INPUT PAPER

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AN EVALUATION OF THE EFFECTIVENESS OF EARLY WARNING SYSTEMS USED IN AUSTRALIA

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Introduction

Early warning systems

Early warning can be defined as:

> 'the provision of timely and effective information, through identified institutions, that allows individuals exposed to a hazard to take action to avoid or reduce their risk and prepare for effective response.' (ISDR, 2006, p. 2)

Early warning systems detect impending disaster, give that information to people at risk, and enable those in danger to make decisions and take action (Mileti, 1999).

The objective of people-centred early warning systems is to empower individuals and communities threatened by hazards to act in sufficient time and in an appropriate manner so as to reduce the possibility of personal injury, loss of life, damage to property and the environment and loss of livelihoods (ISDR, 2006).

According to the Second International Conference on Early Warnings (UNISDR, 2003), there are four parts of an effective early warning system:

1. Risk knowledge. Knowledge of the relevant hazards, and of the vulnerabilities of people and societies to these hazards.
2. Monitoring and warning service. The technical capacity to monitor hazard precursors, to forecast the hazard evolution and to issue warnings.
3. Dissemination and communication. The dissemination of understandable warnings, and prior preparedness information, to those at risk.
4. Response capability. Knowledge, plans and capacities for timely and appropriate action by authorities and those at risk.

A weakness or failure in any one part could result in failure of the whole system (ISDR, 2006, p. 2).

Hazards in Australia

Australia is prone to a range of natural hazards including bushfires, floods, droughts, severe storms, tropical cyclones, heatwaves, earthquakes and landslides. As shown in Table 1, there are also several non-natural hazards that people in Australia are exposed to.

Natural	Technological	Human-caused
Resulting from acts of nature	Involves accidents of failures and structures	Caused by the intentional actions of an adversary
• Bushfire • Cyclone • Drought • Earthquake • Epidemic • Flood • Heatwave • Storm • Tsunami	• Aeroplane crash • Dam/levee failure • Hazardous materials release • Power failure • Radiological release • Train derailment • Urban conflagration	• Civil disturbance • Cyber incidents • Sabotage • School violence • Terrorist acts

Table 1 : Main Australian hazards

While some natural hazards have the potential to occur anywhere in Australia (e.g. severe storm), many occur only in reasonably well-defined regions (e.g. tropical cyclone) and are confined by topography (e.g. storm surge). Similarly, some natural hazards have the potential to occur at any time of year (e.g. tsunami), while others are often seasonal (e.g. thunderstorm) (Middelmann ed., 2007).

Disasters relating to these hazards can cause great financial hardship for individuals and communities, and can result in loss of life. The average annual cost of natural disasters in Australia is estimated at $1.14 billion (over the period from 1967 to 1999), although the actual cost incurred varies greatly from year to year (BTE, 2001).

Tropical cyclones, floods, severe storms and bushfires have had by far the greatest impact historically in Australia. However, a single event, such as a moderate-sized earthquake in Sydney, could fundamentally change this picture of natural hazards (Middelmann ed., 2007).

In recent years, there have been several significant disasters in Australia including the 2009 Black Saturday bushfires in Victoria and the 2011 floods in Queensland and Victoria. There is evidence to show that the number and intensity of weather-related disasters will increase in the future due to anthropogenic climate change (Steffen, Hughes & Perkins, 2014; CSIRO & Australian Bureau of Meteorology, 2014).

Early warning systems in Australia

Some of the Australian hazards may occur suddenly (e.g. earthquake), while in the case of others the threat may be identified in advance and a warning provided (e.g. flood, bushfire, cyclones).

Early warning systems have therefore been developed in Australia particularly for those hazards where there is an opportunity for warning and have had (or may have) the greatest impacts (e.g. bushfire, flood, tropical cyclone, storm and tsunami).

Under Australia's constitutional arrangements, State and Territory emergency management legislation identifies control agencies and guides early warnings. The control agencies are responsible for delivering warnings to the public.

