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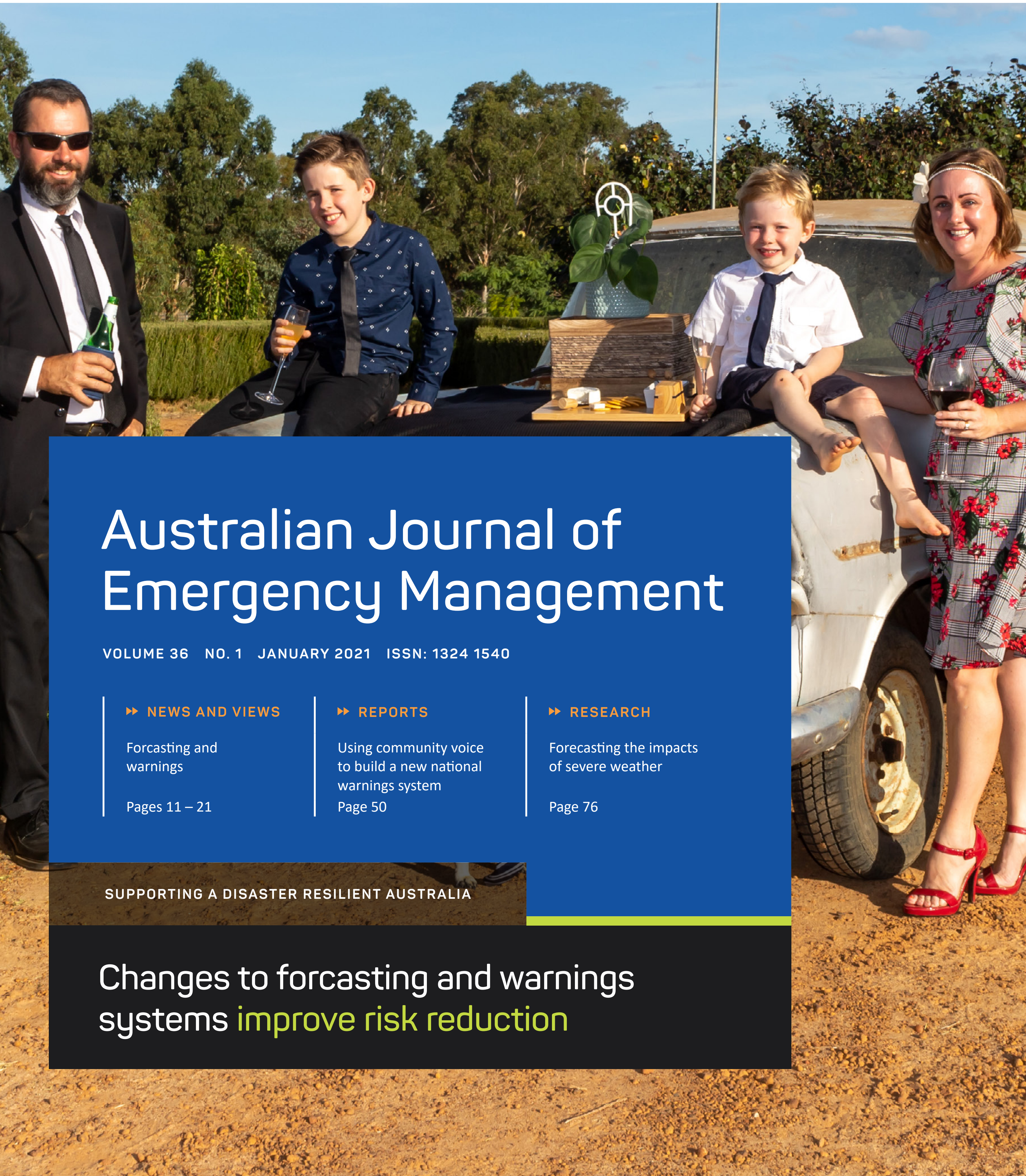

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SUPPORTING A DISASTER RESILIENT AUSTRALIA

Changes to forcasting and warnings systems improve risk reduction

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The *Australian Journal of Emergency Management* is Australia's premier journal in emergency management. Its format and content are developed with reference to peak emergency management organisations and the emergency management sectors—nationally and internationally. The journal focuses on both the academic and practitioner reader. Its aim is to strengthen capabilities in the sector by documenting, growing and disseminating an emergency management body of knowledge. The journal strongly supports the role of the Australian Institute for Disaster Resilience as a national centre of excellence for knowledge and skills development in the emergency management sector. Papers are published in all areas of emergency management. The journal encourages empirical reports but may include specialised theoretical, methodological, case study and review papers and opinion pieces. The views in the journal are not necessarily the views of the Australian Government, Australian Institute for Disaster Resilience or its partners.

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Foreword

Tony Pearce
Inspector-General for Emergency Management Victoria

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Recognising the importance of the subject matter it was a pleasure to be invited to contribute to this edition of the *Australian Journal of Emergency Management* on the topic of warnings.

The Australian journey regarding warnings has been a long one, and while the concept of a national warning system had been under consideration for some time, momentum really started to gain pace following the development, testing and analysis of the Community Information and Warning System in Victoria in 2004. While the systems, processes and technology used for the trial were ahead of their time, Australia has not sat on its laurels. Since then, Australia has developed and implemented a national warning system, Emergency Alert, which has progressed in leaps and bounds.

It would come as no surprise that the issue of warnings and public information comes up frequently in inquiries. In the 2009 Victorian Bushfires Royal Commission and numerous inquiries since including, most recently, the independent Inquiry into the 2019–20 Victorian Fire Season, the Royal Commission into National Natural Disaster Arrangements and the independent bushfire inquiries in New South Wales, South Australia and Queensland, the issue of how to improve capacity to provide timely and meaningful warnings and public information arises. In response to this scrutiny, and with a natural desire for continuous improvement, it is fair to say that the emergency management sector continues to work hard to improve what has been developed. Improvement is based on experience of an increasing frequency and duration of emergencies that present increased complexity, reveal greater community need and create a greater expectation of warning systems that are all things to all people.

Having a technologically advanced warning system is one thing, however, its capacity to provide enhanced community safety outcomes relies on more than just technology. Community awareness of risk is important to ensure that warnings are received in context and community education about the purpose, capacity and limitations of the system is important. It is crucial that a warning system be more than just a method of providing a call to action. It also needs to provide timely and accurate information to assist in community decision-making as, after all, we are increasingly expecting communities to share responsibility for their safety outcomes.

Warning and information systems are integral as part of a broader functional community safety system. Ongoing research, education and appropriate investment are enablers to continuous improvement in this critical space. No system is perfect, and we will always, through a combination of planned improvement activity and the inevitable inquiries, find ways to do it better.

As I frequently say when conducting inquiries, 'Anything that hurts you can teach you, and if it keeps hurting you it's because you haven't learnt'. This applies equally to the improvement of warning systems as it does any other emergency management activity. I look forward to seeing further advances in the provision of warnings and information in the future.

The Royal Commission and the Australian Constitution

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This paper reviews some recommendations from the 2020 *Royal Commission into National Natural Disaster Arrangements* (the Royal Commission). The Royal Commission delivered a nearly 600-page report that contained 80 recommendations. This paper does not review each of those recommendations but focuses on the constitutional and legislative considerations as they relate to recommendations about the proposed role of the Commonwealth in coordinating interstate resource sharing, the power of the Australian Government to declare a national state of emergency and the enhanced used of the Australian Defence Force (ADF) in disaster response.

Recommendation 3.6 Enhanced national preparedness and response entity

The Royal Commission was tasked with inquiring into, inter alia, 'the responsibilities of, and coordination between, the Commonwealth and State, Territory and local Governments relating to preparedness for, response to, resilience to, and recovery from, natural disasters…' (Hurley 2020). The commission recommended:

The Australian Government should enhance national preparedness for, and response to, natural disasters, building on the responsibilities of Emergency Management Australia, to include facilitating resource sharing decisions of governments and stress testing national disaster plans.

With respect to the sharing and coordination of resources during a response to an emergency, and in particular bushfires, the Royal Commission identified the role of the Australasian Fire and Emergency Services Authorities Council (AFAC) and, within AFAC, the Commissioners and Chief Officers Strategic Committee (CCOSC), the National Resource Sharing Centre (NRSC) and the National Aerial Firefighting Centre (NAFC). Up until now, it has been AFAC that has coordinated resource sharing and the movement of personnel and resources across interstate and international borders. The Royal Commission (2020, [3.70]) noted that:

Each of CCOSC, NRSC and NAFC has evolved and expanded to respond to emerging needs in emergency management, responding to gaps and the evolution of emergency response in the face of significant natural disasters. They have done so incrementally, with the objective of enhancing emergency management across Australia, noting AFAC's focus on a particular subset of disasters.

Note: The reference to a 'subset of disasters' related to the fact that AFAC and the CCOSC are made up of various fire agencies and State Emergency Services and so have a focus on the work of those agencies, being fires, floods and storms. AFAC does not play a coordinating role in any other type of disaster that has or may occur.

The Royal Commission (2020, [3.93]) noted that the Australian Government's coordinating body is the National Crisis Committee (NCC). The:

... NCC is recognised in the AGCMF [Australian Government Crisis Management Framework] as being the appropriate crisis committee to facilitate cooperation and coordination between the Australian Government and the relevant states and territory government(s) in response to domestic crises. The AGCMF, then, and now, recognises CCOSC but states that 'CCOSC's role in Australian Government crisis management arrangements is limited to information sharing on operational matters during significant events'.

Even so 'CCOSC appeared to function in lieu of the NCC during the 2019–2020 bushfires' ([3.94]) The CCOSC met at least 9 times whereas the NCC met only twice ([3.92]).

At [3.164] the Royal Commission said:

The Australian Government should assume, and make, standing arrangements for, the coordination and procurement functions of NAFC and NRSC.

With respect to the commissioners, their recommendation appears doctrinal with a view of the role of government and the Commonwealth rather than a clear exposition of why the Australian Government making 'standing arrangements for, the coordination and procurement functions of NAFC and NRSC' would work better than the arrangements currently in place, with state agencies working collaboratively with their interstate and, in the case of wildland fire, international colleagues. The rationale for their recommendation was ([3.109]–[3.110]):

Discussions and decisions that facilitate consideration of national policies and the sharing of government resources in natural disasters should fall within the clear auspices of governments.

The functions performed by NRSC and NAFC should be subject to public sector accountability and oversight, to provide greater public confidence.

And at [3.156] '... the Australian Government is well positioned to coordinate and integrate a greater range of resources beyond just fire and emergency service resources'.

The Australian Government could establish a body to perform the functions currently performed by the NRSC and NAFC but it is not clear why that would 'provide greater public confidence'. That outcome would require the public to have greater confidence in Australian Government bureaucrats, rather than fire and emergency chief officers. This is a proposition that, albeit without evidence, I suspect is controversial. Former NSW Rural Fire Service Commissioner Shane Fitzsimmons is the New South Wales 2021 Australian of the Year and Professor Brendan Murphy who initially led the Australian Government's response to the COVID19 pandemic, is the Australian Capital Territory 2021 Australian of the Year (National Australia Day Council 2020). This suggests no lack of confidence in operational leaders.

Further, and with respect to the royal commissioners, it is not at all clear how this recommendation would work or what it would add, at least in the context of fire and floods. It is a fundamental principle of Australian constitutionalism that Australia is a federation made up of the states and a federal government. The states are independent entities, not created by nor subject to the Commonwealth, except as provided in the Australian Constitution (*Melbourne Corporation v Commonwealth* (1947) 74 CLR 31, discussed in more detail below). It follows that even if the Australian Government establishes a federal coordinating body, it would have no power to compel the states and territories to work through that office.

Given that the states and territories are independent, the suggested arrangements will only work if the states and territories believe it will add value to existing arrangements. The commissioners did not suggest that 'the Australian Government (or another jurisdiction for that matter) should have the ability to command or requisition another state or territory government's resources' ([3.76] and the 'Australian Government would only facilitate interstate and international deployments after the Australian, state and territory governments make decisions about their own resources' ([3.160]). If the Australian Government cannot commandeer assets, even in 'the national interest', and will only get involved after states and territories have made their own decisions, which could include resource sharing decisions, it is unclear what the recommendation would add.

The Royal Commission also noted (at [3.106]–[3.107]) that 'AFAC and some state and territory government agencies' have concerns about the commission's recommendation. Further, the NSW Independent Inquiry into the 2019-2020 Bushfires expressed concerns, suggesting:

... that changes to this overarching structure would lead to greater bureaucratisation of AFAC functions, which in turn could have a negative impact on existing flexibility and responsiveness. The [NSW] Inquiry notes that NAFC and NRSC functions are largely operationally focussed, and that moving away from the current model may be perceived as contrary to the widely accepted principle that combat agencies are best placed to determine operational requirements.

And, while it may show a certain cynicism, it's not clear why a federal government authority would be better positioned to coordinate and integrate resources more than the people who own the resources and who have responsibility for actually deploying those resources on the ground. If one can draw an analogy, the situation is akin to wanting to borrow a hammer. You could go next door and ask your neighbour or go to the Hammer Sharing Office and ask the Hammer Coordination Officer to ask your neighbour if you can borrow their hammer. No matter how well-run the Hammer Sharing Office is, neighbours can still ask each other for what they want. And, in the emergency services sector, the agencies in AFAC have established relationships that are key to effective coordination.

The recommendations in Chapter 3 went well beyond resource sharing during operational times and looked at the entire spectrum from prevention to recovery and the development of resilience within the Australian community. This discussion cannot do justice to the entire recommendations in that chapter, but it is argued that the recommendation that the Australian Government 'should assume, and make, standing arrangements for, the coordination and procurement functions of NAFC and NRSC' is controversial, constitutionally problematic and is not supported by evidence that during 2019–2020 there was any failing by NAFC or the NRSC or that the Australian Government would do a better job. Rather, that particular recommendation seems to be driven by a doctrinal belief in the role of government, and a federal government in particular. A claim that transferring decision-making during heightened operations from operational leaders to the Australian Government would 'provide greater public confidence' is, I suggest, at best optimistic.

'Make provision for a declaration of a state of emergency'

A government faced with an emergency of catastrophic proportions requires powers that allow it to take immediate and urgent action that may not be justified in the normal course of events (Fatovic 2009, p.4). The New Zealand Law Commission (1991, [4.12]) says:

Emergencies are likely to call for immediate and drastic action. It follows that legislation authorising an appropriate response should be in place in advance of the emergency itself. This factor, and the likelihood that the emergency response will involve interference with established rights, points to the desirability of preparing emergency legislation at leisure rather than under the pressure of an actual or imminent emergency.

The Australian states and territories have emergency management legislation in place. Some of that legislation, such as the Victorian Emergency Management Acts 1986 and 2013 are generic and can be applied to any type of emergency. Others, such as the *Public Health and Wellbeing Act 2008* (Victoria) are more limited and have application to only one type of emergency.

The Commonwealth of Australia did not have generic emergency management legislation even though the argument for pre-established powers and authority has been made many times. Following Cyclone Tracy's devastation of Darwin in 1974, Major General Alan Stretton commandeered property and restricted the movement of people without clear legal authority (Stretton 1976). Notwithstanding his ability to rely on de facto authority and goodwill, he recommended that legal authority was required to allow a coordinator to operate in a disaster (Stretton 1978). Lee (1984, p.192) notes that following the bombing of the Sydney Hilton Hotel in 1978, the then Leader of the Opposition (and later, Governor-General) Mr Hayden argued for Commonwealth emergency legislation:

… not so much in order to confer sweeping new powers but rather to circumscribe, confine and define their exercise, and to remove some of the extraordinary uncertainties which now prevail.

Others, including the author of this paper (Eburn 2011) continued the argument that the Commonwealth should have standing emergency management legislation in place to allow the Australian Government to set aside 'business as usual' in order to respond with flexibility and agility to an event that is 'beyond knowledge, skills, experience and imagination' (Crosweller 2015, p.50; see also Department of Home Affairs 2018, p.5 definition of 'Severe to catastrophic disaster').

The Royal Commission also recommended that the Australian Government should have power to declare a national emergency. The commissioners said (Royal Commission 2020, [5.3]–[5.4]):

To better assist states and territories in responding to and recovering from such disasters, the Australian Government should create a legislative mechanism for the making of a declaration of a state of national emergency.

A declaration would signal to communities the severity of a disaster early, act as a marshalling call for the early provision of Australian Government assistance when requested, facilitate coordination with state and territory emergency management frameworks, and, in very limited circumstances, allow the Australian Government to act without a request from a state or territory.

The value of signalling should not be overlooked. During the 2009 Black Saturday bushfires, there was no formal disaster declaration. The 2009 Victorian Bushfires Royal Commission (2010 [2.5.1]) notes:

The Commission considers that declaring a state of disaster would offer benefits beyond the grant of additional powers. First, it would provide symbolic recognition of the gravity of a situation—a recognition that … might have sharpened the focus of emergency services agencies on community safety factors such as warnings. Second, it would place the State's political leaders firmly in charge of the emergency, reassuring the public that their government had the situation in hand and facilitating rapid mobilisation of Cabinet and high-level government attention if required.

There is no doubt that the Australian Government has the power to introduce emergency management legislation that would include a power to declare a national emergency or disaster (Royal Commission 2020, [5.48]–[5.56]). What may be controversial is the recommendation that 'in very limited circumstances, [the legislation should] allow the Australian Government to act without a request from a state or territory'. However, that too is clearly within power as may be shown with an analogy with the Commonwealth's defence power.

The Australian Government can act on its own initiative when required to defend the Commonwealth or the 'several states' (*Australian Constitution s* 51(vi)) or on the state's request when the state requires help to deal with domestic violence (*Australian Constitution s* 119). Where the ADF is called out to protect Australia's interests, the permission of the states or territories is not required (*Defence Act 1903* (Cth) ss 33 and 35). If, for example, there was an attack on a foreign mission in Sydney, by virtue of its responsibility for external affairs and its obligation to protect foreign diplomats, the Australian Government could deploy the ADF without first obtaining a request from the NSW Government. If, however, an equivalent protest was directed at a NSW Government building because of anger about the behaviour of a NSW Government agency, the ADF could only be used if there was a request from NSW. If the state was being attacked by foreign forces, the Australian Government could act under its authority to defend both the Commonwealth and the states, even if the state did not ask for that assistance.

There are parallels with the Australian Government's role in natural disasters. Given the terms of the *Australian Constitution*, there are 3 scenarios that could be said to constitute a national emergency or disaster (Eburn, Gissing & Moore 2019):

1. The need to use emergency powers to manage the Australian Government's response where a disaster is having impacts on areas allocated to Australian Government responsibility by the *Australian Constitution*. For example, the need for emergency powers to allow the Australian Government to exercise its powers with respect to external affairs and quarantine and to manage and coordinate international assistance.
2. The need to use emergency powers in a catastrophic disaster where an event is so large that it overwhelms the ability of state governments to function. If a state government effectively collapsed, it would self-evidently be beyond its power to restore itself. Restoring the government would be a legitimate exercise of Commonwealth executive power, which 'extends to the execution and maintenance of this Constitution' (*Australian Constitution s* 61) because:

   > *The foundation of the Constitution is the conception of a central government and a number of State governments separately organized. The Constitution predicates their continued existence as independent entities (Melbourne Corporation v Commonwealth (1947) 74 CLR 31).*

3. Where the Australian Government is required to intervene because the event is truly national in character or effect so that it is 'peculiarly within the capacity and resources of the Commonwealth Government' (*Pape v Commissioner for Taxation* (2009) 238 CLR 1, 63).

Responding to any of those scenarios would not require either a state request or state permission but there could be controversy if a federal government determined either that a state had failed to function, or the event was so large that it was only the Australian Government that could manage the response. The potential for political conflict where, for example, a state government is not responding as the Australian Government would like it too. The Australian Government may be tempted to declare that the recalcitrant state is 'unable' to cope rather than it is choosing to cope in a way that the Australian Government does not prefer. To that end, the Royal Commission (2020 [5.57]) did recommend:

> *The introduction of a declaration should be supported by legislation. Legislating for a declaration model would provide clarity of the circumstances in which a declaration may be made and the actions that the Australian Government could take in support of states and territories. It would also better define the role of the Australian Government in relation to that of the states and territories.*

Setting out, in advance, what constitutes a national emergency and when and how the Australian Government would react would allow the processes of government to develop cooperative legislation and would avoid states and territories being surprised by unilateral and an unexpected Australian Government response. We will return to that issue when discussing the role of the ADF.

The Commonwealth has indeed responded to this recommendation by passing the *National Emergency Declaration Act 2020* (Cth). This Act meets the Commission's recommendations in name, if not in substance. The Act allows the Governor-General to make a disaster declaration in the sort of circumstances listed, above. What is disappointing is the limited effect of any such declaration. It allows ministers to amend or suspend Commonwealth legislation where compliance would hinder the response or recovery effort.

The Act, as passed, says nothing about Commonwealth power to manage an emergency nor does it appoint a federal coordinating officer to coordinate the entire Commonwealth government response. There is no link between the declaration and natural disaster relief and recovery funding or the use of the ADF as provided for by the *Defence Legislation Amendment (Enhancement of Defence Force Response to Emergencies) Act 2020* (Cth). The Act does not empower the Commonwealth to take the lead in the response or direct the states how to manage the emergency occurring in their jurisdiction.

This is a very conservative Act that does not meet the recommendations of the Royal Commission. It allows the government to make a public declaration but does little to 'mobilise and activate Australian Government agencies quickly'. It does not provide for the Commonwealth a power to 'take action' to deal with an emergency other than to modify legislative requirements with respect to 'a relevant matter'.

The role of the Australian Defence Force

The ADF played a significant role in the response to the 2019–2020 bushfire season. However, expectations were great including unrealistic expectations that the ADF could 'assist in every aspect and was always readily available' (Royal Commission 2020, [7.7] and [7.8], Barber 2020).

The Prime Minister originally answered questions about the Australian Government response consistent with the

Commonwealth Disaster Plan (COMDISPLAN). This is, that the Australian Government provided support in response to requests from the states and territories (Davidson 2020). Even though the Australian Government was acting in accordance with pre-arranged plans, the demand for a more visible response led the Australian Government to take the extraordinary step of calling reserve soldiers to full-time duty. The call-up gave the Australian Government access to resources but did not change the position that the ADF would wait for a request before moving in (Eburn 2020). In response, the Prime Minister said he wanted the Australian Government to move:

… from a respond to request posture, to a move and integrate posture. Which means the defence force moving in and then coming in and working with the local effort without requests, without any instigation at a state level… (Spiers 2020)

The Royal Commission considered the role of the ADF in providing Defence Aid to the Civil Community (DACC). There was a number of recommendations including better incorporation of the ADF in disaster planning and taking steps to improve understanding of ADF capabilities. Importantly, the Royal Commission recommended (at [7.56]) that the 'use of the ADF should remain dependent on a request from a state or territory, except in the limited circumstances proposed in Chapter 5: Declaration of national emergency' (discussed above). There were recommendations regarding the thresholds that must be met before states and territories can call upon the ADF, legal protection for ADF members when tasked to respond to natural disasters and updating the DACC manual that governs ADF operations when providing assistance to the states.

None of these are controversial, at least from a constitutional perspective. It is the Australian Government that operates and governs the ADF, so all of those matters are clearly within the area of Commonwealth legislative responsibility. As noted, the Royal Commission did not recommend the use of the ADF without a specific request from the states or territories except in the case of a declared national emergency.

Unfortunately, the Australian Government did not wait for the Royal Commission's report before introducing and passing the *Defence Legislation Amendment (Enhancement of Defence Force Response to Emergencies) Act 2020* (the Act). The Act adds a new s 123AA to the *Defence Act 1903* (Cth) that says:

1. A protected person (see subsection (3)) is not subject to any liability (whether civil or criminal) in respect of anything the protected person does or omits to do, in good faith, in the performance or purported performance of the protected person's duties, if:

a. the duties are in respect of the provision of assistance, by or on behalf of the ADF or the Department, to:

i. the Commonwealth or a State or Territory, or a Commonwealth, State or Territory authority or agency;

ii. members of the community; and

b. the assistance is provided to prepare for a natural disaster or other emergency that is imminent, or to respond to one that is occurring or recover from one that occurred recently; and

c. the assistance is provided at the direction of the Minister under subsection (2).

2. The Minister may, in writing, direct the provision of assistance in relation to a natural disaster or other emergency if the Minister is satisfied of either or both of the following:

a. the nature or scale of the natural disaster or other emergency makes it necessary, for the benefit of the nation, for the Commonwealth, through use of the ADF's or Department's special capabilities or available resources, to provide the assistance;

b. the assistance is necessary for the protection of Commonwealth agencies, Commonwealth personnel or Commonwealth property.

The provision of legal indemnity *per se* is not an issue as it provides legal protection for members of the ADF that is similar to the protection provided to the members of the emergency services under state legislation (but cf Dingwall 2020). The issue is the circumstances when that assistance may be provided. That is where the Australian Government believes it is in the best interests of the nation (s 2(a)) to provide assistance to 'members of the community' (s 1(a)(ii)). This is an authority to respond the ADF without a request from the state or territory in circumstances where there is as yet no definition of what constitutes a national emergency. In short, the Act goes further than the Royal Commission's recommendations that the use of the ADF should still depend on a request from the affected state or territory and that the time when the Australian Government should act unilaterally should be narrow and defined in legislation.

The risk is that a minister, faced with public demand, may deploy the ADF without consulting with or effectively incorporating that response into a jurisdiction's emergency management arrangements. We may see the ADF as de facto 'spontaneous volunteers'; an organisation (albeit well trained and resourced) that turns up in an emergency area with its own priorities and command arrangements.

Conclusion

The Royal Commission into National Natural Disaster Arrangements delivered a 600-page report with 80 recommendations. Some of those recommendations were directed to state and territory governments, some to the non-government and civil society sectors and some towards the Australian Government. Recommendations covered the entire spectrum of emergency management from prevention to response and the development of national resilience. Not all, or even most, raised constitutional issue.

This brief review cannot do justice to the report or all of its recommendations. It has focused on 3 that deal with emergency response. The recommendations subject of this review were:

1. that the Australian Government 'assume, and make, standing arrangements for, the coordination and procurement functions of NAFC and NRSC'
2. that the Australian Government legislate to provide for a national emergency declaration
3. that the Australian Government review arrangements for the provision of DACC.

It has been argued that the recommendations identified as (2) and (3), above, are clearly within the Australia Government's power and remit and the Commonwealth has now passed relevant legislation. The legislation that has been passed, however, fails in many ways to implement the Commission's recommendations.

Recommendation (1) seems to extend the Australian Government's power. With respect to the commissioners, the justification for that recommendation is not well set out and it will be up to the states and territories to determine whether they want to work with a national office or continue to coordinate their own arrangements.

Dr Michael Eburn is a well-known commentator on the law as it relates to emergency management. This article was commissioned by the Australian Institute for Disaster Resilience to give readers the benefit of his views on aspects of the Royal Commission into National Natural Disaster Arrangements.

One of the royal commissioners, Professor Andrew Macintosh, is a close colleague at the ANU College of Law.

This article was authored prior to legislation being passed on 20 December 2020. Subsequent information is at https://emergencylaw.wordpress.com/2020/12/15/federal-parliament-passes-the-national-emergency-declaration-bill-2020/ as well as https://emergencylaw.wordpress.com/2020/12/15/federal-parliament-passes-the-defence-legislation-amendment-enhancement-of-defence-force-response-to-emergencies-bill-2020/.

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Australian Warning System

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Chair, AFAC Public Information and Warnings Working Group

The 'Scaled Advice and Warning Framework for Bushfire' was agreed nationally in 2009 following the Black Saturday bushfires in Victoria in February 2009. While it was developed with urgency and national commitment, it is acknowledged that there was limited opportunity for community involvement or feedback on the framework.

These warning arrangements for bushfire have worked well since the Australasian Fire and Emergency Service Authorities Council (AFAC) facilitated their development. They have been widely accepted over the past 10 years and understood by media and communities likely to be affected by bushfire.

Since 2009, considerable work to build a national capability to deliver timely and tailored warnings to communities has included developing the *Public Information and Warnings Handbook* and the National Warnings Principles as well as training and professional development for warnings practitioners. Fire and emergency services agencies have also invested in digital platforms to convey warnings to communities including websites and apps, and Australia's Emergency Alert telephone alerting system continues to be improved.

The National Review of Warnings and Information conducted in 2014 allowed for investigation across a multi-hazard and national sphere of how warnings and information were provided to communities. The review considered both warnings about hazards, such as those provided by the Bureau of Meteorology, and warnings about the potential impact of an incident on a community, typically provided by fire and emergency services and other statutory authorities.

The review recommendations included establishing the dedicated, multi-hazard National Working Group for Public Information and Warnings. Subsequently, the Australian New Zealand Emergency Management Committee endorsed the creation of the National Public Information and Warnings Working Group as part of the AFAC Collaboration Network (Warnings Group). The Warnings Group has been progressing the concept of a multi-hazard, all state and territory warning system in line with the review's Recommendation 3:

Pursue greater national consistency of warning frameworks across jurisdictions by leading a coordinated review of current frameworks, assessing the evidence base for change, and identifying opportunities for harmonisation. While this requires a longer term focus, in the short term, build national consistency within individual hazard areas.

In response to Recommendation 3, in October 2017, the Commissioner's and Chief Officers' Strategic Committee (CCOSC) committed to a consistent 3-level national warnings framework across all states and territories and multiple hazards. In February 2018, the Warnings Group established a project plan, 'Towards a National Warning Framework'. Following consultation with the states and territories, the project plan was endorsed by CCOSC in May 2018.

CCOSC also endorsed the Multi-hazard Warning System Social Research Project[1] in July 2018. This research was an extension of the Australian Fire Danger Rating System social research project. Research commenced in August 2018, with a fourth and final round of research taking place in July 2020.

The research was conducted to understand, from a community perspective, how people perceive and take action in response to warnings. This was the first time a national study of community perceptions of warnings at this scale had been undertaken. The research found broad community support for a 3-level warning system that is the same across multiple hazards. That is, people do not want different warning systems for different

From December 2020, new icons will be used to display bushfires on the NSW RFS website and Fires Near Me NSW smartphone app.

hazards. They want one system that is simple to understand and encourages them to take action.

Using the research, and the experience of emergency services agencies, the Australian Warning System includes 3 warning levels: Advice, Watch and Act and Emergency Warning. These levels will be combined with the hazard type (e.g. bushfire, flood, severe storm, cyclone, extreme heat) and a call-to-action statement (e.g. prepare to leave, seek shelter) that gives the community clear direction about what to do during the emergency.

Using the outcomes of the community research, a consistent set of hazard icons has been developed that include:

- a triangle shape with sharp corners
- yellow, orange, red colour palette showing increasing risk
- icon size and type escalating in size as the warning level increases.

New hazard icons for bushfire were implemented in December 2020 for all states and territores except Western Australia and the Northern Territory, which will implement the hazard icons at a future date. For other hazards, these icons will be adopted progressively. Call-to-action statements have been finalised based on research conducted as part of the Bushfire and Natural Hazards Cooperative Research Centre program.

Endnotes

1 Multi-hazard Warning System Social Research Project at https://knowledge.aidr.org.au/resources/multi-hazard-warning-system-social-research/.

Research to improve community warnings for bushfire

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Following Australia's Black Summer of 2019–20, research is being done to improve community warnings and information. Importantly, this will inform and support the ongoing development and refinement of community engagement and communications before, during and after bushfires.

Spring and summer of 2019–20 resulted in the most devastating bushfire season in NSW history. Over the course of the season, fires spread south from the Queensland border to the Victorian border. By season's end, fires had burnt a record 5.5 million hectares, destroyed 2448 homes and impacted on community and commercial infrastructure and assets across NSW. Tens of thousands of people were displaced by the fires and many were affected by smoke. Tragically, 25 people lost their lives, including 4 NSW Rural Fire Service (NSW RFS) volunteers and 3 US aerial firefighters. The season was truly unprecedented, with the largest area burnt, the most houses destroyed and the greatest number of deaths due to bushfire in a single season.

But NSW has experienced other destructive bushfires in recent years. In 2017, the Sir Ivan Fire razed farms and homes in the NSW central west around Leadville and Uarbry. In 2018, the Reedy Swamp fire devastated the small coastal communities of Reedy Swamp and Tathra. These and other bushfires have presented opportunities to examine issues of community awareness, preparedness and response. A particular focus of this work has been to understand how people obtain, interpret and respond to information and warnings provided by the NSW RFS and other emergency services organisations.

In recent years, NSW RFS commissioned the Bushfire and Natural Hazards Cooperative Research Centre to conduct research with communities affected by bushfires. These included studies with people threatened and affected by the bushfires of 2017, the 2018 Reedy Swamp Fire and the fires in 2019–20. The research involved interviews and surveys with thousands of people affected by the fires.

Insights into community responses to warnings and information

Just as every fire is different, every community is also different. Each study has therefore yielded unique insights into how people understand bushfire risk and how they obtain, interpret and use warnings and information. For example, our research showed how people understand and respond to warnings about fire danger conditions rated as 'catastrophic'. On Sunday 12 February 2017, a 'catastrophic' fire danger rating was issued for the NSW Central Ranges, North Western and Greater Hunter fire areas. This research found that while most people understood the warnings they received and considered them timely and useful, many did not respond in the ways intended by emergency services agencies. Despite advice that leaving early is the only safe option on 'catastrophic' days and that houses are not defendable under these conditions, over 30 per cent of survey respondents indicated that they only began preparing to defend property after receiving the warning. In-depth interviews highlighted that many people believed it was impractical to leave on 'catastrophic' fire danger days before there was a fire. This research also highlighted people's tendency to seek confirmation of emergency warnings, often by travelling to observe fires for themselves before taking protection action.

Research into the 2018 Reedy Swamp Fire provided insights into how people respond to bushfire threats when communication is impeded. For example, many people in Tathra had not considered themselves to be at risk from bushfire so they did not initially think that fire warnings applied to them. Others did not receive warnings,

Tourist Leave Zone - South Coast Bush Fires

Dangerous conditions for holiday makers on the South Coast of NSW this Saturday 4 January 2020

- Widespread Extreme Fire Danger is forecast for the South Coast this Saturday 4 January 2020
- These will be dangerous conditions, the same or worse than New Year's Eve
- If you're holidaying on the South Coast, particularly in the general area of Bateman's Bay to the Victorian border as shown on the map, you need to leave before this Saturday
- If you are planning to visit the South Coast this weekend, if is not safe. Do not be in this area on Saturday
- For more information go to www.rfs.nsw.gove.au

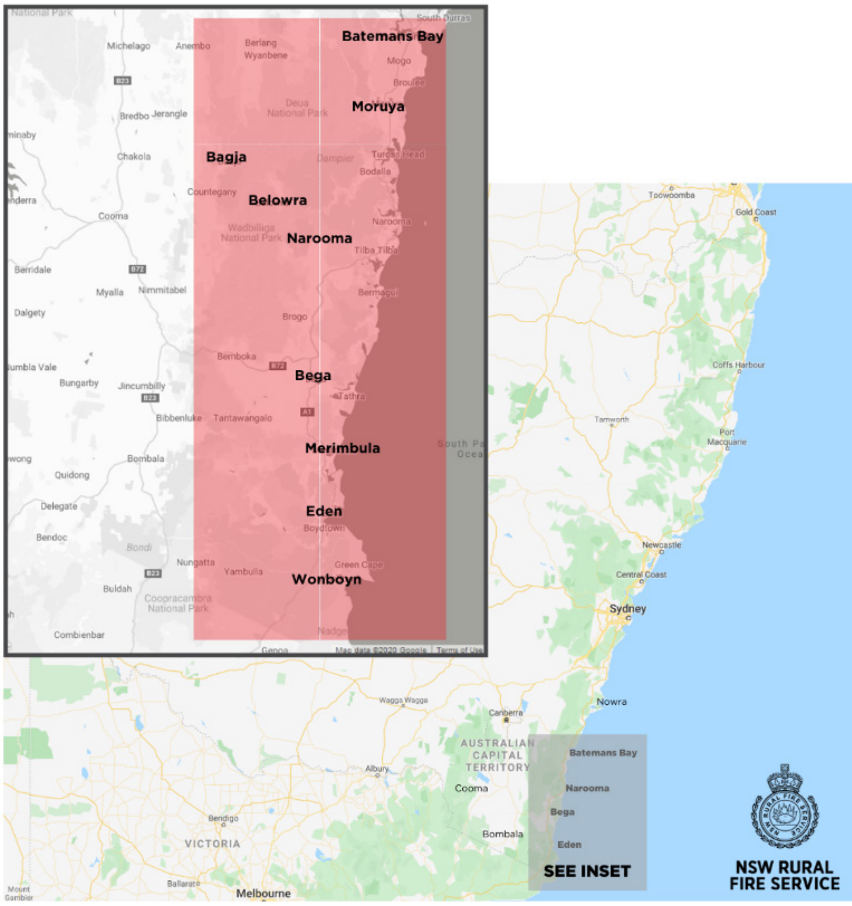

Figure 1: NSW RFS declared a 'Tourist Leave Zone' for coastal areas between Batemans Bay and Nadgee in January 2020.

Source: www.facebook.com/nswrfs/photos/a.10150499693320552/10157570291500552.

or received warnings late, due to the mobile phone reception blackspots in the area or power and telecommunications outages that occurred during the fire. As the fire threatened Tathra, respondents indicated there was uncertainty and confusion about whether, when and where to evacuate to. Fortunately, those who were able to leave Tathra did so in a calm and orderly manner, while those who were unable to leave (or decided not to) were mostly able to identify safer places within their community where they could shelter, such as beaches and other cleared, open spaces.

In the most recent research into the 2019–20 bushfires, we have gained new insights into how tourists and visitors responded to fire threats and associated warnings and information. Key findings were that many respondents were aware of fire activity in the vicinity of their travel destination but many chose to continue with their travel. Reasons for travelling, despite this awareness, included to continue holiday plans, to escape the smoke that was affecting other areas and to assist relatives and friends within the fire-threatened area.

