THE FAILURES OF JAPAN'S DISASTER MANAGEMENT SYSTEM

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ABSTRACT:

This paper outlines the structure of Japan's natural disaster management system and highlights some of the problems experienced during the Kobe earthquake of 1995 and in other natural disasters in recent years. It highlights some of the constraints in Japan's political system, the approach to crises and crisis management within Japanese society, and the post-Kobe reforms to the legal and administrative structures for disaster management. The paper concludes that effective disaster management depends in Japan, as in other countries, on social and political responses to crisis, not just laws and plans.

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Natural disasters such as earthquakes are a regular part of life in Japan. Accordingly, managing natural disasters is an integral part of the governmental system. Complex political, legal and administrative mechanisms have been developed over a long time to cope with the perpetual task of dealing with the aftermath of natural disasters and maintaining a reliable system of disaster prevention and awareness. At the same time, this elaborate structure was found to be thoroughly flawed when the Great Hanshin-Awaji Earthquake struck on 17 January 1995.

This paper outlines the Japanese emergency management system and points to the difficulties under the Japanese system of dealing with natural disasters -- notably earthquakes -- in Japanese cities. Earthquake engineering can help minimise the physical impacts of earthquakes; the broader processes of the management system, however, will determine how deeply the disaster affects the social fabric of the community.

1. THE DISASTER MANAGEMENT SYSTEM IN JAPAN

Japan does not have an emergency management agency. Responsibilities are spread throughout the government system, which relies for its authority in relation to disasters on the Disaster Countermeasures Basic Act of 1961, the Central Disaster Prevention Council, located in the Prime Minister's Office, and the Basic Plan for Disaster Prevention. The Act allocates jurisdictions between levels of government and between relevant organisations, sets up disaster prevention systems, preparedness and plans, provides for emergency measures and operational plans at all levels of government, financial arrangements in disasters and provisions for states of emergency. Allied to the Basic Act is a myriad of more specific laws, such as the Large-Scale Earthquake Countermeasures Act of 1978, which is premised on the belief that a large-scale earthquake can be predicted. A host of provisions is designed to come into play once the prediction is confirmed.

The Basic Plan for Disaster Prevention is based on the established public awareness of the need for readiness, enhanced prevention measures in terms of research, technology, engineering, monitoring, urban planning and design, education and training. Again, the fundamental approach is that, providing countermeasures are designed and set up, the legal and administrative framework will come into play when disasters strike, and will deal effectively with the situation.

At all levels of government in Japan, and within all public corporations, disaster prevention and disaster management plans are supposed to be in place, all linked back to the national countermeasures. The level of public education and awareness in Japan is also high, as one would expect in a country where natural disasters, or intimations of them, are a daily occurrence somewhere in the nation.

2. PROBLEMS IN DISASTER MANAGEMENT

Case studies of disaster management in Japan, including the Kobe earthquake, reveal a consistent pattern of problems relating to the legal structure, the relationship between levels of government and the patterns of communication within the disaster management system. While it is easy to be wise after the event, the Kobe earthquake showed that the national disaster management system just did not work, and major changes have been made to the Basic Law as a consequence, with operational plans at all levels of government also having to be revised.

There were well-known failures in Kobe, such as not informing the Prime Minister of the scale of the disaster (he first heard about it on the morning news), not holding a Cabinet meeting for four hours after word was received, not establishing a Kobe disaster headquarters for four days, not requesting help from the Defence Forces for four hours (even though the Forces were ready and waiting), lack of preparation in Kobe itself for a large earthquake, and no communications network between the National Land Agency and Hyogo Prefecture. The disaster management plan for Kobe did not incorporate preparations for a major earthquake, and the plan was premised on only part of the city being affected. External help was therefore not seen as necessary and, although emergency supply plans were in place, many of the suppliers were themselves affected by the earthquake. Importantly, while there was a system for disaster relief, there was no comparable organised system for recovery after the earthquake.[1]

The list could go on, but Kobe was not the first disaster site to experience these sorts of problems: in the Miyagi Prefecture Earthquake of 1978, it was discovered (when the authorities finally found the disaster prevention plan) that it did not include information on earthquakes; during the torrential rains in Nagasaki in 1982 the mayor, who had to issue the order to establish the countermeasures, could not be found, and only one loudspeaker car was available to issue evacuation orders; when the Izu Oshima Island volcano erupted in 1986, information was slow to reach the Prime Minister's Office, no one was clearly in charge, the National Land Agency switchboard closed at its normal time of 6pm and no one was on duty, and only independent action by the Chief Cabinet Secretary enabled an evacuation plan to be put into effect; when Mt Unzen erupted in 1991, there was no city disaster prevention plan, there were no siren or warning cars, warning zones were not established, evacuation was haphazard, risk assessments were found to be faulty, and there were serious breakdowns in communication and trust between the authorities and affected residents.[2]

3. DEALING WITH DISASTER MANAGEMENT PROBLEMS

In a country where natural disasters are frequent, problems in dealing with these disasters can also be expected to be a common occurrence. But the outpouring of criticism after the Kobe earthquake suggests that there are some fundamental problems with the way in which the disaster management system is working in Japan.

