The Total Flood Warning System: Concept and Practice

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INTRODUCTION

In most countries, flood warning systems are incomplete and fragmented and, tend to function sub-optimally. The full complexity of the ideal system is not widely recognised, and severe flood events in particular illustrate flaws in system operation which are serious and potentially dangerous when viewed from the perspective of the flood liable community. This paper attempts to sketch the elements of an ideal 'Total Flood Warning System' and offers some suggestions as to how such a system might be constructed. The history and experience underlying it is Australian, but most of the principles adduced are likely to have general application to the problem of warning communities about impending riverine flooding.

TOWARDS A BRIEF HISTORY

Flood warning activity has no doubt been going on since floods became problematic to human interests: indeed, there are records from ancient times of Egyptians rowing down the River Nile to warn of coming floods. The earliest warnings could have amounted to no more than the passage of messages from upstream to downstream locations about the existence and severity of an event. But in more recent times warnings have become more sophisticated as science and technology have been brought to bear both to predict flood severity, timing and rate of rise, and to assist with the communication of warning messages to communities about to be affected. The development of warning systems has been Topsy-like, however, rather than carefully and purposefully planned, and in such circumstances the various elements are likely to have developed to differing degrees and to be only flimsily tied together. Some important facets may have been neglected altogether.

Community self-help: flood warnings by and for local people. Nineteenth and early twentieth century flood warning activity included the passage of 'flood signals' (daily river height bulletins) by telegraph, newspapers and eventually radio to the masters of steamers plying the larger rivers, along with the radioing or telephoning of flood heights and general predictions to people in communities in the path of flood waters. These 'systems' were informal, reflecting local needs, local resourcefulness and local expertise, and operated co-operatively as a result of the activities of farmers (the usual creek and river readers), postmasters (who controlled the telegraph or telephone transmission) and police (who sometimes organised doorknocks in the low-lying streets of towns expected to experience inundation). Over time, some of ",the people involved in warning-related activities became highly knowledgeable about their rivers and developed considerable expertise in the prediction of river heights and flow times despite their lack of formal scientific training. Such systems were clearly non-technical and non-bureaucratic, small of scale and had high degrees of local community ownership. Very likely, their products were well understood by their clients in rural areas and small towns.

Towards formalisation: the incorporation of science and procedure. The evolution of public weather forecasting during the twentieth century led, inevitably, to the provision of specialist services including flood forecasting. Networks of rain and river gauges were established and hydrologic modelling was employed in the development of general qualitative and then quantitative forecasts of heights which often reached high levels of technical accuracy. With the passage of time many of the manual gauges were telemetered to allow remote access to data by telephone and by the late 1980s radio- telemetered ALERT (Automated Local Evaluation in Real Time) and similar data collection systems were being established on some of the faster-responding rivers. Meanwhile, formal co-operative arrangements were developed between government agencies to facilitate the exchange of hydrological data, and between agencies and radio stations to govern the transmission of height predictions to communities expected to experience flooding. The predictions, which were forwarded by telegram and telex, took on standard formats dictated by agreed definitions and procedures laid down in formal flood warning plans indicating the responsibilities of the various players involved. In the formation of these more technocratically and procedurally oriented systems, many of the old community-based self-help systems declined to the point of virtual disappearance as the new ones took over their function (Brown, 1986, 64). Especially in rural and small- town areas, though, some of the earlier systems remained operational.

The extent to which the products of the new systems were comprehended in flood prone communities was and is problematic, however. While there is evidence that they can be effective in reducing flood damage (Smith, 1990), there are also cases in which they appear not to have been helpful in this regard (Handmer, 1988: 46).

Multi-dimensionality and meshing: the total flood warning system. It is doubtful whether any warning system justifying this title yet exists, but its basic characteristics can be identified nevertheless and attempts are being made in Australia to develop it. In a sense such a system will weld together the advantages of its two predecessors: that is, it will reflect and address the needs of flood prone communities while at the same time providing a high level of accuracy in the forecasting realm as regards both timeliness and accuracy of height prediction. Most importantly, the products of the total flood warning system will be clearly understood by its clients -the people who will be affected by flooding'- and these people will use the warnings to inform their own decision making to best cope with the coming flood.