With the large number of tourists and visitors to the NSW South Coast over the Christmas and New Year period, the NSW RFS took an unprecedented step of declaring a 'Tourist Leave Zone' for coastal areas between Batemans Bay and Nadgee (see Figure 1). A survey of tourists and visitors to these areas found that more than 60 per cent followed advice to leave the Tourist Leave Zone. The remainder stayed within the Tourist Leave Zone, most often because they were unable to leave. Interviews revealed that most tourists, visitors and holiday home owners in fire-affected areas understood the purpose and were supportive of the Tourist Leave Zones. This supports the use of such a measure in the future.

Research into hazards warnings conducted in recent years has helped inform community engagement programs across NSW, including for farming, and has identified at-risk groups. It has also allowed for continuous improvements to the NSW Fires Near Me[1] website and smartphone app as well as the display, structure and wording of public information and warnings scripts for communities.

1 NSW Fires Near Me, at www.rfs.nsw.gov.au/fire-information/fires-near-me.

Hope for our future generations

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Australian National University

During the 2019–20 bushfire season, 30 million hectares of bush burned, over 3000 homes were destroyed and 33 lives were lost. Over 80 per cent of Australia's population was affected by bushfire smoke and some locations were blanketed with smoke for weeks even though fires were not local.

The unprecedented bushfire situation was a traumatic event. For many young people, this was the first time they had experienced a large-scale disaster. Adults were not able to immediately say how they planned to cope, despite the hard work and efforts of the people who fought the bushfires. As a bushfire data scientist, I too felt anxious and powerless due to the incredible scale of the bushfire season. However, I recognise the need to better understand how fires are changing with the climate. Australia's emergency management sector also needs to change the way bushfires are monitored and fought.

In the last few years, space data from satellites has played an important role in the management and understanding about how weather, climate and vegetation conditions affect bushfires. This information helps land managers and emergency management agencies respond to fires.

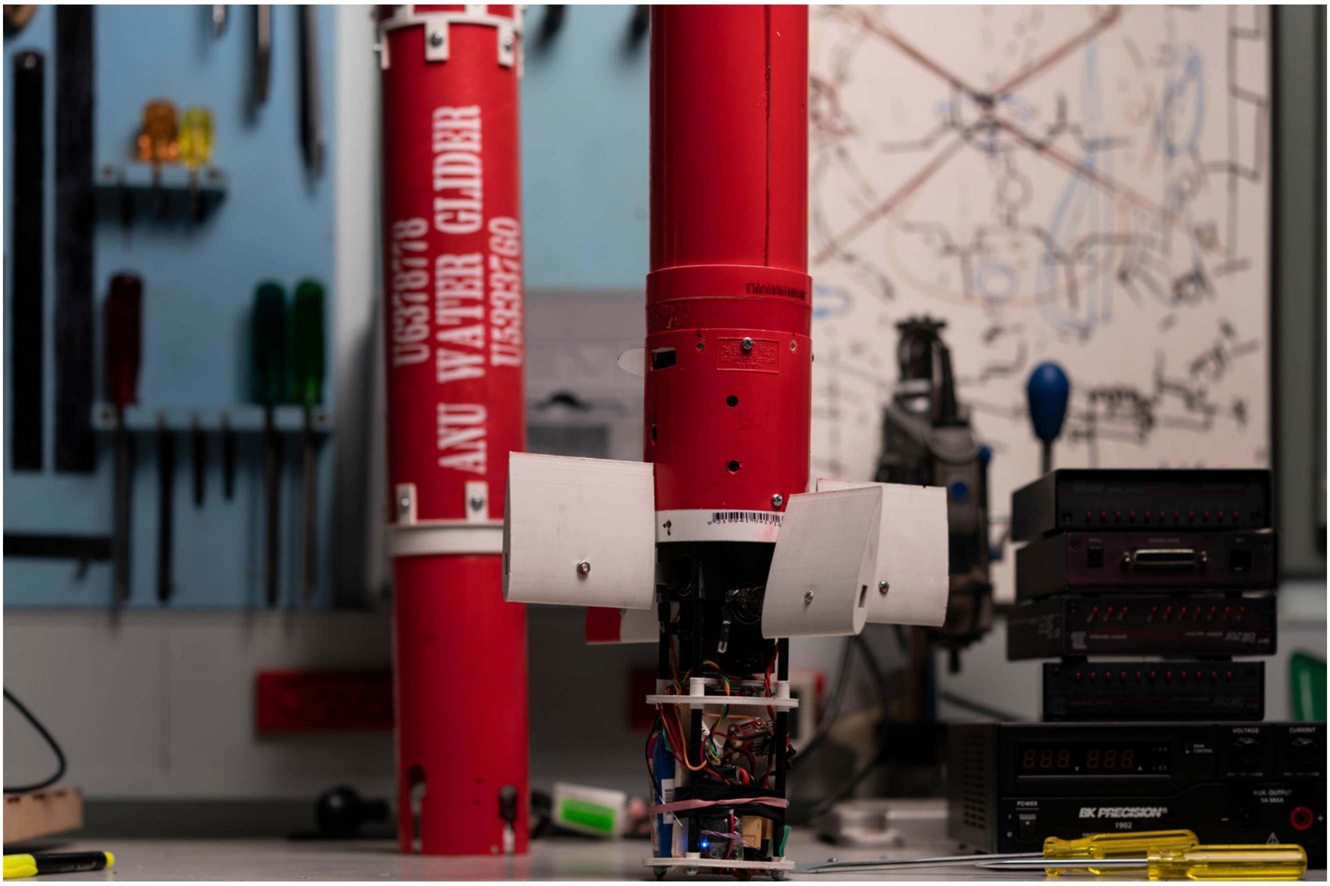
In 2019, I joined bushfire researchers from several national and international universities to comment in the journal, *Nature*[1] and presented analysis of the previous 20 years of bushfire damage using data from the European Space Agency. We analysed the data and written records of all major bushfires in Australia since 1851 to gain a geographical and historical perspective. We found that the extraordinary scale and intensity of the 2019–20 Black Summer bushfires were driven by climate conditions not seen in a century, including 3 years of drought. Importantly, we showed inconsistencies between government records and the satellite analysis.

We recommended that the Royal Commission into National Natural Disaster Arrangements establish a national fire monitoring agency to collect consistent information. This could help the public, researchers and the government to understand the frequency, extent and severity of bushfires. This would include bushfire impacts on biodiversity, society, the economy as well as the greenhouse gas emissions from fires and the health effects from bushfire smoke.

The biggest lesson from the last bushfire season was the understanding that through coordinated efforts and additional data and technology, land and emergency managers as well as policy makers could have more control over how bushfires affect populations in the future. We cannot stop bushfires, nor do we want to as they can regenerate lands. But through science discoveries and learnings from past events we can, for example, better understand how and where bushfires may start and how to protect people and homes. Satellite data can play a major role.

Currently, Australia receives satellite data from other nations because Australia does not have its own satellites. However, this is not a barrier to designing an Australian satellite payload or mission that will provide the exact data that land management and emergency agencies need to detect small fires and identify bushfire fuel and moisture content. Both are indicators of whether or not an ignition source could create a devastating fire. Australia has the opportunity to create bespoke satellite space missions. These can help monitor the entire continent while also considering the way that Australian's unique vegetation, like eucalypts, require different sensors to fully understand their conditions.

At the Institute of Space at the Australian National University (ANU), we are already planning to build satellites to monitor the continent. Optus and other industry partners are taking a holistic approach in the hope that within 5 years we can detect bushfires within one minute and put them out within 5 minutes of ignition. No single technology can do this. It takes a symphony of data from ground, space and the atmosphere to succeed. The ANU-Optus Bushfire Centre of Excellence will



Prototype water gliders are used to suppress small fires.

Image: ANU-Optus Bushfire Research Centre of Excellence

initially use ground sensors and cameras in fire towers to monitor areas of high risk until Australia has fit-for-propose satellites built and launched into space. We will also use drones to watch for bushfire and respond quickly. We will develop clever algorithms to compress data, archive and synthesise satellite imagery to help with fire modelling that can tell us where bushfires may travel. Low cost auto-piloted water gliders will achieve accurate and very rapid fire suppression of small bushfires at any time and in all weather conditions.

This is ambitious, but it is an answer to the powerless state many people feel during a bushfire disaster. To succeed, we will need help from the next generation of scientists as we broaden our understanding of how the climate and the land interact so we can protect families, their health, homes and livelihoods for generations to come. The hope is to create an integrated system that allows fire managers to have the most accurate landscape data, the best modelling and innovative systems to forecast and extinguish fires before they become threats to lives and property.

Endnote

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Australia's Black Summer heatwave impacts

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In Australia, the methodology used for heatwave warnings is different across its states and territories. The Bureau of Meteorology is redesigning its heatwave product suite to provide nationally consistent heatwave forecasts and warnings.

Australia's sequence of unprecedented disasters during the 2019–20 Black Summer were not unexpected. There has been declining rainfall over the southern half of Australia with Australia's average temperature rising by 1.4° C since 1910.[1] Record 2- and 3-year rainfall deficits over eastern Australia (Figure 1) created tinder-dry fuels and an environment prone to extreme heatwaves (Figure 2). Subsequent fires and persistent smoke were responsible for 33[2] and 417 excess deaths[3], respectively, and an increase in respiratory problems and other health impacts in New South Wales and the Australian Capital Territory.[4]

It takes longer to detect heatwave mortality due to strict medical and coronial conventions. However, the death toll may be in the hundreds, noting studies that have demonstrated the disproportionate impact of heatwaves over other climatic hazards.[5]

Indirectly, heatwaves played a large part in the size and severity of the Black Summer bushfires.

Heatwaves are defined by the combined effect of high minimum and maximum temperatures with the former playing the greatest role. Higher minimum temperatures reduce the diurnal cooling cycle and sets up earlier and more sustained high temperatures, rapidly building heat stored in the environment. The Bureau of Meteorology combines long- and short-term daily (average of maximum and minimum) temperatures over a 3-day period to determine heatwave severity as shown in Figure 2.[6]

High minimum temperatures are extremely significant as it is difficult, if not impossible, to form a surface inversion, allowing the upper wind structure to remain coupled with the fire overnight. Without the cooling effect and higher relative humidity of a nocturnal surface inversion, fires burn as intensely at night as during the day. Fires expand further and burn more erratically without the normal benefit of reduced overnight fire danger.

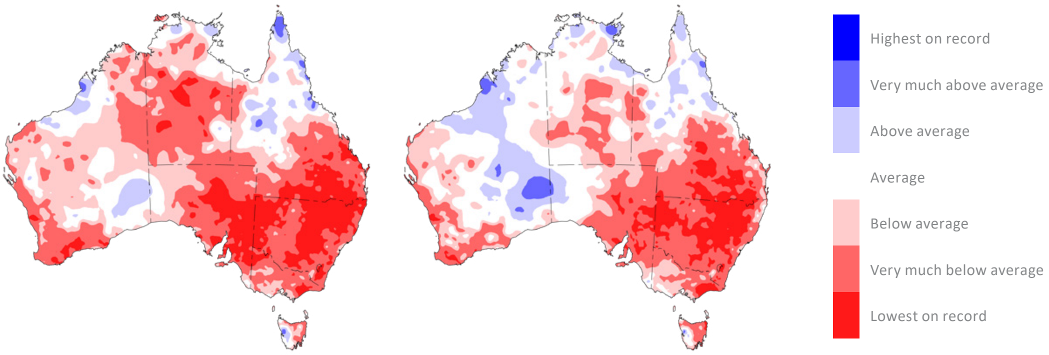

Figure 1: Rainfall deciles for the 24 months from January 2018 to December 2019 (left) and 36 months from January 2017 to December 2019 (right), based on all years from 1900.

The NSW sequences of heatwaves and property impacts are shown in Figure 3. The proportion of NSW that was affected by low-intensity or severe heatwaves can be seen to correlate with property losses the week finishing 23 November. At that time, nearly 80 per cent of NSW experienced a low-intensity heatwave (18 per cent severe) and over 500 homes and structures were destroyed.

The next 2 major destructive bushfire events in January 2020 followed a 6-week heatwave affecting most of NSW, with a major heatwave in early February aligning with further damage.

Antecedent heatwave severity and accumulated heat load is yet to be systematically explored for the relationship with subsequent fire and smoke activity and presents rich grounds for further research.

The Bureau of Meteorology heatwave product is statically displayed and based on a national view of Australia.[7] These forecasts do not support the different needs of stakeholders; their processes or geographical factors. The Bureau's heatwave project team has carried out extensive interviews with health and emergency services stakeholders from government agencies, as well as not-for-profit groups such as Australian Red Cross, to ensure new products meet their needs. Beta products including town and weather district summaries will be trialled with partners in the 2020–21 summer season. Feedback received will help build an operational product intended for release in 2021–22.

The challenge of quantifying the direct human health impacts of heatwaves has been recently studied through a collaborative research project. A 12-month DIPA[8] funded PEAN[9] project was completed during 2020, which aimed to 'Reduce Illness and Lives Lost from Heatwaves' (RILLH). A multi-agency collaboration between the Bureau of Meteorology, Department of Health, Australian Bureau of Statistics, Geoscience Australia, Department of Agriculture, Water and the Environment, Australian Institute of Health and Welfare and the Bushfire and Natural Hazards CRC, the RILLH used big data to demonstrate the utility of linked

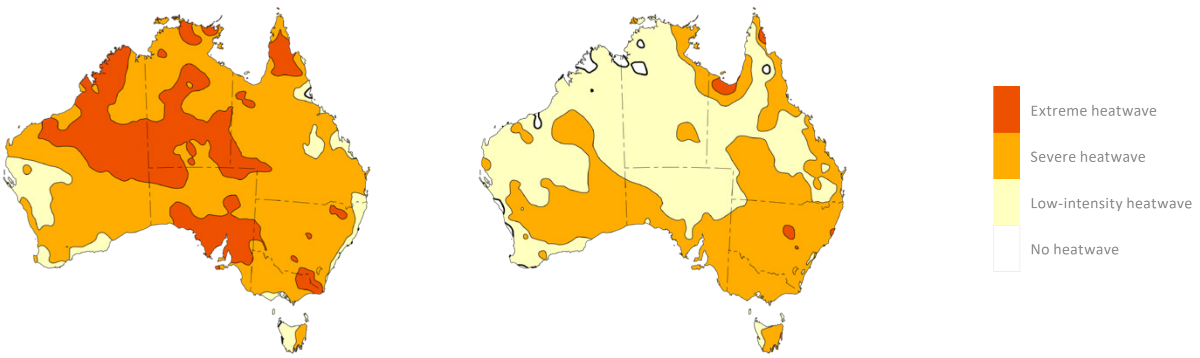

Figure 2: Highest heatwave severity for December 2019 (left) and January 2020 (right).

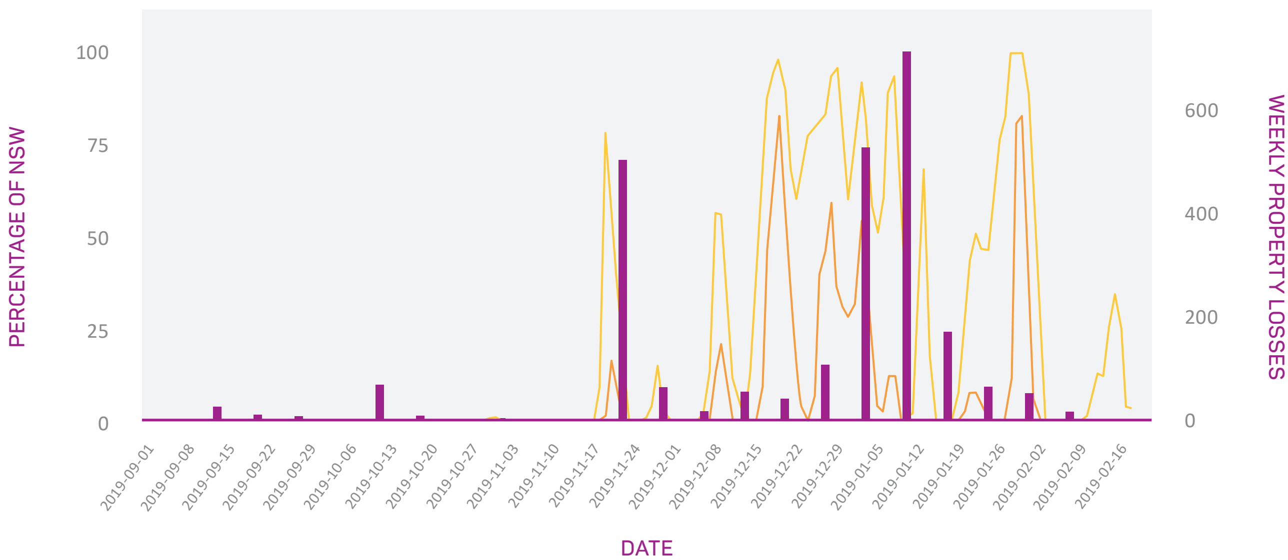

Figure 3: Chronology of heatwave severity and homes lost in NSW from September 2019 to February 2020. Proportion of NSW affected by all (orange line) and severe (red line) heatwaves (left axis). Homes destroyed (purple bar) sourced from NSW Rural Fire Service Building Impact Assessment.

social and environmental data from multiple agencies through the MADIP[10] data asset to understand complex, coupled social and environmental problems. Heatwave vulnerability has been calculated at neighbourhood-level and for individual-level factors for mortality and morbidity.

There is also an opportunity for warning agencies such as the Bureau and partners in health and emergency services to tailor advice to communities, agencies and individuals according to the risks inherent in where they live or their type of health and environmental exposures.

The study determined neighbourhood and individual-level risk factors separately (Table 1). Most of the study's neighbourhood-level spatial results were validated using the linked individual-level data, demonstrating the value of the neighbourhood-level results.

As an example, Figure 4 demonstrates spatial variability in mortality risk and heat-health vulnerability for NSW. Relative Risk in Figures 4 and 5 is a measure of increased or decreased impact during heatwaves compared to comparable non-heatwave periods. Heat vulnerability index is a measure of the combined effects of demographic, socioeconomic, health and the natural and built environment. The results show there is an opportunity to tailor advice to the needs of different regions.

Similarly, the contrast in vulnerability across Sydney in Figure 5 can help authorities develop policy, mitigation and response strategies to effectively manage exposure, sensitivity and adaptive capacity measures.

Heatwaves impact segments of the population in different ways with impacts related to individual characteristics of people and the types of places they live in (social and built environment). Vulnerability to heatwaves exhibits distinct geographies.

The RILLH project has generated a rich set of results with implications for strategic policy and education programs to position and prepare communities for the dangers of increasingly severe heatwaves.

The RILLH project highlights the value of high-quality multi-agency partnership studies and supports a strategic aim to enhance warnings with local behavioural recommendations to improve the value of future heatwave warnings.

Acknowledgments

Advice on redevelopment of the Bureau's heatwave service was received from Monica Long, National Manager Fire Weather, Heatwave and Air Quality Services and Biju George, Project Officer. A version of Figure 3 was presented to the Black Summer joint briefing for commissions of enquiry by Jane Golding, NSW State Manager Bureau of Meteorology, 2020. RILLH results produced under a 12-month DIPA[8] funded PEAN[9] project. The Bureau of Meteorology led the RILLH project, partnered by the Australian Bureau of Statistics, Department of Health, Australian Institute of Health and Welfare, Geoscience Australia and the Bushfire and Natural Hazards CRC. This article does not represent the express view of the Department of Health.

Table 1: RILLH results show the influence of neighbourhood-level and individual-level factors on the heatwave-mortality relationship in New South Wales.

Theme	Neighbourhood-level	Individual-level
Heat Exposure	• Low amounts of vegetation • No residential air-conditioning • Higher average temperatures	
Socio-economic status	• Low-equivalised household income	• Low-equivalised household income
Household composition and instance of disability	• Over 65 years and living alone • Single parent households • Need assistance	• Living alone • Over 65 years and living alone • Dwellings with single parent • Need assistance
Language and culture	• Insufficient English language proficiency	• Insufficient English language proficiency
Housing and transportation	• Private rental property • No access to a vehicle	• No access to a vehicle
Health status and risk factors	• Diabetes • Asthma • Poor mental health • Severe mental illness • Self-reported health being poor • Obesity	• Diabetes • Poor mental health • Severe mental illness
Consistent risk factors across levels	Low-equivalised household income, over 65 years and living alone, dwellings with single parents, need assistance, insufficient English language proficiency, no access to a vehicle, diabetes, mental health conditions.	

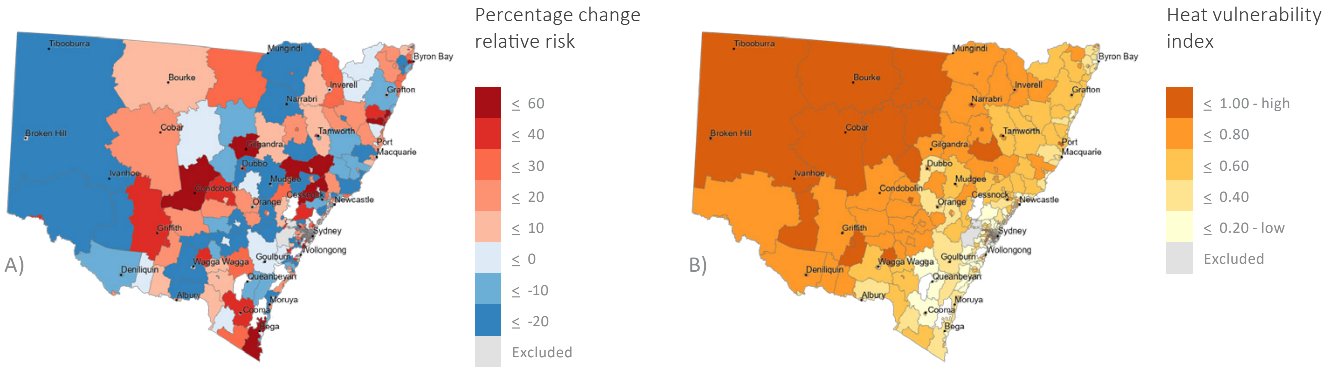

Figure 4: A) Relative Risk of heatwave-related mortality and B) overall heat health vulnerability index in New South Wales, (2007–17).

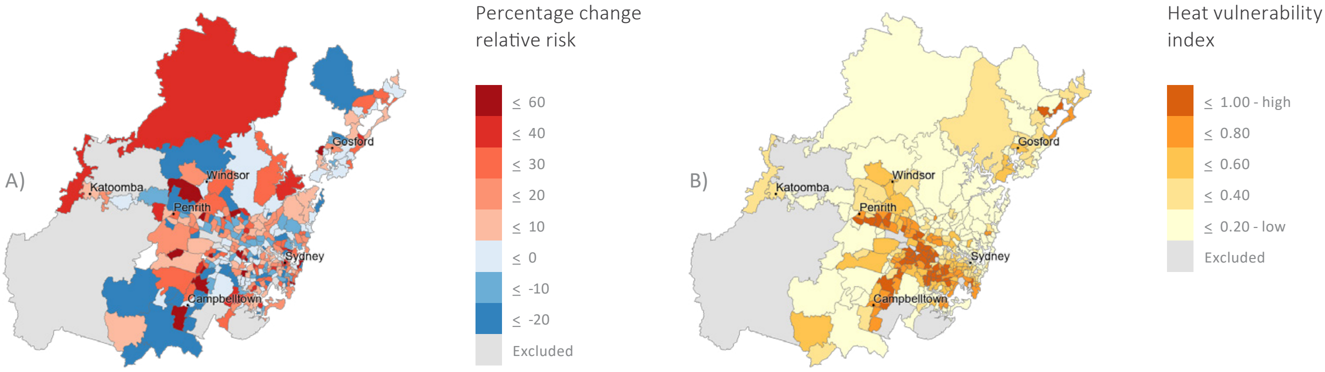

Figure 5: A) Relative Risk of heatwave- related mortality (2007–17) and B) overall heat health vulnerability index in the Sydney Greater Capital Area Statistical Area.

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8 Data Integration Partnership for Australia is a 3-year (2017-20) investment to maximise the use and value of Australian Government data assets. See www.pmc.gov.au/public-data/data-integration-partnership-australia.

9 Physical Environment Analysis Network, Australian Government agencies working together to analyse government data to generate case studies and insights into complex problems. www.pean.gov.au/

10 Multi-Agency Data Integration Project is a secure data asset combining information on health, education, government payments, income and taxation, employment, and population demographics (including the Census) over time. At: www.abs. gov.au/websitedbs/ D3310114.nsf/home/Multi-Agency%20Data%20 Integration%20 Project%20(MADIP), [15 January 2021].

The New South Wales air quality alert system: a brief history

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Air pollution causes premature deaths and is a significant environmental hazard. In 1975, the New South Wales Government established an air quality alert system, which has been regularly upgraded and expanded.

Outdoor air pollution contributed to 4.2 million deaths globally in 2015.[1] In Australia, air pollution was attributable to 2566 premature deaths in 2015.[2] Air pollution affects people's health via chronic effects due to long-term exposure and acute effects from short-term exposure. The short-term effects were brought keenly to the attention of the community during the 2019–20 Black Summer Australian bushfires with estimates of 417 deaths from exposure to bushfire smoke.[3]

An effective air pollution alert and forecasting service provides community benefit by alerting people when air pollution exceeds standards and by providing advice that assists individuals to minimise their exposure.[4] Short-term air pollution forecasts extend this service by providing locally specific information that allows people to plan ahead.

Beginnings and the Sydney Pollution Index

Air pollution has been monitored in NSW since 1951 and continuous monitoring of ozone and fine particles (visibility) started in the early 1970s. Daily reports of air quality issued from 1975 initially reported particulates (visibility), carbon monoxide, sulfur dioxide and ozone. However, these reports used scientific terminology and people could not easily interpret the information.

On 19 March 1976, 13 children suffering chest pains and breathing difficulties were taken from a Sydney high school to a district hospital.[5] Partly in response, the Sydney Pollution Index (SPI) was established in 1978. The SPI was intended to simplify air pollution reporting. It provided daily media releases and was available on a phone message service. The SPI used a simple linear scale (Equation 1) based on the maximum hourly daytime (6am to 3pm) levels of particles (visibility measured in the CBD) and ozone (measured at Lidcombe). The 2 levels were combined and expressed as a single number. The index was classified into categories of low (0–25), medium (26–50) and high (>50) (Table 1). On high pollution days, SPI media coverage was good and hundreds of calls were made to the recorded phone message.

Equation 1:

$SPI = \max\{100 \frac{P_i}{S_i}\}$ where P_i = conc.of pollutant i and S_i = pollutant standard for i

The SPI report included an air pollution forecast for Sydney for the next day. The forecast was based on empirical methods and relied on air pollution observations and the Bureau of Meteorology weather forecast for Sydney for maximum and minimum temperatures, atmospheric stability and mixed layer height.

The NSW Regional Pollution Index

In May 1991, Sydney experienced a major air pollution episode when many hazard-reduction burns were underway around the city. The weather conditions resulted in calm days and still nights that lead to a build up of smoke. This resulted in significant community concern about air quality and health. The NSW Government conducted public air quality summits and produced the Metropolitan Air Quality Study (MAQS). The MAQS aimed to develop an extensive understanding of air pollution in the Sydney, Illawarra and lower Hunter regions as well as a system to predict air quality in the future to support long-term air quality management.

MAQS delivered an updated Regional Pollution Index (RPI).[6] The RPI was produced for 3 Sydney regions (central-east, northwest, southwest), 3 sites in the lower Hunter (Newcastle, Wallsend, Beresfield) and 3 sites in the Illawarra (Wollongong, Kembla Grange, Albion Park). It kept the categories and index numbering of the SPI but was expanded to cover an entire day with morning and afternoon reports (Table 1). Forecasting continued to use empirical methods but was enhanced with daily air pollution weather forecasts from the Bureau of Meteorology tailored to NSW Government needs.[7]

The NSW Air Quality Index

In June 1998, the introduction of the National Environmental Protection (Ambient Air Quality) Measure led to major changes to air quality reporting. Changes included new national air quality standards, measurement requirements and a consistent national reporting process. Standards were introduced for ozone, carbon monoxide, sulfur dioxide, nitrogen dioxide, particles (PM10, PM2.5) and lead. In 2008, the RPI was replaced by an Air Quality Index (AQI) based on these criteria pollutants and visibility (Table 2).

The NSW alert system was expanded and alerts were now triggered automatically when any pollutant at a station exceeded standards. Any member of the public could subscribe to receive alerts, tailored to their specific region or location of interest, delivered via SMS or email.

As the PM10 and PM2.5 standards were based on a daily average, NSW used a rolling 24-hour average to provide hourly updates on particle pollution. While this allowed PM10 and PM2.5 to be integrated into the AQI, a downside was that often alerts would be issued with a lag of several hours and could stay in place long after peak particle levels had subsided.

This was the first automated air pollution alert system in Australia. The AQI served NSW well through many significant air pollution events (e.g. Red Dawn dust storm 2009, Blue Mountains fires 2013, hazard-reduction burns in 2015–16, Kooragang Island fire 2019). It also expanded over time to include regions such as the upper Hunter (2010), Northern Tablelands (2018) and the Southern Tablelands (2019).

Table 1 : The Sydney Pollution Index (1978–94) and Regional Pollution Index (1994–2008).

Regions	Pollutant	Categories/Thresholds		
SPI - Sydney	O_3 (1 hr)	Low (60 ppb)	Medium (61–120 ppb)	High (>120 ppb)
	Visibility (1 hr)	Low (1 bsp)	Medium (1–2 bsp)	High (>2.1 bsp)
RPI - Sydney, Lower Hunter, Illawarra	O_3 (1 hr)	Low (50 ppb)	Medium (51–100 ppb)	High (>100 ppb)
	Visibility (1 hr)	Low (1 bsp)	Medium (1–2 bsp)	High (>2.1 bsp)
	NO_2 (1 hr)	Low (60 ppb)	Medium (61–120 ppb)	High (>120 ppb)

Table 2: The NSW Air Quality Index (2008–20).

Regions	Pollutant	Categories/Thresholds					
Sydney (3 locations), Lower Hunter, Upper Hunter, Illawarra, Central Coast, Northwest Slopes, Southwest Slopes, Central Tablelands	O_3 (1 hr)	V.G 0–33 ppb	G 33–66 ppb	F 66–100 ppb	P 100–150 ppb	V.P 150–200 ppb	H 200+ ppb
	O_3 (4 hr)	V.G 0–27 ppb	G 27–54 ppb	F 54–80 ppb	P 80–120 ppb	V.P 120–160 ppb	H 160+ ppb
	Visibility (1 hr)	V.G 0–0.7 Mm^{-1}	G 0.7–1.4 Mm^{-1}	F 1.4–2.1 Mm^{-1}	P 2.1–3.2Mm^{-1}	V.P 3.2–4.2Mm^{-1}	H 4.2+ Mm^{-1}
	PM2.5 (24 hr)	V.G 0–8.3 μgm^{-3}	G 8.3–16.5μgm^{-3}	F 16.5–25.0μgm^{-3}	P 25–37.5μgm^{-3}	V.P 37.5–50μgm^{-3}	H 50+ μgm^{-3}
	PM10 (24 hr)	V.G 0–16.5 μgm^{-3}	G 16.5–33μgm^{-3}	F 33–50 μgm^{-3}	P 50–75 μgm^{-3}	V.P 75–100 μgm^{-3}	H 100+ μgm^{-3}
	NO_2 (1 hr)	V.G 0–40 ppb	G 40–80 ppb	F 80–120 ppb	P 120–180 ppb	V.P 180–240 ppb	H 240+ ppb
	SO_2 (1 hr)	V.G 0–66 ppb	G 66–133 ppb	F 133–200 ppb	P 200–300 ppb	V.P 300–400 ppb	H 400+ ppb
	CO (8 hr)	V.G 0–3.0 ppm	G 3.0–6.0 ppm	F 6.0–9.0 ppm	P 9.0–13.5 ppm	V.P 13.5–18 ppm	H 18+ ppm

V.G = very good, G = good, F = fair, P = poor, V.P = very poor, H = hazardous

From 2014, air pollution forecasts also matured with the development of the NSW Air Quality Forecasting Framework. The framework expanded the forecasting of particle pollution and added statistical models, chemical transport modelling and trajectory and plume modelling (for incidental emissions) to the forecasting system.[8]

Air quality categories and the current alert system

The Black Summer bushfires led to substantial changes to presenting air quality data and communicating health advice. During the bushfires, in response to community feedback, NSW began reporting hourly averages of PM10 and PM2.5, replacing the rolling 24-hour average. This provided up-to-date reporting of smoke impacts and made alerts more effective. Following the bushfires, a major review of the AQI and air quality health messaging was conducted.[9] It examined how AQIs were reported nationally and internationally, with particular focus on particle measurements.

In November 2020, the AQI was replaced with the Air Quality Category[10] (AQC), together with the introduction of a new health activity guide (Table 3). Like the AQI, the AQC is based on the concentrations of criterion air pollutants as well as visibility. This approach reduced the number of air quality categories and changed the thresholds for some pollutants. A new health activity guide[11] provides detailed information on how people can protect themselves from air pollution and messaging targets at-risk people as well as the general population.

Figures 1 and 2 are examples of current alert messages using the AQI and the AQCs.

Next steps

The NSW Government continues to work with other jurisdictions to improve health messaging for pollutants such as PM10 and ozone. There are currently proposed changes to the national air pollution standards for ozone, nitrogen dioxide and sulfur dioxide. The government will incorporate changes to the AQC and alert system as soon as practical after the new standards are gazetted. The overall messaging and communication about air quality issues will be improved. This will assist people to be better informed about the effects of air pollution and how the NSW alert system can help them to minimise exposure.

Table 3: The current NSW air quality categories.

Regions	Pollutant	Categories/Thresholds				
Sydney, Lower Hunter, Upper Hunter, Illawarra, Central Coast, Lake Macquarie, Northwest Slopes, Southwest Slopes, Central Tablelands, Mid-North Coast	O_3 (1 hr)	G 0–66 ppb	F 67–100 ppb	P 100–150 ppb	V.P 150–200 ppb	E.P 200+ ppb
	O_3 (4 hr)	G 0–54 ppb	F 54–80 ppb	P 80–120 ppb	V.P 120–160 ppb	E.P 160+ ppb
	Vis. (1 hr)	G 0–1.5 Mm^{-1}	F 1.5–3.0 Mm^{-1}	P 3.0–6.0 Mm^{-1}	V.P 6.0–18.0 Mm^{-1}	E.P 18+ Mm^{-1}
	PM2.5 (1 hr)	G 0–25 μgm^{-3}	F 25–50 μgm^{-3}	P 50–100 μgm^{-3}	V.P 100–300 μgm^{-3}	E.P 300+ μgm^{-3}
	PM10 (1 hr)	G 0–50 μgm^{-3}	F 50–100 μgm^{-3}	P 100–200 μgm^{-3}	V.P 200–600 μgm^{-3}	E.P 600+ μgm^{-3}
	NO_2 (1 hr)	G 0–80 ppb	F 80–120 ppb	P 120–180 ppb	V.P 180–240 ppb	E.P 240+ ppb
	SO_2 (1 hr)	G 0–133 ppb	F 133–200 ppb	P 200–300 ppb	V.P 300–400 ppb	E.P 400+ ppb
	CO (8 hr)	G 0–6.0 ppm	F 6.0–9.0 ppm	P 9.0–13.5 ppm	V.P 13.5–18 ppm	E.P 18+ ppm

G = good, F = fair, P = poor, V.P = very poor, E.P = extremely poor

Sydney air quality for tomorrow
WEDNESDAY 1 NOVEMBER 2007
is forecast to be

POOR due to PARTICLES

HEALTH MESSAGE: Unhealthy for sensitive people, and could cause symptoms, especially in people with **heart or lung disease.**

More about air quality health alerts.

For current levels see the hourly air quality index.

Figure 1: Example of air pollution alert using the Air Quality Index.

Sydney air quality for tomorrow
WEDNESDAY XX NOVEMBER 2020
is forecast to be

POOR due to PARTICLES

Sensitive Groups – AVOID outdoor physical activity if you develop symptoms such as cough or shortness of breath.

When indoors, close windows and doors until outdoor air quality is better.

Follow the treatment plan recommended by your doctor.

If you are concerned about symptoms call the 24-hour HealthDirect helpline on 1800 022 222 or see your doctor.

In a health emergency, call triple zero (000) for an ambulance.

More about air quality health alerts.

Everyone else – REDUCE outdoor physical activity if you develop symptoms such as cough or shortness of breath.

For current levels see the hourly air quality index.

Figure 2: Example of air pollution alert using the Air Quality Categories.

Endnotes

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11 Air Quality concentration data - updated hourly, at www.dpie.nsw.gov.au/air-quality/air-quality-concentration-data-updated-hourly.

Queensland investigates contemporary review methods

Alistair Dawson
Queensland Inspector-General Emergency Management

In September 2019, parts of south-east Queensland were subjected to severe to catastrophic bushfire activity, similar to activity experienced the year before.

On 26 September 2019, the Queensland Minister for Fire and Emergency Services requested the Office of the Inspector-General Emergency Management (IGEM) conduct a review into the response to selected Queensland fires in Sarabah, Stanthorpe and Peregian Springs. The purpose of the review was to provide observations and insights regarding the bushfire events in Queensland, and to consolidate recommendations in the 2018 Queensland Bushfires Review.

The methodology and approach undertaken for the review was different to previous reviews. There was a recognition by IGEM that the 2019 review would be commencing 3 months after the 2018 bushfire review was publicly released.

The focus, therefore, was on fostering a positive lessons culture through highlighting good practice and opportunities for improvement. IGEM focused on identifying Observations, Insights, Lessons Identified and Lessons Learnt using the OILL process.

Observations were gathered through interviews with first responders, telephone surveys with residents, a call for public submission and a review of relevant documents. Through this method, 12 insights were captured, with 3 relating to community warnings. Specifically, that community messaging was not always clearly understood, could benefit from including fire location and direction maps and could be enhanced if officers on the fire front could issue these warnings directly to the local area.

A lesson for IGEM following the 2019 review was to investigate contemporary alternatives to a traditional data-collection method, the use of telephone surveys with residents. In the past, IGEM has been reliant on market research companies to provide qualitative research to help inform its reviews and assurance activities. This has proved costly and provided static data from a limited number of residents.