The Australian Government provides national leadership around emergency warning activity, contributing to a whole-of-nation, resilience-based approach to preventing, preparing for, responding to, and recovering from disasters (Attorney-General's Department, 2013). This includes assisting states and territories to enhance their warning capabilities (e.g. the national telephone-based emergency warning system, Emergency Alert) and developing resource material, such as *Emergency Warnings: Choosing your Words* (Attorney-General's Department, 2008a).

Under the authority of the *Meteorology Act 1955*, the Bureau of Meteorology disseminates warnings, watches and advices on weather events such as severe thunderstorms, fire weather, coastal hazards, high winds, flood and tropical cyclone warnings and, in collaboration with Geoscience Australia, tsunami warnings. A significant number of warnings issued for natural hazards in Australia are issued by the Bureau.

The Bureau disseminates warnings via the broadcast media, and directly to the public via the internet. The Bureau directly informs emergency services organisations of risks through a range of digital channels, phone calls, emails and face-to face briefings. Warnings issued by the Bureau are the basis for many of the warning messages that state and territory emergency services organisations and the broadcast media disseminate to the public.

Emergencies are not always contained within state and territory borders. A number of states and territories have procedures in place to liaise with other jurisdictions in the event of an emergency to ensure affected communities receive adequate, timely and coordinated warnings from authorities.

State and territory governments, in collaboration with local government, also have a responsibility to educate, prepare and warn people who are vulnerable, or who may have special needs in the event of an emergency. Warning arrangements between state and local governments vary in each jurisdiction.

Communities and individuals also have responsibilities including preparing themselves for emergencies that might affect them and taking appropriate action in response to emergency warnings. According to the Australian Government:

> *'A key element in building the disaster resilience of Australian communities is that individuals, households and businesses should be prepared and have action plans for emergencies that might affect them. Preparation and planning at the individual, household and community levels supports informed decision making.' (Attorney-General's Department, 2013, pp. 5-6)*

Broadcast media play an important role in emergencies, both in disseminating and collecting information about an incident. Codes of practice ensure that broadcasters have well-established procedures in place to enable, in consultation with emergency services organisations, the timely and tailored broadcast of warnings and information to the public during an emergency. Additionally, a number of broadcasters and industry peak bodies, such as the Australian Broadcasting Corporation (ABC), Special Broadcasting Service (SBS), Commercial Radio Australia (CRA), and Free TV Australia, have established Memorandums of Understanding (MOUs) with state and territory governments (which complement their broadcaster codes of practice) to ensure optimal outcomes in the dissemination of emergency warnings to the public.

National Warning Principles

In October 2008, the then Ministerial Council for Police and Emergency Management - Emergency Management (MCPEM-EM) endorsed the following twelve National Emergency Warning Principles. The principles (Attorney-General's Department, 2008b) provide a framework that guides public warning activities. A number of states and territories have developed their own protocols that reference these principles. According to the principles, effective early warning systems should be:

1. Coordinated - a warning system should avoid duplication of effort where possible.
2. Authoritative and accountable - warnings are to be disseminated on the decision of an authorised person.
3. Consistent/ standards-based - messages must be consistent across different sources.

4. Complete - content should include relevant pertinent details.
5. Multi-modal - warnings are to be disseminated using a variety of delivery mechanisms.
6. All-hazards - systems can provide warnings for any type of emergency.
7. Targeted - messages should be targeted at those communities at risk.
8. Interoperable - have coordinated delivery methods, including across state boundaries.
9. Accessible and responsive - capable and responsive to demographic, political and technological change.
10. Verifiable - the community is able to verify and authenticate warnings.
11. Underpinned by education and awareness-raising activities - system, delivery mechanisms and language should be underpinned by education and awareness-raising activities.
12. Compatible - with the telecommunications networks and infrastructure.

In 2009, to underpin the implementation of Emergency Alert, state and territory officials agreed to a further two principles:

13. Compliant with relevant legislation - Commonwealth, State and Territory
14. Integrated - to ensure timely notification to multiple stakeholder organisations and communication channels.

This paper
Disaster Risk Reduction (DRR) aims to reduce the damage caused by natural hazards like earthquakes, floods, droughts and cyclones, through an ethic of prevention (UNISDR, 2014).