Such a system will give as much attention to the reception of warning messages and the way people react to them as it will to those elements which relate to the development of the predictions and the technical and procedural elements of their dissemination. A number of the elements of the total flood warning system will be unique to it in the sense that they were not present in pre-existing systems or were present in only very rudimentary forms.

BUILDING THE TOTAL FLOOD WARNING SYSTEM

The starting points for developing the total flood warning system must be an understanding of the nature and needs of those being warned, and a recognition that the sole purpose of the system is to help people to cope effectively with flooding by maximising their safety and minimising their financial and other losses. The scientific, technical and procedural elements of the system must focus on its clients. A seminal contribution which makes this point with especial clarity is Frank's (1990).

There will be many elements to the total flood warning system because flood warning is, by definition, a multi-dimensional activity which is likely to require inputs of expertise from a number of different organisational and professional cultures. Technical interests will be involved, as well as those from the social and behavioural sciences and the field of emergency management (Goulter and Myska, 1987). Ensuring that these inputs mesh effectively and are each developed optimally will be one of the major challenges involved in the development of the system -as will overcoming sometimes significant inter-cultural barriers between the different interest groups involved. In all of this, input from the flood liable community will also be required.

Let us take these individual points further by examining the various components of the system. For each component, we can identify the kinds of skills which will be needed for optimal system development and the kinds of agencies which are likely to be involved. The components are titled as in *Flood Warning: an Australian Guide* (Emergency Management Australia, 1995: 3-5).

Prediction

Flood forecasting is widely thought to be **the** central element of flood warning systems. In two senses this is unfortunate. Firstly, the view focuses on warning production rather than community need, and secondly, it raises one element to a position of primacy and helps create the mind set that the warning system is pre-eminently a system for predicting floods and their severity. Australian experience suggests that the words 'prediction' and 'warning' are often used synonymously in the flood management field, and that flood warning systems are often thought of as **technical** systems comprised of gauges, transmission devices, computers and software. ALERT systems, similarly, are sometimes construed as warning systems when the reality is that they function primarily as systems for the transmission of data. These usages developed during the second phase of flood warning development as described above and illustrate the centrality of technocratic cultures during that phase. At worst, the thinking implied here can lead to the mistaken notion that weaknesses in the performance of flood warning systems must be rectified by technical solutions -more gauges, for example -and searching for solutions to problems which may arise outside the technical realm can be discouraged as a result.

Flood warnings are not simply predictions, and flood warning systems are not merely technical systems geared to the derivation of forecasts. There is much more to flood warning activity than predicting how high a river will get at a gauge or a series of gauges along a river and disseminating that information to communities at risk.

This does not mean, of course, that flood forecasting is unimportant: indeed it is vital, and skilled and trained hydrologists with well-developed data-collecting and modelling tools are crucial to the successful operation of the total flood warning system. It is likely that those responsible for the predictions will need to be well networked organisationally to a weather forecasting agency -presumably a national meteorological office -and may be part of it. This means that flood forecasting is likely to be carried out at a distance from areas which are prone to flooding and places an onus on the forecasters to develop links to flood liable communities so that appropriate predictive services can be negotiated and relevant local expertise tapped and incorporated within warning systems.

Flood forecasting seeks to establish how severe a coming flood will be and to predict its staged development through to the flood peak and beyond. Typically, the predictions incorporated in warning messages are likely to provide quantitative assessments of the levels a river will reach at a location or locations at specified times, though in the early stages of development it may be possible to do this only by indicating broad classes of flood severity. A best-practice orientation, however, suggests that this approach will be a short-term one as historical data and models are built to the point that more specificity becomes possible. Other improvements are likely to involve increasing the density of gauge networks, automating the data transmission systems so as to secure and quicken the flow of information, upgrading the predictive models, better integrating the oceanic and riverine flooding contexts in tidal and estuarine situations and developing predictions of short-time (flash) flooding particularly in major urban areas. Improvement in these forecasting-related elements should lead to increased accuracy and timeliness of predictions and to the development of new prediction services.

