Australia's role in the International Decade for Natural Disaster Reduction

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Contents

Preface

On 11 December 1987 at its 42nd session, the General Assembly of the United Nations designated the 1990s as the International Decade for Natural Disaster Reduction (IDNDR). As part of the Decade, October 10 was nominated Natural Disaster Reduction Day. This volume contains three papers presented at a half day seminar organised by CRES to mark the occasion. As far as the editors are aware, this was the only formal event in Australia to commemorate the inaugural Day.

The Resolution adopting the Decade was proposed by Japan and Morocco and co-sponsored by 93 UN member nations. Australia was not one of these co-sponsors, but supported the resolution in the General Assembly debate. Resolution 42/169 has the general objective:

> to reduce through concerted international actions, especially in developing countries, loss of life, property damage and economic disruption caused by natural disasters....

The declaration of the Decade is chiefly the result of activity by the US National Academy of Sciences. In 1987 the Academy produced a report *Confronting natural disasters* which articulated the case for the Decade. Phil Cheney, who was a member of the Ad Hoc Group of Experts advising the UN Secretary General on the Decade, details the development of the concept in his paper. The US report and the initial thrust of the Decade appeared to be preoccupied with high-technology fixes: for example, satellite-based severe weather warnings, earthquake prediction programs, modern seismic design and slope-stabilising works.

This emphasis has led to criticism and some allegations that instead of fulfilling the promise of reducing disaster for the developing world, the Decade might simply provide a research bonanza for the scientists of the industrialised countries. The lure of high-technology is seductive. It is also supported by sophisticated scientific and industrial organisations. There is no question that the products of the information age and other aspects of contemporary science have important roles to play in disaster reduction, but it is most important to remember that the central purpose of the Decade is to improve people's lives by reducing losses from natural disasters. In this context the major issues may well include reasons for the failure to apply much of the existing knowledge, and the political and social causes of disaster.

Each member state of the UN is to implement the Decade as it feels is appropriate, and if it believes it appropriate. Australia's participation was announced by the Prime Minister, Robert Hawke, on 21 April 1989. The Prime Minister also announced the formation of an Australian Coordination Committee for the IDNDR, to be chaired by the Director-General of the Natural Disasters Organisation (NDO). The NDO is a small federal agency within the Department of Defence. It coordinates federal government assistance during disasters and runs the Australian Counter Disaster College. The Australian Decade Committee consists primarily of representatives from various government departments and agencies. There are also representatives from research and NGO aid groups: academics, a member of CSIRO (Commonwealth Scientific and Industrial Research Organisation), and representatives from the Red Cross and from AODRO (Australian Overseas Disaster Response Organisation).

In the opening paper to this volume Commodore Littleton, who chairs the Coordination Committee, points out that a major Australian contribution to the Decade will be in the form of disaster preparedness assistance for the nations of the South-west Pacific. Phil Cheney presents the overall background for the IDNDR, and Jack Rynn and Dingle Smith discuss the prospects for damage reduction in Australia from the hazards of earthquakes and floods.

Australia's involvement in the Decade was officially launched by David Simmons, Minister for Defence Science and Personnel at a meeting at the Australian Counter Disaster College, 11-13 February. Other presentations at the meeting dealt with the role of the Coordination Committee, the UN Committee, the Bureau of Meteorology, intergovernmental action on climatic change and the role of research. Despite the occurrence of the Newcastle earthquake and severe flooding just prior to the launch, the event received disappointingly little media coverage.

Those of us interested in seeing the Decade achieve its goal might like to consider why some international years and decades are successful while others fail to have any impact. The "Year of the Disabled" appears to have been an outstanding success. Was this because of its community orientation, where existing groups had a clear idea of what was required, because the concept fitted into societal trends to reduce all types of discrimination, or because it had a large well organised bureaucracy with local constituencies? Attention to these questions should help identify paths to success for the International Decade for Natural Disaster Reduction.

John Handmer
Member of the Australian IDNDR
Coordination Committee

Opening address

Commodore C. Littleton
Director-General
Natural Disasters Organisation
Chairman of the Australia IDNDR Coordination Committee

October 10, 1990 was the first of ten days which will be observed each year until the end of this decade to mark the International Decade for Natural Disaster Reduction (IDNDR).

The United Nations Organisation has nominated this decade as a period during which we should all endeavour to reduce the enormous loss of life and property damage resulting from natural disasters, especially in developing countries.

Australia is participating in the IDNDR and the Prime Minister has appointed the Director General of the Natural Disasters Organisation as chairman of the Australian IDNDR Coordination Committee. I am pleased that Dr John Handmer, D I Smith and the Centre for Resource and Environmental Studies have so quickly entered into the spirit of the IDNDR.

By participation in the IDNDR, Australia is not entering uncharted waters. For several decades the Australian counter disaster community has steadily improved organisations and infrastructure to cope with the range of natural and man made disasters affecting this continent. Indeed, during the past few years capabilities at state and territory level have advanced so much that my organisation has been able to devote more time and effort to assisting our less developed neighbours in the Papua New Guinea and South-west Pacific area.

I recently represented Australia at an IDNDR international conference in Japan. There were some 1000 participants including representatives from most Pacific Rim nations. The conference was opened by the Japanese Crown Prince and Prime Minister which is an indication of the importance that nation attaches to the event. I am very proud to say that by comparison with other nations, Australia is a world leader in dealing with natural disasters.

I would now like to discuss Australian International IDNDR contributions.

As Australia has only modest financial and population resources, we must be selective in our international contributions. These are mainly channelled into the South-west Pacific area. Nevertheless, we are, as an Australian IDNDR contribution, producing a series of emergency operations and training manuals for worldwide use.

Experts from each Australian emergency and response agency, funded by the natural disasters organisation, are jointly preparing manuals which have wide application. These manuals may be reproduced free of copyright fees, subject to suitable acknowledgement. For developing countries we will provide copies in English, free of charge.

Let me turn now to the South-west Pacific region. As a result of disaster response experiences gained over a number of years in this region, it became obvious that Australia needed to provide more than response assistance to nations in this area.

It has been decided that a major Australian contribution to the IDNDR will be the Pacific disaster preparedness program. This program, which is funded by the Australian International Development Assistance Bureau offers participating nations assistance with the development of their national disaster preparedness. It is anticipated that most assistance will be provided in the form of national packages designed to meet the particular needs of each country. Initially, these packages can be funded for up to three years but extensions may be negotiated. The programme also has the flexibility to provide assistance with smaller projects.

Elements available for inclusion in packages are: hazard and vulnerability analysis; national policy advice; counter disaster planning; operation of emergency operations centres; preparation of operating procedures; training; exercise writing and organisation; damage assessment; public awareness and education; and equipment. Some of these elements have already been initiated with some countries - training is a notable example.

However, I should sound a note of caution in respect to the South-west Pacific region. Constrained population and financial resources preclude these nations from the high technology path. Solutions need to be simple. Systems must be capable of operation without costly repair and maintenance. We must ensure that any assistance provided does not create an unsustainable demand for future maintenance in terms of finance and time.

There are still major improvements needed in our knowledge of disasters in Australia and in our ability to prevent them, prepare for them, respond to them and recover from them. This means that research projects should be directed towards practical outcomes and academic and research communities should constantly bear this in mind.

Developing an international program to confront natural disasters

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Abstract

The concept of a cooperative international program to reduce the impact of natural disasters was proposed by the US National Academy of Sciences in 1984. It has now evolved, through a series of international technical committees, to Australia's participation in an International Decade for Natural Disaster Reduction (IDNDR), the 1990s, sponsored by the United Nations. An International group of experts appointed by the Secretary General to advise on planning for the decade has recommended a change in attitude from one concentrating on the technology of early warning systems and post-disaster relief operations to one placing emphasis on pre-disaster prevention and preparedness. Much of the required technology and knowledge is available in developed countries so a high priority of the decade is to extend this knowledge to developing countries.

Australia is well placed to provide valuable advice on the appropriate planning and mitigation measures to reduce the impacts of natural disasters in the south-west Pacific region. Social problems which work against the implementation of disaster mitigation problems must be addressed. These can be overcome by concerted international action, during the 1990s, to combine the knowledge and technical resources within a wide range of disciplines to promote both security from natural disasters and sound economic development in the island nations of our region.

In the last 20 years, it has been estimated that natural phenomena have killed about three million people throughout the world. Up to one billion people have probably been adversely affected by natural disasters and have suffered devastating hardships, ill health and severe economic loss. In 1989 alone, two earthquakes in Armenia killed more than 35 000 people, floods in Bangladesh claimed 1500 lives and disadvantaged 45 million people and Hurricane Gilbert raged through the Caribbean islands causing physical damage and economic losses running into millions of dollars.

This paper will discuss some of the events leading up to the declaration of the IDNDR, and provide brief examples of the type of national and international exchange of ideas envisaged for the Decade.

The US National Academy of Sciences

The concept of a cooperative international program to reduce the impact of Natural Hazards was first presented by Dr Frank Press, President of the U.S. National Academy of Sciences, in a speech to the Eighth World Conference on Earthquake Engineering in 1984. Press proposed an International Decade for Natural Hazard Reduction with a focus on reducing the toll of earthquakes and other geophysical events. As international interest in this program began to build, it extended to reducing the impacts of other natural phenomena.

The U.S. National Academy of Sciences appointed a National Research Council Advisory Committee on the International Decade for Natural Hazard Reduction. In 1987 this committee published a glossy report *Confronting Natural Disasters* (NRC, 1987). This discussed the impacts of earthquakes, landslides, volcanoes, tsunamis, windstorms, floods and wildfires and listed potential projects on each hazard which might be undertaken during the IDNHR. Many of these projects included research and the development of new technology. The report was not without its critics as many of the projects proposed seemed quite inappropriate for developing nations where the need to reduce the impacts of natural hazards is perhaps greatest. However the U.S. National Academies of Sciences and Engineering, and in particular Dr Frank Press, have continued to promote the concept of international cooperation to reduce the impact of natural hazards.

The United Nations

The proposal for a United Nations International Decade for Natural Disaster Reduction was promoted by delegates from Japan and Morocco.

At its 42nd session on 11 December 1987, the General Assembly of the United Nations adopted Resolution 42/169 which designated the 1990's as the International Decade for Natural Disaster Reduction (IDNDR) with the general objective:

> to reduce through concerted international actions, especially in developing countries, loss of life, property damage and economic disruption caused by natural disasters such as earthquakes, windstorms (cyclones, hurricanes, tornadoes, typhoons), tsunamis, floods, landslides, volcanic eruptions, wildfires and other calamities of natural origin such as grasshopper and locust infestations.

Already the presence of a developing country had expanded the scope of the decade activities. The goals of the decade are:

- to improve the capacity of each country to mitigate the effects of natural disasters expeditiously and effectively, paying special attention to assisting developing countries in the establishment, when needed, of early warning systems;
- to devise appropriate guidelines and strategies for applying existing knowledge, taking into account the cultural and economic diversity among nations;
- to foster scientific and engineering endeavours aimed at closing critical gaps in knowledge in order to reduce loss of life and property;
- to develop measures for the assessment, prediction, prevention and mitigation of natural disasters through programs of technical assistance and technology transfer, demonstration projects and education training, tailored to specific hazards and locations, and to evaluate the effectiveness of those programs.

The resolution calls on all governments to:

- participate during the decade in concerted action to reduce the impact of natural disasters;
- establish national committees;
- to keep the Secretary-General informed of their country's plans and of assistance that can be provided so that the United Nations may become an international centre for the exchange of information.

The General Assembly charged the Secretary-General to develop, in cooperation with the appropriate organisations of the United Nations system and relevant scientific, technical, academic and other non-governmental organisations, an appropriate framework to attain the objective and goals for the Decade and to submit a report thereon to the General Assembly at its 44th session through the Economic and Social Council. To assist him, the Secretary-General established an Ad Hoc Group of Experts with expertise in the relevant scientific disciplines as well as experts in disaster relief operations.

The International Ad Hoc Group of Experts

The International Ad Hoc Group of Experts (IAHGE) was chaired by Dr Frank Press and was asked to:

- develop a framework for the International Decade for Natural Disaster Reduction
- identify priority areas for the application of existing knowledge
- identify gaps in the existing knowledge and
- provide recommendations concerning matters of implementation.

The group was composed of 25 scientists and technical experts, each from a separate country which had been selected to ensure a suitable global representation according to UN specifications. Due to this selection process I was invited to join the group, not for my expertise in disaster management (which is little) but for my technical expertise in bushfire (wildfire) behaviour and control.

The group collectively spoke more than a dozen languages but quite a number, like me, could converse only in their native tongue. Disciplines represented ranged from seismology to sociology. The meetings were translated into three or four languages but in the working groups, which were formed to draft individual chapters of the report, communication was not so easy. The group that I chaired spoke only English, French/Arabic or Portuguese.

Yet in spite of these apparent communication difficulties, I was astounded at how rapidly the group came to a consensus on the major issues, and how well we were able to work together. We rapidly came to the conclusion that although a technical fix was often possible, new technology was not the main answer; that there had to be a change from emphasis on warning and disaster relief (although these would always remain important activities) to prevention and preparedness;and that much could be gained by adopting an interdisciplinary approach.

In the early enthusiasm to promote the IDNDR, many extreme events were called disasters when in fact they were not. We defined a disaster as being any disruption of a human ecology that exceeds the capacity of the community to function normally. The UNDRO definition of a disaster requiring international attention is: 'a serious disruption of the functioning of a society, normally occurring with little or no warning causing widespread material and human losses with which the affected society cannot cope using only the internal resources available to the country in question'. For statistical and practical purposes, UNDRO sets a lower limit of 25 people dead and/or property damage in excess of US$10 million. Thus what would be classed as a disaster in one country would, in another, pass almost without notice or be handled within routine emergency management procedures.

To gain political support for promoting the Decade, the group wanted to estimate the cost of disasters around the world. The task was irrational. We were comparing dollars with lives: and with meagre statistics. In the developed countries, the numbers of lives lost have been steadily decreasing but the costs of so called disasters have been rising exponentially. In the developing countries, the numbers of lives lost are probably increasing, yet the estimated costs appear to be static.