(a) crisis management: recognition and acceptance of the concept of "crisis" is central to the disaster management problem in Japan. The term is not a popular one in Japanese political parlance, giving the sense that it does of some weakness in the system. Some commentators argue that reliance on supra-legal crisis management measures evokes concern about the possibility of a departure from the carefully nurtured postwar constitutional system based on the separation of powers and the rule of law, and a return to prewar days of military control. Historically Japan has not confronted many major external threats. The government system today is not geared towards management of serious crises. Consciousness of crisis is said to be profoundly lacking in the Japanese mind: response to natural threats is one of resignation rather than response, and acceptance of responsibility within Japanese society is weak.[3]

(b) the governmental system: one of the most serious problems to emerge from the Kobe disaster (and one seen in many other natural disasters previously) was the response of the bureaucratic and political system to the pressures placed on decision-making processes by the crisis. Points of responsibility in the Japanese political system are notoriously difficult to pinpoint. Numerous analyses have referred to Japanese politics as the "politics of irresponsibility", where political authority is vague, the power relationship between politics and the bureaucracy is ill-defined, and the vertical divisions between elements of the bureaucracy makes for extremely difficulty communication processes across the government system.[4] Management by committee is the norm, and adherence to procedures is strict. The Basic Law prior to Kobe placed responsibility for initiating a national response on the Prime Minister, but the Prime Minister in the postwar Japanese political system has never been a powerful position, hemmed in by a byzantine party factional system, a complex array of party politics, long-standing bureaucratic consciousness within politics, and a traditional policy-making process that emphasises officials rather than parliament.

While the response to the Kobe disaster may have had a lot to do with the character of the Prime Minister himself, Mr Murayama, it was the reliance of his office on the actions of officials throughout government that initially created the lack of decisiveness and command, a problem compounded by weaknesses in the disaster management system that left it unable to cope with the scale of the disaster.

(c) the disaster management system: the widespread reforms to the Basic Law that were enacted after Kobe in 1995 were designed to provide better information, a chain of communication direct to the Prime Minister, and capacity for more authority and initiative at lower levels. The Basic Law reflected the character of the Japanese political system itself: authority was vested in name in the highest levels and action could only flow officially once orders had been given. For those orders to be given the national government relied on requests for assistance from the responsible local governments. The scope for authority within the vast governmental system at national and several local levels of government was proscribed by the complexity of the legal mechanisms in place.

The government did not declare a state of emergency immediately after the Kobe earthquake, using its power under Article 107 of the Basic Law. It opted instead for a lesser declaration, concerned that Article 107 would be regarded as an excessive response that could infringe individual rights. The National Land Agency was put in charge, a technical economic agency of little power within the Tokyo bureaucratic structure, and an advisory body rather than an action body. Impact assessment was the major problem for all levels of government in the early period after the earthquake, and inadequacy of information here led to inappropriate responses early on.

The Basic Law revisions have made it easier to establish local disaster management headquarters, have given stronger powers to the Prime Minister as chair of the national headquarters, made it easier for local authorities to call in the defence forces and use volunteers and to take emergency measures to deal with traffic and street control in affected areas. The Basic Plan for Disaster Prevention was also substantially amended and has led to the overhaul of operational plans at all levels of government, including measures for information gathering, emergency transport, stockpiling of supplies, refuge and housing, and acceptance of overseas assistance. A new Law concerning Special Measures for Earthquake

Disasters was also passed, to require all prefectures to establish specific planning for earthquakes and how to deal with them.

4. LESSONS FROM JAPAN

The disaster management system in Japan failed in the Kobe earthquake. Its weaknesses had been seen in earlier smaller-scale disasters and derived from the both the philosophy underlying the approach to disasters and the relationship between the disaster management system and the politico-bureaucratic system of Japan. Reliance in Japan on the traditional ministry and agency structure to provide a crisis management system proved to be a failure; the same problem has been seen in a range of other major domestic and foreign policy areas where rivalry between the powerful ministries in Tokyo has effectively stymied attempts to establish administrative structures to cope with new demands on government. A misplaced reliance on "coordination" between vertically separated bureaucratic structures has led to breakdowns in management and excessive competition for power between rival ministries and agencies.[5]

The problems of the Japanese disaster management system point to some challenges for countries with less experience of natural disasters such as earthquakes. At the same time, however, it is clear that a nation's emergency management system is not the only factor that determines the nature of the response to disasters. In Japan's case, social, political and administrative traditions and practices were key factors in how disaster was dealt with.