Though much can be done to improve flood forecasting, it is likely that where height-prediction systems have been significantly funded they will be better developed than other aspects of the total flood warning system. This is certainly the case in Australia (see, for example, Heatherwick, 1990: 10).

Interpretation

Flood prediction attempts to establish the severity of a coming flood in terms of the **vertical** plane, but flood waters spread **horizontally** as they rise and it is this spread which creates the consequences of flooding by determining what it is that is inundated. Moreover it is this dimension which will be **understood** in the community, whereas the existence of a gauge and an understanding of its calibration cannot be guaranteed. To make sense of a flood prediction, then, and to form a practical basis for communicating it, any prediction cast in terms of gauge height must be translated into terms which describe the coming flood's likely consequences in the area which will experience inundation. This means adding value to the prediction by giving it horizontal expression and meaning.

A useful tool here is a record of flood information for the area around a gauge for which predictions are made. For each such area, it is important to know the gauge heights at which flood waters are likely to begin to encroach upon farmlands, low points on roads, dwellings, industrial and commercial premises, community institutions and utilities. Equally it is useful to have indications of the heights at which levees could be overtopped or communities become isolated as well as the heights by which significant decisions must be made or actions carried out if, for example, evacuation tasks are to be completed before escape routes are cut. A fuller list of the kinds of data which are likely to be useful is included in Emergency Management Australia (1995: 18-22).

A flood information record may usefully be held on cards designed to a proforma for listing heights and effects. In some instances, because a particular consequence of flooding may take place at different gauge heights in different floods, a **range** of heights may be more appropriate and less misleading than a single value. This point serves to reinforce the fact that records of flood effects cannot be precisely accurate because of the individuality of flood events, no two of which are identical in their impacts even if they peak at the same height, and because of changes in floodplain and other catchment characteristics since earlier floods. Nevertheless, good flood records give excellent general pictures and form a much better basis

for developing warnings than simple guesswork. They provide in advance an impression of where the water will go as the flood rises towards the predicted level and indicate what will happen, in what order, and according to what approximate timings in relation to the time when the peak will be reached.

Such information, by indicating the approximate reach of a coming flood, permits meaningful and persuasive descriptions to be made of what will happen. It therefore provides a basis for giving advice intended to stimulate appropriate actions (for example, to avoid a particular road) and forestall inappropriate ones (for example, to ensure that unnecessary evacuations do not occur). Knowing where the water will go provides the basis for an authoritative and credible advisory message, whether this is. to lift furniture, gather important papers and family mementoes together and prepare to evacuate, stock up on food, avoid particular roads and bridges, or lift pumps and move stock from low-lying
paddocks.

In many jurisdictions the formal development of flood information is absent or rudimentary, and a vital ingredient for high-quality communication is lacking. For the most part, the necessary information needs to be built up locally -that is, **within the** flood liable community -and both within and outside of flood time. Gathering the data will help responders to build expertise about the characteristics of flooding in their own areas and help them to develop appropriate contents for warning messages. During flood time, of course, people from the flood-affected community (perhaps from the local authority) may need to be co-opted to ensure that the appropriate information is collected. After a flood, this information needs to be carefully vetted and collated to ensure that the cards are kept up to date and accurate and, where possible, incorporated with Geographic Information Systems which will allow quick appraisals of the likely impacts of future floods as they rise.

Message Construction

Precisely what needs to be said in warning people, and how the messages should be couched, constitute vexed questions. Some messages that are disseminated are jargonistic and bureaucratic in tone and fail to create the necessary bridge between the appraisal of flood characteristics (prediction and interpretation) on the one hand and the making of decisions about protective behaviour on the other. Messages can all too easily be neither user-friendly nor persuasive and can fail to incorporate all the appropriate information.

Warning messages need to describe the coming flood, say what it will mean to those who may be affected by it and indicate what actions they should take. Simple but evocative language should be used, with an emphasis on the creation of word pictures designed to create arousal and overcome apathy and denial. The ‘community memory’ should be tapped, where possible, by referring to known floods of the past and referencing the likely severity of the coming event to them.