How does one compare an earthquake in Morocco or China which wipes out tens or even hundreds of thousands of people living in ancient masonry structures, with a hurricane in the United States which kills ten people yet has a damage bill which runs into billions of dollars?

In my own field of bushfires, I consider that a fire which burns palatial homes in Beverly Hills, California, or holiday homes along the Great Ocean Road, Victoria, does not qualify as a disaster if the homes are replaced by insurance and the community, apart from a lighter pocket, otherwise functions normally.

It is clear that many natural disasters cause a nation economic hardships and hinder development in ways that are not accounted for. It is a challenge for the IDNDR to produce a way of equitably assessing the real costs of natural disasters in countries with very different standards of living and economic development. I also believe that in the Decade, Australia should look to assisting the developing countries in our region to mitigate the impacts of natural phenomena with an even higher priority than seeking to mitigate disasters at home.

The group was composed mainly of experts in the earth and atmospheric sciences. We had only one social scientist - an Italian expert in cognitive systems. The report to the Secretary-General gave no impression of the difficulties we had in addressing the social problems involved in disaster mitigation. Yet without people, disasters do not occur. Social factors are the prime factors which result in a natural hazard creating a disaster.

Understanding the social factors in different communities which predispose that community to disaster, is far more difficult than understanding the physical nature of natural phenomena. In places, it may be that the political elite place a low value on human life and prevent known mitigation and preparedness measures from being undertaken. More often lack of action relates to a low degree of economic development, complicated by high population densities and a highly altered environment which shape an almost fatalistic attitude that nothing can be done to prevent disasters.

In Morocco we visited the city of Agidir which was devastated by an earthquake in 1960. The main medina (walled city and casbah) was of masonry construction, crowded with people and flattened by the earthquake. The only buildings to remain standing were of the most recent reinforced concrete construction and although they were not built to special building codes, they were constructed soundly enough to withstand the earthquake. Agidir has been rebuilt, taking into consideration principles of micro-zonation to select the least vulnerable sites, and using appropriate building codes. The earthquake problem in Morocco lies now, not in Agidir, but in a dozen other cities located in a zone of lower seismic activity. All have dense populations crowded into unstable masonry medinas.

It is easy to point to the problems of developing countries and offer pious solutions. The plight of

Bangladesh was often cited but without any feasible solutions. However, we need look no further than Australia for recent examples of social and political factors outweighing the logic of preparing for disasters. Darwin, located in the middle of the cyclone belt, was built without applying the cyclone building codes known and applied elsewhere. It is interesting to speculate if Cyclone Tracy had not occurred and demolished the city, would all the existing buildings now be re-engineered to withstand a possible event of that magnitude - I doubt it. Even more recently, engineers have been critical of building standards in Newcastle for not engineering to appropriate building codes in a recognised earthquake prone area.

In most countries, I believe that people are reluctant to spend money if the frequency of hazardous phenomena is perceived to be low. Politicians mostly reflect community attitudes and are likely to make important decisions after events with a high news profile but they have little desire to plan for a remote catastrophic event regardless of scientific predictions. A crucial task for the Decade is to convince policy makers that disaster planning and management is a part of normal government administration.

Disaster prevention requires a degree of organisation, standardisation and associated regulation that many individuals and societies find unacceptable. They view this situation as an unnecessary restriction on free enterprise and individual freedom. Homeowners in the United States do not accept the degree of building regulation for cyclone resistance that is commonplace in Australia. On the other hand, it is increasingly common for individuals in Australia to ignore the advice of bushfire authorities and build homes surrounded by flammable shrubs and accumulated litter debris. At times, communities resist the efforts of others to protect themselves. For example, during a fire study tour of California in 1979, I was shocked to learn that a homeowners' association had placed a writ on a disabled person who wished to build a home with a roof of artificial non-flammable shingles and clear the highly-flammable chaparral scrub from his property. The normal standard was for flammable cedar shingles and the individual was considered to be lowering the property values of the area.

Apart from recognising that social factors are an integral part of disaster management, the group was unable to offer practical solutions. Rather, we felt that concerted international action during the decade would convince governments that they had a moral responsibility to provide their people with a level of security against natural disasters. On top of this, there is now an ecological and economic interdependence of world communities which does not allow any nation to remain in isolation - either to bear the consequences of natural disasters alone or to avoid the responsibility of caring for others.

For me, participation in the Ad Hoc Group of Experts demonstrated the effectiveness of drawing together people from a wide range of disciplines to exchange ideas and plan for the reduction of natural disasters. The group became convinced of the very substantial economic benefits of international action to reduce disasters and the Decade now offers the opportunity to exchange information from an international data base.

Iceland, for example, is an island on the mid-Atlantic ridge with a population of 250,000. There is a high risk of earthquakes and volcanic activity. There is a year-round threat of snow avalanches and mud slides, and in winter the country can experience blizzards and windstorms of hurricane force. Iceland has an excellent integrated disaster management program. It has been implemented since 1971 through legislation, development of administrative structures, building and planning control, organisation of local volunteer groups, education and training at all levels and the establishment of a catastrophe fund.

The system obviously gains impetus from the relatively high frequency of potentially catastrophic events. Nevertheless, I believe that Australia, and particularly the island nations in our region, have much to gain by examining the Icelandic model and adapting those aspects of it which are suitable to the local environment.

In Australia, there is much to be gained by the closer integration of hazard management authorities. I will mention three areas from my own field of bushfire management which can have a much wider application.

Planning for the 'worst possible' event

In bushfire management the first step in planning is to develop a scenario of the 'worst possible' fire event for an area. This involves using actual and potential fuel loads in the area, the maximum potential of fire weather variables and calculating the fire behaviour likely to result from single or multiple ignitions, and the damage it will cause. It immediately becomes obvious that under extreme weather the fire will overwhelm the best suppression forces available and that damage can be minimised only by action at an individual level and by modifying fuels in critical areas.

Of course 'worst possible' cannot be calculated but the exercise does help to place clearly in focus what can be achieved with existing resources, where fuels management can be most effectively applied, and the scale of activities likely to be required for post disaster relief. Historical evidence can be used to illustrate the problem but that often brings about the 'it can't happen here' syndrome or seriously underestimates the potential for disaster. Exactly the same proposal was recommended by the Russian seismologist Keilis-Borok, for earthquake management.

Volunteer involvement in disaster mitigation

Traditionally, volunteers in most emergency services have been involved in post-disaster relief efforts. This has been particularly true of international relief operations. Michael Lechat, from the School of Public Health, Brussels, has described this as 'well-meaning groups rush off on safari to disaster areas where they are often ill-prepared for the local conditions and resented by local organisations'.

In Australia, bushfire brigades have been the foundation stone of fire control in rural areas. In addition to fire suppression they have an extremely important role in educating the rural population in aspects of fire control and home protection, and in places have been involved in hazard reduction operations on private and public lands. Volunteers in other fields should be encouraged to become actively involved in disaster mitigation efforts. Many have expressed interest in doing so.

A significant task of the Decade is to expand the role of volunteers in Australia and to assist in organising volunteer disaster mitigation groups in other countries in our region. The experience of the volunteer bushfire brigade organisations and State emergency services groups will be invaluable. At home, sociological research into the needs and motivation of volunteers is needed to ensure their numbers do not decline.

The Australian Inter-service Incident Management System

The Australian Association of Rural Fire Authorities is developing a common incident management system - AIIMS for control of bushfires (AARFA, 1989). It has been modified from the National Interagency Incident Management System developed by the US Forest Service and is similar to the large fire organisation structure employed by several Australian forest services.

AIIMS provides for a common incident management structure which is applicable from the smallest to the largest incident, common terminology and common titles for all people involved in the incident. This will allow different emergency services to work together efficiently and share resources.

The AIIMS incident control system establishes the four major functional responsibilities for incident management under an Incident Controller: operations, planning, logistics and finance

The degree of organisation required depends on the nature and complexity of the incident. AIIMS ensures that each participating service or organisation retains their own command structures while being fully integrated into the incident management system.

AIIMS can be applied to any emergency incident regardless of the complexity or the causal phenomena. To date it has been applied by fire authorities to incidents ranging from bushfire control to the saving of beached whales in Western Australia. I commend the system to all emergency service organisations in Australia.

Conclusion

At times it seemed that the International Ad Hoc Group of Experts was unlikely to form into a cohesive group and develop a united approach. 'The planning for the IDNDR is an absolute disaster' was a despairing cry at more than one bar room post mortem of the day's activities. However, when good communications were established and a common terminology understood, it transpired that there was a high degree of agreement and an excellent exchange of ideas. The recommended priorities are listed in the report to the Secretary-General (IAHGE, 1989) - I will mention only three:

- The Decade is a moral imperative for all governments. It is the first coordinated effort to prevent unnecessary loss of life from natural hazards.
- A new emphasis should be placed on pre-disaster planning preparedness and prevention to complement post-disaster relief.
- There should be a wholly integrated approach to disaster management.

Australia is already well advanced in several areas of disaster management. I believe that the International Decade for Natural Disaster Reduction is an outstanding opportunity to combine our knowledge and resources within Australia to improve our own capabilities and to extend this knowledge to other nations in our region.

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The potential to reduce losses from earthquakes in Australia

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Abstract

At 10.27am on Thursday, 28 December, 1989 the devastating Newcastle earthquake shattered the commonly held myth that Australia, a stable continent far removed from the earthquake-prone areas associated with the Earth's plate margins, does not have serious earthquakes. Newcastle, Australia's first 'killer' earthquake claimed 13 lives and left a total damage bill estimated at approximately A$4 billion. The lessons learnt from Newcastle, including responses to the disaster and the post-earthquake recovery phase, clearly showed that Australia *must* prepare immediately for such disasters in the future to reduce the now far too obvious consequential losses. The goal of all earthquake related studies must be directed towards the mitigation of the earthquake hazard. This necessitates a multidisciplinary approach integrating the earth sciences, engineering and sociology through cooperative efforts from all avenues in society – academia, industry, government and emergency service agencies. Based on our past and present research programs and with the integration of all available information, the potential to reduce losses from earthquakes in Australia is both a realistic and achievable goal, well within the capabilities of the Australian community.

Introduction

'Disastrous earthquakes in Australia?' 'Never!' This was the public perception based on the notion that Australia was a stable continent and as such could not be subjected to major earthquakes – until 10.27am on Thursday, 28 December 1989, when this myth was shattered by the devastating Newcastle earthquake which brought this densely populated and highly industrialised region to its knees.

The statistics from disastrous earthquakes present in stark realism the consequences that befall a community. Records of the history of civilization indicate that earthquakes have claimed the greatest total loss of human life and damage to property. Some examples of such catastrophic earthquakes are given in Table 1 (taken from Bolt, 1988).

Most peoples of the world are familiar, in some way or other, with the phenomenon of earthquakes. They can certainly equate the effects of an earthquake with either disruption to the surface of the earth or devastation to the facilities of modern civilisation. They are also aware of the potential for earthquakes to occur in California, Japan, Chile, New Zealand and the Mediterranean – that is, in geological terms, in those areas designated as the 'plate margins'.

But how many have heard of the events at New Madrid, Charleston, or Tangshan? These are some of the disastrous continental, or 'intra-plate' earthquakes that are many more times as devastating as the plate margin earthquakes. Such events have been totally unappreciated in the danger they pose to human life and property.

One can consider several descriptive terms to account for such 'lack of awareness' – ignorance, apathy, complacency, lack of communication, paucity of information exchange. The key to this human perception could possibly lie in one's own definition of the word 'TIME'. Specifically, the

Table 1. Some disastrous world earthquakes

1811	New Madrid (USA)	ML 8.3	Several killed; felt area covered half of continental USA and eastern Canada; damage area 5 million sq km.
1886	Charleston (USA)	ML 8.2	Greatest historical earthquake in eastern USA; about 60 killed; damage US$5.5 million.
1906	San Fransisco (USA)	ML 8.3	700 killed; great fire; damage US$400 million; slip on San Andreas Fault of 6.5 m.
1923	Kwanto (Japan)	ML 8.5	Vast destruction and loss of life; major tsunami devastated Hawaii and caused damage to east coast of Australia.
1960	Chile	ML 8.5	Vast destruction and loss of life; major tsunami devastated Hawaii and caused damage to east coast of Australia.
1964	Alaska (USA)	ML 8.6	131 lives lost; damage over US$300 million; permanent displacement of shorelines up to 10 m; tsunami generated with serious damage to Hawaii.
1976	Tangshan (China)	ML 7.6	Estimates of 1 million killed; great economic damage.
1985	Michoacan (Mexico)	ML 8.1	9,500 killed; damage more than US$3 billion; devastation in Mexico City.
1988	Armenia (USSR)	ML 6.2	More than 25,000 killed; 58 towns or villages completely destroyed.
1989	Macquarie Is. (Aust)	ML 8.3	Possibly largest earthquake in Australian territory; strongly felt at Macquarie Is. Base; tsunami generated observed in Tasmania.
1989	Newcastle (Aust)	ML 5.6	Australia's first fatal earthquake with 13 killed; total damage estimate of A$4 billion.
1990	Iran	ML 7.5	More than 20,000 killed; many villages totally destroyed.

reference is to the 'recurrence interval' or 'repeat time' for the occurrence of a major earthquake. In broad terms, the human memory is short when it comes to understanding the potential for disasters when they are not an intimate part of our everyday lives.

The people of California, Japan, New Zealand etc. totally accept the potential for earthquake damage and are consequently well prepared for future occurrences. They experience the phenomenon many times in their life span. Those of us who reside in places like Australia or the central and eastern USA do not have such experiences. Major earthquakes may have occurred once in a lifetime (say, 100 years) or once in a few hundred years. The 'repeat time' may have been statistically determined at 1000 years, so the apathy of 'why worry' is clearly understood. But, the question that really must be considered is: 'When did the last major earthquake occur?' In other words, when did the countdown begin for the next 1000 years? To answer this question, one must appeal to the earth sciences.

