharing between agencies.

5.2. The criticality of communication, information and warnings

Community information and warnings are a key component in managing emergencies and are used to empower the public to make informed decisions about their safety prior to and during events. The Australian Institute for Disaster Resilience *Handbook on Public Information and Warnings* is intended to support organisations in developing and disseminating community information and warnings. There is overall positive feedback on focused safety messaging and safety-critical warnings to the public. Providing these through a range of communication systems (websites, smart phone apps, social media, broadcast media, mobile phone messages, 1800 information lines) is valued by the public as this ensures that messaging reaches those with no or limited internet connectivity. However, having different warning mechanisms within each state creates confusion, and there is a case for a national approach to consistent defined terminology, symbols and visualisations enhancing messaging, and a 'single point of truth' approach to avoid conflicting messaging. There has been some community concern expressed that that in rural areas fire locations and directions could be misleading due to the coarseness of scale applied. An 'all-hazards' approach such as 'Vic Emergency' app allows integration of alerts relating to multiple incidents i.e. fires, road closures, air quality, and builds community familiarity with a single point of information.

The National Public Information and Warnings Group facilitated by AFAC has work underway on a Warning System designed to be used for bushfire, flood, cyclone, heatwave and extreme weather. This work leverages Australian Fire Danger Rating System research and was intended to be rolled out concurrently in 2022. There is an opportunity to accelerate implementation to 2020/21.

Beyond immediate advice, individual agencies continue to deliver community education programs. While these may be aligned through AFAC, there is no agreed approach nationally to community awareness and disaster preparedness. Differing jurisdictions face differing hazards, in different seasons. The Australian Institute for Disaster Resilience is working on capacity building through a national approach to disaster awareness and resilience and preparedness as a topic in schools. Investment in hazard, disaster resilience advice and education at a community level, with businesses and for individual households through a range of channels is warranted and AIDR is a suitable vehicle to deliver this.

5.3. The role for research science and technology

As mapping and intelligence products become increasingly automated and digitised their accessibility is increasingly vulnerable to failures in power and communication systems which are often under pressure during events. Technological developments in Earth observation, including satellite and near-Earth aerial and remotely piloted aircraft systems not dependent on ground-based wires or towers which are vulnerable to natural hazards, provide real potential. There is potential for their increasing role in emergency management in an intelligence gathering role and in supporting situational awareness, from the location of human and technology assets in an event, to visualising the disaster spatially in real time.

The availability of predictive tools such as fire behaviour and flood modelling are valuable and important to enable first responders to make strategic and tactical decisions, identify high risk areas for target response and anticipate likely impacts. Post-event reviews and inquiries highlighted that predictions directly influence key decisions (e.g. suppression strategies, community warning messaging, evacuations).

The performance of predictive tools is highly dependent on currency, consistent approach, availability, quality and reliability of data and information, suitable scale and training of operators. Quality and accuracy of predictive tools are critical for emergency services to have confidence in their outputs; uncertainty in model predictions can prove challenging for emergency service managers, and there needs to be clarity around the limitations of predictive models and the reliability of predictions to ensure that there is not an over-reliance on them.

For example, as the sophistication and capacity of fire simulators develops, their accuracy improves, and in general improved predictions generate improved warnings. However, interpretation of model outputs is highly dependent on skilled personnel, requiring extensive training and availability of expert advice. Fire behaviour knowledge is also captured in modelling platforms such as Phoenix, Aurora and Spark. Use of different prediction systems and tools between agencies can create delays in reconciling outputs and agreeing on a common view and tactical and strategic decisions. Ongoing research is adding to our understanding of fuel management in natural and managed landscapes.

Harmonisation of approaches, such as the AFAC's recent decision to pursue development of Spark platform as a common predictive platform available to all states and territories, and the proposed extension of the smoke forecasting tool AQFx to cover all States, reduces such risks.

Access to appropriate intelligence, inform efficient and strategic used of limited resources in emergency response. Resource management starts with registration of vehicles, equipment and personnel, which can then be used for planning, tasking, tracking, and coordination of emergency response at incident, state and national levels. For example, contracting and tracking of aerial firefighting resources throughout Australia is done by AFAC's National Aerial Firefighting Centre. Similarly, AFAC's National Resource Sharing Centre was established in 2016 to support and coordinate the deployment of interstate and international deployments of ground crews, enabling the provision of specialised skills to areas where they may not be readily available locally and this has recently been extended to include aerial resources. While a database registry currently exists for international deployment, there is no similar database yet for interstate deployments, and no consistent picture across Australia of where and when resources are deployed.

At the incident level, timely and regular reports on crew location are critical for incident controllers to effectively distribute resources and ensure the safety of personnel. Situational awareness needs to be timely, accurate and reliable to ensure the safety of first responders and the community and to inform strategic and tactical decision-making between different agencies. In the absence of automated systems, tracking the location and status of all deployed resources during a coordinated response can be a time-consuming task for managers and more efficient resource allocation can result in enhanced personnel safety.

Climate variability is resulting in compounding or consecutive extreme events across Australian jurisdictions, with increasing severity and frequency of events. Consequently, resource sharing within and between agencies and states will be further subject to increasing pressure from competing demands, requiring integrated and strategic resource management systems at state and national level.

The findings and recommendations from post-event reviews and inquiries have prompted implementation of cross-agency information management systems within jurisdictions. These systems aim to assist with information sharing between agencies during complex incidents. Improved interoperability of communication tools within incident areas, could lead to more effective decision-making, improve situational awareness, enhance personnel safety through real-time tracking of deployed resources and ensure more effective use of limited resources and between states and territories. As equipment is replaced it would be useful to deploy robust, commonly available solutions rather than the highly bespoke arrangements currently being procured by State agencies. While some States have pursued Government Radio Networks, cross border communication systems remain a significant challenge and this becomes mission critical for example along the border between NSW and Victoria. A nationally agreed pathway, including sufficient bandwidth and dedicated frequencies for emergency communication systems, potentially drawing on satellites rather than on-ground systems, would be an enormous advantage. Likewise, identifying and hardening communication infrastructure such as communication towers, and provision of mobile broadcasting units for deployment in mobile phone blackspots or areas where telecommunications are lost will improve community resilience, reduce risk for emergency workers and aid community recovery. In the short term, the Commonwealth Government has funded the deployment of satellite phones, batteries and solar panels to evacuation centres and rural fire depots in the wake of the 2019-20 bushfire season.

Recovery

6. Economic and social impact and recovery

SUMMARY:

Following the response to natural disasters are emergency relief activities which are critical to facilitate recovery. Many aspects of disaster recovery take time to implement and are especially challenging when impacts are sequential or concurrent. To understand the basic needs and intangible costs of health and wellbeing impacts requires an assessment of the capabilities and vulnerabilities of a community in response to various risk scenarios. Health and well-being are key issues. Analysis of extreme weather events shows mixed negative and positive results by sector but also by season. Better harmonisation of information flows around assistance is imperative. Just as some natural disasters can negatively impact a particular region, so too can certain parts of a community suffer perverse impacts which can exacerbate existing economic, social, health and wellbeing inequalities. Natural disasters can also have a devastating impact on biodiversity and cultural heritage sites and there is need to develop nationally agreed species and significant site distribution maps.