All too often, flood warning messages are ‘singular’ in the sense that one message is provided for a whole community. In many instances this is sub-optimal, since it fails to recognise that the community is not a single mass of people but is stratified in terms of degree and type of risk, past experience, language and other differentiating characteristics. Different groups will need different information presented differently, so a matching of message and group will be necessary -a factor which will often create severe difficulties for those responsible for

providing warnings in the normally brief and hectic real time of a flood event. To assume that single broad brush messages will communicate effectively with everyone who might need to be informed of flooding, however, is akin to believing that the same size of shoe fits all feet.

Communication

Broadbrush warnings are often necessary, of course, but except in low-level events with few impacts they are likely by themselves not to be sufficient. It is a characteristic of many flood events that the only means of dissemination of information and warnings utilised is the airwaves, which are accessed by using radio stations. While this may be reasonable for the more common and lesser events, severe floods with complex and widespread impacts are likely to require a more variegated approach involving both specifically targeted ('narrowcast') warning messages and the use of a range of dissemination channels which may include telephone trees, loud hailers, fax and computer transmissions, doorknocking and even, for long-response events, newspapers. The choice of modes will be dictated by onset time, likely flood severity and nature of community but, in general, the principle of using methods in layers should be observed since different people hear and respond to differing degrees to various means of receiving information. Using a range of disseminating messages also helps to satisfy the need for confirmation -as does the provision of a telephone number which people can call for clarification, repetition or other assistance.

Where evacuation is likely to be necessary, it is wise to attempt to personalise message delivery by individually doorknocking those buildings from which people will have to move. This will ensure that the safety requirement is optimally discharged since personally-received warnings are more likely to be understood and believed and therefore acted upon than those received by more remote means (which, in any case, will almost certainly not be heard by all who need to hear them).

The responsibility for constructing and delivering warning messages is best vested in an agency which is charged with the management of flood response. **In** many instances, this is likely to be a local authority. Such an agency must be able to carry out the crucial flood interpretation work which is central to the creation of comprehensible warnings. It must have high-quality liaison to the forecasting agency from which predictions will be received and, if not itself locally based, to organisations with strong links in the community at risk of flooding. Beyond these linkages it may need to call on specialist communications skills to ensure that its messages and their delivery recognise appropriately the psychology of mass and small-group communication -though this must be done in quiet time well before the onset of flooding rather than during the actual event.

Review

The design of flood warning systems needs to be regarded as a continuous process of construction and review which will have periods of intense activity (especially during and immediately after floods) and periods of less intense but highly important planning work. All phases (prediction, interpretation and message construction and dissemination) need to be reviewed in a debriefing context for weaknesses of detail and design, and deficiencies should be rectified in the ongoing planning phase. In all of this, contact needs to be consciously sought with members of flood liable communities, perhaps by means of focus groups or through local organisations and key individuals. While system modification is especially

likely after a flood, it will also be appropriate when significant flood-altering environmental change occurs, when relevant technological innovations become available, or when additional resources are obtained.

In many environments, flooding is infrequent and occasional periods of drought make it even more so. To counter the accompanying negative consequences as far as system readiness is concerned, reviews need to be held occasionally even if there have been no floods and no significant environmental or technological changes to consider. These may take the form of workshops designed to bring together the various interests involved in system development and warning service delivery so that the potential participants can see their own roles in the context or those of other players and so that new players can be introduced to the process. Equally, workshops may take the form of test exercises in which new or alternative methods can be trialed and evaluated.

In all of this it is important to involve the flood liable community. There is a sense in which people need to be prepared for flood warnings as well as to be warned about impending flooding, and this requires a willingness to develop public awareness initiatives out of flood time. Flood plans which describe operating warning systems and procedures can be made available in public libraries and advertised or exhibited in local media outlets, and flood awareness material can be distributed to households and businesses in particularly flood prone locations. It is important to recognise, however, that there are times -periods of drought or periods outside normal flood seasons, for example -at which the appropriate information is difficult to impart because the community mind is not tuned to receiving it. Not all moments are ‘teachable moments’ (Filderman, 1990: 223), and indeed the times when public attention can be focussed on flood warnings may be few and brief. Some extension of these times may nevertheless be achieved by, for example, occasional public commemorations of well-remembered events during which communities may be informed about related matters such as warning services and how to react to warning messages. That said, it must also be true that it is not the convenience of agencies with responsibilities for educating the community but the receptiveness of that community which must dictate how and when the educational task is undertaken.