The science of geology is the unique subject to provide the answers. It is underrated and hence considered a minor player for our existence on Earth, although it is the essence of the Earth itself. Many people still consider that if there is not a San Andreas Fault in their region then they are not prone to earthquakes. They fail to realize that such an obviously exposed fracture as this is not the sole evidence for earthquake sources. As geological studies of continental areas progress (for example: Johnston and Kanter, 1990), it is becoming more evident that the earthquake problem is very real in such regions. Such information begins to unlock the deep-seated structures of the Earth's crust indicating that such 'buried features' are lines of weakness which may be the source of earthquakes in the future. An integral part of the studies includes the time factor. Our knowledge of the age of such fractures, the timing of geological events, including the dating of a possible large earthquake in the past, and hence a better understanding of Earth processes, is ever increasing.

We do have earthquakes in Australia. Several damaging earthquakes have occurred since European settlement began in 1788 and the prognosis for others is evidenced in our geological record. Unfortunately, Australia has not realized that such information is openly available in our historic records. As a consequence, governments and the community at large, have not considered that serious studies into the potential earthquake problem are worthy of scholarship. Maybe the fact that our fel-

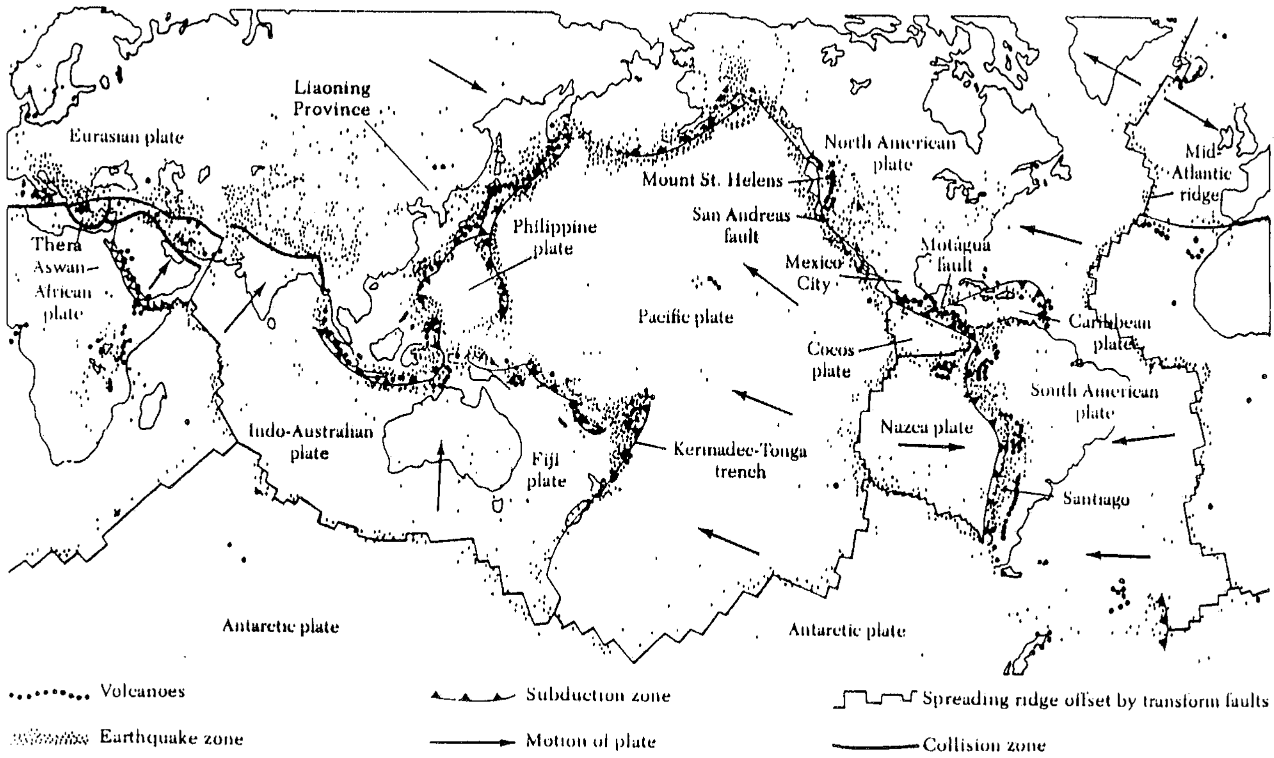

Figure 1: Bolt's (1988; Figure 4) world map showing Plate Tectonics with the relationships between earthquakes (small dots), volcanoes (large dots) and major tectonic plates.

low citizens have been killed and injured and immense property damage has been inflicted on our community as a result of the 1989 Newcastle earthquake will shock Australia into realism and promote serious attempts to study the problem.

Australia has much to learn from our international colleagues on the potential consequences of the earthquake phenomenon. In return, we have a lot to offer through the studies of continental geology, tectonics and earthquakes per se. The potential to reduce losses from earthquakes in Australia is an achievable goal well within the capabilities of the Australian community. Our participation in the International Decade of Natural Disaster Reduction (IDNDR) will only serve to improve the well-being of both Australians and the whole international community. The 'bottom line' is simple, yet most pertinent, to all Australians – the preservation of human life and the minimisation of serious damage to all structures and facilities in the event of future potentially damaging earthquakes.

Planet Earth is alive!

The surface of the planet as we know it today is the result of geological processes within the Earth. These processes are manifested primarily by earthquakes and volcanoes. Secondary effects such as beaches, floods, droughts, landslides etc. result from the interaction of the geological processes with those of the atmosphere and biosphere. Further perturbations are evidenced through humanity's action of pollution.

The Earth supports mankind. It is the platform on which we live and provides all our resource requirements whether they be for sustainable development, recreational beauty or urban development. The price humanity must pay is the acceptance of natural disasters.

The generally accepted model to explain the actual features of the Earth is the theory of 'Plate Tectonics' (Figure 1). This postulates that the Earth's surface is comprised of several crustal plates which are continually moving in relation to each other. To maintain the physical balance of the planet, earthquakes and volcanoes release the stress build-up, most frequently in specific regions – the plate margins. For those regions distant from these margins – the intra-plate or continental regimes – there are also stress concentrations in the crustal rocks, but this stress release occurs far less frequently. It is, however, just as violent.

Planet Earth is thus alive and well. It will continue to be so for years to come. Consequently, no region on the surface of the Earth can claim to be devoid of earthquakes. Developed intra-plate areas, such as urban Australia, must therefore be fully aware of the potential for these natural disasters, albeit at much lower frequency than their plate margin counterparts.

It is apparent that the extent of earthquake damage in many regions has increased over the last few decades. No conclusive evidence has been given to prove the premise that the frequency of damaging earthquakes is increasing. It is, however, a fact that urbanisation is expanding at a great rate and, as such, the damage potential of a future earthquake must also increase. This latter point must be the premise as to why an international effort to mitigate the earthquake hazard is vital for humanity's survival.

Mitigating the earthquake hazard

The earthquake hazard is always present. As science cannot predict the occurrence of earthquakes at this time, we must realize and accept the adage that earthquakes occur 'anywhere, at any time, of any size'. Experience has clearly shown that this is indeed the case. It is thus the duty of all citizens, whether they be scientists, engineers, seismologists, government or the general public, to clarify their roles in mitigating the potential effects of a disastrous earthquake. That is, there must be awareness and preparedness before that event such that the emergency plans can be put into operation efficiently in the post-earthquake phase.

The situation was most succinctly described by Professor Frank Press in his keynote address to the Eighth World Conference on Earthquake Engineering in San Fransisco in 1984 (Press, 1985):

> But (earthquake hazards) come with the territory. They are rare, low probability events with disastrous consequences that are large in terms of destruction – which leads me to my first generalisation. The class of hazards characterised by low probability of occurrence and high consequences presents a difficult public problem: how to sustain public interest and involvement; how to attract adequate government resources for mitigation programmes? It's easy to understand how a country with a recent severe catastrophe such as Tokyo in 1923 or Tangshan in 1976, can become concerned and organise national programmes. But it is the height of a civilised society to anticipate and control rather than to react only after a disaster. My second generalisation: earthquakes are a special category of hazards in that most human losses are due to failure of human-made structures – buildings, dams, lifelines, and so on. Therefore, in principle, with sufficient resources for research, development, education, followed by necessary investments in hazard reduction, earthquakes are a hazard that are within our power to respond to.

Recent studies of continental earthquakes have raised a question as to the definition of the 'rare' event. In the light of the 1989 Newcastle earthquake, studies of the earthquake history of the Newcastle region (Rynn and Hunter, 1990) reveal that three damaging events have occurred since habitation of the region: 1868, 1925 and 1989. Many citizens experienced two of these in their lifetimes. Several floods and severe storms have occurred in this region in the last 150 years. In considering the southeastern USA, the last major events to occur (indeed the only ones recorded in European history in that region) were in 1811-1812 (New Madrid, Missouri) and 1886 (Charleston, South Carolina), 100-200 years ago. Certainly in terms of geological time, the above are not rare events. It is conceivable that the community may need to temper the definition of 'rare events', at least in terms of the lifetime of engineering structures and critical facilities.

Mitigation measures are now common practice in high frequency prone earthquake areas such as Japan and the western USA. This contrasts to Australia where recognition of the need was unusual. This situation must be immediately rectified – but with a *caution* to the decision makers in both government and private sectors not to over-react to the magnitude of the task bought home by the 1989 Newcastle earthquake.

Risk and affordability

Despite all the scientific and political rhetoric, the end product is the basic perceived need for the community to be able to afford the proposed mitigation programs. While seismology can provide a quantitative estimate of the earthquake risk for a region, there is the need for extreme caution (a) in applying such risk estimates in engineering design so as not to over-state the risk, and (b) not to under-state the risk for expediency and financial gain (the engineering 'consultant/client' and/or the insurance 'company-insured' relationships).

There needs to be a realistic balance between the need for preservation of human life and the economic consequences of a disastrous earthquake. The essential ingredient for this is the provision of practical earthquake codes and building regulations, a task well within governmental responsibility.

It has been clearly demonstrated by the post-earthquake studies of the Newcastle event that the consequences of the earthquake could have been substantially reduced if some simple, minimal cost engineering practices had been taken into account (Page, 1990). The lesson is that preparedness must include these important social issues.

Table 2. Earthquakes in Australia

1892	Tasman Sea	ML 6.9	Largest earthquake known in eastern Australia, to NE of Tasmania (MM max VII).
1897	Beachport (SA)	ML 6.5	Damage in Kingston-Beachport area (intensity MM max IX).
1918	'Queensland'	ML 6.3	Damage in Rockhampton and Bundaberg (MM max VII)
1941	Meeberrie (WA)	ML 7.2	Severe damage to 'Meeberrie' homestead and facilities (MM max VIII); widespread damage small due to low population.
1954	Adelaide (SA)	ML 6.2	Considerable damage to property in Adelaide and environs; insurance claims A$4 million.
1968	Meckering (WA)	ML 6.9	Devastated the small town of Meckering (MM max IX) and caused some damage in Perth; fault scarp produced.
1973	Picton (NSW)	ML 5.5	Damage in Sydney area; insurance claims A$0.5 million.
1979	Cadoux (WA)	ML 6.2	Considerable damage to small town of Cadoux.
1989	Newcastle (NSW)	ML 5.6	Disastrous effects on Newcastle and region; Australia's first recorded deaths, 13 people; felt over area of 200,000 sq km with damage area over 9,000 sq km; damage est. A$4 billion including insurance losses A$1-2 million.

IDNDR: a vital cause

The International Decade for Natural Disaster Reduction (IDNDR) offers the opportunity for international scientific cooperation into the reduction of suffering from all types of natural disasters. Based on the initiatives of Professor Frank Press and the US National Academy of Sciences, the concept was unanimously accepted in December 1987 (Advisory Committee on the IDNHR, 1987; U.N. General Assembly, 1987; Oaks, 1988). The premise was based on interdisciplinary cooperation worldwide wherein a free exchange of ideas and information would lead to mitigation of all natural hazards in all countries. Australia's role is to show a concerted effort both for our own nation and our neighbours in the South-west Pacific Islands.

With specific regard to earthquake mitigation, our local efforts have obviously been boosted by the 1989 Newcastle earthquake. For example, consider the efforts of the Centre for Earthquake Research in Australia (CERA) based at the University of Queensland. Many of its suggestions for needs in earthquake engineering have now been formalized through a multidisciplinary research team investigating the seismic hazard (Figure 2). Within Queensland close associations have been forged with the emergency service agencies, local government authorities, engineering companies, the insurance industry and sociological groups integrating their needs with the earth sciences. Interstate links have been made with the Newcastle City Council and the University of Newcastle. Internationally, two projects are currently being planned with the US National Academy of Sciences and the Lamont-Doherty Geological Observatory of Columbia University in New York – all in the true spirit of international cooperation.

The scene is now set to produce meaningful and practical results. As stated by Dr Riley Chung (US National Academy of Sciences) in his Distinguished Lecture to the Australasian Institute of Mining and Metallurgy PACRIM 90 Congress at the Gold Coast in May 1990 (Chung, 1990):

> [For hazard mitigation], disaster preparedness can reduce death and injuries but it does little to prevent property damage and sometimes devastating economic impacts associated with disasters. This is where hazard mitigation plays a key role:
>
> - *prevent or modify* the occurrence of the hazard;
> - *site structures* and functions away from the hazard – land use planning;
> - *design and construct* new structures using modern building codes and regulations;
> - *design cost effective techniques* for strengthening existing vulnerable buildings;
> - *improve design* of new lifeline systems and develop methods to economically strengthen existing systems.

