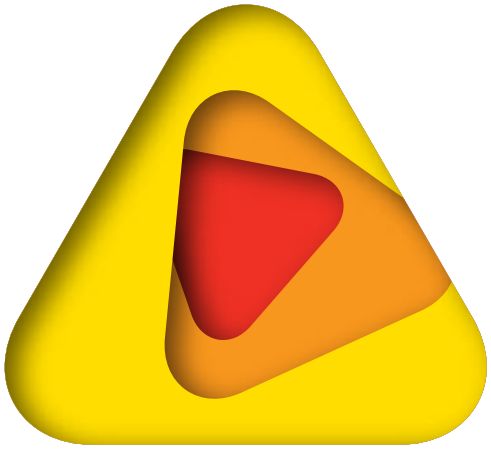

bushfire&natural
HAZARDSCRC

RESEARCH PROJECTS, ACHIEVEMENTS AND OUTCOMES

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THE RESEARCH CHALLENGE

In the last decade, we have seen natural disasters cause more damage and destruction across Australia and our neighbouring region than ever before.

Fire, flood, cyclone, earthquake, tsunami and heatwave cause injury, death and widespread damage.

Through these challenges we are reminded of the relevance of science and research. Now four years into an eight-year funding program, the research of the Bushfire and Natural Hazards CRC is delivering significant benefits to our partners and communities.

While we have learnt much, there is still more to do. A suite of new projects will enhance the broader program over the next four years.

In coming decades, our growing population will continue to undergo demographic changes, exposing vulnerable people to natural disasters. There will be significant pressure on government policy, particularly around risk communication, land-use planning and infrastructure development.

The policies and settlement patterns of the past are proving inadequate for the challenges of the future and in many instances are intensifying the exposure to risk.

There is no silver bullet for natural hazards safety. We must continue to ask the difficult and complex questions, and continue to identify what we do not know. That is the role of research, and the mission of the Bushfire and Natural Hazards CRC

– Dr Richard Thornton,
Chief Executive Officer
Bushfire and Natural Hazards CRC

A RESEARCH PROGRAM FOR BUSHFIRE AND NATURAL HAZARDS

The Bushfire and Natural Hazard CRC is conducting research to build a disaster-resilient Australia.

The centre draws together all of Australia and New Zealand's fire and emergency service authorities with the leading experts across a range of scientific fields to explore the causes, consequences and mitigation of natural disasters.

The CRC coordinates a national research effort in hazards, including bushfire, flood, storm, cyclone, earthquake, heatwave and tsunami.

From 2013, $47 million over eight years in Australian Government funds under the Cooperative Research Centres Program have been matched by support from state and territory government organisations, research institutions and NGOs.

The CRC is four years into its current program with much of the research now being used by partners around Australia and New Zealand. Several new research projects began in July 2017, building on this work.

Research partners include universities, the Bureau of Meteorology and Geoscience Australia, and several international research organisations.

The research program has developed under the direction of the researchers and end-user agencies. The research has three major themes covering 12 clusters of projects, most of which span a multi-hazard environment.

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PEOPLE AT THE CRC

GOVERNANCE

The Bushfire and Natural Hazards CRC is an incorporated not-for-profit public company limited by guarantee. It is managed through a central office co-located with the Australasian Fire and Emergency Service Authorities Council (AFAC) in Melbourne. It has a skills-based Board of Directors elected by its members. The Board is chaired by an independent Director, Dr Laurie Hammond. The Chief Executive Officer is Dr Richard Thornton.

Name	Organisation
Dr Laurie Hammond	Independent
Mr Stuart Ellis	AFAC
Ms Kathy Gramp	Independent
Mr Lee Johnson	Independent
Ms Katherine Jones	Commonwealth Attorney-General's Department
Commissioner Craig Lapsley	Emergency Management Victoria
Prof Alistar Robertson	Independent
Ms Naomi Stephens	Office of Environment and Heritage, NSW
Mr Karl Sullivan	Insurance Council of Australia
Mr Doug Smith	Queensland Fire and Emergency Services

Back row from left: Commissioner Craig Lapsley, Dr Richard Thornton, Prof Alistar Robertson, Mr Stuart Ellis, Mr Lee Johnson.

Front row from left: Ms Kathy Gramp, Ms Naomi Stephens, Dr Laurie Hammond, Ms Katherine Jones, Mr Karl Sullivan.

STAFF

Name	Position/Role
Dr Richard Thornton	Chief Executive Officer
Dr Michael Rumsewicz	Research Director
David Bruce	Communications Manager
Trevor Essex	Business Manager
Sarah Mizzi	Partnership Development Manager
Matthew Hayne	Research Utilisation Manager
Loriana Bethune	Utilisation and DEWLP Program Manager
Leanne Beattie	Executive Assistant
Desiree Beekharry	Projects Officer
Nathan Maddock	Senior Communications Officer
Vaia Smirneos	Communications Officer (Events)
David Boxshall	Research Program Support Officer

PARTICIPANTS

Government and agencies

Attorney-General's Department
Bureau of Meteorology
Department of Defence
Geoscience Australia
ACT Emergency Services Agency
ACT Parks and Conservation Service
Fire and Rescue NSW
NSW Rural Fire Service
NSW State Emergency Service
Office of Environment and Heritage, NSW
Northern Territory Government
Bushfires NT
NT Fire and Rescue Service
Inspector-General Emergency Management, QLD
Queensland Fire and Emergency Services
South Australian Government
Country Fire Service, SA
Department of Communities and Social Inclusion, SA
Department of Environment, Water and Natural Resources, SA
Department of Planning, Transport and Infrastructure, SA
Metropolitan Fire Service
SA Fire and Emergency Service Commission
SA State Emergency Service
Tasmanian Government
Department of Primary Industries, Parks, Water and Environment, TAS
Tasmania Fire Service
Tasmania State Emergency Service
Country Fire Authority, VIC
Department of Environment, Land, Water and Planning, VIC
Emergency Management Victoria
Inspector-General for Emergency Management, VIC
Metropolitan Fire and Emergency Services Board, VIC
Victoria State Emergency Service
Department of Fire and Emergency Services, WA
Department of Parks and Wildlife, WA
Office of Emergency Management, WA
Western Australian Land Information Authority (Landgate)
Fire and Emergency New Zealand

Academic and research

Australian National University
Charles Darwin University
CQUniversity
Deakin University
Flinders University
James Cook University
Massey University
Macquarie University
Monash University
Queensland University of Technology
RMIT University
University of Adelaide
University of Canberra
University of Melbourne
University of New England
University of New South Wales
University of Southern Queensland
University of Sydney
University of Tasmania
University of Western Australia
University of Wollongong
Victoria University
Western Sydney University

Associations

Australian Road Research Board
Australasian Fire and Emergency Service Authorities Council
Australian Red Cross
Council of Australian Volunteer Fire Associations Ltd
Fire Protection Association Australia
RSPCA QLD
Volunteering Queensland

Collaborations

Asian Disaster Preparedness Centre
Australian Local Government Association
CSIRO
Department of Community Safety and Emergency Services, QLD
Department of Housing and Public Works, QLD
Department of Transport and Main Roads, QLD
DLR - German Aerospace Centre
Federation University
Integrated Research on Disaster Risk
Karlsruhe Institute of Technology, Germany
Lockyer Valley Regional Council
Los Alamos National Laboratory, United States
North Australian Indigenous Land and Sea Management Alliance
Queensland Reconstruction Authority
Roads and Maritime Services, NSW
Save the Children
Surf Lifesaving Australia
Swinburne University
United Nations University
University of Alberta, Canada
University of Canterbury, New Zealand
University of Gothenburg, Sweden
University of Queensland
University of Twente, Netherlands
VicRoads

ACHIEVEMENTS AND OUTCOMES

Over the first four years of the CRC, the ongoing development of the research program included extensive engagement with end-users, researchers and the broader community with a stake in natural hazards management.

Under the watch of a new International Science Advisory Panel, the research program was reviewed to identify and map the progress for utilisation opportunities and to develop new projects for the coming years. Major achievements and outcomes for the research program so far include:

- **Multi-hazard mitigation planning** - to support decision making on mitigation activities for bushfire, flood, earthquake and heatwave, applied to a South Australian case study, with additional hazards and objectives being explored in Victorian and Tasmanian case studies already underway.
- **Emergency warnings** - focus group research and social media analysis examining community comprehension of messages that has led to recommendations to improve phrasing and content of warnings.
- **Advancing the science and development of a National Fire Danger Rating System** – leading the development of requirements of a new National Fire Danger Rating System under the National Emergency Management Projects Program, and improving the science of key components such as estimating soil and fuel moisture, fuel load, and fire behaviour.
- **Australian Flammability Monitoring System** – a pre-operational prediction system of live fuel moisture content and flammability across Australia.
- **Fuel load estimation techniques** - developed and tested a beta smartphone application to allow the rapid and quantitative characterisation of the 3D structure of fuels of fire prone environments.
- **Disaster resilience for schools** - to provide emergency management agencies with a strategic, evidence-based approach for school programs that reduce risk and increase resilience.
- **Bushfire education kit** - 'Guide to Working with School Communities', a New South Wales Rural Fire Service schools kit based on research to help children understand bushfire preparation and safety.
- **Tsunami warning** - national program reviewed for the Australian Tsunami Advisory Group of the Australia–New Zealand Emergency Management Committee (ANZEMC).
- **Non-traditional volunteers** - identified key changes and impacts on the recruitment and engagement of volunteers by emergency organisations and contributing to the development of the Australian Spontaneous Volunteering Handbook
- **Flood fatalities** - findings on the nature of flood fatalities have significantly contributed to the Prevention of Flood Related Fatalities Working Group of the Community Engagement Sub-committee of the Australia-New Zealand Emergency Management Committee with their investigations into preventing flood fatalities. The NSW State Emergency Service and Queensland Fire and Emergency Services have used this research to inform their community campaigns and training.

COLLABORATIONS

National research agenda

A document on national research priorities for natural hazards emergency management was developed from a series of workshops conducted with end-user stakeholders to explore major issues across hazards, resilience and the community. The workshops identified the critical issues that could addressed by research.

National institute

The 2015 launch of the Australian Institute for Disaster Resilience commenced a partnership between the CRC, AFAC, the Australian Red Cross and the Attorney-General's Department. The new Institute was formed to deliver products and services around Australia that have been developed by, and for, the emergency management sector. The CRC has taken a lead role in the Institute's *Australian Journal of Emergency Management*.

Annual conference

The CRC and AFAC co-host an annual conference in a capital city each September, along with the partner organisations from that state. The CRC is prominent throughout the conference and in particular at the opening day Research Forum, which has attracted as many as 460 participants. The full conference attracts up to 2000 people and the CRC has a prominent display in the exhibition hall.

Research Advisory Forum

Held in Queensland, New South Wales, the ACT, Victoria, Tasmania, South Australia and Western Australia over the last four years, these two-day events take place twice a year, providing the opportunity for CRC partners, project leaders and end-users to gain a complete overview of all the research activities within the CRC and participate in workshops to shape project research and utilisation directions

International Science Advisory Panel

Established to provide independent strategic oversight of the research program and to ensure the research is of high quality.

United Nations International Strategy for Disaster Reduction

The CRC is the national coordinator for a United Nations-backed committee that promotes and supports disaster risk reduction research. The Integrated Research on Disaster Risk (IRDR) National Committee for Australia is sponsored by the United Nations International Strategy for Disaster Reduction, the International Council for Science and the International Social Science Council.

International research

Natural hazards research findings are exchanged between Australia and New Zealand under an agreement signed between the CRC and the New Zealand Natural Hazards Research Platform.

The CRC also has Memoranda of Understanding with the US Forest Service and Association for the Development of the Industrial Aerodynamics (ADAI, Portugal),

Southern and Northern Australia Fire Managers forums

These forums include participation from AFAC, the Bureau of Meteorology, many universities and all fire and land management agencies to discuss issues of local and national relevance. The national Bushfire Seasonal Outlooks are formulated and released in conjunction with these forums. These Outlooks are used by fire and emergency service agencies to work with state and federal governments to prepare resources for the bushfire season.

Disaster management

The CRC is a key partner in the annual Australian and New Zealand Disaster and Emergency Management conference in Queensland, the Emergency Management Conference in Victoria, and the biannual Australasian Natural Hazards Management conference. It takes a prominent role in the Emergency Media and Public Affairs conference, the Floodplain Management Australia conference, and several international conferences, plus many rural fire and emergency service regional conferences in NSW, Queensland, South Australia, Western Australia, Tasmania and Victoria.

Consultancies

The CRC entered into a number of consultancies, mainly with its existing end-user partners.

Submissions

The CRC regularly provides expert submissions to natural hazard inquires. Examples include the Natural Disaster Funding Productivity Commission (2015), the Inspector-General for Emergency Management Victoria review of performance targets for bushfire fuel management on public land (2015), the Senate inquiry into the Tasmanian World Heritage area bushfires in (2016) and the Victorian Legislative Council inquiry into fire season preparedness (2016).

FURTHER RESEARCH

The CRC conducts research in addition to the science funded through the Cooperative Research Centres Program. This complementary research is undertaken through consultancies and various extra programs.

Commissioned research

The CRC conducts research on a consultancy basis, mainly with its existing partners.

The Victorian Department of Environment, Land, Water and Planning further extended its contract research program that began with the Bushfire CRC, across several projects on fire behaviour and fuels, planned burning, bushfire smoke dispersal and remote sensing.

Post-event studies are highly valued by end-user partners, and are an effective way to gather important data after a major hazard. To date, community-focused research has been undertaken after major bushfires in New South Wales in 2013 and 2017, South Australia in 2014 and 2015, and Western Australia in 2014. Partners benefiting from this research are the NSW Rural Fire Service, Country Fire Service South Australia and the Department of Fire and Emergency Services Western Australia.

Fire and Rescue NSW also received additional insight into the effectiveness of equipment and training provided to their Community Fire Units during the Blue Mountains bushfires in 2013.

The Queensland Fire and Emergency Services sought out the CRC to provide advice on how 2015's Severe Tropical Cyclone *Marcia* would impact vegetation for the following fire season and beyond. More recently, QFES asked the CRC to lead an effective review of incident management activities after Severe Tropical Cyclone *Debbie* in 2017. It is envisaged that this research could informed future operations and policy.

The Office of Bushfire Risk Management on behalf of State Emergency Management Committee (now Office of Emergency Management) for Western Australia requested a review into the Lower Hotham Block and O'Sullivan Block fires.

The CRC has been engaged to review emergency management traffic management policy in WA for the Office of Emergency Management.

Tactical Research Fund

This fund began in 2017 to encourage the development of short duration research projects meeting near term needs of end-user partners. These short-term fund projects address strategic issues of national significance.

Research is being undertaken on how to improve the Australian Incident Reporting System, preventing residential fire fatalities, synthesising recommendations from natural hazard inquires and reviews, assessing community resilience and firefighting foam.

End-user partners benefiting from this work include AFAC, Melbourne's Metropolitan Fire Brigade and Emergency Management Victoria.

Quick Response Fund

Established in 2016 to provide support for researchers to travel to areas affected by natural disasters, this fund provides an additional means to ensure that the impacts and perishable data are captured in a timely manner. This can help to identify significant research questions arising from major natural hazards and provide a context for developing more extensive research proposals.

The impact of a bushfire on destabilisation of coastal sand dunes near Esperance in Western Australia and how the June 2016 East Coast Low affected the homeless have been investigated through the Quick Response Fund, with reports available on the CRC website.

Photo: Bushfire and Natural Hazards CRC

EDUCATION

A key goal of the CRC is to build the capacity and capability of the sector to undertake high quality research through highly skilled researchers. The CRC is building this capacity by developing a new cohort of researchers, offering an education program for postgraduate students working on natural hazards science.

The CRC funded 51 PhD scholarship students, and has a further 62 associate students, more than double its initial target of providing support to 34 PhD students for the life of the CRC. The CRC is on track to meeting the target of 28 student completions by June 2018, with 14 students already completing their PhD studies.

Both scholarship and associate students have the opportunity to engage with industry leaders and gain an understanding of the sector though their involvement with the CRC. Each scholarship recipient is required to have an end-user sponsor who has indicated the project has relevance to the industry and that their organisation is interested in the outcomes.

End-users also provide the opportunity for placements, where students are immersed in an organisation to gain an understanding of how research is used in an emergency management context.

Further support is also offered through a range of events centred on learning and networks. The annual conference and twice-yearly Research Advisory Forums and industry working groups (run by partner organisation AFAC) are key gatherings where students present their findings. Many students have also received support to present their research at international conferences.

Students are also trained in presentation skills to promote their research using the Three-Minute Thesis format. Their presentations are included in the programs at key industry forums and conferences.

Photo: Bushfire and Natural Hazards CRC

OUTREACH

A program of interactive and engaging events, publications and online activities for the natural hazards sector and for the research community, as well as the general public, is a key part of promoting the research of the CRC.

The chief benefit of promoting this research is the direct connection made with people interested in the outcomes of the research program, and to encourage them to get involved, be engaged, and follow the progress of the CRC.

The annual conference, held jointly with AFAC, attracts in excess of 2000 people from the emergency services sector and research organisations, and increasingly, from fields including government, fire protection, health, and utilities. The week of activities includes presentations, professional development sessions and field tours around a multi-hazard theme.