DISCUSSION

Effective total flood warning systems will not be easy to develop. In most jurisdictions only parts of them are in existence, and there will be much planning and liaison required to introduce those elements which are either not yet formed or which exist at only very basic levels. Many flood warning systems presently in use tend to take a reductionist, even minimalist view of the warning process, and it is often only the more technical facets (including flood forecasting) which can be said to have evolved to an advanced state. The challenges are to incorporate or raise the level of operation of the other components, particularly those most directly related to eliciting appropriate protective behaviour from flood-threatened communities, and then to maintain the synchronous development of all the elements so that the system is kept in a state of operational readiness and subjected to continuous improvement.

The details of the construction process will differ greatly between flood prone areas, depending on their flood problems and community compositions, and between national and other jurisdictions according to their agency structures and potential for inter- organisational

interaction. Interestingly, the building of better flood warning services will not necessarily be highly expensive: apart from the forecasting components, most elements are more labour- than capital-intensive.

Frank (1990) argues that while national meteorological organisations tend not to have legal responsibilities for the non-forecasting components of warning systems, they must have a **moral** commitment to the 'complete warning process'. This does not mean that such organisations must be me central players, and it may be mat there IS no appropriate single agency to take on the pre-eminent planning or operational role. The multi-dimensional nature of the warning task, in fact, militates against this and makes it unlikely that a single agency can take on the entire process. With rare exceptions, the job will need to be undertaken by a number of organisations and the effective meshing of their activities will be vital.

In Australia, a nation with several states each with its own flood management arrangements, the national forecaster -the Bureau of Meteorology -has taken the lead in the setting up of state Flood Warning Consultative Committees which have become the key policy-setting bodies in the flood warning arena. These committees have memberships drawn from the Bureau, water management agencies, emergency management organisations, local authorities and flood-interested community organisations (for example farmers' associations and flood mitigation lobby groups). On these committees, potential improvements to warning systems are examined and responsibilities for carrying out tasks can be defined and allocated to appropriate member organisations. The Flood Warning Consultative Committees have no legal power over their constituent agencies, but they have helped in a necessary re-conceptualising of the flood warning task as well as in providing a forum in which liaison can be fostered. Certainly they have played a part in Australia's tentative steps towards building total flood warning systems and elements of their experience are likely to be of value in other jurisdictions.

CONCLUSION

Existing flood warning systems, even with their manifest deficiencies, can be effective in the mitigation of flood damage. It is very likely that if they are recast in terms of completeness, carefully planned and kept alive, their effectiveness can be augmented considerably. If there is a single key to the attainment of this goal, it lies in harnessing the wide range of skills and interests with stakes in the warning process.

REFERENCES

Brown, R.F. (1986), Flood Forecasts and Warning Dissemination: the New South Wales State Emergency Services' Role. In Smith, D.I. and Handmer, J. (eds) *Flood Warning in Australia: Policies, Institutions and -Technology.* Canberra: Australian National University, Centre for Resource and Environmental Studies: 63-71.

Emergency Management Australia (1995), *Flood Warnings. an Australian Guide.* Mt Macedon: Australian Emergency Management Institute.

Filderman, L. (1990), Designing Public Education Programs: a Current Perspective, in Handmer, J. and Penning-Rowsell, E. (eds), *Hazards and the Communication of Risk.* Aldershot: Gower: 233-45.

Handmer, J. (1988), The Performance of the Sydney Flood Warning System, August 1986. *Disasters.* 12 (1): 37-49.

Heatherwick, G. (1990), *Digest.* 5 (2-3): 7-10. The Nature and Purpose of Flood Warnings. *The Macedon*

Smith, D.l. (1990), Flood warnings, Response and Damage Reduction: the Australian Experience. Paper presented to *Flood Plain Management Conference, Toronto,* 1990.