Emergency relief activities directly follow and at times overlap the response to natural disasters and are critical for to facilitate recovery. Many aspects of disaster recovery take time to implement and are especially challenging when impacts from events are sequential or concurrent. To understand the basic needs and intangible costs of health and wellbeing impacts requires an assessment of the capabilities and vulnerabilities of a community in response to various risk scenarios. Health and well-being are key issues. Better harmonisation of information flows around assistance is imperative. Just as some natural disasters can negatively impact a particular region, so too can certain parts of a community suffer perverse impacts which can exacerbate existing economic, social, health and wellbeing inequalities. Natural disasters can also have a devastating impact on biodiversity and cultural heritage sites and there is need to develop nationally agreed species and significant site distribution maps.

Economic and social recovery is the domain of the recovery agencies, and both the National Drought and North Queensland Flood Response and Recovery Agency and the National Bushfire Recovery Agency will publish their own information, so we provide an overview only.

Following closely to the response effort to natural disasters, which at times are still unfolding, emergency relief and ‘second response’ activities are critical for driving recovery and helping to build resilient communities, businesses and environments.

Internationally, Australia rates highly for overall preparedness and economic and social resilience, and for resilience of the physical environment. Yet reviews suggest that disaster recovery remains difficult for Commonwealth, State and Local governments, community organisations and charities, driven in part by political pressure, public expectation and media scrutiny, and by potentially unrealistic expectations about the amount of relief and the speed with which it can be disbursed. Scenario planning in advance can inform and improve the speed and effectiveness of recovery.

Many aspects of disaster recovery take time to implement, often due to factors beyond the control of governments, and in some cases the complexity of the tasks overwhelm the systems designed to address them. This is particularly a challenge when impacts are sequential, such as experienced in the past year in some communities with the accumulation of impacts from drought, followed by bushfire, followed by flooding rains or damaging hail, and then overlain with the challenges of managing the COVID-19 pandemic. Emergency response and recovery management is delivered through a range of government, volunteer and community resources. The sustainability of this approach is increasingly challenged by the frequency and, at times, longer duration of events. Many of these resources must deal with both preparation and planning and

the operational and recovery phases which can last for extended periods causing fatigue and potentially impacting livelihoods.

As well as some regions bearing greater economic costs of natural disasters, so too are some people in communities more vulnerable, and access to relief can be inequitable; an analysis of the period 2006 to 2011 of areas affected by the 2009 Victorian Black Saturday bushfires showed an adverse impact on people's incomes, but with that impact being greater on average for women, people on low incomes, renters, and people employed in the primary industries.

In the short term, despite improvements and learnings from previous events, there remain challenges for individuals accessing shelter, food, money and medical care post-event. Assessments of the impacts of past disasters thus highlight that emergency situations can exacerbate existing economic, health and wellbeing inequalities. It is worth noting the strong inter-relationships and reinforcing effects across economic, social, health, and environmental impacts from disasters. For example, loss of incomes and assets can have a dramatic effect on mental health, which can in turn limit financial recovery, and so on. Loss of employment due to impacts on business can exacerbate these effects. Understanding differences in vulnerabilities and needs for recovery are central to ensuring that these vulnerabilities (and inequalities) are not further entrenched through rebuilding under business-as-usual approaches that fail to fundamentally build resilience and proactive disaster responses.

Understanding the basic needs and intangible costs to health and wellbeing requires involvement of individuals and the communities in assessment of their capabilities and vulnerabilities in response to various risk scenarios. Lessons learned from past recovery efforts highlight that both the disaster and the recovery process can have a significant impact on people's health and wellbeing. For example, loss of personal identification (e.g. passport, driving licence) makes it difficult for people to access personal banking, register for aid and support services, while delays in accessing emergency relief funds, grants and loans limit people's ability to access housing and basic supplies, and begin rebuilding.

Lack of insurance or under-insurance also impedes household recovery, meaning that people may be unable to rebuild. Initiatives to 'build back better' may complicate this if new building requirements increase the cost of replacement or retrofitting above previously insured like-for-like replacement costs. Increasingly, as the climate changes homes and other assets are becoming unaffordable or impossible to insure.

6.1. Health and wellbeing

Physical and mental health and well-being are also key issues both over the short and longer terms. During the 2019–20 bushfire season, smoke posed a range of health risks well beyond bushfire affected regions, especially for those with pre-existing heart or lung conditions. The Australian Academy of Health and Medical Sciences noted that the health impacts of bushfires are not well understood and that there are gaps in our knowledge regarding impacts on first responders, affected communities and the wider population, especially when exposure is prolonged. The recent announcement of the release of $5 million from the Medical Research Future Fund will go some way to addressing this, with $3 million for research into the physiological impacts of prolonged bushfire smoke exposure and $2 million for research into the mental health impacts of bushfires on affected communities. During the 2019–20 bushfire season, limited health advice was available to the public, both because of a lack of evidence in some instances and because existing evidence had not been collated and synthesised. It was not always practical to follow advice to remain indoors. Clear, evidence-based health advice is needed, along with targeted advice and plans for vulnerable groups, including infants, children, the elderly, individuals with pre-existing conditions, pregnant women, those with a disability and Aboriginal and Torres Strait Islander peoples and communities. Currently the Australian Institute of Health and Welfare are utilising emergency department, homelessness, pharmaceutical and Medicare data to examine some of the more immediate health impacts from the 2019–20 bushfires on Australians and will be releasing their biennial *Australia's Health* report later in 2020 (see Section 9.2). Up-to-date information is crucial so that that preparations to enable rapid adaptation of health systems in the face of natural disasters can be made.

The health impacts of bushfire smoke in Australia

An Australian study shows that smoke during the 2019/20 bushfire season was responsible for 417 premature deaths[9]. This is in contrast to smoke pollution between 2001 and 2013 resulting in an estimated 197 premature deaths[10].

Work is ongoing to improve fire smoke forecasts and to estimate the health burden in near real time to inform health risk communication and fire management practices.

Current health protection advice related to bushfire smoke mainly focuses on short term actions aimed at reducing personal exposure to pollution. In situations like the 2019–20 bushfire smoke events in eastern Australia, where severe smoke pollution persists over longer periods and affects large population centres, there is a need for more nuanced and detailed health advice based on location-specific air quality data and forecasts. Currently, state and territories use a range of different air quality metrics. Discrepancies in the presentation of air quality information and related health advice across jurisdictions is confusing for the public.

Managing the health impacts of smoke should be integral to planning activities such as planned hazard reduction burns, as well as bushfire emergency response. Close collaboration between health, education, environmental, fire management and emergency response agencies is essential for achieving the best overall outcomes for population health and wellbeing. Further research is needed into the longer-term impacts of bushfire smoke, as well as the effectiveness and health equity implications of related health protection advice.

Longer term resilience and adaptation of the health system will also be required. Data can provide insights into health impacts and what a resilient health system looks like, and who it may need to target to achieve better health outcomes. Internationally, the Centre for Disease Control in the United States has developed a Building Resilience Against Climate Effects (BRACE) framework to prepare communities for the health impacts of climate change. It includes projects on the burden of disease. Experience of the COVID-19 pandemic illustrates the ability of the health system to provide support in novel ways in the face of disaster and provide remote access to care.

6.2. Impacts on agriculture

Analysis of extreme weather events shows mixed results by sector but also by season. Based on data from the Australian Bureau of Statistics, incomes of workers in agriculture, forestry and fishing showed the greatest decrease (2006-2011) in areas affected by Victoria's Black Saturday bushfires in 2009. Agricultural impacts are also likely to be prolonged, but these impacts are likely to differ between crop and livestock operations, and longer timeframe operations such as forestry, viticulture and horticulture. Agriculture is also highly at risk from sequential events, which is a focus of a parallel report being developed by the National Drought and North Queensland Flood Response and Recovery Agency (see section 9.2). Reviews of previous natural disasters and adaptation to a changing climate have pointed to the resilience of farmers and their innovative approach to adopting risk management and resilience building strategies, but also pointed to the need to better recognise the perspectives, needs and vulnerabilities, and roles of women in rural areas and the agriculture sector.