Earthquakes in Australia

The public perception was, until recently, that Australia is a stable continent and therefore not sus-

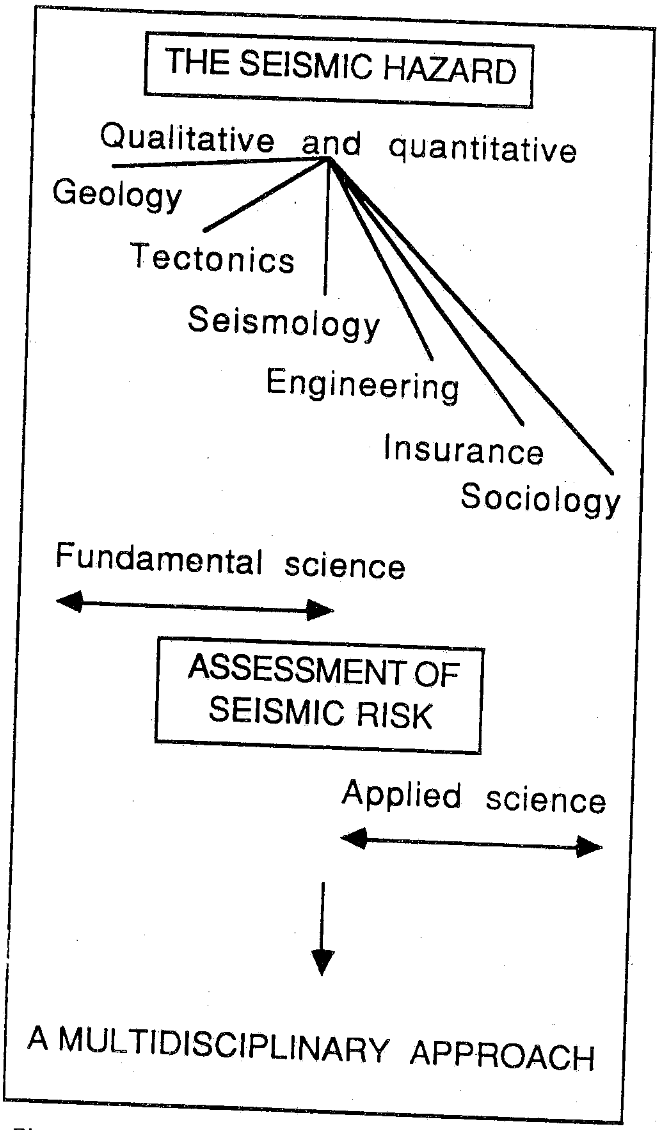

Figure 2. A multidisciplinary approach to understanding and defining the seismic hazard for the mitigation of the consequences of earthquakes.

ceptible to damaging earthquakes. In our short history (202 years), several thousand earthquakes ranging from micro-earthquakes (Richter magnitudes ML 0.0) to major earthquakes (ML 7.0) are known to have occurred. The most recent map of earthquake epicentres is shown in Figure 3.

Earthquake distribution can be broadly classified into seven loosely defined major regions of activity: central Australia (Simpson Desert); southwest Western Australia; north of Adelaide; northwestern Western Australia (Canning Basin), Wide Bay-Burnett region (north of Brisbane); Sydney-Canberra area; and the Bass Strait region. The first reported earthquake occurred two months after the First Fleet landed at Botany Cove. Since that time, more than 200 events have been felt by the local populace, some of these causing considerable damage (see Table 2).

Other major earthquakes have occurred but their locations have been in remote areas of the continent and thus no property damage was inflicted, for example Marryot Ck (SA) in 1986 (ML 6.0, fault scarp produced) and Tennant Ck (NT) in 1988 (ML 6.7, three earthquakes in 12 hour period of ML 6.2, 6.4 and 6.7; fault scarps produced).

It is important to emphasise the area over which the effects of these intra-plate earthquakes are experienced. These areas are much larger than earthquakes of the same size (Richter magnitude) occurring on plate margins. As an example, consider the 1918 ML 6.3 'Queensland' earthquake, the effects of which were felt over an area of more than 300,000 sq km up to 500 km from the epicentre (Figure 4).

The 1989 Newcastle earthquake

At 10.27am (local time) on Thursday, 28 December 1989, the cities of Newcastle and Lake Macquarie and their environs were devastated by a moderately-sized (in seismological terms) ML 5.6 earthquake. This was Australia's first recorded fatal earthquake claiming 13 lives, with more than 160 persons injured.

The epicentre has been located near Boolaroo about 15 km WSW of the City of Newcastle (McCue, Wesson and Gibson, 1990). Previous damaging earthquakes occurred in 1868 and 1925 (both with ML 5.5) and since the establishment of the southeast Australia seismolograph network in 1954, many other smaller events (ML 4.0) have been located in the region (B Kennett, ANU, pers comm 1990). The locations of these earthquakes are shown in Fig. 5.

The effects of this earthquake were experienced over an area of 200,000 sq km (Figure 6). Damage was extensive with more than 50,000 buildings affected. The area of damage (Modified Mercalli intensities MM V to VIII) covered an area of about 9,000 sq km extending south to Sydney (140 km distant), northwest to Scone (145 km) and Cassilis (100 km) and north to Kempsey (320 km). Residents in high-rise buildings on the Gold Coast (650 km north) and Melbourne (800 km southwest) reported 'swaying motions'. At this time, the insured loss stands at A$1.2 billion with a total estimated loss of A$4 billion. This earthquake has completely changed the nature of the Australian earthquake hazard.

Other important results include the long duration of shaking of up to 42 seconds, the large proportion of long-period energy observed on the seismograms, reports of effects to shipping and the ocean floor off Newcastle, some initial damage to life-lines and the still-continuing sociological effects.

Of significant note are the geological conditions which appear to have controlled the damage to buildings and the extent of this damage (Brennan 1990). Most of the damage effects can be directly related to the siting of buildings and the wet sediments of river and estuarine areas. This may be related to

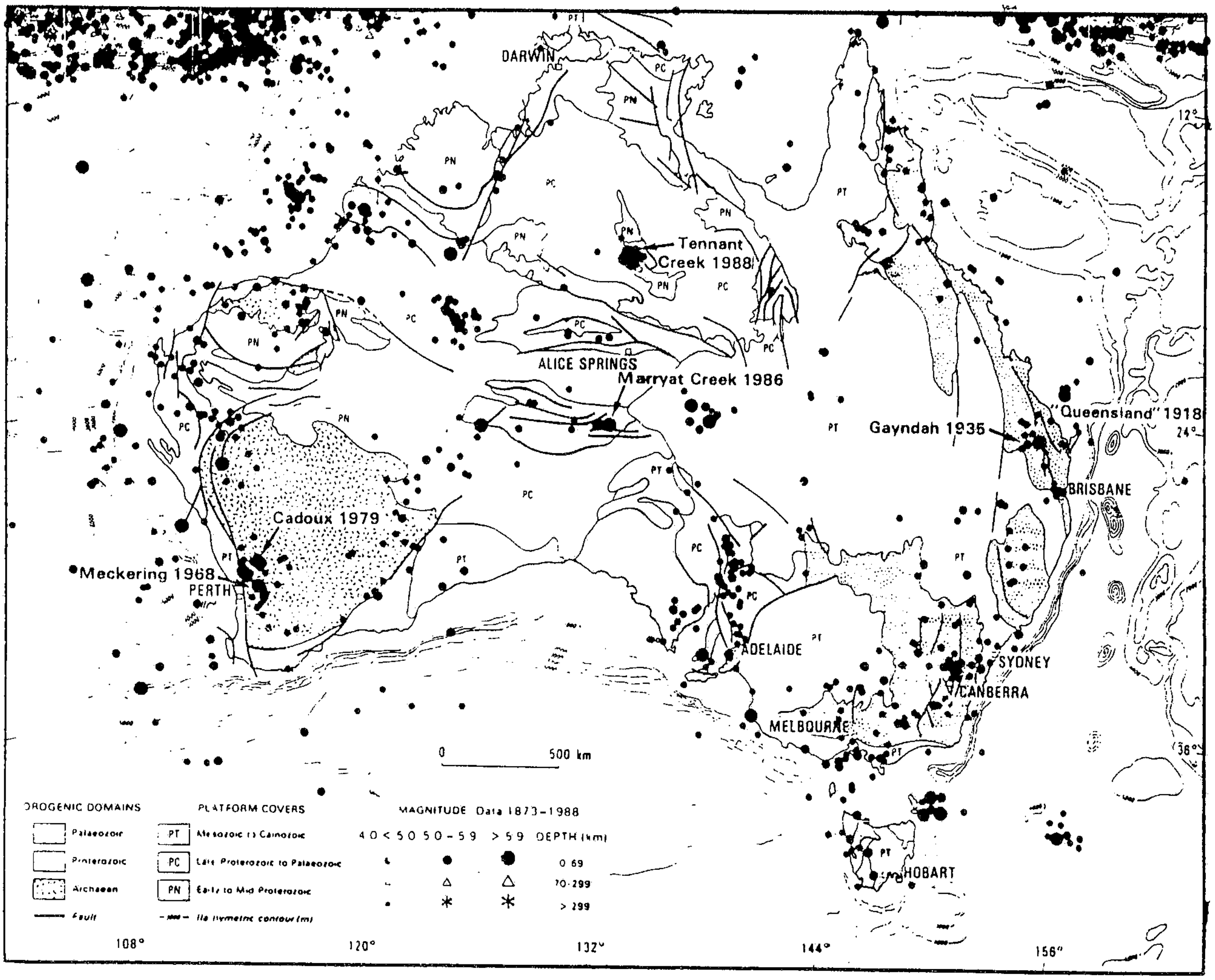

Figure 3: Earthquake epicentres in Australia for ML 4.0 (Bureau of Mineral Resources, Canberra, Australian Earthquake Data File; from Gaull, Michael-Leiba and Rynn, 1990).

the liquefaction of sediments (although no direct evidence has been observed) and the amplification of the seismic waves at the surface, as evidenced in the 1985 Mexico earthquake.

Published information has now become available on the seismological effects (Rynn, 1990), geological controls (Brennan, 1990), engineering effects (Melchers, 1990; the Institution of Engineers, Australia, 1990) and other reports by the Newcastle City Council, the University of Newcastle Faculty of Medicine, and various governmental agencies.

Earthquake risk in Australia

Since 1979, Australia has operated under the Standards Association of Australia 'Earthquake Code' AS2121-1979 (Figure 7). This was based solely on the available (Bureau of Mineral Resources) earthquake catalogue for events before 1976. Although of limited use to the practising engineers, it has been Australia's only guide to potential earthquake loads for the design of structures.

New probabilistic earthquake risk maps have recently been published (Gaull et al, 1990; Figure 8). These are a vast improvement on the earlier version as they employed the most comprehensive earthquake catalogue available (up to 1985) and the most recent risk computation methods. Revisions to AS2121-1979 are being based on these results.

Preliminary analyses of the 1989 Newcastle earthquake data have yielded results which identify several shortcomings of the current philosophy in revising AS2121-1979. Vulnerability to an ML 5.5 earthquake must be based on the experience in Newcastle. Kanter (1989) clearly indicates that such 'low magnitude events occur in about any tectonic setting'. This in no way precludes the need to consider large magnitude earthquakes up to ML 8.0 or greater. Such events have occurred in continental eastern USA. The Newcastle earthquake has also shown that qualitative geological information, including liquefaction and amplification, must be in-

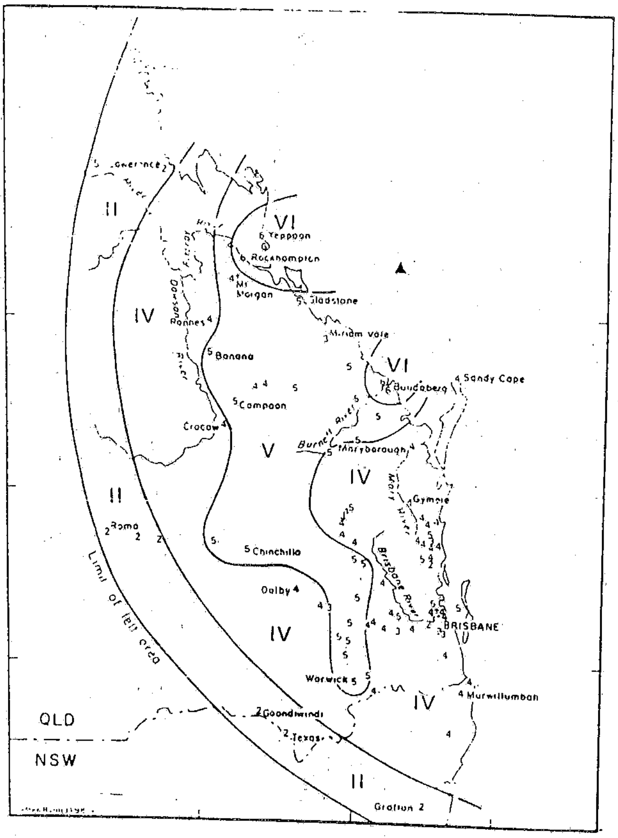

Figure 4:Isoseismal map (contours of Modified Mercalli intensities MM asigned to 'felt reports') for the 6 June 1918 'Queensland' earthquake of ML 6.3.

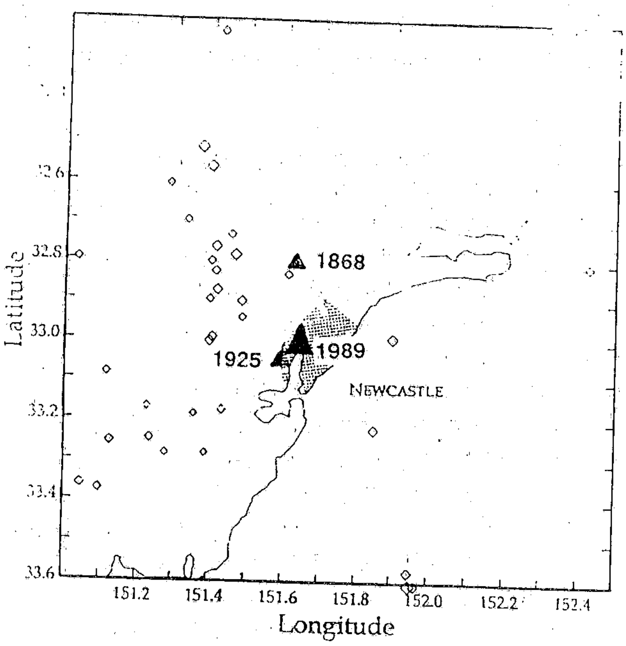

Figure 5:Epicentral map for the 1989 earthquake and historic seismicity. 1958-1989, 2.0<ML<5.0 (from B. Kennett and J. Weekes, RSES, ANU, Canberra). Historic earthquakes: 1868 ML 5.3 (McCue 1989), 1925 ML 5.3 (Rynn et al 1987). 1989 earthquake, ML 5.6., epicentre 15 km WSW Newcastle, focal depth 11km, thrust fault mechanism. McCue et al 1990.

cluded in risk estimates in a quantitative way. This is already noted in the literature (for example: results of studies into the 1985 Mexico earthquake).