The 10-year Hyogo Framework for Action (HFA) came out of the World Conference held in Kobe, Hyogo, Japan in January 2005. The HFA is the first plan to explain, describe and detail the work that is required from all different sectors and actors to reduce disaster losses. It was developed and agreed on with the many partners needed to reduce disaster risk - governments, international agencies, disaster experts and many others - bringing them into a common system of coordination.

The HFA outlines five priorities for action, and offers guiding principles and practical means for achieving disaster resilience. Its goal is to substantially reduce disaster losses by 2015 by building the resilience of nations and communities to disasters.

The United Nations Office for Disaster Risk Reduction (UNISDR) has issued a call for input papers as part of the development of the 2015 Global Assessment Report (GAR15). The GAR15 will be published prior to the World Conference on Disaster Risk Reduction in 2015, in which governments will adopt a successor framework to the HFA.

This input paper addresses Research Area 4, Priority for Action 2 – Core Indicator 3 from the HFA:

> *Early warning systems are in place for all major hazards, with outreach to communities.*

In relation to this indicator, this paper evaluates the effectiveness of early warning systems used in Australia since the commencement of the HFA in 2005.

Methodology

The fourteen national emergency warning principles described above were used as a general evaluation framework to examine the effectiveness of early warning systems in Australia since 2005.

However, international literature provided some additional measures and issues that were considered in the evaluation. For example, Parker and Neal (1990) identified four approaches that should be considered in post-flood evaluation of flood forecasting and warning systems.

1. Extent of coverage of flood warning service. Although this approach does have strategic planning value in particular, it does not measure the quality of a warning system and therefore does not take into account any failures or shortcomings within a warning system. As du Plessis (2002) notes, 'It is therefore indeed possible when employing only the approach mentioned, to have a situation where the quality of the warning system decreases while the area covered is expanded.'

2. Flood losses. A second approach is to determine the losses that can be prevented by a flood warning system. The larger the benefit that can be achieved, the better a flood warning system can function. According to du Plessis (2002), 'the greatest problem with this method is that it is necessary not only to determine the tangible direct flood damage, but also to identify the indirect, non-tangible losses. By not quantifying the latter impacts, a distorted picture could be obtained of the behaviour of a flood warning system.' The advantages of an improved forecasting and warning system are the differences in the impact of floods that occur with a longer warning time or the greater accuracy with which floods are forecast, rather than the difference between maximum potential damage and the total true flood damage (Smith and Handmer, 1996).

3. Community satisfaction with the service.

4. Performance evaluation. The shortcomings of a warning system can be evaluated by identifying, categorising and documenting the shortcomings of flood warnings. Du Plessis (2002) believes 'the advantage of this method is, *inter alia* that a specific division of a system could easily be improved, while on the other hand the greatest problem posed to the approach is the gathering of suitable information after a flood, when other clearing works are enjoying priority.'

Handmer (2002), in an article about warning system reviews in North America and Europe, lists the following approaches to reviewing systems including supporting warning services:

- Outcomes in terms of lives saved and property loss avoided.
- The primary output of prediction timing and accuracy.
- Assessment of each stage of the warning process against targets such as proportion of audience reached and time taken to reach them.
- Satisfaction with warnings by those at risk.
- Warning system design and function including the quality and reliability of inputs.
- The principles and assumptions, underlying design and operation, for example, is it based on the needs of those at risk assessed through processes of community engagement?

This evaluation focussed on the main hazards for which early warning systems have been developed in Australia i.e. floods, bushfires, tropical cyclones and tsunamis.

The data for the evaluation was collected from a variety of sources including:

1. From consultation with emergency agencies from the Australian states and territories. About half of these agencies responded to the request for data for this evaluation. They provided agency strategies, relevant reports, articles and papers.
2. Post-disaster evaluations. These included reports from royal commissions, government inquiries and after action reviews.
3. Between event evaluations. These evaluations were conducted to gauge progress with particular improvements e.g. recommendations from a previous disaster inquiry.

Findings

Floods

Flood warning systems are a critical linkage between emergency agencies and affected communities just prior to and during a flood event. The purpose of a flood warning is to provide advice on impending flooding so people can take action to minimise its negative impacts.