An initial option examined by IGEM included using freely available and de-identified big data analytics from social media via a pilot project with Griffith University's Professor Bela Stantic and the Big Data Lab. The accuracy of the predictive analysis has received significant media attention, using big data to analyse social media sentiment to predict the outcomes of recent events such as Brexit, and the 2019 election of the Australian Government. These accurate predictions have achieved what traditional methods of telephone polling have failed to do.

Big data analysis could be used in the lead-up to, during and following disaster events to analyse community sentiment, to understand the level of community comprehension of warnings and actions and to myth-bust or address issues relating to reluctance or complacency to evacuate. The real-time availability of social media data allows for the capture of opinions of the community in a ubiquitous manner and enables timely interventions by government. IGEM will continue to evaluate contemporary data-collection options in future review activities.

New technology boosting early warning capability in New Zealand

Sarah Stuart-Black
National Emergency Management Agency

Sarah Stuart-Black finished at the National Emergency Management Agency on 4 December 2020 and is now Secretary General of the New Zealand Red Cross.

New Zealand's geographical and geological position in the Pacific puts its communities at risk, so early warning systems are a critical component of New Zealand's emergency management system.

New Zealand communities are exposed to a broad range of natural hazards including earthquakes, tsunami, storms, flooding, fire, landslides and volcanic activity. New Zealand also faces hazards and risks from other sources; from plant and animal diseases, pandemics, technological disruptions and security threats. Early warning systems that enable individuals and communities threatened by hazards to act quickly to reduce the likelihood of death, injury and damage to property are critical to reducing risk and saving lives.

Over the past decade, the National Emergency Management Agency (NEMA), formerly the Ministry of Civil Defence & Emergency Management (MCDEM), aided by its partner agencies, has been on a journey to boost its ability to provide early warning of significant threats to communities.

Two core pieces of technology, Emergency Mobile Alert and Deep-ocean Assessment and Reporting of Tsunami (DART) buoys, have made a significant difference.

Emergency Mobile Alert

In the early hours of Sunday 18 February 2018, many residents of Bell Block, a small town north-east of New Plymouth, were woken by a loud noise emanating from their mobile phones. The alert warned people to shut doors and stay inside due to a serious and life-threatening ammonia gas leak. This was the first time New Zealand's new early warning technology had been used for a real event.

When there are serious threats to life, health or property, the Emergency Mobile Alert system is used to send alerts to compatible mobile phones within a defined geographical area. The alerts can only be sent by authorised emergency agencies.

Emergency Mobile Alert uses cell-broadcast technology, which is reliable in an emergency. Cell-broadcast technology uses a dedicated channel on mobile networks and it is not affected by network congestion. Unlike text messages, Emergency Mobile Alert is secure and doesn't require the phone numbers and other private details of recipients to operate. There is also no need to download an app or subscribe to a service. Alerts are broadcast directly to all capable phones in range of the cell towers in the defined geographical area.

In order to speed up the warning process, the system contains message templates for a range of hazards and scenarios. These have been written in line with best practice guidelines for writing effective short warning messages. Issuing warning messages that can be comprehended by the people receiving them is critical for people to take the necessary actions to stay safe.

Since the system launched on 26 November 2017, Emergency Mobile Alert has been used more than 20 times for a range of events. These have been for local notices to boil water, evacuations due to flooding and fire, alerts for gas and ammonia leaks and, more recently, for nationwide COVID-19 pandemic alerts.

Research following a nationwide test of the system in November 2019 showed that among New Zealanders who have access to a mobile phone, 79 per cent received the test alert and a further 8 per cent who didn't personally receive the alert were near someone who did. New Zealand's Emergency Mobile Alert is an effective system for reaching people directly in an emergency.

DART buoys

Over recent years, we have increased our understanding of tsunami risk to New Zealand thanks to international experiences and research undertaken. In particular, seismic modelling completed in August 2018 confirmed that some earthquakes capable of generating a tsunami along the Kermadec subduction zone, up to and including Magnitude 8 to 9, will not be strongly felt in the regions closest to the source. The first waves with heights of over 5 metres and potentially over 15–20 metres in susceptible coastlines may arrive at the nearest coast in less than 60 minutes. This means the well understood public education message of 'Long or Strong, Get Gone' will not protect people for these events. A large tsunami with very little warning time and no natural warning signs creates a specific challenge for keeping people safe.

It is clear that New Zealand faces significant life-threatening tsunami risks and it is critical that we are able to provide early warning to at-risk coastal communities.

Work had been progressing to assess the possibility of a New Zealand-owned DART buoy network. Following the Kermadec modelling, this work was accelerated and, in late 2018, MCDEM, the Ministry of Foreign Affairs and Trade, the Ministry of Business Innovation and Employment, GNS Science and New Zealand Institute of Water and Atmospheric Research (NIWA) commenced work to establish a NZ$48.3 million New Zealand-owned DART buoy network to provide coverage for New Zealand and the south-west Pacific. The establishment of the network has been supported by the Australian Government who contributed A$2.5 million to support coverage for Pacific island nations.

DART buoys are deep-ocean instruments that monitor changes in wave pressure at the sea floor. They are currently the only accurate way, in near real-time, to confirm a tsunami has been generated before it reaches the coast.

DART buoys detect tsunami threats by measuring associated changes in wave pressure via sea-floor sensors. They are capable of measuring sea-level changes of less than a millimetre in the deep ocean. Two-way communication between a DART buoy and a 24/7 monitoring centre allows rapid assessment of threats and provision of advice to NEMA. When a threat is identified, NEMA issues subsequent warning advice to the public. Figure 1 shows how the buoys work by monitoring sea floor wave pressures and sending the information to shore.

Not all disturbances at the sea floor such as underwater earthquakes or volcanoes cause tsunami. The DART buoys also provide rapid confirmation when no tsunami has been generated following large earthquakes and other possible ‘trigger’ events in the ocean, enabling us to quickly get out the message that there is no tsunami threat.

New Zealand has obtained the latest 4G DART buoys, which can be positioned closer to tsunami-generation sources and are able to detect and precisely measure tsunami better than older-technology DART buoys.

NIWA is deploying the DART buoys using their research vessel Tangaroa and the first deployment voyage took place in December 2019 with the second in August-September 2020. A third and final deployment voyage is scheduled for 2021.

Seven of the DART buoys have been located to provide the best protection from the highest-risk areas close to New Zealand. Locations were based on geological and ocean science

DART buoys on board the NIWA RV Tangaroa on the first deployment voyage into the Pacific Ocean.

Image: National Emergency Management Agency

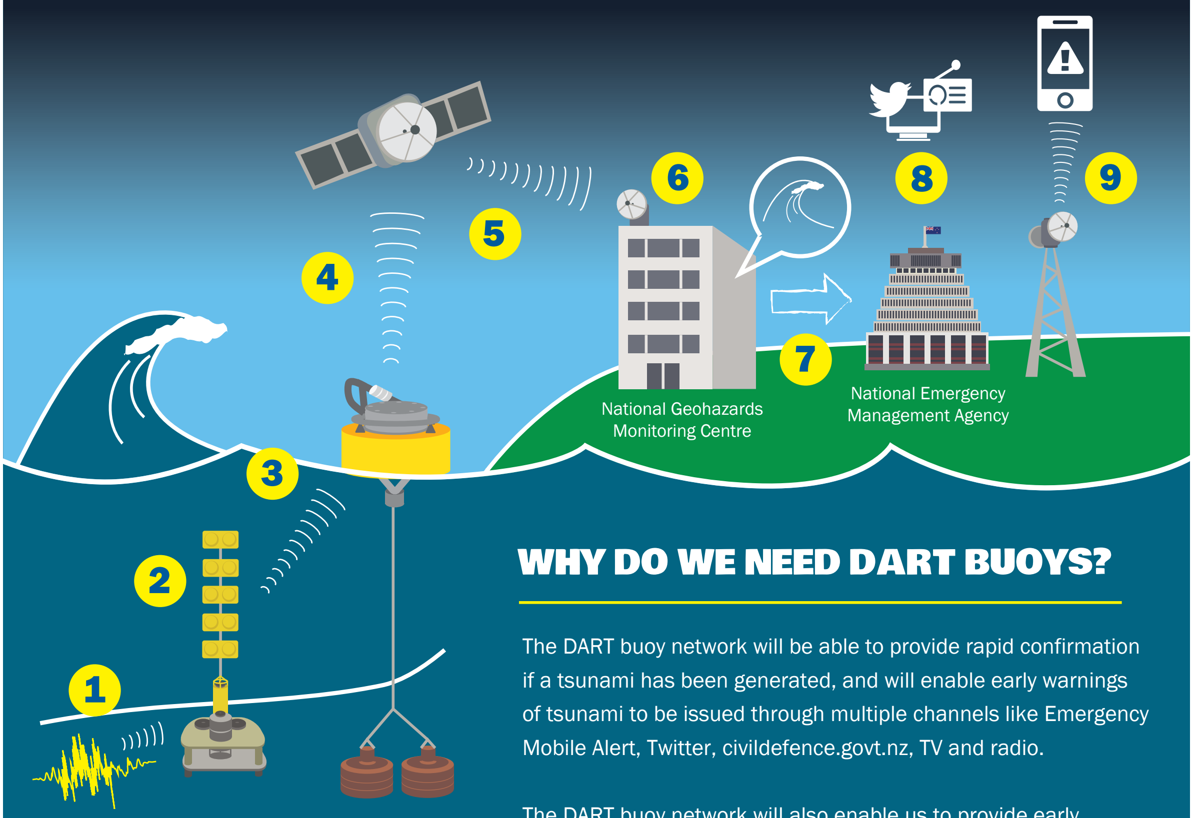
information. Another 5 of the DART buoys will be located closer to New Zealand’s Pacific neighbours and near significant southwest Pacific risk areas. Additional DART buoys will be kept on land as back-ups and to make maintenance and servicing more efficient.

We have been able to develop this network now because we have two critical elements in place. The GNS Science National Geohazards Monitoring Centre was established in December 2018 and provides the necessary 24/7 monitoring capability to receive, process and analyse the data from the DART buoys. Our Emergency Mobile Alert system also means NEMA is better placed to issue tsunami alerts to people in New Zealand so they can take appropriate action.

Our Pacific neighbours will also benefit from more accurate tsunami warnings as the network also provides tsunami monitoring and detection information for southwest Pacific countries including Tokelau, Niue, the Cook Islands, Tonga, Samoa, Australia and South and Central America depending on where the tsunami may be generated. The Pacific Tsunami Warning Centre will use data the buoys generate to provide tsunami threat advice to other Pacific countries.

HOW DO DART BUOYS WORK?

1. An undersea event (earthquake, volcanic eruption, landslide) occurs.
2. A sensor on the ocean floor detects significant changes in water pressure.
3. The data is sent by acoustic signal to a buoy on the surface.
4. The buoy sends the signal to a satellite.
5. The signal is sent to the 24/7 National Geohazards Monitoring Centre based in Lower Hutt.
6. Geohazard experts analyse the data.
7. If a tsunami has been detected, the National Geohazards Monitoring Centre will notify the National Emergency Management Agency.
8. The National Emergency Management Agency will issue a tsunami warning directly to the public via their website and Twitter and to CDEM Groups, emergency services and media.
9. If the tsunami is expected to inundate (flood) land areas, an Emergency Mobile Alert will be sent to all capable mobile phones in the affected areas.



WHY DO WE NEED DART BUOYS?

The DART buoy network will be able to provide rapid confirmation if a tsunami has been generated, and will enable early warnings of tsunami to be issued through multiple channels like Emergency Mobile Alert, Twitter, civildefence.govt.nz, TV and radio.

The DART buoy network will also enable us to provide early confirmation when an earthquake has NOT generated a tsunami.

New Zealand Government

Figure 1: The DART bouy monitoring and alert system for tsunami.

Why some people don't respond to warnings: writing effective short warning messages

Dr Sally Potter
GNS Science, New Zealand

Warnings aim to empower people to respond to hazards in an appropriate and timely manner in order to reduce the risk of death, injury and damage. An important part of effective warnings is the message.

Research shows there are many influences on people's responses to warnings, including message characteristics. It is becoming increasingly possible to issue short messages using channels such as social media, hazard apps and cell-broadcast alerting via the mobile network (e.g. New Zealand's recently implemented Emergency Mobile Alert system). People who issue warnings want to know: how can a warning be written as effectively as possible?

People who receive warnings respond in a variety of ways, according to many factors and influences.[1] For example, women are more likely to respond to warnings than men, as are people with dependents, those who have higher self-efficacy (i.e. they believe they are capable of responding), and those with stronger social networks. Observing and understanding the significance of environmental cues, such as the sea receding prior to a tsunami or storm clouds gathering are an influence. Social cues can prompt people to respond, including seeing neighbours prepare, or being aware of transport assistance for evacuation.

The way in which people receive warnings is a factor, including:

- the frequency of message dissemination by the information sources
- the level of detail they contain
- the ability for the alert to disrupt the receiver's activities
- the equipment requirements.

People's preferences in accessing channels is also a factor. For example, their exposure to TV, radio, internet, social media and mobile phone usage. The warning message itself can influence responses through content, format, design and accessibility to the receiver.

Situation-specific factors on behavioural response to warnings include whether the person receives the warning message, whether they pay attention to it and how well they comprehend it. Assuming they receive and understand the warning, further influences are their perceptions about the severity of the impending threat that is influenced by their prior experience and proximity to the hazard, their beliefs about the protective action options and their perceptions about the agency issuing the warning (including trust). The action that they take may be to search for further information to fill any gaps in their understanding about the situation. Other situational factors can help or hinder their response, such as physical obstacles or enablers to evacuating, looking for children or pets and helping vulnerable neighbours.

Agencies responsible for warnings can influence these factors so that there is a higher likelihood of an effective and timely response. Ensuring the warning message is optimal is one way to do this. Prior research[2] has highlighted the key elements that should be included in a warning message. These are summarised in Figure 1. The optimal order of these elements differs according to the length of the message[3], however, it is more important that the message is clear and understandable.

In the context of warning messages up to 1395 characters, longer messages are more effective than shorter messages as they provide enough detail so that seeking more information is minimised. On a mobile phone, having paragraph breaks in text helps make the message easier to read.

Content to include in a warning message

Source	Agency issuing the message
Hazard	Hazard characteristics and location
Impacts	What might happen to people and property
Guidance	Suggested actions to decrease the impacts
Location	Who the warning applied to
Time	Time of issue; time to have responded by
Link	Link to more information to reduce delays

Figure 1. Elements of a warning message

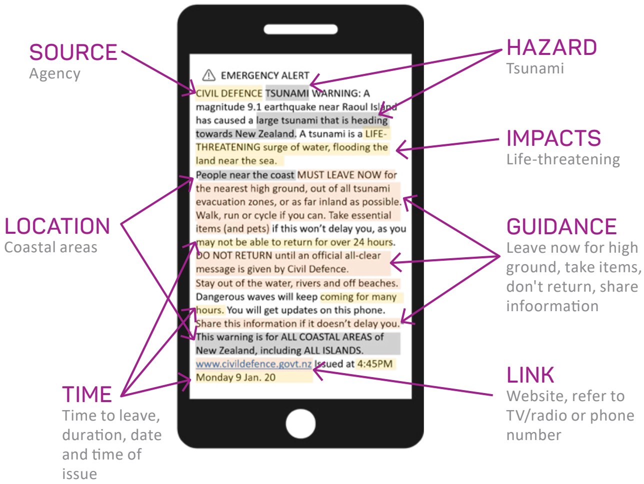


Figure 2: Example of short warning message showing key elements shown on a mobile phone.

A warning message needs to:

- be simple and accurate with no acronyms (including in the source name, unless studies demonstrate that the public understand it)
- be specific enough that people personalise it
- include achievable actions.

If the message is an update, it should say so.

Messages should not use only ALL CAPS because this is perceived as one being shouted at and is more difficult to read. Figure 2 shows an example message and includes the important elements of a message on a mobile device.

Guidelines for writing effective short warning messages (Potter 2018[4]) have been used by New Zealand's National Emergency Management Agency and local government emergency mobile alerts since 2018. The guidelines include templates and examples.

The guidelines are based on evidence from international research and were developed in 2017–18 with a steering group of local and central government agencies who issue emergency mobile alerts in New Zealand. The guidelines were tested in a New Zealand context in 2017 with a sample of public participants (N=28)[5]. In this research, participants from four locations across Wellington were presented with one of two example emergency mobile alerts about tsunami evacuation. This was to test differences in the guidance messaging and in the format that time was given in relation to their intended actions. Results showed that information about the time should be given in 12-hour format as fewer people understand 24-hour format, however, further research would confirm this. Within five minutes of receiving the message, 86 per cent of participants indicated they would intend to evacuate. However, caution is advised as the sample size in the research was small and not representative of the New Zealand population. Findings highlighted that more education and research is required related to public awareness of tsunami evacuation zones.

Endnotes

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An Australian alternative to alerts

Gavin Bernstein
UgoRound Australia Pty Ltd

An Australian team of tech enthusiasts has taken on the challenge to offer another option when it comes to disseminating serious information such as in an emergency.

The question asked was, 'Is there an alternative that offers emergency managers an exclusive platform to curate serious information such as emergency alerts?'

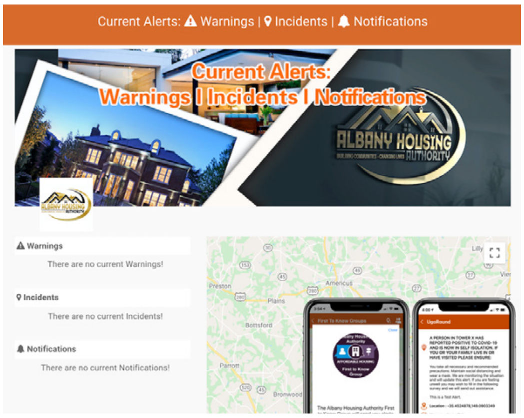
Considering this, it was concluded that people still look to local websites for information relevant to them. Relevant because information disseminated by local managers who are familiar and most likely to work for and live in the community carry a lot of credibility. This is particularly relevant because these same managers are more likely to be trusted and can distribute valid and timely information.

The view is that the local website is still the 'original' source of truth when it comes to information for a community. Yet community websites are not consistently displaying or curating a dedicated area for current alerts, whether it be for warnings, incidents and other important notifications. In the main, this information is being posted elsewhere and tweeted and is easily lost among perhaps more trivial content. This requires readers (if they see it) to figure out what is relevant and important.

An alternative is a web-based solution that offers an easy way of creating a map-based Common Alerting Protocol[1] alert. Alerts are accessible via a unique map and alert-list webpage as well as a mobile app. There is no need for people to register on the system. Users are completely anonymous, but can access all the information.

The system devised by the UgoRound team allows community websites to integrate a dedicated and interactive web-based alert map. The map is location relevant and alerts are visibly relatable to that community.

This decentralised approach to community alerts has been finding success in the USA. For example, the Albany Housing Authority in Georgia caters to a community of around 4000 people. The Authority was trying to distribute COVID-19-related information and was struggling to find a way to reach people so that they could access information, understand the seriousness and act accordingly.



The geo-alerting platform sends alerts to devices of people in affected areas.

The Authority adopted the alert map and people had access to a dedicated and current alert map page on the Authority's website. In addition, users could download the UgoRound app and join the Authority's First to Know group.

In Australia and New Zealand, this system is now available to all communities as well as emergency services organisations. This is a decentralised and whole-of-community approach to distribute critical information that can augment and also provide an alternative to SMS and social media channels.

Additional information at: www.ugoround.com.

The Australian Government, Australian Institute for Disaster Resilience and its partners do not endorse products or accept any responsibility for the use of this website.

Endnote

1 Common Alerting Protocol is data format for exchanging public warnings between alerting technologies. It allows a warning message to be consistently disseminated simultaneously over other warning systems to other applications.

Shifting the paradigm: emergency management to disaster risk management in Tonga

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Tonga is drafting its Disaster Risk Management Bill to replace the existing *Emergency Management Act (2007)*. The proposed Disaster Risk Management Act will be a new legal framework for both disaster risk reduction and emergency management in the country.

The Kingdom of Tonga is a Polynesian sovereign state and archipelago comprising 169 islands of which 36 are inhabited. Tonga, like other islands in the South Pacific, is highly susceptible to the effects of climate change and resulting disaster risks. Its susceptibility is due to its geographical, geological and socio-economic characteristics. Tonga experiences at least 1-2 cyclones every year (November-April) and is at risk of tsunami and earthquake due to its proximity to the ring-of-fire volcanoes in the Pacific Ocean. As per the World Risk Index 2020, Tonga is ranked as the 2nd highest at-risk country in the world.

Tonga's *Emergency Management Act (2007)* is the legal framework for Tonga to deal with emergencies and disasters. However, the Act focuses on responding to an event rather than recognising and dealing with the risk beforehand. The *Sendai Framework for Disaster Risk Reduction 2015–2030* (SFDRR) sets clear targets for risk reduction. It advocates for:

> *The substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries.*

The concept of 'risk' is not new but, in many parts of the world, disasters are still claimed to be a curse from God or some supernatural soul for human misdeed. A more contemporary awareness and understanding of the natural sciences is growing and the global community stance is that there is nothing natural about 'natural disaster'. All disasters result from human interaction with external events, called hazards, which may be 'natural' or 'anthropogenic'.

Tonga's existing Act has limited scope to set up the legal policy and institutions to work towards disaster risk reduction. Only recently, Tonga approved a Cabinet Submission for policy changes put through by the National Emergency Management Office under their Ministry of Meteorology, Energy, Information, Disaster Management, Environment, Climate Change and Communications. The new Act, when finalised, will establish governance and the institutional frameworks for Tonga to coordinate disaster risk reduction activities. The National Emergency Management Office will then become the National Disaster Risk Management Office with a mandate, authority and responsibility to:

- develop the National Disaster Risk Management Policy framework
- establish, review and monitor relevant emergency and disaster risk management plans and standard operating procedures under the Act
- coordinate and oversee emergency management activities
- implement policies and decisions established under this Act
- liaise with and provide support and advice to government as well as non-government agencies in Tonga for emergency management, operations and recovery.

The Disaster Risk Management Bill shifts the paradigm in Tonga from traditional emergency response practices to a comprehensive disaster risk management approach. It is expected that this will provide a direction for other Pacific nations that are facing the greater risks from climate change and the resulting natural hazards.

Emergency management evaluations: beyond the lessons-learned paradigm

Emeritus Professor Frank Archer
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Evaluations, although widely used, are often regarded as complex and confusing.

Simply put, an evaluation is a systematic and objective collection of information that helps decision-making about the worth or value of an activity. This can be for programs, projects or interventions. Evaluations may be used as either formative (i.e. used to help shape an activity) or summative (i.e. conducted at the end of the activity) and they are often classified as process, monitoring, outcome or impact evaluations. Specific evaluation methods are multiple and complex, probably one reason why evaluations are considered as varied and confusing.

One approach to evaluation is 'lessons learned', which is the predominant method of evaluation in the Australian emergency management sector. Classically, this approach includes operational debriefs, after-action reviews and assurance activities within a quality improvement philosophy. This sophisticated process of moving from 'identifying' to 'learning and translating' the lessons into practice, in a learning organisation with a culture of continuous improvement, provides the core principles of the Victorian EM-LEARN Framework[1] launched in 2015.

Developing the lessons-learned approach has been an initiative at the national level evolving over recent years. Respective comprehensive assurance frameworks for emergency management have been established by the Inspectors-General for Emergency Management in Victoria[2] and Queensland[3] since 2015. The Australian Institute for Disaster Resilience (AIDR) and the Australasian Fire and Emergency Service Authorities Council have conducted the Annual Lessons Learned Forum[4] and the *Australian Journal of Emergency Management* (AJEM) devoted a special issue in 2018 to lessons learned papers.[5] AIDR also devoted one of the AIDR National Handbooks[6] and a specific AIDR collection[7] to lessons management. However, there is little evidence of other evaluation methods being used in the emergency management sector.

One frequent, anecdotal criticism of the lessons-learned approach is that many reports remain confidential within emergency services organisations and are not available in the public domain to benefit others. Nationally, the lessons-learned paradigm is critiqued as being 'lessons not learned'. Iain S MacKenzie, the then Inspector-General Emergency Management of Queensland, noted in the 2018 AJEM issue on lessons management:

> *So, what confidence can we give our key internal and external stakeholders that we really do learn?*
>
> *My observation is that many processes are overly focused on examining how emergencies were managed rather than considering a complete PPRR approach. Equally, they also often seem to look for deficiencies rather than actively discovering and sharing the very good practices that occur.*
>
> *(Australian Journal of Emergency Management, vol. 33, no. 2, p.4)*

Expanding these reflections, we frame a bigger challenge, 'does the lessons-learned approach identify if the intervention or practice actually works'? Is it a matter of 'learning about what happened', or of determining and adopting 'what works'?

There are other evaluation strategies, methods and typologies better suited to answer this question and augment the lessons-learned approach.[8] One specific method is applicable to this argument (beyond the lessons-learned paradigm) being 'impact evaluations'[9] sometimes seen as one form of outcomes measures. The OECD[10] defines 'impacts' as, 'positive and negative, primary and secondary, long-term effects produced by a development intervention, directly or indirectly, intended or unintended'. An impact evaluation provides information about the impacts produced by an intervention, which might be a program, project, specific action or practice, or a policy. This helps to determine what works and what doesn't, and why.

Fundamental to an impact evaluation is the requirement for a measure of attribution. For example, does the intervention relate to the effects observed? These are complex and challenging evaluations requiring thorough planning and sound design. However, they are achievable in this domain and are being increasingly reported in the disaster-related literature. The Victorian Assurance Framework for Emergency Management[2] includes these concepts. Key to the study design is the use of a control group or the process known as a 'counterfactual' or what would have happened had there been no intervention. It all sounds a little mystifying, but they are non-the-less achievable and are able to be publicaly diseminated. A repository of evaluation studies, of all types, would facilitate public dissemination and benefit others in the sector. Bodies such as the International Federation of Red Cross and Red Crescent Societies, UNICEF and 3ie provide publicly accessible repositories of evaluation studies. We have previously recommended that Emergency Management Australia should develop such a repository for Australian-funded emergency management projects to be located within the AIDR Knowledge Hub.

In Australia, there are national and state-based grant schemes for emergency management projects, all of which are required to produce a 'report to funder' and many include a structured evaluation component. It is becoming standard practice to include 10 per cent of the budget of these projects to undertake an evaluation. We suggest that it be a requirement of all funded projects that the summary of the final report to the funder and the evaluation be submitted to the proposed publicly accessible Knowledge Hub evaluation repository.

In the humanitarian setting, all projects funded by the Department of Foreign Affairs and Trade (DFAT) through AusAID are required to include a project Monitoring, Evaluation and Learning Plan and a project evaluation report within the funding agreement.[11] Failure to undertake such evaluation precludes that agency from future DFAT funding. Publicly accessible monitoring and evaluation reports in the domestic emergency management sector are noticeably lacking, depriving the sector of a rich knowledge resource. One noticeable exception is the AIDR Monitoring and Evaluation plan released in November 2020.[12] This innovative, inclusive and comprehensive plan is publicly available on the AIDR website and serves as a contemporary, exemplar and as a guide for others to consider as they incorporate monitoring and evaluation plans in their projects.

As is demonstrated in the AIDR Monitoring and Evaluation plan, a key element is a 'Theory of Change', or Logic Model. Evaluations are often interpreted as end-of-project summative activities, but they are also increasingly seen as beneficial to use the Theory of Change as a formative process to guide the project's structure and activities at the beginning and during the project.

The benefits of identifying and disseminating what works is worth the effort for the community with the expectation that, over time, outcomes will improve. It is up to the emergency management sector to respond to the challenge.

Endnotes

1 EM-LEARN Framework at: www.emv.vic.gov.au/how-we-help/reviews-and-lessons-management/lessons-management-framework-em-learn.

2 Victorian Assurance Framework for Emergency Management at: www.igem.vic.gov.au/our-work/assurance-framework-for-emergency-management.

3 Queensland Assurance Framework for Emergency Management at: www.igem.qld.gov.au/assurance-framework.

4 2019 Lessons Management Forum at www.aidr.org.au/resources/2019-lessons-management-forum/.

5 *Australian Journal of Emergency Management*, April 2018, at: https://knowledge.aidr.org.au/resources/ajem-april-2018.

6 Lesson Management Handbook at: https://knowledge.aidr.org.au/resources/lessons-management-handbook/.

7 AIDR lessons management at: https://knowledge.aidr.org.au/collections/lessons-management/.

8 Science and Evaluation in Disasters at https://wadem.org/wp-content/uploads/2020/04/WADEM-PS-Science-and-Evaluation-in-Disasters.pdf.

9 Outline of Principles of Impact Evaluation at www.oecd.org/dac/evaluation/dcdndep/37671602.pdf.

10 Glossary of Key Terms in Evaluation and Results Based Management at www.oecd.org/dac/evaluation/2754804.pdf.

11 Department of Foreign Affairs and Trade 2016. Monitoring, Evaluation and Learning Framework, at: www.dfat.gov.au/sites/default/files/ancp-monit-eval-and-learning-framework.pdf.

12 Australian Institute for Disaster Resilience 2020, Monitoring and Evaluation plan, at: www.aidr.org.au/media/8324/aidr_monitoring-and-evaluation-plan_2020-10-15.pdf.

Resilience rewarded as projects meet challenges of unique year

Alana Beitz
Australian Institute for Disaster Resilience

The 21st Resilient Australia Awards celebrated initiatives that built stronger connections and hazard awareness within communities to build their capacity before, during and after disaster.

In a year that saw widespread and intense bushfires across much of Australia's landscape, compounded by the local and global effects of pandemic and the declaration of a *La Niña* season anticipated to bring increased storm and flooding hazard, the need for – and public awareness of – disaster resilience has been amplified.

This was reflected in the record number of submissions to the Resilient Australia Awards program in 2020, with 35 national finalists selected from a total of 173 submissions across 6 categories: business, community, government, local government, schools and photography.

Federal Minister for Agriculture, Drought and Emergency Management The Hon. David Littleproud MP attended the event to present the awards to the winning and highly commended projects. 'By celebrating innovation and best practice, these awards showcase work that is often unrecognised, inspiring others to think about how they can be more disaster resilient,' he said.

In her address at the awards ceremony, Australian Institute for Disaster Resilience Executive Director Amanda Leck acknowledged the many creative and adaptive responses to the challenges of 2020, and the importance of sharing, celebrating and building upon these achievements.

'Australians have proved themselves to be resilient in the face of adversity - but we are not unbreakable. Which is why we continue to celebrate the Resilient Australia Awards.

'Our work is never done, so it's important we seize these moments to encourage each other and to share successes. To renew our resolve to keep working towards safer communities,' she said.

National Award: Building resilience with children, on farms, into homes

In 2011, clinicians at the Queensland Centre of Perinatal and Infant Mental Health (QCPIMH) noticed a sharp increase in babies and young children presenting with anxiety and other emotional and behavioural disturbances. These symptoms appeared linked to the tropical cyclone and widespread catastrophic flooding that affected three-quarters of Queensland that year.

In response, QCPIMH developed Birdie's Tree, a suite of colourful, child-friendly resources to help families prepare for, cope with and recover from such events. Launched in November 2018, the Birdie's Tree universal resources include more than 8 storybooks that follow characters Birdie and Mr Frog as they cope with various hazard events.

Complementary online games help children learn about natural hazards, emergencies and explore the 'big feelings' that go with these situations. Parents, teachers, carers, emergency responders and health professionals can get more support through information and resources linked to the website.

To ensure the Birdie's Tree resources are suitable for Queensland's diverse population, a number of the Birdie's Tree books can be read online in different languages, and the website provides links to culturally appropriate resources for Aboriginal and Torres Strait Islander families. Two Birdie storybooks, 'Birdie and the Big Sickness' and 'Birdie and the Virus', have video Auslan translations to help support the resilience of young children who are Deaf or hard of hearing in the context of the COVID-19 pandemic.

Minister Littleproud presented Andrea Baldwin (on behalf of the Queensland Centre for Perinatal and Infant Mental Health) with the Resilient Australia National Award for the 'Birdie's Tree' children's storybooks and resources.

Image: Gary Hooker

Birdie's Tree resources have been used in 374 community events, leading to a total of 5649 people across the age range being screened for mental health issues and 530 receiving mental health treatment and support.

The Birdie's Tree project was awarded the 2020 National Resilient Australia Award for providing resources that help children to process their experience and emotions during disaster and provide them with the tools to communicate their feelings with others. The resources can and have been used to support children in other locations, with 34,000 new users during the Black Summer bushfires and 31,000 users accessing the site in May from across all Australian states and territories.

Another 2 Queensland initiatives were highly commended in the National Resilient Australia Award category, one for empowering farmers to better manage drought and climate risk, the other for building flood resilience.

Farming in Australia's most disaster-prone state and managing one of the world's highest variable rainfall areas is a daily challenge for Queensland farmers. The Queensland Department of Agriculture and Fisheries developed the Drought and Climate Adaption Program (DCAP) to support those working on the land through improved seasonal forecast products, tools and on-property activities. Climate scientists, government and non-government agencies, farmers and industry leaders are working together on a number of cutting-edge projects targeting the grazing, cropping, sugarcane and horticulture industries.

DCAP was borne out of the need to build the resilience and capacity of farmers and their agribusinesses to drought and climate risks. Increasing resilience at the farm level can apply more broadly to rural and remote communities in which they are located. Significantly, over 770 primary producers indicated that some practice change has occurred in their enterprise as a result of using DCAP projects.

Almost 10 years ago, architecture firm JDA Co Pty Ltd began the Building Australia's Flood Resilience initiative. It began as pro-bono grassroots action in the wake of extensive floods in Queensland in 2011, providing building assessments for uninsured homeowners and coordinating 60 architects and 100 students to record damage in 250 assessments.

The firm approached their work with a focus on 'learning through doing' and offered advice to homeowners on how to build back better while observing how building materials react to floodwater, and importantly, how much of an adverse effect such an event has on people.

Since then, the initiative has grown into work for government, non-government, industry and academic clients. This includes a community 'build back better' program, designing a number of flood resilient private homes, writing the Queensland Government residential flood resilience guide, designing the Flood Resilient Homes Program for Brisbane City Council, writing the flood resilience guides for the City of Gold Coast and successfully lobbing the insurance industry to recognise flood resilient design and lower their clients' insurance premiums accordingly.

ABC Emergency was also recognised at the awards ceremony for their outstanding contribution to national resilience. The ABC's role as an emergency broadcaster was critical during the 2019–20 bushfire season, with ABC Local Radio teams providing emergency broadcasting for more than 950 incidents – a threefold increase on previous years. In 2020, The ABC also delivered more than 3000 emergency broadcasts related to the COVID-19 pandemic.

Suncorp National Community Award: Planning for individual needs and nourishing communities

While autism is currently indicated by the World Health Organization as 1:68 of the population, A literature search indicated that there was little to no research into the needs of people with autism in relation to disasters.

The Ask Me What I Need project from Next Step Inc was initiated to fill this gap and provide awareness, acknowledgement and acceptance of the needs of people with autism when in an emergency.

With funding from the Natural Disaster Resilience Program through the Office of Emergency Management NSW Justice Community Resilience Innovation Program, a 5-minute austism awareness training video for emergency services organisations was developed to provide basic strategies for their personnel to implement when dealing with youth and adults who identify as autistic.

It is the first project to address these needs in relation to management planning and was awarded the 2020 Suncorp Resilient Australia National Community Award, sponsored by Suncorp.

As the project's title suggests, Ask Me What I Need reflects that each person is an individual and has individual needs depending on their circumstances.

Another disability-inclusive project was highly commended in the Suncorp Resilient Australia National Community Award. The Queenslanders with Disability Network partnered with the University of Sydney and the Queensland Government to launch Person-Centred Emergency Preparedness Planning for COVID-19.

This planning guide has practical tools and information to assist people with disability and those who support them to make a plan for their individual needs and situation during the COVID-19 pandemic, redressing the exclusion that people with disability have experienced in accessing emergency information.

The project was co-led by people with disability and the planning guide has been endorsed as part of the Department of Health's national response to COVID-19 for people with disability.

Suncorp CEO Lisa Harrison presents the winners of the Suncorp Resilient Australia Community Award, Berinda Karp and Richard Eifler of Next Step Inc., with a $5,000 prize from Suncorp for their autism awareness project, 'Ask Me What I Need'.

Image: Gary Hooker

The other highly commended project was the Bendigo Foodshare (BFS) Rescue, Grow, Cook and Share project, a partnership across businesses, volunteers and community groups to reduce food poverty. The project is community owned, volunteer-based and operates on the value of empowerment, not dependence.

With a 40 per cent increase in demand for food due to the COVID-19 pandemic, BFS recruited an additional 246 volunteers and worked with local supermarkets and donors to increase food rescued from 25,000 to 46,000 kgs per month.

Meals and food were distributed through 87 agencies to assist 12,800 people doing it tough every week, and the online Bendigo Community Pantry assisted in reducing stigma and improving access to food relief.

BFS believes a whole-of-community problem requires a whole-of-community response, and credits the broad, deep and active partnerships across their community for their ability to quickly engage in response to a crisis.

Local Government Award: Rising above flood impacts, providing food for thought

On the evening of 10 May 2018, Hobart recorded 128 millimetres of rain, double the previous May record. The subsequent flood inundated homes, businesses and community hubs, swept cars away and cut power to many locations. This event become known as Southern Tasmania Extreme Weather Event (STEWE).

In response, the City of Hobart's 'Resilient Hobart' project was established to deliver 5 initiatives to meet the recovery and resilience needs of the community. The project provided an opportunity to hear and learn from experiences, equip community leaders with skills support their communities now and into the future, and acknowledge the resilience of people directly and indirectly affected by this extreme weather event.

Resilient Hobart was awarded the 2020 National Resilient Australia Local Government Award for its efforts that spanned stories of resilience, a community resilience assessment pilot project, public artworks, creative recovery for family and children and Australian Red Cross Workshops for community organisations and leaders.

Collectively, the initiatives gave voice to people in communities, increased communication skills, assisted children to process emotions, and shared stories and art that acknowledge the event and inspire reflection on the need for preparedness and resilience.