Research is featured in the quarterly magazine, *Fire Australia*, and in regular research briefing papers, *Hazard Notes*, and promoted to communities across Australia and internationally through the media, online media and industry publications.

The CRC plays a leading role in the *Australian Journal of Emergency Management*, through the Australian Institute for Disaster Resilience.

For the media, CRC research is highly topical and relevant across hazards such as bushfires, heatwaves, floods, storms, earthquakes and cyclones. With experts across all of these areas, the CRC is well positioned to provide expert media comment that supports agency partners.

Peak times centre around the CRC's Seasonal Bushfire Outlooks for southern and northern Australia, the Research Forum and annual conference, and major hazard events such as bushfires, floods and cyclones over the summer months.

Social media is a key communications tool, with Facebook, Twitter, YouTube, Linked In and SoundCloud used regularly to engage with the community. An active engagement strategy has seen both the popularity and interactivity of these channels increase. Collaborating closely with our partners has seen the reach of CRC posts on social media extend considerably.

POLICY AND ECONOMICS OF HAZARDS

This theme deals with economics and the interface between risk-based priorities and the practice of decisions to allocate resources where the potential for some of the greatest tangible benefits can be made.

GOVERNANCE AND INSTITUTIONAL KNOWLEDGE

Lead End-User: John Schauble, Emergency Management Victoria

Research Leader: Prof Stephen Dovers, The Australian National University

Policies, institutions and governance of natural hazards

Lead Research Organisation: The Australian National University

Project Leader: Associate Prof Michael Eburn

Building community resilience to natural disasters is a complex challenge that spans many policy areas. This project, which has transitioned to its utilisation phase, tackled this intricate problem by delivering policy options that could help governments and emergency services to strengthen resilience in communities. The research identified barriers to community resilience and potential policy solutions that could be factored into the preparation, response and post-event phases of emergency management.

Three research themes were covered:

1. What is 'community' and how can governments share responsibility with both communities and individuals?
2. How can insurers play a more active role in communicating risk and encouraging hazard mitigation?
3. Is there a better process or institution for effective lesson sharing after natural hazard events?

Findings revealed significant tensions in the shared responsibilities between governments exercising power and community empowerment; between the conflicting needs of insurers and their clients; and within traditional models of post-disaster inquiries.

In regards to effectively sharing lessons after an event, the team has proposed the trialling of restorative practices as a powerful alternative to adversarial post-event inquiries.

Having identified these inherent tensions across the three themes, the researchers propose new policies are needed that could resolve or ease the tensions identified, or, in the case of disaster insurance, highlight the need to develop better models.

This could be applied in various contexts, including the selection of appropriate policy choices to encourage communities to share responsibility for emergency management with government. It could also help agencies to be better informed about how policy options can be tailored to encourage or facilitate desired outcomes.

Australia could trial restorative practices for post-disaster events by starting locally, such as for internal inquiries into accidents and near misses. If the system is effective and fosters learning without harm, then the practice could be applied to larger inquiries involving the emergency agencies and broader community interests.

While active research has concluded, further outputs are expected, including a book on disaster justice and promotion of the concept of restorative practices in post-disaster inquiries.

End-user says...

John Schauble, Director Emergency Management Resilience, Emergency Management Victoria

> Creating sound emergency management policy in government remains an iterative process in all Australian jurisdictions. This project has demonstrated that translating public policy into readily identifiable and measurable community resilience outcomes presents a range of challenges. Among the tools that contribute to resilience are those driven by the private sector, such as insurance, and the inquisitorial processes employed post-event. This research has underlined some misconceptions, such as the minor extent to which insurance loss from bushfire is significant in an actuarial sense, while pointing to the problems of implementing highly theoretical approaches on the ground in local communities. The findings in relation to the restorative justice approach is indicative of a need for further innovation and research in this context.


Photo: Keith Pakenham, CFA

Scientific diversity, scientific uncertainty and risk mitigation policy and planning

Lead Research Organisation: Western Sydney University

Project Leader: Dr Jessica Weir

There is a significant knowledge deficit concerning how science and other forms of knowledge are used and integrated into emergency management policy and practice, leading to incorrect and counter-productive misunderstandings. The emphasis on the value of scientific knowledge within the natural hazards sector – and particularly in regards to risk mitigation – is legitimate. However, to this point, this valuing of science has not been accompanied by research into the actual opportunities and challenges of using science in policy and practice.

Science is a diverse world of knowledge and as such, it is ripe for debate, whether by scientists, politicians, policymakers or others. The fact that the research process is open-ended, in which uncertainties can often be reduced but not resolved, means there are often abundant reasons to delay decisions about how to proceed.

There are many obstacles to integrating science within government agencies, not the least of

which are resource constraints. Other factors of institutional culture also influence how, and if, new research is utilised.

Without greater insight into how science and other forms of knowledge are used and integrated into sector policy and practice, the ability of policymakers and practitioners to explain risk mitigation and translate its scientific basis is compromised. The sector is also vulnerable to the perpetuation of received ideas and myths about science, its use and its utility.

This project, which has transitioned to its utilisation phase, has produced a number of journal articles documenting issues related to scientific uncertainty in bushfire and flood risk mitigation.

Case studies were undertaken in the Otway region of Victoria, and greater Darwin in the Northern Territory, both around bushfire and mitigation. A third case study explored flood risk in the Hawkesbury-Nepean Valley in New South Wales.

It is clear that scientific research, whether in a laboratory or a landscape, is never simply technical. The ways in which decision-makers and practitioners integrate and utilise science is a thoroughly social question, shaped by the capacities and affordances of the contexts in which they operate. While it is important to continue to place a high value on scientific research in the natural hazards sector, it is also important to remember that this research is embedded in social dynamics and social networks.

End-user says...

John Schauble, Emergency Management Victoria

> The increasing demand for evidence-based formulation of public policy is placing a higher than ever premium on the need to translate scientific knowledge into common understandings.
>
> Developing a common language between risk professionals, policy makers and the broader community will be a significant step towards managing differing opinions and uncertainties in relation to natural hazards.

ECONOMICS AND STRATEGIC DECISIONS

Lead End-User: Ed Pikusa, Department of Environment, Water and Natural Resources, South Australia

Research Leader: Prof Holger Maier, University of Adelaide

Decision support system for optimal natural hazard mitigation

Lead Research Organisation: University of Adelaide

Project Leader: Prof Holger Maier

What if an earthquake hit central Adelaide? A major flood on the Yarra River through Melbourne? A bushfire on the slopes of Mount Wellington over Hobart?

'What if?' scenario modelling through this project is helping government, planning authorities and emergency service agencies think through the costs and consequences of various options on preparing for major disasters on their infrastructure and natural environments and how these might change into the future.

The research is based on the premise that to reduce both the risk and cost of natural disasters, an integrated approach is needed to consider multiple hazards and a range of mitigation options.

A case study for Adelaide and surrounding regions is now complete, while case studies for Melbourne and surrounding regions, along with Tasmania, are well developed. An additional case study in Western Australia is in the process of being scoped out.

Taking into account future changes in demographics, land use, economics and climate, the modelling will be able to analyse areas of risk both now and into the future, test risk reduction options, identify mitigation portfolios that provide the best outcomes for a given budget, and consider single or multiple types of risk reduction options, such as land use planning, structural measures and community education.

The results for greater Adelaide highlighted the variability in regional risk based on variability of the drivers into the future. They also showed the importance of effective planning of new regional developments to ensure a safer future. It is hoped that more integration of this scenario work can build strategic capacity across agencies in the understanding of future risk

CRC partners, along with local governments, have been engaged in the entire process, from direction on the hazards to include and feedback on process, to advice on how the modelling will be used when complete and by whom.

The approach taken through this project is the only study that compares different natural hazards and their mitigation options, while also taking into account long term planning. The ultimate aim is to

develop a decision support framework and software system that is sufficiently flexible to be applied to large and small cities around Australia, helping planners from local councils through to state treasury departments answer the vital question on mitigation options that balance cost and impact: 'what is the best option for us?' Training materials will be developed, along with courses for end-users to enable ongoing use of the system.

This project is an outstanding example of the collaborative process that the CRC is all about, and incorporates findings from other CRC work on recognising non-financial benefits of management and policy for natural hazards, for example, the economic, social and environmental benefits of prescribed burning, the vulnerability of buildings to hazards, such as how they can be made more resilient through cost-effective retro-fitting for improved safety, and the benefits and understanding of community resilience efforts like improved warnings, community engagement, education, volunteering and community resilience.

End-user says...

Ed Pikusa, Manager Policy and Reporting – Fire & Flood Management Unit, Department of Environment, Water and Natural Resources South Australia

"All emergency management practitioners and land managers across Australia make choices in an effort to minimise losses from natural disasters.

They ask questions like 'what are the benefits and costs of mitigation options?', 'how do we quantify many of the intangibles?' and 'who owns the risk?'

In a multi-stakeholder environment this is complicated, and it is hoped tools such those developed through this research will help agencies answer these important questions, leading to better decisions in mitigating future natural hazards."

Mapping and understanding bushfire and natural hazard vulnerability and risks at the institutional scale

Lead Research Organisation: Victoria University

Project leader: Prof Roger Jones

Current government spending on natural disaster response is more than 20 times the spending on preparedness. Many climate-related natural hazards are increasing, along with the number of people living in hazard-prone areas. Large natural disasters also cross domains, moving from the private to the public realm, and shifting from a local, to a state or national concern. This raises the potential of future, unmanaged risks.

The spending mismatch is well understood, but potential deficits in important social and environmental values are also faced that may not be adequately compensated. If a risk is owned, then the balance between preparedness and response can be assessed. If the risk is un-owned, these values may be damaged and degraded, or lost.

The project, now in its utilisation phase, mapped a broad range of economic, social and environmental values and related them to natural hazards across several case studies. It explored who owns these values and what happens when they cross domains, as well as how a range of alternative strategies may contribute to improved resilience by sustaining economic, social and environmental values in a changing environment.

Three decision making areas were identified where risk ownership can be assessed as part of strategic decision making.

- **Risk ownership was found to show an imbalance between the public and private sectors, which is potentially unsustainable.** In particular, allocation for state and local government was considerably higher for risk and consequences and risk actions than was for the ownership of values at risk.
- **Coordination between contributing agencies and agendas is needed to clarify ownership and support more effective management of activities and use of resources.** Risk ownership in areas contributing to resilience and risk reduction were found across multiple agencies and agendas. This was particularly the case in agencies who work with regional and community development and climate change adaptation. Coordination between contributing agencies and agendas is needed to clarify ownership and support more effective allocation and use of resources.
- **Risk ownership relevant to strategic decision making is ill-defined, particularly for longer term activities focusing on recovery and resilience building.** No long-term (two or more years) policy, plans or strategies for environmental or social recovery to natural hazards were found.
- **Knowledge gaps were found across long-term strategic horizons (two or more years)** in relation

to mapping and identifying ownership of risks and consequences, and resilience and recovery activities – particularly for flood and heatwave hazards, and for social and environmental values.

To assist decision-makers, emergency managers and planners, the team developed a governance framework to support better understanding of risk ownership. The next stage of utilisation will involve training for practitioners on the best way to use the framework for their needs.

Achieving effective risk ownership requires a common understanding of how risks are changing and consensus and acceptance around who owns these risks and how they own them. This research goes beyond simple linear approaches, to a more adaptive and flexible approach focused on what values are identified as most important by risk owners.

End-user says...

Greg Christopher, Emergency Management Victoria

> The mapping of hazard data combined with a range of social and economic measures will provide useful information for prioritising more detailed analyses, leading to enhancing mitigation controls. The outputs of this activity have the potential to inform the efficient allocation of resources for mitigation, therefore enhancing resilience.

Economics of natural hazards

Lead Research Organisation: University of Western Australia

Project Leaders: Associate Prof Atakelty Hailu and Dr Veronique Florec

The 2015 Productivity Commission's report on natural disaster funding arrangements in Australia found that governments overinvest in post-disaster reconstruction and underinvest in mitigation activities that would limit the impact of natural disasters. Given the multitude of natural hazards that require mitigation and response from government agencies and the tighter budgets at both state and national levels, natural hazards managers are increasingly under pressure to justify the use and allocation of resources for mitigation efforts.

Governments need to ensure that the benefits justify the cost and that they are getting the best value for money out of these investments. However, most existing government decisions are not informed by formal analyses examining the value for money of the alternatives. There are several reasons for this.

1. Economic analyses of natural hazard management options are rare for some hazards.

2. Many of the benefits of natural hazard management are intangible (or non-market), such as lives saved, health benefits, environmental benefits, and social values.
3. There is a general lack of information to carry out economic analyses.
4. Economic analysis of natural hazards can be complex, and there is a lack of economics capacity in the sector.

To date this study has addressed some of these issues by developing a tool for generating estimates of non-financial benefits (called the value tool) and undertaking integrated economic analysis of management options for floods in Adelaide and for prescribed burning in private land in South Australia's Mount Lofty Ranges.

The next stage will build on this work and create tools that will help emergency service and land management agencies conduct and utilise more rigorous economic analyses of management options and identify the options that generate the best value for money. These new tools, which consider both market and non-market (intangible) values, will help meet important end-user needs. The intangible values will include social, environmental and health related values so that decisions are made to maximise the benefits to society in the management of natural hazards.

Expected outcomes will be:

- An online platform for the value tool that will be updated and maintained after the study concludes so that end-users can easily integrate intangible values in their analyses.
- Fill major knowledge gaps identified in the literature on intangible values that are affected by the management of natural hazards.
- An economic analysis tool for the evaluation of the tangible and intangible costs/benefits of risk treatment options that enables end-users to evaluate and prioritise the treatment options that are likely to provide the best value for money.
- Training materials relating to the application of economics to the assessment of natural hazard management options.

Optimising post-disaster recovery interventions of Australia

Lead Research Organisation: Deakin University

Project Leader: Prof Mehmet Ulubasoglu

The economic impacts resulting from natural disasters are often overlooked in the economic planning process. This is because the immediate focus in the wake of natural hazards is typically placed on the emergency response, and it takes time to realise the economic effects of the disasters. In Australia, the disaster management arrangements across all stages (mitigation, preparedness, response and recovery) have proven to be very successful at saving lives, however, less attention and resources have been devoted to the economic impacts of natural disasters.

One of the problems identified in this setting is the lack of estimates of the full economic impact of natural hazards covering all the affected sectors of the economy. An ideal estimation should reflect both the primary and secondary effects of the natural disasters so that persistent losses throughout the economy originating from various sectors are taken into account.

The project team has conducted a case study on the 2010-2011 Queensland floods, which involved comparisons between the flooded areas and unaffected areas of 19 economic sectors. This involved comparing the economic conditions of individuals residing in flooded and non-flooded areas before and after the floods, and revealed the sectoral decomposition of income and employment differences reflected in household well-being because of the floods.

Findings indicate that individuals working in 12 of the 19 sectors experienced no income difference due to the floods. Three sectors (retail trade, accommodation and food services, administrative and support services) were negatively impacted, while two sectors, (education and training, and health care and social assistance) were positively impacted.

The main objective in the next stage of this research is to estimate the sector-disaggregated economic effects of the floods, the Black Saturday bushfires, and Cyclone Oswald (Queensland, January 2013) to support the decision-making process in the design of post-disaster recovery interventions.

Particular objectives are:

1. To estimate the sector-specific economic effects of Queensland floods and Cyclone Oswald on firms, and of the Black Saturday bushfires on individuals and firms;
2. To develop a ranked list of the economic sectors that seek more attention for post-disaster resource allocation in minimising potential negative effects of natural disasters;
3. To inform budget allocation decisions across economic sectors in both pre-disaster mitigation as well as post-disaster recovery phases.

This stage of the research will place the microscope on how the key variables change in the wake of disasters:

i) at the individual level, income, employment-type (full-time, part-time), status of employment, and the number of working hours, all investigated with respect to the social vulnerability status of individuals (i.e., gender, age, income-level),

ii) at the firm level, the volume of output, revenue, profit, and employment, again all examined with respect to the vulnerability status of firms, such as small vs large enterprises.

It is expected that the findings of this project will act as a catalyst in designing post-disaster recovery interventions at the federal and state level that will not only be customised to directly support individuals, but also be tailored in directly assisting firms to ensure their survival and keep their workforce employed.

End-user says...

Ed Pikusa, Manager Policy and Reporting – Fire & Flood Management Unit, Department of Environment, Water and Natural Resources South Australia

"This project is seeking to address the broader economic impacts of natural disasters. Insights from this analysis could be used to tailor investments in recovery to meet the needs of the most disadvantaged sectors of the economy."

Urban planning for natural hazard mitigation

Lead Research Organisation: University of Melbourne

Project leader: Prof Alan March

This new project commenced in July 2017, and aims to produce new and innovative ways of integrating urban planning and natural hazard risk management. It will increase the understanding of what planning and emergency management can and cannot do, separately and in synergy, and develop new approaches to applying tools and methods available to planning systems to the design and management of communities as they change.

A range of fundamental challenges exist to the integration of planning with natural hazard risk management and the potential to build resilient processes for natural hazard risk management into integrated urban planning.