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[1] There is a huge amount of material written on the Kobe earthquake, in Japanese and English. Two useful sources in English are Disaster Prevention Bureau, National Land Agency (1995), *The Great Hanshin-Awaji Earthquake: Damage and Response*; Wellington City Council Emergency Management Office (1995), *The Great Hanshin (Hyogo-ken nambu) Earthquake of Southern Hyogo Prefecture, Japan, 17 January 1995: Emergency Management Implications on Kobe City, Full Field Study Report 12-24 March 1995*

[2] Yamamoto, K. (1985), *Interorganisational Coordination in Crises: A Study of Disasters in Japan*; Yoshii, M. (1992). "Disaster Warnings and Social Response -- the eruption of Mt Unzen in Japan" *Disaster Management*, Vol.4, No.4, p.213; Takemura, K. and Sassa, A. (1996) *Nihon no kiki kanri wa kore de ii no ka*, Tokyo, Keichi shuppansha

[3] Morimoto, S. (1995), *Nihon no kokka senryaku to kiki kanri, Tokyo*

[4] Van Wolferen, K. (1989), *The Enigma of Japanese Power*, New York, Knopf

[5] Seen clearly in the policy area of foreign economic aid: refer to Rix, A. (1993) *Japan's Foreign Aid Challenge: Policy reform and aid leadership*, London, Routledge

DISASTER RISK MANAGEMENT AS APPLIED AT THE LOCAL GOVERNMENT LEVEL

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Graeme Nicholas commenced his working career as a cadet at the Royal Military College, Duntroon, Canberra in 1972. Graeme graduated from Duntroon in 1975 and entered what was to be a 20 year career as a commissioned officer in the Australian Regular Army. After a number of appointments as a junior officer, Graeme served with a UN ceasefire supervising team on the India/Pakistan border in 1984/85. Subsequently Graeme served in a number of staff appointments involved in Civil/Military Cooperation, training and military operations.

Graeme attended the Army's Command and Staff College in 1989. He completed his military career in 1993. He has also worked in both the private and public sector as a trainer, sales manager and HRM consultant. Graeme is currently the Acting Manager Education and Training with Disaster Management Service of the Department of Emergency Services.

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ABSTRACT:

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DISASTER RISK MANAGEMENT AS APPLIED AT THE LOCAL GOVERNMENT LEVEL

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INTRODUCTION

Queensland's Disaster Environment

Queensland has a high incidence of natural disaster events, and an increasing vulnerability as the population base, infrastructure, industry and commerce continue to expand rapidly.

The Australian Water Resources Council(1) (AWRC) in its 1992 paper "Floodplain Management in Australia" puts the cost of natural disasters in Australia at an average of $1,250 million per year.

Queensland's share runs to an average of $492 million at a per capita cost of $175. This compares with the next highest figure of $395 million for New South Wales.

The growing risks from technological and agricultural disasters such as a major oil spill impacting on the Great Barrier Reef or an outbreak of a major animal or plant disease, significantly adds to Queensland's hazard environment.

The Queensland Disaster Management System

The disaster management system in Queensland incorporates the following elements:

- Adoption of the nationally espoused concepts of All Hazards, All Agencies, Comprehensive Approach and a Prepared Community;
- Adoption of key considerations relevant to the Queensland environment and experience, eg the need to focus on large scale events;
- A whole of government management framework with responsibilities shared between State, Local Government and the community, as set out in the State Counter Disaster Act 1975.

This paper will discuss the application of the Risk Management Standard-AS/NZS 4360(2), as it relates to disaster management in Queensland, with particular emphasis on Local Government. Unlike most other States, Queensland's system for disaster management includes Local Government as a coordinating authority during disaster response and recovery operations. While the system has proved to be effective during numerous cyclones or floods that have impacted on communities throughout Queensland, the focus of disaster management is changing.

As a result of the 1995 Senate Standing Committee Report on disaster management, there has been an increasing emphasis on prevention and preparation prior to a disaster, rather than the more traditional response and recovery approach. The report noted that Australia's disaster management arrangements were too focussed on response. It identified the need to address the other critical areas of prevention, preparation and recovery.

It is from this perspective that the relevance of a Risk Management methodology in a disaster management context, is approached.