Studies of recent disastrous earthquakes in all regions of the world emphasise the need for engineering input in seismic risk studies, a situation well known and highly utilised for many years in the western USA. Engineering provides the 'link' between the fundamental earth sciences and the necessary applications for community benefit. One aspect that is of great importance to earthquake engineering is the level of uncertainties in seismic risk estimates. This has been included in the studies of northeastern Australia (Rynn, 1989) where it is shown that risk estimates could be underestimated by a factor of two when seismologically reasonable uncertainties were incorporated in the required earthquake parameters for risk calculations.

All aspects necessary to provide a practical code for earthquake design loads must be taken into account when revising the Earthquake Code. In the current revision of AS2121-1979 for Australia, Boyce (1990) succinctly states the objectives. These include a detailed analysis of all available earthquake data for provision of an internally consistent and reliable data base, the use of a multidisciplinary team to research the necessary provisions for the code, the adoption of the US Applied Technology Council and UK Comité Euro-International da Beton provisions as bases for the code, the incorporation of all available local and international information, giving consideration to community requirements and revising the code on a regular basis.

It is only with a realistic and practical earthquake loading code, and its integration into relevant building codes, that Australia can begin to prepare for a safe future through the engineering approach to the mitigation of earthquake hazard.

The potential to reduce losses

The potential to reduce losses from earthquakes in Australia must now be considered in earnest. The necessary information and research aims are available from both within Australia and the international arena. A dual approach is required (Hamilton and Johnston, 1990; Rynn, 1989) (Figure 9):

- goals for community actions
- a multidisciplinary approach.

This can be translated into the vital concepts of awareness, preparedness and mitigation. The prognosis of hazard and risk assessment has been discussed by Chung (1990):

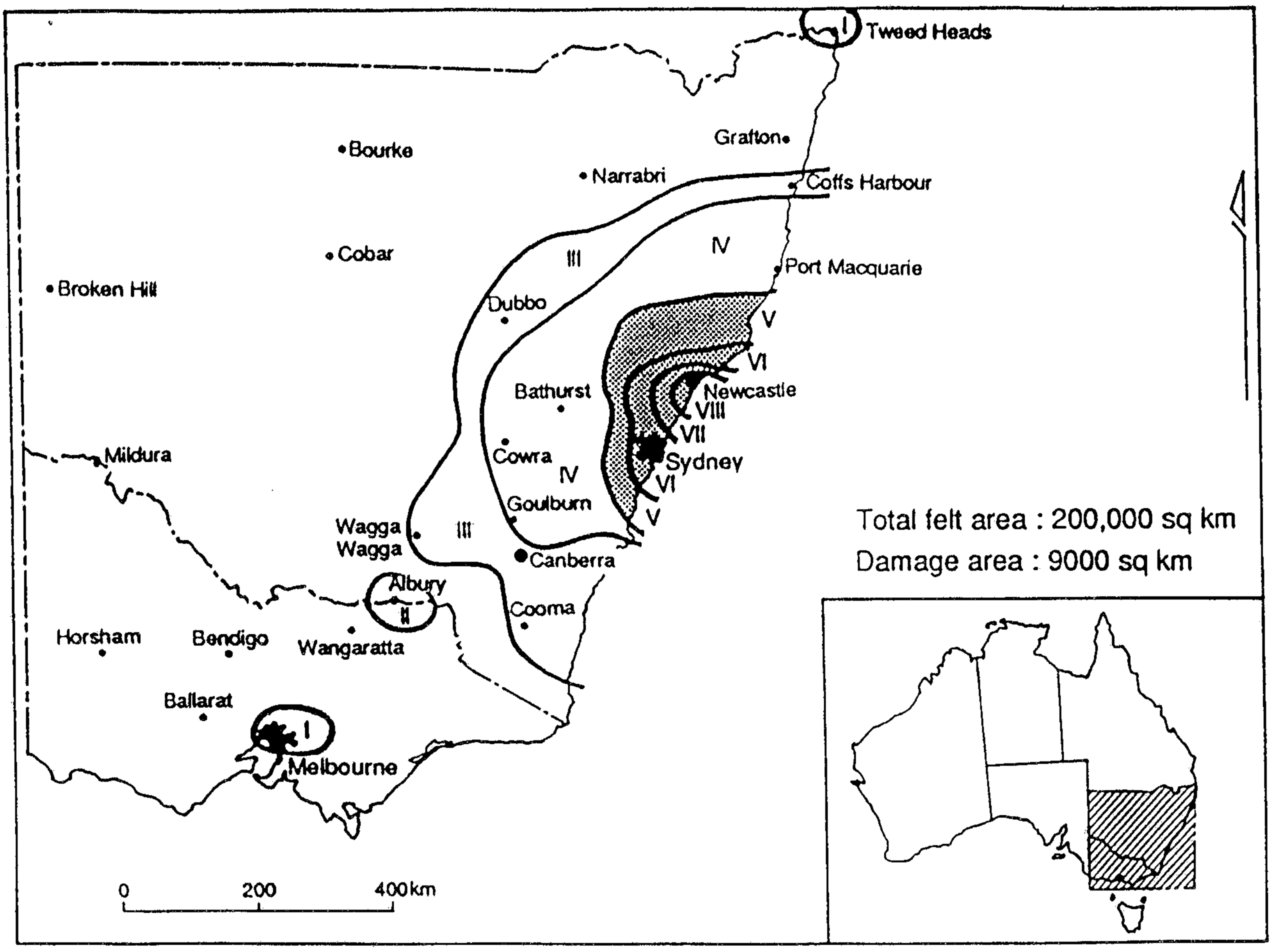

Figure 6:Isoseismal map for the 1989 Newcastle earthquake.

Risk assessments of the nature, extent and consequences of natural hazards lie at the core of adopting efficient and economic actions to lessen catastrophic potential. Assessment has three essential features:

- determination of the hazard
- determination of the vulnerability of the structures and facilities exposed
- determination of the significance of the impacts.

Earthquake hazard as a natural disaster must be clearly understood:

- it is most devastating of all natural disasters
- there is no warning at all
- it is significantly different from other more common disasters to which the community is accustomed;
- natural disasters include cyclones, floods, winds, severe storms, bushfires, storm surges, droughts
- man-made disasters include road accidents, fires, chemical spills, explosions, pollution.

The primary aspects of all the earthquake hazards are: ground displacement, ground shaking, landslides, mudslides, soil liquefaction, tsunamis, damage to facilities such as buildings and lifelines, dam failures, levee bank failures. Secondary aspects include: fires, floods, disruption to services, insurance costs, sociological effects, economic effects and long-term effects.

The Australian community must realise that, with the exceptions of dam and levee bank failures and floods, Australia has experienced all the other effects.

One must now consider the situation today. Firstly, a comparison between Australian and Californian earthquakes will serve to establish a significant level of vulnerability as shown in Figure 10. Secondly, in a purely Australian situation there must be recognition, and understanding, of the following 'lessons from Newcastle':

1. Devastating earthquakes can occur in Australia;
2. Serious earthquakes can strike any region of Australia whether it be the uninhibited deserts or the highly urbanised cities;
3. Continental (intra-plate) earthquakes affect large areas;
4. The engineering community must be more responsible in its attitudes toward earthquake design of structures; this would lead to more ef-

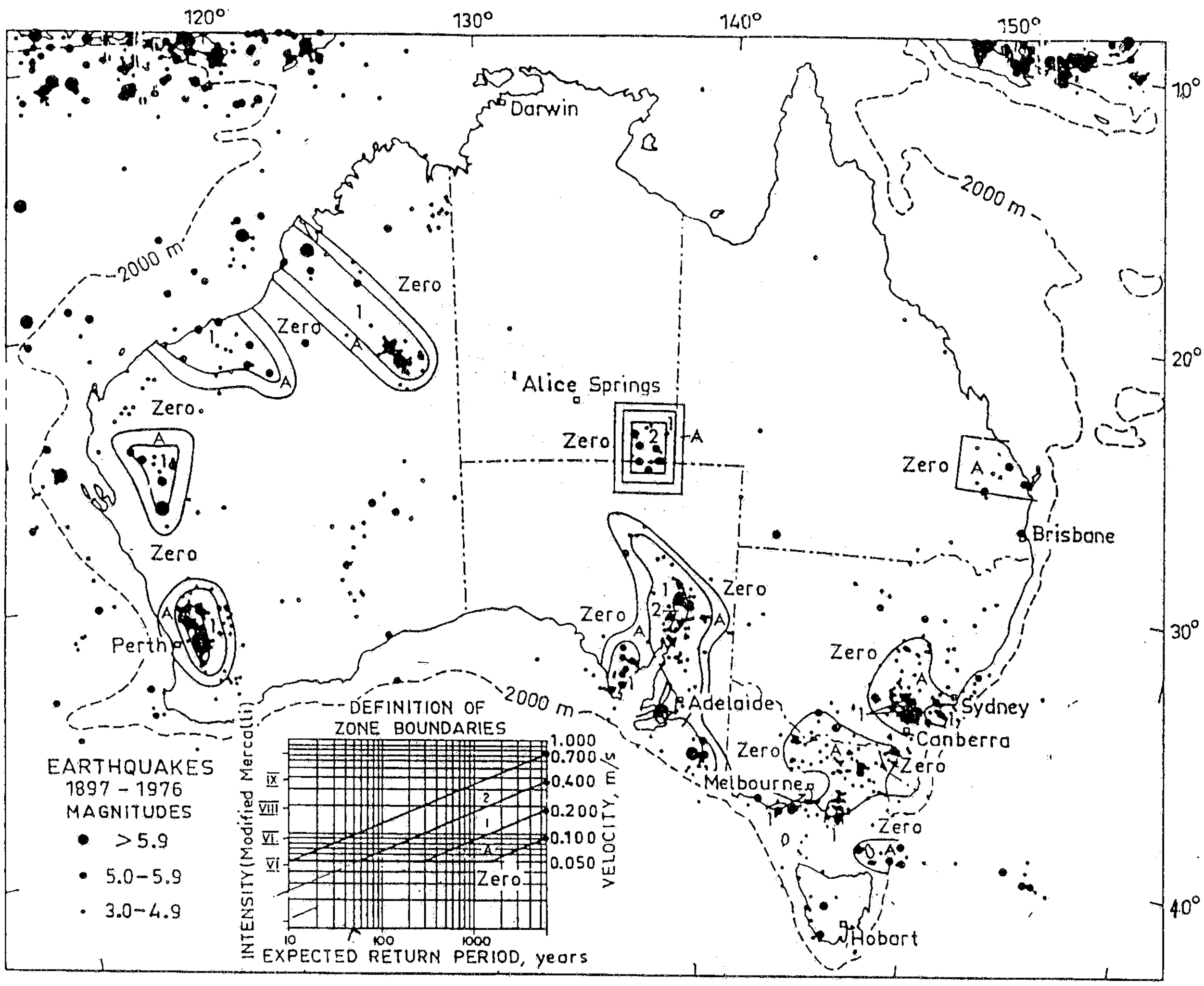

Figure 7: Standards Association of Australia Earthquake Code AS2121-1979 seismic risk map of Australia.

fective regulatory procedures through relevant codes of practice;

5. The vital importance of geological controls must be recognised;
6. A moderate sized earthquake ML 5.6 inflicted major damage on communities - and effective measures to mitigate larger earthquakes must be considered seriously.

To these ends, Australia must support, both with encouragement and realistic funding, continued efforts in earthquake research. There is an obvious need for more instrumentation, including seismograph stations and accelerometer sites. There is just as obvious a need for the total cooperative efforts of *all* parties involved. Attitudes of pure personal gain, professional jealousy and lack of commitment must be excluded from our studies. Professional ethics must be strictly maintained as we are dealing with a 'life-and-death' situation. Australia's commitment to the United Nations IDNDR program will also be a vital addition. These endeavours are essential to promote research, provide information exchange, improve disaster planning and management and thus educate the community to this hazard.

The potential to reduce losses from future earthquakes is indeed both a realistic and achievable goal, well within the capabilities of the Australian community. The way ahead is clear and concise - undertake a multidisciplinary approach to fundamental and applied research in the Australian continental context to mitigate the earthquake hazard for the betterment of the future welfare of Australia. Our efforts can take the ultimate lesson from the boy- and girl-scouts of the world - be prepared!

