Bells and whistles, belts and braces: designing an integrated flood warning system for the Hawkesbury Nepean Valley

Part 1: bells and whistles—available technologies

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Background

The Nepean Catchment includes the Southern Highlands, the Blue Mountains and Western Sydney and covers 12,000 square kilometres upstream of Windsor. The river runs along the foot of the Blue Mountains between Penrith and Windsor and changes its name to the Hawkesbury River between these two urban centres. At Windsor the river is virtually at sea level but winds through steep sandstone gorges for another 100 kilometres before reaching the ocean at Broken Bay. It picks up another 10,000 square kilometres of catchment along the way.

There is a 400 square kilometre floodplain between Penrith and Windsor which is home to more than 60,000 people living in urban centres, rural townships and villages, rural residential developments and farms. Further downstream in the gorge area the population is smaller and more scattered with farms, weekenders and mobile homes being the common forms of accommodation. In the urban areas there are also nearly 4,000 commercial and industrial premises as well as schools, hospitals, nursing homes and prisons that may all need evacuation during floods.

In 1997, the NSW State Government formed the Hawkesbury-Nepean Floodplain Management Advisory Committee to undertake investigations and make recommendations to the Government regarding management of the flood risks faced by the Hawkesbury-Nepean Valley communities.

A key recommendation of the Committee's 'Achieving a Hawkesbury-Nepean Floodplain Strategy' was:

'That the funding provision for flood warning sirens... be applied to the installation of a cost effective flood warning network comprising a combination of sirens and other appropriate technology' (HNFMAC 1997, p13).

Molino Stewart was engaged to identify and evaluate a range of potential flood warning dissemination technologies that could have an application in the Hawkesbury Nepean. This paper summarises the findings into available technologies. A second paper explains how they were evaluated and an integrated warning system devised.

Bells and whistles

According to Rogers and Sorensen (1988a), warning people of impending danger encompasses two conceptually distinct aspects—alerting and notification. Alerting deals with the ability of emergency officials to make people aware of an imminent hazard. Alerting frequently involves the technical ability to break routine acoustic environments to cue people to seek additional information. In contrast, notification focuses on how people interpret the warning message. It is the process by which people are provided with a warning message and information. Dual systems incorporate both the alert and notification functions.

To these three categories (alert, notification and dual) can be added 'unofficial warning systems', whereby people warn those within their personal networks. These four categories form the basis for the following discussion of warning dissemination technologies. A fuller description of the technologies can be found in Molino, Begg and Opper (2001).

Alerting technologies

Alerting deals with the ability of emergency officials to make people aware of an imminent hazard. Following is an outline of siren/alarm systems, aircraft, modulated and coded power supplies and visual cues as means of alerting populations to impending danger.

Sirens/alarms

Sirens are designed to provide a very rapid alert to potentially threatened populations. They are currently the only reliable means of alerting outdoor populations. Traditionally, sirens have only been used as an alerting technology, limited in their utility by the lack of instructional messages. At best they have told people to seek further information unless an intensive program of public education is used to instruct people what to do when the signal sounds. However, some of today's sirens can provide high-power voice messages as well as traditional warning tones, taking them closer to a dual alert/notification classification (Moore 2000).

Aircraft

In special cases airplanes and helicopters can be used as part of the warning process. Sirens or bull-horns can be carried by low-flying aircraft to provide an alert or warning message. In addition, they can drop prepared leaflets containing a warning message. This type of warning channel is useful in reaching remote populations or populations that cannot be reached by normal communication channels. Disadvantages include access to aircraft, maintenance and cost. A further problem is obtaining sound systems that can broadcast a message that can be heard over the noise of the aircraft itself (Rogers and Sorensen 1988b).

Modulating electrical voltage

Most electricity distribution authorities have a SCADA system which controls the functionality of all components of the network down to zone substation level. Such systems have the capability to control voltage on the transformer at the substation. Large increases in voltage could result in damage to electrical appliances, but most can withstand significant voltage drops.

This capability could be used in one of two ways. Firstly, it could be used to reduce electrical voltage in a periodic manner in the form of a morse code letter or fluctuating signal (Moore 2000). Alternatively, it could be possible to set the system to fluctuate the voltage to around 15% and place a device in people's homes that would be triggered by the reduction in voltage and emit a warning tone or flashing light. Such a device would be relatively inexpensive.