DEVELOPMENT OF DISASTER RISK MANAGEMENT POLICY

The release of the 1995 Senate Standing Committee Report on disaster management coincided with the release of Risk Management Standard AS/NZS 4360.

It was realised that this standard could be used as a useful tool in pursuit of the required broader approach to disaster management.

Commonwealth / State endorsement of the adoption of a risk management methodology in respect to comprehensive disaster management was obtained in 1996, resulting in the following initiatives:

Commonwealth Level:

- preparation of disaster (emergency) risk management guidelines;
- incorporation of a risk management approach in disaster (emergency) management competency standards;
- incorporation of a risk management approach in disaster (emergency) management training curriculum;
- progressive incorporation of risk management concepts and procedures in disaster (emergency) management doctrine and training publications.

State Level:

- the preparation of a Local Government disaster planning guide incorporating concepts of risk management;
- the development of a template Local Government counter disaster plan based on a risk management approach;
- the preparation of disaster risk management guidelines for application in a Queensland context;

- development of a protocol between the Queensland Government and Local Government which deals in part with the issue of a risk management approach to disaster planning.

Local Government:

Based on the above, it is expected that individual Local Governments will progressively revisit their existing counter disaster plans with a view to addressing the issue of community vulnerability from a comprehensive risk management perspective.

ADAPTING AS/NZS 4360 IN PRODUCING DISASTER RISK MANAGEMENT GUIDELINES

Guidelines are being prepared which deal with the application of a Risk Management methodology in a disaster management context.

These guidelines will have application to organisations and groups with disaster management responsibilities or functions. These might include:

- Commonwealth Government;
- State / Territory Government;
- Local Government;
- Full-time Agencies;
- Volunteer Agencies;
- Community Groups;
- Industry.

The purpose of these guidelines is to bring risks to which a community is exposed to acceptable levels. The guidelines may be applied by single agencies or multi agency partnership. They embrace all facets of disaster (emergency) management from development of policy to implementation of intervention strategies.

THE DISASTER RISK MANAGEMENT PROCESS

The main elements of the disaster risk management process are:

- establish Risk Management Context;
- determine Risk Evaluation Criteria;
- identify risks;

- analyse risks;
- evaluate risks;
- treat risks;
- risk communication;
- monitor and review.

The risk treatment element occurs within a Comprehensive disaster management (prevention, preparation, response and recovery) context and involves the key stages:

i. Identify Intervention Options;

ii. Select Intervention Options;

iii. Plan and Implement Strategies.

The entire process is iterative and may be re-entered at any point when the inbuilt review mechanism indicates such a necessity.

The main elements of the disaster risk management process are shown in figure 1.

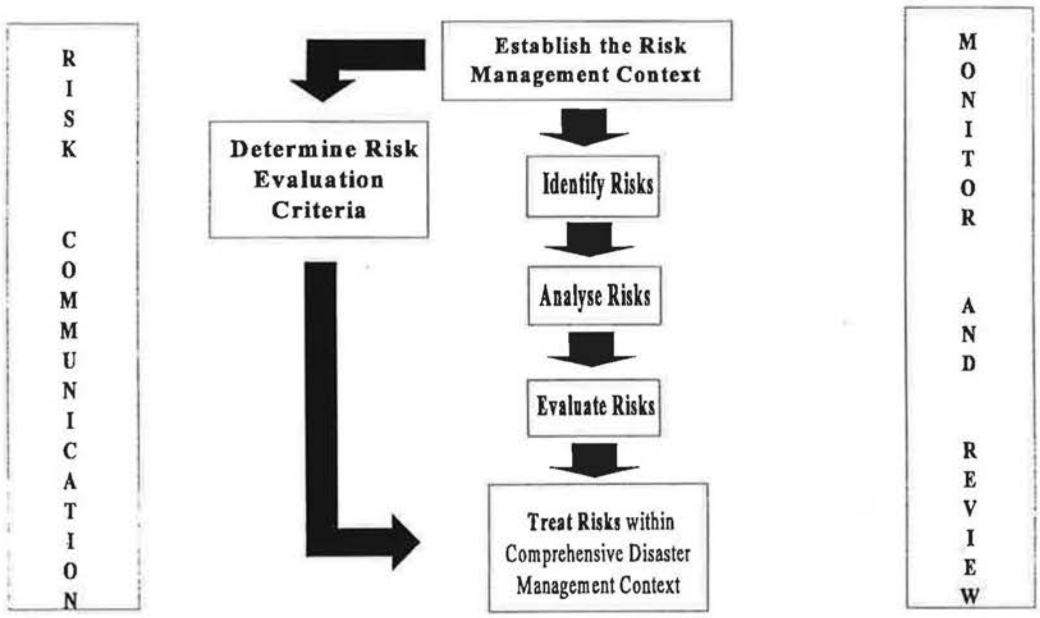

FIGURE 1 - MAIN ELEMENTS OF THE DISASTER RISK MANAGEMENT PROCESS

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ADOPTION OF A RISK MANAGEMENT APPROACH AT LOCAL GOVERNMENT LEVEL

May. P J(3) in his paper 'Addressing Natural Hazards: Challenges and Lessons for Public Policy' raised a number of issues in relation to adopting a risk management approach to disaster management. These include;