Acknowledgements

The comments reflected in this paper are a result of the multidisciplinary team effort afforded over many years through CERA at the University of Queensland with particular acknowledgement to R. Barchard, W.H. Boyce, E. Brennan, C. Featherstone, J.M. Fenwick, P.R. Hughes and D.J. Williams, and in

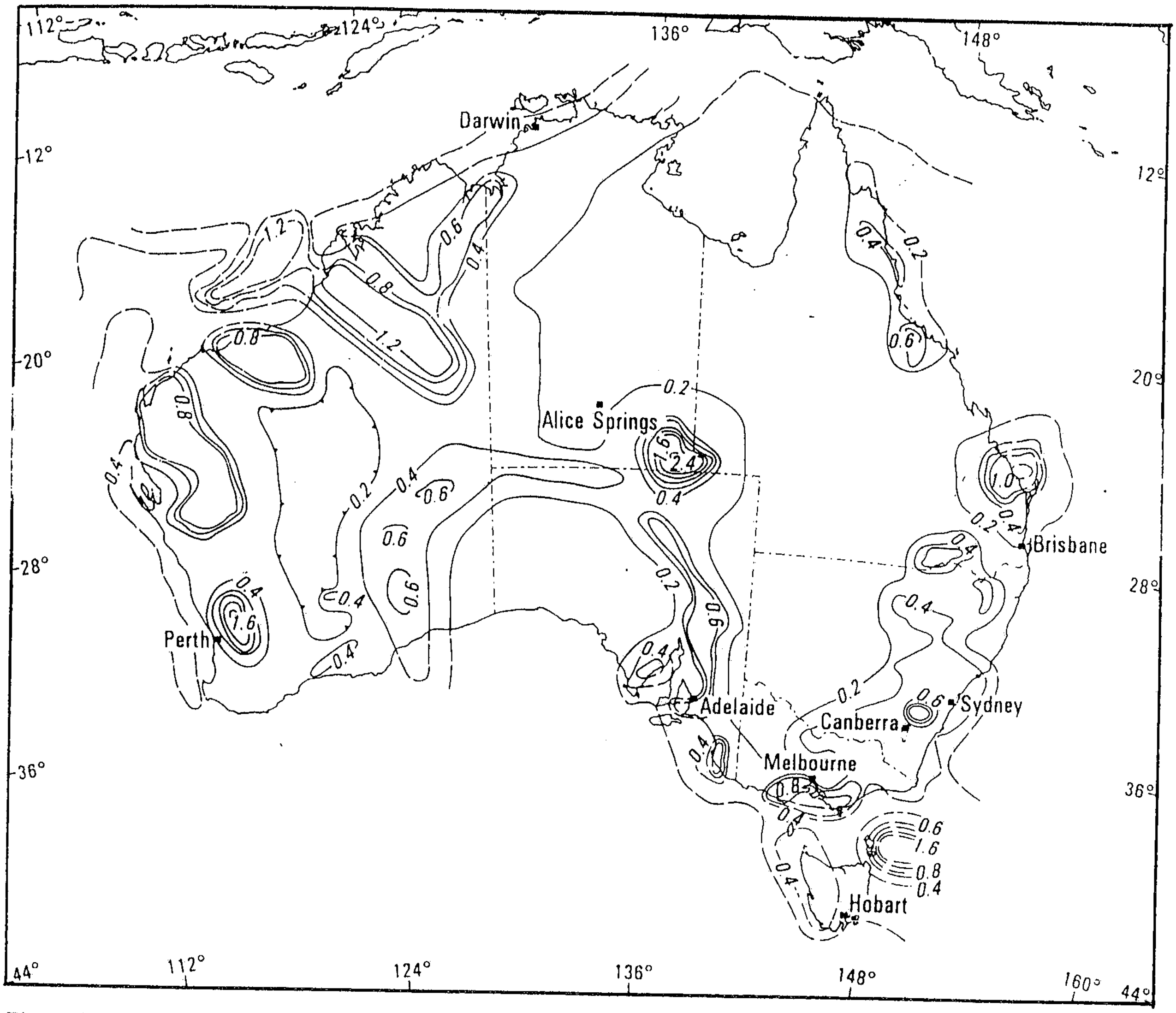

Figure 8: Probabilistic earthquake risk map of Australia in terms of peak ground motion acceleration (M sec $^{-1}$) with a 10% probability of being exceeded in a 50 year period (ie the 500 year event). (Gaull, Michael-Leiba and Rynn, 1990).

relation to the 1989 Newcastle earthquake with particular acknowledgement to Alderman J. McNaughton (Lord Mayor of Newcastle, Newcastle City Council (H. Stuart), Queensland Government Task Force (led by Sergeant J. Hopgood, Queensland Police), Newcastle Police District (Chief Superintendent R. Cook, Inspector T. Collins and Sergeant E. Riggs), and the University of Newcastle (Professor R.E. Melchers and Professor I. Plimer).

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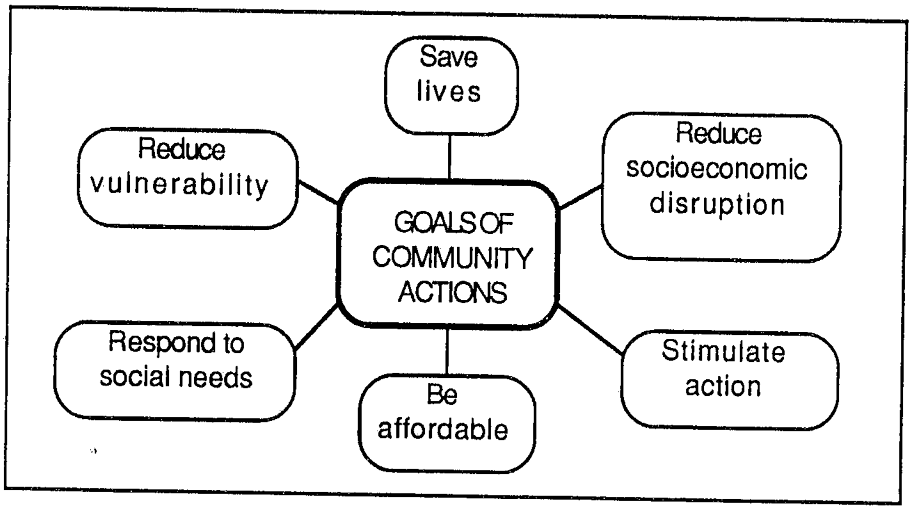
(a) Goals of community actions in implementing loss reduction measures (per W.W. Hays USGS, from Hamilton and Johnston, 1990)



(b) The multidisciplinary approach to earthquake research (Rynn 1989)

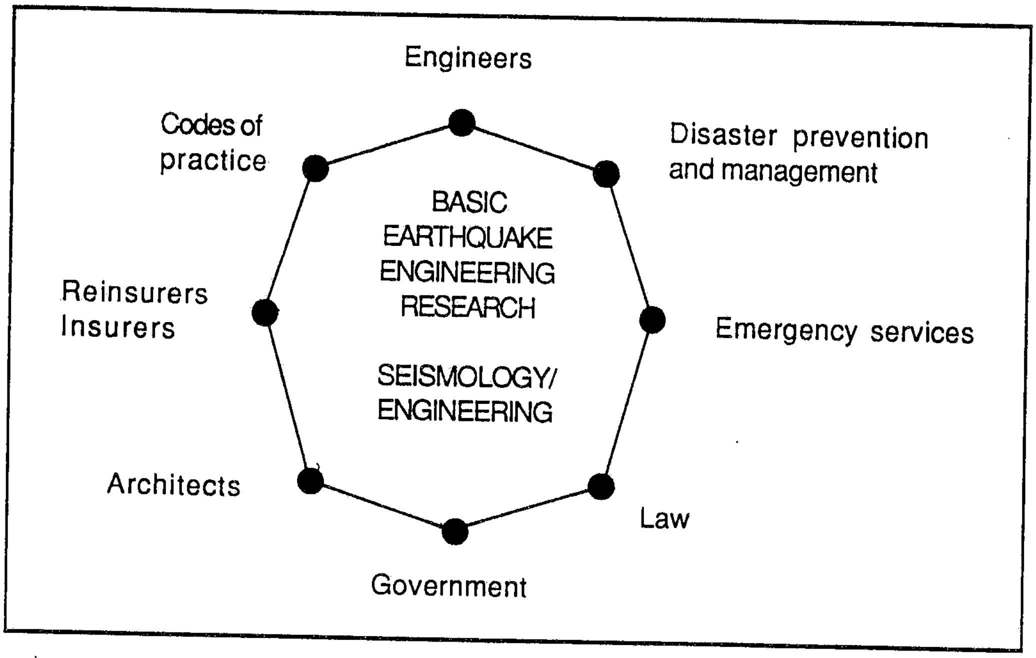


Figure 9: The dual approach for the reduction of losses from earthquakes.

	Intra-plate	*Plate margin*
Earthquake	28 December1989 Newcastle	28 February1990 Upland (Los Angeles)
Magnitude	ML 5.6	ML 5.5
Total felt area	200 000 sq km	9000 sq km
Damage area	9000 sq km	about 50 sq km
Total damage	US$4 billion (est)	US$10 million
Aftershocks	5, ML (max 2.7)	more than 400, ML (max) 4.8

Figure 10: Comparison of a continental (intra-plate) earthquake and a plate margin earthquake of the same Richter magnitude.

The potential to reduce losses from flooding in Australia

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Abstract

The natural hazard of flood poses ever-present risks for both rural and urban Australia. The potential for the reduction of flood losses is much greater for the latter. An analysis of urban flood damage shows that losses for the commercial and industrial sectors are more than twice those for residential property. Most available data for flood damage relates to floods with an annual recurrence probability of more than 1% (the 1 in 100 year flood). The magnitude of damage from more extreme flood events is much greater due to the increased depth and velocity of floodwater causing building collapse. For some regions floods larger than the 1 in 100 year event contribute as much to the average annual damage as those below.

The further development of floodwarning systems has the potential to greatly reduce urban flood losses. However to accomplish this potential it will be necessary to improve the methods of disseminating the flood forecast to the community at risk and to improve the response of the residents. This will require new approaches to the problem although the benefits are thought to far outweigh the costs. The IDNDR could act as a focus for the research and implementation of methods to achieve the potential savings offered by floodwarning systems.

Introduction

Over the last twenty years natural disasters have killed nearly 3 million people and disrupted the lives of over 800 million others (Press, 1988). National and personal tragedy is illustrated by the following statistics from Bangladesh. The floods of 1988 inundated 84,000 km^2 (well over half of the country), directly affected 30 million people (5 million of whom were marooned), totally destroyed nearly a million homes and severely damaged a further 1.5 million, 70,000 km of road were damaged and over 1500 lives were lost. This flood, arguably the worst on record, followed extreme floods the previous year which inundated 57,000 km^2. These data are taken from an excellent account of the flood problems in Bangladesh (Ahmad, 1989). This reviews not only the losses but provides information on the technical aspects of flood risk, the mitigation options and the part that could most usefully be played by overseas aid. What is required are contributions from the developed world to fund an agreed national plan for flood damage reduction.

Before considering the Australian flood problem, let me give one further statistic. Some 500 million Chinese are at risk from river flooding, they represent some 15-20% of the population of the world.

Both natural disasters and flooding are matters of worldwide concern. The emphasis placed upon these problems by the United Nations Assembly in declaring the 1990s the International Decade for Natural Disaster Reduction is completely justified. There is no doubt that Australia should join other member nations in providing assistance, technical and financial, to poorer, disaster prone nations. However, there remains ample scope for the Decade to act as focus for measures to reduce flood losses in Australia itself.

Defining flood losses

There is no reason to doubt the overall magnitude of global natural disaster damage given as background to the IDNDR. However, estimates of damage for individual disasters are notoriously poor. This also applies to flood losses which are arguably among the easiest to assess. Floods are visible, spatially easy to delimit and much of the damage is easy to cost. Despite this, estimates of overall annual flood damage at national level are sparse and frequently based on information gleaned from contemporary newspaper accounts. The availability of reliable estimates for hazard damage is a necessity if they are to be of value in studies designed to reduce losses from future flood events. There is also a need to classify losses into precise categories.

Detailed studies and classification of flood losses began some fifty years with the pioneering work of Gilbert White in the USA (White, 1945). Indeed, there is a strong case that cost benefit analysis itself was first used (by the US Corp of Engineers) to assess the effectiveness of flood mitigation measures for the lower Mississippi Valley. The study of flood losses has a longer history and more refined analytical tools than that for any other natural disaster. Although this account is concerned with the reduction of flood losses in Australia, much of the methodology is applicable elsewhere, and for other hazards.

Definitions of damage

The definition and classification of damage categories is important in order to highlight those that are capable of reduction and to give an understanding of the size of damage reduction that could be achieved. The initial classification, basic to all natural disaster damage, is into tangible and intangible losses; the former is divided into direct and indirect categories.

- Direct damages are those that result from the inundation of crops, buildings and their contents by flood waters and their sediment load.
- Indirect damages are from the disruption caused by the presence of the floodwaters. These typically include the costs of alternative accommodation and storage, loss of trading profit, disruption of the transport network etc.
- Intangible damages include death and injury and a range of stress related effects.

While it is possible to quantify some aspects of the intangibles, such as costs of hospitalisation, in monetary terms it is usual practice to consider these effects qualitatively. It is now widely accepted that the intangible effects on health and well-being can be substantial and if they can be reduced the benefits are large.

Damage Sectors

Tangible and intangible losses are important but is also necessary to allocate these to distinct sectors. The basic division is into urban and rural. The emphasis is normally on urban losses and these are usefully further sub-divided into residential, commercial and industrial sectors with a further class for infrastructure. Information on residential, commercial and industrial losses is further subdivided into losses to buildings and to contents. In Australia the data for these categories and methods for their assessment are readily available, the major deficiency is often the provision of reliable information for infrastructure losses.

There is however, a paucity of information for the rural sector. This stems from difficulties in assigning values to crop and pasture losses. Such losses depend on the timing and duration of the inundation, compounded by debate over whether the gains in soil quality and water availability in floodplain locations are matched by the risks of flooding. Bluntly, whether the risks of inundation from floodplain agriculture should be considered a normal farm management risk. It is interesting to note that the recently released National Drought Policy (Drought Policy Review Task Force, 1990) presents powerful arguments that drought is a result of climatic variability and should be treated as a basic factor in farm management comparable to world prices, exchange rates and the like. It recommends that drought will no longer be eligible for Commonwealth relief payments. The same case can be argued for floodplain farming — purists would argue that the same principles apply to floodprone urban development. An additional classification of value for policies to reduce damage is into private and public sector losses.

Actual and Potential

The division of losses into actual and potential is of particular significance for studies that aim to highlight the scope for future reduction in flood damage. Actual damage is the loss that results from a particular flood event. Potential damage is the worst case scenario and corresponds to the losses that would occur if no attempt is made to reduce flood damage. Initially these definitions may appear to have little practical significance, but this is not the case. The difference between potential and actual is termed 'avoidable damage'. How to decrease the actual damage and thereby increase the avoidable damage is a key to flood loss reduction in Australia.