SCENARIOS AND LOSS ANALYSIS

Lead End-User: Corey Shackleton, NSW Rural Fire Service

Research Leader: Dr Katharine Haynes, Macquarie University

An analysis of building losses and human fatalities from natural disasters

Lead Research Organisation: Macquarie University

Project Leader: Dr Katharine Haynes

This study has informed community flood warning campaigns, emergency services training and national policy initiatives by investigating the circumstances of all flood fatalities in Australia from 1900 to 2015. It has also compare the impacts of disasters from more than 100 years ago with more recent events.

By exploring the socio-demographic and environmental factors surrounding the 1,859 flood fatalities over 115 years, the research found distinct trends in relation to gender, age, activity and the circumstances of the death. These trends were analysed in the context of changes to emergency management policy and practice over time.

The NSW State Emergency Service has used the findings of the research for its 'FloodSafe' community campaign and training, while the Queensland Fire and Emergency Services has used it to inform its 'If It's Flooded, Forget it' campaign.

The results of this research have significantly contributed to investigations into preventing flood fatalities by the Prevention of Flood Related Fatalities Working Group of the Community Engagement Sub-committee of the Australia–New Zealand Emergency Management Committee. This working group comprised policy makers, practitioners and researchers involved in flood risk management from Australia and New Zealand.

Similar analysis has recently been completed for fatalities due to cyclones, earthquakes and severe storms across the same time period (1900 to 2015). At least 406 fatalities occurred, with three quarters due to severe storms. The majority of these fatalities have been males.

As well as fatalities, the project has also explored building damage, by hazard, across time and by state or territory. Historical losses have been adjusted for known societal changes (i.e. numbers of homes, the value of these homes and improvements in building codes and construction). While there is substantial variability across time, there is no statistically significant upward trend in the cost of natural hazards. This result implies that no signal has yet been detected to indicate that

insured losses from causes other than societal changes (such as population changes and wealth growth) are increasing.

No single hazard dominates or is responsible for most insured building losses— hailstorms, cyclones, floods, earthquakes and bushfires all feature as the most damaging events in Australia.

End-users say...

Dr Elspeth Rae, Planning and Research Officer, NSW State Emergency Service

> As a consequence of risky behaviour, flood fatalities and rescues are a constant issue for emergency services. This study has highlighted the significant number of fatalities that have occurred as a consequence of flooding compared to other hazards, particularly as a result of driving through floodwater.

Andrew Richards, Manager Community Engagement, NSW State Emergency Service

> The research showed us that fatalities involving a 4WD have dramatically increased in the last 15 years – people think that they are invincible if they are in a 4WD, but the reality is far from that. We really want to reach this group of people in the hope that the next time they come across a flooded road, they will make the safest decision.

Using realistic disaster scenario analysis to understand natural hazard impacts and emergency management requirements

Lead Research Organisation: Macquarie University

Project Leaders: Dr Thomas Loridan (Macquarie University) and Dr Matthew Mason (University of Queensland)

Realistic disaster scenarios help emergency managers better understand disasters. They allow for visualisation of potential impacts before disasters happen, and enable proactive planning for these events. This project, now in its utilisation phase, developed realistic disaster scenarios using catastrophic loss models so that vulnerable areas, utilities and assets within our major cities can be identified.

The scenarios explored were a 6.0 magnitude earthquake under the Adelaide CBD, a number of different earthquakes under the Melbourne CBD and a category 4 cyclone in south east Queensland.

While an earthquake of 6.0 magnitude may be considered unlikely by many, a 5.6 magnitude earthquake occurred in Adelaide in 1954. Fortunately, its epicentre was far from populated areas,

however today this area is densely populated. The scenario modelling considered the impacts if the earthquake occurred at 2am and 2pm, as these times were expected to result in the highest casualties. It is predicted that an earthquake like this would result in a large number of homes being destroyed or unsuitable for occupation. For both time periods, casualties could be more than 300, with over 100 life-threatening injuries expected. Basic medical aid that could not be self-treated is estimated to be required for approximately 5,000 people.

For the Melbourne earthquake scenario, three different magnitudes were examined (5.5, 6.0 and 7.0). These are all considerably larger than earthquakes that have occurred in Melbourne, and do not lie on any known faults that are considered active. As with the Adelaide scenario, impacts were modelled based on a 2am and 2pm occurrence. Under all scenarios examined, damaged caused by shaking and liquefaction would render parts of Melbourne inaccessible for large extents of time and cause long term infrastructure damage. Immediate casualties would range from under 200 for a 5.5 magnitude occurring at 2am, to more than 8,500 for a 7.0 magnitude occurring at 2pm. Those with life threatening injuries would range from less than 100 to more than 4,500. Under the most severe scenario, basic medical aid that could not be self-treated is estimated to be required for approximately 100,000 people.

The south east Queensland cyclone scenario was modelled on the track taken by Severe Tropical Cyclone *Dinah* in 1967. In the modelled scenario, the cyclone remained offshore, but made its closest passage to the mainland near Harvey Bay, and then moved offshore as it moved south, but staying close to the coast until south of the New South Wales border. Approximately 50,000 buildings were simulated to experience moderate structural damage, which may lead to occupants needing to seek emergency shelter. A further 8,000 would suffer major structural damage, and in many instances will need to be completely rebuilt. Older homes would bare the brunt of this damage (70-90%) as they werre constructed prior to any stringent wind resistant design requirements. As a result of the damage, 50,000 people would need alternate accommodation. The cost of the damages would run into the tens of billions of dollars.

Modelling plausible scenarios such as these quantifies the impacts on society, critical infrastructure, lifelines and buildings, along with the natural environment. This allows emergency managers to understand the implications for their agencies so they can better prepare for, or mitigate the impacts of, events that are beyond their experience.

RESILIENCE TO HAZARDS

This theme aims to improve the conceptualisation of resilience and the factors that both promote and inhibit its development. An improved understanding of these factors will optimise the development of a capability to identify vulnerability, manage the risk and enable resilience.

COMMUNICATIONS AND WARNINGS

Lead End-User: Andrew Richards, NSW State Emergency Service

Research Leader: Prof Vivienne Tippett, Queensland University of Technology

Effective risk and warning communication during natural hazards

Lead Research Organisation: Queensland University of Technology

Project Leader: Prof Vivienne Tippett

With the multitude of warnings issued when an emergency hits, how can emergency services ensure their critical safety advice is heard and acted upon, rather than dismissed as noise? This project is helping emergency services warn communities by actively testing the wording and structure of warning messages to better understand how messages are understood and translated into direct action. The team is supporting broader initiatives in the communications and warnings space, not just for individual organisations, but also at the national level by providing reviews and assisting with the development of evidence-based warning doctrine.

The researcher team is collaborating closely with the emergency management sector, with the Inspector-General Emergency Management Queensland, Queensland Fire and Emergency Services, Emergency Management Victoria, Victoria State Emergency Service, Country Fire Authority, New South Wales State Emergency Service, Country Fire Service, the Department of Fire and Emergency Services Western Australia and the Bureau of Meteorology all requesting reviews of their warning information.

A key component of the study was undertaking ten focus groups and 77 experiments of 3,615 Australians to examine the structure of emergency warnings. The testing provided very clear directions as to the order in which information should be presented and the nature of that information. The research findings have been shared with end-users through AFAC committees, invited presentations, private meetings, conferences, and translated into practice via audits of agency messages.

This research is providing valuable insights that will make a difference, and local councils are also

End-users say...

Andrew Richards, Manager Community Engagement, NSW State Emergency Service

"We have seen some great outputs in the warnings space from this research. The NSW State Emergency Service will review its warnings in light of the recommendations. We will look how warnings are structured and designed, the language used and how to target different audiences. This will help us deliver our message to affected communities better so we can illicit the desired response during a disaster."

Anthony Clark, Director Corporate Communications, NSW Rural Fire Service

"This research is a really important piece of the puzzle. It is a game-changer for us as we had been sending out information and warnings in a format that met the needs of the emergency services. This research tips the process on its head and put the community first and foremost. Emergency services are forming warning messages with the community in mind, so we can get the best possible response from the community in a time of disaster."

Katherine Philp, Manager Regional Engagement, Bureau of Meteorology

"We are working to constantly improve our communication, particularly during severe weather, so the observations and findings are of huge interest."

Matt Dyer, Disaster Management Officer, Bundaberg Regional Council

"Improvements to existing pre-formatted warnings will be captured in the next review of the Bundaberg Local Disaster Management Plan and subordinate plans. Minds have been expanded; opportunities have been glimpsed and there has been a realisation had that there is an existing and emerging body of information that can be integrated into local arrangements. The Bundaberg Local Disaster Management Group is proud to model an example of how to build relationships across sectors to the greater disaster management good."


Photo: cksydney CC-BY-NC-ND 2.0

benefiting. The Bundaberg Regional Council is looking at the frequency of their warnings, the wording of the information they disseminate during an emergency, along with the delivery methods.

The council is also considering how to involve the community in future warning development and identifying how local citizens would best receive warnings that are practicable and timely.

SEQwater are also benefiting from the science, and have sought input from the project team on how to improve their messaging about releasing water from dam's during a flood, with a focus on achieving proactive action by the community.

Highlighting the wide-reaching implications of this research, ABC local radio in Wide Bay Queensland are also engaged with the research team, looking at ways they can improve their emergency broadcasting.

On the social media front, the project team completed a social media pilot study on Twitter, covering decision-making and risk communication, and the current approach for official messages during response and recovery of natural disaster. This involved analysing around 50,000 tweets generated during Severe Tropical Cyclone Marcia in February 2015.

The next stage of the project will continue developing templates for emergency warning messages, focusing on how the inputs into the pre-decisional process change environmental cues, social cues, information sources, channel access and preference, warning messages and how receiver characteristics inform protective action during the response and early recovery phases of natural hazards.

Child-centred disaster risk reduction

Lead Research Organisation: CQUniversity

Project Leader: Prof Kevin Ronan

Children represent the most vulnerable demographic group in disasters – across the globe it is estimated that 30-50% of fatalities are children - while they are also most vulnerable to psychosocial impacts. Early research indicates that children are a resource for reducing current disaster risks and can also mitigate future risks.

The role of children's disaster education in managing risk has been recognised as a major priority in the federal government's National Strategy for Disaster Resilience. Yet, despite a recent surge in child-centred disaster research, the social, psychological, economic and political mechanisms that enable children to both understand and take action to reduce disaster risk remain largely unexplored and the evidence-base for best-practice remains limited.

This project is conducting a nationwide evaluation of programs and strategies based on a child-centred disaster risk reduction framework. It will develop cost-effective programs that reduce the risk and increase resilience for children, schools, households and communities.

This research is already supporting bushfire education for primary school students, with the New South Wales Rural Fire Service utilising findings, along with the knowledge, skills and experience of researchers to develop a bushfire education kit. The 'Guide to Working with School Communities' has been rolled out to all schools through the NSW Rural Fire Service. This places primary schools students front and centre in state-wide bushfire plans, based on the research identifying the importance of involving children in active bushfire preparations for the benefit of the whole community.

The Guide follows the earlier publication of an ebook, available nationally, and based on the same principles that if you educate children on hazards safety, their families and the wider community will also benefit.

This line of research has provided fundamental insight into how children learn about bushfires and how they share those learnings with their families. Collaboration with the NSW Rural Fire Service is continuing, and the team will evaluate the guide over upcoming fire seasons to gather data to measure its impact on community safety over successive seasons.

Collaboration is at the heart of the research at every stage, with researchers and end-users involved in all aspects of the study, from undertaking the research to developing utilisation plans and writing journal papers. This collaboration will produce enhanced benefits when the research reaches maturity and is embedded across the country. Utilisation will include developing best practice guidelines and appropriate training.

The project has been highly active on the international scene, with Prof Kevin Ronan representing the CRC on the United Nations Integrated Research on Disaster Risk committee, as well as presenting at the Third UN World Conference on Disaster Risk Reduction in Sendai, Japan, in 2015, and the 2017 Global Platform for Disaster Risk Reduction in Cancun, Mexico. Prof Ronan is also assisting in the development of a science and technology research plan to support the Sendai Framework for Disaster Risk Reduction, 2015-2030. Researcher Dr Briony Towers has also contributed to a World Vision project to deploy the Lumkani fire detector device to slums in Dhaka, Bangladesh. Her ongoing children's bushfire education research was selected by the UNISDR Scientific and Technical Advisory Group as a best practice case study.

End-users say...

Andrew Richards, Manager Community Engagement, NSW State Emergency Service

"This study is enabling emergency services to see where their education programs are having the best affect for both school children, the school itself and the community. We will be able to extract the best elements of these programs and tweak the areas that need improvement. This will lead to agency programs that have a greater impact on emergency management within the school environment.

"We have typically seen these programs implemented on an ad-hoc basis – this research will look at how emergency services can implement to best programs in a scalable and sustainable way."

Tony Jarrett, Community Engagement Coordinator, NSW Rural Fire Service

"This project will assist emergency services by providing an evidence base for us to be able to design and develop education programs. This will assist agencies in achieving our community safety objectives and contribute to how this affects community safety outcomes broadly."

Managing animals in disasters: improving preparedness, response, and resilience through individual and organisational collaboration

Lead Research Organisation: Macquarie University

Project Leader: Dr Mel Taylor

During a disaster responsibility for animals lies with the owner. However, owners are often ill-prepared for themselves and their animals, which can lead to people risking their lives by failing to evacuate or evacuating too late, which endangers both human and animal lives. This recognition that animals need to be considered and integrated into emergency management and disaster preparedness, response, and recovery poses additional challenges for traditional responding. Extra preparation, knowledge and skills are required to ensure the safety of animals, their owners, and responders.

In this context, animal emergency management has emerged as a relatively new area, with a more complex and often less experienced set of stakeholders requiring integration and coordination.

Most research in the area has emerged from the United States following extensive and widely-reported animal-related challenges associated with Hurricane Katrina in 2005. Although animal owners in the US and Australia will share many of the same characteristics and behaviours, the emergency management arrangements and typical scale of disasters are quite different, making translation of US research to Australia difficult.

The National Strategy for Disaster Resilience states that communities should be empowered to take shared responsibility for disaster resilience. Animals provide an avenue to connect communities, and to enable community members to work together in disaster preparedness and planning.

This study, now in its utilisation phase, sought to address the lack of Australian research by identifying challenges for end-users and studying the disaster experiences of animal owners and responders. Subsequent publications have led to an extended knowledge base, and identification of best practice approaches.

Case studies were undertaken on the 2015 Sampson Flat bushfire in South Australia, as well as with the Tasmania Fire Service and its Bushfire Ready Neighbourhoods program. More recently, the team collaborated with a newly-formed community-led group in the NSW Blue Mountains called Blue Mountains Animal Ready Community (Blue ARC). The research explored a 'community-to-community' approach to enhancing awareness, preparedness and planning for animals in emergencies.

Key findings show that over 60% of respondents expected the emergency services would provide information or advice regarding what they could do with their animals in an emergency situation.


Photo: Ashley Hosking CFS Promotions Unit

This expectation was higher than other groups, such as veterinarians or the RSPCA. A generally low level of planning was reflected in the experiences of those who had evacuated during the 2013 fires. Although most respondents reported taking animals with them when they evacuated, some reported leaving a person behind to look after the animals, and others had to choose which animals to leave.

This research will inform the production of a community guide to establishing an animal ready community; a resource that could be used by other communities to promote emergency preparedness and planning through a focus on animals. This will include helpful advice for the steps involved, the networks and collaborations required, how to identify the needs of local animal owners, and suggestions for community activities.

End-user says...

Andrew Richards, Manager Community Engagement, NSW State Emergency Service

"This research has allowed us to map animal ownership, and to survey animal owners as to what their response arrangements may be in a disaster. We hope to see some more tailored tools and products for the industry as a result of this research, which will be a real blessing for what has been a wicked problem for emergency services in the past."

Improving the role of hazard communications in increasing residents' preparedness and response planning

Lead Research Organisation: University of Melbourne

Project Leaders: Associate Prof Jennifer Boldero and Dr Illona McNeill

The increasing frequency and complexity of natural hazards poses a challenge for community resilience. Communication and education of risk mitigation strategies play an essential role in building and maintaining resilience through preparation and planning by residents.

This project, now in its utilisation phase, has combined expertise in communication, social and consumer psychology, and disaster and emergency management. It identified barriers and enablers in residents' decision making, preparing, and planning by examining residents' intended use of different types of triggers for action during hazards. This included when to start evacuating and what information source to use, with the aim of trying to understand why some residents form a better-quality household plan with safer intended triggers than other residents.

Surveys were conducted across bushfire and flood-prone areas in New South Wales, South Australia, Tasmania, Victoria and Western Australia. Findings include that the majority of people do not use official information sources about these hazards, so changing the content in these sources will only have limited overall effect. However, those that do use official information sources are better prepared and more motivated to prepare due to a greater sense of risk perception.

End-user says...

Andrew Richards, Manager Community Engagement, NSW State Emergency Service

> A multi-hazard preparedness tool has been developed that enables people to plan and prepare for a range of natural hazards that they may face. It is exciting to see this being piloted in Western Australia.

Community understanding of the tsunami risk and warnings systems in Australian communities

Lead Research Organisation: University of Tasmania

Project Leader: Prof Douglas Paton

This project aimed to better understand the factors that shape community resilience to tsunami in Australia, and effective tsunami warning risk communication. The research phase is now completed.

The need for this work derived from the fact that the Australian coastline faces some 8,000km of active tectonic plate boundary capable of generating a tsunami that could reach Australia in two to four hours. Recognition of this risk led to the development of the Australian Tsunami Warning System.