- Evidence from the United States that local policy makers(Local Government) prefer disaster relief(response and recovery) programs rather than what is viewed as more intrusive mitigation policies.

- There is a significant issue of who bears the cost of hazard reduction programs. The cost of disaster response and recovery tends to be borne at a National or State level, while the cost of mitigation falls largely at a local government level. This raises the issue of equity i.e. who pays and who benefits from mitigation policies.

- There has been a shift in policy development from strict regulation (land use, building codes) to the use of more flexible measures that specify building performance or that permit low levels of development which meet certain criteria. This has been achieved by permitting Local Governments to develop hazard management programs that are suited to local circumstances and include a degree of flexibility when dealing with development decisions.

- There has been contrasting policies developed on liability and the consideration of insurance. In New South Wales, for example, the State flood policy provides immunity to local governments from legal liability for flood losses if they follow the recommended floodplain management planning process. In contrast, New Zealand places the liability of the risk squarely on the creator of the risk, and.

- There are different roles and responsibilities for the various levels of government. In our federalist system of government, State and Local Government share responsibilities for public safety, with a degree of involvement from the Commonwealth. But there is a natural suspicion at the local governments level of State and Federal governments, who are perceived as prescriptive and coercive. Lack of funds, inflexibility and the shift of political blame to Local Government for failure impinge on the relationship. Pressure groups create a backlash to those effected by environmental and development regulations. This further muddies the waters in relation to comprehensive disaster management policies.

To solve these problems, May suggests a blueprint which includes,

- Creating constituencies that advocate attention to issues of sustainability and hazard mitigation.

- Get Government out of the business of subsidising risk.

- Enhance the commitment and capability of Local Government to identify sustainable futures and the means to accomplish them.

- Seek better coordination and integration of hazard policies across different types of hazards, and.

- Improve the knowledge base and practise.

LESSONS LEARNED AND APPLICABILITY AT STATE AND LOCAL GOVERNMENT LEVELS

In April 1990 Charleville suffered the effects of an 8.5 metre flood which inundated some 85% (1170) of the residences and 100% of the town business area.

The first week of February 1997, again saw Charleville impacted by a serious flood. This time to a heigh of 7.45 metres, and inundating some 60 homes and 13 businesses.

In the 1990 event, due to the rapid onset of the flood and the flood height reached, the cost of preventable losses to residents and business operations was high, compared to losses associated with the 1997 event.

A comparison of these events provides an opportunity to assess progress made in terms of effective disaster management from both a State and Local Government perspective.

A preliminary comparison reveals significant improvements have been made in respect of such response planning issues as:

- **Forecasting**: Improvements in timely and accurate flood forecasting was evident in the fact that the community was provided with appropriate warning and sufficient time to react;

- **Warnings**: Based on timely forecasts, effective evacuation and loss reduction actions were implemented;

- **Evacuation Centre Management**: All evacuees were efficiently supported in the form of accommodation, catering and medical support systems;

- **External Support**: A feature of the operation was the effective mobilisation and provision of State level operational and functional support, and the efficient coordination and delivery through the Disaster District structure.

The operation exposed the continuing focus on disaster response management to the exclusion of disaster mitigation strategies as a component of a comprehensive disaster management approach.

As a consequence of this, a Disaster Risk Management study based on Risk Management Standard AS/NZ 4360 is to be conducted of the flood threat to the Charleville community.

The objectives of the study are:

- to develop a comprehensive disaster plan, based on current hazard and vulnerability information and resource availability;
- to identify possible mitigation strategies which could or should be pursued either individually by Murweh Shire or in collaboration with Commonwealth and State agencies;
- to use the disaster plan produced for Charleville as a template for Local Government generally relative to the adaption of a Disaster Risk Management Methodology and the production of a comprehensive disaster plan;
- to present identified mitigation strategies to the Queensland Flood Coordination Committee as input into the development of a State Floodplain Management Policy and the identification of cost sharing implications associated with the adoption of a State mitigation focus.