Flood risk in Australia

It is a difficult task to provide national assessments of where and what is at risk from flooding. Indeed,

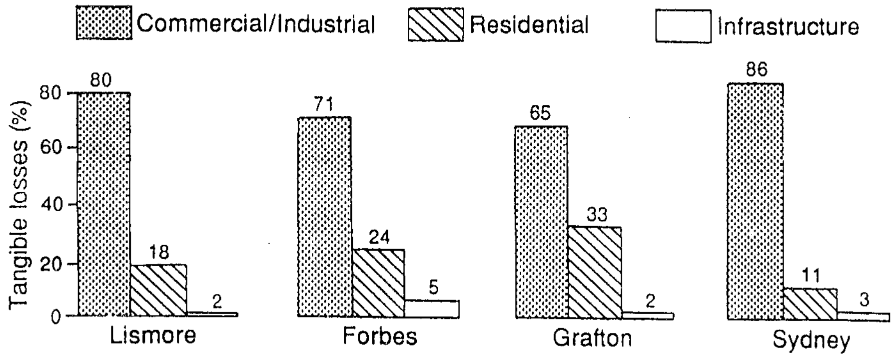

Figure 1. Losses as a proportion of average annual tangible damage.

it is difficult to reference a single national set of statistics that are comprehensive and reliable. The first problem is to define what is meant by flood prone. For urban regions the usual definition is to include areas within the 1 in 100 year flood zone. This is because that limit is frequently selected in Australia and elsewhere to define floodplain management policy. We shall see below, that such a definition poses difficulties for flood awareness and strategies to decrease damage. Planning standards for building development are based on the liability of the site to the 1 in 100 year flood. However, not all Australian urban communities have flood maps that clearly define the 1 in 100 year zone.

For rural areas the situation is worse; few areas have detailed maps of flood risk. This handicap is such that all national estimates of potential flood damage lack rural data. It is known however, that vast areas of Australia can be inundated, for example 30% of New South Wales was under water during the 1974 floods and huge areas were flooded in inland Queensland and NSW during the floods of early 1990.

These limitations are very real but Devin and Purcell (1983) published estimates for the number of urban centres and floodprone buildings at risk throughout Australia. These data are for structures within the 1 in 100 year flood limit and are grouped by major drainage division. The national total was 61,000; an earlier estimate, by Irish and Devin (1978), suggested a figure of 150,000. Subsequently, more detailed studies have been undertaken for NSW (Smith, 1984) and the number of buildings within the 1 in 100 year limit was assessed to be 45,000. The NSW study was the first to attempt to distinguish residential and commercial buildings; it is estimated that some 8500 of the NSW total are in the commercial and industrial sectors. More recent data, which have become available from detailed local studies following actual flood events, would likely increase this number. Another review of the Australian flood risk is found in Handmer (1989).

How big are the damages?

To assist with studies of damage reduction the areas liable to inundation and details of the buildings at risk need to be converted to damage estimates. The single most useful damage statistic is the annual average damage (AAD). This is the value that is pertinent for cost-benefit analysis of mitigation measures.

Because information is normally only available for floods to the 1 in 100 year limit the AAD values are also based on this value. There is no allowance for the contribution that the really big floods make to average damage. Like so many aspects of natural disaster research the nub of the problem is the balance of magnitude and frequency. This is particularly pertinent for floods as the larger the flood event the larger the flood depth and the greater the flood velocity. Big floods demolish building structures, smaller floods do not, thus the contribution of the extreme event is proportionately larger. Suffice it to say that for the floodprone area of the Georges River in Sydney approximately half of the AAD is contributed by floods greater than the 1 in 100 year (Smith et al, 1990). As the region has not experienced a worse than 1 in 20 year flood this century the full significance of extreme events has yet to be realised.

The literature on methodologies to assess flood damage, especially to the urban built environment, is extensive — far in advance of that for other natural hazards. The initial work was by White (1945) and Kates (1965) with major contributions and refinements by Penning-Rowsell et al (1975) and Parker et al (1987). In Australia such studies are the equal of those elsewhere and the computer package, ANUFLOOD, designed in CRES and marketed by the Australian National University, is widely used by government agencies and consultants. An account of ANUFLOOD is available in Smith and Greenaway (1988).

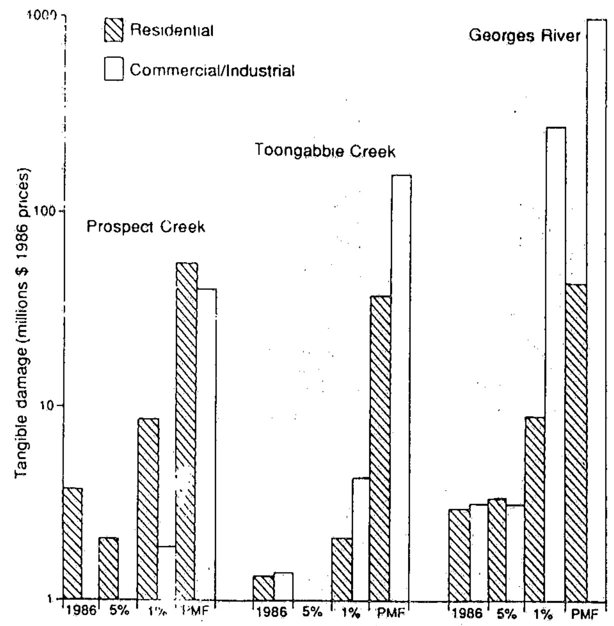

Figure 2. Tangible damage for flood events for three Sydney catchments.

What lessons can be learned from Australian studies on urban flood damage that could assist with measures to reduce flood damage?

The first is that damage to the commercial and industrial sectors normally far exceeds that in the residential sector. Figure 1 summarises the results of annual average damage (direct plus indirect) by sector for a selection of detailed flood studies. Figure 2 provides damage estimates (again direct plus indirect) for specific flood events for three urban flood prone catchments in Sydney, see Smith et al (1990) for further detail. It is clear that commercial and industrial damage far exceeds that for the residential sector.

Devin and Purcell (1983) used their national data on buildings at risk to estimate the AAD. The overall Australian value was $19m (1983 prices), but this is a gross underestimate for two reasons:

- All buildings are treated as though they were residential, i.e. there is no allowance for commercial and industrial losses.
- The damage data included only those buildings within the 1 in 100 year flood zone.

From the improved NSW data, Smith (1984) estimated the residential and commercial AAD for that state to be $10 and $15m respectively (1984 prices). This too, was limited to a consideration of property below the 1 in 100 year limit.

Detailed studies of the August 1986 floods in Sydney (see Smith et al 1990) incorporated information on damage to the probable maximum flood limit. The combined AAD for the Georges River, Toongabbie Creek and Prospect Creek catchments are $1.8m for the residential sector and $14.4m for the commercial/industrial sectors (at 1986 prices). Of the latter, $13.5m is contributed by properties in the Georges River.

Reducing losses

The accepted classification of strategies to reduce flood losses is into structural and nonstructural measures.

- Structural measures are designed to prevent loss by protecting buildings and the like from floodwaters. They comprise a range of engineering options such as levees, river diversions or flood mitigation dams. In Australia these are provided by government; for major schemes the costs are shared by local, state and federal government.
- Nonstructural measures modify losses; they are sometimes categorised as 'living with the flood'. The options are numerous and include all forms of land use zoning of flood liable land, building regulations, the provision of emergency services and flood warning systems. Many are institutional and are controlled and financed by government agencies. Some however, can be undertaken by individuals, for example house raising or the floodproofing of dwellings.
- Relief and insurance do not modify or protect against flood damage but have a significant role in redistributing the losses among a wider community.

A more detailed consideration of the classification of flood adjustments is given in Smith and Handmer (1984).

There is no doubt that the aim of all floodprone communities is to have a structural solution to its problems. This is based on the perception that the effects of floods will be removed and the comforting thought that the bulk of the funding would be from state and federal governments. The benefits however, accrue to the local community and the largest windfall is to the commercial and industrial sectors.

Unfortunately, this simple concept of the gains from structural measures is incorrect. 'Protection' is never complete; engineering structural works are based on design limits. Thus a levee system may afford protection up the 1 in 100 year flood (it is often less and sometimes unknown) but does not offer protection for more severe floods. In addition, there is the risk of the structure failing.

Further, once a structural measure is in place the community considers that it is safe from the threat of floods. The pace and style of new development in the 'protected' zone assumes there is no flood risk. When the next major event occurs, and occur it most certainly will, the losses are larger that they would have been without the structural flood mitigation works. The increased losses are compounded by the loss of experience of the community in dealing with the more frequent and less damaging floods. This, as we will see below, can have significant implications for the damage bill.

The combination of these adverse effects of 'protection' has been referred to as the 'flood protection paradox'. The effects are well documented in the literature and stem from the initial description by White (1964). The paradox is not simply a theoretical concept as it can be shown to have meaning in economic terms. For example it is the major factor in the USA that explains why floodplain losses increased at a faster rate than the monies put into structural protection. An excellent review of the problems, illustrated by examples from New Zealand, is presented in Ericksen (1986). Significantly his government funded study is entitled 'Creating Bigger Disasters?'.

There are no similar studies that compare the costs of structural works to changes in flood losses for Australia. Those concerned with urban flood hazard management in Australia have been aware of the pitfalls of the flood protection paradox for many years and have attempted to move away from the structural solutions to flood mitigation. However, there is no doubt that pressure from floodprone communities, and from their elected representatives, is for such solutions to continue. For some inland communities in eastern Australia ring levees around the whole community are the only possible measure. However, the Nyngan floods of April 1990 illustrate the problems that can occur with reliance on structural flood protection.

The fallacies of flood protection and the relative merits of other mitigation measures were well illustrated by White et al (1975). The key diagram is reproduced here as Figure 3, although designed for flood measures, there is considerable scope for adaption to other natural hazards.

The figure provides a diagrammatic assessment of the effectiveness of differing measures to reduce the catastrophe potential and to obtain net benefits (i.e. damage averted). The centre point represents a threshold of flood-loss tolerance in respect to benefits. Upward movement represents increases in the catastrophe potential and downward movement a decrease. A move to the right increases benefits and to the left decreases them. The optimum is movement to the bottom right quadrant which represents increased benefits and decreased catastrophe potential.

It can be argued that for specific locations the results do not fit the idealised model. However

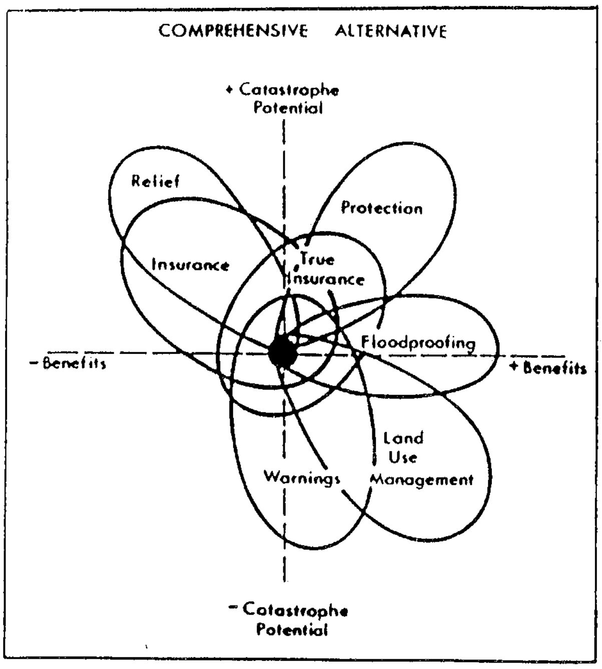

Figure 3. Relative effectiveness of flood adjustment measure in reducing catastrophe potential and providing net benefits to the nation (White et al 1975).

Figure 3 serves as a synthesis of the flood reduction options. It is important to note that benefits are at the national level and not for individual beneficiaries within the floodprone area. For example, if a commercial enterprise has insurance cover for flood (this is the usual case in Australia) it is clearly a major gain. This is not the case for other clients of the same insurance company located elsewhere, especially as such flood cover is rarely related to flood risk!

Although data are not readily available it is likely that overall expenditure on flood adjustments is weighted towards the provision of structural protection. It is also likely that floodprone communities would like to see more protective measures and increases in the availability of insurance and relief. These unfortunately lie in the increased catastrophe portion of Figure 3. There is little community pressure, or votes, in land use management which is the ideal option. Improved floodplain management in Australia and elsewhere can be viewed as a battleground between the crusaders for land use management against the assembled ranks of floodprone householders and commercial and industrial interests who want the government to provide flood protection. An example of what land use management for floodprone land is all about can be found in the NSW *Floodplain Development Manual* (NSW Govt, 1986).

Where are the major gains to be made? Without doubt the potential for flood damage reduction in Australia, over the current decade, lies with the design and implementation of floodwarning systems with land use management as the continuing long term goal. Value for money, understandably the concern of government who underpin the finance for flood adjustments, will be best achieved in these areas. A review of recently installed flood warning systems for flash-floods in the United States is given in Gruntfest and Huber (1989).

It is essential that floodwarnings are seen as an overall system. Too frequently they are seen solely in terms of flood forecasting. Floodwarning systems at their simplest comprise three major components. These are the forecast, the distribution of the forecast message (dissemination) and the response of the community of risk. For further details and a bibliography to other studies see Handmer and Ord (1986).

The forecast

The forecast requires a range of field installations to provide reliable and quick information on rainfall and streamflow. These data are then processed, using a blend of computer-based models and experience, to provide the forecast. The responsible body for the production of flood forecasts is the Bureau of Meteorology.

Until the late 1980's Australia was poorly served with the necessary hardware and communications that are fundamental to providing acceptably accurate forecasts. This stemmed from a lack of funding — the technical inadequacies of forecasting can easily be solved by the provision of the necessary funds. The background to this unfortunate underfunding is described in detail in 'Flood Warning in Australia'(Smith and Handmer, 1986). Funding has now improved and the focus must now change to implement improvements for the dissemination and response to warnings. This is essential if the full benefits are to be realised. While the standard of the forecast can be improved by the injection of funding, improvements in dissemination and response require the development of new skills in addition to financial backing.

The forecast presents an estimate of river height at a future time. For urban communities the heights are normally for a flood gauge situated in a central location in the town at risk. The first priority is how to convert this forecast information into a form that is meaningful for the individuals at risk. Only in extremely experienced floodprone communities can the residents translate gauge height into what it means for their property.