The guiding document for the development, implementation and evaluation of flood warning systems in Australia is Manual 21 Flood Warning (Attorney-General's Department, 2009). According to Manual 21:

> 'Flood warning systems and services are integral to the achievement of high-quality community flood response. The development of flood warning services requires information, knowledge sharing and effective communication. Well-developed flood warning services that are understood and acted upon by the communities for which they are provided can contribute significantly to saving lives and protecting property. They should be regarded as central to the management of flooding.' (Attorney-General's Department, 2009, p. 3)

Manual 21 (Attorney-General's Department, 2009, p. 6-7) states that an effective flood warning system can be defined as having six integrated 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 which 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.

Australia experienced few major floods between 2005 and 2009 due to prolonged drought conditions over much of its southern area. However, the period from late November 2010 to mid-January 2011 was extremely wet through much of eastern Australia. Six major rain events affected large parts of the eastern states during this period, resulting in widespread flooding on many rivers and culminating in severe flooding (including river and flash flooding) in Brisbane and nearby areas of south-east Queensland and northern New South Wales during the second week of January. Other significant floods affected the Fitzroy, Burnett and Condamine-Balonne catchments in Queensland in late December and early January, the Murrumbidgee, Lachlan and Castlereagh catchments in inland New South Wales in early December, and large parts of northern and western Victoria and northern Tasmania in mid-January. The flooding, in terms of extent, impact and severity, was amongst the most significant in Australia's recorded history (Bureau of Meteorology, 2011).

The Queensland Government commissioned an inquiry into the 2011 floods (Queensland Floods Commission of Inquiry, 2012). In relation to early warning services, the main issues identified related to the lack of flood studies to assist in flood prediction and interpretation, and the lack of evacuation planning (response) in some communities.

The Victorian Government commissioned a *Review of the 2010-11 Flood Warnings and Response* (Victorian Government, 2011). The Victorian Floods Review found that improvements are required to Victoria's Total Flood Warning System 'which needs to be better tailored to meet local requirements'. The use of local community knowledge was viewed as critical in relation to this.

The Victorian Floods Review found that:

> *'The lack of clarity over roles and ownership is an impediment to achieving a best practice flood warning system. At best, these roles are shared or fragmented which does not provide accountability. This situation includes the Bureau of Meteorology and consequently the level of service it provides to Victorian communities needs revisiting.' (Victorian Government, 2011, p. 4)*

The Review also found that:

> *'there are gaps in the gauging network, however, more flood gauges will be of limited benefit without communities knowing what warnings mean for them so that they can take the necessary steps to ensure their safety and reduce property damage. Enhanced flood risk planning, including coverage and quality of mapping, coupled with community education is required.' (Victorian Government, 2011, p. 4)*

The Emergency Alert telephone warning system was used extensively in Victoria for the first time during the floods. The Review noted that:

> *'While this intrusive warning system was generally effective, its use and operation in some instances by emergency services reduced its overall effectiveness. Clear directions are required on standardising the messaging and application of the system, including the circumstances in which it is used.' (Victorian Government, 2011, p. 5)*

The Victorian Floods Review made 93 recommendations for improvement of which 30 related to the adequacy of flood predictions and modelling, and 12 to the timeliness and effectiveness of warnings and public information.

Floods in Victoria in 2012 provided an opportunity to review progress with the some of the recommendations made by the Victorian Floods Review. In relation to a flood in the north-east of Victoria (Molino Stewart, 2012), further effort in this part of the state was required in the coverage of local flood warning systems using river gauges and associated telemetry, and for flood mapping and ongoing community education programs. For the 2012 Gippsland Flood (Office of the Emergency Services, 2012), although there was evidence of progress with the flood warning systems in that area there were still limitations identified related to the lack of clarity in managing flood intelligence due in part to incomplete local strategies, plans and inputs, and the need for greater use of local, on-the-ground intelligence in the affected areas.

Bushfires

The most devastating bushfires in Australia since 2005 were those of Black Saturday, 7 February 2009 across Victoria that caused the death of 173 people. The 2009 Victorian Bushfires Royal Commission was an important part of ensuring that lessons from the Black Saturday fires were clearly defined and learnt (Parliament of Victoria, 2010). The Commission conducted an extensive investigation into the causes of, the preparation for, the response to and the impact of the fires that burned throughout Victoria in late January and February 2009.