Acknowledgements:

1. Australian Water Resources Council(AWRC)
   "Floodplain Management in Australia" Vol 2: Main Report 1992
2. Standards Australia
   AS/NZS Standard 4360:1995 Risk Management
   Standards Australia, Sydney, 1995
3. May, Peter J. **"Addressing natural hazards : challenges and lessons for public policy"** in 'The Australian Journal of Emergency Management' Vol 11, No 4, Summer 1996/97

EARTHQUAKE REPAIRS TO CHRIST CHURCH CATHEDRAL

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Paul Wilhelm is Structural Design Manager of the Brisbane office of Hughes Trueman Ludlow. He has been actively involved in the management, design, documentation and site supervision of a wide range of structural projects including commercial, domestic, educational, heritage, retail and sporting facilities, industrial and mine infrastructure projects. He has special expertise in the restoration and conservation of heritage buildings.

ABSTRACT:

The Christ Church Cathedral in Newcastle (1890's) was subjected to significant ground movements on 28th December 1989 during the Newcastle Earthquake.

The earthquake gave analysts a result sheet to compare the theoretical model with actual conditions encountered on site. This provided the greatest level of confidence in the method by which the building was modeled, and subsequently if, and where retro reinforcing was required.

Upon resolving the appropriate design parameters design loads were applied to a finite element model. The analysis indicated that retro reinforcing would be required and a suitable reinforcement system had to be adopted to minimise damage to the building fabric. A dry drilling and socked reinforcement system was adopted. The resultant works returned a degree of ductility to the building fabric, was of an inorganic/stainless steel base and the anchor entry points were concealed by the replacement of brick units - satisfying requirements of the conservation study.

The experience gained in the modeling of the Christ Church Cathedral, the ability to compare theoretical results with as loaded conditions has been invaluable and is critical knowledge in the assessment of undamaged buildings which potentially require upgrading.

Alternative reinforcing systems for the Bell Tower were investigated and various crack repair methods trialed.

The proposed paper discusses the background to all aspects of the reconstruction of the Cathedral, from the event itself, to design criteria negotiations, analysis methods of repair and experiences learnt during the works.

Earthquake Repairs to Christ Church Cathedral - by Paul Wilhelm (Hughes Trueman Reinhold)

General

The Christ Church Cathedral in Newcastle was subjected to significant ground movements on 28th December 1989 during the seismic event known as the Newcastle Earthquake.

The Cathedral consists of unreinforced masonry walls that vary both in construction and quality as a result of the staged construction (8 significant stages) since works began in the 1890's (the most recent being the construction of the bell tower in the 1970's).

The masonry construction varied in height due to previous stages of construction not being adequately protected until the next vertical extension was carried out resulting in "soft zones". Similarly construction techniques changed with cavity construction used to varying degrees throughout the building.

Analysis

The earthquake gave analysts a result sheet to compare the theoretical model with those actually encountered on site. This provided the greatest level of confidence in the method by which the building was modeled, and subsequently where reinforcing was required. Generally there was very good correlation between areas of high stress that was identified in the analysis and the resultant cracking noted on site.

Upon resolving the appropriate design parameters (based on recommendations in the current Earthquake Code and NSW PWD guidelines) the following loads were applied to the finite element model:

DESIGN CRITERIA

ITEM	VALUE	AS 1170.4 CLAUSE No. / COMMENTS
Structure Classification	General Type II	2.2
Acceleration Coefficient	a = 0.11	2.3
Site Factor	S = 1.5	As determined by Douglas
Importance Factor	I = 1.25	As determined by BA Working Party
Earthquake Design Category	C (aS = 0.165)	2.6
Analysis Method	Static	2.7.4
Current Structure	Non Ductile	App B1
Current Structural System	Bearing Wall	2.8
Proposed Structural System	Dual system (Moment frame and Shear walls)	2.8

Building Configuration	Plan Irregularity Vertically Irregular Torsionally Irregular	2.9.2 (b) Confirmed by HTR
Building Height	35m	Less than 50m
Beam Truss Support Minimum Fixing	5% of gravity load	4.3.2 Applicable to roof connections
Minimum Wall Anchorage Detail	1.65 kN/m	4.3.3 10aS
Non Structural Components	0.5 G_c	Section 5.2 $F_p = aSa_c a_x C_{cl} I G_c$ a=0.11, S=1.5, a_c=1, a_x=2, C_{cl}=1.8 I=1.25, Gc=Self weight F_p = 0.11x1.5x1x2x1.8x1.25 = 0.74 G_c > 0.5 G_c
Structure loading	100 % in One direction 30 % in other direction V=0.086 G_g	Section 6.2.1 Section 6.2.2 $V=I(CS/R_f)G_g$ I=1.25, $C=1.25a/(T^{2/3})$ $= 1.25x0.11 /((35/58)^{2/3}) = 0.193$ R_f= 4 Table 6.2.6 (a) * $V=1.25(0.193x1.5)/4xG_g = 0.09\ G_g$ $V < I(2.5a)/R_f\ x\ G_g, = 0.086\ G_g$