The most immediate needs in the agricultural sector include replacement fencing, attending injured and dead livestock, ability to move product, and the flow of emergency financial assistance. Assessments of damage and stock losses which release aid are conducted by insurers, state government primary industry departmental staff and include an initial rapid assessment, followed by a detailed damage assessment; these assessments are frequently slowed by the enormity of the task. Online submissions may be hindered by lack of access to telecommunications, or training in use of interactive forms, and the perceived or real complexity of the submission.

[9] Borchers-Arriagada N, Palmer AJ, Bowman DMJS, Morgan GG, Jalaludin B, Johnston FH. Unprecedented smoke-related health burden associated with the extreme 2019-20 bushfires in eastern Australia. *Med J Aust*, accepted 18 February 2020. http://dx.doi.org/10.5694/mja2.50545

[10] Horsley JA, Broome RA, Johnston FH, et al. Health burden associated with fire smoke in Sydney, 2001-2013. *Med J Aust* 2018;208(7):309-10. [published Online First: 2018/04/13]

In the longer term, rural extension services are a key mechanism in capacity-building and resilience in agricultural communities. The benefits of their services in bushfire response efforts, as well as other natural disaster responses, has been demonstrated — their strength lies within their pre-positioning, being readily available for deployment when skilled professionals were required, and established existing networks. The 'build back better' principle discussed in Section 7also applies in the agricultural sector where new management systems, crops, products and supply chains can be considered and implementing thorough post-disaster recovery.

6.3. Impacts on small and medium enterprises

Small businesses, or Small and Medium Enterprises (SME) are important economic contributors in Australia but due to their size often lack the necessary resources to rebound from an event quickly. They are highly dependent on the availability of economic infrastructure and supply chains. Because of the great diversity in their features — for example, the nature of business, products or services, and location – disasters can have wide-ranging implications for small businesses. Impacts may be direct, and immediate, including damage to assets, loss of income, livelihoods and employment, and exposure to interrupted supply chains. Many of these impacts persist for long periods. This is illustrated in the tourism industry which relies on natural and cultural assets to generate business. Small businesses may also suffer from indirect impacts that are slower to eventuate and more diffuse, such as migration of residents away from the region, loss of economic and community vitality, and erosion of consumer confidence.

The immediate objective of recovery for small businesses is restoring operations and enabling the business to get back on its feet. In the tourism example, short-term responses include communication and marketing campaigns to correct misperceptions about the scale and extent of a disaster and promoting a destination as 'open for business'. Yet another aspiration that is increasingly expressed is to improve the adaptability and robustness of small businesses to future disasters while they move through the longer-term recovery process. There is some scope for this under Disaster Recovery Funding Arrangements as part of a Community Recovery Fund, to ensure that local impacted businesses are better prepared next time a disaster occurs. An example of this approach is the Commonwealth Government's Small Business Rebuild Package announced in March 2020, deploying experts into bushfire affected communities to assist and advise businesses. A primary avenue for supporting small business recovery is through financial assistance in various forms. This includes insurance and recovery loans; for disaster-declared jurisdictions, disaster assistance can be activated for small businesses under the joint Commonwealth-State Disaster Recovery Funding Arrangements. However, while a range of loans and grants may be available, there is often a lack of coordination across levels of government and between jurisdictions, making the process of identifying assistance complex and challenging to navigate, with likely implications for individual small business owners. Better harmonisation of information flows around assistance is thus an imperative.

6.4. Impacts on environmental and cultural heritage

Over 18 million hectares had burned by mid-January during the 2019–20 Australian bushfire season. Early scientific assessments suggest that these fires had a devastating impact on biodiversity, including the loss of an estimated one billion birds, mammals and reptiles, and threatening habitat both for remaining populations and for migrant species yet to return.

Commonwealth, state and territory governments and their agencies, non-governmental organisations and charitable and philanthropic organisations, communities and individuals rallied to provide immediate relief and support recovery, particularly of fauna. Some of this outpouring of goodwill lacked focus and coordination.

A Wildlife and Threatened Species Bushfire Recovery Expert Panel, chaired by the Threatened Species Commissioner, was convened by the Commonwealth Government to assist in prioritising recovery actions for native species, ecological communities, natural assets and their cultural values for Indigenous Australians, which were affected by 2019-20 bushfire events. The Expert Panel has reported on the impacts on protected and imperiled species in bushfire affected areas and identified the vertebrate, invertebrate and plant species of highest priority for intervention, including general actions that could support the recovery of

impacted species. Core to this process has been the development of multi-jurisdictional species distribution maps, and the compilation of trait response databases for recently fire-impacted flora and fauna. This has been largely due to the goodwill of individual academics and agency staff supported by the National Collections but has highlighted a gap in Australia's understanding of the distribution and vulnerability of its biodiversity assets to natural disasters. Collaborative national resources need also be devoted to the complex issue of determining the degree of risk reduction that can be achieved per unit input of management and financial input.

The Department of Agriculture, Water and Environment's Threatened Species Scientific Committee will review and update the Conservation Advices of taxa affected by the 2019-20 fires, but federal and state listings need to have resources devoted to Recovery Plans, Action Statements or their equivalents so that the listings also come with management guidance. Risks to biodiversity assets should be explicitly built into and accounted for in the management of individual fires, with for example Victoria's Department of Environment, Land, Water and Planning developing a framework to integrate ecological values into bushfire management planning.

The role of citizen science

In response to the 2019-20 bushfires, CSIRO was asked to identify opportunities for the public to engage in citizen science projects, and to maximise the likelihood of these activities delivering science-ready data. Two national forums brought together stakeholders to explore how the sector could be supported and coordinated to help deliver research-ready data, and to share ideas and discuss opportunities for how the science, and citizen science sectors could work together. The scope of the forum included the natural and built environment.

Participants were encouraged by the role of citizen science in supporting our nation's bushfire response, and recent events have precipitated a timely conversation between the science and citizen science communities. Citizen science capability can include both individuals that can be mobilised to collect in-situ data, and the broader science community being engaged to help classify, interpret and validate observations.

The forum recognised that in a time of crisis citizen science can provide an important complement to traditional research-led monitoring campaigns. It was agreed that in the short term there would be benefit in the research sector communicating fundamentals of data acquisition. Citizen scientists are confronted by a plethora of tools and protocols which means capturing data in a consistent manner remains challenge. The science community noted that more could also be done to align field protocols to deliver to multiple science questions, for example botanical data captured to answer ecological questions could also assist in the calibration of remote sensed imagery. The longer-term challenge is to integrate citizen science programs within a research-led 'experimental design' which can only be achieved by closer coordination during the design of a research study. CSIRO, the Atlas of Living Australia, and the Australian Citizen Science Association have developed and launched the bushfire citizen science project finder as a first step in building awareness of the range of bushfire-related citizen activities currently underway. **www.csiro.au/bushfireprojects** CSIRO has developed the beginnings of an online citizen science resource hub to support this initiative. This is available at **www.csiro.au/citizenscience**

The 2019–20 bushfires also damaged cultural heritage sites, including sacred sites. Amid the devastation, bushfire management efforts managed to protect the ancient Wollemi pines in the Blue Mountains, the rare Nightcap Oak and other endangered species in the Gondwana rainforests. The bushfires also revealed undiscovered elaborate sections of ancient stone-lined channels in the World Heritage-listed Budj Bim Cultural Landscape in southeast Victoria.