Since STEWE, there have been 2 subsequent emergency events; the Huon Valley Fires in January 2019 and the COVID-19 pandemic in 2020. The shared responsibility for recovery from STEWE has strengthened relationships and increased the sharing of knowledge, skills and resources among southern Tasmanian councils.

Kimbra Parker accepted the Resilient Australia Local Government Award from Minister Littleproud on behalf of the City of Hobart for its project 'Resilient Hobart'.

Image: Gary Hooker

Department of Fire and Emergency Services WA Commissioner Darren Klemm presents Nikki Woods with the Resilient Australia National Photography Award for her image *The Driveway Project*. As a component of the award, the image features on the front cover of this edition of the *Australian Journal of Emergency Management*.

Image: DFES WA

In March 2020, at the height of the pandemic, a fire destroyed the only supermarket and hardware store in Bruce Rocks, Western Australia. With many community members self-isolating and in need of supplies close to home, the council and community acted swiftly to establish the Bruce Rocks Community Supermarket in the Shire Hall. This activity was another of the highly commended projects in the Resilient Australia Local Government Award category.

Working around COVID-19 pandemic restrictions, food and equipment was purchased and donations and volunteer labour were coordinated. Vegetable boxes were dropped to residents only days after the fire and the store was open for business within a week.

Bruce Rocks Community Supermarket project has reminded the community of their strength, and boosted confidence that they can operate on a business as usual basis, even when they are dealing with multiple events.

Food was the focus of the other highly commended project in the Resilient Australia Local Government Award category. When COVID-19 pandemic restrictions interrupted food festivals and day trips, local producers from the Scenic Rim region sent their food to customers' doors through the Scenic Rim Farm Box initiative, supported by the Scenic Rim Regional Council.

In the first 3 weeks the venture had dispatched over 1100 boxes to customers throughout southeast Queensland. In the first 7 weeks over 2000 boxes were sold at an average of $140 per box, amounting to over $280,000 in revenue.

The economic boost delivered through the Scenic Rim Farm Box was welcomed after the devastating bushfires and drought conditions in 2019 and flooding that had altered transport routes during 2020.

Photography Award: Capturing family strength and sacrifice, and commitment to service

As COVID-19 pandemic restrictions closed borders and isolated families, photographer Nikki Woods travelled from driveway to driveway in Gingin, Western Australia to capture what families were doing during this strange time, and to spread some laughs and smiles along the way.

Her Resilient Australia Photography Award winning image captured the Todd family and their dog in their driveway ‘dressed to the nines’ as they enjoyed a cheese platter on the bonnet of their vintage car, pulled out of the shed especially for the occasion. As father and husband Leith works away from home, the family usually treat themselves to a night out for dinner when he returns. With everything closed due to the pandemic, the family recreated the experience in their driveway. The Todd family are just one of the many Gingin families that were involved in #thedrivewayproject.

The Driveway Project - Winner, 2020 Resilient Australia National Photography Award.

Image: Nikki Woods

From a different angle - Highly Commended, 2020 Resilient Australia National Photography Award.

Image: Blair Horgan

Toddler of hero father presented with bravery medal - Highly Commended, 2020 Resilient Australia National Photography Award.

Image: James Morris

Minister Littleproud with Wendy Bode and Kaitlyn Hotz from Thuringowa State High School, who accepted the Resilient Australia School Award for the project 'Disaster Resilience for a Change Climate Grand Challenge'.

Image: Gary Hooker

One of the most memorable and emotional images from the 2019–20 bushfire season was highly commended in the National Photography Award category. James Morris's image depicts then NSW Rural Fire Service Commissioner Shane Fitzsimmons pinning a Commissioner's Commendation for Bravery badge to toddler Harvey Keaton's shirt in memory of his father, Geoff Keaton, who was killed while undertaking firefighting operations in Sydney in December 2019. The heart-wrenching image captures the significant sacrifice and service of firefighters during a particularly dangerous and devastating bushfire season.

The other highly commended image in the photography award was presented to Blair Horgan for the image 'From a Different Angle'. The image captures a Tasmania State Emergency Service volunteer peering through a smashed car window during a joint training exercise with student doctors on dealing with mass causalities.

School Award: Students find tech solutions, forge connections for resilience

Monsoon activity in North Queensland in 2019 created a significant flood event that closed schools and roads and forcing evacuations. Following this distressing incident, questions arose about the resilience of young Queenslanders and how they can better prepare for disasters and the effects of climate change.

Thuringowa State High School found one solution in technology, with the Disaster Resilience for a Changing Climate Grand Challenge course delivered through the school's Queensland Virtual STEM Academy. The 10-week course for students in Years 5-9 is a virtual platform that connects like-minded students from different schools with university and industry experts. In collaboration with Townsville City Council, emergency managers and James Cook university, students developed resilience and community activities to help people be safe, seek assistance and help others before, during and after events.

To reflect the diversity of the people and hazard profiles in Queensland, the course focuses on a variety of hazards that are experienced across Queensland. Students use scientific inquiry and problem-solving skills and collaborate with each other and experts to solve the Grand Challenge. Importantly, 92 per cent of students indicated that the course improved their understanding of climate change and the need for resilience. The education project was awarded the 2020 National Resilient Australia School Award.

The 2 highly commended projects in the school category were designed to introduce students to emergency service agencies and their personnel. This project boosted young people's understanding of hazards and their possible roles and responsibilities before, during and after events.

Minister Littleproud with representatives of winning and highly commended projects in Queensland.
Image: Gary Hooker

Augusta Primary School's pilot program 'Exploring Emergency Services' was a coordinated effort by the school and local emergency services to lead change in disaster resilience among youth and their families in Augusta, Western Australia. The program focused on increasing student understanding of local risks, emergency services resources and empowering students and their families to take responsibility for their actions, prepare and plan for emergencies. The program also inspired students to consider volunteering and increased social cohesion between students, families, primary school staff, community members and emergency services in the Augusta community.

A similar project at Timboon P-12 School in Victoria increased student awareness and experience of emergency services activity through the Timboon Agriculture Project. The initiative links the school to its local community, creating champions for effective school-industry engagement among its staff, families and community. In 2019, the annual celebration of the school's curriculum focused on volunteering through the theme: Step Up! Almost 500 students from Timboon and neighbouring Nullawarre Primary School were introduced to the gamut of volunteering in all sectors across our community. The expo was followed by age-tailored workshops for students and community visitors to continue this engagement and learning about the roles of emergency services volunteers and the training activities and technologies they use. The workshops and rescue scenarios reinforce the importance of community connections, demystify emergency personnel, build relationships based on trust and appreciation, and encourage new volunteers.

Information about the Resilient Australia Awards is on the Australian Institute for Disaster Resilience website: aidr.org.au/raa.

The Principles of Effective Warnings

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The e-book *The Principles of Effective Warnings: For Emergency Agencies, Health and Education Authorities, Local Government, Media, Business* focuses on how effective warnings might be developed for different emergency situations, so that people can take action to protect themselves. Ian Mannix is the editor of this publication, and he has drawn from a range of experts to provide input. He has also contributed to many chapters himself. The book provides a starting point for people learning about the basic aspects of what constitutes effective warnings.

Unlike many warnings publications, the book starts with a human-centred focus, rather than technical. The first chapter summarises some of the key components of effective warnings from a people perspective, such as the aims of a warning (i.e. understanding the threat and taking appropriate action) and the components that might affect such responses (e.g. interpretation, consistency, trust). It links with key warning principles recommended in Australia (e.g. by the Australian Institute for Disaster Resilience).

Subsequent chapters dive more into the context and specifics of warnings. Chapter 2 outlines different disasters and how warnings might apply within those contexts, and delves into issues regarding ethics, duty of care and legal issues. Trauma psychologist Rob Gordon contributes a chapter (Chapter 3) on how humans respond to disasters across response through to the recovery phase. Given that disasters can be highly stressful for people, he also touches on how you might communicate with people in a stressed state, an important consideration when issuing warnings and subsequent supporting information. Additionally, he covers the needs of diverse and vulnerable communities before and after emergencies. There are brief chapters (4 and 5) on global warming and risk. These chapters touch lightly on the topics themselves, but do not have in-depth discussion of their relationship with warnings.

Chapter 6 focuses heavily on warnings, and the research behind them. It draws from prominent researchers in the warning space (e.g. Dennis Mileti, John Sorenson) to understand the key social components that influence the warning process. It discusses the context for different types of warnings (e.g. for different hazards) and proposes a framework for different warning pathways. Aspects of warnings such as frequency, timing, alert levels and more are also presented. The final two chapters (7 and 8) look more closely at how to create an effective warning in terms of wording, content and source, and provide commentary on the holistic nature of warning systems. At the back in the appendices, there is a long list of warning examples, and resources for further reading.

While this publication is based on relevant literature, some aspects are referenced well throughout the text, and others are missing key references. In particular the new conceptual 'frameworks' and 'models' presented in the book would have benefited from referencing the sources behind the concepts. Additionally, while the publication has some great background material on effective warnings, the chapters tend to jump around a bit, reducing the flow of the book. As highlighted earlier, some do not seem to address the topic of warnings in detail. However, given its general readability, this is a good publication to flick though for an overview. It contains some useful material that can be further explored via the links to the background resources (for example, the Australian Disaster Resilience Handbook on Public Information and Warnings published by the Australian Institute for Disaster Resilience). It also presents a number of examples that might be useful to practitioners when considering how to develop effective warnings.

Australia's intergovernmental agreement on bushfires, floods and extreme events

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Introduction

Extreme meteorological and ocean-related events, including the tragic Victorian Black Saturday bushfires in 2009, heat waves that preceded the catastrophic bushfires, and severe tropical cyclones, resulted in the Australian Government implementing recommendations from a comprehensive independent review (Bureau of Meteorology 2013). The review received significant and positive response from government and the Bureau of Meteorology (Bureau) over the following years. One of the major recommendations and subsequent government response was the standardisation and harmonisation of Bureau services to jurisdictions in order to maximise the efficiency and value of its partnership with emergency service organisations.

For hazard warning systems to be effective, they must be multi-faceted and be developed and operated collaboratively and across different levels of government and jurisdictional boundaries. Emergency services organisations use the Bureau's information, forecasts, warnings and advice to plan for and manage the effects of natural hazards.

The Bureau worked closely with Emergency Management Australia and all jurisdictions, as well as the Australasian Fire and Emergency Services Authorities Council (AFAC) and the Australian Local Government Association (ALGA) over a period of 3 years. This was a unique opportunity for a strengthened 'natural hazards partnership' similar to that in the United Kingdom. The teams from all emergency services agencies and the Bureau established a landmark intergovernmental agreement (Council of Australian Governments 2018) as well as an ongoing peak consultation body: the Hazards Services Forum.

The work was undertaken within the Australian-New Zealand Emergency Management Committee (ANZEMC 2020) through a joint Standardisation of Bureau of Meteorology Services Taskforce. Outcomes from this work included significant improvements to bushfire, flood and extreme event services; addition of further embedded meteorologists in incident control centres and a high-level policy accomplishment: an intergovernmental agreement under the Council of Australian Governments (COAG) in 2018, which was endorsed by state and territory governments and the Australian Government. The intergovernmental agreement enshrines the Hazards Services Forum and provides additional clarity of roles and responsibilities for emergency management agencies at all levels of government. The substantial outcomes resulting from the collaborative process are discussed in this paper with a focus on shaping government and agency policies and operations to enhance community safety.

The work described here to achieve national consistency and standards across major hazards, especially forecast and warning types, structure and technical content, will be an important input to the Australian Warning System, which was recently launched (see AFAC Warnings Group, Australian Institute for Disaster Resilience 2021). While the AWS is now in place for bushfires, the intergovernmental agreement and Hazards Services Forum should also assist that framework development as other hazards are introduced. The outcomes described in this paper are essential to the national consistency of the forecasts and warnings for particular hazards, while the AWS will provide the essential national consistency of messaging and icons and calls to action. Both are necessary for an effective Total Warning System.

Forecasting and warnings services

Economic activity and public safety are heavily affected by severe weather, climate and floods. The forecasting and warning services of the Bureau (several million each year) are relied on whenever there are heatwaves, fires, tropical cyclones, gales, floods, thunderstorms, fog, frost and other weather and ocean-related events such as storm surge and marine services. Further, the Bureau provides an extensive range of other forecast and warning services, including smoke and radiation atmospheric modelling, volcanic ash warnings for aviation, space weather services and tsunami warnings and advisories for Australia and the Indian Ocean region. In addition, the Bureau provides extensive climate services such as seasonal outlooks. The effects of extreme weather in Australia, combined with its growing population, infrastructure and assets, has increased demand on the services offered by the Bureau.

The Bureau's mission is to 'provide trusted, reliable and responsive weather, water, climate and ocean services for Australia - all day, every day'. In undertaking this mission, the Bureau has partnerships with state and territory emergency services organisations to ensure the safety and resilience of Australian communities.

The 2011 review (Bureau of Meteorology 2013) examined the Bureau's capacity to respond to future extreme weather and disaster events and to provide seasonal forecasting services. The review identified 13 priority actions to mitigate risks and 16 options that could provide savings and enhance efficiency. The first 2 priority actions - bolstering meteorologist and hydrologist numbers and upgrading flood warning systems, were addressed by the Bureau with Australian Government support.

In response to the review, the Australian Government, in partnership with the states and territories, progressed the other issues raised under:

- Priority Action 3: formalise and standardise service levels provided to emergency services
- Priority Action 4: agree clear allocation of responsibilities to state and local government for flood management, with defined boundaries on the Bureau's role
- Option 21: apply a consistent cost-recovery model to all supplementary services delivered to state/territory fire agencies.

This was achieved through the ANZEMC establishing the Standardisation of Bureau of Meteorology Services Taskforce on 4 October 2013, which then reported to the Law, Crime and Community Safety Council (LCCSC) of COAG in 2015.

The Munro Review and the government response

In the years leading up to the 2009 Black Saturday bushfires, the Bureau had been developing high-resolution weather modelling as well as expanding its interactions and collaboration with fire and emergency services organisations. This included specialist severe weather meteorologists being embedded in some incident control centres. Additionally, the Bureau was an active partner in the Bushfire CRC (and the following Bushfire and Natural Hazards CRC), which enabled fire weather research to be advanced and adopted into services.

It was recognised that during extreme weather events, briefing requests from representatives from government and media organisations were often handled by a small number of highly respected and sought-after senior Bureau forecasters. These pressures were particularly acute during protracted severe weather events. The pressure on the Bureau to satisfy a wide-ranging client base was particularly evident during the severe weather season of 2010–11 that included severe floods in many parts of Australia, tropical cyclones (including Cyclone Yasi) and bushfires in Western Australia. These incidents, including an international response to the Fukushima tsunami and associated nuclear radiation fallout modelling, demonstrated the increasing demand for Bureau services and the sustained pressure this can produce.

The Australian Government appointed Ms Chloe Munro to undertake the review with a support team from other agencies. The review noted the imbalance between demand and the Bureau's capacity to deliver critical services to states and territories and Australian Government agencies. Among other findings, the review recommended boosting the numbers of frontline hydrologists and meteorologists. Additionally, the review noted that:

- further storm surge experts were necessary for high-risk regions, especially along the Queensland coastline
- a review of Space Weather services was necessary
- an extreme weather centre should be considered
- standardisation of Bureau services across all jurisdictions was a priority (taking into account differing climate and hazard regimes to optimise current and future services in a sustainable approach).

Consistent with review recommendations to formalise service levels with emergency services agencies, the Australian Government agreed to standardise many bespoke services.

One of the issues highlighted in the review related to the issuing, interpretation and dissemination of flood warnings. The review identified a lack of clarity regarding roles and responsibilities, inconsistent arrangements across jurisdictions and the absence of binding agreements on service levels in relation to flood management. This situation had the potential to cause confusion and elevate the risk that not all communities would have access to the highest standard level of information.

Standardisation of forecast and warning services

The Bureau's weather, flood and ocean forecasting and warning services, as well as critical climate services, are essential to decision-making, especially for emergency management. Australia's states and territories have, historically, had different needs and governance structures for emergency management. The evolution of locally focused arrangements and models of operation had resulted in variations in the services provided by the Bureau. These variations led to increasing complexity in the delivery of services and were inhibiting its ability to effectively meet expectations and respond nationally to concurrent hazard events.

The taskforce recommended that the Bureau standardise its hazards services and allocated responsibilities across the Bureau, states, territories and local governments for flood management. The taskforce provided an implementation plan that was endorsed by the ANZEMC and the LCCSC. Additionally, the taskforce recommended a time-limited working group to focus on flood warning infrastructure and risk-based network planning.

The taskforce members from state and territory emergency services agencies were at the senior operational and policy levels (Deputy Commissioner, Chief Officer, CEO) as well as the CEO of AFAC and the Senior Policy Advisor of the Australian Local Government Association. The Australian Government was represented at Division Head level by the Bureau and Emergency Management Australia (part of the Attorney-General's Department at the time and now within the Department of Home Affairs). The taskforce members' roles and contributions to this work were critical and enabled an effective decision-making body for the standardisation to be overwhelmingly successful. The taskforce was very effectively supported by working groups of senior officers in all jurisdictions who specialised in fire, flood, extreme weather events and community understanding and response to warnings.

The taskforce was operational for 3 years and used face-to-face and video meetings as well as numerous working group meetings to examine the substantial jurisdictional variations in fire, flood and extreme weather services. The key achievements were:

- standardising 117 of the 129 (subsequently updated to 131) identified hazard services provided by the Bureau to states and territories
- agreeing roles and responsibilities for flood management, including ownership and maintenance of flood warning infrastructure
- producing an intergovernmental agreement under COAG on the 'Provision of Bureau of Meteorology Hazard Services to the States and Territories'
- establishing the Hazards Services Forum
- creating a services-focused National Flash Flood Information Repository
- establishing the National Flood Warning Infrastructure Working Group.

ANZEMC, and subsequently the LCCSC, agreed to all recommendations, including the intergovernmental agreement to provide the Bureau's hazard services to states and territories. Figure 1 shows the 9-year timeline (2009–18) of the major event triggers and the critical steps to establishing the intergovernmental agreement. These steps included the 2011 review, the Australian Government response and the ANZEMC Standardisation Taskforce Report in 2015 and the intergovernmental agreement in 2018.

A substantial action agenda was established to achieve the agreed standardisation of the 117 services. In accordance with the intergovernmental agreement, the ongoing Hazard Services Forum was established to:

- complete the remaining standardisation actions of the taskforce
- consult with state and territory emergency services agencies on current and future development of the Bureau's hazard services
- provide advice to the Bureau on the appropriateness and relative priority of requested changes to ensure its services meet the expectations of the national emergency services community
- consider the 12 services yet to be agreed for standardisation and to oversee the implementation of the 3 hazard-specific action plans for fire, flood and extreme weather.

Figure 1: The timeline of the major event triggers and the critical steps to establishing the intergovernmental agreement (2009–18).

Other hazard services that had not been agreed originally were addressed by the forum and by March 2019, forum members and specialised working groups had completed 98 of the 131 standardisation actions.

The National Flood Warning Infrastructure Working Group was very active and in 2019 met its 3 year timeline for completion of its work. The National Flash Flood Information Repository was developed by the Bureau in consultation with state and territory flood stakeholders.

The intergovernmental agreement

The intergovernmental agreement was endorsed by the ANZEMC and the LCCSC in 2015 and was agreed by COAG in 2017–18 after extensive consultation, over 2 years, between the Bureau (Canterford, personal communication) and all state and territory senior officials and emergency services ministers and federal ministers. The agreement sets the roles and responsibilities and implementation of standards for meteorological and hydrological services across governments in Australia. It also added clarity on agency responsibilities and roles within total warnings systems. Although this may have appeared to be a relatively simple problem to solve, over 100 years of Bureau operations, forecast and warnings services had grown organically to over 129 variations of services across the country. Additionally, products and outputs from emergency service agencies were at times divergent and the taskforce addressed many of those.

To illustrate, while the Bureau undertakes a national heatwave forecast service (www.bom.gov.au/australia/heatwave/) that provides maps (see Figure 2) of the next 5 3-day periods, which show the heatwave forecast areas and intensities, more 'detailed high-resolution advisory' services are undertaken in collaboration with jurisdictions. However, Figure 3 is an example of one of these bespoke extreme heat 'detailed high-resolution advisory' services, which was developed and used by South Australia from 2010 until 2019 to support all heatwave warnings within only one jurisdiction. Heatwaves are Australia's most deadly and costly disaster, and because of the non-standard approaches in each state and territory for detailed high-resolution advisories, work initiated by the Hazards Services Forum is currently being progressed by a time-limited National Heatwave Working Group. It was established by ANZEMC at the request of the forum to finalise a national heatwave warning framework to bring a consistent approach and consensus to heatwave public information and warnings in all Australian jurisdictions.

Other examples of jurisdictional variations and Bureau variations that have been addressed by the intergovernmental agreement and the forum include the resolution of variations of jurisdictional input to fire danger ratings, such as grassland curing and fuel mapping, cell-based thunderstorm warning services (now available in all capital cities) and major advances and standardisation of flood infrastructure and warning services.

Having so many unique services at the jurisdictional level created community misunderstanding and uncertainty and risk. These services were analysed in the categories of fire weather, flood services and extreme weather and hazard-impact services. The intergovernmental agreement established roles in the warning process, established over 100 agreed standards for services and created a governance framework centred around the Hazards Services Forum to oversee the agreement and ensure the completion of the harmonisation and standardisation of the over 100 services. This means that the forecasts and warnings are in the same form and provide the same detail no matter where the service is provided. The national arrangements are also more efficient in building new services on a national basis that is based on the latest technology and expertise, and communities will receive similar types of warning independent of where in the country they live. With workforces being more mobile in emergency services and populations continuing to move, such standardisation across jurisdictional boundaries simplifies community education and understanding of particular warnings.

However, the agreement recognises that jurisdictions do not always have uniform requirements for weather services and products. Queensland, for example, makes extensive use of tropical cyclone products, whereas Tasmania may rely heavily on frost warnings. When states or territories receive the same service, it is now delivered in accordance with an agreed standard. The agreement also identifies supplementary services that can be provided on a cost-recovered basis for specific demands.

Outcomes of the intergovernmental agreement

For fire weather services, as well as the Bureau progressing its own services, the Hazards Services Forum supported the AFAC Predictive Services Group to progress several fire weather service improvements. This was valuable and successful in agreeing common products across borders (firefighters need consistent national products for firefighting) and the Bureau improved its special fire weather forecasts. The main features of improvement were:

- hourly time steps
- spatial variation information
- forecast uncertainty information
- focus on wind changes.

A range of other fire weather services have also been standardised, developed and implemented across all jurisdictions, in partnership with emergency services agencies. These include improved fire weather danger indices and ratings.

Flooding in Australia causes significant direct and intangible costs. Floods have major financial and social impacts on individuals, communities and businesses (Department of Home Affairs 2018). The agreement formalises the responsibilities of the Bureau, state, territory and local governments for flood management. It also leads to increased cooperation among agencies for flood warnings and river gauge networks.

The intergovernmental agreement recognises the role of Flood Warning Consultative Committees in developing service-level

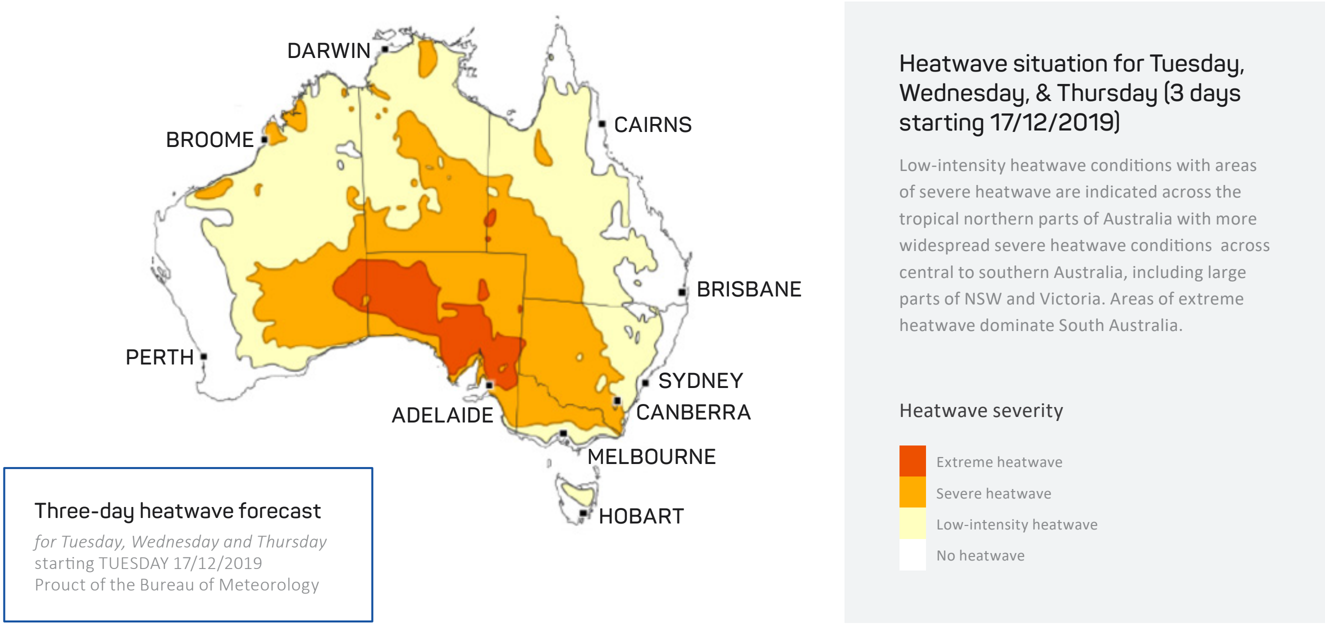
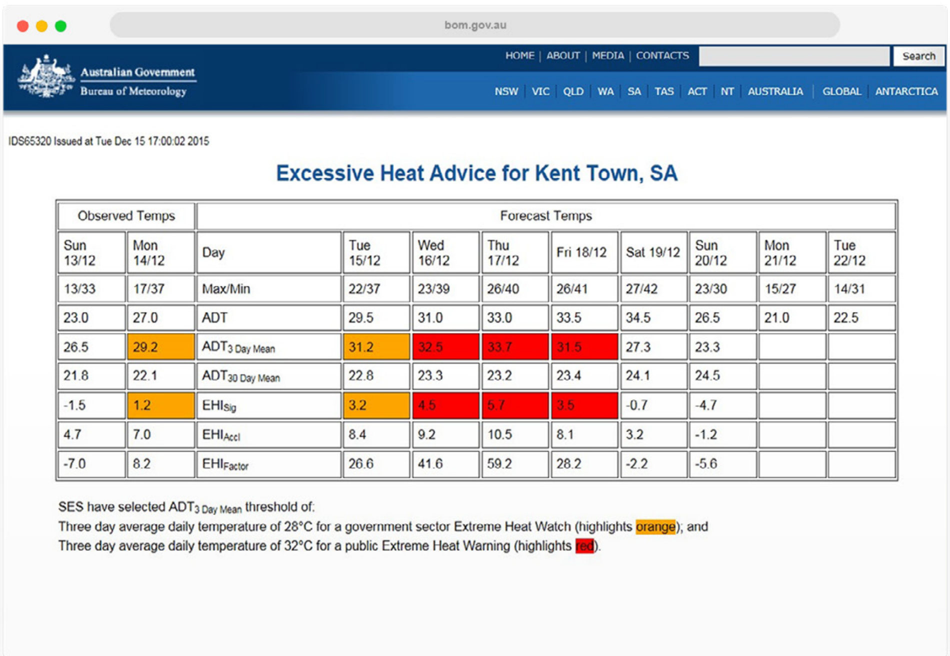


Figure 2: Output map from the Bureau of Meteorology National Three-Day Heatwave Forecast Service.

Source: www.bom.gov.au/australia/heatwave/



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IDS65320 Issued at Tue Dec 15 17:00:02 2015

Excessive Heat Advice for Kent Town, SA

Observed Temps		Forecast Temps								
Sun 13/12	Mon 14/12	Day	Tue 15/12	Wed 16/12	Thu 17/12	Fri 18/12	Sat 19/12	Sun 20/12	Mon 21/12	Tue 22/12
13/33	17/37	Max/Min	22/37	23/39	26/40	26/41	27/42	23/30	15/27	14/31
23.0	27.0	ADT	29.5	31.0	33.0	33.5	34.5	26.5	21.0	22.5
26.5	29.2	$ADT_{3\ Day\ Mean}$	31.2	32.5	33.7	31.5	27.3	23.3		
21.8	22.1	$ADT_{30\ Day\ Mean}$	22.8	23.3	23.2	23.4	24.1	24.5		
-1.5	1.2	EHI_{Sig}	3.2	4.5	5.7	3.5	-0.7	-4.7		
4.7	7.0	EHI_{Accl}	8.4	9.2	10.5	8.1	3.2	-1.2		
-7.0	8.2	EHI_{Factor}	26.6	41.6	59.2	28.2	-2.2	-5.6		

SES have selected $ADT_{3\ Day\ Mean}$ threshold of:
Three day average daily temperature of 28°C for a government sector Extreme Heat Watch (highlights orange); and
Three day average daily temperature of 32°C for a public Extreme Heat Warning (highlights red).

Figure 3: Example of a bespoke heatwave warning service developed for South Australia.

specifications and describes the responsibilities of all parties for flood arrangements, including riverine and flash flooding.

The National Flood Warning Infrastructure Working Group undertook an extensive investigation of networks and has detailed the gaps and variable processes across the nation. This work showed that further national leadership is necessary to ensure effective sustainable investment at all levels of government. The group's report provides recommendations on what is required to achieve effective uplift of networks, their maintenance and where investment is best targeted. All states and territories and the Bureau have undertaken considerable analysis of their networks as a pathway for this national network uplift.

Another major achievement of the National Flood Warning Infrastructure Working is a national technical performance standard for flood forecasting and warning and an agreed path to consistently improve networks across all jurisdictions, including those of the Bureau.

The Bureau's flood services have also been enhanced by a flash flood information portal requested by all jurisdictions. The National Flash Flood Information Repository, renamed the Flash Flood Advisory Resource (FLARE) (Bureau of Meteorology 2020), was initially funded by the Disaster Resilience Australia Package and supported further by the Bureau. Since its launch, over 50 activities were completed in all states and territories. In 2018, the number of registered FLARE users had increased by 150 per cent (86 to 207) and the number of registered organisations increased by 100 per cent (42 to 86). Consultants have access to the repository and FLARE services are managed by the Bureau's flood services teams.

For extreme weather and high-impact services, all 48 jurisdictional variations of services were agreed to be standardised. Achievements include thunderstorm warnings that provide a threat of severe thunderstorms and graphical content, and tsunami threat bulletins and warnings that are consistent.

Other services that have been standardised include coastal wind warnings, hazardous surf warnings, ocean wind warnings, extreme heat advice, pre-season briefings and tropical cyclone services, including updated frequencies and bulletins.

Conclusions

Through a review of Bureau services and an intergovernmental agreement, Australia now experiences improved standardised services and a higher level of cooperation and collaboration in forecasting and warnings and in preparing for and responding to disasters. The major outcomes of this collaborative approach with the Bureau are due to the level of attention and understanding provided by emergency services commissioners and chief officers, together with Emergency Management Australia, AFAC and ALGA.

This work, initiated to harmonise and standardise, has resulted in benefits and services across Australia. It has improved Bureau services and collaboration with emergency agencies, provided a high-level national forum to maintain standards and incorporate new services, established a new flash flood information portal and enabled advanced flood planning and standardisation of risk-based national networks, instruments and infrastructure.

Acknowledgments

The dedication and vision of the taskforce senior emergency experts from all jurisdictions and many Bureau of Meteorology specialists who contributed over several years is acknowledged, particularly, Shoni Maguire, Bureau of Meteorology for his essential support, Stewart Ellis, AM, CEO of AFAC and his AFAC colleagues as well as Robert Cameron, OAM, retired Director-General Emergency Management Australia for his support and co-chairing of the Hazards Services Forum. Additionally, the lead author acknowledges the current Bureau leadership for their continuing support of the intergovernmental agreement and advancement of its outcomes in partnership with state and territory emergency services agencies, EMA and AFAC. The authors also acknowledge the invaluable review and editing by Christine Belcher. The author may be contacted at Ray.Canterford@icloud.com.

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Using community voice to build a new national warnings system for Australia

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Abstract

The provision of public information and warnings plays a vital role in supporting safer communities before, during and after an emergency. The variability of Australia's hazard warnings has led to lower levels of trust and credibility in warning systems. This presents a significant barrier to effective community comprehension and response to warning messages. In 2018, a national social research project was initiated to examine community understanding and response to current warning systems to identify the features of a best-practice national system incorporating community voice. This project involved 4 stages of quantitative and qualitative research that surveyed 16,585 people in Australia between 2018 and 2020 to achieve a statistically robust evidence base. Hazards investigated included bushfire, cyclone, flood, extreme heat and extreme weather. This paper presents the findings of this research and discusses implications for the development and implementation of a new 3-tiered national warning system for multiple hazards.

Introduction

In Australia, warning systems vary significantly across hazards and jurisdictions, with only bushfire and tsunami having established national warning frameworks. This presents a significant barrier to people to comprehend and respond to warnings messages. In recent years, emergency services organisations have collaborated to pursue and develop a national warnings system. The aim of this study included investigating what a new multi-hazard communication tool would look like that assisted communities to understand threats and encouraged people to take protective action.

Emergency services organisations and research institutions have invested significantly to improve community comprehension and response to warnings messages. A comprehensive review (Emergency Management Victoria 2014) compiled then-current systems and set clear directions for improvement, including a call for governance and coordination of public information practice at the national level. Since that time, research through the Bushfire and Natural Hazards Cooperative Research Centre (BNHCRC) Effective Risk and Warning Communication project has identified how warning messages can be better constructed and translated into direct action through testing of wording and structure (Greer *et al.* 2020a, 2020b, 2020c). In addition, a national direction for best practice was set and a Total Warning System was published in the *Public Information Warnings Handbook* (Australian Institute for Disaster Resilience 2018).

Post-incident and BNHCRC studies identified barriers to comprehension of warnings during emergencies. For example, in two fires, the Reedy Creek Swamp fire of 2018 in NSW and the Sampson Flat fire of 2015 in South Australia, the communities failed to understand the meaning of the message 'take shelter'. The result was people failed to appropriately act either because they did not understand (Whittaker *et al.* 2020) or because they misinterpreted the actions required, which ranged from 'wait and see' to 'leave now' (Every *et al.* 2016). In response to BNHCRC and other research findings, several jurisdictions have reviewed their warning systems to make warning messages effective and easier to understand by bringing critical information upfront and simplifying the wording. However, not all emergency services agencies have the capacity to change systems and there has been resistance to developing consistent messaging across borders and hazards.

In 2018, these challenges were explored by Anderson-Berry and co-authors (2018) in their comprehensive review of the total warning system concept and how it might be applied in Australia. Their findings reinforced the importance of taking a 'people-centred' approach to achieve an effective warning system, rather than a hazard-based approach. In a people-centred system, the messaging is directly relevant to those at risk and is about protective actions to take and the likely consequences rather than about the hazard.

Acknowledging the priority of consistent warnings across hazards, the Commissioners and Chief Officers Strategic Committee (CCOSC) of the Australasian Fire and Emergency Services Authorities Council (AFAC), committed to establishing a nationally consistent 3-level warning framework across multiple hazards. In 2018, CCOSC supported seeking community voice to inform a national warning system for multiple hazards in conjunction with the Australian Fire Danger Rating System (AFDRS) social research. The AFDRS research findings are currently informing the development of the new risk communication tool for fire danger (O'Donohue & Dunstan 2019, AFAC 2019).

This paper explores warning systems from a national multi-hazard perspective to inform the development of a consistent 3-tiered national warning system to communicate hazard threat and promote desired protective behaviours for bushfire, cyclone, flood, extreme weather and extreme heat. Regional, state and territory as well as national data was collected (Metrix 2020 multiple reports), including results from within jurisdictions (not discussed here).

Methodology

This research was undertaken alongside the National Fire Danger Ratings Social Research with the methodology previously published (O'Donohue & Dunstan 2019). A fourth stage was added for the warnings project as illustrated in Figure 1. The methodology was co-developed by Metrix and a Project Steering Group with all subsequent project survey tools and reports drafted by Metrix and reviewed in consultation with steering and reference group members. The Metrix natural-hazard transtheoretical model, Seven Stages of Behaviour Change, was applied to support data analysis. This model is described in the Stage 1 Report (Metrix 2018) and differs from the traditional model:

- Recognition of risk is more complex (transitioning from general risk recognition to personal risk assessment to personal risk recognition).
- The decision to prepare does not always follow knowledge.
- Action is separated into 2 low- and high-engagement categories.

Table 1 summarises the sampling dates, sizes and error margins. The quantitative data was weighted by age and gender for representativeness at national and jurisdictional levels. Qualitative research sample locations included areas where minor or major incidents have occurred in the past 5 years, areas where no incidents have occurred in the past 5 years and low-risk areas. A cash incentive of up to $100 was provided to focus group participants to maximise participation. Some participants were filmed discussing their personal experiences of recent emergencies. In Stage 4, testing scenarios were restricted to 3 hazards of bushfire, floods and cyclones. Each participant was asked questions relating to 2 hazards on a randomised basis.

The study was conducted inline with the Research Society Code of Professional Behaviour, accredited by the Association of Market and Social Research Organisations (AMSRO) requiring adherence to the Privacy (Market & Social Research) Code and the AMSRO Code of Professional Behaviour and certified by the International Standard for Market, Opinion and Social Research certification (ISO 20252).