Either system would be able to operate down to a granularity of zone substation level only. However, devices would only need to be placed in the homes concerned, making the second option more targeted. Neither system can be used if electrical systems fail, and any other causes of voltage drop could generate false alarms.

Modulating electrical frequency

Existing electrical power distribution technology enables specialised warning systems that use data signals transmitted over the power lines to activate an alarm system. When the system frequency is altered, devices linked to electrical circuits (similar to smoke detector alarms), can be activated.

A slight variation on this arrangement would involve the use of a 'ripple control signal' which can be sent down the electricity wires to activate the device, without endangering other electrical appliances. This mechanism is used to activate off-peak hot water systems. Advantages of this type of warning device include quick dissemination time and 24 hour availability. However, it cannot be used if electrical systems fail.

Coded visual signs

Visual cues can be used to alert populations of impending danger. In the far north Queensland town of Weipa, cyclone alerts are colour-coded. Road signs featuring the colour codes are displayed when there is a cyclone threat (Doherty 2000).

The advantage of using visual cues is that they can be a simple and effective means of warning the population. The disadvantages are that people need to be educated about the meaning of the symbols, and visibility may be compromised at night-time.

The use of signs with variable message signs (VMS) technology was also investigated. This warning mechanism falls into the dual alert/notification category and is explored later.

Laser lights

Lasers can be used to project a thin beam of light some considerable distance. The idea of setting up lasers at the beginning of a flood warning to project the expected flood level onto houses was explored.

Apart from the cost of $3,000 or more for each laser, this idea would have a number of disadvantages. Firstly, the cheapest lasers are those that cast a red beam of light. These are not very visible outdoors in daylight and therefore would only really be suitable for night-time use. Furthermore, they can only project a beam about 50 metres, so a very large number of them would be needed. To get a better projection or visibility it would be necessary to increase the strength of the laser but this carries with it the risk of causing eye damage to anyone who looks into the beam.

The chief advantage of personal contact is that people are more willing to respond to a warning because they are more likely to believe that a danger exists.

Green light lasers can be used to get greater projection and daytime visibility without increasing power, but these cost about three to four times as much as a red laser. Lasers also run the risk of being tampered with, stolen or lost in the flood.

Dual alert and notification technologies

Dual systems incorporate both the alert and notification functions. An outline of dual technologies, from low technology personal notification, through to use of PA, tone alert and dial-out systems follows.

Personal notification

Personal notification, as defined in this study, involves using emergency personnel to go door-to-door or to groups of people to deliver a personal warning message. The chief advantage of personal contact is that people are more willing to respond to a warning because they are more likely to believe that a danger exists. The disadvantage is that it is time consuming to implement this method and it may require the commitment of many vehicles and personnel (Rogers and Sorensen 1988b).

Military experience gained during the wartime use of warden systems suggests that it takes six minutes to doorknock each house. Using two person teams, which must be done for safety, ten teams (20 personnel) plus control personnel will be required to doorknock 100 homes in one hour. To doorknock 20,000 homes in 12 hours will require 167 teams (334 personnel) in the field at any time plus control personnel (Opper 2000). This assumption was used when evaluating this technology.

A field exercise was carried out in McGraths Hill in the Hawkesbury Nepean subsequent to Molino Stewart completing the investigation to which this paper relates. It found that pairs of volunteers were able to doorknock the whole suburb at a rate of between two and three minutes per house.

Fixed and mobile public address systems

Dedicated PA systems can be installed specifically for the purposes of warning populations. As noted in the sirens/alarms section, some of the latest sirens incorporate a voice message function.

Portable loudspeakers can be used from vehicles to warn nearby populations. Often these are used in conjunction with personal notification procedures. Portable loudspeakers increase the speed of warning populations without other means to receive the warning. Their chief disadvantages are that it is often difficult for people to hear a warning broadcast from a moving vehicle and it is difficult for people to confirm the warning, particularly if they only heard a part of it (Rogers and Sorensen 1988b).

Component costs for installation and operation of dedicated PA systems are less than those for sirens, however as PA systems have a lower effective coverage radius than sirens, up to 50% more installations could be required.

Tone alert radios

Tone alert radios are a specialised warning device that can be remotely activated. They provide a warning signal and some types can subsequently broadcast a verbal warning message. The radio operates in a standby condition. Upon receipt of a code the radio emits a tone and broadcasts a pre-recorded or read message. The code and message are broadcast from a radio transmitter. The radio receivers operate on normal electrical power and some have battery back-ups.