The Australian Archaeological Association has made a series of recommendations for cultural heritage sites and has called for an audit of burned country, undertaken in consultation with affected Aboriginal and non-Aboriginal communities and heritage professionals. This would identify and assess damaged and destroyed sites as well as previously unknown sites which have been exposed by the fires.

These aims complement one of the recommendations from New Zealand's holistic framework for disaster recovery, which highlights that pre-identifying amenities—including culturally significant sites—that are important to "peoples' social and emotional recovery [and] will help prioritise recovery activities" in the future.

7. Planning, Infrastructure and Built Environment

SUMMARY:

Planning, land use and zoning and investment decision making are critical to achieving the most appropriate use of land, ensuring we build or develop in the right locations and building back better after events. Explicitly embedding the consideration of resilience in decision making frameworks is essential to drive increased resilience in these areas.

Moving towards more resilient infrastructure requires an understanding of future scenarios in a changing environment. In the case of the built environment post event analysis can help inform a forward-looking approach on what to build and where. Examples of a proactive approach to hardening housing stock and even whole communities against future impacts, such as the Household Resilience Program for cyclone prone areas are few but provide promising models.

Another area for particular attention is critical infrastructure such as roads and transport, electricity networks, and communication systems including radio, telephony and internet all of which are vulnerable to natural hazards. Loss of essential infrastructure is costly in terms of both financial cost and suffering of communities affected by disasters. What, how and where critical infrastructure is built is mostly determined by regulation and legislation, which establishes minimum requirements largely based on past experience rather than a more forward-looking resilience focus to inform infrastructure investment. While the long-term benefit of a resilience approach is recognised, the short-term cost and resourcing pressures often mean this is not implemented. Infrastructure plays a critical role in boosting community resilience by helping them withstand and recover from disasters. The interdependent nature of networks which supply food, water, energy and communications mean failure in one or more networks can cause wide-ranging disruption and if not properly managed leads to increased vulnerability.

Commonwealth, State and Territory governments define critical infrastructure as: 'those physical facilities, supply chains, information technologies and communication networks which, if destroyed, degraded or rendered unavailable for an extended period, would significantly impact the social or economic wellbeing of the nation or affect Australia's ability to conduct national defence and ensure national security'[11]. This captures roads and transport, electricity networks, water supplies, waste streams and communication systems including radio, telephony and internet.

Australia's critical infrastructure includes private and publicly owned and operated assets, networks, services and supply chains. A growing population is putting ageing infrastructure under strain, with demand for roads and transport, social infrastructure, and health, driving forecast expenditure of $1.1 trillion between 2016 and 2050[12]. Ensuring critical infrastructure is developed within a resilience framework, and that Australia has the resilience strategies and information sets to support that framework is important to protect this investment.

Critical infrastructure is not only highly vulnerable to disasters but may also be a catalyst (e.g. power line ignition of bushfires). Loss of essential infrastructure is costly both in terms of financial cost for direct replacement, estimated at $17 billion between 2015 and 2050[13], and suffering of communities affected by

[11] Australian Government Critical Infrastructure Centre https://cicentre.gov.au/infrastructure
[12] Infrastructure Australia 2019 An Assessment of Australia's Future Infrastructure Needs: The Australian Infrastructure Audit 2019 https://www.infrastructureaustralia.gov.au/sites/default/files/2019-08/Australian%20Infrastructure%20Audit%202019.pdf
[13] Infrastructure Australia 2019 An Assessment of Australia's Future Infrastructure Needs: The Australian Infrastructure Audit 2019 https://www.infrastructureaustralia.gov.au/sites/default/files/2019-08/Australian%20Infrastructure%20Audit%202019.pdf

disasters. As well as disaster events, climate risks pose a growing vulnerability of infrastructure, such that improved resilience is required to reduce future costs.

Australia's NDRRF and Disaster Preparedness Framework translate the UN Sendai Framework in an Australian context, and the Critical Infrastructure Resilience Strategy sets the Government's approach to enhancing resilience of crucial infrastructure in the face of all hazards.

Most importantly, the concept of resilience must be incorporated into planning, land use and investment decision processes, including critical infrastructure and capability investment, to influence how and where we build and drive ongoing improvements in the standard and design of the built environment and critical infrastructure. This essentially forms the foundation of the next cycle of planning and preparation on which future resilience can be built as illustrated in Figure 8 below.

Figure 8 Building resilience in communities, infrastructure and the natural environment requires an ongoing up-to-date and informed understanding of hazard, vulnerability and exposure to drive continual improvement, and needs to be strongly linked to land use planning and zoning to avoid unnecessary exposure to new hazards e.g. flooding and inundation associated with sea-level rise; or tropical cyclones tracking further south.

While the need for coordinated efforts to reduce disaster risk is acknowledged, strong demands on time and resources mean that operational imperatives are often prioritised over longer term strategic challenges, and there is a lack of tools to facilitate coordinated action.

What critical infrastructure we build, and how and where we build it, while generally subject to cost benefit analysis, doesn't necessarily capture the long-term costs and benefits of resilience. Accordingly, assets are often constructed to minimum requirements based on regulation and legislation, much of which is based on past experience rather than being forward looking. Decisions made now will affect future infrastructure resilience, but governments, regulators and business do not consistently include resilience when making infrastructure investment decisions, and there are often no requirements to do so.

For example:

- Many powerlines and timber poles are destroyed during bushfire events. In most cases these are replaced with more timber poles, susceptible to the next bushfire event. In Victoria, in the aftermath of Black Saturday the Powerline Replacement Fund program invested $200 million replacing bare wire powerlines with insulated overhead and underground power lines or new conductor technologies. The

program's focus was on preventing ignition, and an opportunity to consider the ability of the lines to withstand the next fire event was lost.

- Where timber bridges are washed out during flood events or burn during bushfires, in some cases limited funds may only extend to construction of a like-for-like replacement, rather than an alternative that is more costly in the short term but will withstand subsequent floods and fires. While there is some scope for states and territories to take a resilience approach this is a topic for the current review of Disaster Recovery Funding Arrangements.
- Where public buildings such as community halls are destroyed, there is an opportunity to build back better in a location and using materials that make them suitable as a future refuge or shelter from natural disaster.

Commonwealth Government policy requires that all transport infrastructure projects receiving over $100 million in funding from the Commonwealth Government consider resilience in their applications, by undergoing an independent assessment by Infrastructure Australia which provides for a long-term consideration of climate resilience[14]. There is some capacity for states and territories to seek assistance for building back better under the Disaster Recovery Funding Arrangements, but application for this is currently infrequent.

7.1. Infrastructure and community resilience

Infrastructure plays a critical role in making communities more resilient by helping them withstand and recover from disasters, for example the availability of internet and app-based warnings and situation reports provided through the telecommunication network informs the community and bolsters their ability to respond in a disaster situation. However, in the event of system failure, ABC radio may provide a more reliable and accessible mode of communication where it is available in vehicles. There is place for community education around how best to access disaster information.

The interdependent nature of networks which supply food, water, energy and communications mean failure in one or more networks can cause wide-ranging disruption to communities and businesses as outlined in the Profiling Australia's vulnerability report. Development of stand-alone systems such as off-grid solar by individuals, and systems where cells of the electricity grid can operate independently can help reduce the impact of highly interconnected critical infrastructure.