The exposure of coastal areas and short lead times makes it important that communities exposed to tsunami threat accept their risk and act on this to increase their response capability.

Interviews in communities in New South Wales, Queensland, Tasmania and Western Australia identified diverse views on what people should be warned of, and how to warn them. Views on what people should be warned of include long term issues (problems evacuating, long term impact on infrastructure, resourcing) and immediate actions (knowing one's evacuation route). A need to adapt warnings to specific geographical localities and to enhance community readiness was also identified.

The findings of the project have been presented to the Australian Tsunami Advisory Group and the NSW SES, and will be used to inform the development and implementation of a community engagement strategy that can be used by end-user agencies to develop community warning and response strategies.

End-users say...

Sarah Anderson, Surf Life Saving Australia

> In representing Australian Tsunami Advisory Group as an end-user of this research, I have worked closely with the research team to prepare the research deliverables.

Andrew Richards, Manager Community Engagement, NSW State Emergency Service

> The NSW SES has recently developed tsunami impact maps that allow people to pinpoint the at-risk areas and show evacuation areas, especially in relation to their home or places that they frequent. It really starts to stimulate action and preparedness in the face of what is a disaster that is often underestimated.

Photo: South Australia SES

Flood risk communication

Lead Research Organisation: Macquarie University

Project Leaders: Dr Mel Taylor and Dr Katharine Haynes

This study commenced in July 2017. It will build on the recently completed CRC project on the analysis of Australian flood fatalities, which identified several important trends in relation to gender, age, activity at the time of death and reasons behind the actions taken. The research discovered many new fatalities, making floods the second most deadly natural hazard (following heatwaves) in terms of the total number of fatalities since 1900.

This new project will develop an understanding of the motivations, beliefs, decision making processes and information needs of at-risk groups for flood fatalities. It will cover both age and gender, including an understanding of what a Plan B would look like, how to motivate proactive decision making ahead of the journey, what the current challenges and barriers are to this and what further support and information is needed.

Specific high risk behaviours include:

1. Those driving and entering floodwaters, including those in 4WDs. While young males comprise the highest risk group for this activity, there are also high proportions of women and older men dying in recent years. Of note are the high numbers of fatalities among passengers, particularly females.
2. Those recreating in floodwaters. Children and young adults, particularly boys and men, comprise the highest risk group. Parents are an associated risk communication target group for this category.

Outcomes will include targeted risk communication materials, which will be developed in partnership with end-users.

EMERGENCY MANAGEMENT CAPABILITY

Lead End-User: Heather Stuart, NSW State Emergency Service

Research Leader: Dr Chris Bearman, CQUniversity

Improving decision-making in complex multi-team environments

Lead Research Organisation: CQUniversity

Project Leader: Dr Chris Bearman

How can incident management teams function to the best of their ability in challenging and high stakes environments? This research has developed practical techniques and strategies to help emergency managers to function in complex situations – situations which can exert extreme pressures on response and management teams, sometimes causing breakdowns in teamwork that can lead to impaired operational response.

Two tools have been developed, the Emergency Management Breakdown Aide Memoire and the Team Process Checklist. The tools' flexibility and ease of use helps emergency managers to strengthen teamwork before, during and after emergencies. The tools can be used during training, during emergencies, and in after-action reviews. Agencies that are already trialling these techniques include the South Australian Country Fire Service, Tasmania Fire Service and NSW State Emergency Service.

The tools are a very flexible way to examine teamwork from many perspectives. They are being used as a health check to ensure the team is functioning effectively, to identify suspected problems, as a debrief tool and to foster better teamwork. They are utilised in real time during an incident, as a way to reflect on teamwork during periods of relative calm, and as an assessment and/or debrief tool during training. They are being used by team members, team leaders, external people who have operational oversight (for example, regional coordinators) and by independent observers.

End-user partners have been engaged throughout the study, with information sought from 18 separate agencies ranging from state emergency services, urban fire, rural fire and local councils.

The project has also investigated organisational learning, identifying broad challenges that agencies need to manage in order to enhance and sustain learning. These include shifting value from action post an event, to reflection, focusing on the bigger picture and allowing enough time to effectively embed the new practices after an emergency. A key insight for agencies interested in facilitating improvements in learning is to locate potential weak links in the learning cycle and to develop a better understanding of how to learn.

Longer term utilisation of this research will embed the techniques, strategies and tools in the formal emergency management system, as well as development of an improved learning culture across the sector.

About the Emergency Management Breakdown Aide Memoire

The Emergency Management Breakdown Aide Memoire is a checklist that helps people to recognise teamwork breakdowns through team outputs (for example, incident action plans) and formal/informal organisational networks. It also provides some practical resolution strategies.

About the Team Process Checklist

The Team Process Checklist is designed to provide a health check for teams and, if there is a problem, to help determine what that problem is. This tool is designed to assist people to think through three aspects of teamwork: communication, coordination and cooperation.

End-users say...

Mark Thomason, Manager Risk and Lessons Management, South Australia Country Fire Service

"Good teamwork is an increasingly important part of emergency management. When teams are not working effectively a variety of problems can result, including confusion, miscommunication, differing plans and unexpected actions. To manage incidents effectively and to ensure safety, it is vital that teams are performing as well as possible. The straight-forward, practical tools developed through this research are of great benefit to emergency managers to ensure their teams are functioning to the best of their ability. They cover communication, coordination and cooperation, and include suggestions for how to best resolve problems. Those who work in incident management teams and strike teams, or at higher levels such as Regional or State Operations Centres, team leaders and people close to, but outside the team (such as neutral observers), will find the tools invaluable during operational response, but also in debriefs and training."

Heather Stuart, Manager, Knowledge and Lessons Management, NSW State Emergency Service

"This research provides evidence that will help lessons practitioners across the emergency services ensure that lessons from events and experiences are learned. The project helps to articulate some of the barriers to organisational learning that most emergency service agencies are struggling with. Agencies will be able to utilise this research to inform the development of strategies to address some of these barriers, which will help them move from merely identifying lessons to achieving changes in behaviour. Then we will truly be able to say that lessons are being learned."

National mental health and wellbeing study of police and emergency services

Lead Research Organisation: beyondblue and the University of Western Australia

Project Leader: Prof David Lawrence

For the first time, a nationwide research project will investigate the mental health and wellbeing of Australia's emergency service staff and volunteers. This new project, led by beyondblue in collaboration with the CRC, will invite up to 20,000 current and former personnel from 35 police and emergency organisations across Australia to participate in a survey about their mental health and risk of suicide.

It is the first time data is being collected on a national scale from police and emergency service organisations. The research is being conducted in three phases after qualitative analysis was gathered by beyondblue in phase one during 2016.

Police and emergency service workers will be surveyed about their wellbeing; common mental health conditions; suicide risk; stigma; help-seeking behaviour; and factors supporting, or jeopardising, mental health in the workplace.

This project will provide important information to understand both the number of people affected and the range of issues they face.

Initial findings from phase one suggest:

- the nature of the stigma associated with mental health conditions differs across police, fire and rescue and ambulance services;
- although exposure to trauma is seen as an underlying cause for post-traumatic stress disorder, workplace culture and practices also contribute to the prevalence of mental health conditions;
- working in police and emergency services, particularly for volunteers, can support workers' mental health.

Evidence-based strategies will be developed to individuals, improve organisational culture and address systemic concerns that impact on mental health and wellbeing across the sector nationally. They will be developed in collaboration with a cross-section of the police and emergency services sector including agencies, unions, government departments, individuals and family and community groups around Australia.

Catastrophic and cascading events: planning and capability

Lead Research Organisation: Macquarie University

Project Leader: Andrew Gissing

This study commenced in July 2017, and aims to better understand the nature of catastrophe and identify ways to improve management approaches in the Australian context.

Catastrophic events are cascading in nature, escalating in their impacts as interconnected essential services fail, causing further impacts and making the recovery more complex and prolonged. Events may not respect borders or boundaries, resulting in unclear accountabilities amongst responding agencies, and conflicting strategies and public messaging as different jurisdictions respond.

The recovery of communities may take many years, with many of the impacted population choosing to re-locate to other areas permanently. Economic losses can be severe as industry is disrupted, businesses close and yet further demands for capital injections from government to support recovery costs.

When managed poorly, a loss of public trust in officials may emerge with resulting political challenges. Official commissions of inquiry are held, which provide opportunities for improving systems, reducing risks and enhancing plans to better manage future events. Often, however, such learnings are forgotten as memory of the disaster fades only for many of the same issues to emerge as problems in the next event. The performance of leaders will be judged through the expectations of others with the obvious advantage of hindsight.

Catastrophic disasters are different from every day disasters. Response strategies that routinely work in smaller events will be quickly overwhelmed and ineffective. The role of emergency management agencies becomes focused on providing leadership, facilitation, subject matter expertise, public information and warnings, and specialist resources. In the United States a government-centric approach has been recognised as being insufficient to meet the challenges posed by large disasters. Government is only one part of the overall team; and that arrangements must leverage all of the resources available.

Forecasting impact for severe weather

Lead Research Organisation: Bureau of Meteorology

Project Leader: Harald Richter

This new project began in July 2017. It will investigate the development of a pilot capability to make useful predictions of community impacts of extreme weather, improving timely mitigation actions. This pilot project will focus on hydro-meteorological events impacting eastern Australia – events in areas where most of our population is concentrated, particularly the coastal regions of southern Queensland, New South Wales and eastern Victoria. These events, which include East Coast Lows, can occur at any time during the year, with gale or storm force winds damaging coastal areas, widespread rain often causing flooding, and very rough seas and prolonged heavy swells damaging the coastline.

Currently, hazard forecasts in Australia are based on meteorological analysis of many data sources (numerical weather prediction models, satellite and radar observations), which is combined with local knowledge, and informed by years of experience issuing and verifying forecasts. Up until recently, forecasts have been general in nature, due in part to uncertainty of forecast accuracy and the short lead time. But there has been substantial improvements in forecast accuracy over the last couple of decades, and the availability of higher and higher resolution models means that the potential for more specific forecasts is ever increasing.

Impact may be qualified and/or quantified by integrating hazard forecasts with data about community vulnerability, exposure to the hazard and localised damage models. The issue of variable quality data will be explored with the nature of the impact-based forecasts to be determined according to available data and end-user needs.

Impact-based warnings could be developed by integrating specific (both spatial and temporal) hazard forecasts with exposure and vulnerability data at the community level. The capability to develop impact assessments has been applied generally within the natural hazard risk modelling community, however the ability to develop such assessments within a forecasting and warning process currently does not exist in Australia. The recent advances in weather forecasting as described above suggest that useful impact-based warnings are now a real possibility.

End-users, especially the operational emergency management stakeholders, may want to understand many things from an impact-based forecast, such as:

- When and where the impacts will occur?
- Who and what might be affected?
- How badly will they be affected?

- Who most urgently needs assistance (and who can help themselves)?
- What are the possible cascading effects (e.g., landslides)?

While it may be some time before an impact prediction capability can specify all this information with sufficient precision, accuracy and reliability to be included as a stand-alone forecast element in addition to current practice, there is an existing capability that could be integrated into an operational forecast that has the potential to greatly improve the quality and local relevance of hazard forecasts.

Diversity and inclusion: building strength and capacity

Lead Research Organisation: Victoria University

Project Leaders: Celeste Young and Prof Bruce Rasmussen

One in four Australians – or some 5.75 million people – were born overseas. Many members of recently arrived culturally and linguistically diverse communities may not understand Australian natural hazards or the information relating to them, and may also have different levels of trust relating to officials in uniforms. Emergency management personnel need to become culturally competent, and aware of the different aspects of local communities to be able to support and respond to their needs. It is also critical to understand what barriers to resilience may exist amongst diverse communities. Diversity is also an untapped area of potential that can have benefits – not only for emergency service agencies, but also for the broader community. It is important to understand how existing forms of community resilience, knowledge and resourcefulness can be harnessed and strengthened, and how the benefits derived from diversity add value, and what that value is.

This new study, which began in July 2017, will focus on understanding how diversity is understood and practiced in the emergency management sector. It will also identify the constraints and enablers in implementing inclusion activities, and explore how diversity can serve to enhance the current operational environment and systems in order to provide a practical evidence-based framework tailored to the emergency management context that supports development and implementation of diversity programs.

Cultural diversity in the emergency management sector encompasses gender, race, disability and cultural diversity. Currently, there are low rates of participation for women and participants from diverse cultural backgrounds in many areas of emergency management. This has ramifications for the capacity of the emergency services to modernise and build human service capability. The 2011 National Strategy for Disaster Resilience rightly identifies the importance of culturally and linguistically diverse variables, the need for disaster services to understand the needs of such communities, and the critical importance of community consultation and partnerships.

Photo: QFES

This project will highlight relevant strengths throughout the emergency management sector, identify and value the benefits of diversity, and investigate what underlies current organisational behaviour.

The research will also develop a guidance framework that supports organisations to undertake such work. This will enable organisations to implement diversity management strategies, and to build business cases to support program development in their own contexts. It will also provide case study examples of current best practice in this area, which are transferable into the Australian context to assist this process. Through developing a framework and then rigorously testing it in different communities, the project will be able to take the different needs across the levels of emergency management organisations into consideration, and provide an evidence-based pathway for building more diverse and innovative work cultures for the future.

SUSTAINABLE VOLUNTEERING

Lead End-User: Paul Davis, Emergency Management Victoria and Deb Parkin, Inspector-General for Emergency Management, Victoria

Research Leader: Prof John Handmer, RMIT University

Out of uniform: building community resilience through non-traditional emergency volunteering

Lead Research Organisation: RMIT University

Project Leader: Prof John Handmer

How people volunteer to keep their community safe from natural hazards is changing. As our work and life commitments change, many people do not have the time to dedicate to traditional ways of volunteering with an emergency service, undergo the required training and develop the ability to respond to potentially dangerous situations. But they still want to help, and they still want to volunteer.

There is also now more attention being given by the emergency management sector to non-traditional or informal emergency volunteers – people who volunteer without affiliation with the established organisations that have recognised roles in emergency and recovery plans. Agency leaders show a variety of attitudes and approaches to non-traditional emergency volunteers – some see them as creating legal and occupational health and safety risks for the agency, and as distracting the organisation from its core business. Others view them as a basis for surge capacity, a valuable resource and almost always the initial responders.

This completed project has investigated current and emerging issues around volunteering and volunteers responding to disaster events, and the different factors that can influence people's participation in non-traditional emergency volunteering. Utilisation is now in progress.

Case studies were undertaken, selected to ensure coverage of different stages of disaster risk management, hazard types and types of non-traditional emergency volunteering. They include community led preparedness (Be Ready Warrandyte), community-led recovery (Community on Ground Assistance in Kinglake), spontaneous volunteer management (Volunteering Queensland's Emergency Volunteering Community Response to Extreme Weather), the role of volunteers from faith-based groups in recovery (Pinery fire, South Australia), digital volunteering following 2015's Cyclone *Pam* in Vanuatu, and a review of the national surge capacity for response that occurred for Cyclone *Tracy* in Darwin (1974).

These case studies have identified four key large-scale forces reshaping the nature of volunteering

in the 21st century. These are changing lifestyles and values and the changing nature of work; the impact of new communications technology; greater private sector involvement; and growing government expectations of and intervention in the voluntary sector.

Five key areas of focus have also been identified to best capitalise on emerging opportunities, providing evidence and impetus to shift away from a reliance on traditional, structured volunteering models, to models that are more flexible, adaptive and inclusive of newer and diverse volunteering styles.

Emergency management organisations are aware of this shift in the volunteering landscape and its impacts, and in some instances are already responding. Findings from this project are being used to address these areas, with change makers at organisational, jurisdictional and national levels driving a shift towards more flexible, adaptive and inclusive volunteering models.

The research has influenced key national initiatives, with findings used extensively for the development of the National Spontaneous Volunteer Strategy by the Australia–New Zealand Emergency Management Committee. The strategy provides advice to emergency service agencies on best practice principles, as well as what they need to be aware of, and what they need to consider and plan for when working with spontaneous volunteers. Important issues such as legal obligations and social media are also covered, with this research integral to the strategy's content.

Building on this, the Australian Institute for Disaster Resilience is drawing directly on the research to develop a new handbook on spontaneous volunteer management. The handbook will provide important guidance for organisations on how to incorporate the principles of the National Spontaneous Volunteer Strategy, and the most recent research on spontaneous volunteering, into their own plans and procedures.

The research is also impacting the development of new strategies in volunteer management at the organisational level, for example informing new directions and developments in the Department of Fire and Emergency Services Western Australia and the New South Wales SES. Be Ready Warrandyte, a community group in one of Melbourne's high bushfire risk suburbs, has also drawn extensively on the research to help educate and support their local community.

The project has provided an important and comprehensive resource to benchmark best practice in supporting and integrating spontaneous volunteerism for emergency service agencies across Australia. The scope and relevance of the project will provide a valuable framework of knowledge for the future

End-users say...

Paul Davis, Manager, Volunteer Development and Change, Emergency Management Victoria

> This research helps to shift the narrative around emergency volunteering from one of crisis and decline, to one of transformation and opportunity. This is in fact good news as it may be the very shift that we need to drive organisational change. This is where we must focus our energy and efforts; as communities change, so must we. If we don't, we face a very real chance of being left behind, and looking back at what might have been.