The advantages of tone-alert systems include a quick dissemination time, the combination of an alerting signal with specialised messages, their-around-the-clock availability, and the fact that they can be heard inside buildings that may be insulated from the sounds of outdoor sirens. Disadvantages include maintenance problems, availability during power failures, limited broadcast range, and difficulty for using outdoors (Rogers and Sorensen 1988b).

Dial-out systems and related technologies

Dial-out systems work by having a computer database of pre-selected telephone numbers for the areas in which the warning has to be disseminated. When the system is activated the computer dials each number on the database. If the recipient answers the phone they are instructed to press the keypad to receive further details of the warning. The system can dial as many numbers simultaneously as there are dedicated phone lines connected to the system.

It rings the numbers in succession until all numbers have been rung. If the number is unanswered then it is rung again after all numbers on the database have been rung once. The system is programmed to keep ringing the unanswered numbers on rotation indefinitely or for a set number of times.

The chief advantage of telephone warning systems is the ability to quickly disseminate a message. This can be an efficient way to warn people because most people hear and answer phones when they ring. Furthermore, nearly all will listen to the message, particularly if the message makes it clear that 'this is an emergency'. The telephone system also offers the recipient two-way communication via information numbers, further reducing uncertainty by providing additional information (Rogers and Sorensen 1988a).

Problems with dial-out systems include the fact that people who are not near a phone will not receive a message, a database of numbers must be constantly updated and people with silent numbers will need to give permission to be included on the database. Furthermore, cordless telephones are becoming increasingly popular. These phones rely on the supply of electricity to function, and would not work in a black-out situation.

Finally, there is a likelihood that in an emergency situation, the telephone network very quickly experiences service level quality problems (ie, lines are 'clogged' by people making calls). The effectiveness of a dial-out system would therefore be significantly downgraded as the event unfolded. It is even conceivable that it would 'melt-down' and prove an ineffective form of communication (Cronan 2000).

Enhanced dial-out system

Telcordia Technologies' Community Notification Solution (CNS), developed in the USA is an enhancement to dial-out systems in that it operates over the existing telephone network, but is designed to impose far less of a burden on the network while delivering far more alerts within a given period. A patent for CNS was recently issued in Australia.

Unlike dial-out systems, the warning is not sent by phone message, but is delivered by a choice of devices including:

- standalone device (about US$10) with or without Caller ID that will plug into a normal phone jack
- display or advanced screen-display phones (offered by a local telecommunications company)
- computer modems
- home security systems
- set-top boxes.

Alerts are sent as a data burst in less than one second compared with 30-60 second calls. The system notifies people of an emergency by creating a time stamped text message (limit of 60 characters + 10 digits), activating a corresponding light (red, yellow) and if instructed, one of seven alarm sequences. The system will send whatever message is entered into the message create application (including other languages).

The Telcordia system has yet to be used in an emergency situation (Telcordia website).

Paging and mobile phones

There are a number of pager or mobile phone alerting applications on the market. Some stand-alone dial out systems have the capability to alert all selected personnel carrying pagers or mobiles. At this time it would be difficult to offer a solution where every person in the affected zones would be provided with a portable device to be used only in emergencies without them being a subscriber to a particular network.

However, in the USA, technologies are being investigated that can locate and reach citizens with pagers or mobile phones who are in the path of a disaster or inclement weather. In Australia, it is theoretically possible to locate the cell that a particular mobile phone user is in and send a text message to those phones with SMS (short message service) receive capability. In 1999, 42% of Australian households, and 69% of small businesses either owned or had access to a mobile phone.

Most GSM (Global System for Mobile—most phones have this type of connection) and CDMA (Telstra's new digital network—Code Division Multiple Access) phones have an SMS receive function. Newer technology phones that support GPRS services will also support SMS. However, as well as SMS capability, the service also needs to be activated, e.g. Telstra subscribers must have an active MobileNet Memo service to receive SMS.

The phone would also need to be turned on to receive the message, and it would have to be retrieved by a key sequence entered by the phone user. In Australia there are as many as 60 different mobile phone carriers and re-sellers.

A single mobile phone carrier does not have visibility of mobile phones not registered on its network. In other words, to reach all mobiles within a given area it would be necessary to have each carrier send the message to its registered subscribers.

Variable message signs

Variable message signs are electronic programmable signs generally used as a traffic management tools. These signs could be programmed with warning messages and simple instructions in the event of a flood. These signs generally use flashing lights to catch people's attention. Signs can either use mains power or if not available, solar power.