MATERIAL PROPERTIES - ASSUMED IN ANALYSIS AND DESIGN

ITEM	VALUE	COMMENT
f'_m	7.0 MPa	Table 4.1 AS3700
f'_{mt}	0.2 MPa	4.5.3 AS 3700
E	4900 Mpa	Table C4.5.1, AS3700 Commentary
Vertical Bending - Unreinforced	To Section 5.4 AS3700	
Horizontal Bending - Unreinforced	To Section 5.5 AS3700	
Flexural Beam Bending	Maximum tensile stress not to exceed 0.6 x f'_{mt}	
Reinforced Section	To section 6.4.1	
Masonry Density	1.95kg / mm thickness	

The detailed finite element analysis was undertaken using the commercial Finite Element package 'Strand6' by G+D Computing. In-plane analysis of the south wall including the nave, sanctuary and tower walls, and east transept walls was undertaken, as well as out-of-plane analysis of the east wall and east transept walls.

All analyses assumed homogeneous isotropic elastic material properties, and were solved using linear static analysis. Both in-plane and out-of-plane models were developed using 3 and 4-node plate elements. For in-plane analyses with two degrees of freedom relating to in-plane translation, a plane-stress condition was assumed with zero stresses in the through thickness.

Out-of-plane analyses were given five degrees of freedom with the "drilling freedom" (ie nodal rotation along an axis perpendicular to the plate elements) suppressed.

The aim of the analysis was to provide an indication of the 'uncracked' behavior of masonry under earthquake loading. It was possible from the analysis to identify which areas of the unreinforced structure attracted the highest concentration of stresses. These areas could then be considered as potential sites for reinforcement. The implication behind this method is that the final reinforced structure would develop load paths in similar locations to the unreinforced structure in the elastic 'uncracked' range and would therefore provide a more acceptable compatible overload behavior.

Reinforcement

The results of the analsyses were confirmed by site conditions and a suitable reinforcement system had to be devised to minimise the immediate and potential long term damage to the building fabric.

Dry drilling was adopted to minimise potential water damage (and in particular long term damage) and the Cintec reinforcement system was adopted to strengthen the building. The Cintec system was adopted primarily due to the material components (using a cementicous based inorganic grout) and stainless steel reinforcement contained within a sock system which prevents grout leakage damaging the finishes to the building. Further support was the fact that the system was used extensively on heritage structures in the UK and in Europe.

Limitations in the upgrade of the building were primarily geometry based. For example in a few locations it was not physically possible to follow a vertical pier of masonry which could adequately provide cover to more than one reinforcement bar and as a result the theoretical capacity was exceeded under a design event.

The drilling process and anchor system adopted posed no restrictions. In fact, the Nave horizontal anchors are the longest ever installed in the world (32m).

The result was a retro reinforcing system which returned a degree of ductility to the building fabric, was of an inorganic / stainless steel base and the anchor entry points were concealed by the replacement of brick units.

The experience gained in the modeling of the Christ Church Cathedral, the ability to compare theoretical results with as loaded conditions has been invaluable and would be critical knowledge in the assessment of undamaged buildings which require upgrading.

Bell Tower / Spire

The bell tower structure required special consideration and analysis. The geometry of the tower was such that it was not possible to install continuous reinforcement from the top of the tower to foundation level. Access was possible however through fin walls into the main pier supports below. This lapped the bell room floor to which a galvanised steel frame was installed. The trussed sway frame is completely concealed within the bounds of the existing masonry walls and is not visible from ground level.

The "external" nature of this frame and its relationship to the main structure required careful analysis and detailing to ensure that the applied base loads were adequately transferred in shear through the masonry and steel structures to maintain continuity.

Brickwork Crack Repair

Two types of cracks were categorised, those being either "structural" or "non structural"

1. Structural cracks referred to cracks that were deemed to require injection to reinstate a bond, or at least a filler, to provide a uniform masonry fabric when subjected to transient loads. These were cracks that were typically greater than 1mm in width, or that were in high stress locations, or were symptomatic of structural induced movements.

2. Non structural cracks were considered to be those cracks that were of a cosmetic nature or structurally not significant. These cracks were repointed to architectural specifications.