PROJECT IMMERSION	STAGE 1 NATIONAL BENCHMARK SURVEY	STAGE 2 QUALITATIVE RESEARCH	STAGE 3 QUANTIFICATION OF OPTIMISED MODELS	STAGE 4 QUANTIFICATION OF MIDDLE LEVEL NAME
A comprehensive desk review of existing jurisdictional research reports and data, and secondary research sources available in the public domain was conducted. Insights from these reports were used in the development of sampling composition and questionnaire content for further research stages.	As data had never been collected regarding Australia's warning systems, a nationwide online survey was conducted to benchmark current levels of awareness, comprehension and action taken due to exisiting systems.	Insights from the national benchmark survey were used to guide the scope of qualitative research (sampling and content). Existing jurisdictional systems with the highest levels of comprehension were used to assist with the creative process.	Following Stage 2, a select number of optimised systems were developed. A further online survey was run in January 2019 to identify the systems which promote the greatest levels of comprehension and positive action.	Following Stage 3, two potential names for the middle name were identified. To determine the definitive preference of the community, additional quantification was undertaken in 2020.

Figure 1: Overview of research methodology for the Australian National Multi-Hazard Warnings Social Research Project.

Table 1: Dataset summary for the Australian National Multi-Hazard Warnings Social Research Project.

Research stage	Method	Field data collection	Total sample size	Maximum margin of error
Stage 1: National Benchmark Survey				
Benchmarking awareness, comprehension and effectiveness of the warning systems in each jurisdiction and for each hazard.	National online survey	14–27 September 2018	n=5430	±1.33% at 95% confidence
Stage 2: Qualitative Research				
Detailed insight into the required form and characteristics of hazard warning systems including critique of local and interstate systems.	47 focus groups and 1 workshop	October to November 2018	n=340	
Sample locations	ACT (3), NSW (8), NT (3), Qld (9), SA (5) + 1 workshop, Tas (4), Vic (8), WA (7)			
Stage 3: Quantification of Optimised Models				
Quantifying the characteristics of a warning system that promotes the greatest levels of comprehension and positive action. Concepts tested were derived from stages 1 and 2, with the proviso that if a concept was untenable for implementation, it would not be included.	National online survey	24 May to 9 June 2019	n=5408	±1.33% at 95% confidence
Stage 4: Quantification of Middle Level Name				
Identifying the community's definitive preference for the name of the middle level and the optimised order of a nested warning including the warning level name, hazard, location and calls to action at different levels within a multi-hazard warning system.	National online survey	27 July and 9 August 2020	n=5407	±1.33% at 95% confidence

Results and discussion

Results are a summary of the project findings with more detail available in the project reports (Metrix Consulting 2019, 2020). Overall results complement and re-enforce the findings of previous studies, however, detailed examination of the previous findings is beyond the scope of this paper.

The initital challenge was ascertaining a national benchmark for levels of warning awareness and comprehension across Australia, given that there is no consistency across the states and territories. Which agency is responsible for issuing hazard warnings and how the threat information is communicated to the public varies considerably between jurisdictions. Figure 2 shows the variation in style, colours, pattern and content of warning mapping icons across Australia.

Depending on jurisdiction, public information and warnings for flood and storm hazards may be issued by State Emergency Services, local governments, Bureau of Meterology and other agencies. A Flood Watch warning may be used to advise of either potential flood risk or an approaching flood threat depending on where you are. Western Australia has a well-established suite of warning systems including the tiered cyclone warnings of Blue, Yellow and Red Alert that have clear calls to action. In comparison, the Northern Territory uses the Bureau of

Figure 2: Variation in warnings graphics in Australian states and territories in 2018.

Meterology tropical cyclone categories 1–5, which are the severity measures for cyclones, rather than using a targeted warning system.

Of the 5 hazards tested, only bushfire has a nationally agreed 3-tiered Bushfire Warning System (Australian Emergency Management Committee 2009). Even so, implementation is not consistent, as shown in Figure 2 by the differences between colours, shapes and icons. Victoria is the only state to have implemented an all-hazard warning system and this system was used during this research when discussing action-specific, as compared with hazard-specific, warning icons.

How messages are communicated is also not standardised across Australia. Depending on locality and jurisdiction, communities may hear of or see a hazard warning message through official or unofficial channels via radio, television, print media, websites, social media, phone apps, texts, signage (permanent, temporary, manual or electronic) and community networks. For example, the Emergency Alert system[1] is a national product that allows text messages to be sent to mobiles. However, usage and wording varies depending on jurisdictional processes and capabilities.

Personal risk recognition

An increase in personal risk recognition correlates with an increased awareness of the risk of bushfires, cyclones and floods. The Stage 1 report provided a national benchmark for awareness, comprehension and action taken that correlated results with personal risk recognition and levels of behaviour change (Metrix Consulting 2018). The report showed a substantial drop from recognising the risk of bushfires, cyclones and floods, to feeling personally at risk from these hazards (see Figure 3). That is, people are aware that a hazard may occur and may impact on the area, but they don't think it will affect them personally. In contrast, severe storms and extreme heat have stronger conversion likely due to these hazards being more widespread.

Risk recognition was influenced by a person's birthplace, family composition, location and home-type. People born or raised in Australia and living in regional areas or with larger properties and standalone houses tended to have greater personal risk recognition. Proximity to bushland and open water increased subsequent risk recognition of fires and floods. Overall, the findings are consistent with previous studies, with community awareness and comprehension closely aligned to personal experience of emergencies or the risk profile of individuals. This shows the importance of focusing on the personalisation of risk in messaging and engagement activities to improve comprehension and prompt protective action.

'Forecasts' verses 'warnings'

The way the community talks about forecasts and warnings is inconsistent. In the focus groups, references to forecasts, warnings and alerts were common and were used interchangeably, often thought to mean the same thing. While respondents did not have a strong preference for terminology on initial consideration, when speaking about previous experiences most defaulted to the use of the term 'warnings'.

Awareness is limited

When prompted, less than half of respondents recalled warning messages for cyclone, flood and bushfire, but over half recalled warnings for extreme heat and extreme weather (see Table 2). Awareness of warnings increased significantly for participants with personal experience. This was consistent with focus group findings. There was limited familiarity with jurisdictional warning systems overall except for the Western Australia Cyclone Warning System.[2] In most cases, participants could only identify 1 or 2 warning levels and had significant difficulty when asked to create an optimised warning system, as few had an existing reference point.

Varied levels of awareness and motivation

Over half of participants had taken action in response to a bushfire, cyclone, extreme weather or extreme heat warning, but significantly fewer had taken action in response to a flood warning. Levels of awareness and response to hazard warnings varied significantly between states and territories. Half of the participants exposed to a bushfire warning had taken action,

1 Emergency Alert, at www.emergencyalert.gov.au/.

2 Cyclone Warning System, at www.dfes.wa.gov.au/safetyinformation/warningsystems/Pages/CycloneWarningSystem.aspx.

	Bushfire	Cyclone	Flood	Severe storms	Extreme heat
Risk recognition	91%	27%	61%	73%	77%
Personal risk recognition	40%	19%	28%	69%	69%
Knowledge on how to respond to warnings	38%	17%	26%	64%	65%
Decision to prepare	33%	14%	20%	52%	55%
Future intention to prepare	21%	8%	9%	34%	39%

There is a substantial drop in those who recognise each hazard as a **personal** risk for bushfire, cyclone and flood

Figure 3: Natural-hazard behaviour change model. Percentage of participants at each stage of the model for each hazard (September 2018).

Table 2: Prompted awareness of hazard warnings of Australian population n=5430 at 95 per cent confidence level ±1.33 per cent.

	Population	Individuals with experience of the hazard
Bushfire		
Prompted awareness	44%	60%
Have taken action in past due to a warning*	-	49%
Cyclone		
Prompted awareness	41%	79%
Have taken action in past due to a warning*	-	58%
Flood		
Prompted awareness	45%	65%
Have taken action in past due to a warning*	-	35%
Extreme Weather		
Prompted awareness	56%	70%
Have taken action in past due to a warning*	-	52%
Extreme Heat		
Prompted awareness	55%	71%
Have taken action in past due to a warning*	-	56%

* Percentage of those who have been exposed to this hazard in the past.

although significantly more were from regional Western Australia (63 per cent). Awareness of cyclone warnings was significantly higher in the Northern Territory (87 per cent), regional areas of Queensland (77 per cent) and Western Australia (67 per cent). However, the action taken varied by jurisdiction. Awareness of flood warning systems fluctuated regionally and was significantly lower in South Australia (16 per cent), Tasmania (21 per cent) and Victoria (33 per cent), and significantly higher in Queensland (70 per cent) and the Northern Territory (61 per cent). Few respondents exposed to flooding had taken action in response to warnings, even in flood-prone areas. This is significantly lower compared to other warnings systems.

Extreme weather warnings have significantly higher recognition in regional New South Wales (73 per cent), Queensland (77 per cent) and Western Australia (70 per cent) with thunderstorm warnings the most common type recalled (70 per cent). Respondents in regional New South Wales (70 per cent) and Queensland (65 per cent) had significantly higher recognition of extreme heat warnings, most likely due to the frequency and geographic reach of these events.

Low awareness levels and inaction

Low awareness and comprehension and negative perceptions about warnings can result in inaction and inappropriate behaviour. More than half of participants who had received official warnings felt the warnings resulted in frustration and disengagement. Where there had been significant events, participants commonly spoke of receiving official warnings, either after an incident had passed or considerably later than other nonofficial sources. This led to a sense that the warning content was unreliable. Those participants who had received warnings in a timely manner were almost always satisfied with the content. When warnings are perceived to be not current or not relevant, the credibility of the system is called into question and the likelihood of risky behaviour increases.

Identifing required actions

Many respondents were unable to identify the actions required for bushfire warnings. The understanding of the required behaviours was 56 per cent for 'Advice' level, 53 per cent for 'Watch and Act' level and 57 per cent for 'Emergency' level warnings. The Watch and Act warning achieved unprompted recall in the focus groups, but over two-thirds of participants were confused by the contradicting instructions in the name.

Awareness and action taken from flood warning systems varied by jurisdiction and was higher in (wet season) flood-risk areas of regional Western Australia, Northern Territory and Queensland. But there was a marked confusion over desired actions for all flood warning systems and participants had particular trouble identifying the required actions for levels with names that had a similar perceived meaning, for example 'Flood Advice' and 'Flood Watch' (see Figure 4).

Current warning system strengths

Participants identified a variety of strengths and weaknesses in the current warning systems. Focus group participants critiqued current warning systems that were relevant to their location and explored what a multi-hazard warning system might look like. After reviewing existing warning systems in Australia, strengths and weaknesses of hazard warning systems were identified (Figure 5).

Preferred warnings wording

Participants across all focus groups supported a consistent multi-hazard warning system with wording that is:

- **short and simple:** avoiding words that are long, uncommon, difficult and or ambiguous
- **action-orientated:** quickly understood (e.g. prepare, evacuate)
- **consistent:** increases comprehension and decreases confusion.

The majority of participants viewed a 3-tiered warning system as suitable for bushfire, cyclone and flood. However, a different approach was thought to be required for extreme weather and extreme heat warning. Individuals perceive the risk of these

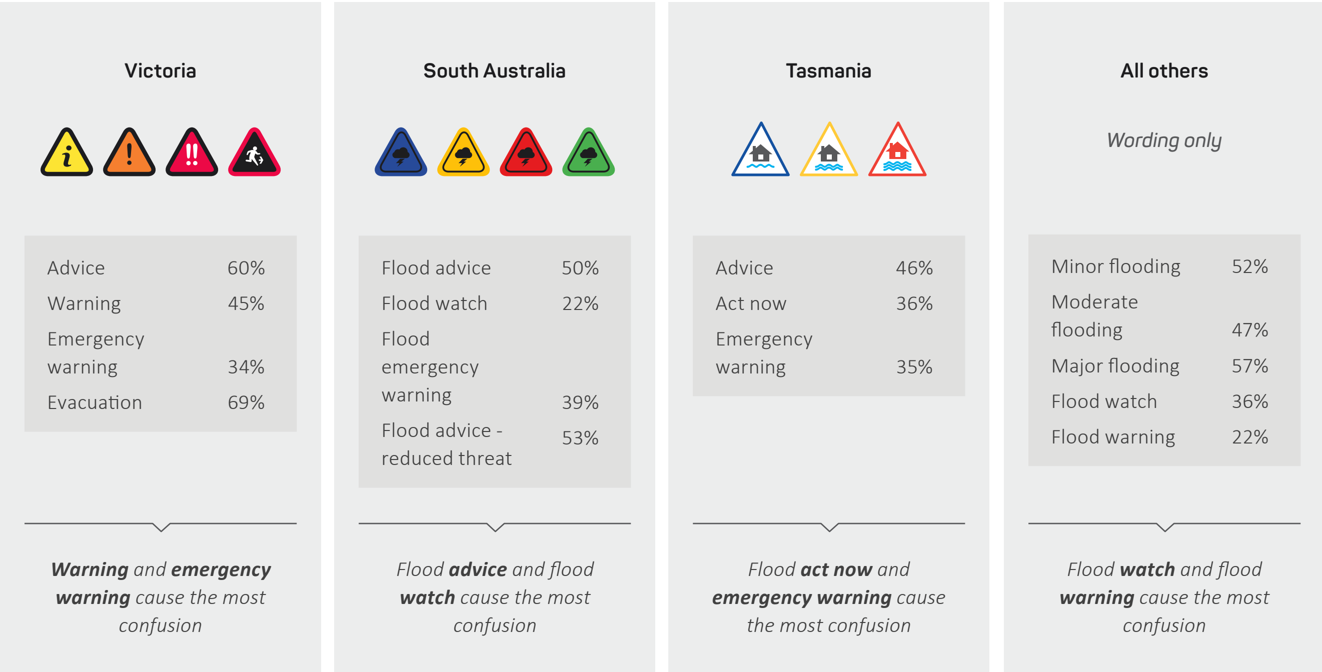


Figure 4: Correct action for a given flood warning. Percentage of Australian population n=5430 at 95 per cent confidence level ±1.33 per cent.

Strengths	Warm colours	Seen as appropriate and align with bushfires.
	Triangle and diamond shapes	Thought to communicate warning.
	Sharp edges	Liked as they align with communicating hazards or warnings.
	A realist style of icon	Seen to increase relevance.
	Escalating icon	Creates perspective and is seen as a stronger communicator of risk.
	Tiered warning system	Thought to be easy to interpret.
Weaknesses	Unrealistic icons	Disliked as they have less relevance.
	Blue and green	Not seen as relevant in a warning as they are perceived to be a safety colour.
	Rounded edges	Seen as too soft to communicate risk.
	Colour blocking	Disliked as it makes the black icon difficult to see against the background.

Figure 5: Perceived strengths and weaknesses of Australian warning systems (2018, n=340).

hazards differently with extreme heat and weather considered a part of life and an 'on-off' warning system was preferred.

Preferred warnings imagery

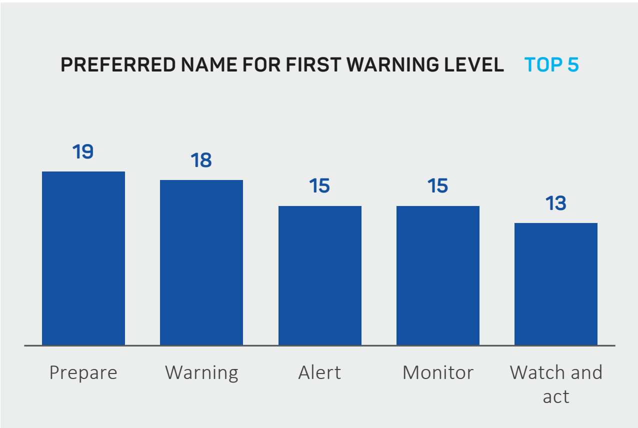
The most effective visual design is a triangle system with hazard-specific icons that increase in severity and a warm colour palette. Participants created and tested their own online warning system using the identified shapes, icons, colours and word sets for each warning level (summarised in Table 3). The majority chose a triangle system with hazard-specific icons that increase in severity, which was consistent across jurisdictions and hazard types. The most effective colour set varied by hazard type, though a warm palette was intuitive for most with red associated with high danger. Although over a third of participants preferred a red-yellow-black colour set, yellow-orange-red was equally as popular. Given that black is associated with burnt areas (on maps), yellow-orange-red was the preferred option to show hazard escalation. Blue is currently in use for bushfire and cyclone warnings but was not supported in survey data.

Preferred warnings names unclear

The Stage 3 findings provided no clear preferences for names of warnings (Figure 6). The first level of warning was associated with alerting the community that something is happening, seeking information or monitoring conditions correlating with words such as 'Prepare', 'Warning' and 'Alert'. The most effective words for the second level were around 'Act', suggesting this is important to include. There was significant confusion associated with 'Watch and Act', which suggests that maintaining the words

Table 3: Preferences for warning hazard icon shape, colour and type (2019, n=5408, ±1.33 per cent at 95 per cent confidence).

Shape		Preference
Triangle		58%
Diamond		42%
Colour set per cent preference		
Yellow, orange, red		35%
Yellow red, black		36%
Blue, yellow, red		29%
Icon type		
Hazard-specific icon that visually increases in severity as warning type increases		59%
Action icons (e.g. information 'i')		19%
Consistent hazard specifications		12%



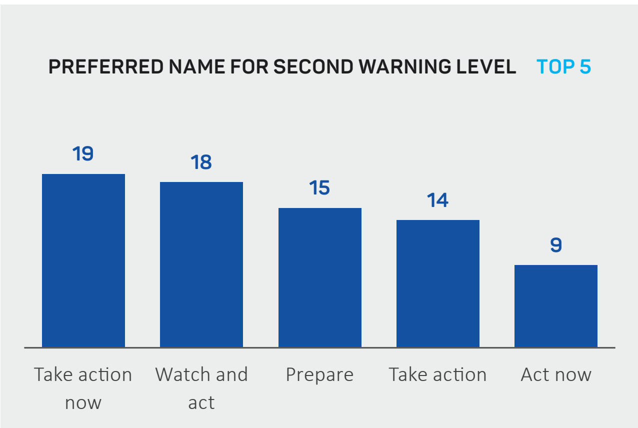


Figure 6: Percentage participant preference for first and second level warning words, where Level 3 is 'Emergency Warning' (2019, n=5408, ±1.33 per cent at 95 per cent confidence).

poses a risk to community understanding without providing additional messaging. The community preference for the naming of the highest-level warning was not tested, as the word 'Emergency' was identified as non-negotiable during co-design.

The term 'Reduced threat' was seen to effectively communicate a warning de-escalation message. This was the first time a de-escalation message has been explored and findings were consistent across jurisdictions, with preferences for 'Reduced Threat' at 47 per cent, 'Reduced Risk' at 33 per cent and 'All Clear' at 20 per cent (Figure 7).

Preferred supporting messages

Preferences for supporting messages were not definitive, but action-orientated statements were preferred with immediate action the focus for emergency warnings. Up to 8 supporting messages were tested in Stage 3 using a variety of scenarios, hazards and warning levels. Only bushfires, cyclones and floods were tested given that previous study results indicated that participants did not think a 3-stage system was relevant to extreme heat and extreme weather hazards. There were no clear preferences for exact wording of the supporting messages given the wider selection, but action-based rather than information-based messaging was preferred. Over half of the participants preferred 'Stay alert' (59 per cent), 'Leave immediately' (52 per cent), 'Prepare for a (Category 2) cyclone in your area' (51 per cent) and 'Seek shelter immediately' (67 per cent) (see Table 4). Preference for 'Stay Alert' was consistent across all jurisdictions for the Level 1 bushfire scenario, except for Tasmania where there was a significantly greater preference for 'Keep up to date' (53 per cent). Preferred messaging referenced 'Preparation' in the Level 2 cyclone scenario and 'Immediate action' in Level 3 emergency warnings scenarios, with 'Leave immediately' (Level 3 flood evacuation) and 'Seek shelter immediately' (Level 3 bushfire, shelter in place) consistently the most preferred across all jurisdictions.

Use of action statements

Action statements are likely to promote action regardless of the hazard. Stage 4 findings demonstrated that the addition of a supporting action statement in the warning was likely to result in action among two-thirds of respondents, regardless of the hazard (see Figure 8). The remaining third of participants indicated that the inclusion of an action statement had little impact on their likelihood to act, noting that this may include people already taking action. Positively, less than 2 per cent of participants felt that an action statement would make them less likely to take action.

Preferred action statement

'Watch and Act' is the definitive preference for the name of the middle level. In Stage 4, the top 2 names for Level 2 (the middle level) identified in Stage 3 were tested for definitive community preference. Overall, 'Watch and Act' was the preferred name for the middle level in a nationally consistent 3-tiered warning system, being most preferred for both escalating and de-escalating scenarios across all hazards (Table 5). Among those who had to

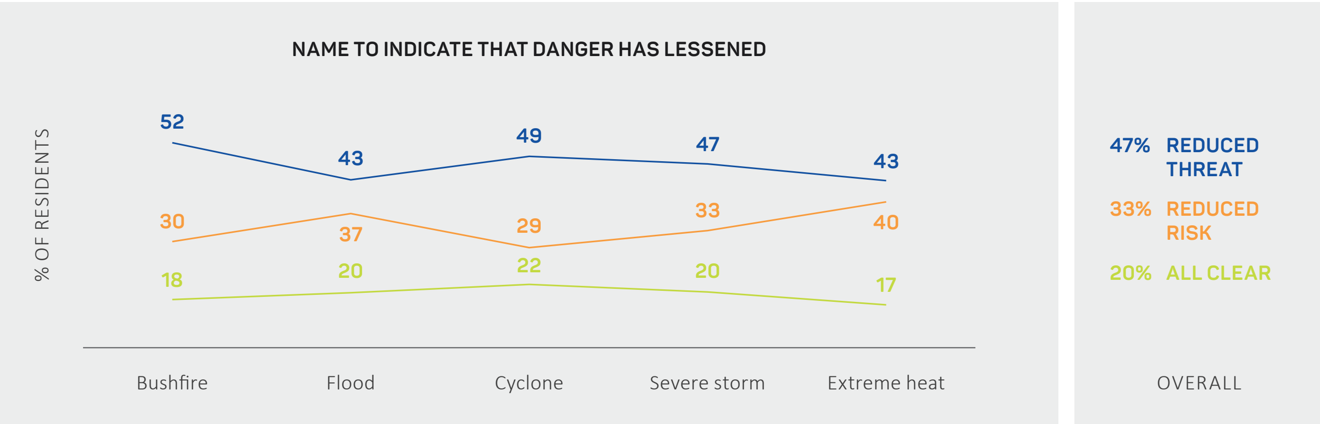


Figure 7: Preference for warning name to indicate that danger has lessened (2019, n=5408, ±1.33 per cent at 95 per cent confidence).

Table 4: Top 3 preferred supporting messaging for bushfire, cyclone and flood warnings (2019).

Level 1 Warning		Level 2 Warning		Leave 3 Warning (evacuation)		Level 3 Warning (shelter in place) bushfire	
Bushfire		Cyclone		Flood		Bushfire	
Stay alert	59%	Prepare for a Category 2 cyclone in your area	51%	Leave immediately	52%	Seek shelter immediately	67%
Stay informed	51%	Make your cyclone preparations now	50%	Take action now	49%	Go to a safe place now	57%
Be aware	41%	Prepare for cyclone impact	46%	Leave now	44%	Immediate danger	50%
Keep up to date	40%	Prepare your home	40%	Prepare to leave	38%	It is too late to leave	40%
Conditions may change	37%	Prepare to leave	36%	Prepare for flood impact	38%	Seek shelter now	39%
A fire has started	36%	Get ready to leave	32%	Make your flood preparations now	33%	Take cover	27%
Take care in the area	35%	Get ready now	29%	Increasing flood risk	24%	Move indoors now	21%
		Conditions are changing	17%	Get ready now	22%		

Note: Weighted variable for national reporting, base n=5408, effective sample size=3839 (71 per cent).

choose a definitive preference (due to their preference changing between hazards), preference was split. In overall preference, two-thirds (65 per cent) preferred 'Watch and Act', compared to 'Act Now' (35 per cent). Across jurisdictions the preference for 'Watch and Act' was also clear, with participant preferences at 61 per cent (Northern Territory), 63 per cent (Tasmania and South Australia), 64 per cent (New South Wales), 66 per cent (Queensland and Victoria) and 69 per cent (Australian Capital Territory).

Given earlier findings that over two-thirds of participants were confused by the term 'Watch and Act' in its current use, deciding on a targeted action statement in a nested warning system to decrease barriers to comprehension (see Greer *et al.* 2020b) will be essential for an effective warning system.

Conclusion

This study provides statistically robust evidence to inform the development of a new national warning system. Findings demonstrate that the perceived complexity of current warning systems leads to reduced awareness, a lack of comprehension and people not undertaking desired behaviours. Unless this situation changes, it is highly unlikely that positive shifts in behaviour will occur when a community receives a warning message.

This study showed that, to be effective, a warning system needs to be applied consistently across hazard types in a tiered 3-level system with simple and consistent naming combined with action-orientated messaging. A Level 3 warning name of 'Emergency'

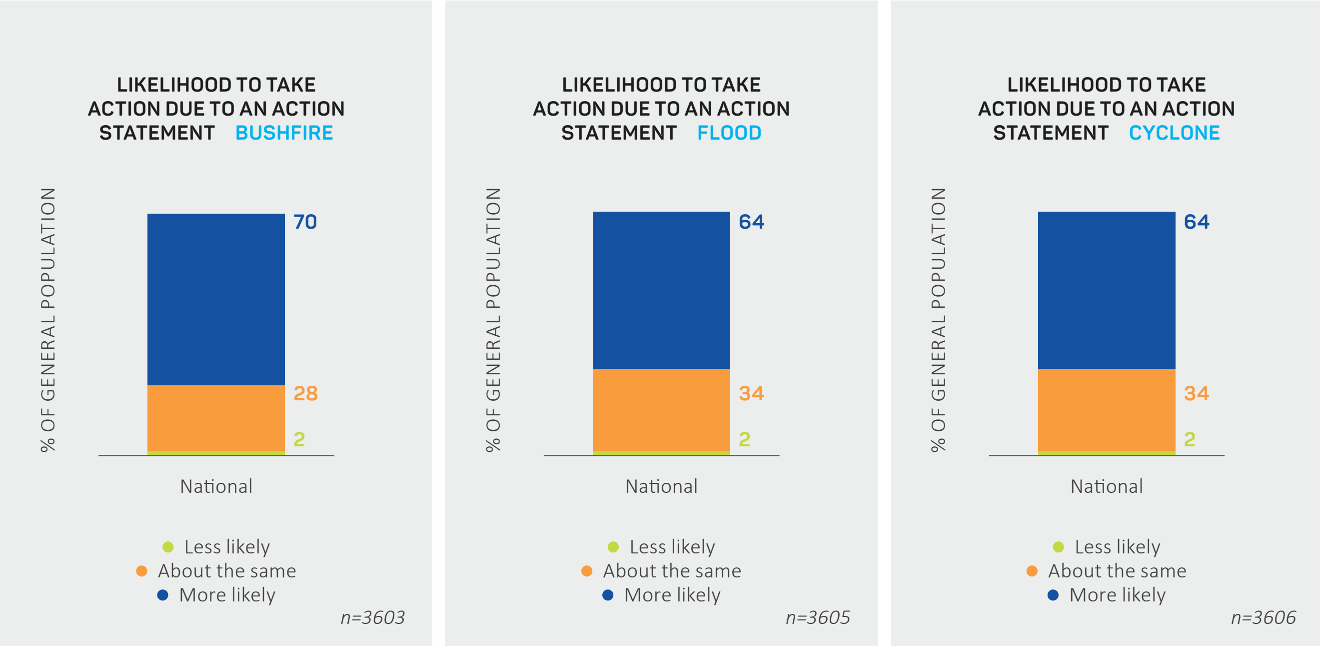


Figure 8: Likelihood to take action due a bushfire, flood or cyclone warning message with a supporting action statement (2020, n=5407 ±1.33 per cent at 95 per cent confidence).

Table 5: Preference for warning names in escalating and de-escalating scenarios for bushfire, flood or cyclone (2020, n=5407 ±1.33 per cent at 95 per cent confidence).

	Watch and Act	Act Now
Bushfire		
Escalating Scenario Name Preference	62%	
De-escalating Scenario Name Preference	74%	26%
Definitive Preference Regardless of Scenario by Switchers*	55%	45%
Definitive Preference Regardless of Scenario - Bushfire	**70%**	**30%**
Flood		
Escalating Scenario Name Preference	54%	44%
De-escalating Scenario Name Preference	67%	33%
Definitive Preference Regardless of Scenario by Switchers*	65%	35%
Definitive Preference Regardless of Scenario - Flood	**66%**	**34%**
Cyclone		
Escalating Scenario Name Preference	53%	47%
De-escalating Scenario Name Preference	58%	42%
Definitive Preference Regardless of Scenario by Switchers*	61%	39%
Definitive Preference Regardless of Scenario - Cyclone	**59%**	**41%**

* Percentage of general population who switched preferences

and 'Watch and Act' was the definitive preference for the name of the middle level. The most effective visual design is a triangle shape with sharp corners, a hazard-specific icon that visually increases in severity as the warning type increases, an icon design that is realistic and a colour set of yellow, orange and red.

This study highlights it is critical that emergency services organisations adopt community language in hazard messaging to improve community safety outcomes. Using a community voice builds credibility and trust and helps people to recognise their personal risk and how to respond to reduce that risk.

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The total flood warning system: a review of the concept

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Introduction

The Total Flood Warning System concept is promoted by the Australian Government and is widely used in the design of Australia's early flood warning systems. The Total Flood Warning System concept is technically robust in comparison with international flood warning system frameworks. However, it is not as 'total' as it might be. This paper looks at six other components identified that make the system holistic and more effective.

Early warning systems are designed to save lives and protect property where possible. According to Mileti and Sorensen (1990, p.2):

> *A warning system is a means of getting information about an impending emergency, communicating that information to those who need it, and facilitating good decisions and timely response by people in danger.*

In Australia, flood early warning systems are an important part of the flood risk management process promoted by the Australian Government and implemented by the states and territories, largely via local government and, in Victoria, by catchment management authorities.

Guidance provided in the *Managing the floodplain: A Guide to Best Practice in Flood Risk Management in Australia* (Australian Institute for Disaster Resilience 2017, p.61), shows that early warning systems are a flood response modification option and are one of 'a range of measures to reduce residual flood risk at a community scale'. In comparison with other flood risk management options, flood warning is assessed in this national guide as having a 'medium' capacity to address safety risks and a 'low' capacity to address property damage risks, both in existing and future urban developed areas (Australian Institute for Disaster Resilience 2017, p.46).

The Australian Government has provided guidance to assess and design robust flood warning systems. It introduced the concept of the 'total flood warning system' (TFWS) to describe the full range of elements that must be developed if flood warning services are to be provided effectively.

The lead document for the development of the TFWS in Australia is *Manual 21 – Flood Warning* (Attorney-General's Department 2009). As shown in Figure 1 and according to Manual 21, at its simplest, the TFWS consists of six components.

1. Prediction - detecting changes in the environment that lead to flooding and predicting river levels during the flood.
2. Interpretation - identifying in advance the impacts of the predicted flood levels on communities at risk.
3. Message construction - devising the content of the message that will warn people of impending flooding.
4. Communication - disseminating warning information in a timely fashion to people and organisations likely to be affected by the flood.
5. Response - generating appropriate and timely actions from the threatened community and from the agencies involved.
6. Review - examining the various aspects of the system with a view to improving its performance.

Manual 21 (Attorney-General's Department 2009, p.7) stresses that for the TFWS to 'work effectively, these components must all be present and they must be integrated rather than operating in isolation from each other'.

Cawood, Keys and Wright (2018) describe the genesis of the TFWS concept emanating from a series of workshops held after severe flooding in parts of Australia in 1990. The workshop participants included representatives from the Australian Bureau of Meteorology and forecasting and emergency management professionals. The document resulting from the workshops, *Flood Warning: an Australian Guide*, was published in 1995 (Australian Emergency Management Institute 1995). This guide was updated through revisions to Manual 21 including the TFWS concept.

The TFWS concept is now widely used in flood risk management in Australia. TFWS is invariably a requirement in the assessment and design of flood early warning systems by local councils and catchment management authorities as well as by the consultants they commission. The *National Arrangements for Flood Forecasting and Warning* (Bureau of Meteorology 2018, p.9) states that 'Flood warning systems in Australia are designed using the concept of the Total Flood Warning System'.

The Total Warning System concept has now been recommended by the Australian Government for all hazards (Australian Institute for Disaster Resilience 2018). Further TFWS advice as an update of Manual 21 will be provided in a companion document to *Flood Emergency Planning for Disaster Resilience* (Australian Institute for Disaster Resilience 2020).

A review of the TFWS concept in relation to Australian and international research was undertaken by the author to ascertain its ongoing value in guiding the design, implementation and evaluation of flood early warning systems. In particular, the review assessed the holistic ideal of the TFWS and the veracity of the six identified TFWS components (Attorney-General's Department 2009).

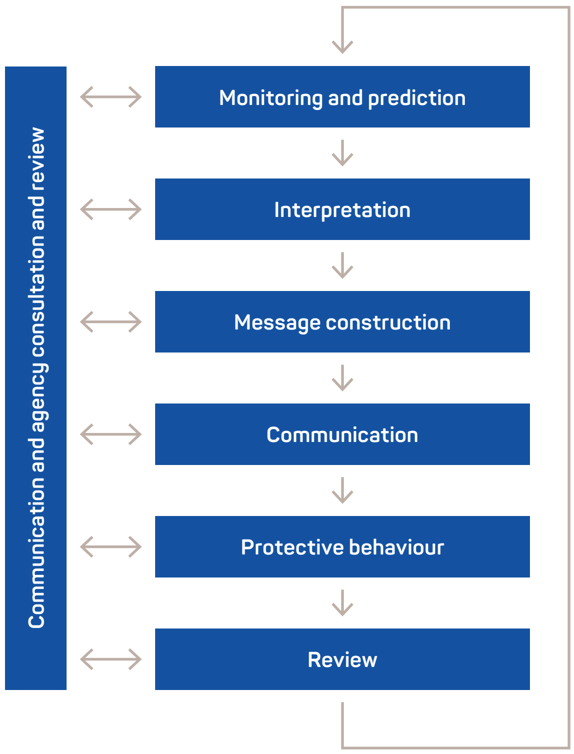

Figure 1: The components of the Total Flood Warning System (Attorney-General's Department 2009, p.6).

Technical legitimacy

The TFWS aligns well with internationally promoted early warning system frameworks. For example, according to the International Strategy for Disaster Reduction (2006), there are four separate but interlinked elements of effective people-centred early warning systems:

1. Risk knowledge.
2. Technical monitoring and warning service.
3. Dissemination and communication.
4. Response capability.

'Risk knowledge' aligns with 'Interpretation' in the TFWS. 'Technical monitoring and warning service' aligns with 'Prediction', 'Dissemination and communication' aligns with the components of 'Message construction' and 'Communication' and 'Response capability' aligns with 'Response'. The TFWS provides an extra 'Review' component to those by the International Strategy for Disaster Reduction (2006).

Holistic ideal

The TFWS has been criticised for not being as 'total' as it could be. For example, as shown in Figure 2, Molino and co-authors (2011) argued for an extension of the TFWS to include six additional components:

1. understanding the flood risk
2. emergency management planning
3. community flood education
4. data collection including location and use of rain gauges and river level gauges
5. community participation
6. integration of the TFWS components.

The additional components have merit. According to Molino and colleagues (2011), understanding the flood risk not only relates to flood risk mapping and modelling as included in the existing 'Interpretation' component of the TFWS but also to pre-flood risk communication (e.g. to residents and businesses).

Flood warning is an integral part of emergency management planning. All jurisdictions have emergency legislation, policies, plans and governance that should include provision for effective flood warning services. For example, in Victoria all local councils with flood risk are required to have a Municipal Flood Emergency Plan, which includes details of emergency agency actions related to triggers such as stream gauge heights.

Community flood education and engagement helps people learn how to prepare for and respond to floods (including to flood warnings) and also recover from them. The prime outcome is public safety, with a secondary outcome being protection of property (Dufty 2020).

For the effective development of a flood warning system, preparedness community education content should include providing learning about flood risk, identifying flood triggers (e.g. river heights), what people should do to ensure the safety of

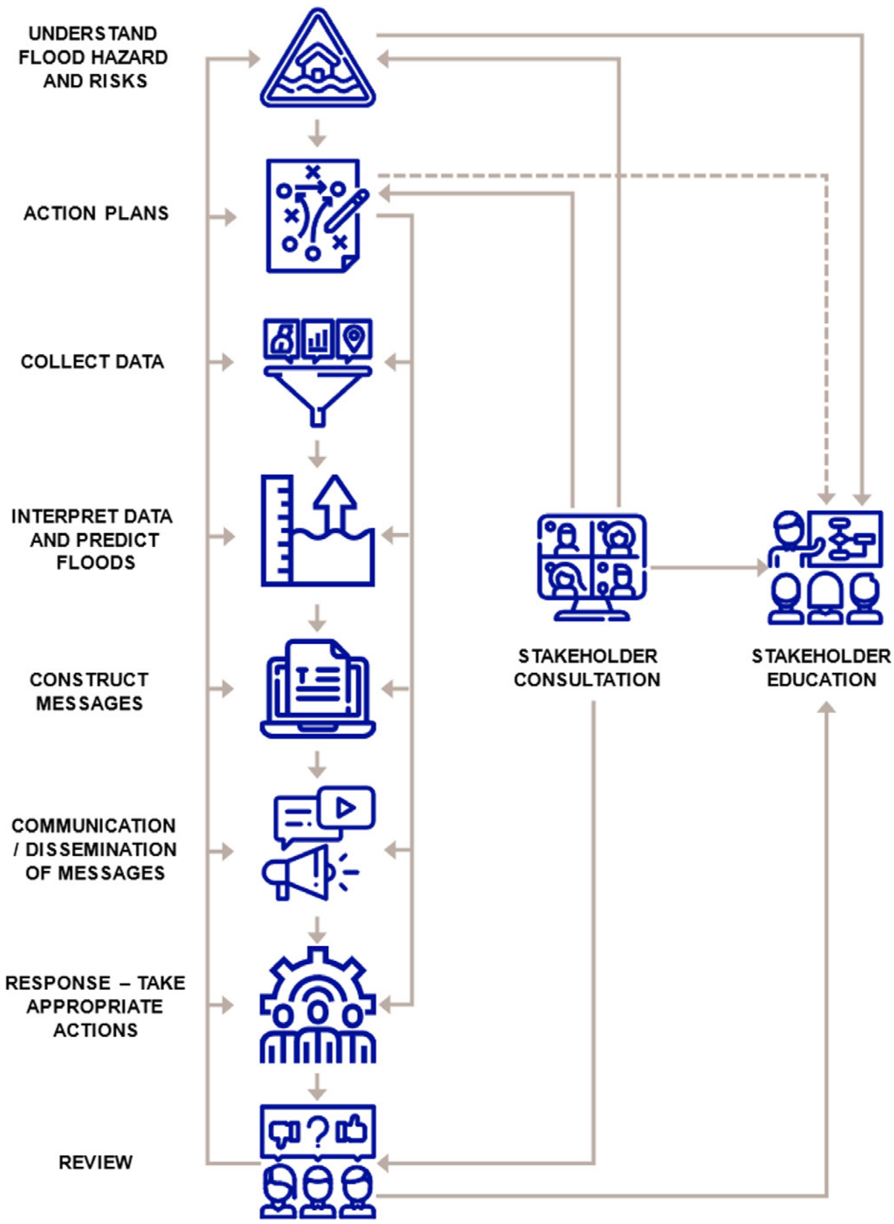

Figure 2: Extended Total Flood Warning System components (Molino *et al*. 2011).

themselves and others if possible (e.g. their family, neighbours, vulnerable people in the community) and what people should do to protect their property, companion animals and livestock (if applicable). People in flood-prone areas should also be aware of the possible flood warning lead times to enable them to carry out safe responses.