This problem of communication of the forecast in a form that is understandable and of value to the recipients is worldwide. In a Commonwealth Science Council meeting in Bangladesh in January 1990 the same problem was emotionally expressed by an army colonel who, with his regiment, was attempting to evacuate tens of thousands of villagers. He had a gauge height forecast but no information on how to translate this into the area about to be inundated. His problem was massive and not helped by the press who accused the army of withholding vital forecasts.

Table 1. A comparison of residential damage components, for Sydney floods August 1986.

	YACS (overfloor) N=527	Loss adjusters (overfloor) N=72
Structure	1002	1575
Contents		
Floor coverings	1024 (27.0)	1546 (33.1)
Bedrooms	395 (10.4)	879 (18.8)
Furniture	619 (16.3)	841 (17.9)
Electrical	-	542 (11.6)
Kitchen	122 (3.2)	-
White goods	451 (11.8)	215 (4.6)
Clothes/personal	466 (12.3)	561 (12.1)
Consumables	-	50 (1.9)
Other	297 (7.8)	-
Contingencies	427 (11.2)	-
Totals	**$4803**	**$6249**

Figures in brackets are percentages.
All dollar values are at 1986 prices.

The need is clear: simple methods to convert gauge height forecasts to ground and floor height for properties at risk must be developed. Suitably produced maps are one approach; marking lamp posts and telegraph poles with flood heights is another. Floor heights, in relation to gauge height (including conversions for the slope of the flood surface) could be affixed to external electricity meters. The CRES ANUFLOOD package can combine flood forecasts with its building data base to provide an immediate listing of what property is at risk and the likely depth of water that can be expected either overground or overfloor. Such data bases exist for at least 30,000 floodprone buildings in NSW. There is no doubt that flood maps of urban areas are integral to the process of interepting the forecast information but they are not available for all communities. Maps themselves are rarely the answer for individual property owners but they are essential for the emergency services. The problem of converting the forecast to usable information is well known, but little progress been made in solving it. Solutions need not be expensive.

Dissemination

In Australia the flood forecasts issued by the media have a content that is agreed between the Bureau of Meteorology and the appropriate emergency service. Details vary slightly between states but the overall procedure is similar and designed to ensure that there is no confusion due to organizations issuing differing forecasts. The overall approach is sensible although detailed studies of actual examples often raise local problems. The assessment of flood warning dissemination for the August 1986 flood in Sydney is such an example (Handmer, 1988).

It is the content of the message that could be improved. These frequently use such terms as 'a moderate flood' with the finer detail of the forecast presenting in terms of gauge height. As discussed above such information is of little value to the recipients.

Response

A further shortcoming of the flood warnings transmitted to the public is that they do not give instructions on what the recipients should do. The message does not say who will be effected and by how much, i.e. depth of flooding. Neither does the message say if buildings should be evacuated nor what measures should be undertaken to reduce damage.

What are the savings from warnings? If ideal warnings were given what be the likely savings? This is important not only to increase the savings in avoidable damage but to provide economic data that may, and in my opinion certainly would, show that the cost-benefits of warning systems are favourable and are potentially greater than the other measures illustrated in Figure 3.

Residential Savings

Few studies have attempted to compare the actual flood damage for households against the potential damage, i.e. to analyse what is saved. Penning Rowsell et al (1977) provide information based on UK research and Australian information is available for Lismore (Smith, 1981) and in a review of the cost effectiveness of warning systems for urban areas presented in Smith (1986).

The Sydney August 1986 flood study can be used to illustrate the potential for residential savings. Valuers visited 72 residential properties that had experienced overfloor flooding, the depths ranged up to a maximum of about 2.0m. They undertook a detailed assessment of room by room damage based on individual items (carpets, beds, white goods etc). These provided information on both the actual and potential losses. The average losses for the 72 properties is given in Table 1. These data indicate that losses to contents exceed the damage to the building structure (which includes built-in cupboards, plaster work etc). It is also clear that the major contents damage is to floor coverings, bedrooms and furniture. An independent survey from the records of the NSW Department of Youth and Community Services (YACS), the agency responsible for relief payments, gives similar results. These are also shown in Table 1.

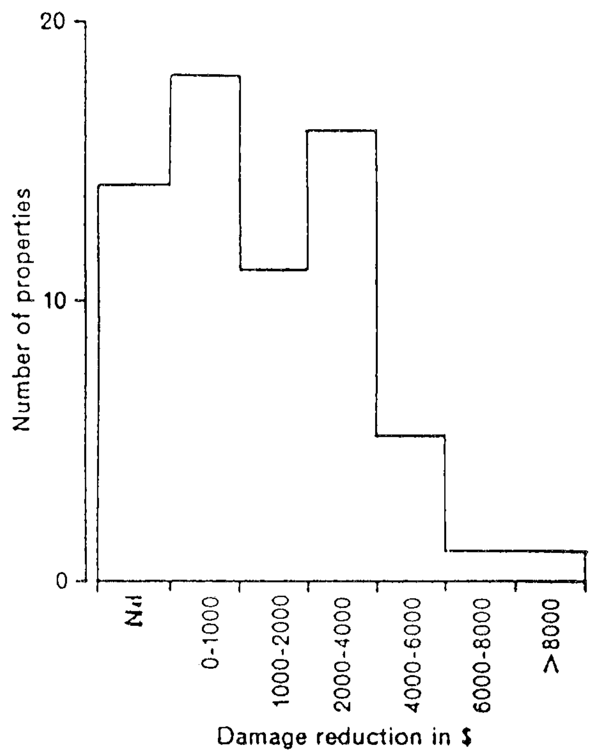

Figure 4. Damage reduction to residential contents, Sydney floods August 1986.

The significant feature of the Sydney data is that close to 25% of the potential contents damage of the sampled flooded households was averted. Approximately half of the savings were to electrical goods, especially smaller higher values items such as TVs, videos and hi-fi equipment. The response was variable and the variation is shown in the frequency diagram in Figure 4, taken from Smith et al (1987). The majority of the sampled households had no effective floodwarning, little prior flood experience and often measures to reduce damage were only taken after floodwaters reached doorstep level. There is clearly scope for future savings if the warning system can be made more effective and public awareness on how to response improved.

Figure 5 (from Smith et al, 1990) presents further analysis of the Sydney data. This considers separately those in the sample who had prior flood experience and those who did not. It also provides information on the likely savings for the experienced and inexperienced in relation to overfloor flood depth and length of warning time.

Figure 6 provides guidance as to the overall residential savings, improvements in the ratio of actual to potential damage, in relation to experience and warning time. This again demonstrates the scope for savings. The problem is to educate the inexperienced to react in a manner similar to those with experience.

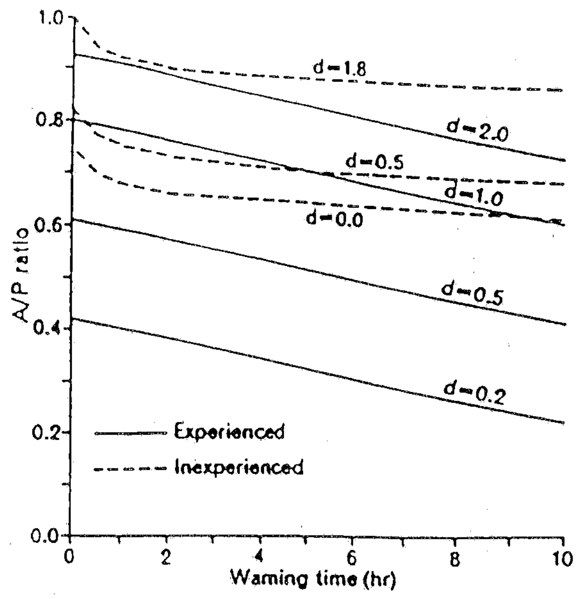

Figure 5. Relationship of actual to potential damage to overfloor flooding (in metres) and flood experience. Data for residential contents – Sydney floods August 1986.

The key to improving contents savings is for better forecasts (longer warning time) and, more importantly, for methods that attempt to replace experience with education.

Commercial/industrial savings

Published literature on the scope for damage reduction in the commercial and industrial sectors is less than for the residential sector. However, there is little doubt that both the savings for individual enterprises and the aggregate total are larger than for the residential sector.

A single case study will suffice to illustrate the potential for commercial reduction in flood loss. Taminda is an industrial estate of some 100 floodprone properties located in Tamworth, NSW. On Friday 27 January 1984 a flood warning was released, and a number of the businesses undertook measures to reduce likely flood loss. These generally involving the lifting of items and the removal of vehicles to flood-free ground. The forecast flood did not occur and everybody left for the Australia Day long weekend. In the early hours of Monday 30 January a separate flood exceeded the floor levels of 81 establishments in the Taminda estate. Access was cut and it was not possible to undertake further loss reduction measures. The 21 establishments that took steps on the Friday to reduce contents damage saved, on average, 70% of their potential losses to contents — the unwise clearly saved nothing and actual loss equalled potential loss. The depths of overfloor inundation were all below 1.0m and the recurrence interval of the event was about 1 in 15 years. A detailed account of this work is given in Smith and Greenaway (1984).

How to achieve these savings?

Forecasts will continue to improve. The need is to provide the forecast in a form that can be used by those at risk. Public awareness has been a byword in flood hazard management for decades but little seems to have been achieved. Funding is poor, but of even more significance the appropriate professional skills are not used. What is required is to sell the message. This requires experience that is not a part of the training of engineers, forecasters or academics. The media, the advertising industry and sociologists have talents that could be used — but rarely are. A detailed collection of papers that present an international review of this subject can be found in *Hazards and the Communication of Risk* by Handmer and Penning-Rowsell (1990).

At a simple level it is strange that there is little pressure and little assistance to enable household or business enterprises to prepare 'flood plans'. Advice on household flood plans, combined with regular reinforcement, would be a valuable contribution. Large savings could be made by assisting commercial and industrial premises to draw up flood action plans. At present few of the major undertakings that contribute to the $13.5m AAD for the Georges River even know that they are in the 1 in 100 year flood zone. Informing them and providing general advice on a flood action plan would be invaluable. The larger the business the more the likelihood of a response. They need to know they are floodprone and to be given background information on how to prepare a flood plan. It is likely that larger undertakings would be prepared to pay an annual fee in order to receive a personalised floodwarning message. This approach becomes more practical as flood forecasting becomes linked to modern communications technology.

Major Australian floods

Little has been said so far of the potential risk to life. Australia's record in avoiding deaths from flooding is outstanding — this reflects most favourably on the whole emergency services sector. However, the potential risks to life from the 'really big flood' are considerable, see Figure 2. Whether 'really big floods' are defined as above or below the level of the 1 in 100 year event depends on local circumstance. For the Georges River there would undoubtedly be building collapse during a 1 in 100 year event, for inland Australia there would not be. Preparedness for the really large floods is minimal. We have seen that information is nearly always related to floods below

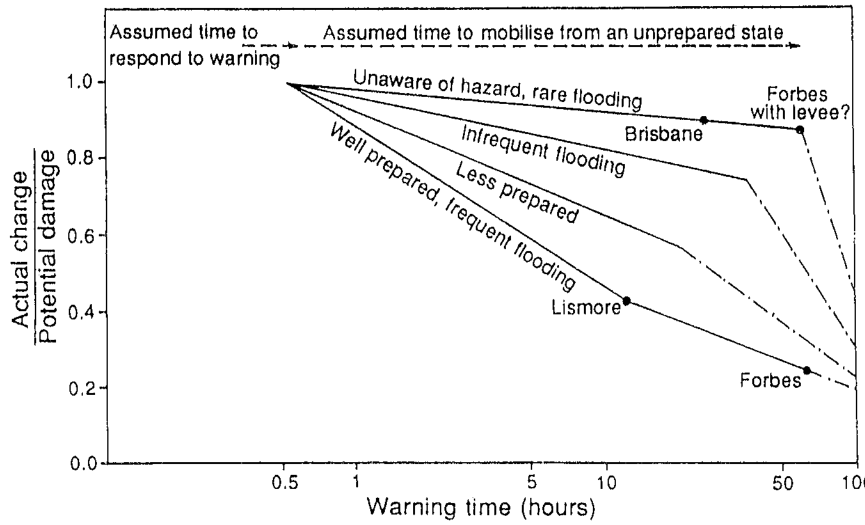

Figure 6. Relationship of actual to potential damage for preparedness (p) and warning time, for residential contents damage.

the 1 in 100 year. The problem is especially serious because, in 1986, the Bureau of Meteorology revised probable maximum precipitation data for Australia. Generally this showed an increase and worst case rainfalls have caused changes to the probable maximum flood. This is currently a major problem as it has caused the spillways of many hazardous dams to fall below accepted design standards (Smith, 1990). However, the same revisions have effects on the estimates of the 1 in 100 year flood line. This means that for some areas what was previously assumed to be the 1 in 100 year flood is now closer to the 1 in 70 year event.

What do we know of the extent of the probable, or near probable, maximum flood? Do we have emergency plans to cope with these? Has the spectre of building failure been taken into account? These are all questions that should be addressed and for which the IDNDR in Australia could act as a focus.

Summary

There are two forms of response to the occurrence of a natural disaster. These are termed crisis response and risk management. The former implies little prior planning while the latter indicates acknowledgement of the risk and planning for its effects. The institutional response to flooding in Australia has acknowledged and taken steps to put into place many diverse forms of risk management. Overall, our national record is good. There remain, however, aspects of our response that could be improved. Many of these relate to strategies that could be used to reduce flood losses. The emphasis should continue to move away from options that attempt to offer protection from flooding to nonstructural responses.

Nonstructural measures generally involve increased public awareness and involvement. These contrast with structural options in which engineering skills are dominant. Thus improvements in public awareness and the involvement of a range of new skills and disciplines are indicated.

This account has focussed on the potential for savings to flood losses that could accrue if flood warning systems were more fully utilised by the communities at risk. This would necessitate increased expenditure but the indications are that the costs and benefits would be extremely favourable — probably very much more than from the extension of structural protection schemes. Further the savings would, in part, result in reduced government relief payments

It is hoped that the IDNDR at national level may act as a focus for measures that could reduce flood losses in Australia. The nation should also play its role in advice and assistance to its less well-endowed neighbours. The two aims are not exclusive; improvements to warning response in Australia could assist in developing methods that could be used elsewhere.

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