The Royal Commission found that there were major issues around the State's overarching policy for community safety in bushfires: 'Prepare, Stay and Defend or Leave Early'. As a result of its inquiries, the Commission concluded that:

> 'the central tenets of the stay or go policy remain sound. The 7 February fires did, however, severely test the policy and exposed weaknesses in the way it was applied. Leaving early is still the safest option. Staying to defend a well-prepared, defendable home is also a sound choice in less severe fires, but there needs to be greater emphasis on important qualifications.' (Parliament of Victoria, 2010, p. 5)

Furthermore, in relation to bushfire warnings, the Commission stated that:

> 'The stay or go policy tended to assume that individuals had a fire plan and knew what to do when warned of a bushfire threat. But many people did not have a well-thought-out plan and were left to make their own decisions without the benefit of assistance from the authorities. In addition, warnings—when they were given—were too narrow: they were directed at getting people to enact their fire plans, rather than giving more specific directions or advice.' (Parliament of Victoria, 2010, p. 5)

The Royal Commission made recommendations to improve the State's bushfire safety policy including to 'enhance the role of warnings - including providing for timely and informative advice about the predicted passage of a fire and the actions to be taken by people in areas potentially in its path'. Several other recommendations were made related to warnings including about the role of information officers in Incident Control Centres (ICCs), evacuations, training of ICC staff to deliver warnings, and standardising systems.

In 2011, a review was conducted by the Victorian Government (Molino Stewart, 2011) to assess progress with the Royal Commission's recommendations in relation to bushfire warnings. The review found that:

> 'considerable progress had been made with policies, procedures, practice and systems particularly in response to the Royal Commission recommendations. These policies etc. were generally found to be appropriate and effective during the recent fire season. Some issues were identified through the review analysis including relating to the current 'clunkiness' of the One Source One Message (OSOM) system, the capabilities and capacity of Information Sections in Incident Control Centres (ICCs) and the management of Information Sections by Incident Controllers.' (Molino Stewart, 2011, p. 1)

The review also found the timeliness of community warnings to be an issue in 2011 fires in Victoria. The timeliness was largely dependent on the speed and accuracy of fire intelligence received by ICCs.

There is evidence to show that many of these issues have been further improved, including the clarity of community education and warning messaging related to Victoria's revised bushfire safety policy (Fire Services Commissioner, 2013).

The recommendations of the 2009 Victorian Bushfire Royal Commission also impacted on bushfire risk management and emergency management in other Australian states and territories, including changes to bushfire safety policies and warnings. Recent fires have provided an opportunity to test these changes.

Social research into community responses to bushfires in Western Australia in 2011 (Heath et. al., 2011) found that seeing smoke was the first warning sign for many that a fire was threatening the area. After learning about the fire, residents typically started searching for more information about the fire. In most cases, people switched the radio on, telephoned friends, neighbours, or family, and/or gathered up their valuables to take to safety. Many residents also consulted the bushfire control agency's website for more information. The research found that:

> 'Approximately one-half of all residents indicated that they either had no plan or that they wanted to wait and see how bad a fire was before taking any action. This result is quite concerning as the investigation into the Victorian bushfires of 2009 revealed that many bushfire related deaths occur after last-minute changes in plan.' (Heath et. al., 2011, p. 2)

Social research into January 2013 bushfires in New South Wales (Mackie, McLennan and Wright, 2013) identified some issues about the effectiveness of bushfire warnings. The main findings included:

- Many people had a basic plan for what to do when threatened by a bushfire, but few had documented it or used the NSW Rural Fire Service (RFS) Bush Fire Survival Plan to document their response.
- Interviewees, once they received information or warnings, often sought more detailed, localised or updated information, such as from the local RFS sources, friends and neighbours, and from the media.

- As the fires spread, the naming of the fires based on their starting point did not reflect their current location, leading to some misconceptions of fire position for some people.
- While telephone alerts (Emergency Alert) are now the preferred method of warning for many in the community, many interviewees were unable to receive messages due to pre-existing lack of mobile phone coverage in the affected areas and this contributed to their delayed decision-making.
- Few residents understood the implications of the different fire danger levels on their safety, and actions to take at each, apart from 'Catastrophic'.