An essential basic input to a total flood warning system is rain and river data. The existing river level gauges (with telemetry) and rainfall gauges (daily and sub-daily) available to a community should be assessed prior to the design of a local flood warning system.

There is a growing body of evidence showing that community participation is critical in the development of effective early warning systems. For example, the United Nations International Strategy for Disaster Reduction provides a checklist for developing early warning systems (International Strategy for Disaster Reduction 2006, p.4). It states that communities:

...should be actively involved in all aspects of the establishment and operation of early warning systems; be aware of the hazards and potential impacts to which they are exposed; and be able to take actions to minimize the threat of loss or damage.

Manual 21 stresses the need for integration of the components of the TFWS.

For a flood warning system to work effectively, these components must all be present and they must be integrated rather than operating in isolation from each other. The view that any one component of the system represents all of it, or is an end in itself, impairs the system's effectiveness.

(Attorney-General's Department 2009, p.7)

Molino and colleagues (2011) note that:

...each of these warning system parts can work well or can work poorly or at worst, not work at all. The overall effectiveness of the warning can only be as strong as the weakest link in the chain and, unlike a real chain, errors or weaknesses can accumulate as they are passed along the chain. For example, poor data plus poor interpretation can be worse than either poor data or poor interpretation.

Thus, the integration of total flood warning system components should be a separate component to ensure that linkages are strong and working effectively.

'Review' is a critical total flood warning system component as it leads to warning system improvements before and after a flood. Manual 21 (Attorney-General's Department 2009, p.71) provides a list of possible performance indicators that can be used as a basis for review. Other guidance to review has been provided (e.g. Parker & Neil 1990). It is important that flood early warning systems are reviewed regularly to ensure all components are working effectively.

It should be noted that recent Australian Government guidance on total warning systems has embraced some of the suggested additional total flood warning system components. For example, *Handbook 16 – Public Information and Warnings* (Australian Institute for Disaster Resilience 2018, p.11), acknowledges prior community education and engagement about warning as an important part of a Total Warning System. As part of emergency management planning, the need to set 'organisational capability, systems and arrangements in place to warn effectively' is also identified.

Conclusion

The TFWS concept promoted by the Australian Government is entrenched in the Australian flood sector. It compares favourably to international flood warning frameworks identifying an additional critical 'Review' component.

However, the TFWS should be extended to include at least six other components, including emergency management planning and community flood education that require actions prior to flood events.

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Testing the effectiveness of your warning system without having a flood

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Understanding the effectiveness of a flood warning system helps emergency services and communities better prepare for and respond to flooding. Using 2 case studies, this paper shows how modelling results can inform total flood warning system development and improvement.

A 'Total Flood Warning System' (TFWS) (Australian Institute of Disaster Resilience 2009) is described as having these components:

- data collection and collation
- detection and prediction (forecasting)
- interpretation
- message construction
- message dissemination
- response (and response planning)
- awareness (and education)
- review.

Implementing or upgrading a flood warning system will, for a variety of reasons, involve concentrating on particular elements of the TFWS. The technical elements (e.g. the data-collection network and forecast model) often receive more attention at the expense of the socially focused elements (e.g. the processes of warning and alerting and maintaining awareness of flood risk and responses). Reasons for this are varied but can relate to a combination of visibility and measurability, rather than to a purely objective consideration of the benefits such improvements might deliver to the at-risk community. There are also gaps in the ability to measure or quantify such benefits. In contrast, a new rain or river gauge, more timely or greater volumes of data, a more accurate or timely forecast can be seen and are easily quantified.

In an ideal world, communities at risk from flooding would be serviced by flood warning systems where the various elements of the TFWS are appropriately developed (or enhanced) to match each community's requirements. However, the data to inform decisions about which elements of the TFWS should receive immediate (or prioritised) attention for (further) development are scarce.

Possible solution

Agent-based simulation system software such as HEC-LifeSim (USACE 2017) can simulate population redistribution during an evacuation. A key input to the model is a warning timeline. The warning timeline consists of 3 parts:

- warning delay time
- warning diffusion time
- protective action initiation time.

HEC-LifeSim was applied to several Australian catchments. This allowed the objective assessment of the benefits of developing or upgrading elements of the TFWS for a selection of communities at risk from severe flooding events.

Case study 1: Testing the TFWS

This case study illustrates the application of HEC-LifeSim and, more particularly, how the results can inform TFWS development.

The aim of the work associated with this case study was to gain a better understanding of how warning times can influence human safety and the capacity of an early warning system to reduce risks to life.

A HEC-LifeSim model was developed to simulate warning and evacuation of a small regional town in

NSW in the event of a major flood. The warning and mobilisation components of the model were informed by a questionnaire developed by Sorensen and Mileti (2015).

The questionnaire comprises 52 questions that are intended to be answered by emergency management stakeholders – both planners and practitioners. The answers are used to generate a set of warning curves that HEC-LifeSim samples as inputs into the modelling. The questionnaire covers

- what emergency plans exist
- when the first public alert would be issued
- how warnings are disseminated
- level of preparedness
- characteristics of the at-risk population and the community.

The HEC-LifeSim model was run with inputs from questionnaire responses reflecting the current no-TFWS situation, for both day and night conditions. The model was rerun with adjusted questionnaire responses to reflect various improvements to each of the TFWS elements. Each improvement was expanded so the scope was clearly documented. This included any underlying assumptions and where responsibility for implementation and operation would reside.

In broad terms, the improvements encompassed:

- the availability of rain and river data - was there a benefit to installing additional gauges or telemetry or in obtaining data from other locations?
- the timeliness of available rain and river data - were data collection, collation and presentation tasks timely and data available when and where needed?
- forecast lead time - was the forecast adequate, what if it was available earlier?
- knowledge of the consequences of flooding - were flood maps and flood intelligence available?
- message construction - were forecasts and consequences shared with the at-risk populations in appropriate language?
- message dissemination - can messages be disseminated quicker, better?
- response planning and response - was there a flood response or other relevant plan?
- education and awareness - what flood preparedness and awareness measures were in place or could be implemented?
- review - was this a part of 'business as usual' with a feedback and improvement loop?

In adjusting the Sorensen and Mileti questionnaire for an improved TFWS, it was assumed there was a portion of the population (i.e. 10 per cent) who took no action, despite being warned (Gissing 2015 and Keys 2015).

Results showed the extent to which people at risk were likely to be caught by floodwaters, either because they failed to receive or act on a warning or were caught on the road network as they evacuated. The results indicated that a combination of early warning (i.e. the quicker the threat is detected the sooner the alerting, warning and response processes can begin) and high mobilisation rates (i.e. a timely response by knowing what to do and where to go) would cause a reduction of risks to life safety during a severe flood.

Case study 2: Targeted warning issuance

This case study shows the application of HEC-LifeSim as an extremely effective tool to illustrate the spatial distribution of areas within a community most at risk throughout any model domain.

In this example, HEC-LifeSim was used to investigate targeted warning issuance in areas at significant risk of flooding. The population at risk along each segment of road and in every structure within the model domain was estimated using the outputs from the HEC-LifeSim model. This allowed results to be thematically mapped in GIS software and presented in various formats.

Thematically mapping each road segment and structure allowed emergency services planners and practitioners to gain a better understanding of the spatial distribution of the areas of greatest vulnerability. It also provided enough detail to:

- determine key egress routes within the floodplain
- visualise the natural flood conditions leading up to the flood peak
- identify areas that become cut-off from egress routes
- appreciate warning diffusion and evacuation in highly populated areas and visualise the evacuation of the population from inundated areas.

With this information, emergency services managers were able to implement procedures on a case by case basis to target particular regions for warning issuance. Implementing these procedures could be expected to lead to a reduction in or the mitigation of flood risk for vulnerable areas without having to implement physical upgrades such as raising levees.

An example of the thematically mapped structures and roads is shown in Figure 1. This shows the spatial distribution of the population at significant risk across the floodplain and the areas targeted for specific warning issuance. Images like Figure 1 can be used to identify areas within the broader floodplain that would require evacuation to reduce the overall risk to the resident population.

Conclusions

This paper introduced HEC-LifeSim and outlined 2 case studies to demonstrate its application to estimate the benefits of improving various elements of the TFWS. It also showed the use of HEC-LifeSim to evaluate emergency evacuation routes and plans. A particular advantage is that the benefits of developing elements of the TFWS, either individually or as a package, can be determined without bias towards either the technical (e.g. data and forecasting) or social (e.g. awareness and behaviours)

Figure 1: Spatial distribution of people at significant risk with evacuation areas highlighted in red (right).

aspects. As HEC-LifeSim tracks the movement of individuals via the road network and provides a representation of population redistribution, it can provide useful insight into effective evacuation routes and destinations. This is an important part of the response element of the TFWS.

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How to improve alert systems: the technical, human, environmental and structural aspects

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Abstract

An effective alerting process is an essential component in emergency and disaster management. Based on a qualitative survey conducted in 5 countries (Australia, Belgium, France, Indonesia, the USA), this study looked at the organisational, socio-political, technical and human aspects inherent in the tools used for warning systems currently in place. This work highlights the similarity of organisational objectives, but also the importance of political choices linked to national culture and the disparity in terms of integration of technological tools. It was found that none of the 5 countries had completed the digital transition of its alert systems. In the future, it will be a question of better linking prevention, technical tools and end users.

Introduction

An effective alert must provide timely information that helps people prepare adequately for an emergency or disaster (Arru, Negre & Rosenthal-Sabroux 2018). However, there is great diversity in the implementation of this process, particularly in areas of alerts, the doctrine, the number of stakeholders authorised to disseminate alerts, the modes of communication and the dissemination tools used (Sorensen 2000, Vivier *et al.* 2019). Since the early 2000s, changes in communication technologies have opened up new perspectives and issues in the fields of alerting and crisis management. Social networks, mobile telephony, the Internet of things and cell-broadcast and real-time information systems have improved the suitability of tools and unpredictability of risks (Houston *et al.* 2015, Laverdet *et al.* 2018, Poslad *et al.* 2015). Over time, many countries have developed effective national warnings systems using these technologies (ETSI 2010). However, changes seem to be driven by political choices, by pitfalls observed after major events or following the failure of certain tools. This raises the question: do alerting tools change the way organisations operate or does the evolution of organisations require changes in the system?

To answer this, existing national alert systems of 5 countries (Australia, Belgium, France, Indonesia and the USA) were analysed by using methods derived from the contingency theory (Burns & Stalker 1969). We focused on 'what', 'when', 'how', 'for what' and 'how to evolve' questions and postulate that:

- national alerting systems depend on the structure and inherited governance more than on social and cultural characteristics of people or the nature of risks
- technological improvements in warning systems are leading to their mutation as some countries appear more advanced than others in the use of new warning technologies (i.e. cell-broadcast in the USA since 2006, social networks in Indonesia since 2011).

Considering this, this paper presents the characteristic elements of alerting systems in selected countries, presents the issues and an analysis, describes the main results and discusses improvements to alerts in France, where transition to digital alerting transition has been delayed.

Method

Five countries with strong differences

This analysis focused on 5 countries that have implemented, or are in the process of implementing, a Location-Based Alerting System (LBAS) (see Table 1). Location-Based SMS (LB-SMS) and cell-broadcast are 2 alerting systems commonly used at national scales. Three countries already use a LBAS (USA since 2006, Australia since 2013 and Belgium since 2017) and 2 others (France and Indonesia) do not yet have LBAS at the national level (although localised uses of these tools are possible).

These 5 countries are of interest for other reasons. Australia has a federalised alerting structure, which makes it possible to adapt the alert to the characteristics of each Australian state and territory. Belgium abandoned its siren network in 2016 to replace it with LB-SMS, while centralising several digital alert tools within a single platform (Be-Alert). France is modernising its siren network. However, attempts to switch alerts by LBAS have failed due to the abandonment of the SAIP (Population Alert and Information System) application and the lack of agreement with operators to acquire LB-SMS or cell-broadcast since 2010 (Vogel 2017). The SAIP application was abandoned following dysfunctions (excessively long delays during the Nice bombing in 2016, and sending of false alerts in 2016 and 2017) and a lack of awareness of the tool by the population. But a 2018 European decree now requires all Europe members to set up a LBAS by June 2022. Indonesia is a multicultural country where the use of social platforms (like Twitter and Whatsapp) has become widespread. As early as 2006, the USA set up a multi-channel platform using the Common Alerting Protocol[1] that integrates wide variety of organisations to disseminate alerts. The USA has also used cell-broadcast since 2012 and tests indicate good performance (Bopp & Douvinet 2020).

Qualitative survey based on contingency theory

An initial bibliography was compiled for each of the countries selected. Few scientific works have focused on the analysis of national alerting systems (Rogers & Tsirkunov 2011, Sorensen 2000) and the bibliography therefore focused on the many national reports and feedback following disasters (Table 2). This literature review highlighted a possible contingent aspect of alerting systems. Contingency theory states that systems must be adapted to their environment in order to be effective (Donaldson 2001). Previous work has shown that crisis organisations are contingent on their political, economic, social and natural environments (Jarman & Kouzmin 1994, Rosenthal & Kouzmin 1997). But what about organisational aspects, that is, procedures, type and number of actors authorised to disseminate the alert, hazard-detection modes, communications modes and interactions with tools? In order to answer this and to test the hypotheses, semi-directive interviews (N=35) with operational crisis managers in the 5 countries were conducted using an interview guide created around four topics:

- The organisational objectives of alerting: What are the objectives of the alert? In which temporalities? What place is given to the interpretation and decision-making?
- The structure of the organisations: Who receives the upward information? Who disseminates the alert? Who are the stakeholders involved?
- The techniques used: What are the means for hazards detection? What are the communications tools and the means for alerting?
- The operational culture: What are the values, beliefs, behavioural norms, lifestyles, symbols, etc.? How do they impact on choices and strategies?

Table 3 details the functions and the organisations of the participants interviewed for this study.

Results

Similar organisational objectives

The purpose of alerts is to warn as many people as possible of the arrival of a threat or a danger so that they can take appropriate protective action. The alert must be context-specific and adjusted to the evolution of the situation (during forecasting, a few hours before impact but also during the upward and downward process and after the event). The main objective is to minimise human and economic losses (Figure 1). From the point of view of the authorities, individuals must be receptive to the signals given in order to apply the instructions. The panic effects of crowds are a challenge to authorities although they are misrepresented in the literature (Weiss, Girandola & Colbeau-Justin 2011, Douvinet 2020). The objectives are achieved when institutions are prepared (through exercises) and citizens are informed of the risks, which is not always the case depending on the territory. Two visions of the alerting process therefore coexist: a binary approach (as in France, Indonesia and Belgium) or a gradual approach (USA and Australia).

Structural differences related to socio-political organisations

A pyramid-like structure is commonly observed that integrates 3 components (see Figure 2): the forecasters (i.e. the 'experts'), the authorities (decision-makers) and the population (people to be protected). The subsidiarity of the alert was common to all the studied countries, except in Indonesia where the treatment of a crises is regional. The differences between federal (USA, Australia, Belgium) and unitary (France, Indonesia) states are secondary, in that, when there is a specific organisation responsible for warnings at the federal level (i.e. for structuring and for specific modes of communication), it is accompanied by harmonisation at the national level. In addition, in federal states, the actors involved in warnings are globally better interconnected than are those in unitary states. For example, incident controllers in Australia and police officers in Belgium are responsible for disseminating alerts. While Indonesia uses automated systems, decision-making remains essentially political and community leaders play a key role at the local level.

Major disasters generally serve as a trigger in the evolution of national warning systems. Crises set the pace for the evolution of alert systems rather than the implementation of new high-performance alert tools.

1 The Common Alerting Protocol is a standardised communication protocol that allows the simultaneous broadcasting of alerts on various media (Bean 2019).

Table 1: Main characteristics of the 5 selected study countries.

Country	Number of inhabitants (millions)	HDI[1]	Name of the national alerting system	Main alerting tool	Number of natural disasters (1970–2020)[2]	Number of deaths (1970–2020)[2]
Australia	25.7	0.938	Emergency Alert Australia	LB-SMS	229	1,388
Belgium	11.5	0.919	Be-Alert	LB-SMS	58	3,295
France	66.9	0.891	SAIP[3]	Siren	164	26,590
Indonesia	269.8	0.689	Indonesian Warning System	Many used	496	200,474
USA	331.8	0.920	IPAWS[4]	Cell-broadcast	893	17,003

[1] HDI (Human Development Index)
[2] EM-DAT database (www.emdat.be/)
[3] SAIP: Population Alert and Information System
[4] IPAWS: Integrating Public Alert and Warning System

Table 2: Selected national reports used in this study.

Selected country	Scientific literature	Technical report
Australia	Dufty 2014	Vivier *et al.* 2019, AIDR 2019
Belgium		Vivier *et al.* 2019, IBZ 2017
France	Douvinet *et al.* 2017, Bopp & Douvinet 2020, Douvinet 2018	Ministère de l'Intérieur 2013, Vogel 2017
Indonesia	Ai *et al.* 2016, Lavigne et al. 2010, Carley et al. 2016, Anggunia & Kumaralalita 2014	AHA Center 2019
USA	Bean *et al.* 2016, Bean 2019	Vivier *et al.* 2019, FEMA 2018

	FORECASTS	CURING THE ALERTING PROCESS		AFTER THE EVENT
AUTHORITIES	*Communication* *Information* *Training* *Planning*	**Upward alert** *Hazard evaluation* *Danger perception* *Reactivity* *Adaption*	**Downward alert** *Information* *Reactivity* *Communication* *Involvement*	*Re-evaluation of tools if necessary* *Improvement* *Communication*
CITIZENS	*Safety knowledge* *Involvement during training* *Messages understanding*	*Information* *Ground lifts* *Appropriate reaction* *Preparedness*	*Safety adaption* *Safety behaviours* *Protection (individual vs. collective)*	*Hazard understanding* *Hazard explanation* *Official feedbacks* *Social attempts*

Figure 1: Overview of the organisations involved in the Public Warning System (Douvinet *et al.* 2020).

Table 3: List of institutions and services (without the name of people interviewed).

Country	Function
Belgium	Head of Crisis Management Task Force, Belgium
	Project Manager, BE-ALERT
Australia	Zefonar Advisory, specialist in the design of requirement-led multi-purpose Public Warning System
	Chief of Staff, Director, Operations Support, Australasian Fire and Emergency Service Authorities Council
	Manager, Emergency Management Community Information
	Public Information and Warnings, State Emergency Service, Victoria
	Deputy Chief Officer, Country Fire Authority, Victoria
	Project Manager, Disaster Mitigation, Bureau of Meteorology
	Assistant Commissioner, Victoria Police
	Manager Consultant in Solution / Everbridge
USA	Professor, University of California, Berkeley
	PhD (with former experience in risk forecasting in Brazil)
	Assistant Fire Director, US Forest Service
	Fire Chief, Sacramento Fire Department
	Deputy Fire Chief, Santa Rosa Fire Department
	Deputy Chief, California Office of Emergency Service
Indonesia	Professor of Geology, Universitas Gadjah Mada
	Psychologist, Institute for Community Behavioral Change
	Merapi Forecast, Center for Volcanology and Geological Hazard Mitigation
	Primary Planner, Regional Development
	Junior Planner, BMKG (Meteorology, Climatology, and Geophysical Agency)
	Vice-President, BMKG
	Researcher, Christian University of Jakarta
	Director for disadvantaged areas, BAPPENAS (Ministry of National Development Planning of Indonesia)
France	Interministerial Chief of Staff for the South-West
	Association of French Departments
	Deputy Director, Association of French Mayors
	Digital Department for Public Safety
	Liaison Officer for the Tour de France, Civil Security and Crisis Management Directorate
	Security and Safety Department Manager, Avignon University
	Security Manager, Orange Vélodrome Stadium
	Prefect, Hérault Department (former director of Civil Security and Crisis Management Directorate)
	Director, SDIS-13, President of the National Federation of French Fire Fighters
	Prefect, Seine-Maritime Department

Tools are not always integrated in a multi-channel platform

From a technological point of view, multi-channel logic is favoured and needs to be encouraged. But each country is not similarly advanced on this point. This doctrine is advanced in the USA (Figure 3), in Australia (Figure 4) and in Belgium (Figure 5). The choice of dissemination tools depends on the nature of the crisis and on the estimated consequences, but all are integrated in a single approach. In Belgium, the LB-SMS is used by mayors for localised and adaptive alerts, as in Australia. In the 2 other studied countries, there is a greater disparity of tools and a lack of coherence between them. France has a large private sector participation in the field of alert systems. In Indonesia, there is a great disparity in access to alerts between inhabitants depending on their place of residence and their means of access to means of communication and social networks.

Pitfalls and drawbacks on human factor

Unsurprisingly, individual perceptions and, more broadly, human factors are difficult to take into account in every alerting system. Survey participants noted the difficulties in reporting information and the difficulties in trusting people to report this information. The contribution of community managers is in its infancy (in France) and is unevenly structured (in Australia and Belgium). In Indonesia, its cultural context makes it possible to use community leaders to improve the acceptability of alert messages, but the overwhelming power of these leaders can lead them to not follow warning recommendations. Exercises with communities are being used in Belgium and Australia. Many interlocutors recognise that certain categories of people remain excluded from alerts (due to disability, age and language barriers), although Australia is better recognising vulnerable or previously excluded sectors of communities for inclusion in emergency planning.

Discussion

This study showed that if organisational objectives are identical overall, the actors involved in issuing alerts do not have the same frame of reference or the same approach. The methods used are influenced by the national context and the crises that have occurred in the past, which have contributed either to the transformation or the improvement of the national warning system. More actors are becoming aware of community involvement during crises. But alerts are still too vertical and standardised to really empower local communities, despite the use of tools that could enable it. Although a vertical approach in terms of warning systems is challenged, the pyramid approach remains predominant (especially in France). Moreover, believing that warning tools can be 'non-political' (like the procedure itself) is a myth. Firstly, government advocates for warning systems to justify the funding allocated to them (Matveeva 2006) and often use them as a 'good excuse' ('We did the best we could'). However, it is not because the tools are available that they are used. This observation, made in the early 2000s (Sorensen 2000), is still relevant today. The multi-channel doctrine has proved its effectiveness and could be better organised by defining a common alert protocol and using secure web-based platforms.

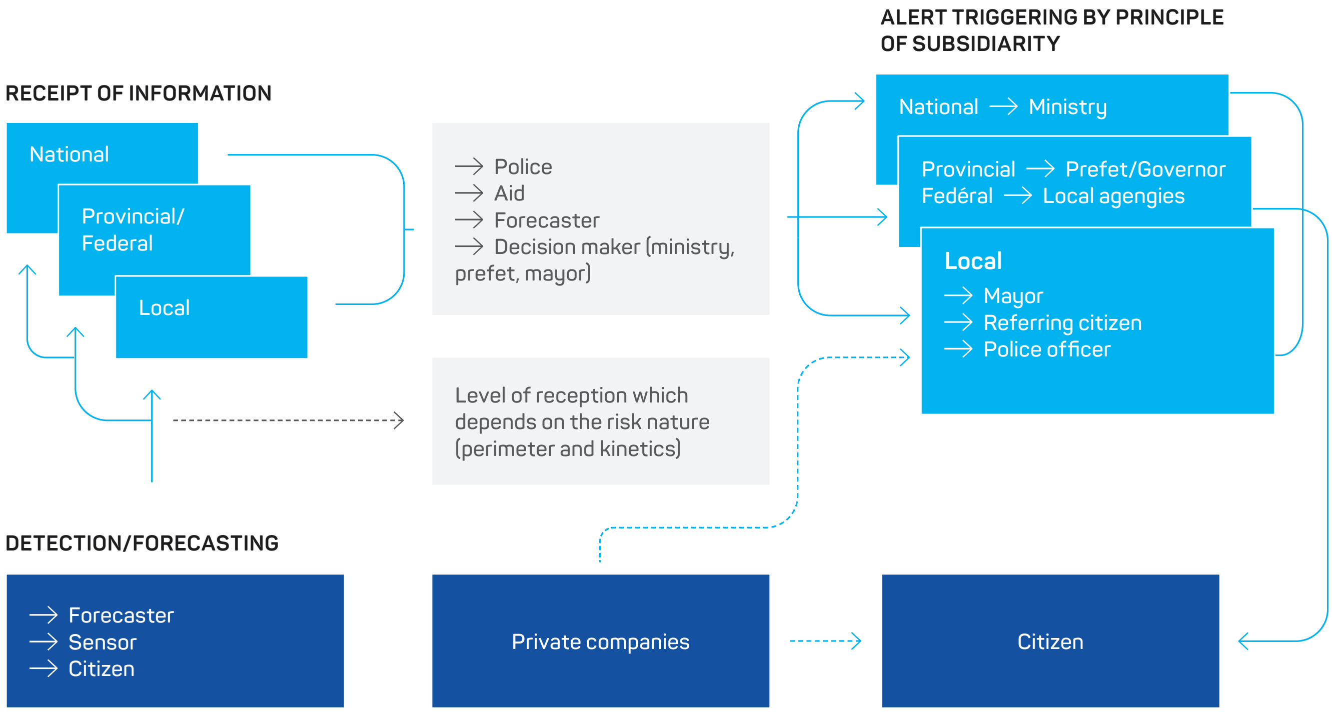

Figure 2: A recurrent pyramid-like structure exists in the studied countries.

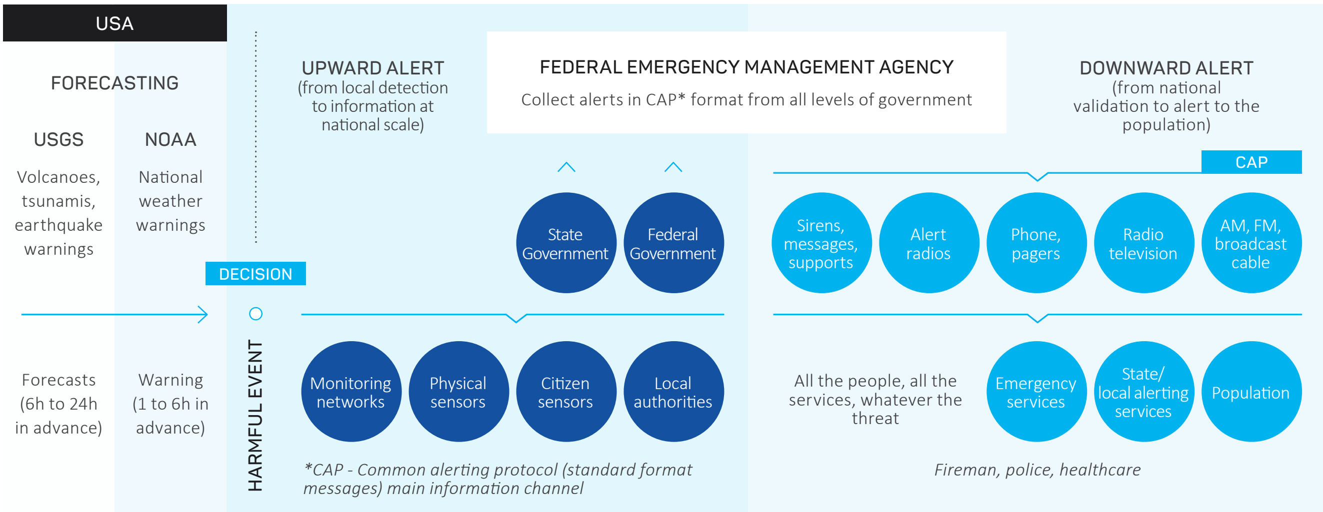

Figure 3: Multi-channel logic in USA with the Integrating Public Alert and Warning System infrastructure.

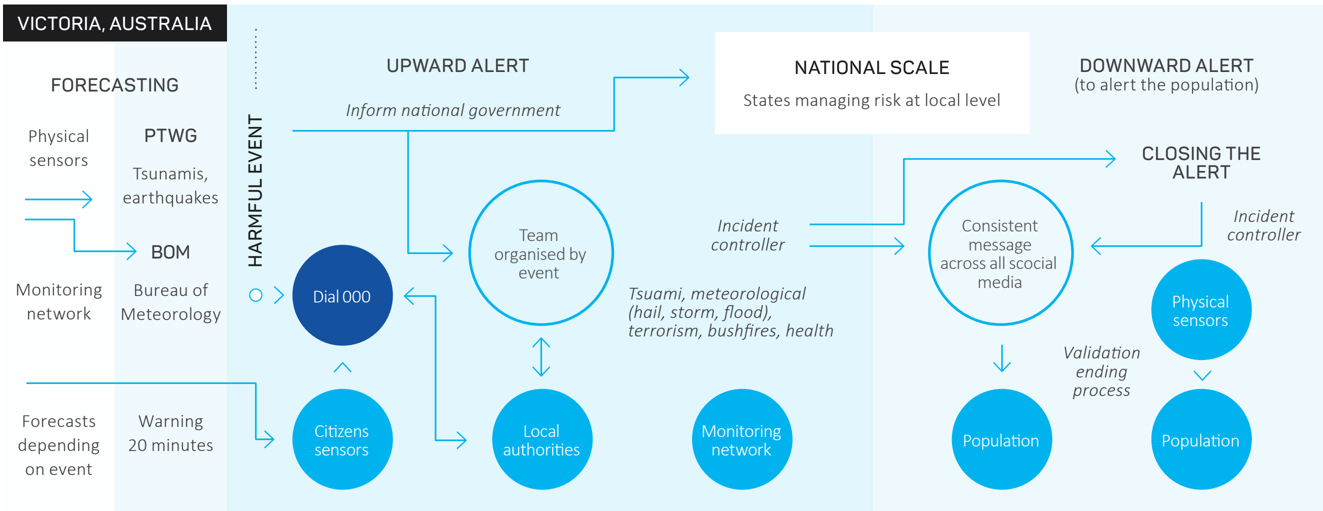

Figure 4: Multi-channel logic in Australia.

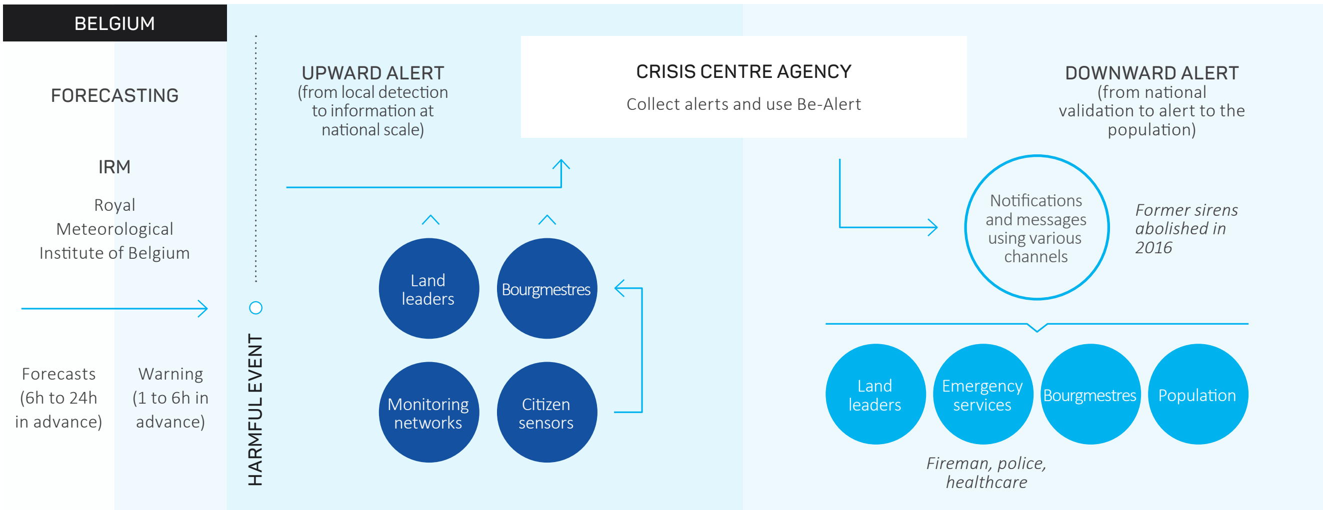

Figure 5: Multi-channel logic in Belgium with BE-Alert.

Three principles must be observed to guarantee an effective warning system:

- Be consistent in the broadcasting of signals and do not leave any 'gray areas'.
- Have the weak signals announcing danger confirmed by the authorities or relevant organisations to provide accurate, complete and honest information without making assumptions,
- Use common references to better engage with communities (Matveeva 2006, Stokoe 2016, Kuligowski 2014).

Creating dedicated and secure web-based platforms requires strong advertising. We could thus envisage a greater accountability of private operators through a delegation of public service associated with the telecommunications 5G network. Similarly, industrial operators or those in charge of a sensitive infrastructure, must be better integrated and made responsible. Nevertheless, a major stake in future warnings will be to take into account the contribution of citizens. Better detection of weak signals on digital social networks, including via artificial intelligence, is an important step. At the local level, the setting up of local watchmen (citizen sensor), perpetuated by repeated exercises, will allow the involvement of communities and the visibility of their actions (Figure 6).

The national warning system in France is representative of the gap that exists between the technical, social and organisational dimensions of alerting systems. In response to the Directive (Eu) 2018/1972 of the European Parliament[2] of 11 December 2018 that established a European electronic communications code, France announced in September 2020 the implementation of a new alert system to be gradually deployed from 2021. The FR-Alert platform is a consequent evolution of old sirens systems made obsolete by urban development. It will combine cell-broadcast and location-based SMS technologies, thus being a hybridisation of systems used in other countries.

2 A Directive 2018/1972 of the European Parliament, at https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L1972&from=EN.

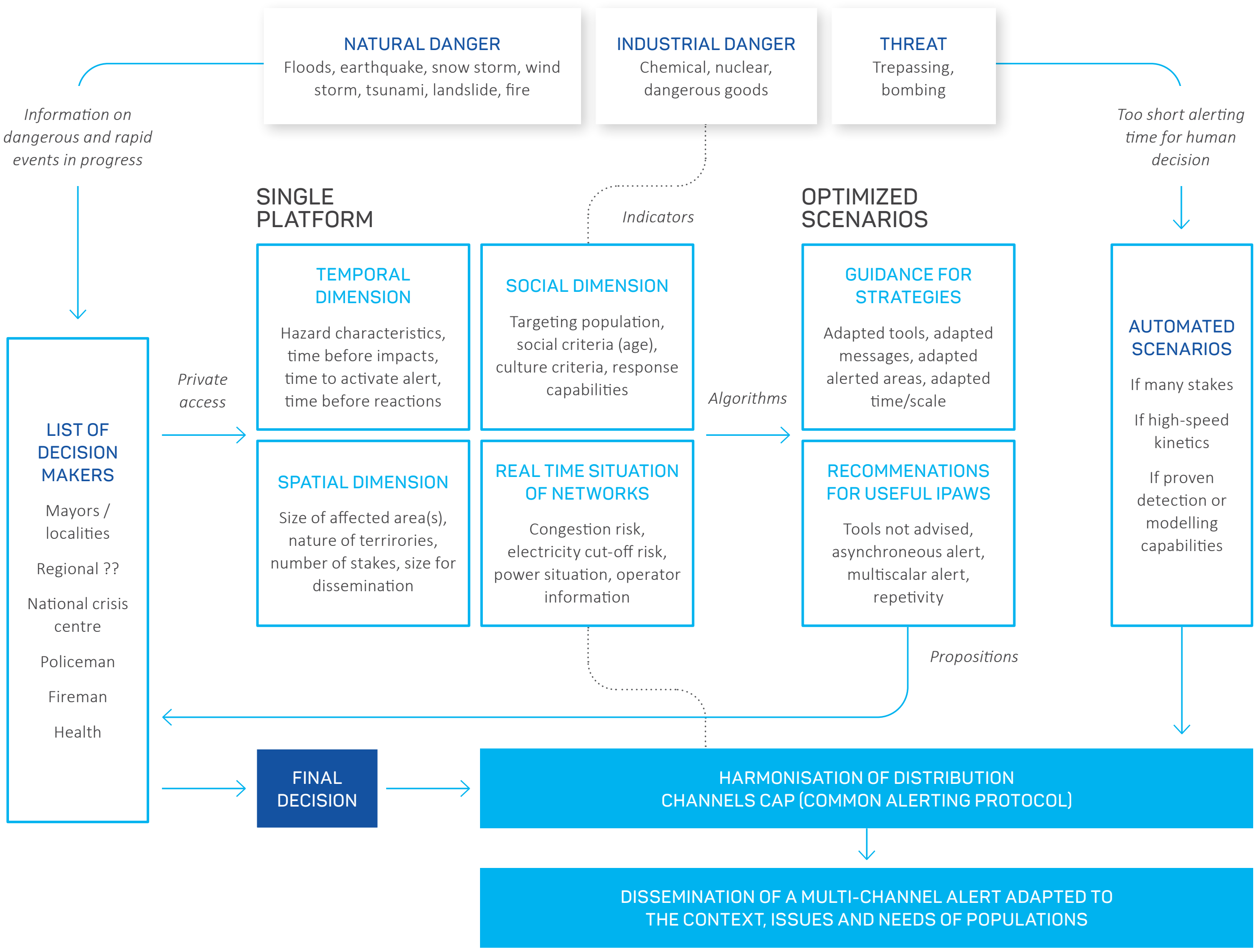

Figure 6: The way to go for creating efficient alerting national systems.