In 2019-20 in some areas being impacted by bushfires, like the southern coast of NSW, power, electricity and telephone reception were all interrupted. In the absence of warnings, and situational reports including regarding road closures, some people attempted to leave, which exposed them to further danger. They were unable to pump fuel where service stations did not have a backup generator and could not pay using EFTPOS. This highlights the need for business continuity planning, backup systems cross-sectoral thinking, early planning and identification of blackspots, and community involvement prior to shocks and stresses. As well as direct costs, such failures can cause indirect impacts like immediate economic consequences, long-term loss of business confidence and psychological distress as recognised by the $76 million government funding set aside for distress counselling and mental health support following the 2019-20 bushfires.

The concept of resilient infrastructure requires an understanding of current exposure and future scenarios in a changing environment. Internationally, requirements for a resilience approach to evaluation of crucial infrastructure occurred in the early 2000s, so Australia is lagging in this regard. Australia's infrastructure sector lacks clear, publicly available guidance on how to manage risk and plan for greater resilience in the future. Current guidance is outdated in some cases and does not reflect new dependencies and technologies such as the Internet of Things, blockchain and drones. Also, where they exist, many asset management plans do not reflect the whole-of-lifecycle benefits and costs of managing risks to balance appropriate levels of risk and cost. This can lead to inappropriate designs, specification and operating procedures.

[14] Infrastructure Australia Assessment Framework 2018

Mitigation provides multiple benefits – Launceston flood levees

A Geoscience Australia study investigated the impact of Launceston's flood levee mitigation works in terms of avoided costs from June 2016 floods in the short and longer term. The study, supported by the Bushfire and Natural Hazards CRC, investigated number of aspects relating to cost benefit analysis and funding models, and highlighted that the community benefits of these flood mitigation works were greater than could be assessed economically. When coupled with the observation that the economic viability of some mitigation works changed when considered from a broader perspective, the case study reinforces the need for holistic assessment of intangibles when applying Australia's frameworks for resilient infrastructure.

Australia's Climate Resilience and Adaptation strategy identifies that government, business, communities and individuals have complementary roles in managing climate risks. A key role for governments is to provide information to support choices which shift from current paradigms to a resilience approach. Resilient approaches may make planning and management more complex, partly due to fragmentation of decision making across Australia's three levels of governments and a range of Australian and international companies which own and operate infrastructure.

The Commonwealth Government and regulators set standards and delivery requirements for some critical infrastructure, but generally consider that owners and operators are best placed to manage risks and determine the most appropriate mitigation strategies. While intergovernmental work on critical infrastructure does occur, each State and Territory government have their own critical infrastructure programs that vary according to the environment and arrangements for each jurisdiction. The stress testing, scenario-based approach outlined in section 2 is already applied for major infrastructure in some cases and is relevant in this regard.

Internationally, principles and frameworks have been developed, for example the Words into Action series by UNDR. However, at a general level, the theoretical nature of resilience frameworks and the need for more practical guidance for decision making and infrastructure operation are recognised.

In the context of the built environment, disaster resilience covers the prevention, risk reduction and resilience to future events, ability to resist the impact of an event and ability to continue to operate and recover post event. State planning policies are beginning to incorporate the likely influence of climate change on future hazard into account and built environment regulation and legislation has evolved to take account of learnings from past events, and there is opportunity to improve in this space.

Vulnerability research including bushfire spread and loss prediction, flood mapping and coastal inundation scenarios can inform planning decisions about where to build. Consideration of where and how to rebuild post disaster is complex. It is informed by public and private risk appetites where the costs of increasing resilience are traded off against the level of risk reduction or residual risk that will be accepted. This trade-off is especially important for capital intensive and widely depended on assets such as critical infrastructure. The cost of building in high levels of resilience can be considerable. The insurance sector holds a wealth of data about loss and hazard which remains largely untapped in public sector decision making and this presents an opportunity.

Case Study – Planning for coastal retreat

The town of Southend's coastal assets, land and infrastructure are experiencing increased storm damage, erosion and inundation risk, which will be exacerbated by sea level rise and the need for a long-term strategic management approach has been recognised. The Southend Adaptation Strategy is a partnership project between the Wattle Range Council, the Local Government Association of South Australia and the Coast Protection. With the assistance of consultants, Council and members of the local community have reviewed the likely impacts of a range of scenarios, to express the changes they could live with, and the values they wanted to protect. Community participation in the process meant a greater level of understanding and acceptance that some difficult decisions would need to be made. Identified adaptation options generally fit into one of five categories, which range from retreat, accommodate, defend, defer or do nothing. The project now provides a 'template' demonstrating a best practice approach for other coastal councils and towns to follow.

There are examples where a resilience approach has been taken – like the rebuilding of Grantham in Queensland in a new location after the 2011 floods, the replacement of houses post-Black Saturday with designs to a revised construction standard. Retrospective upgrading of housing stock in the face of changing hazards is expensive and challenging but there are some examples, such as grants to upgrade existing dwelling to meet cyclone codes in Northern Queensland.

Case Study – Wye River 2015 Bushfire

In December 2015, 116 houses were lost during a bushfire in Wye River and Separation Creek townships on steep slopes adjacent to the Otway Ranges National Park. Post event surveys aimed to provide a better understanding of the mechanisms of house failure or house survival. This study found seven examples of houses built to the regulatory standards, which have been in place since 2010, that were impacted by fire. Of these seven houses, four were lost to fire and three survived. Although the number of buildings in this sample is small, it does suggest a higher survival rate than the 80% loss rate experienced in the region affected by fire.

Wye River and Separation Creek experienced a broad scale, low intensity surface fire spread through a combination of dried grasses and litter fuels. The main impact on houses was through ignition of heavy fuel elements adjacent to or under buildings, including adjacent houses, combustible decking and retaining walls, vehicles, stored equipment, plastic water tanks and firewood. Many buildings were not capable of withstanding the radiant heat or flame contact when heavy fuels ignited. This appears to be a key reason why such a large house loss rate was experienced despite low intensity fire spread within the township. The steep terrain and challenging access in the township meant risk to life of occupants forced to leave burning houses would have been high, and egress by foot or vehicle would be difficult. No clear areas for refuge were found within the fire-affected areas of the townships. Despite these difficulties, no lives were lost, which is testament to the timely warning given to occupants prior to the arrival of the fire.

There are a number of clear directions from which building, planning and community support initiatives can be improved to address hazards presented by township such as Wye River and for houses built in bushfire prone areas across the nation. Much of these identified shortcomings would be effectively identified with a detailed performance review of building regulations and their relationship with planning regulation in achieve efficient and effective life and property risk mitigation.

Post-event loss surveys as illustrated in the case study above have been conducted for fires in collaboration with state and territory government agencies. While this has been effective for large single-day fire loss events, long campaigns with significant losses as seen in 2019-20 may require a revised approach. Post-bushfire loss surveys could be streamlined and extended to a national basis to maximise lessons learned. They could also be expanded to incorporate citizen science collection of time-sensitive data and encourage deeper community involvement in infrastructure planning and decision making. Standing arrangements for deployment of pretrained personnel across jurisdictions with dedicated apps to support incident management teams, and complementary citizen science initiatives could deliver fire reconstruction and behaviour, post bushfire infrastructure impact studies, biodiversity impact and recovery studies, water quality impact and assessment and erosion extent and management.