Tropical cyclones

Tropical cyclones develop over tropical waters around Australia during the warmer months, mostly November to April. The Bureau of Meteorology provides warning services for these cyclones. Warnings are issued for land-based communities under threat and for mariners. Routine outlooks are also issued during the cyclone season.

According to cyclone disaster management expert, Associate Professor David King of James Cook University:

> 'Cyclone education - its warnings, preparation, behaviour and recovery phases are all routines that residents in cyclone vulnerable areas are used to and which they adhere to.' (D. King pers. comm.)

Several devastating major cyclones have occurred in Australia since 2005 including Cyclone Larry in 2006, Cyclone Monica in 2006 and Cyclone Yasi in 2006.

For Cyclone Larry, social research (King and Goudie, 2006) found that weather warnings were effective, although some residents suggested there could be more 'action/how-to' messages with the warnings. A few other issues were identified from the research including:

- *'The Bureau needs to continue to promote its web site, particularly how to get into the high impact weather warning areas as threats manifest. However, computer and internet use are low in this rural area which was reflected by survey respondents.*
- *Respondents perceived that TV, radio and the internet gave different advice.*
- *Broadcasts created an uncertainty as to whether the eye of the cyclone or the area of destructive winds was being referred to. Radio stations were each giving out different information.' (King and Goudie, 2006, p. 2)*

For Cyclone Monica that hit Darwin, there were similar findings (King, 2006) for warning effectiveness. Residents were generally positive about warnings received, although they wanted more information. The Bureau of Meteorology web site dominated internet use.

Vachette and King (2011) conducted social research about the response of backpackers - a particularly vulnerable group – to Cyclone Yasi that struck the north Queensland coast. The research found that the information text messages on Yasi sent by the government were useful to backpackers but television and newspapers were the main source of information and warnings. Word of mouth was equally beneficial for every age.

Tsunamis

Following the Indian Ocean tsunami on 26 December 2004, the Australian Government committed funding of $68.9 million over four years in the 2005-2006 Federal Budget to upgrade the Australian Tsunami Alert System (ATAS) to an operational, early warning system - the Australian Tsunami Warning System (ATWS).

The ATWS is is a national collaboration between the Australian Bureau of Meteorology, Geoscience Australia and the Attorney-General's Department which provides a comprehensive tsunami warning system delivering timely and effective tsunami warnings to the Australian population. It is also a key element of the Indian Ocean Tsunami Warning and Mitigation System, and contributes to the facilitation of tsunami warnings for the South West Pacific (Bureau of Meteorology, 2014).

There have not been many tsunami warnings issued since the ATWS commenced. However, social research (King, 2007) was conducted with residents in the Townsville and Cairns areas of northern Queensland immediately following a tsunami warning issued on 2 April 2007. About three-quarters of these residents heard the warning mainly through radio, television and word-of-mouth. Most people sought no extra information (70%) and took no action (53%). Of particular concern was the fact that significant proportions of residents did not know whether or not they lived in a storm surge zone.

Public awareness and understanding of the tsunami warnings appears to be low in Australia compared to that for early warning systems for the other main hazards. Bird and Dominey-Howes (2006) in a pilot investigation into public awareness of tsunami risk in the Sydney region found that:

> *'Knowledge of the tsunami warning system operating for the Pacific (and Sydney region) was very limited. Astonishingly, only 8 per cent of the council officers knew about the tsunami warning system whereas, 29 per cent of the public did. Surprisingly, some participants believed that Sydney does not need such a system even though most participants believed Sydney is at risk.' (Bird and Dominey-Howes, 2006, p. 34)*

Discussion

Progress since 2005

The Australian emergency management agencies consulted for this review all believed that there had been considerable progress with early warning systems since 2005. Some of this progress had been triggered and guided by post-disaster reviews and inquiries as described above.