"Established emergency management organisations need to adapt and embrace emerging opportunities through more flexible, diverse and inclusive volunteering models and closer partnerships with community groups, businesses, and the not-for-profit sector. This will involve confronting very real challenges and barriers to current organisational structures and cultures, and the desire to often want to do it all ourselves. Failure to accept and adapt to the changes means running a very real risk of falling behind as new voluntary and community-based organisations pursue their own ways to get involved in disaster management, powered by new technology, start up business models, very clear purpose and smart volunteer value propositions. There is much to learn from this and a joined up approach with these new 'organisations' offers a way to augment our own capacity and possibly achieve better community outcomes."

Karen Roberts, Director of Human Resources, Department of Fire and Emergency Services Western Australia

> Our long-term volunteering strategy includes establishing an agency position on non-traditional volunteering. The learnings and knowledge generated by this research will be critical to informing our policy.

Improving the retention and engagement of volunteers in emergency service agencies

Lead Research Organisation: University of Wollongong

Project Leader: Dr Michael Jones

It is economically impractical to employ the number of emergency service workers needed to adequately respond to fires, storms and floods. As a result, Australia benefits from the support of around 235,000 emergency services volunteers.

Volunteer brigades and units are managed by the volunteers themselves. This quasi-independence

of volunteer groups – in contrast to the corporate environment of paid staff in a regional, district or head office – can sometimes cause tensions, especially related to communication and authority along hierarchical structures. However, these tensions also occur within volunteer groups, where effective leadership is a critical element for job satisfaction and for the retention of recruits. Many volunteer-based emergency service agencies experience high rates of volunteer turnover, in some cases as high as 20% each year. At times, up to half of all new recruits leave within the first two years.

Volunteer turnover is an economic liability to volunteer-based agencies. Training, uniforms and protective equipment are expensive. More importantly, volunteer turnover has a bearing on operational capacity, flexibility, resilience, and to some degree, morale. Research on poor volunteer retention is therefore valuable.

Finding out why this happens – and developing ways to improve volunteer retention – has been the focus of this study, which is now in its utilisation phase. While the team determined there was no need for a leadership program per se, because most agencies offer a variety of programs that meet the traditional needs of leadership development, self-determination theory has been identified as a simple method to introduce to volunteer leaders.

Self-determination theory recognises that people have three basic psychological needs for optimal functioning and wellbeing:

- Autonomy – having the opportunity to express personal initiatives and ideas
- Belonging– perceiving themselves to be part of the group
- Competence – feeling effective through positive feedback and appropriate training.

A nine-week program, called Inspire.Retain.Engage, was developed, which consisted of:

- One day of learning about leadership, self-determination theory and generation of ideas
- Nine weeks of on-the-job application and active reflection on the principles of self-determination theory with the support of an online mentor
- A final day of reflection and sharing within communities of practice.

The program was piloted with volunteer leaders in 2014 with the NSW State Emergency Service and the NSW Rural Fire Service. It was delivered again in 2016 to volunteer leaders and staff of Victoria State Emergency Service and Queensland Fire and Emergency Services.

The Inspire.Retain.Engage training and the use of self-determination theory improved the retention rate of volunteers, as shown by the statistical effectiveness of the program on behavioural change in the participants, job satisfaction and turnover intention of team members.

The program is available to all emergency service agencies in Australia.

Photo: South Australia SES

Enabling sustainable emergency volunteering

Lead Research Organisation: RMIT University

Project Leader: Dr Blythe McLennan (RMIT University) and Dr Patrick Dunlop (University of Western Australia

This new project began in July 2017, and has two parts:

1. Adapting the sector
2. Changing management practice

Adapting the sector

This section of will investigate why change is needed, and explore the developments that are likely to occur over the next decade that will require adaption by emergency service organisations. Current models, frameworks and processes will be reviewed, with a survey conducted with key stakeholders to understand the key barriers to organisational change. Outcomes will highlight the best ways to enable change and overcome barriers, or emphasise if new approaches are needed.

Changing management practice

This component aims to measure culture for inclusion and change at emergency services and improve emergency service volunteers' retention. Two tools will be developed to achieve this – a cultural diagnostics tool for volunteer groups, and retention through effective on-boarding. Outcomes of this work will be actionable steps on how to help brigades and units build or improve a culture of inclusiveness, and then undertake an evaluation of the effectiveness of those actions taken.

Retention through effective on-boarding will investigate the volunteer retention issues within emergency services by reviewing recruitment practices, reviewing current socialisation and training, and understanding the implications of diversity amongst volunteers.

UNDERSTANDING AND ENHANCING RESILIENCE

Lead End-User: Suellen Flint, Department of Fire and Emergency Services, Western Australia

Research Leader: Dr Phil Morley, University of New England

The Australian Natural Disaster Resilience Index: A system for assessing the resilience of Australian communities to natural hazards

Lead Research Organisation: University of New England

Project Leaders: Dr Phil Morley and Dr Melissa Parsons

Resilience is the capacity of individuals and communities to cope with disturbances or changes and to maintain adaptive behaviours. Australia's National Strategy for Disaster Resilience (NSDR) takes an internationally progressive approach in the application of a disaster resilience paradigm. This strategy gives communities greater options and diversity in managing natural hazards, and places natural hazard preparation, prevention, response and recovery in the context of societies learning from and adapting to change.

The NSDR recognises four characteristics of disaster resilient communities: 1) they function well while under stress 2) they adapt successfully 3) they are self-reliant and 4) they have strong social capacity. Building these characteristics of disaster-resilient communities is seen as a shared responsibility among individuals, households, businesses, governments and communities. Yet how could progress towards the development of these characteristics be assessed? Where are the areas of high and low disaster resilience in Australia? How could investments to develop disaster resilience be prioritised, evaluated and reported?

This project is developing an index of the current state of disaster resilience in Australian communities – the Australian Natural Disaster Resilience Index.

The Index is a tool for assessing the resilience of communities to natural hazards at a large scale and is designed to provide input into macro-level policy, strategic planning and community engagement activities at national, state and local government levels.

First, it is a snapshot of the current state of natural hazard resilience at a national scale. Second, it is a layer of information for use in strategic policy development and planning. Third, it provides a benchmark against which to assess future change in resilience to natural hazards. Understanding resilience strengths and weaknesses will help communities, governments and organisations to build the capacities needed for living with natural hazards.

Deliverables will include development of disaster resilience indicators, maps of disaster resilience at multiples scales, a State of Disaster Resilience Report, and examples that use the Index in a natural hazard resilience planning context.

Photo: Damien Ford, NSW Rural Fire Service

The Index has application across local (e.g. local emergency management committees, local councils), state (e.g. emergency service organisations) and national (e.g. Attorney-General's Department, Red Cross, ANZEMC, AFAC) levels.

The project team is working with end-users to align the results and outputs from the Index with agency policy and programs. The researchers will work with agencies to develop fact sheets that agencies can use in community profiling and community engagement tools. The Index results can also be included in risk assessments. The maps provide quantitative spatial information about resilience for community planning and community engagement activities.

End-user says...

Suellen Flint, Director Community Engagement, Department of Fire and Emergency Services, Western Australia

"The Australian Natural Disaster Resilience Index will support national, state and local governments and, most importantly, communities. The ability to identify hot spots of high or low disaster resilience in Australia will potentially embed disaster resilience into policy and legislation, and increase shared responsibility and resilience across Australia."

Enhancing remote north Australian community resilience

Lead Organisation: Charles Darwin University

Project Leader: Prof Jeremy Russell-Smith

Remote north Australian communities are susceptible to cyclones, floods and bushfires. Cultural and socio-economic factors combine with the challenges of remote service delivery - including cost, low levels of infrastructure and distance from the urban centres that host key service delivery organisations - to create situations where communities can be highly vulnerable to natural hazards. In this context, it is important to understand how these variables can be navigated to enhance community resilience. This task requires a detailed understanding of current capacities, preparation and response strategies, communication pathways and local governance structures.

A challenge for enhancing community resilience is to develop culturally appropriate, environmentally sustainable economic opportunities. The lack of wealth generation at the local level impedes community capacity to develop infrastructure and build human capital through training and experience of the workplace. The ability of these communities to respond in a coordinated way at an appropriate scale is largely non-existent.

The project comprises two major strands – Scoping resilience issues in remote Indigenous communities, and developing economic resilience through payments for environmental services projects.

The scoping resilience issues in remote Indigenous communities component has three main areas.

- The Aboriginal Research Practitioners Network - Indigenous researchers trained in Participatory Action Research - are working in two Northern Territory communities (Ngukurr and Gunbalanya) documenting community understandings of natural hazards, risks, current response strategies and community capacity.
- At these same study sites, the hard, institutional and cultural assets that underpin local capacity and the delivery of emergency services and which are at risk during a hazard are being mapped.
- Working with community members and end-users to explore the challenges faced by agencies in the delivery of emergency services to remote communities.

The project conducted case studies at Ngukurr and Gunbalanya, and in areas of north east Arnhem Land impacted by Cyclone *Lam* in 2015.

A report detailing the key findings, and a preliminary set of recommendations and protocols for how remote Indigenous communities can be more effectively engaged in emergency management, is in development. The research highlights the significant gap between the roles and responsibilities of emergency service agencies on the one hand, with the expectations of community members on

the other. A critical challenge for government authorities is to effectively engage with Indigenous community governance structures in order to develop mutually respectful partnerships.

The developing economic resilience through payments for environmental services projects component is:

- Articulating key contemporary terrestrial land use management, institutional, and policy challenges facing Indigenous people and local communities in north Australian savanna regions
- Exploring opportunities afforded through emerging economies related to climate change mitigation, carbon trading, and ecosystem services to help address identified challenges
- Undertaking rigorous valuation of ecosystem services to be derived from savanna landscapes of northern Australia, and associated scenario modelling of payment for environmental service benefits which can be derived from emerging land use options (e.g. savanna burning, carbon sequestration, diversified/mixed pastoral management activities, environmental stewardship arrangements)
- Identifying beneficial culturally appropriate institutional/governance arrangements which can effectively support community development and resilience aspirations, providing authoritative analysis of the above findings to help inform Indigenous community policy development and community resilience outcomes in northern Australia.

The research illustrates that, to better inform regional development policy, significant challenges remain for appropriate valuation of ecosystem services from north Australian savannas, including recognition of socio-cultural services and wellbeing benefits incorporating Indigenous values.

End-user says...

Suellen Flint, Director Community Engagement, Department of Fire and Emergency Services, Western Australia

> This is a complex multi-faceted project that aims to support Indigenous communities to learn from and empower each other, with each sub-project having a theme of strengthening governance and improved resilience.

Northern Australian bushfire and natural hazard training

Lead Organisation: Charles Darwin University

Project Leader: Steve Sutton

Fire and emergency management in northern Australia is quantitatively and qualitatively different to that in the south of the continent. To meet the needs of fire and emergency managers in northern Australia, this project has established training units that meet the requirements of emergency management in the north. The factors differentiating between northern and southern training needs are significant, ranging from geographical (the scale of northern natural disasters and distances), to social and cultural, including the impacts of natural disasters on remote Indigenous communities.

Nearly 360,000 of the people living in northern Australia live in communities with varying degrees of remoteness from 'outer regional' to 'very remote'. These communities are predominately inhabited by Indigenous Australians with the percentage rising in direct proportion to remoteness.

The project, now in its utilisation phase, has developed a training program that builds on the current assets in place, such as the ranger programs, and leads to increasing levels of competence and confidence and in its turn, resilience. The project is a response to north Australian stakeholder concerns that existing training is inadequate for their needs.

New training materials were developed, with courses or packages that provide remote communities the skills and knowledge to manage landscape scale fire regimes, as well as a range of other natural disasters. Pilot training courses begin in late 2016.

The project study reviewed 21 training courses offered through Charles Darwin University and its Registered Training Organisations. Five new training units were completed, and additional units developed to suit the needs of northern Australia. These adapted and new units will provide a comprehensive training package that is sensitive to Indigenous cultural and language variations and reflects local knowledge and contexts. This will allow qualified trainers to deliver training in ways that can be tailored to suit remote locations. The project has also developed a Course Delivery Handbook based on the training materials.

End-user says...

Suellen Flint, Director Community Engagement, Department of Fire and Emergency Services, Western Australia

> The development of training for north Australian landscape-scale bushfire and emergency management is seen by many in Western Australia as a crucial platform for improved resilience in remote communities in the state's north.

Photo: Bushfire and Natural Hazards CRC

Factors affecting long term community recovery

Lead Organisation: University of New England

Project Leaders: Dr Phil Morley (University of New England) and A/Prof Sarb Johal (Massey University)

Since the Hyogo Framework for Action was developed in 2005, nations have been prioritising investments in more targeted preparedness, relief and mitigation policies in an attempt to reduce the financial and human costs of disasters. Often it is after the media spotlight fades on a major disaster that the real recovery process begins, and regardless of the level of interest and the effectiveness of the response during the event, the recovery process extends over time and passes through stages of short-term, medium and long term recovery. However, rarely is there a concerted long-term dimension for plans, particularly from the perspective of enabling disaster impacted communities to effect full recovery of their livelihoods.

Successful recovery is about building back better and smarter and can provide opportunities to enhance social and economic systems, as well as natural and built environments. To do this though, it must be recognised that both communities and individuals have complex and interrelated needs which have to be understood and addressed. It is important that people, communities, organisations and government agencies play complementary roles in this process and understand the interrelations between the social, community, cultural, political, economic and built environments. The manner in which recovery activities are planned and undertaken is critical and can require appropriate enablers to be present to optimise the effectiveness of any recovery intervention. Conversely some activities fail to reach their potential due to presence of various barriers. There is a need to be able to assess and understand the enablers and barriers present within a recovering community so as to ensure that the right actions are taken at the right time.

This project, which began in July 2017, will address two complementary areas of research relating to the long term recovery of communities after a disaster.

Firstly, the project will investigate how a person's history of moving house or town influences the likelihood of their willingness to dissolve social ties?

The second area will be an examination of the enablers and barriers to successful recovery using a framework of community capital and the tracking of capital flows. This will look at natural, cultural, human, social, political, built and financial capital resources, their interconnectedness and interactions in disaster recovery. Examination of these assets through case studies and working with end-users will identify both potential areas for improvements, as well as recognise what has worked well in recovering communities. This process will provide feedback and a guide for the planning of recovery activities in a range of communities.

Hazards, culture and Indigenous communities

Lead Organisation: Western Sydney University and Deakin University

Project Leader: Dr Jessica Weir (Western Sydney University) and Dr Timothy Neale (Deakin University)

This project commenced in July 2017. Within the context of reducing natural hazard risk and increasing resilience in southern Australia, it focuses explicitly on the risk and resilience priorities of Indigenous communities in southern Australia, the emergency management sector's priorities for these communities, and how these interests interact. Its intention is to identify where improvements might be made to reduce natural hazard risk and increase social and ecological resilience. This research complements existing and completed CRC projects.

Drawing upon and supporting innovation where it is occurring, this project will engage with natural hazards practitioners and decision-makers (including those of Indigenous and other cultural backgrounds) and Indigenous communities. The project's intention is to build an inclusive narrative of intercultural hazard risk management which Indigenous peoples and practitioners can buy into. Building trust, capacity and knowledge in these intercultural contexts will reduce risk to Indigenous peoples, the wider community, and the environments in which we live.

This action-research project has three objectives:

- Investigate the hazard priorities of diverse Indigenous communities in southern Australia, and the emergency management sector's engagement with these communities;
- Conduct collaborative research with Indigenous peoples and sector practitioners to explore how better engagement can be supported, with a focus on the interaction of scientific, Indigenous and other knowledge sources;
- Analyse and report on what this dynamic intercultural context can offer practice and policy, including with respect to the merging of risk and resilience agendas.

UNDERSTANDING AND MITIGATING HAZARDS

This theme seeks better forecasts of likely events and precursor conditions; greater accuracy of forecast tools and more timely forecasts. This leads to increased preparedness for the impacts of natural hazards, improved communications and warnings and enhanced ability to predict and mitigate the risk.

FLOOD AND COASTAL MANAGEMENT

Lead End-User: Dr Miriam Fernande-Middelmann, Geoscience Australia

Research Leader: Dr Scott Nichol, Geoscience Australia

Developing better predictions for extreme water levels

Lead Research Organisation: University of Western Australia

Project Leader: Prof Charitha Pattiaratchi

The occurrence of extreme water levels can lead to loss of life and damage to coastal infrastructure. Potential impacts and hazards of extreme water level events along our coasts are significantly increasing as populations grow and mean sea levels rise. To better prepare, coastal engineers, emergency managers and planners require accurate estimates of extreme water levels.

It is vitally important that the exceedance probabilities of extreme water levels are accurately evaluated to inform risk-based flood management, engineering and future land-use planning. This ensures the risk of catastrophic structural failures due to under-design or expense due to over-design are minimised.

This project, which is now in its utilisation phase, developed better predictions and forecasts for extreme water levels arising from storm surges, surface waves, continental shelf waves, meteorological tsunamis, mean sea level rise and the transition from tropical to extra-tropical cyclones.