Variable message signs allow messages to be updated. Messages can be scrolled, but not for moving traffic as this is considered too distracting and would probably not be allowed by the RTA.

In general, a library of messages is stored in the sign and remote commands simply reference the message identification number. Warnings can be broadcast to all signs, taking around 30 seconds. Alternatively, signs can be addressed individually or in groups, with each contact taking around 15 seconds.

Notification technologies

Notification focuses on how people interpret the warning message. It is the process by which people are provided with a warning message and information. The principal notification mechanism used to warn of emergencies is the mass media, with internet technology increasingly considered as a potential additional communication mechanism.

Mass media

The general pros and cons of using the mass media to disseminate warnings are neatly summarised in Handmer and Parker 1998. They can distil the most important information to a large audience even if the audience is poorly prepared. Following is an outline of technologies used to disseminate warnings via the electronic media of radio and television. Print media is not discussed as this mechanism would be too slow to be effective in the context of the Hawkesbury-Nepean River Valley.

Radio

Radio is often a major channel for disseminating warning information because it can quickly reach a large number of people during non-sleeping hours. The use of radio as a warning channel will continue to be a major practice in emergencies. Often prearranged plans for notification and use of standardised messages accelerate the speed in which a warning can be issued over radio. One disadvantage of radio is that often a broad area is covered by the broadcast including areas not at risk. Second, all information must be conveyed verbally which excludes the use of graphic materials.

Third, radio reaches only a small portion of the population during certain hours. Fourth, due to the private operations of stations, problems can arise in priorities regarding warning broadcasts although this can be largely eliminated with formal agreements and exercises (Rogers and Sorensen 1988b).

Television

Warnings can also be broadcast over commercial television. This can be done by interrupting normal programming with a bulletin, or by displaying scrolled text on the bottom of the screen. TV reaches a large number of people, particularly in the evening hours. Like radio, it is a poor channel during sleeping hours. TV is a particularly good channel for warning of slowly developing events. One major advantage of TV is the ability to use graphic information such as maps or diagrams in the warning (Rogers and Sorensen 1988b).

In Sydney, the average weekly reach of television is 94%, with 71% of people able to be reached between 6pm and 10.30pm any day Monday to Friday. The average person watches just over three hours of television per day with peak viewing between and 8pm and 9pm (AC Nielsen 2000).

As with radio, information can be broadcast at the station's discretion, or pursuant to formalised agreements.

Internet

With the increasing numbers of individuals and workplaces having Internet access, it may be worth considering internet technology as a supplementary means for rapidly and widely disseminating warning messages. In Australia, as of January 1999, 1.7 million people (approximately 11% of the population) accessed the Internet on a regular basis (Australian Communications Authority 2000).

In the past, the internet has not been seriously considered, since recipients must be logged in to their email service to receive messages. In other words, the Internet has been mainly a 'pull' technology, where users needed to actively seek and access information. The problem has been that unless one knew that a warning existed, one wouldn't know to go and look for it.

Internet PUSH+ technology will solve this problem, as a person need only be connected to their Internet service to have warnings 'pushed' right onto the monitor screen. The '+' part of 'PUSH+' would cause some sort of audio or visual alert to show up. This could be a flashing icon on the recipient's monitor screen, or an audible tone, or both. This would allow the recipient to become aware of the warning immediately, thus giving him or her more time to take appropriate action.

> It was apparent that the Hawkesbury-Nepean flood warning system has to use several technologies if most of the population is to be reached and contingencies such as loss of power or telephone systems can be accommodated.

Unofficial warning systems

Although the main focus of this research project was to consider technologies used in the official warning dissemination system, it is important not to forget that an unofficial warning system will be present at the same time as the official one. According to Handmer and Parker (1998), overall warning system performance is enhanced by integrating official and unofficial flood warning mechanisms.

Unofficial warning systems are those whereby people warn those within their personal networks, e.g. passing on official warnings, seeking information, personal observation. People tend to employ their personal networks to assist with interpreting messages and decision-making.

One warning mechanism that could be classified as unofficial as it is community driven, is the system of asking flood wardens to warn their local communities. The use of flood wardens has been pioneered in the Thames Region of the UK. There are over 50 wardens in place across the Thames region with plans to expand this even further in the next few years.