Detailed onsite surveys combined with experimental material and systems testing and risk and vulnerability modelling provide a predictive or interpretive capability for bushfire-related urban design. Current standards for construction in bushfire prone areas focus on the family home in isolation. Research opportunities for system modelling of townships – integrating multiple dwellings and their associated infrastructure (water, phone, electricity, roads) would better inform local government decision making.

Cyclones – Retrofitting for resilience

In 2018, based on research conducted by James Cook University supported by the Bushfire and Natural Hazards CRC, the Queensland Government introduced its Household Resilience Program. This program provides grants for up to 75% of the cost of cyclone proofing homes built between Bundaberg and Cooktown before 1984, when the current cyclone building code was introduced in the aftermath of Cyclone Tracy. To date 1,749 Queensland households between Bundaberg and Cooktown have seen their insurance premiums reduced by an average of $310 due to improvements made under the program. In May 2020 a renewal of the program was announced as part of the Queensland Government's *Unite and Recover for Queensland Jobs* stimulus package designed to address the economic impact of the COVID-19 pandemic.

8. Conclusion

Australia's achievements by governments, the private sector and communities in increasing resilience to climate and disaster risk are to be commended. More information on the topics outlined in this Overview report, including examples, is available in a detailed supporting Technical Report. This study should be considered in conjunction with of other current relevant activities and reporting which will provide complementary commentary and insights to this work. There is an opportunity to take a harmonised national approach in the face of increasing climate variability and hazard exposure and drive a truly national response to further build the resilience of our infrastructure, our communities, our industries and our environment.

9. Supporting literature

9.1. Technical report chapters

More detailed and technical information about the topics covered in this overview report is included in the chapters of the supporting Climate and Disaster Resilience Technical Report.

Report	**Key authors and contributors**	**Topics covered**
Scope and Context	Russ Wise, Michael Grose	Disasters in a climate change context
Scenarios, models and early warning systems	Michael Grose, Andrew Sullivan, Dan Metcalfe	Predicting changes to weather and climate, and associated risks
Frameworks and harmonisation	Russ Wise	Challenges to mitigating risks and building resilience; potential benefits from harmonisation; progress to date and next steps
Empowering Indigenous leadership in cultural burning and natural disaster recovery and resilience measures	Cathy Robinson, Oliver Costello	Empowering Indigenous leadership; actions to support prevention, response and recovery
Hazard reduction efficacy, implementation and impacts	Andrew Sullivan	Bushfire fuels; prescribed burning; non-burning fuel reduction; efficacy of hazard reduction burning
First responses – knowledge systems, tools and platforms	Fabienne Reisen	Performance of knowledge systems and tools available to first responders – weather forecasts, mapping and monitoring tools, predictive models, resource management systems, situational awareness, communications, community messaging
Practical relief measures to build community-level resilience following a natural disaster	Cathy Robinson, Dan Metcalfe	Practical measures to support health and wellbeing in the aftermath of natural disasters; impacts on agriculture, tourism and SMEs; cultural and ecological impacts
Improving built environment resilience	Justin Leonard, Mark Burgess	Standard setting and regulation; overview of infrastructure threats; complexity of combined threats; forward looking approaches

9.2. Relevant key reports being delivered in parallel

The reports and activities outlined below consider some of the issues outlined in this.

Report/activity	Lead agency	Areas related to this report
Report of the Royal Commission into National Natural Disaster Arrangements, 2020	Office of the Royal Commission	Review of recommendations of previous reports and inquiries, and their implementation; community engagement to assess first and second-response effectiveness
National Bushfire Recovery Plan	National Bushfire Recovery Agency	National response to the 2019/20 bushfires
Australia's Health 2020	Australian Institute of Health and Welfare	Long-term impacts of natural disasters on mental health and chronic diseases
The Preliminary Report into the Appropriateness, Efficacy and Identified Gaps in the Government's Drought Response *and* 2019 Queensland Monsoon Trough. After the Flood: A Strategy for Long-Term Recovery	National Drought and North Queensland Flood Response and Recovery Agency	Responses to Drought and Flood
Policy Papers on Pandemic, Cyber and Natural Hazard Resilience	Infrastructure Australia and Infrastructure NSW	Work on infrastructure risk and resilience
Inquiry into the 2019-20 fire season	Victorian Inspector General for Emergency Management	Climate impacts on fire
Independent review (SA 2019/20 Bushfires)	South Australian Fire and Emergency Services Commission	2019/20 bushfire season with a focus on the Kangaroo Island and Cudlee Creek bushfires
Northern Australia Insurance Inquiry	Australian Competition and Consumer Commission	Insurability, enhanced resilience
NSW Bushfire Inquiry	NSW Government independent review	Causes of, preparation for and response to the 2019-20 bushfires in NSW
Australia's Health 2020	Australian Institute of Health and Welfare	Impact of disasters on health
Lessons to be learned in relation to the Australian bushfire season 2019-20	Senate Standing Committee on Finance and Public Administration	Preparation and planning for, response to and recovery efforts following the 2019-20 Australian bushfire season
Minister Andrews' Bushfire Science Roundtable	Department of Industry Science, Energy and Resources	
Wildlife and threatened species bushfire recovery expert panel	Office of the Threatened Species Commissioner, DAWE	

10. Acknowledgements

This Overview Report has been compiled from an underpinning Technical Report, the chapters of which were led by Peter Mayfield, Dan Metcalfe, Jenny Baxter, Michael Grose, Russ Wise, Andrew Sullivan, Cathy Robinson, Fabienne Reisen, Mark Burgess and Justin Leonard.

They were enormously assisted by Amy Warnick, Helen Cleugh, Russell Gorddard, Paul Box, Erin Bohensky, Carol Farbotko, Kirsten Maclean, Oliver Costello, Petina Pert, Ricky Archer, Joe Morrison, Kerry Collins, Liana Williams, Anne Seitzinger, Ben Creagh, Nick Kachel, Jo Ashley and Rachel Harm.

We gratefully acknowledge the following people who contributed data, insights or written contributions to case studies in this overview report or the technical reports that sit behind it: Jessica Benthuysen (AIMS), Dan Christie (JCU), Garry Cook (CSIRO), Simon Dunstall (CSIRO), Mark Edwards (GA), Cameron Fletcher (CSIRO), Robert Glasser (ASPI), Alex Held (CSIRO), Anu Kumar (CSIRO), Steve Martin (Powerlink), Louise Mendel (TAS Fire Service), Mick Meyer (CSIRO), Geoff Morgan (U Syd), Glenn Newnham (CSIRO), Jeff Perkins (BoM), Matt Plucinski (CSIRO), Mahesh Prakash (CSIRO), Suzanne Prober (CSIRO), Anna Richards (CSIRO), Stephen Roxburgh (CSIRO), Barry Sandison (AIHW), Jenny Styger (TAS PWS), David Westcott (CSIRO), Andre Zerger (CSIRO, Atlas of Living Australia).

We also acknowledge the advice and guidance of the Expert Advisory Panel chaired by Chief Scientist Dr Alan Finkel; Dr Karl Braganza, Mr Oliver Costello, Mr Stuart Ellis, Professor Jane Hall, Ms Romily Madew, Dr Andrew Stoeckel and Dr Katherine Woodthorpe. Office of the Chief Scientist staff including Sarah Brown, Isabelle Capomolla and Emma Wisdom provided invaluable support throughout this process.

We appreciate the contributions made by Members of the Australian Government Disaster Climate Resilience Reference Group and the representatives of the States and Territories as members of the Adaptation Working Group convened by the Department of Agriculture, Water and Environment, and of AFAC member organisations.