The progress identified by the agencies included:

1. Forecasting and prediction. The Bureau of Meteorology has upgraded its forecasts and warnings services. For example, in Queensland the number of locations across Queensland that obtained weather forecasts for seven days were significantly increased after early October 2013. The forecasts were presented as a combination of text and graphics. During 2014, services will expand further to include map based graphical forecasts and the capability to generate a forecast for any location, including the coastal waters zones. The recently-launched MetEye™ will be a

doorway to maps of temperature, rainfall, winds and weather all designed to make weather-based decision-making easier. In addition, rainfall information including forecast probabilities of rain and average rainfall amounts will be issued for major centres across Queensland.

The Bureau also provides predictions of the expected height of a river at a town or other important locations along a river, and the time that this height is expected to be reached. This type of warning is normally the most useful in that it allows local emergency authorities and people in the flood threatened area to more precisely determine the area and likely depth of the flooding. This type of warning can only be provided where there are specialised flood warning systems and where flood forecasting models have been developed. Progress has been made since 2005 in increasing the coverage of these warning systems and flood forecasting models across Australia.

2. Intelligence. Agencies identified improvements in risk assessment and related GIS mapping as evidence of progress since 2005. With better understanding of the hazard risks and resultant emergency planning, agencies can provide more effective response and recovery.

3. Interoperability. There has been considerable improvement in agencies working together to prepare and disseminate warning messages for different hazards. Provision of warnings is an important function of the Australasian Inter-Service Incident Management System (AIIMS) and the widespread use of the system provides a structure for cross-agency cooperation in incident control.

Progress with interoperability is also demonstrated by the integration of online warning and messaging into cross-agency alert websites. For example, Vic Emergency (http://emergency.vic.gov.au/map#now) is a single cross-hazard, cross-agency portal to communicate warnings across Victoria.

4. Public information officers. In those states and territories that responded the public information officer role in the incident control centre has been elevated to being directly responsible to the incident controller in the ICC. The public information officer and other public information staff have the role of preparing and disseminating warning messages during an emergency. According to the emergency agencies, direct involvement with the incident controller appears to have enabled more efficient and effective dissemination of warnings to the public.

5. Range of warning mechanisms. All Australian governments support a multi-modal approach to issuing emergency warnings. A multimodal approach maximises the likelihood that as many people as possible will receive and comprehend a warning. This makes it more likely that people will be in a position to take appropriate action to protect against loss of life, or injury, and to mitigate against damage to property (Attorney-General's Department, 2013).

These warning mechanisms range from traditional methods such as television and radio broadcasts, community meetings and sirens, to more modern methods, such as mobile telephone SMS messages and social networking posts (e.g. Facebook and Twitter).

Of particular note is the emergence of Emergency Alert and social media in this suite of warning mechanisms. Emergency Alert is the national telephone warning system used by emergency services to send voice messages to landlines and text messages to mobile phones within a defined area about likely or actual emergencies. It was established by the Australian Government in response to the Black Saturday bushfires of 2009.

The first widespread use of social media in an Australian disaster was by the Queensland Police Service in the 2011 Queensland floods. It provided an additional effective warning mechanism in this event (Bruns et. al., 2012) and in subsequent emergencies across Australia.

6. The Standard Emergency Warning Signal. In September 2004, the then Australian Emergency Management Committee (AEMC) supported a recommendation from the Bureau of Meteorology that a set of clear, prescriptive and nationally consistent guidelines for the use and application of SEWS should be developed. These guidelines were subsequently developed and provide direction and support to the State and Territory Emergency Management Authorities. The states and territories now implement these guidelines as appropriate to their jurisdiction.

The Standard Emergency Warning Signal (SEWS) is a distinctive audio signal used in Australia to alert the public to the broadcast of an urgent safety message relating to a major disaster or emergency. It is meant to attract listener's attention to an impending emergency message. For example, Emergency Alert warnings sent to landline telephones commence with the SEWS signal.

In addition to the audio signal, SEWS also has a visual identity which includes a logo and slogan (Chart 1) for use by the media. The visual identity facilitates greater awareness of SEWS.

Chart 1 : Logo and slogan for the Standard Emergency Warning Signal (SEWS)

7. Principles and protocols. As noted previously, national documents such as the National Emergency Warning Principles (Attorney-General's Department, 2008b) and the Manual 21 Flood Warning (Attorney-General's Department, 2009) have been developed to provide guidelines for early warning systems. Furthermore, several states have produced cross-hazard, cross-agency guidance documents such as the Victorian Warning Protocol (Victorian Government, 2013). The Victorian Warning Protocol which commenced in 2009 provides emergency response agencies with coordinated and consistent direction on advice and/or warnings to inform the Victorian community of a potential or actual emergency event.