Storm surges caused by tropical cyclones are well known to pose a risk. Recent technological advances allowed the team to develop a high-resolution numerical model capable of analysing ocean dynamics to better understand how storms will impact local beaches on an Australia-wide scale. The advanced, high resolution 3D hydrodynamic model coupled with a wave model included the effects of waves breaking on top of storm surges caused by wind and pressure. An experiment based upon Tropical Cyclone *Yasi* indicated that wave setup contributed up to 35 per cent of total surge height and was 6-10 per cent of wave heights at 10 m depth. This supports the commonly applied engineering approach of applying a 10 per cent factor for waves in estimates of

water levels. Another important factor included the orientation of the coastline to waves and wind. The experiments showed large variations in setup and surge over the scale of tens to hundreds of kilometres that was mostly related to the relative intensity and direction at which Cyclone *Yasi* impacted the coast. The results suggest that coupling a wave and surge improves the accuracy of storm surge predictions and provides a useful tool to determine areas of the Australian coastline are more susceptible to flooding and erosion from extreme waves.

However, a lesser-known effect of landfalling cyclones is the generation of coastally trapped waves that can propagate along the coast and influence water levels thousands of kilometres away. Examples of such waves include continental shelf waves that travel to the left along the coastline in the southern hemisphere and are common along the Australian coastline. Numerical modelling by the team has demonstrated how particular cyclone properties influence the generation of continental shelf waves and through this improves the ability to predict the influence of continental shelf waves on extreme water levels along the coast.

Meteotsunamis are generated by meteorological events, particularly moving pressure disturbances due to squalls, thunderstorms, frontal passages and atmospheric gravity waves. Relatively small initial sea-level perturbations, of the order of a few centimetres, can increase significantly to create destructive events through the superposition of different factors. In August 2014, a meteotsunami propagating along the mouth of the Swan River in Fremantle resulted in a ship breaking its moorings and impacting on a rail bridge. The team has made significant impact in understanding the mechanisms underlying the development of meteotsunamis and their potential threat.

As tropical cyclones move toward the poles they can interact with the surrounding environment causing the tropical cyclone to lose tropical characteristics and become more extra-tropical in nature – this is known as extra-tropical transition. Storms that undergo extra-tropical transition pose a serious threat by extending tropical cyclone–like conditions over a larger area and to latitudes that do not typically experience such storms. Findings show that in Australia the south west of Western Australia is the area most at risk from extra-tropical transitions of cyclones, late in the cyclone season, when intense cyclones are most likely to interact with approaching cold fronts.

The data generated by the project will be made available via web interfaces with the possibility to develop the data into a spatial interface. Access to this information will support state and local government planning departments, the Bureau of Meteorology's severe weather warnings and forecasts, and state and federal government emergency management planning, coordination and response activities.

Resilience to clustered disaster events on the coast – storm surge

Lead Research Organisation: Geoscience Australia

Project Leader: Dr Scott Nichol

The fundamental processes that cause erosion during storms are generally well understood and management strategies are available. However, the response of beaches to successive storms (storm clusters), such as those that damaged Australia's east coast in 1974, is not well understood or managed, with the response of any given beach depending on its physical characteristics. Because of this, the likely effectiveness of a given management strategy may not be clear, such as beach nourishment (a remedial process where sand is added to a beach to restore its shape). This project developed a methodology and demonstrated it through two case study sites, which had different oceanographic and geological settings. The methodology combined expertise in statistical modelling, hydrodynamics, coastal geology, hazard mapping and impact analysis. The project, now concluded, integrated these approaches to develop tools, information and methods that can be used by others nationally. Utilisation is now in progress.

In consultation with end-users, two case studies were selected: Old Bar on the New South Wales mid north coast (between Newcastle and Port Macquarie) and the Adelaide metropolitan beaches. These beaches were identified as key localities where erosion is an ongoing issue and where field studies and modelling would provide new insights into the problem.

Findings shows that for Old Bar, erosion and property loss are centred on a section of coast where sand cover is limited by shallow bedrock and offshore reefs. This means that the potential for natural beach recovery is hindered by a finite local sand supply, and modelling indicates that further shoreline retreat is possible. Other parts of the beach are more stable due to larger sand reserves onshore and offshore, as evidenced by sand dunes up to 200 metres wide. These findings support previous observations and are consistent with independent hydrodynamic modelling for Old Bar that shows erosion associated with a near-shore circulation cell under storm conditions.

For the Adelaide metropolitan beaches, erosion is managed effectively through an established beach-nourishment program. This project demonstrated that nourishment strategies could be fine-tuned and made more cost-effective by mapping beach thickness using ground-penetrating radar.

As part of the project's utilisation plan, a workshop was held with end-users in April 2017. The workshop focused on two aspects: the software that enables statistical modelling of storm events and the results from shoreline modelling at Old Bar. Feedback from end-users was centred on the value of improving on-the-ground knowledge regarding the processes driving coastal erosion at case study sites and the potential for end-users to make use of data and software modelling tools.

While the modelling to date has focused on Old Bar in New South Wales, the South Australian

end-users wish to compare the current beach management strategies with the modelling results and make changes if required. South Australian coastal managers are also planning similar studies for other beaches using the methodology showcased in this project. In New South Wales, the project results will be part of a broader conversation about how to manage the coastal erosion hotspot of Old Bar. For instance, the sub-surface investigations using ground-penetrating radar are being used by the New South Wales Office of Environment and Heritage to re-assess hazard lines as it develops a coastal management plan for the area. For all end-users, seeing the data, methods and tools being published and made open source is a positive step towards enabling others to apply this method at other locations.

End-user says...

James Guy, Team Leader Coastal Programs, Department of Environment, Water and Natural Resources, South Australia

> This project has played an important role in building the body of knowledge around shoreline response to clustered storms. The new data, modelling tools and summary information for case study sites are essential reference materials for coastal managers. This allows agencies like my own to take a more informed approach to future coastal management strategies. For example, as the agency responsible for implementing the South Australian Government's Adelaide's Living Beaches Strategy, DEWNR will use the outcomes of this research to refine our annual beach replenishment program, which is used to maintain adequate storm buffers for the protection of infrastructure along the Adelaide coast.

Improving flood forecast skill using remote sensing data

Lead Research Organisation: Monash University

Project Leader: Associate Prof Valentijn Pauwels

Accurate flood predictions are critically important for limiting the damage caused by floods. Flood forecasting systems are based on models that require large volumes of data, such as rainfall forecasts, detailed measurements and high-resolution topography. However, flood forecasts are prone to uncertainty due to a lack of detailed measurements, and possible errors or oversimplifications in the models and/or data sets. Remote sensing is the science of obtaining information about objects or areas from a distance, typically from aircraft or satellites. This research is integrating this type of data on soil moisture and flood extent with rainfall and runoff models, which will lead to more accurate flood predictions. It will develop a remote sensing-aided

methodology that can eventually enable forecasting models that predict the volume of water entering the river network to be applied anywhere in Australia.

The team set up a forecasting system for two test basins: the Clarence in northern New South Wales and Condamine-Balonne-Maranoa in southern Queensland. Both areas were chosen because they are prone to frequent flooding. The team has determined the parameters of the hydrologic model using discharge data and remotely sensed soil moisture data and are developing strategies to correct model outputs automatically. The hydraulic model calibration and incorporation of remotely sensed data is ongoing. Specifically, the project is developing a method to determine effective river cross-sections because it is difficult to measure the river bathymetry (riverbed topography) in a detailed way for large basins. The team has acquired river cross-section data in strategic locations on two field visits.

For the hydrologic model, it was found that joint calibration using discharge and soil moisture leads to more robust results than traditional calibration using only discharge data. In other words, the model degraded slightly during the calibration period but improved during the validation period. Including soil moisture in the calibration improved the simulations for the ungauged sub-basins.

Because rainfall is highly uncertain, streamflow data was used to estimate the rainfall volumes for the duration of the flood.

The team have also completed a preliminary analysis of a proposed new method for improving the detection of flooded areas in densely vegetated catchments. It involves using simplified river geometries that are based on a combination of limited field data sampled at strategic locations, global databases and remote sensing data.

A workshop at Geoscience Australia was held in October 2016, streamlining the use of the remote sensing techniques developed in this project for the Geoscience Australia Water Observations from Space product. Geoscience Australia will use the method developed in this project to classify the areas monitored as being flooded or not flooded. This will start in the second phase of the project.

By improving real-time flood prediction, this research is expected to improve the accuracy of flood warnings, resulting in a decrease in flood damage and potentially loss of life.

The researchers are completing phase one of the study and have a broad program planned for phase two. It includes a comparison of different remote sensing-based, soil-moisture products, such as surface soil-moisture retrievals and root-zone, and soil-moisture analysis, for hydrologic model updating. The team will also develop a model-data fusion algorithm for a hydrologic forecasting system to optimally use both remotely sensed soil moisture and stream-flow measurements.

The project will validate rainfall estimations using remotely sensed soil moisture observations. It will also develop a remote sensing-aided methodology to derive effective river-transect data for large catchments, and to improve the accuracy of digital elevation models for large catchments. This methodology will eventually enable hydraulic models to be applied anywhere in Australia.

Photo: Shutterstock

End-users say...

Norman Mueller, Emergency Response Coordinator, Geoscience Australia

"This research will provide a way to help predict the magnitude and timing of flood peaks to enable Geoscience Australia to better target satellite image acquisitions. It will also fill the gaps in satellite coverage and flood extent determination where satellite images are either unavailable or obscured by clouds."

Soori Sooriyakumaran, Manager Flood Policy Unit, Bureau of Meteorology

"The project will provide a vehicle to test the utility of now increasingly available remotely sensed data in predicting flood movement. Improved remotely sensed data with much improved latency and better spatial and temporal resolution, such as from the Himawari-8 satellite, will allow the Bureau to look at ways to improve its flood forecasting capability in areas where sufficient ground observations are not available. The hydrologic and hydraulic modelling capacity being developed will complement the current capabilities."

PRESCRIBED BURNING AND CATCHMENT MANAGEMENT

Lead End-User: Naomi Stephens, Office of Environment and Heritage, NSW

Research Leader: Associate Prof Tina Bell, University of Sydney

Optimisation of fuel reduction burning regimes

Lead Research Organisation: University of Sydney

Project Leader: Associate Prof Tina Bell

Fuel reduction burning is often patchy as a result of fuel and climatic conditions and inherent landscape-related features such as topography and soil moisture, with a strong sampling design required to capture this variation. With bushfires becoming more intense the larger they become, affecting soils and vegetation more. It is unknown if the same situation arises with prescribed burning.

The relationships between burn size and soil, water, vegetation and fuel outcomes has yet to be quantified. The ability to predict the effects of prescribed burns of different size across landscapes is currently negligible.

To design an a priori sampling scheme of prescribed burns with appropriate statistical power, it is important to define what a 'small' fire is compared to a 'big' fire. Logically, larger fires will need to be sampled at a different scale and frequency than smaller fires.

To determine historical fire size, data relating to fire size, location and timing for the last 10 years will be used from New South Wales, Victoria, South Australia, Western Australia and Tasmania. Patterns in fire size and timing that will provide valuable information for the project's sampling design are emerging.

Sampling has been undertaken in sites in mixed-species eucalypt forest in southern Victoria, the ACT and western and southern NSW. This sampling will determine the effect of prescribed fire on changes in fuel load, carbon pools and tree water use. The sampling scheme investigates 'burn units' – pairs of sites that have been measured and compared. The pair of sites can be burnt and unburnt areas near each other, sampled at the same time, or are a single site sampled at different times before and after prescribed burning. Nearly 50 burn units have been sampled across south eastern Australia. The data collected has been used to test if environmental variability is adequately captured for measurements made at different spatial scales and if fire size affects the optimal number of samples required for characterising burnt and unburnt areas.

The predictive model developed by this project will quantify the optimisation of environmental service outcomes for water and carbon management against the effectiveness of the fuel

End-user says...

Max Beukers, Fire and Incident Management, Office of Environment and Heritage NSW

> The fuel reduction burning research will improve the efficacy of prescribed burning programs by providing more evidence on the impact of burning on biodiversity, surface and groundwater quality and quantity, and carbon sequestration. Burn program planners and managers are seeking better tools for forecasting the impact of burn programs on the capacity of the soils to deliver the environmental services required. These tools are efficient survey designs and sampling techniques that are integrated with new predictive spatial models. The application of these tools will give fire management agencies more confidence when assessing the cumulative environmental cost and benefits of the burn programs they propose.

reductions outputs. This will assist fire and land management agencies by giving them greater confidence in forecasting results for their actions.

Ultimately, this project will move research and management capabilities to its next logical focus – building a predictive model and framework for planning of prescribed burns.

This will help predict the effects of fuel reduction burning on fuel loads, broad vegetation types and carbon and water potential (for example, capacity for carbon sequestration, water yield) of forests at a manageable spatial scale.

Delivering effective prescribed burning across Australian ecosystems

Lead Research Organisation: University of Wollongong

Lead Researcher: Prof Ross Bradstock

The 2009 Victorian Bushfires Royal Commission recommended an annual treatment target of 5% of public land in Victoria. Subsequently, concerns were formally raised (for example in the Bushfires Royal Commission Implementation Monitor 2013 Annual Report) that such an area-based target may not deliver the most effective levels of risk reduction. Victoria has now moved to a risk-based approach for prescribed burning.

Concurrently, some other states have adopted prescribed burning targets, but formal attempts to evaluate its effects on risk to people, property and environmental values across different jurisdictions are lacking. Such extrapolation of the 2009 Royal Commission recommendation

presupposes that there is a 'one-size fits all' solution to the problem. While many agencies are moving toward planning systems supposedly based on risk assessment, knowledge of the best way to use prescribed fire to reduce risk to key values is generally lacking.

The project aims to deliver:

1. A Prescribed Burning Atlas to guide implementation of tailor-made prescribed burning strategies to suit the biophysical, climatic and human context of all bioregions across southern Australia. The Atlas will define the quantitative trajectory of risk reduction (including resultant residual risk) for multiple values (such as property, water, carbon, vegetation structure) in response to differing prescribed burning strategies (including spatial configurations and rates of treatment), across different Australian environments based on their unique climatic, biophysical and human characteristics.
2. Continental-scale, biophysically-based models of ignition and fuel accumulation for Australian ecosystems, for use in dynamic risk management planning and operational decision-making about prescribed burning at seasonal and inter-annual time scales, accessible via the Atlas.
3. Detailed scenarios of future change in risk mitigation effectiveness of prescribed burning strategies in response to integrated scenarios of changes to climate, fuel (including elevated CO_2 effects) and ignitions. These will also be accessible through the Atlas.

Case study areas have been selected for fire spread simulations across southern Australia, based on the need to explore climatic, population and land use variation across the region.

While the initial focus has been on fire history, fire severity and a variety of layers needed to run the Phoenix RapidFire model, the project is also examining a broader range of biophysical datasets, which will inform both the simulation studies and also the empirical analyses. Simulations will be conducted, with the initial focus on peri-urban areas near Canberra, Adelaide, Hobart and the Gold Coast.

The Prescribed Burning Atlas being produced will provide quantitative risk-response relationships for prediction of the most probable outcome of different treatment strategies across varied bioregions.

The Atlas will have an interactive interface for end-users that allows them to explore not just these risk-response relationships, but also fuel accumulation and ignition probability models as well as projections of changes to risk under different climate, land use and management scenarios. The Atlas will also potentially provide access to relevant data sets, reports and publications.

The Atlas is likely to be used in a range of ways, from strategic and tactical decision-making to policy development, resource allocation and education.

A prototype Atlas will be piloted amongst end-users in 2019 prior to full release in 2020. The Atlas is designed to be a living and updateable resource beyond the timeline of this project with the capacity to integrate new data and design features.

End-user says...

Dr Felipe Aires, Fire Science Interpretation Officer, Office of Environment and Heritage, NSW

> Projects like this are critical to the strategic burn decision making process. It provides policy and decision makers with the right tools and knowledge, leading to improved capability and expertise. Ultimately, this project will provide truthful assurance that the hazard reduction activities undertaken deliver strategic value on future bushfires.

Tools supporting fire management in northern Australia

Lead Research Organisation: Charles Darwin University

Project Leader: Prof Jeremy Russell-Smith

Northern Australia is an extensive area with a small population and minimal infrastructure. There is considerable summer rain (the 'wet') and very little in winter (the 'dry'). In the 'wet', vegetation growth is considerable, producing abundant fine fuel. Temperature is relatively high all year, so that when the rain stops at the end of the 'wet', the fine fuels dry quickly and are extremely fire prone. One simple ignition in the latter half of the 'dry' can create a bushfire that will burn for months. Planned, or prescribed, burning is the main tool for halting bushfire by reducing fuel loads.

This project has built on existing work to created more sophisticated mapping and modelling tools. The information can be used for planning, operations, and suppression including summaries of past and present fire regimes.

The research team is applying this information and developing the Savanna Monitoring and Evaluation Reporting Framework, to provide a standardised assessment report on fire regimes for all Australia's savannas and rangelands.

The savanna burning research story has many components that all tie together and overlap. In parallel this project examines two significant programs:

1. **Satellite-derived mapping.** The team has developed, and continues to develop, satellite-derived fire and habitat mapping to describe the extent, occurrence and severity of fire at various scales to assess fire effect in various habitats.
2. **Extensive long-term field sampling.** The team has sampled savanna vegetation in detail on the ground at permanent sites for more than 20 years to understand the impacts of different fire management on the environment. A suite of permanent sites exist across the Kimberley, Cape York,

the western Top End, and the Gulf region bordering Queensland and the Northern Territory that describe fuel accumulation and tree growth with respect to fire regimes.