According to Haggett (1998), flood warden schemes have a number of advantages:

- they get local people involved in their flood warning scheme
- recipients are more likely to believe in a warning issued by a local warden who they know
- local wardens can take over the maintenance of contact details and can be used to distribute flood warning literature
- it is easier for emergency management agencies to provide quality information to a relatively small number of wardens rather than everyone at risk
- flood wardens can also supply emergency management agencies with local information during flood events.

Disadvantages listed by Haggett include:

- reliance on members of the public to issue warnings can sometimes be prone to failure — it is important to establish deputy wardens in case of absence
- warning schemes need maintaining
- in low risk areas it is often difficult to get volunteers and maintain commitment
- in some urban areas community spirit is lower and people do not want to get involved.

Outcomes

A preliminary evaluation of the technologies eliminated the following for practical reasons:

- aircraft—weather and noise limitations
- modulated electrical voltage—frequent false alarms
- laser lights—health risks and potential loss of equipment

- pagers and mobile phones—too many service providers and limited effectiveness
- internet—PUSH+ technology not sufficiently developed.

For each remaining technology a conceptual option was developed for its implementation in the Hawkesbury Nepean Valley. These options accounted for the distribution and density of settlements, topography and infrastructure capacities. For some options there were sub-options to allow comparisons between different configurations of the same technologies but which trade off different performance criteria such as cost and speed of notification.

A methodology called multi-criteria analysis was used to compare these conceptual options. This allowed options with different performance characteristics to be compared objectively while making provision for subjective judgements to be made about the importance of the criteria used to compare options.

The SES and Department of Land and Water Conservation identified 28 criteria for evaluating the performance of the options. They also provided a range of weightings for these criteria depending on their opinions as to how important each criterion is in making a decision.

The analysis included some sensitivity analysis to see how sensitive the ranking of options was to assumptions about option performance and criteria weightings.

What emerged was that the traditional lower technology options such as door knocking and public media broadcasts are extremely valuable. It was also clear that these cannot be relied upon to alert and notify all 60,000 people in the floodplain. In fact no single technology can.

It was apparent that the Hawkesbury-Nepean flood warning system has to use several technologies if most of the population is to be reached and contingencies such as loss of power or telephone systems can be accommodated.

The next step was to determine what combination of technologies would be the most affordable, effective and reliable. Details of the multi criteria analysis and the methodologies for developing an integrated warning system are the subject of a second paper.

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Steven Molino is a Principal of Molino Stewart who has considerable experience in a wide range of water cycle projects and has spent a considerable part of the last decade investigating flood damages, mitigation and preparedness. He was the project manager for the Warragamba Flood Mitigation Dam EIS and the Warragamba Auxiliary Spillway EIS and has advised the Hawkesbury-Nepean Inter Departmental Committee and the Hawkesbury Nepean Flood Management Advisory Committee. He recently prepared a flood preparedness strategy for the Woronora River in southern Sydney which is now being implemented. He has also used multi-criteria analysis and other techniques to evaluate options and facilitate conceptual development of sewerage schemes, water supply schemes, waste management strategies and eco-tourism developments. Steve can be contacted at:
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Graham Begg was a senior consultant with Molino Stewart and has had a long involvement in the water industry. He has developed methodologies for estimating agricultural flood damages and has investigated flooding induced by mine subsidence. Before joining Molino Stewart, Graham was the General Manager of a company whose services included installation and maintenance of remotely operated metering, information technology and communication systems utilising new technologies. Graham is now a strategic and business planner with the Sydney Catchment Authority. He is helping it identify its risk management, including flood risk, responsibilities and is preparing a report on these for the regulator.

Lyndall Stewart has spent the last five years working in public relations and communications and is currently a senior communications consultant with Molino Stewart. She has prepared a community education and communication strategy for flood preparedness on the Woronora River in Southern Sydney and has designed and implemented community education strategies for stormwater pollution in several NSW catchments. Lyndall's strong research skills were used in this project to undertake an international literature search to identify technologies, case studies and suppliers.

Steve Opper has 27 years experience in emergency management, and for the last 15 years he has been as a full time officer of the NSW SES. He has been involved in the management of floods at the local field level, and in both regional and state operation centres. He holds the Disaster Services Administration Certificate from Emergency Management Australia (EMA) and has completed a number of specific emergency management training courses offered by that organisation (EMA). Steve also holds a Graduate Certificate in Applied Management from the Australian Institute of Police Management and has been awarded the National Medal for emergency service to the community. He is the project manager for the Hawkesbury-Nepean project within the SES.

Part two of this article will be in the next (Winter) edition of the Journal.

This article has been refereed