This Report has been reviewed by Dr Larry Marshall and Dr Cathy Foley for CSIRO. Numerous others have kindly given their time and insights to support the development of various parts of this Report and the technical reports that underpin it.

Our discussions were conducted under the conditions imposed by CSIRO's Social and Interdisciplinary Science Human Research Ethics Committee (029/20).

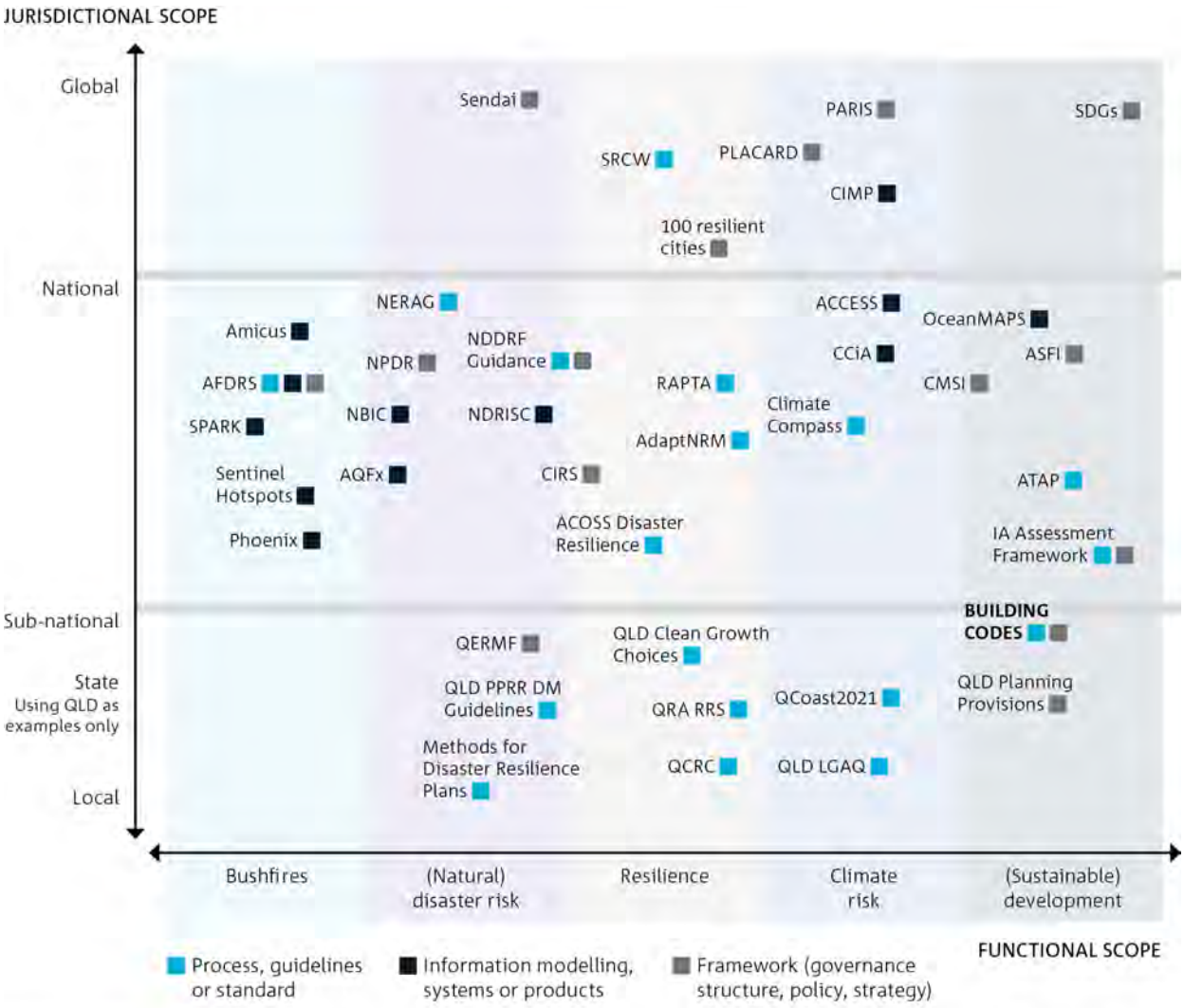
10.1. Stakeholder meetings

Various topic-specific meetings and interactions informed the development of chapters of the Technical Report on Climate and Disaster Resilience. Key meetings which informed the development of this report included:

Organisation	**Participants**
Australasian Fire and Emergency Service Authorities Council	Stuart Ellis, Noreen Krusel, Richard Alder, Amanda Leck, Paul Considine, Greg Esnouf, Simon Heemstra
Australian Capital Territory Government	Minister Mick Gentleman, Alicia Turner, Ian Walker
Australian Competition & Consumer Commission	Derrick Calder, Nick O'Kane, Dimitra Dimitropoulos, Luke Adams, Winnie Cheung, Scott Xu
Australian Institute for Health and Wellbeing	Barry Sandison
Australian Sustainable Finance Initiative & Insurance Australia Group	Ramana James, Shauna Coffey
Bureau of Meteorology	Peter Stone, Shoni Maguire, Karl Braganza, Jeff Perkins, Kevin Parkyn

Organisation	Participants
Bushfire and Natural Hazards Cooperative Research Centre	Richard Thornton, John Bates, Katherine Woodthorpe
Commonwealth Department of Agriculture, Water and the Environment	Matt Cahill, Beth Brunoro, Nick Post, Joanna Irving, Felix Bowman-Derrick, Sally Box and others
Commonwealth Department of Home Affairs – Emergency Management	Rob Cameron, Michael Crawford
Commonwealth Department of Infrastructure, Transport, Regional Development and Communications	Gayle Milnes, Rithy Lim
Commonwealth Department of the Prime Minister and Cabinet	Helen Wilson, Roland Trease, Sally Kuschel and others
Fire and Rescue NSW	Mark Whybro
Firesticks Alliance Virtual Fire Circle	47 Indigenous and non-Indigenous fire practitioners engaged in cultural burning practices and partnerships
Forum of Australian Chief Scientists	Paul Bertsch, Amanda Caples, Stan Corrigan, Hugh Durrant-Whyte, Peter Klinken, Caroline McMillen, Martin Redhead
Geoscience Australia	Leesa Carson, Mark Edwards
Infrastructure Australia	Romily Madew, Rory Butler
National Bushfire Recovery Agency	Andrew Colvin, Ilse Kiessling, Nicole Spencer; Janelle Walker facilitated our inclusion in community forums
National Drought and North Queensland Flood Agency	Paul McNamara, Hannah Wandel, Kate Woodbridge, Nico Padovan
New South Wales Government	Dom Bondar, Fatima Abbas
New South Wales Rural Fire Service	Shane Fitzsimmons, Rob Rogers, Laurence McCoy
Northern Territory Government	Minister Eva Lawler, Gerard Redmond, Joanne Townsend, Karen Avery
Queensland Government	Minister Leeanne Enoch, Jamie Merrick, Karen Hussey
Queensland Government Department of Environment and Science	Mark Jacobs, Manda Page, Leigh Harris, Bill McDonald (retd.)
South Australian Government	Premier Stephen Marshall and Courtney Morcombe
South Australian Department for Environment and Water	Mike Wouters
Tasmanian Government	Premier Peter Gutwein, Andrew Finch, Craig Limkin, Perry Jackson
Tasmanian Police	Ricki Eaves
Tasmania Fire Service	Bruce Byatt
Victorian Government	Minister Lily D'Ambrosio, Tim Sonnreich, Dean Rizzetti, Mark Kettle, Kylie White, Christine Ferguson.
Western Australian Government	Minister Francis Logan, Darren Klemm and others
Western Australian Department of Biodiversity, Conservation and Attractions	Margaret Byrne, Lachie McCaw, Stefan de Haan
Western Australian Department of Fire and Emergency Services	Jon Broomhall, Danny Mosconi