This technological leap should not hide remaining gaps. Technological fetishism led, for example, to the abandonment in 2018 of the SAIP (Population Information and Alert System) application set up by the French Ministry of the Interior. This technically robust application had failed to take into account the dimensions of use and was not as successful as expected. However, other technical devices exist and are well suited to end users, for example 'kidnap alert' (inspired by the Amber Alert system set up in the USA in 1996) or motorway warning systems that combine technical and social dimensions. The technical aspects are only one part of the problem. Indeed, one may wonder about the efficiency of a system that could send thousands of messages in a few seconds if it is not adapted to the kinetics of the event or if it is not understood by those who receive it or if it takes hours for the authorities to make the decision to alert. France has made a bold choice, but the decision-making process, based on control-and-hierarchical command, raises questions about the real capacity to alert communities in good time. The lack of a long-term vision or political courage may prevent organisational changes.

Conclusion

None of the 5 countries studied has established a real upward alert platform and we consider that they have not yet completed a digital transition of their alert systems. This is, however, a major lever for the future. This study showed that a very hazard-centred approach to systems continues to persist. We note that contingency theory only partially explains the form and functioning of the national warning system. Two visions are opposed: on one hand there is no differentiation between the tools used to disseminate information according to the hazard; on the other hand, only the message must vary and be adapted. A third way seems relevant, which is the possibility of adapting the dissemination tool to the hazard type.

The 4 stages of this technological transition can be summarised:

- Step 1: Better crisis prevention. Modernisation of hazard measurement tools, priority given to sensor networks.
- Step 2: Internal reorganisation of the system, adaptation to the data from the (rapidly arriving) sensors. Reorganisation of communication modes. Start of communication on digital social networks. Use of a LBAS sparingly.
- Step 3: Official and national use of a LBAS.
- Step 4: Ability to receive upward citizen alerts.

A recurring aspect is the evolution of systems in response to major disaster events. These disasters reveal the limitations of traditional warning systems, leading countries to reform their warning systems and equip themselves with more powerful tools. This, in turn, conditions hazard-centred systems rather than people-centred ones (Gaillard *et al.* 2010). The race for technological innovation must not boil down to a race for technical performance but must, on the contrary, put the individual back at the heart of the system. Warnings and alerting can only be approached in a global way, with a multidisciplinary view, an inter-ministerial position and which places the end user, the citizen, at the heart of the system.

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Forecasting the impacts of severe weather

Abstract

National meteorological and hydrological services provide severe weather warning information to inform decision-making by emergency management organisations. Such information also helps communities to take defensive and mitigating actions prior to and during severe weather events. Globally, warning information issued by meteorological and hydrological services varies widely. This can range from solely hazard-based to impact-based forecasting encompassing the exposure and vulnerability of communities to severe weather. The most advanced of these systems explicitly and quantitatively model the impacts of hazards on affected assets or infrastructure such as vehicle traffic or housing. Incorporating impact information into severe weather warnings contextualises and personalises the warning information, increasing the likelihood that individuals and communities will take preparatory action. However, providing useful and detailed impact information remains a challenge. This paper reviews a selection of current severe weather warnings and impact forecasting capabilities globally and highlights uncertainties that limit the forecasting and modelling of multi-hazard events.

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Introduction

The cost of severe hydrometeorological weather events is substantial (e.g. Kousky 2014), encompassing injury, loss of life, displacement, inhibiting access to services and causing extensive damage to property, infrastructure and the natural environment. Infrastructure expansion due to increasing population and urbanisation increases the potential for disruption from severe weather events. Changing weather conditions, such as the intensification of severe weather under climate scenarios, expose communities that may have had little prior experience with these events, making them more vulnerable (Wuebbles *et al.* 2014, Venner & Zamurs 2012). However, despite multi-day prediction of severe weather events and the dissemination of warnings by national meteorological and hydrological service (NMHS) forecasters, there remains a disparity between warning information and the likelihood of the community taking action to defend against or mitigate the potential effects of associated hazards (WMO 2015). One of several contributing factors is 'impact forecasting' that helps bridge the divide between forecasts of hydrometeorological events and mitigation action taken by emergency management organisations, communities and individuals by translating forecast hazard information into 'forecast impacts' at various scales (WMO 2015). A hazard-only warning may forecast a severe thunderstorm with damaging winds and heavy rainfall. Specifying that expected winds will damage trees and powerlines incorporates community vulnerability. Localised knowledge and exposure data can flag potential road closures and traffic delays. To ensure accurate, localised impact information in impact forecasting, a high level of coordination and knowledge sharing is required between meteorological agencies, custodians of exposure and vulnerability information and other stakeholders (Anderson-Berry *et al.* 2018; Taylor, Kox & Johnston 2018).

A recent study comparing the impacts of two storm systems with similar characteristics on the New York City region found that impact-based decision-support services used in response to one event improved decision-making, enhanced inter-agency communication and reduced societal and economic effects (Lazo *et al.* 2020). They estimated that impact-based services reduced costs to the aviation industry by over USD$17 million, reduced recovery time for ground transport by 5 days and saved over USD$90 million for the energy sector. A number of other studies have found that including impact information within warnings leads to improved community understanding and response (e.g. Kox, Lüder & Gerhold 2018; Weyrich *et al.* 2018; Ripberger *et al.* 2015; Harrison *et al.* 2014). In these studies, severe weather warnings encompassing the probability of occurrence and expected impacts were generally considered by end users (including emergency managers, broadcast media and the public) to be more useful than traditional hazard-based methods. In contrast, in a hypothetical study, participants were given hazard- and impact-based warning information but were only slightly more likely to take defensive or mitigating actions (Potter *et al.* 2018). However, even in this study, impact-based warnings were strongly associated with greater understanding, threat perception and concern about an event. The importance of personalising warning information and conveying risk motivated the issuance of a recommendation that emergency services organisations shift from hazard-based to impact-based warning systems (WMO 2015).

Impact-based forecasts and warnings exist along a spectrum of levels of sophistication. At the lower end, maps of hazard predictions are simply relabelled as impact categories (Pacific Disaster Center 2018). More sophisticated approaches relate impact to the climatological frequency of a specific predicted hazard magnitude or parameterise vulnerability through proxies such as population density (e.g. Robbins & Titley 2018). At the upper end of the spectrum, hazard-impact models incorporate detailed specifications of vulnerability and exposure to qualitatively or quantitatively derive the impact resulting from a hazard (Hemingway & Robbins 2018).

Despite its utility, impact forecasting is a relatively new field of modelling and efforts towards this goal vary widely. For example, while many European meteorological and hydrological services are currently transitioning to impact-based criteria from fixed or climatology-based hazard thresholds, almost 70 per cent of these do not run impact models for the production of impact-based warnings (Kaltenberger, Schaffhauser & Staudinger 2020). The same study notes that this could be due to issues relating to cost, a lack of impact data and verification, which makes it difficult to assess the performance of impact models under development.

This paper reviews the current status of impact-based forecast and warning guidance globally. Longer-range risk assessment tools (such as catastrophe-loss models) are excluded to focus on the shorter-range (less than 2 week) guidance. The focus is on impact systems relevant to emergency management and, as such, does not consider recent developments in the business sector. Examination of the details of the systems and their utility from a user-perspective is beyond the scope of this paper. The current state of impact models, which aim to explicitly forecast the effects of severe weather, are included. Gaps are highlighted for future investigation and provide suggestions to reduce the uncertainties in impact modelling.

Fundamentals and uncertainties in impact forecasting

The probability of impact from a hazard is the intersection of the likelihood of the hazard and the vulnerability and exposure of an individual, community or asset to the hazard (Figure 1). Hydrometeorological forecast uncertainty allows the estimation of the likelihood of the hazard, most often through the use of ensemble prediction systems (EPSs). In EPSs, multiple numerical weather prediction (NWP) model runs (termed *members*) with varying initial conditions and/or physics parameterisation schemes form an ensemble forecast. Ensemble forecasts provide an indication of the confidence in the overall forecast through the spread between the individual ensemble members, with a small (large) spread indicating less (more) uncertainty in the atmospheric conditions (Gneiting & Raftery 2005). Thresholds on probabilistic forecasts derived from EPS can be set to alert forecasters and other users to the likelihood of a hazard occurring, which can substantially increase the lead time of useful forecasts for end users.

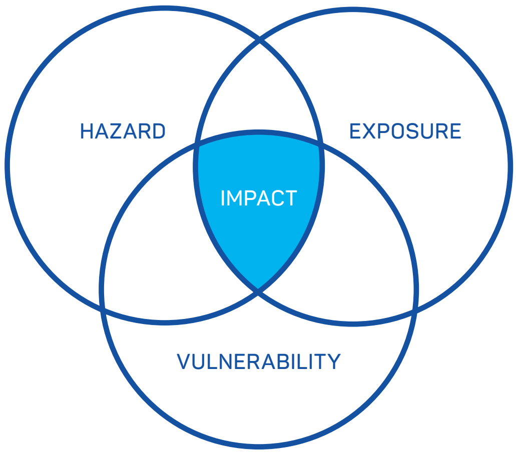


Figure 1: Venn diagram showing impact as the intersection of a hazard and the vulnerability and exposure of individuals, communities and assets to the hazard.

Uncertainties also exist in the exposure and vulnerability components. For our purposes, exposure describes people, property, infrastructure or other elements exposed to a particular hazard during an event. Where information regarding an individual building is not available, missing exposure data can be statistically inferred using known attributes of geographically similar regions. However, this introduces uncertainty into the exposure information. National, state or local standards are often not applied consistently for capturing and maintaining individual building attributes. Due to the sheer size of Australia, data is collated at different scales for different purposes and captured over extended periods of time, which also contributes to different levels of uncertainty across the country.

Vulnerability describes the degree to which a building (or other exposed element) is damaged by a given intensity of hazard, with different hazard-specific relationships applicable to different types of assets. Uncertainty in vulnerability arises from many sources such as variation in asset types, the magnitude of the causative hazard (which often cannot be directly measured and must instead be estimated from numerical reconstructions) and the level of defensive or mitigating action taken.

Finally, the tem 'impact' is used to refer to a wide range of consequences from a hazard including physical damage, disruption, denial of services and more. One example of quantifying physical impacts is the damage index, which is the ratio of repair cost to replacement cost for the asset (Wehner *et al.* 2010).

Impact forecasts and warnings from hazard mapping

Basic impact forecasts incorporate vulnerability and exposure information into hazard forecasts.

Climatology-based

The likelihood of occurrence of hazardous weather phenomena during a forecast window can be estimated using exceedance probabilities of climatology-based hazard thresholds. A noteworthy example is the UK Met Office *Decider* forecast product that allocates each member of a long-range ensemble forecast (one week and beyond) to the closest match from a set of 30 predefined weather regimes (Neal *et al.* 2016). Probabilities are calculated to deduce the regime with the highest likelihood of occurrence and exceedance of climatological hazard thresholds for any given location within the forecast range. Probabilistic methods such as this exploit known (historical) severe weather impact statistics for a range of synoptic weather patterns. This allows for the provision of multi-week probabilistic impact forecasts based on no more than a comparatively robust prediction of these larger-scale weather patterns.

Impact-based

While the climatology-based approach estimates only hazard, overlaying hazard forecasts onto proxies for exposure and vulnerability extends hazard forecasts towards impact estimation. A common type of hazard-based forecast uses geospatial maps depicting the probability of occurrence of a hazard, using symbols and colour-coding for ease of interpretation by forecasters or end users. For example, the Pacific Disaster Center *DisasterAWARE* Early Warning and Decision Support Platform (2018) produces real-time global geospatial maps of a range of hazards including tropical cyclones, high winds, severe storms and floods (Figure 2).

The red-filled circle in Figure 2 denotes an earthquake of magnitude greater than 5 on the Richter scale. The green-filled circles denote earthquakes of a magnitude between 2 and 4. Three current tropical cyclones locations (squares with a white cyclone symbol inside) are shown south of Hawaii, between

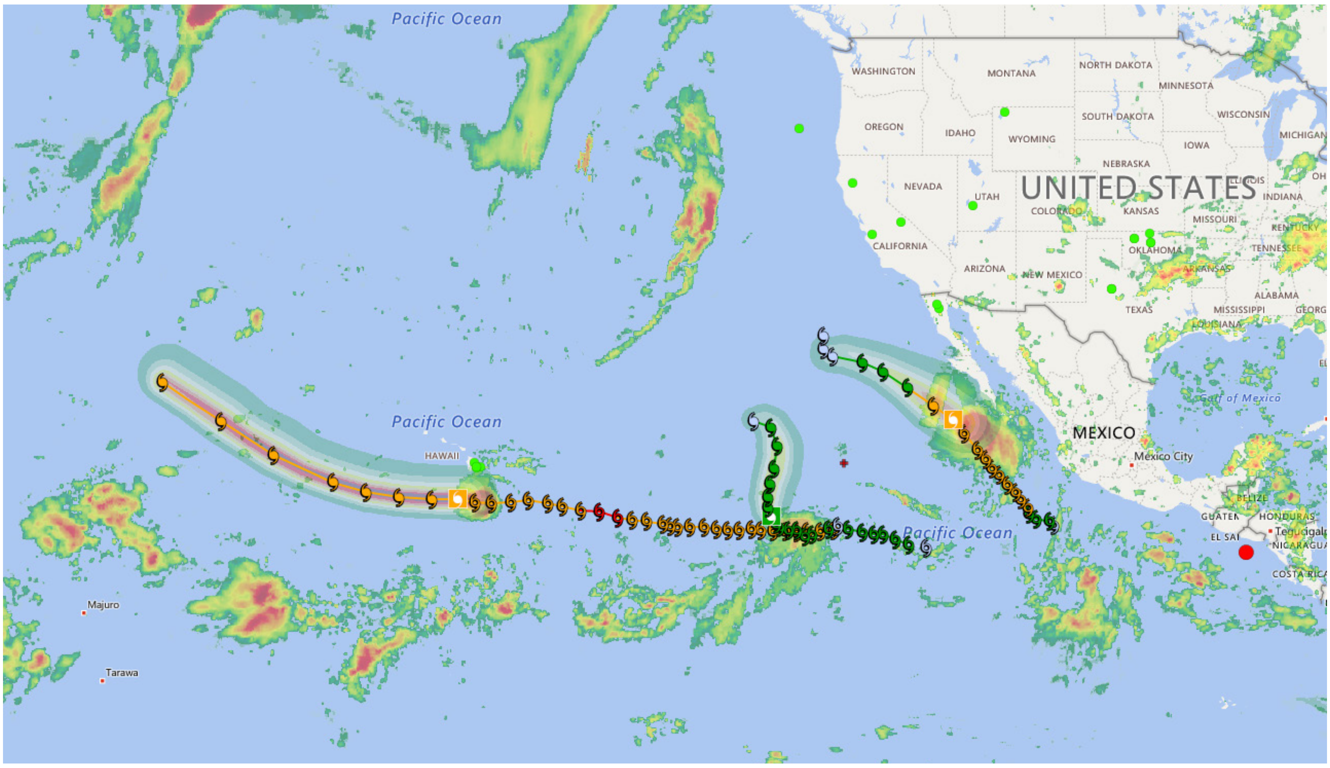


Figure 2: A snapshot of the Pacific Disaster Center global hazard map over the central and eastern Pacific Ocean (taken at 04:49 UTC 9 August 2018 from the publicly available version of the Pacific Disaster Center DisasterAWARE hazard mapping product).

Hawaii and Mexico, and just west of the Baja California Sur in the eastern Pacific. Tropical cyclone intensities, using maximum sustained wind speeds, are colour-coded below 40 miles per hour (mph) in blue, 40–70 mph in green, 70–150 mph in amber and in red for sustained winds in excess of 150 mph. The NASA IMERG 24-hour precipitation estimate is also shown ranging from green for light rainfall through to red for intense rainfall.

Spatial hazard probability forecasts can also be overlaid directly onto exposure information. This maps the assets that will be exposed to the hazard. Examples include the US National Oceanic and Atmospheric Administration Storm Prediction Center Convective Outlook (2018) and the Met Office Global Hazard Map (GHM) (Robbins & Titley 2018). The GHM allows the layering of antecedent conditions (such as rainfall and soil moisture) and vulnerability and exposure data (using proxies such as population density, age of housing and socio-economic status) to determine the likely impact. Unlike impact models, layered impact guidance products such as these leave it to the user to combine the individual layers of hazard, exposure and vulnerability information into an impact estimate.

Early warning systems

Impact-based severe weather warnings across many agencies and countries use a matrix similar to that implemented by the UK Met Office (Figure 3). This system estimates the impact of a hazard through the severity and likelihood of occurrence using 4 colour categories indicating 'very low', 'low', 'medium' and 'high' (Neal *et al.* 2014). For example, the MOGREPS Warnings tool (MOGREPS-W) presents the probability of occurrence of a weather event (severe wind, rain, snow, fog and ice) at individual grid-points using the colour scheme of the impact matrix. The impact thresholds vary between counties to localise the warning level to the vulnerability and exposure of individual counties. The Network of European Meteorological Services product, Meteoalarm (2018), uses the same colour framework to colour-code and overlay hazard symbols on administrative and geographical regions, from an international to national and regional scales. Other examples include the colour-coded regional maps of the Météo-France Vigilance Early Warning System (Borretti, DeGrace & Cova 2012; Kolen, Slomp & Jonkman 2013) and the Shanghai Multi-Hazard Early Warning System platform (Tang *et al.* 2012).

Quantitative impact modelling

The examples presented demonstrate the common use of spatial hazard mapping among hydrometeorological agencies. However, few systems integrate vulnerability and exposure information and those that do typically do so as additional 'layers' that must be interpreted by the user. More complex models directly forecast the impact of hazards on a community or a sector of interest. The insurance and reinsurance industries have developed vulnerability measures and impact (or catastrophe) models to predict loss and damage to the built environment from severe weather events using a financial perspective (e.g. Dunn *et al.* 2018). The challenge for hydrometeorological modelling

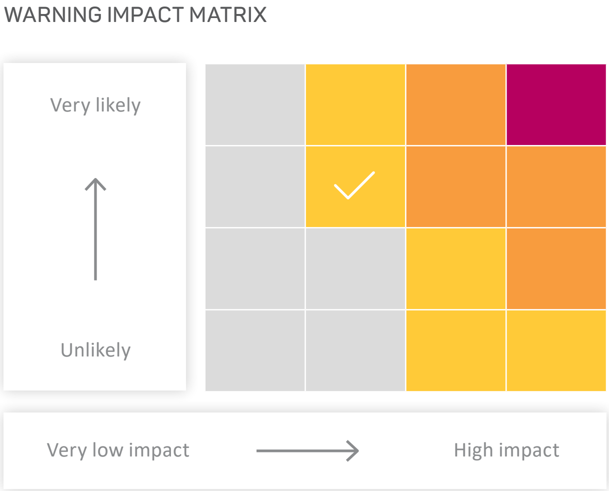


Figure 3: UK National Severe Weather Warning Service Impact Matrix (Neal *et al*. 2014).

is to translate impact information into tangible information that can be used (such as in emergency management planning) in a real-time operational environment (Hemingway & Gunawan 2018). This challenge, despite its importance, is being considered by relatively few agencies across the world. One example is the UK Natural Hazards Partnership, in which hazard-impact models are developed to support operational impact forecast decision-making (Hemingway & Gunawan 2018). In Australia, a partnership between the Bureau of Meteorology and Geoscience Australia is developing a prototype hazard-impact model for east coast lows.

Surface water flooding hazard-impact model

The surface water flooding hazard-impact model developed within the UK Natural Hazards Partnership uses operational ensemble rainfall forecasts as input into a hydrological model. This produces probabilistic surface runoff forecasts as the hazard for input into a pre-calculated Impact Library (Aldridge *et al.* 2016). The maximum impact is determined from 4 categories:

- danger to life
- damage to the built environment
- denial of access to key sites or infrastructure
- damage to transport networks.

The maximum surface water runoff during a given period is calculated and compared with flood spatial datasets to produce a map of potential flood impacts (Figure 4).

The impact severity for each county is determined by whether the proportion of cells affected exceeds a given threshold. By repeating across the entire ensemble, the model provides guidance on both the likelihood and the potential impact severity of surface water flooding at a county scale. A flood-risk matrix, similar to Figure 3 (Flood Forecasting Centre 2017) is then used to assess the highest overall surface water flood risk (e.g. Figure 5).

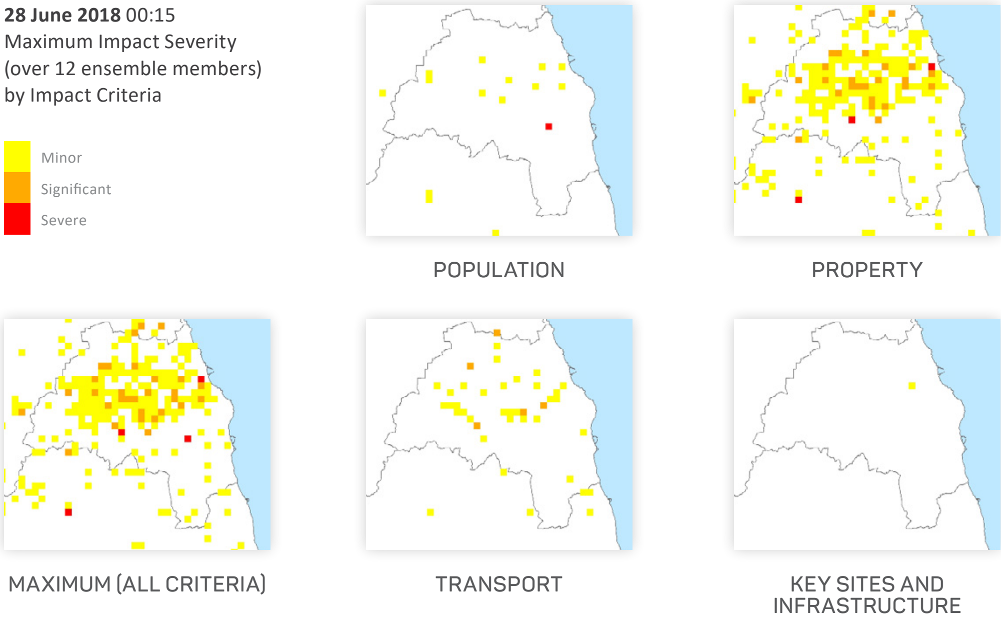


Figure 4: An example of the surface water flooding hazard-impact model for an ensemble rain forecast at every 1 km grid cell over Durham County in north-east England (Aldridge *et al*. 2020). The bottom left panel shows the maximum impact across components in each grid cell.

Severe wind hazard-impact models

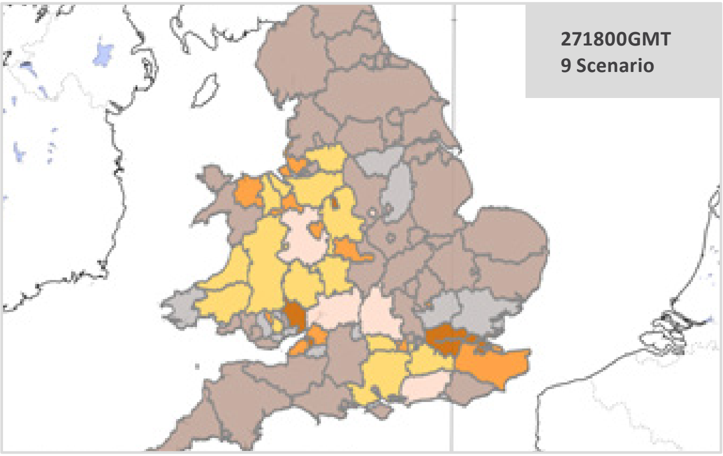
Under the UK Natural Hazards Partnership, the UK Met Office is developing the Vehicle OverTurning model, the Camping and Caravanning model and the Bridge model (Hemingway & Gunawan 2018). The (currently) pre-operational Vehicle OverTurning model takes operational ensemble forecasts and calculates the probability that wind gusts will exceed vehicle-specific thresholds at sections of the road network. Vulnerability depends on several factors, for example, altitude of a road sector, number of lanes (multi-lane roads are lower risk of complete closure), infrastructure (tunnels and roundabouts) and road orientation with respect to wind direction. The model is supporting UK Met Office meteorologists issuing impact-based wind warnings (Hemingway & Robbins 2020). The Camping and Caravanning model uses the same algorithm as the Vehicle OverTurning model to forecast the impact risk from high winds on campsites and large gatherings. They use seasonally dependent exposure and lower wind thresholds due to the increased vulnerability of tents and caravans. The Bridge model forecasts the effects of high winds on bridges and road states and informs decisions regarding speed restrictions and closures during severe wind events.

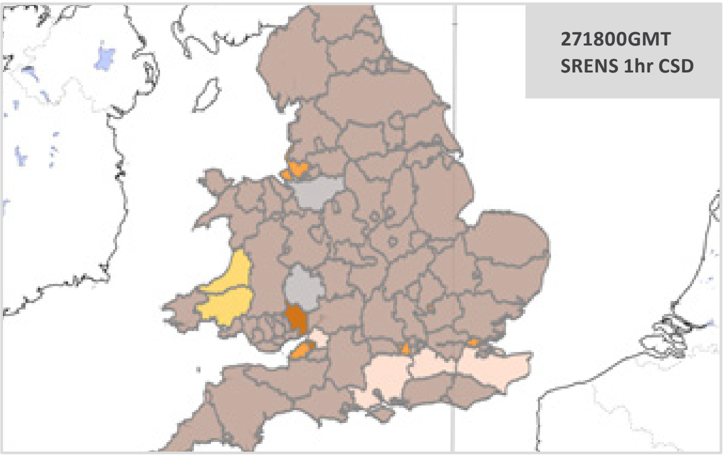
The Australian Bureau of Meteorology and Geoscience Australia have developed a pilot quantitative forecast model for wind impact on residential housing using hazards provided by high-resolution NWP predictions (Richter *et al.* 2019). The project focuses primarily on east coast lows, which are complex low-pressure systems that affect the eastern Australian coastline and are capable of producing strong winds, very heavy rainfall and storm surges (Holland, Lynch & Leslie 1987). The impact model takes building information from the National Exposure Information System (Power *et al.* 2017) and uses existing heuristic wind vulnerability functions for residential buildings based on tropical and extra-tropical cyclone events. The expected mean structural loss ratio due to wind is aggregated over Statistical Area level 1 (SA1) areas, which contain between 200–800 people. In this way, the forecast highlights regions expected to be most affected by an event. This can be consistently mapped and communicated to emergency services organisations. This approach is demonstrated using reanalysis surface wind gusts from high-resolution NWP (BARRA-SY, Jakob *et al.* 2017) shown in Figure 6. Performance assessment of the 'forecast' is currently underway and has produced encouraging preliminary results.

Current challenges in quantitative impact modelling and forecasting

The quantitative impact models forecast single-hazard impacts, whereas severe weather events such as east coast lows, usually produce multiple and compounding hazards. Difficulty isolating the dominant cause of damage (e.g. wind, water ingress or treefall) impedes the derivation of accurate vulnerability relations. If the cause of the damage cannot be identified, impact forecast verification is limited (Richter *et al.* 2019; Kaltenberger, Schaffhauser & Staudinger 2020).

In Australia, damage assessments are undertaken to evaluate the level of impact from a disaster. This includes assessing the physical safety of affected structures and informs recovery planning and operations (AFAC 2016). Minor changes in the collection of damage assessment data, however, can ameliorate some of the issues outlined above. One suggested change is to include connections between observed damage and the underlying hazard (e.g. wind or water ingress). A second





Cheshire

27 May 2018 18:00:00
Threshold = 11 sq. km.

Impact/#members	9 scenario	1 hour	3 hour	6 hour
None	19	23	20	20
Minimal	1	1	2	1
Minor	4	0	2	3
Significant	0	0	0	0
Severe	0	0	0	0

W Midlands

27 May 2018 18:00:00
Threshold = 9 sq. km.

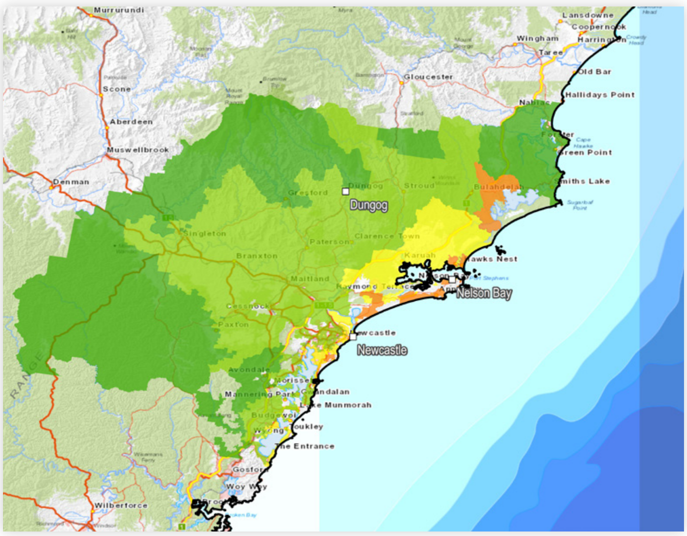
Impact/#members	9 scenario	1 hour	3 hour	6 hour
None	12	24	20	12
Minimal	4	0	1	5
Minor	2	0	2	1
Significant	5	0	1	6
Severe	1	0	0	0

Gtr London

27 May 2018 18:00:00
Threshold = 9 sq. km.

Impact/#members	9 scenario	1 hour	3 hour	6 hour
None	19	24	20	19
Minimal	1	0	0	1
Minor	0	0	2	2
Significant	2	0	1	0
Severe	2	0	1	2

Figure 5: A surface water flooding hazard-impact model of county level summary impacts for an ensemble rain forecast (R. Cowling 2018, personal communication, 6 June).



Mean damage state

- Negligible
- Slight
- Moderate
- Extensive
- Complete

Figure 6: Results of the wind gust impact 'forecast' developed by the Australian Bureau of Meteorology and Geoscience Australia. Mean structural loss ratio (calculated for residential buildings) due to the surface (10 metres above ground level) wind gust is averaged across the area for an east coast low on 20–22 April 2015.

proposed alteration is the inclusion of categorical damage ratings to a structure. The National Damage Assessment Data Set and Dictionary for Phase 2 Assessments (AFAC 2016) outlines a minimum set of attributes to standardise damage assessment data collection and reporting by Australian emergency services agencies. However, uptake across jurisdictions has been varied and has limited the utility of collected data for impact research. Indeed, recommendations 4.6 and 4.7 of the *Royal Commission into National Natural Disaster Arrangements Report* (Commonwealth of Australia 2020) stipulate that the collection and sharing of consistent impact data be standardised across Australian states and territories. To advance quantitative impact-based forecasts and warnings and ensure collected damage data can be used in model development and testing, close collaboration between national meteorological and hydrological services, emergency services organisations and custodians of vulnerability and exposure data is vital.

Conclusions

This study provides an overview of approaches to produce impact-based information to improve weather warnings and forecasts. Impacts can be included in a hazard forecast in a simple manner by presenting the predicted hazard magnitude within a climatological context. However, impact information can also be added through stand-alone layers of exposure or vulnerability (assets or people). This common approach is not constrained by specific damage data attributes nor their connection to the nature and magnitude of the causative hazard. However, such layers leave it to the end user to subjectively integrate the qualitative layers to obtain the final impact, and therefore lacks consistency across multiple users.

The most sophisticated impact forecasts use quantitative hydrometeorological hazard-impact models. Examples are the UK Met Office Vehicle Overturning model and an Australian pilot project assessing wind damage associated with east coast lows. These models integrate hazard, exposure and vulnerability information quantitatively to provide pointwise or spatial impact magnitudes. Hazard-impact models are rare and, because of their need to ingest quantitative impact data, are strongly reliant on the accuracy of connections between physical impacts and the underlying hazard, exposure and vulnerability. This review highlights that improved damage assessment datasets is an important first step towards improved quantitative impact modelling.

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Implications of artificial intelligence for bushfire management

Abstract

A country's history and development can be shaped by its natural environment and the hazards it faces. As a response to the threat of novel and unexpected bushfire disasters, scholars and practitioners have turned to the area of artificial intelligence. This paper explores the underlying principles of artificial intelligence tools and to investigate how these tools have been used to mitigate the risks of catastrophic bushfires. In doing so, this research provides an overview of applications of artificial intelligence tools to enhance effective management of bushfires through preparedness capability, responding capability and recovery capability. The future evolution of tools in artificial intelligence is discussed in the bushfire management context based on emerging trends.

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Introduction

Australia has a long history of bushfires and the most recent bushfire disaster of 2019–20 will not be the last. Bushfires can be tragic but, at the same time, are regular events in many parts of the country. As a response to the threat of bushfire, emergency management policies in Australia have pushed the concept of bushfire management as a means of mitigating bushfire risks (Philips *et al.* 2016). However, the conventional view of bushfire management may no longer be sufficient to cope with the increasing complexity of bushfire disasters (Linnenluecke & Griffiths 2013). The traditional approach advocates for the use of qualitative methodologies to obtain knowledge and an understanding of the issues surrounding the bushfire disaster (Pooley, Cohen & O'Connor 2010). However, the qualitative view of bushfire management partially analyses interactions between people, resources and the environment (Minas, Hearne & Handmer 2010). This perspective fails to provide a complete representation of complex interactions between the elements of complex natural systems exposed to recurring bushfires. The necessity for the development and delivery of an effective bushfire management framework that can deal with novel and unexpected threats has motivated scholars and practitioners to turn to the area of artificial intelligence (AI). Modern computing allows AI to be used as an effective tool to support disaster and recovery operations. However, there is a lack of research on how AI has been applied in bushfire management. The objective of this work is to explore the current state of the science in applying AI to bushfire management practice. This paper offers a lens through which researchers and practitioners might better understand key concepts and links of AI to the functional areas of bushfire management.

The practice of bushfire management is conceptualised as a set of capabilities that provide a reliable recovery process and a minimal adverse consequence when bushfires occur. Three distinct stages in bushfire management are used and each stage addresses the required capabilities for effective management, being:

- preparedness capabilities are the abilities to prepare for disruptive events to reduce the detrimental effects of natural disasters (Madni & Jackson 2009)

- responding capabilities are the abilities to develop solutions to resist destruction when an unexpected event occurs (Jaques 2007)
- recovery capabilities refers to adjustments in the aftermath of crises (Limnios *et al.* 2014), which helps the affected community to recover.

The key contribution of this study is to provide an overview of example applications of AI tools to enhance the 3 capabilities of preparedness, response and recovery.

A synopsis of artificial intelligence

It is common to think of AI as a relatively modern concept in computer science. However, the concept of AI can trace its origin to the 8th Century BC in *The Iliad*, an epic poem by the Greek poet Homer. In this poem, Homer portrayed Hephaestus, the god of fire, as an inventor who built golden automata, or self-operating machines (Abbott 2020). 'Artificial intelligence' as a term was first coined by John McCarthy in 1956 at the second Dartmouth conference. Since the first use of the term AI, the understanding of what AI entails and how it is designed has evolved. There is no universally accepted definition of AI. However, modern definitions have been widened in line with the definition suggested by Russell and Norvig (2016) as 'the designing and building of intelligent agents that receive precepts from the environment and take actions that affect the environment'.

With the advent of modern computers, there is a rise in the employment of AI based methods. These methods have traditionally been classified into 2 paradigms: Symbolic AI and Connectionist AI. Symbolic AI develops computational models to mimic human expertise on the basis of symbol representation (Sun 2015). In this approach, the modeller generates rules for software to follow (Abbott 2020). Examples of methods used in this approach are fuzzy logic and Bayesian networks. Connectionist AI focuses on learning. This approach involves the adjustment of weights in a large network of units. In this approach, unlike the symbolic AI, the modeller does not specify the rules of the phenomenon under scrutiny. The rules are generated by computers based on learning from examples (Abbott 2020). Machine learning, artificial neural networks and deep learning are examples of the most widely used tools in this paradigm.

Research methodology

An integrative literature review was performed to summarise the research on the applications of AI in the bushfire management context. In conducting the integrative literature review, an iterative approach was adopted to define appropriate keywords, analyse and synthesise data and finalise the classification results (see Figure 1).

Step 1 - Identifying data sources: An initial search was conducted using Google Scholar, EBSCOhost and the Scopus citation database. The articles were mainly obtained from the publishers including Emerald, Elsevier, Taylor & Francis, Springer, CSIRO Publishing, the Australian Institute of Disaster Resilience, the Australian Emergency Management Institute and Canadian Science Publishing. In order to provide a coherent sequence of the development of the AI tools in bushfire management, the span of time over which the research articles were published was not restricted. The final list of papers in this work contained 34 articles from 2000 to 2020.

Figure 1: Schematic diagram of the research methodology.

Step 2 - Search methodology: The search methodology was based on selected keywords including 'bushfire', 'wildfire', 'artificial intelligence', 'fire suppression', 'disaster management', 'fuel treatment', 'post-disaster', 'prediction', 'emergency evacuation' and 'emergency relief'. Boolean operators 'AND' and 'OR' were used to combine the keywords. For instance, one such combination was 'bushfire OR wildfire AND artificial intelligence'.

Step 3 - Study selection and evaluation: Substantively irrelevant papers were eliminated by reviewing the abstracts of the identified papers in Step 2. The remaining papers were then read in their entirety to ensure substantive relevance. Further, backward-tracking was used to find the relevant papers that were cited and forward-tracking was used to find the relevant articles that cited the central source. This helped to find papers that were not identified through the search process.

Step 4 - Data extraction and synthesis: The findings of each individual study were synthesised into different arrangements based on different stages of bushfire management. Information from each paper was organised under the 3 main categories of preparedness capabilities, responding capabilities and recovery capabilities.