There are many beneficiaries of a new Savanna Burning Methodology including Federal Department of Environment and Energy, numerous Indigenous Resource Agencies, all the northern land councils, the Indigenous Land Corporation, numerous pastoral lease holders, Queensland Parks and Wildlife, the Department of Parks and Wildlife Western Australia and the Parks and Wildlife Commission NT.

Currently north Australia is generating over $30 million dollars annually through payments for ecosystem services on over 330,000 km2, an area which is still only 40% of the potential extent for these projects. The new methodology being developed will open the industry up to more of these stakeholders, particularly in East Arnhem Land and on Cape York, where it is sometimes more difficult to undertake prescribed burning until later in the season.

The Savanna Monitoring and Evaluation Reporting Framework will gather all aspects of the research to date and provide end-users with a simple ability to monitor their fire management and evaluate its effects through time.

End-user says...

Andrew Turner, Director of Strategic Services, Bushfires NT

"With the emergence of new industries such as carbon farming, bushfire management is rapidly changing, requiring decision to be prioritised based on risk. This research will provide a suite of science based information to help identify and communicate risk between stakeholders."

BUSHFIRE PREDICTIVE SERVICES

Lead End-User: Dr Simon Heemstra, NSW Rural Fire Service and Andrew Stark, Country Fire Service South Australia

Research Leader: Dr Trent Penman, The University of Melbourne

Mapping bushfire hazard and impacts

Lead Research Organisation: Australian National University

Project Leader: Dr Marta Yebra

Understanding and predicting fire behaviour is a priority for fire agencies, land managers and sometimes individual businesses and residents. This is an enormous scientific challenge given bushfires are complex processes, with their behaviour and resultant severity driven by complicated interactions involving vegetation, topography and weather conditions.

A good understanding of fire risk across the landscape is critical in preparing and responding to bushfires and managing fire regimes, and this understanding will be enhanced by remote sensing data. However, the vast array of spatial data sources available is not being used very effectively in fire management.

This project uses cutting-edge technology and imagery to produce spatial information on fire hazard and impacts needed by planners, land managers and emergency services to manage fire at landscape scales. The team works closely with agencies to better understand their procedures and information needs, comparing these with the spatial data and mapping methods that are readily available, and developing the next generation of mapping technologies to help them prepare and respond to bushfires.

The project is focused on two related activities:

1. Fire hazard mapping and monitoring – this focuses on spatial information of fuel load, structure that can assist fire preparedness through better fire danger ratings and fire behaviour predictions. This supports logistics and resources planning by emergency services, and can also improve fire management by helping guide activities such as scheduling and implementing prescribed burning.
2. Fire impacts on landscape values – land managers also need spatial information on the expected fire impacts on landscape values, such as water resources, carbon storage, habitat and remaining fuel load.

The team has developed, tested and published software to classify a dense point cloud derived from a mobile laser scanner into different vegetation components: ground returns, near-surface vegetation, elevated understory vegetation (shrubs), tree trunks and tree canopy. The resulting classified point cloud is used to automatically derive information on the different fuel components

Photo: Carolina Luiz

that are important for fire hazard assessment such as total biomass, fractional cover and height. These results open a pathway of automatically deriving detailed vegetation structure information from ground-based LiDAR.

The team have also developed a pre-operational near-real time flammability data service (The Australian Flammability Monitoring System) to support fire risk management and response activities such as hazard reduction burning and pre-positioning firefighting resources and, in the long term, the new National Fire Danger Rating System. The prototype service is being built in consultation with end-users to make sure the system is adapted to their needs in terms of data content and formats. Ongoing evaluation and improvement is key aspect of the prototype development.

In 2017, project leader Dr Marta Yebra was awarded the prestigious Max Day Environmental Science Fellowship from the Australian Academy of Science.

Fire surveillance and hazard mapping

Lead Research Organisation: RMIT University

Project Leaders: Prof Simon Jones and Dr Karin Reinke

This project seeks to optimise the use of earth observing systems for active fire monitoring by exploring issues of scale, accuracy and reliability, and to improve the mapping and estimation of post-fire severity and fuel change through empirical remote sensing observations. Understanding the trade-offs between sensors and their ability to map and measure fire-related attributes over a range of different landscapes and fire scenarios is important.

The study has is improving the accuracy of vegetation monitoring for flammability, as well as saving critical man hours, through the development of a beta smartphone application. Fuels3D, built on the Android platform, will allow land managers to rapidly collect imagery in the field, and uses computer vision and photogrammetric techniques to calculate measures of fuel and severity metrics.

Additionally, this project is leading Australian contributions to integrate and enhance Australian-led existing disaster monitoring and reporting systems with next generation earth observation technology and systems from the German Aerospace Centre and other agencies.

Outcomes will enable satellite measures of fire activity to be made, which in turn have the potential to inform or support efforts in bushfire response planning and fire rehabilitation efforts. A particular focus is on the analysis of data obtained from Himawari-8, which is able to provide updated imagery on a 10 minute basis.

The project is currently using simulations and real world experiments to determine the accuracy with which fires can be detected, their temperature and shape determined, for a range of landscapes.

The project is also creating new techniques and protocols for the rapid attribution of fire landscapes (pre- and post-fire). These techniques seek to add quantitative vigour to existing fuel hazard estimation practices.

End-user says...

Simeon Telfer, Department of Environment, Water and Natural Resources South Australia

> This project has engaged end-users through development of prototype products, workshops and circulating outcomes and published materials. The Fuels3D app has been of particular interest, and has the potential to reduce fire fuel sampling times from hours per site to minutes. This would enable many more data points to be collected, benefiting several emergency management areas.

Fire spread prediction across fuel types

Lead Research Organisation: Victoria University

Project Leader: Associate Prof Khalid Moinuddin

Bushfires occur on a scale that may be measured in kilometres. However, a challenge faced in developing next generation bushfire models is to capture the significant contributions that small scale phenomena make to the spread of bushfires.

This project is applying physics-based approaches to fire scenarios. It attempts to simulate fire with unprecedented detail and in the process obtain useful application tools for end-users. To address existing gaps in the mathematical and computational modelling of bushfire dynamics, an ideal fire scenario is subdivided into four parts.

Modelling wind speed through tree canopies

The rate of spread of a bushfire depends both on fuel types and the wind velocity profiles at ground and tree canopy levels. Ground cover, tree trunks, branches and leaves all affect the velocity profile. This particular aspect of the project aims to understand the velocity profile within the tree canopy in order to predict the wind reduction factor, which is present in some empirical models of fire spread. This work will improve the modelling of wind-driven fire behaviour as it enters, traverses and leaves a wooded area. The project will develop a set of user-friendly tools to calculate wind reduction factor (WRF) and improved wind field generating software. WRF will be computed as a function of existing forest parameters and prevailing weather conditions and will assist fire behaviour analysts to utilise WRF to predict the rate-of-spread and intensity of a fire.

Spread and distribution of firebrands

Embers and firebrands carried ahead of the main fire front often dominate the rate of spread of bushfires. The team is harnessing its expertise in aerodynamics to design, construct and operate a firebrand generator to accurately quantify how embers disperse. Along with wind speed, bushfire spread rates strongly depend on the physical and chemical properties of vegetative materials, such as grasses, wood and leaves. To prepare for experiments using the generator, the team invested in equipment and training for measuring properties such as thermal conductivity, specific heat, density, heat of pyrolysis, heat of combustion and reaction rate constants. These studies will assist in understanding the propensity of grasses and litter fuels to ignite from firebrands.

Improving computational methods

Physics-based models of bushfires must consider phenomena that occur on length scales that range from a fraction of a millimetre (e.g. flame thickness) up to several hundred metres (e.g. in terrain). The researchers have addressed this challenge by considering how the average of the small-scale phenomena would affect large-scale phenomena, such as the length and intensity of flames.

Bushfire-driven airflow over surface features

This aspect of the study applies the principles of engineering science to calculate bushfire-generated airflows above buildings, structures and forests. The aim is to quantify the behaviour of airflow and heat transfer in order to calculate how the wind profiles above the surface features of variable heights changes. The approach is to calculate details of the flow and heat transfer to produce highly accurate solutions, from which simple-to-use equations are extracted for operational use.

Threshold conditions for extreme fire behaviour

Lead Research Organisation: University of Melbourne

Lead Researcher: Dr Trent Penman

While a number of advances have been made in understanding bushfire development under extreme conditions, these have not been quantified in a manner that is suitable for inclusion in fire behaviour modelling framework. This project aims is to develop statistical models that allow for the inclusion of dynamic effects when they are important – that is, when fires grow sufficiently large and complex.

The study is identifying the thresholds beyond which dynamic fire behaviour becomes a dominant factor, the effects that these dynamic effects have on the overall power output of a fire, and the impacts that such dynamic effects have on fire severity. This will necessarily include consideration of other factors such as how fine fuel moisture varies across a landscape.

The research team is investigating the conditions and processes under which bushfire behaviour undergoes major transitions, including fire convection and plume dynamics, evaluating the consequences of eruptive fire behaviour (spotting, convection driven wind damage, rapid fire spread) and determining the combination of conditions for such behaviours to occur (unstable atmosphere, fuel properties and weather conditions).

There are three overlapping research activities:

1. Collating fire behaviour observations - creating a database of observations of extreme fire behaviour to use in model development and verification, working with government agencies to develop reconstructions of past fires.
2. Understanding extreme fire weather and fire behaviour - determining the thresholds in fire and environmental conditions (weather, fuel, topography) that lead to extreme fire phenomena, such as fire tornados and ember storms.
3. Factors linked to extreme fire behaviour - developing simple statistical equations to represent dynamic fire phenomena that can be integrated into existing fire-behaviour models.

It is expected that both the research and operational management communities will benefit by greatly

improving knowledge of extreme bushfires. Currently, there is limited information with which to develop new models or test theories about extreme fire behaviour.

This project will create new observational datasets of such fires and use them to describe empirical relationships between fire phenomena and the key environmental conditions that drive them. These relationships could be incorporated into existing fire simulation systems and generate further research, including the verification of physics-based models and the development of new theories of fire propagation.

The research will be utilised through the development of guidelines for identifying environmental conditions causing the extreme fire behaviour phenomena during operational fire behaviour analysis and improved fire behaviour simulators through the inclusion of extreme fire behaviours.

These outputs will result in improved prediction of fire behaviour at the point where damage to property and loss of life is more likely. Improved predictions will improve the knowledge base of fire managers and their ability to make informed decisions during fires and about landscape vulnerability. This will include improving the efficiency and safety of fire suppression activities, better targeting of public information and warnings, and an improved understanding of the potential effectiveness strategies for managing landscape fire risk.

Fire coalescence and mass spot fire dynamics

Lead Research Organisation: University of New South Wales

Lead Researcher: Associate Prof Jason Sharples

Fire behaviour in dry eucalypt forests in Australia is characterised by the occurrence of spotfires—new fires ignited by the transport of embers ahead of an existing fire. Under most burning conditions, spotfires play little role in the overall propagation of a fire, except where spread is impeded by breaks in fuel or topography. Spotfires allow these impediments to be overcome.

However, under conditions of severe bushfire behaviour, spotfire occurrence can be so prevalent that spotting becomes the dominant propagation mechanism and the fire spreads as a cascade of spotfires forming a ‘pseudo’ front.

It has long been recognised that the presence of multiple individual fires affects the behaviour and spread of all fires present. The converging of separate individual fires into larger fires is called coalescence and can lead to rapid increases in fire intensity and spread rate, leading to the phenomenon of a ‘fire storm’. This coalescence effect is frequently used in prescribed burning, with multiple point ignitions used to rapidly burn out large areas.

This project is focusing on:

- Fire coalescence to provide better predictions of fire propagation
- The intrinsic dynamics of flame front propagation as a contributor to fire spread across different spatial and temporal scales
- Within a simulation framework an end-to-end model of the behaviour of mass spotfires, from firebrand/ember launch to fire coalescence.

The modelling and simulation aspects of the project have contributed to understanding the processes that drive fire coalescence and dynamic fire spread. In particular, the research has addressed the role that fire-line geometry (especially curvature) plays in the dynamic propagation of bushfires.

The team has demonstrated the performance advantages of fire propagation models incorporating curvature dependence when applied to simple wind-driven fires at both laboratory and field scales. The research has also produced fundamental insights into how the shape of the fire line affects the dynamic behaviour of the fire as a whole. Coupled fire-atmosphere modelling was used to investigate how fire-induced air movements (pyroconvection) can produce significantly enhanced rates of spread for certain fire shapes.

Utilising the research outcomes will include development of education and training materials relating to dynamic fire behaviour and extreme fire development, which will incorporate the research findings on fire coalescence and mass spotfires.

Research findings will also be used to develop metrics of relevance to the National Fire Danger Rating Project. In particular, existing measures of 'convective fire power' based solely on information relating to the fire perimeter will be extended to include contributions from within flaming zones where spot fire coalescence can contribute significantly to pyroconvective release.

End-user says...

Dr Simon Heemstra, Manager Community Planning, NSW Rural Fire Service

"We need better understanding and modelling of how a fire will progress and when it will impact on communities. Greater precision in predicting the size and timing of bushfires will enable fire agencies to better target their warnings and that will help to save lives. Increasing knowledge of the role and influence of weather and ember dispersion ahead of the main fire front is critical for fire agencies in warning and preparing communities under those extreme events."

BUILT ENVIRONMENT

Lead End-Users: Leesa Carson, Geoscience Australia and Andy Hinton, Department of Fire and Emergency Services, Western Australia

Research Leader: Prof Michael Griffith, University of Adelaide

Natural hazard exposure information modelling framework

Lead Research Organisation: Geoscience Australia

Project Leader: Dr Krishna Nadimpalli

Exposure in disaster risk reduction describes what is at risk; including people, buildings, infrastructure, businesses, hazardous substances and primary industries. Exposure information comprises the details needed to support situational awareness at all levels of governance and in various phases of disaster management.

The severity of a disaster depends on how much impact it has on exposure. The scale of impact in turn depends on the decisions made as a part of disaster mitigation. Therefore, exposure information is a fundamental requirement for decision making in disaster mitigation.

This project, now in its utilisation phase, has addressed the data and knowledge gaps and requirements for disaster resilience, resource assessment, emergency management, risk mitigation policy and planning. It identified the fundamental data requirements and modelling framework to derive exposure information to enable a better understanding of the vulnerability of people, buildings and infrastructure.

The project is a significant step towards developing national exposure information capabilities in Australia. The framework will support impact assessments on people, economy, infrastructure and the environment, caused by natural hazards such as bushfires, floods, cyclones and earthquakes.

A number of nationally consistent frameworks were developed, which will help a diverse range of end-users. The frameworks include:

- Built environment exposure – considers the attributes of assets to assess their vulnerability to natural hazards. The building exposure considers usage, type, structural system, number of storeys, size, age, attachments, replacement value and contents value. The infrastructure sectors considered are transportation, energy, communication, urban water supply, waste management, hazardous substances and major industries. The primary industries considered are agriculture, fishing, forestry and mining sectors.
- Business and economics exposure – consists of business definitions, assets and activities which

are deemed necessary for assessment of business continuity, disruption, resilience and recovery indicators in disaster management.

The study also reviewed current exposure information provision capabilities to identify key issues, needs, gaps, overlaps and deficiencies. An extensive literature review has been undertaken, along with stakeholder consultations to identify comprehensive list of information requirements. A survey with end-users identified significant gaps in the availability of existing data and the translation into meaningful information for evidence based disaster decision making. The built environment exposure information framework has been completed. To reduce the complexity, it categorises the information into three levels depending on the requirements of the user: policy and planning; response and recovery; research and analysis. The framework presents the fundamental characteristics of exposed assets to natural hazards as components, elements and attributes. The exposure components considered in the framework are buildings, people, businesses and infrastructure.

Improving the resilience of existing housing to severe wind events

Lead Research Organisation: James Cook University

Project Leaders: Associate Prof John Ginger and Dr David Henderson

Typically, older Australian houses built prior to the mid-1980s do not offer the same level of performance and protection during severe wind as houses constructed to contemporary building standards. Given that these existing older houses will represent the bulk of the housing stock for many decades, practical structural upgrading solutions based on the latest research will make a significant improvement to housing performance during storms, and to the economic and social well-being of the community.

This project is developing the evidence base for risk mitigation by devising simple practical and economic upgrading options for existing houses. The outcomes will promote retrofit investment by home owners and provide a basis for incentives to encourage this action through insurance and government initiatives.

The primary objective is to develop cost-effective strategies for mitigating damage to housing from severe windstorms across Australia. Outputs from this project will target a range of end-users, from policy development through to homeowners and builders on recommended actions to improve resilience of existing housing. The uptake of the research will reduce the cost of natural disasters in Australia.

The project has collected and analysed information from the impacts of tropical cyclones and thunderstorms, which will provide valuable input into the development of vulnerability modelling. It has published reports on recent events including the 2014 Brisbane thunderstorm, 2015 tropical cyclones *Nathan, Marcia* and *Olwyn*, and 2017's Cyclone *Debbie*.

Photo: Cyclone Testing Station

Storms outside of the tropics are also part of the study, with the team conducting surveys in Adelaide and Canberra. The geometry of houses in south east Australia is the least understood, and to address this the team undertook a desktop examination using aerial imagery and Google Street View of 467 houses in Canberra to determine the most common geometries from houses constructed in the 1960s.