Appendix 1 Map of processes, systems and frameworks in Queensland as an example



100 resilient cities – a global network of cities working to improve their resilience

CIMP – Coupled Model Inter-comparison Project

PARIS – Paris climate agreement

PLACARD – EU PLAtform for Climate Adaptation and Risk reduction

SDGs – Sustainable Development Goals

Sendai framework for disaster risk reduction

SRCW – Stockholm Resilience Centre Wayfinder

National

ACCESS – Australian Community Climate and Earth System Simulator

ACOSS Disaster Resilience – 6 Steps to Disaster Resilience

AdaptNRM – The NRM Adaptation Checklist

AFDRS – Australian Fire Danger Rating Scheme

Amicus (Sullivan et al. 2013, Plucinski et al. 2017), a decision support software developed by CSIRO

AQFx – the air quality forecasting system

ASFI – Australian Sustainable Finance Initiative

ATAP – The Australian Transport Assessment and Planning (ATAP) Guidelines

CCiA – Climate Change in Australia

CISN – Critical Infrastructure Resilience Strategy

Climate Compass

CMSI – Climate Measurement Standards Initiative

IA Assessment Framework – Infrastructure Australia Assessment Framework

NBIC – National Bushfire Intelligence Capability

NDRISC – National Disaster Risk Information and Services Capability

NDRRF – National Disaster Risk Reduction Framework (NDRRF) Guidance

NERAG – National Emergency Risk Assessment Guidelines

NPDR – National Principles for Disaster Recovery

OceanMAPS – ocean prediction system, developed jointly by CSIRO and the BoM

Phoenix

RAPTA – CSIRO Resilience, Adaptation Pathways and Transformation Approach ver 2 Guidelines

Sentinel Hotspots

SPARK

State

Methods for disaster resilience plans at local level

QCoast2021 – Minimum standards and guideline for Qld Local Govts

QCRC – Queensland Climate Resilient Councils Program

QERMF – Queensland Emergency Risk Management Framework

QLD Clean Growth Choices – Transition strategy, regional plans

QLD LGAQ – Adapting to Climate Change: A Qld Local Govt Guide 2007

QLD Planning Provisions – Queensland Planning Provisions

QLD PPRR DM Guidelines – Queensland Prevention, Preparedness, Response and Recovery Disaster Management

QRA RRS – Queensland Recovery Agency Regional Resilience Strategies

Appendix 2 Terms of Reference

CSIRO Report on Climate and Disaster Resilience

Australia's climate is changing. The science tells us the effects of emissions already in the atmosphere will continue to be felt in coming decades, even under the most ambitious global emissions reduction scenarios.

This will require Australia to build our ability to resist, absorb, accommodate, recover and transform in the face of our changing climate, including the effects of longer, hotter, drier summers, coupled with changes to the frequency and severity of cyclones and floods.

Climate and disaster resilience is the collective responsibility of all sectors of society, including all levels of government, business, the non-government sector and individuals, with the Commonwealth playing an important leadership role.

This will require the Australian community to engage with issues including how we manage native vegetation, design public infrastructure, allow asset protection zones on private property, where we allow structures to be built, the materials used and standards to which they are built, and how we manage seasonal and structural risk reduction activities, such as hazard reduction burning and construction of flood levees.

To support these efforts and ensure they are informed by science, the Prime Minister has asked the Commonwealth Scientific and Industrial Research Organisation (CSIRO) to report on practical measures for Australian governments to improve Australia's climate and disaster resilience. CSIRO will work in close partnership with the Chief Scientist, Dr Alan Finkel, who will chair an expert advisory panel.

Timeframes and deliverables:
CSIRO will provide a report to the Prime Minister on practical options for Australian governments to support and improve Australia's climate and disaster resilience through the following key deliverables:

Early March 2020:
A preliminary report, for consideration at the Council of Australian Governments (COAG) March meeting, with

- explanation of the key scientific issues for Australia's climate and disaster resilience;
- detail on strengths and gaps in Australia's preparedness and comparison with international counterparts;
- options to be considered in advance of the 2020-21 bushfire season; and
- identification of practical resilience measures that warrant further investigation.

30 June 2020:

- A final report with implementable recommendations on building Australia's climate and disaster resilience in the immediate and long-term.

Scope of the Review
The report will identify practical measures to build climate and disaster resilience at local, regional and national scales, including:

a. Measures for Commonwealth, state and local governments as well as business, not-for-profits and the community, including
   i. short term measures that can be implemented ahead of the 2020-21 bushfire season, and
   ii. medium and longer-term measures for broader climate and disaster resilience.

Areas to be considered will include, but not be limited to:

b. Integrating climate and disaster resilience considerations into land use and infrastructure planning, zoning and development approvals, construction, environmental management, and agricultural practices;
c. Capability of governments and government agencies, including emergency services, to target threat warnings and public safety communications;
d. Strengthening hazard modelling and weather satellite data through improved prediction models and data collection;
e. Protecting Australia's unique natural assets;
f. A strategic and scientific approach to hazard reduction burning and vegetation management incorporating traditional indigenous knowledge and management; and
g. Improved use of science and technology, including for early detection and management, and situation reporting to support responses to natural disasters by Australian governments, volunteer organisations and the community.
h. The review should build on the Government's National Climate Resilience and Adaptation Strategy, Climate Science Strategy and the National Disaster Risk Reduction Framework and synthesise past scientific work where appropriate, but not duplicate existing work such as the National Environmental Science Program.

The report will have regard to:

a. Evidence on best practice and cost effective approaches, including internationally;
b. Current and already completed work on climate and disaster resilience and adaptation, including state and territory-based resilience and adaptation initiatives, inquiries to be delivered in early 2020, the 2015 Productivity Commission report on Natural Disaster Funding Arrangements, and the 2012 Productivity Commission report on Barriers to Effective Climate Adaptation;
c. Work being coordinated by the Government through the bushfire roundtables, including mapping of research and technology capabilities by the Office of the Chief Scientist;
d. The work of Commonwealth Ministers in delivering the Commonwealth's climate resilience initiatives; and
e. Likely global emissions scenarios under existing international emissions reductions frameworks.

Expert Advisory Panel:

CSIRO will work in close partnership with an Expert Advisory Panel (EAP) chaired by the Chief Scientist, Dr Alan Finkel. The EAP will include individual experts in areas such as climate, weather, bushfire and natural disaster science, emergency management, agriculture, environment, land use planning and construction, and government.

Stakeholder consultation:

CSIRO will undertake direct consultation with state and local government bodies, community and industry stakeholders during the second phase of the project.

Governance arrangements:

CSIRO will provide an independent report to the Prime Minister to underpin discussions in COAG on future actions.

The Australian Government Disaster and Climate Resilience Reference Group co-chaired at the Deputy Secretary level by the Department of Agriculture, Water and Environment and the Department of Home Affairs will provide a forum for CSIRO to update agencies on its work.

As Australia's national science agency and innovation catalyst, CSIRO is solving the greatest challenges through innovative science and technology.

CSIRO. Unlocking a better future for everyone.

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