Applications of AI in bushfire management

To illustrate how AI can enhance bushfire management practice, 16 AI tools and 7 application areas were identified within the 3 stages of bushfire management (see Figure 2).

Preparedness capabilities

AI tools are effective in the prediction and prevention of bushfires. In this stage, the ultimate goal of using AI is to improve preparedness capabilities to prepare communities and fire agencies for unprecedented events. AI possesses 2 desirable features; it can be used to characterise and map susceptibility to bushfires through predictive modelling techniques, and it can provide tools for establishing an effective fuel treatment system.

Bushfire predication

Rooted in AI, an array of methods has been developed to predict the likelihood and spatial pattern of bushfire occurrence. For example, Zhang, Lim & Sharples (2016) developed a Logistic Regression Analysis model to generate a fire occurrence probability map for south-eastern Australia. Thompson (2013) built a Markov chain model to predict the location and timing of fire events in the USA. Massada and colleagues (2013) used machine-learning algorithms to develop an ignition-distribution method. The proposed method aimed to predict the likelihood of fire occurrence across Huron-Manistee National Forest in Michigan, USA. Adab (2017) adopted artificial neural networks to evaluate the potential of bushfire hazards based on the frequencies and distributions of bushfires in Golestan Province in Iran.

Fuel treatment

Reducing hazardous fuels is a primary objective of fuel treatment. The commonly used fuel treatment methods are commercial timber harvest, mechanical thinning, mastication and prescribed burning. Many studies have explored the potential of using AI in fuel treatment planning. These studies have investigated a range of decision making paradigms to find optimal solutions for locating fuel treatment resources, scheduling fuel treatment activities and economic efficiency. Wei, Rideout and Kirsch (2008) employed Mixed Integer Programming to find the optimal locations of fuel treatment resources in the USA. Kim, Bettinger and Finney (2009) attempted to optimise the scheduling of fuel treatment activities in Oregon, USA by means of the Great Deluge algorithm. Konoshima and colleagues (2010) developed a stochastic dynamic programming model for the cost-efficient allocation of fuel treatment with the intent of optimising fuel management decisions.

Responding capabilities

AI can be used to enhance responses to bushfire. In this stage, researchers and fire agencies have used AI to achieve 2 objectives:

- to safely contain and suppress bushfires as quickly and effectively as possible
- to prevent bushfire fatalities and injuries by developing and implementing an effective emergency evacuation and rescue plan.

Figure 2: The 3 stages of bushfire management and their 7 application areas.

Fire suppression

Researchers have successfully introduced a range of AI tools to manage fire suppression activities. Two common types of fire suppression activities are:

- initial attack that prevents the further extension of the fire
- extended attack that refers to the actions taken for the bushfire that has not been contained by initial attack forces.

In this context, AI has been employed to minimise the extent of the uncontained fire, thereby improving the effectiveness of initial attack activities. Various optimisation methods have been used to determine the optimal time, location and deployment of the initial attack resources. Furthermore, AI has been applied to solve the problem of scheduling firefighting resources. For example, Hof and colleagues (2000) proposed a linear programming model to delay the timing of fire spread for the bushfire events that exceed containment capabilities of suppression resources. Haight and Fried (2007) constructed an integer programming model for the optimal deployment of fire suppression resources in California, USA. Rachaniotis and Pappis (2011) adopted heuristic algorithms to address the problem of scheduling firefighting resources when fire escapes initial attack. Hansen (2012) used regression analysis to quantify the quantity of water required to suppress the fire by taking into account the fire suppression time, the size of the affected bushfire area and the flame height.

Emergency evacuation

Evacuation of people within a restricted time window is a major concern for fire services and emergency management organisations. To date, most literature on emergency evacuation advocates the use of optimisation methods for planning evacuation during bushfires. Rui, Shiwei and Zhang (2009) used a genetic algorithm to develop an evacuation plan to minimise the total evacuation time in the city of Gulfport, USA. Kulshreshta, Lou and Lim (2014) optimised the use of public transportation in emergency evacuation planning by employing Tabu search heuristic. In particular, the authors determined the optimal pickup locations and bus allocations for emergency evacuation in South Dakota, USA. Shahparvari, Abbasi and Chhetri (2017) proposed a vehicle routing problem approach to facilitate evacuation of short-notice evacuees during a bushfire in Victoria, Australia.

Disaster robotics

Disaster robotics including unmanned ground vehicles and unmanned aerial vehicles are currently the most promising and safe methods for response and rescue operations. At the most basic level, robotics technology is used for mapping affected communities, firefighting, search and rescue (Sun, Bocchini & Davision 2020). Significant advances in robotics technology can be credited to the use of machine-learning techniques for acquiring new robotics skills and deep-learning tools for visual detection.

Recovery capabilities

AI has propelled research into the recovery stage of bushfire management with the aim of returning communities to normal. In practice, AI has been widely adopted to assist communities to recover from bushfire disasters.

Emergency relief operations

AI tools have been used to facilitate post-disaster relief operations. Specifically, AI methods help to develop decision-support systems for the humanitarian supply chain. For example, Wei and Kumar (2007) used the ant colony optimisation technique to solve logistics problems of relief activities. The outputs of the proposed method intended to minimise the delay in transportation of commodities from suppliers to distribution centres in disaster affected areas. Lei and colleagues (2015) adopted the rolling horizon heuristics method to optimise the scheduling of medical teams and the provision of medical supplies for New York with a network of 80 hospitals. Bodaghi and colleagues (2020) developed an emergency operation model drawing on mixed integer programming to assist in scheduling and sequencing multiple resources in a Victorian bushfire case study.

Post-disaster recovery response

To address the recovery needs of affected communities, AI tools have been applied in the post disaster recovery phase. Öztayşi and colleagues (2013) proposed a volunteer management framework using fuzzy logic for the recovery process in Greece. Lin and Wang (2017) employed a Markov Chain model for the recovery process for a portfolio of community buildings. Sublime and Kalinicheva (2019) used deep-learning techniques to create post-disaster damage mapping following natural disasters in Japan. Raza and colleagues (2020) used a machine-learning model to facilitate communications between emergency services organisation and affected communities.

The roadmap for the future applications of AI in bushfire management

Since 2000, there has been major progress in the application of AI-based methods in bushfire management. Figure 3 illustrates the applications of AI tools in various stages of bushfire. Among these methods, the optimisation tools have received considerable attention. One explanation for this can be that fire agencies are confronted with a plethora of choices to optimise objective functions. This has propelled research to find the best solutions to achieve objectives such as optimal allocation of constrained resources for fire suppression and optimal allocation of response personnel.

Based on emerging trends in the application of AI in bushfire management, there are other possible future applications that would provide benefit.

Table 1: Applications of AI tools in different functional areas of bushfire management.

Application	Location	Method	Author(s)
Modelling spatial patterns of bushfire occurrence	South-eastern Australia	Regression Analysis	Zhang, Lim & Sharples (2016)
Bushfire distribution modelling	Michigan USA	Machine Learning	Massada *et al.* (2013)
Modelling bushfire complexity	USA	Markov Chain Model	Thompson (2013)
Frequency and distribution of bushfires	Iran	Artificial Neural Network	Adab (2017)
Locating fire treatment resources	California USA	Mixed Integer Programming	Wei, Rideout & Kirsch (2008)
Optimisation of fuel treatment activities	Oregon USA	Great Deluge Algorithm	Kim, Bettinger & Finney (2009)
Optimal pattern of fuel treatment and harvesting	Hypothetical	Stochastic Dynamic Programming	Konoshima *et al.* (2010)
Delaying ignition time	Hypothetical	Linear Programming Model	Hof *et al.* (2000)
Deploying and dispatching fire suppression resources	California USA	Integer Programming Model	Haight & Fried (2007)
Scheduling firefighting resources	Hypothetical	Heuristic Algorithms	Rachaniotis & Pappis (2011)
Estimating bushfire suppression resources	Hypothetical	Regression Analysis	Hansen (2012)
Determining pickup locations and bus allocations for emergency evacuation	South Dakota USA	Tabu Search Heuristic	Kulshreshta, Lou & Lim (2014)
Optimising transit evacuation plan	Gulfport USA	Genetic Algorithm	Rui, Shiwei & Zhang (2009)
Scheduling for short-notice bushfire emergency evacuation	Victoria Australia	Vehicle Routing Problem	Shahparvari, Abbasi & Chhetri (2017)
Solving logistics problems for disaster relief activities	Hypothetical	Ant Colony Optimisation	Wei & Kumar (2007)
Personnel scheduling and supplies provisioning in emergency relief operation	New York USA	Rolling Horizon Heuristics	Lei *et al.* (2015)
Scheduling of multiple resources for emergency operations	Victoria Australia	Mixed Integer Programming	Bodaghi *et al.* (2020)
Volunteer management	Greece	Fuzzy Logic	Öztayşi *et al.* (2013)
The recovery process of community building portfolios	Hypothetical	Markov Chain Model	Lin & Wang (2017)
Post-disaster damage mapping	Japan	Deep Learning	Sublime & Kalinicheva (2019)
Communication between emergency service authorities and communities	Hypothetical	Machine Learning	Raza *et al.* (2020)

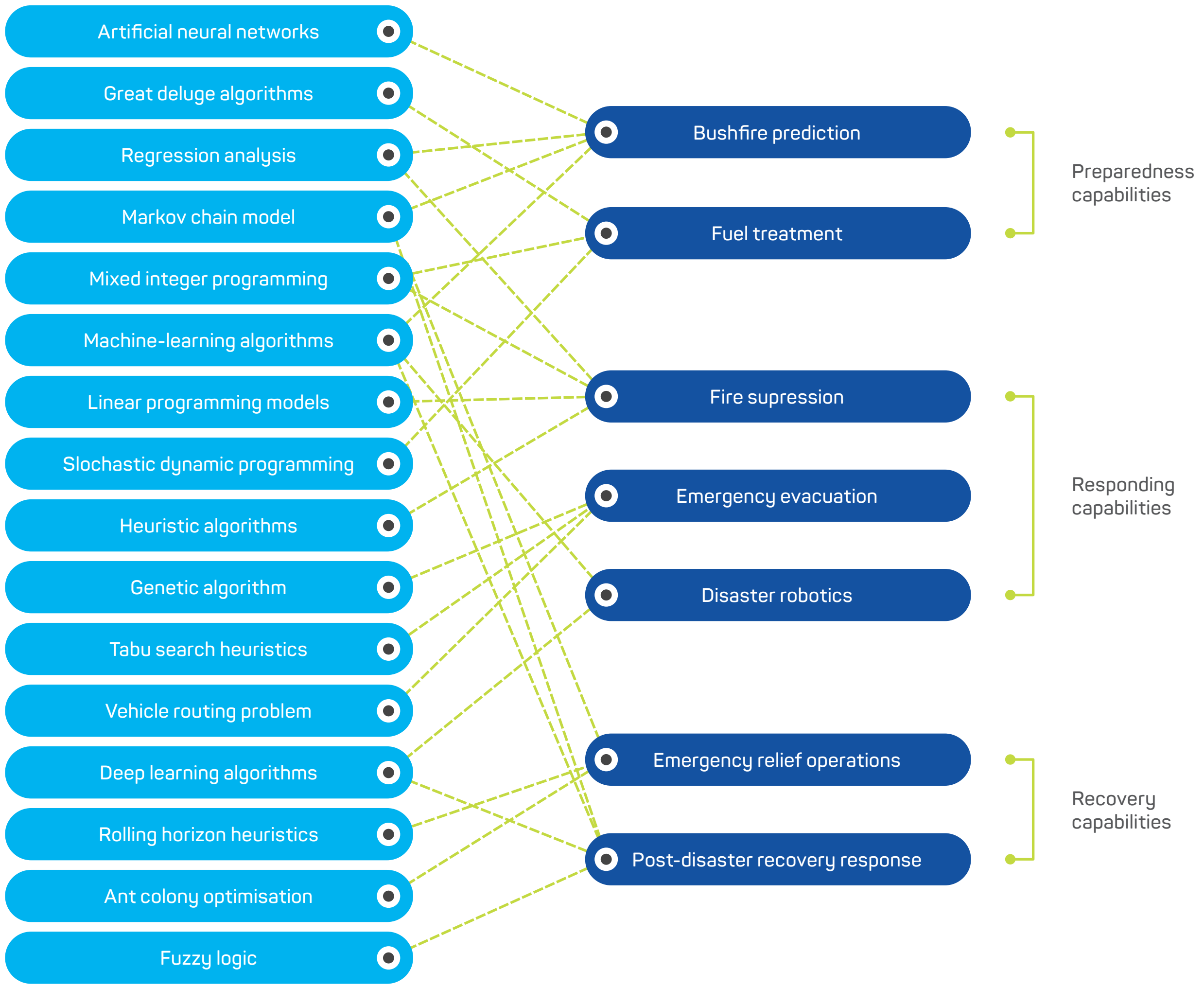

Figure 3: Current applications of AI tools in bushfire management.

Many activities in bushfire risk mitigation are concerned with the prediction and projection of elements such as predicting the amount of time for fire suppression and forecasting the behaviour of bushfires. As such, most of the decision-making for bushfire management takes place under conditions of uncertainty. This uncertainty can be managed when AI methods are used in conjunction with human intuition and judgement. Smith (2016) argued that the human, as the final decision maker, should have a pronounced presence in the next generation of AI tools. The strength of human decision making lies in the ability to take new and innovative actions in uncertain environments.

The connectionist AI paradigm is gaining attention in bushfire management compared to the symbolic AI paradigm. Although the connectionist models have helped emergency managers to make decisions, these models do not account for human cognition. Moreover, the connectionist methods are data-sensitive and require a vast amount of structured training data. The function of robots used in bushfire preparedness and response operations are restricted to the specific problem applications that they are designed for. These shortcomings render the use of purely connectionist methods as ineffective. Given the different strengths of connectionist and symbolic paradigms, the applications of hybrid methods that combine 2 paradigms are likely in the near term. An example of successful hybridisation of AI is Google's search engine in which sentence transformers (connectionist AI) are coupled with the knowledge graph reasoning tools (symbolic AI). The successful implementation of hybrid AI tools can trigger the development of hybrid methods usable in the bushfire management context.

Bushfires exhibit unique characteristics not shared by other events and bushfire management requires specific types of predication, mitigation and recovery activities. Existing AI tools lack the function-specific capabilities required to minimise the harmful effects of bushfires. Despite AI being reliant on training data as human input, it does not replace human judgement. This highlights the need for new perspectives on the development of new function-specific AI tools that are fine-tuned using both training data and the human judgement of bushfire experts.

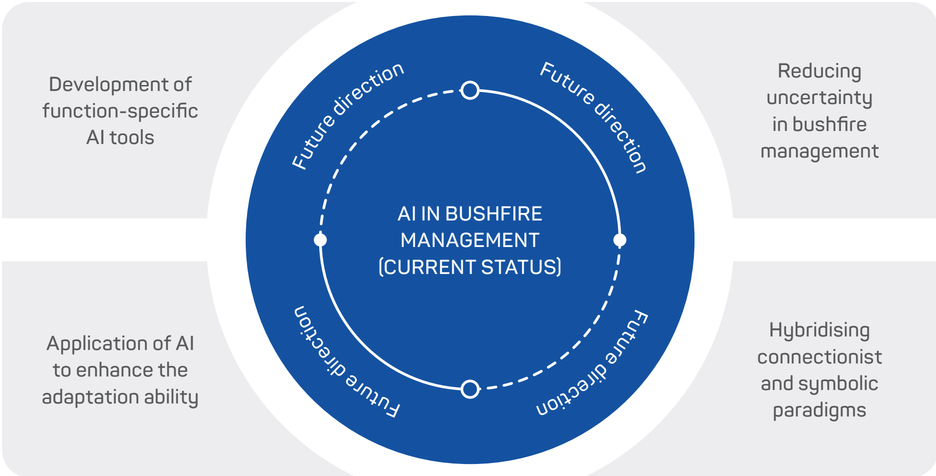

Figure 4: A roadmap of future applications of AI in bushfire management.

There is a paucity of research on adaptation to bushfire including long-term learning, which enables communities to develop new norms through lessons learnt from past events. Adaptation is indeed the main antecedent for the anticipation dimension of resilience in disaster management (Duchek 2020). The few existing studies are predominately anecdotal and descriptive. Future research could harness AI potential to incorporate insight from bushfire disasters into the knowledge base of fire service agencies and government departments. The knowledge-based platforms, which house information on historical bushfire disasters, can be assisted by the development of AI-focused hubs that tap the benefit of this technology.

Figure 4 is a schematic of future prospects for the applications of AI in bushfire management.

Conclusions

The aim of this paper was to answer the question: What is the current state of the science of applying AI to enhance bushfire management practice? A review of research on the applications of AI in the bushfire management context was undertaken. Three distinct perspectives were identified on the resilience capabilities of bushfire management practices and analysis provided an overview of links between AI and resilience capabilities.

This overview indicated that bushfire management has benefited from the applications of AI over the past 2 decades and it has resulted in several novel methods that mitigate the risk of catastrophic bushfires. Future bushfire scholars and practitioners will be encouraged to develop and implement function-specific AI methods. Bushfires exhibit unique behaviour and the development and implementation of function-specific AI tools will provide insight into the unique characteristics of fire behaviour and progression. The growing complexity of bushfires, as well as other hazard events, reinforces the need to manage this complexity using new methods as well as the next generation of AI tools.

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Abstract

Digital platforms have become valuable resources to citizens as they allow immediate access to quality information and news. Staying up to date with information and news is particularly vital in crises such as bushfires. The 2019–20 bushfire season in Australia was extreme, resulting in widespread devastation and loss of life, property and wildlife. Communicating with affected communities is a critical component of community response and resilience in a disaster. Organisations, such as ACT Emergency Services Agency and the NSW Rural Fire Service, need to provide timely, accurate and reliable information. This study investigated official communication using Facebook during the Orroral Valley bushfires from these two emergency services agencies and considers to what extent messaging demonstrated the characteristics of effective crisis communication, including application of the National Framework for Scaled Advice and Warnings to the Community. A content analysis of over 600 posts revealed marked differences in approaches. The study revealed the benefits of using a combination of text, images and infographics in communication activities. Suggestions are provided about how social media could be used more effectively by truly connecting with communities to improve community preparedness and resilience.

Facebook as an official communication channel in a crisis

Peer Reviewed

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Introduction

The Australian 2019–20 bushfire season was extreme, resulting in loss of life, property and wildlife and caused environmental destruction. By early December 2019, large swathes of NSW were blanketed in smoke and poor air quality had become an issue for many areas, including Canberra and the ACT. The uncontrolled bushfires that surrounded Canberra were reminiscent of the bushfire tragedy of 2003 in which 4 lives were lost and over 500 houses were damaged or razed when bushfires crossed into Canberra suburbs. During a crisis such as a bushfire, information from trusted sources about risk and safety becomes crucial, as it may influence life-and-death decisions.

The Royal Commission into National Natural Disaster Arrangements was established in February 2020 to investigate the 'coordination, preparedness for, response to and recovery from disasters as well as improving resilience and adapting to changing climatic conditions and mitigating the impact of natural disasters' (Royal Commission 2020a). The final report, tabled in Parliament in October, noted that 'there are confusing and unnecessary inconsistencies in some of the information provided to the public' (2020b, p.28) and that 'governments should educate people and provide accessible information to help them make informed decisions and take appropriate action' (p.21). Findings in the report highlight the need for improved communication with the public, including timely and accurate warnings, echoing recommendations from previous reviews. From the perspective of emergency services organisations, digital communication platforms, including social media, have become crucial communication media to keep communities informed (Yell & Duffy 2018). While many studies have been undertaken to learn what constitutes good social media practices in crisis communication from a practical perspective, there are fewer on how to apply research and evidence-based recommendations to improve strategic and tactical crisis communication.

Significance of trusted sources during a crisis

Clear and unambiguous information from trusted sources about risk and safety becomes crucial in a crisis. A report on

COVID-19 news and misinformation found that government was the second most trusted source of information after scientists and health experts. People in Australia were also less inclined to think that government exaggerated claims about the virus and its effects, compared to news media and social media (Park *et al.* 2020a).

In Australia, the trusted organisations and sources of information in a bushfire context are government agencies such as emergency services organisations, rural fire services and the Australian Broadcasting Corporation (radio, television and online). While news media remains the most important source of information during crises, government agencies are significant contributors to crisis communication as the most trusted and critical source of information. Previous studies, with a focus on organisational crisis communication, suggest that community resilience in preparedness for a bushfire event is enhanced by deep and sustained engagement and communication with communities prior to, during and after the event (Prior & Paton 2008; Sharp, Millar & Curtis 2009). While receiving accurate, timely and reliable information is important, affected community members need to ask questions and seek information from authoritative personnel and be approached in a dialogic, rather than didactic way (Sharp, Millar & Curtis 2009). Further, community engagement, coupled with mass communication techniques, encourages better collective preparedness. Specifically, this can help individuals build trust and confidence in the organisations that are responsible for providing information and, consequently, promote collective action and better outcomes (Prior & Paton 2008).

Characteristics of effective crisis communication

Steelman and McCaffrey (2013) identified characteristics of effective crisis communication. Their framework brings together best practice and theoretical literature from risk communication and crisis communication to derive key characteristics associated with best communication practices. The work highlights that 'effective communication is often identified as a key practice to move towards the desired goal which is more disaster-resilient communities' (p.683). The framework consists of 5 characteristics:

1. Engage in interactive processes or dialogue.
2. Strive to understand the social context in which the threat is situated.
3. Provide honest, timely, accurate and reliable information.
4. Work with credible sources, including authority figures when appropriate.
5. Communicate before and during a crisis.

Evaluating the data collected in this study against this framework draws out the areas of crisis communication where Facebook can usefully contribute.

Social media and crisis communication

Digital platforms have become valuable resources, allowing immediate access to quality information and news. Staying up to date with information is particularly essential in a crisis with citizens thirsty for credible, fast news and information (Park *et al.* 2020b). Social media has become increasingly popular as a source of information and news. In the study 'COVID-19: Australian news and misinformation', Park and colleagues (2020a) found that social media is the second most used source of information about COVID-19 and the pandemic. Crisis communication research shows that social media is a critical component of crisis communication as 'it creates opportunities for immediate transmission of important crisis information to as many people as possible' (Eriksson 2018, p.538). In this context, it would be limited to as many people who are using Facebook and who have sufficient capability to understand English. Research into crisis communication during health crises highlights the need for organisations to pre-establish a strong social media presence on multiple platforms before the crisis to optimise communication during the crises (Guidry *et al.* 2017). Frequent, consistent and interactive communication with users, where the conversation is already taking place, plays a significant role in building trust (Guidry *et al.* 2017). People go to the source of information they trust in times of crisis and are, increasingly, searching for current and local information using social media channels.

Researchers have recognised the importance of social media use in crisis communication practice. Eriksson (2018) highlights the contribution of research to evaluation, particularly the use of social media, and how research can develop evidence-based recommendations to improve communication practice. In line with other researchers (Steelman & McCaffrey 2013; Prior & Paton 2008; Sharp, Millar & Curtis 2009; Eriksson 2018) demonstrated the need for crisis communication to be based on community engagement principles and practices, which means extensive community involvement during all phases of the crisis life cycle. Guidry and co-authors (2017) revealed that social media messages are likely to be most effective when they come from organisations that people are familiar with and trust. Message effectiveness is also enhanced when based on 'the strategic use of risk communication principles such as solution-based messaging, incorporation of visual imagery, and acknowledgment of public fears and concerns' (Guidry *et al.* 2017, p.477).

The study

Why and how organisations build trust with audiences and stakeholders before an event and how they balance the gravity of a situation with a hopeful outlook is of direct relevance to this study. This study focused on the use of social media by particular organisations as part of their communication plans. The organisations chosen were the NSW Rural Fire Service (NSWRFS) and the ACT Emergency Services Agency (ACT ESA). The Orroral Valley bushfire in January 2020 was used to examine the interplay between the 2 agencies and compare the use of social media in the context of this fire and how it contributed to community engagement and communication during the crisis. The Orroral Valley fire was selected as a case study as it was the only fire during the last bushfire season that began within the ACT and had the potential to threaten property and lives.

As the ACT is geographically located within NSW and fires are not confined within state boundaries, residents of the ACT were sourcing information from NSW sources as well as those from the ACT. In the period immediately before the outbreak of the Orroral Valley fire, ACT residents were monitoring fires over the border in NSW via the NSW RFS.

Method

This study used content analysis in a mixed-method approach to explore how the 2 agencies managed their social media communication during the Orroral Valley bushfire. The data collected comprised unique Facebook posts from the official ACT ESA and NSWRFS Facebook pages between 20 January and 5 March 2020. The Orroral Valley fire started on 27 January and was declared as extinguished on 27 February. The peak fire days were from 27 January to 10 February, when the fire was declared as contained.

The total number of posts was 613; 397 from the ACT ESA page and 216 from the NSWRFS page. Of these, 47 per cent of posts on the ACT ESA page were related to the Orroral Valley bushfire and 13 per cent of posts on the NSWRFS page were about the Orroral Valley/Clear Range fire. Focusing on the peak fire period enabled an in-depth analysis of the posts explicitly relating to the fire and reduced the risk of diluting the findings with non-related posts. The content analysis was conducted against 4 characteristics and measures from the Steelman and McCaffrey (2013) framework (see Table 1).

Posts were categorised by type of content (text, video, images, banners) and attributes of content (tone and style, length, number and frequency and accessibility). This was used to analyse each agency's understanding of the social context and information provided. The different Facebook properties such as numbers of followers, shares, likes and comments was used to analyse interaction with users. In addition, the number and frequency of posts related to forums and engagement activities were measured. Posts were qualitatively analysed to draw out similarities and differences in approaches by the agencies in connecting with users and increasing the credibility of sources.

Results

By examining the types and attributes of the content, comparisons were made between the agencies to evaluate the different approaches against the characteristics of effective crisis communication as defined in Steelman and McCaffrey's (2013) framework. Table 2 shows a quantitative comparison.

Characteristic 1 - Engage in interactive processes or dialogue

Table 1: Steelman and McCaffrey (2013) framework and measures.

Characteristic	Quantitative measures	Qualitative measures
Engage in interactive processes or dialogue to understand risk perspectives and how they might be addressed.	Statistics (followers, shares, likes, comments).	Opportunities to engage the agencies.
Strive to understand the social context so that messages and content can fit the circumstance.	Types and attributes of content. Use of visual content. Application of theNational Framework for Scaled Advice and Warnings to the Community.	Provision of location or region-specific information.
Provide honest, timely, accurate and reliable information.	Number and frequency of posts. Types and attributes of content.	Key messages in media conferences.
Work with credible sources that have legitimacy, including authority figures, where appropriate.	Statistics (followers, shares, likes, comments).	Visibility and credibility of leaders and spokespeople.

In line with their official communication plans, both agencies use Facebook as a one-way communication channel to provide information to the community during bushfires. While this one-way broad cast of information 'improves transparency' as defined by the Australian Government 2.0 Taskforce Report (2009), the data does not support a finding that either agency used Facebook to increase 'participation' and 'collaboration', the other headline goals of the government's 2.0 strategy. Within the framework for official communication in natural disasters, the ACT's strategies to provide 'timely, effective fire danger information, advice and warnings about bushfire events' specify a wide range of communications methods and appropriate public information protocols (ACT Government 2019, p.38). The NSW Government *State Emergency Management Plan* specifically lists social media platforms such as Facebook, Twitter and Instagram as appropriate channels to broadcast warnings and messages (NSW Government 2018, p.14). Neither agency prescribes two-way engagement or collaboration with communities using social media.

To examine the engagement in interactive processes of the two agencies, the number of followers, shares, likes and comments were compared. Table 2 shows the comparison for the peak fire period 27 January to 10 February 2020. The data highlights a high level of community interest in the information provided by the

Table 2: Comparison of types and attributes of content and interactions.

		ACT ESA	NSWRFS
# of posts		397	216
# of posts about Orroral Valley/Clear Range Fire		188 (47.4%)	28 (13.0%)
Types of content	Text only	213 (53.7%)	43 (20%)
	Video	66 (16%)	26 (12%)
	Images	125 (31%)	143 (66%)
	Infographics	28 (7%)	93 (43%)
	Coloured banners	188 (47.4%)	66 (30.5%)
Tone	Positive	11%	12%
	Neutral	87%	88%
	Negative	2%	0%
Length	Short (less than 50 words)	30%	94%
	Medium (50-150 words)	29%	6%
	Long (over 150 words)	41%	0%
Facebook followers as percentage of population*		102,941 (>25%)	748,927 (10%)
Interaction	Likes	158,834	230,219
	Shares	41,046	53,971
	Comments	33,096	17,658
Response posts		4	-
Community forums		9	-
Door-knock campaigns		4	-

*at 10 May 2020

2 agencies and the desire to engage with the content. We also looked for opportunities for people to seek further information and clarification, including response posts (in response to community questions), promotion of community forums and door-knock campaigns. These were observed in ACT ESA posts only.

Characteristic 2 – Strive to understand the social context

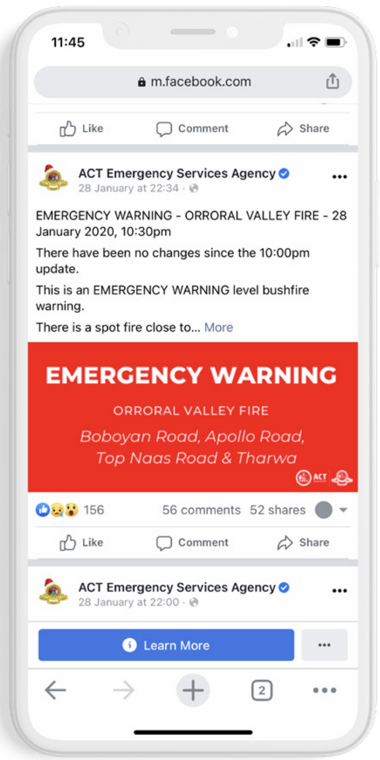
To assess the extent to which each agency demonstrated this characteristic, a comparison was made of the types and attributes of content, the use of visual content, whether the posts included location or region-specific information and if the National Framework for Scaled Advice and Warnings to the Community was used. The results showed striking differences in the social media communication approach between the 2 agencies (Table 2).

NSWRFS fire posts consisted predominantly of images and infographics, text in dot points and were short in length, whereas ACT ESA fire posts included the warning system coloured banners, were long and text dense without headings. Overall, NSWRFS included many more images and infographics in its posts (66 per cent for NSW and 31 per cent for ACT ESA) with 43 per cent of their total posts including an infographic such as a graph, table or map to visually represent information. The majority of NSWRFS posts about specific fires included an infographic such as a fire prediction map or chart. Only 7 per cent of the ACT ESA's posts included an infographic.

In terms of attributes of content used by the agencies, most posts, text and audio were neutral (official) in tone. Both agencies tailored messages to localised audiences to some extent through titles of their posts and specific content within the posts. During the peak fire period, both agencies posted videos to their Facebook pages in approximately the same proportion.

Use of visual content in social media crisis communication

As shown in Table 2, NSWRFS used a combination of text and images with infographics. These appeared in 44 per cent of its posts, whereas the ACT ESA included infographics in only 7 per cent of posts. More than half of the ACT ESA posts comprised text only, whereas approximately 1 in 5 NSWRFS posts used words exclusively. The majority of ACT ESA posts containing critical information about the fire were commonly over 350 words where none of NSWRFS posts were in the long category; the majority (94 per cent) being in the short category.



ACT ESA posts were lengthy containing over 350 words with the warning banner at the end.

Characteristic 3 - Provide honest, timely, accurate and reliable information

Consideration of the types and attributes of content and number and frequency of posts provides a gauge of how well the agencies met this criterion.

ACT ESA erred on the side of providing more detail rather than less, whereas NSWRFS posts were more likely to be short with critical messages and an image. Not surprisingly, the number and frequency of posts increased as the fire activity and warning level increased (Figure 1). For example, on the day the fire started (27 January), there were 11 posts on the ACT ESA page. The following day, there were 37 posts, 29 posts on 31 January, 24 posts on 1 February and 18 posts on 2 February. On those days, the fire warning level was at 'emergency' level. Similarly, on the NSWRFS page, there was one post on 28 January, 2 on 30 January, 3 on 31 January and 14 on 1 February when the fire crossed over into NSW and reached emergency level. During the media conferences, both agencies presented factual information about the fires and conditions on the firegrounds, including clear advice that fires were unpredictable and concrete predictions could not be given.

Application of the National Framework for Scaled Advice and Warnings to the Community

Both agencies provided regular updates on their Facebook pages about what was going on in the various firegrounds and, observing the requirements of the national warning system, provided predictable updates depending on the level of warning. 'Emergency' warning level requires an update every 30 minutes, 'watch and act' every 2 hours and 'advice' level every 24 hours. Both agencies provided different levels of detail in their posts but were consistent in the provision of that information on a predictable basis. In line with the framework, both agencies consistently used coloured banners to highlight the current warning level so that people could see it at a glance. However, on a small mobile screen, the coloured banner was not visible until the user scrolled to the bottom of the post.

Figure 1: Orroral Valley Fire/Clear Range fire posts per day.

Characteristic 4 - Work with credible sources who have legitimacy

This specific criterion was evaluated based on qualitative analysis of the media conferences streamed by both agencies and the visibility and credibility of their leaders and spokespeople. Eriksson (2018) emphasised that using an official representative and credible source will positively influence the sharing and propagation of information online. Both NSWRFS and ACT ESA had leaders with a high personal level of trust and credibility; Commissioner Shane Fitzsimmons (NSWRFS) and Commissioner Georgeina Whelan (ACT ESA). These individuals were front and centre for their agencies during the fire season and were often flanked by other senior members of their agency and from other organisations.

The media conferences were used to present messaging related to the unpredictable nature of bushfires and that successfully fighting the fires was dependent on many factors such as wind speed and direction, humidity levels, temperature and terrain. The ACT ESA streamed these conferences live on Facebook, which gave people the opportunity to see the people directly in charge and to build credibility and provide comfort to the viewers. Both agencies took opportunities to mention the good work of firefighters, other agencies and organisations through posts about awards, sacrifices, acts of generosity and gratitude.

Facebook as an official crisis communication tool

In 2010, Government 2.0 emphasised the importance of government to be more open, accountable and responsive and it articulated a commitment to communicate using online technologies (Heaselgrave & Simmons 2016). Public sector organisations are increasingly using social media for corporate and organisational communication and public relations (Macnamara & Zerfass 2012). However, research has found that government agencies are extensively using social media mainly for traditional one-way communication and less for increasing participation and collaboration (Heaselgrave & Simmons 2016, Alam 2016).

Within the framework of official communication during disasters, the ACT Government's official stance is to provide 'timely, effective fire danger information, advice and warnings about bushfire events' specify a wide range of communication methods and the use of appropriate public information protocols (ACT Government 2019, p.38). The NSW Government official plans specifically list social media platforms such as Facebook, Twitter and Instagram as appropriate channels for broadcasting warnings and messages (NSW Government 2018, p.14). This shows that the importance of immediate and interactive communication using digital communication tools in a crisis is well recognised. While effective social media communication is well documented, the data in this study demonstrate that both ACT ESA and NSWRFS use Facebook as a one-way (broadcast) communication channel to provide information about bushfires and other emergencies. During the 6 weeks nominated for this study, the ACT ESA posted 397 distinct posts and nearly 50 per cent of those concerned the Orroral Valley/Clear Range fire. NSWRFS posted 216, 13 per cent concerning the fire. On the peak fire days, the number and frequency of posts increased as did the level of detail provided. However, there was little evidence that Facebook was being used as a collaboration or engagement tool. This study did not look in any detail at the public comments on the posts, however, a high-level perusal showed that many of the comments were people 'tagging' others to share information and to express gratitude for the work of the agencies, staff and firefighters. There were a considerable number of comments seeking clarification of information posted and information about specific services and local conditions.

In addition, over 98 per cent of active Facebook users accessed it through the app on a mobile device (Statista 2020). As such, information designed for a webpage may not be easily read on a smaller mobile phone screen. Long posts full of text are difficult to read on a mobile device. While the national warning level system provides for the use of a coloured banner, the ACT ESA Facebook posts had the banner at the bottom of the post, which is not visible until the user scrolls down.

Close engagement with communities through dialogue prior to a crisis supports the government in creating the right conditions for community resilience (Eriksson 2018). Through active engagement on social media a robust digital connection and relationship can be formed before a crisis occurs. That is, the organisation is more likely to become a hub for information as people know where to go for information when they need it. A known hub for authorised information can also provide a platform for combating false information and encouraging community and individual preparation activities. Many researchers recognise that crisis communication needs to be based on community engagement principles and practices (Prior & Paton 2008, Steelman & McCaffrey 2013, Sharp *et al.* 2009), which means extensive community involvement during all phases of the crisis. Prior and Paton (2008) also highlight that the quality of relationships with a community is as important as the information provided.

Conclusion

This study leveraged Steelman and McCaffery's (2013) framework to highlight where agencies, in their use of Facebook, demonstrated the characteristics of effective crisis communication and identified areas for improvement. Both the ACT ESA and NSWRFS provided timely, accurate and reliable information and used credible and trusted sources and spokespeople. However, several opportunities exist to enhance their use of Facebook.

Strategically targeted engagement with affected communities will enhance government understanding about the maturity level of communities to prepare and respond in times of crisis. Active and ongoing engagement will help build capability and resilience within communities and trust in the organisation. Understanding the social context, what information people need in a crisis and when and how they use it to make critical decisions, will help agencies design effective communication products to promote a better community response.

As the number of Facebook users grows, the usefulness of text data for research is increasing and Facebook has become a useful platform to conduct empirical research about its users. A comprehensive analysis of the words (statements and questions) in the comments would yield a deeper understanding of what information people find useful and, combined with user research to design and test effective communication methods, would provide evidence for organisations to inform future strategic communication planning.

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National bushfire situational awareness

Bushfire.io now integrates more than 30 different data feeds to provide an unmatched national picture of:

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- nation-wide alerting and notification zones
- road closures
- computer simulated wind modelling
- real-time weather observations
- satellite detected hot spots
- firefighting aircraft tracks.

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