However, according to the responses from the Australian emergency agencies and the above findings, there are some aspects of early warning systems that can still be improved. Apart from those already identified in the findings, the following aspects could be improved:

1. Low levels of community preparedness. For tropical cyclones which occur reasonably regularly there appears to be relatively high levels of preparedness (King and Goudie, 2006), whilst for less frequent events such as flooding less than 20 percent of those impacted usually have some kind of emergency plan including a part on warnings (Molino Stewart, 2009). More effective community education is recommended (Dufty, 2008) to improve preparedness levels and adherence to early warnings.

2. Flash flooding. A major issue is early warning systems for flash flooding. Flash flooding in Australia is defined as flooding that occurs within six hours of the start of rain that causes it (Bureau of Meteorology, 1996). The Victorian Floods Review (Victorian Government, 2011) clarified the role of the Bureau of Meteorology in providing flash flooding warning services and the roles of state and local government in the purchase, installation and maintenance of flash flood warning systems. The Review identified five core issues underpinning flash flood warning systems in Victoria:

    - The lack of definitive state policy and direction on roles and responsibilities – the role of the Bureau and of other stakeholders in the delivery of forecasts and warnings of conditions likely to lead to and of actual flash flood events is not as clear as it needs to be.
    - Local government's ability, in terms of both financial and technical capacity, to establish, maintain and operate an effective flash flood warning system with regard for both technical and social aspects; unless there is active participation from local government, the framework breaks down.
    - A key tool in extending the warning lead time available in flash flood catchments is weather radar and timely local (community and agency) access to (as a minimum) raw information on the likelihood of rainfall likely to lead to flash flooding.
    - Awareness within the at risk community that flash flooding is a credible risk and the circumstances that may give rise to an event.

- Dissemination of meaningful and timely pre-scripted warning messages (that impart essential information in a way that is understandable and elicits appropriate responses) to those at risk from flash flooding.

3. Understanding response behaviours. As discussed in the findings, there still appears to be some public confusion and reticence about bushfire warnings and appropriate responses, even though the warning messaging is much clearer (in terms of evacuating early), relevant and tailored since the 2009 Black Saturday fires. Further work is being conducted by the Bushfire Cooperative Research Centre (CRC) into the psychology of defending or evacuating once warnings are heard (e.g. McNeill et. al., 2013).

4. Evaluation of early warning systems. The evaluation of early warning systems after emergencies and disasters is patchy (Dufty, 2013). It is confined mainly to major inquiries and reviews for major disasters, and agency after action reviews for emergencies. As cited in the findings, in some cases reports are commissioned to evaluate some aspects of early warning systems. Unfortunately, these evaluations tend not to be consistently conducted after major emergencies and are not based on a standard set of indicators for the assessment of early warning system performance (Dufty, 2013).

Comment on the HFA indicator

Based on the above, there has been considerable progress in Australia related to Research Area 4, Priority for Action 2 – Core Indicator 3, although work is still required in several areas to improve coverage and effectiveness for the main hazards in Australia. Thus, from an Australian perspective the indicator is still appropriate for inclusion in the successor framework to the HFA.

Conclusion

The general principle underpinning the HFA Thematic Research is that it is a retrospective review looking forward. In this spirit, this paper reviewed the effectiveness of early warning systems used in Australia since 2005, the year of the commencement of the HFA.

The review found that considerable progress had been made in Australia since 2005 in the provision and effectiveness of early warning systems for the major hazards. However, major disasters such as the 2009 Black Saturday bushfires and the 2011 floods in Queensland and Victoria severely tested early warning systems. Resultant government inquiries into these disasters identified issues with the systems and community responses to warnings prompting further improvements by Australian emergency agencies.

There are still some areas of concern that were identified in this research including low levels of community preparedness and awareness of warning systems (for some hazards), lack of effective flash flood early warning systems, understanding of community responses to warnings and lack of regular and consistent evaluations of the performance of early warning systems.

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