The team has also collaborated with the insurance company Suncorp to analyse 25,000 insurance claims from cyclones *Larry* (2006) and *Yasi* (2011), with the purpose of gaining a better understanding of the drivers of cyclone damage.

The project will categorise residential structures into types based on building features that influence windstorm vulnerability using Geoscience Australia and Cyclone Testing Station survey data. From these a suite will be selected to represent those contributing most to windstorm risk.

The project has engaged heavily with key stakeholders and will continue to involve end-users and stakeholders (homeowners, builders, regulators, insurers) to assess amendments and provide feedback on practicality, cost-effectiveness and aesthetics of potential upgrading methods for a range of buildings. A webinar series has also been piloted, allowing home owners to understand the importance of making appropriate decisions at various stages of the building process, and providing information on various aspects of building to resist wind loads for builders, certifiers and designers to become aware of issues that have caused failures previously.

Vulnerability models will be developed for each retrofit strategy using survey data, the authors' existing vulnerability models, and the NEXIS database of Australian housing characteristics. Case studies will be used to evaluate effectiveness of proposed retrofit solutions in risk reduction. Economic assessment using these case studies will be used to promote uptake of practical retrofit options.

Cost-effective mitigation strategy development for building related earthquake risk

Lead Research Organisation: University of Adelaide

Project Leader: Prof Michael Griffith

The objective of this research is to develop strategies to mitigate damage, injury and business disruption associated with the earthquakes in the most vulnerable buildings of Australia's cities.

Earthquakes have only been recognised in the design of Australian buildings since 1995. This failure has resulted in the presence of many buildings that represent a high risk to property, life and economic activity. These buildings also contribute to most of the post-disaster emergency management logistics and community recovery needs following major earthquakes. This vulnerability was in evidence in the Newcastle earthquake of 1989, the Kalgoorlie earthquake of 2010 and with similar building types in the Christchurch earthquakes in 2010 and 2011. With an overall building replacement rate of 2% nationally, the legacy of vulnerable building persists in all cities and predominates in most business districts of lower growth regional centres.

This study is drawing upon and extending existing research and capability within both academia and government to develop information that will inform policy, business and private individuals on their decisions concerning reducing vulnerability. It is also drawing upon New Zealand initiatives that make use of local planning as an instrument for effecting mitigation.

The project's scope includes all typical building construction types in Australia as specified in Australian Standard for Earthquake Loading AS 1170.4. It excludes special construction such as power plants, offshore structures and other industrial/manufacturing structures. A case study is being undertaken in the earthquake-prone town of York in Western Australia.

While the focus of this project is on buildings, many outputs will also be relevant for other infrastructure such as bridges, roads and ports, while at the same time complementing other CRC projects for severe wind and flood.

To achieve this, the project has sifted through the data that is available from the Christchurch experience to establish what earthquake retrofit techniques worked and what did not as a starting point in developing a menu of economically feasible seismic retrofit techniques that could be used in Australian cities.

Other research studies conducted have investigated the effects of local site conditions on ground shaking, assessed buckling and instability failures of lightly reinforced concrete walls, and reviewed the economic loss modelling of earthquake damaged buildings, among others.

This information will be fed into a decision support tool being developed that will be used by

end-users to develop consistent national policies for the application of seismic design of new buildings and retrofit of existing buildings.

Development of the research outcomes in utilisation will include a rapid screening procedure. It will be used during post-disaster emergency management to swiftly flag unsafe buildings and reduce the operational costs at that time. State governments are increasingly become aware and concerned about the risk that earthquake poses to older unreinforced masonry and low ductility reinforced concrete buildings in communities. Regulations are likely to be developed for requiring the building owner to assess their buildings and retrofit/demolish if required. The first step in the seismic assessment of buildings is screening as done in many other seismically active countries. It is fast and suitable and only earthquake prone buildings will need to undergo further detailed assessment.

Other outputs include a report on the economic impact of a proposed change in the earthquake hazard in Australian cities. The newly developed hazard map rationally represents the earthquake risk posed than the existing map in the current code. For a change to be made, the economic impact on construction industry will need to be assessed.

A further output includes a demonstration for end-users of the benefits of retrofitting older buildings and reducing the expected earthquake loss. This will encourage governmental to develop regulations for seismic retrofit of risky buildings and to eventually make communities safer.

Cost-effective mitigation strategy development for flood-prone buildings

Lead Research Organisation: Geoscience Australia

Project Leader: Dr Tariq Maqsood

The motivation for this project came from observations of widespread devastation during the 2011 and 2013 flooding in Queensland. A fundamental reason for this damage was inappropriate development in flood plains and a legacy of high risk building stock in flood prone areas.

The project is developing cost-effective strategies to mitigate damage to residential buildings from riverine floods. The research is providing evidence-based retrofit strategies for decisions concerning buildings with the greatest vulnerability in Australia.

Floods impact many Australian communities, with some communities inundated repeatedly due to inappropriate urban development in flood plain areas. This results in significant logistical issues for emergency management, disruption to communities, and considerable cost to all levels of government to repair damage and to enable communities to recover. There is a need for supporting information on the cost effectiveness of mitigating the risk posed by existing buildings either through retrofit, reconstruction on the site or relocation.

End-user says...

Leesa Carson, Branch Head, Community Safety, Geoscience Australia

> This project will provide an important evidence base to assist governments and householders make informed decisions on retrofit options for existing houses to reduce the vulnerability of these buildings to flooding.

This project is building on existing research to broaden the knowledge of the vulnerability of Australian building stock to riverine flooding and is identifying suitable retrofitting strategies.

Existing building schema have been assessed, both national and internationally. This led to the development of a new building classification schema to categorise residential buildings into a range of typical storey types. Mitigation strategies developed nationally and internationally have been reviewed.

A flood-proofing matrix has been developed to assess appropriate strategies for the five selected building types.

After the June 2016 flooding in Launceston, the significant mitigation works that had recently been completed to project the city were reviewed. This work highlighted the benefits of the mitigation (flood levees) in terms of likely damage had the levees not been in place. The research also assessed the effectiveness of further investment in mitigation works to reduce the residual flood risk.

Utilisation of this research involves gathering an evidence base comprising of vulnerability information and cost effective mitigation options along with the costs and benefits of investment to inform decision making by home owners to reduce flood risk.

This research will also be suitable for integration in a guideline document to estimate flood damage and to assess mitigation measures in consistency with the ADR Handbook 7. Flood risk managers will be able to utilise increased knowledge of flood vulnerability and mitigation at a suitable resolution which is compatible with existing level of exposure information.

Enhancing resilience of critical road infrastructure

Lead Research Organisation: RMIT University

Project Leader: Prof Sujeeva Setunge

Road networks and critical road structures such as bridges, culverts and floodways have a vital role before, during and after extreme events to reduce the vulnerability of the community.

A major gap in the current research is the lack of assessment techniques and tools to reduce the vulnerability of road structures to enhance both community and structural resilience. This project is developing tools and techniques to enhance the resilience of road infrastructure to hazards such as floods, bushfires, earthquakes and climate change-related weather events.

The study is undertaking research to:

- Advance the understanding of the factors required for quantifying the impact of hazards on road structures.
- Understand failure mechanisms under different hazards and vulnerable structural forms, with structures grouped according to vulnerability.

Case studies have been completed and numerical analyses have been conducted to understand the vulnerability of roads to different hazards.

Flood, bushfire and earthquake have been investigated, with two case studies on bridges, and one on floodway failure. The project has also begun the development of the methodology for vulnerability modelling of bridges and floodways. A field study was undertaken to examine the community impact due to failure of road structures during the 2011 and 2013 floods in the Lockyer Valley in Queensland.

A number of workshops were also held to identify case study data and refine the methodology for vulnerability modelling.

Australian design standards for bridges and floodways have been examined and a comparative study of international standards undertaken, along with an analysis of design standards and applied loads on road structures under extreme events.

The next stage of the study will expand the vulnerability modelling and develop a GIS tool which can be used to demonstrate the benefits of the approaches developed.

Photo: Hessam Mohseni

End-user says...

Leesa Carson, Branch Head, Community Safety, Geoscience Australia

"This research will assist stakeholders, from governments and emergency management agencies, through to individuals, make informed decisions about how they can best mitigate damage to buildings and crucial road infrastructure. Incorporating flood and storm vulnerability, the research will provide an important evidence base about the most cost-effective ways to reduce damage to buildings and ensure our roads can withstand natural hazards, allowing local communities to resume business as usual as quickly as possible. For earthquake, our most vulnerable infrastructure is unreinforced masonry and low ductility reinforced concrete frames, and testing will achieve practical outcomes to strengthen our buildings."

SEVERE AND HIGH IMPACT WEATHER

Lead End-User: John Bally, Bureau of Meteorology

Research Leader: Dr Jeff Kepert, Bureau of Meteorology

Improved predictions of severe weather to reduce community impact

Lead Research Organisation: Bureau of Meteorology

Project Leader: Dr Jeff Kepert

This project is using high-resolution modelling, together with a range of meteorological data, to better understand and predict important meteorological natural hazards, including fire weather, tropical cyclones, severe thunderstorms and heavy rainfall. The outcomes from the project will contribute to reducing the impact and cost of these hazards on people, infrastructure, the economy and the environment.

Specific case studies undertaken include the New South Wales Blue Mountains bushfires of 2013; ember transport by fire plumes; pyrocumulus cloud simulation and prediction, and the NSW April 2015 East Coast Low.

Ember transport

The study has been developing understanding of how fire embers generated during bushfires can be lifted into the atmosphere and carried by winds ahead of a fire front, potentially starting new fires downwind. The team has undertaken simulations for ember transport for a wide range of wind speeds and ember fall speeds. It is important to consider a range of fall speeds, since different types of embers have different densities and aerodynamic properties which affect how far they are carried.

Pyrocumulonimbus

Plume modelling has also been utilised to study pyrocumulonimbus clouds (PyroCb). Intense fire plumes in suitably moist environments can lead to PyroCb development, with the possibility of strong downbursts which can exacerbate already extreme fire conditions. A survey of current understanding and forecast techniques has been completed, and the team will be working towards developing improved techniques.

Blue Mountains bushfire

A detailed case study of the Blue Mountains fires of October 2013 was undertaken, focusing on 17 October when some 200 houses were destroyed. Analysis uncovered a weather phenomenon known as mountain waves which contributed to the severe fire behaviour. Mountain waves are atmospheric oscillations that occur due to air flowing over hills or mountains. They can arise in several different ways, some more predictable than others. Often they cause strong downslope winds on the lee slope of the hill or mountain.

April 2015 East Coast Low

Collectively, the ensemble weather simulations accurately predicted the position and intensity of the low, the strong winds and the rainfall. The differences between them give insight as to the forecast uncertainty, the overall envelope of areas at some risk, and the areas at highest risk. The ensemble also enables insight into the processes that lead to the rapid intensification of these systems. The team is continuing to learn from ensemble simulations about predictability of East Coast Lows and how to use this information to benefit both forecasters and the emergency services.

Specific outcomes of this project will:

- Improve the scientific understanding of severe weather phenomena in Australia.
- Improve the knowledge of how to best predict these phenomena, including model configuration and interpretation.
- Contribute to the post-event analysis and lessons learned of selected severe events that occur during the course of the project.
- Inform the development of numerical weather prediction systems specifically for severe weather.

End-users say...

Lachie McCaw, Principal Research Scientist, Department of Parks and Wildlife Western Australia

"This research has drawn attention to an important but hitherto neglected weather phenomenon that can cause bushfires to behave with unexpected severity on downslope terrain in the lee of a mountain range. An interesting finding from the work is that, under some conditions, mountain wave phenomena may occur in areas where the local relief is as small as one or two hundred metres. High resolution numerical weather modelling has contributed to improved understanding of the factors associated with strong downslope winds. Having the ability to identify situations where strong downslope winds are likely to occur would allow better planning of fire suppression operations, reducing risks to firefighters and the community in affected areas. Further work is required to develop weather products that can convey information about the location of areas prone to downslope winds and the likelihood of wind speeds exceeding specified thresholds."

Dr Paul Fox-Hughes, Research Meteorologist, Bureau of Meteorology

"Severe weather events can affect large areas, but their most damaging aspects tend to be concentrated in relatively small regions, and the mechanisms that underlie this observation are not always obvious. For this reason, the high resolution numerical weather modelling that this project has undertaken is vitally important for our understanding of the processes leading to severe weather."

Photo: CFA

Coupled fire-atmosphere modelling

Lead Research Organisation: Bureau of Meteorology

Lead Researchers: Dr Jeff Kepert and Dr Mika Peace

Bushfires affect the surrounding atmosphere because of the large amount of heat and moisture released as a result of combustion. The atmospheric response to this energy input includes changes to the local winds, modification of the boundary layer, and the development of pyroconvective clouds. These changes can profoundly modify the evolution of the fire. This project is:

- Developing an Australian coupled fire-atmosphere modelling capability based upon the national numerical weather prediction infrastructure.
- Developing a better understanding the contribution of fire-atmosphere interaction and three dimensional atmospheric structure to fire behaviour, including spread, intensification, and 'low-up' behaviour.
- Developing a better understanding the impact of fire on the atmosphere, including fire-generated winds and their damage potential, ember transport and plume development.

- Progressing towards an eventual operational capability for coupled fire-atmosphere modelling within Australia.
- Improving operational fire prediction services by efficiently transferring the knowledge gained in this project and others to fire weather forecasters and to fire behaviour analysts.
- Exploring the development of computationally efficient methods for robustly accounting for fire-atmosphere coupling in fire prediction.

The project uses the premier operational Australian high-resolution weather prediction model, the Australian Community Climate and Earth-System Simulator (ACCESS), coupled to a fire spread model.

The coupled fire-atmosphere model ACCESS-Fire will be installed on national Australian computing infrastructure for research application, with future capability for operational use. The model will be used to run a series of case studies. Detailed examination of high impact events and verification against available meteorological and fire behaviour data will highlight the importance of assessing and predicting the likelihood of fire-atmosphere interactions in anticipating fire evolution. The close links of the project team with operational and training activities will provide a clear pathway for implementing research findings.

The January 2016 Waroona bushfire in Western Australia has been selected as the first case study to test the model. Over a two-day period, there were two separate pyro-convective thunderstorms, triggered by different processes during the diurnal cycle. In addition, analysis of Doppler radar data shows detail of the rapid plume development that contributed to the ember shower which burnt Yarloop, causing two fatalities.

This research into interactions with topography, potential for pyro-convection, potential for three dimensional interactions, potential for winds to change substantially around a fire, water vapour dry slots, plume development and spotting process will be integrated into a formal, quantitative system for use with the current fire forecasting system.

Improving land dryness measures and forecasts

Lead Research Organisation: Bureau of Meteorology

Project Leader: Dr Imtiaz Dharssi

Good estimates of landscape dryness underpin fire danger ratings, fire behaviour models, and flood prediction. Soil dryness also strongly influences heatwave development by driving the transfer of solar heating from the soil surface into air temperature rise.

Fire intensity, spread rate and ignition are sensitive to the fuel dryness, which is strongly linked to soil moisture content. Estimates and forecasts of fuel dryness and soil moisture are the foundation of the fire danger calculations used to rate and manage bushfires and to warn of developing fire

End-user says...

Mark Chladil, Fire Management Planning Officer, Tasmania Fire Service

> The results so far are both encouraging and tantalising. Fire danger forecasting and operational fire-behaviour prediction is limited by the relatively crude soil moisture modelling we commonly use. The availability of the advanced, finescale, multi-layer soil-moisture information arising from this project will be a boon to fire behaviour analysts everywhere in Australia, even though the richer data will be a challenge for us to understand, exploit and communicate.

danger. Similarly, estimates and forecasts of soil moisture are essential ingredients to be able to forecast with accuracy river flows on a seasonal scales (one to three months), which is much in demand by water managers and reservoir operators.

This research has developed a prototype, high-resolution soil-moisture analysis system called JASMIN, which is a significant improvement in accuracy compared to currently used models. It is based on research that examines the use of land surface models, remotely sensed satellite measurements and data assimilation techniques to improve the monitoring and prediction of soil dryness. The new information will be calibrated for use within the existing fire prediction systems. This retains the accuracy, temporal and spatial resolution of the new product without changing the overall climatology of Forest Fire Danger Index and other calculations based on soil moisture.

A pilot project is being initiated, where rescaled outputs from routine JASMIN runs with daily updates will be published in registered user webpages for fire agencies to assess. The routine updates will also be disseminated to the Bureau of Meteorology's extreme weather desk, where the severe weather forecasters can assess the product using the forecasting tools (for example, the Bureau of Meteorology's Visual Weather product) available to them. Also, fire agencies using Visual Weather will be able to use the outputs directly.

A case study of the State Mine fire in the Blue Mountains in October 2013, compared JASMIN with the traditionally used Keetch-Byram Drought Index. JASMIN is far drier compared to KBDI, which may be under-predicting the soil dryness, as verifications have shown that it generally has a large wet-bias.

Immediate benefits for emergency and land management agencies will be improvements to the fire danger rating and warning system, fire behaviour and flood prediction models, which will flow on to emergency warnings issued to the public. The project's long-term goal is to integrate JASMIN's outputs into the new National Fire Danger Rating System.

bushfire&natural
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