The structural cracks that required injection were done so with a cementicous based material that was as compatible as possible with the parent fabric. There was perceived to be no need to install costly epoxies, which, whilst they had superior flow properties, there were concerns regarding their proven long term durability and potential differential thermal and strength stress patterns.

A micro cement low viscosity grout was developed specifically for the project by ACS to meet the basic project requirements of fully penetrating cracks to widths less than 1mm and of a compressive strength of less than 18MPa.

The injection procedure consisted of drilling port holes (10mm - in bed / perp joints) at intervals as required to achieve full penetration (typically at every alternate brick course) Injection points were placed in the holes (typical screw-on nozzles that are available from hardware stores). The cracks were then sealed for their full length with foam a fill type products (which had to be fully removable from the masonry without damaging the units). The grouts were mixed in a pot similar to the cintec pot system and the tubes filled. The procedure was to commence at the lowest port and fill under low pressure until material flowed out of the next port. At this time the first port was plugged with a tapered timber dowel and the procedure continued.

The grout had another property that allowed its surface to congeal quickly. This allowed for the dowels and ports to be removed prior to the material setting.

A problem that was commonly faced was the problem of grout leakage where the back face of the subject wall was in a cavity. Care had to be taken in these situations to ensure that the cavity was not filled with grout. In these situations as soon as the grout applicator noticed the pressure drop he would move onto the next hole and so on. When all ports were filled he would then inject all holes again until adequate pressure was encountered which indicated that the crack had been successfully sealed.

Proving 50mm core holes were taken through masonry units that were to be replaced. These cores indicated the depth of penetration, and if found to be inadequate then the crack were re injected.

Grout Filling of Cavities

In a few locations the cavities had to be filled with a grout to allow drilling to occur. This typically was a problem in areas where the geometry of the structure did not allow for straight drill holes, e.g. at the top of the window sections of the transepts where it was required that a structural head was required to span horizontally to the side walls.

This grouting was achieved simply by providing an access location (typically 2 courses wide by 2 or 3 high. A concrete pump hose was then used to fill the cavity in controlled heights with a low strength waterproof mix.

ESTIMATING THE RISK TO INSURANCE COMPANIES FROM EARTHQUAKES - A CASE STUDY BASED ON SYDNEY

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George Walker began PhD studies in earthquake engineering research in 1961 at the University of Auckland, obtaining his degree in 1966. After 21 years at James Cook University, where his major specialisation was in wind engineering, and 5 years at CSIRO, he now works in the reinsurance industry as a specialist in modelling catastrophe insurance losses.

ABSTRACT:

Currently the insurance industry is going through a major period of change in the way it analyses and copes with catastrophic risks such as earthquakes and tropical cyclones. GIS based models simulating the impact of natural hazards on property portfolios, originally developed by earthquake engineering researchers, are being increasingly used as the basis for a sound financial risk management approach to the determination of company policy in regard to catastrophe insurance.

The paper describes the current state of art of these developments through a case study approach based on a hypothetical insurance company with a major concentration of its portfolio in the Sydney area. It will demonstrate the particular problems which insurance companies face in insuring for earthquake losses in a relatively low risk environment. The purpose of the paper will be to demonstrate the role of earthquake loss modelling in the financial risk management of insurance companies, and foster discussion on the reliability of the scientific data being used in these models.

1 THE SCENARIO

Company XYZ Home Insurance Limited is a fictitious small locally based insurance company operating in the Sydney area in conjunction with a home lending institution. Its operations are solely concerned with the insurance of single family houses and their contents. It has a portfolio of a 50,000 homes with an average value of $125,000, from which it receives an average annual premium of $500 per property. It has net assets of $50 million including general reserves of $10 million dollars. The company has requested an assessment of its earthquake risk for use in designing its financial risk protection program.

2 THE NEED

In designing the financial risk protection program for an insurance company, a major objective is protection of its balance sheet to ensure it will be able to remain in business, and meet its obligations to its policy holders, after a major loss. Natural hazards such as earthquakes are just one of the types of risk to which the balance sheet of an insurance company is subject. The term volatility is used to describe a company's variability of financial performance due these combined risks. Systems now exist that enable all the risks to a company to be rationally analysed in an integrated manner, the outcomes of various alternative approaches to be simulated, and optimum solutions to be determined. These systems are heavily based on probability and statistics, and input to them is required to be in probabilistic form.

Figure 1 shows the estimated financial position of XYZ Home Insurance Limited at the end of the next financial year assuming no major catastrophe losses and no protection against them. The variation primarily reflects uncertainties about claims, the performance of the stock market, and interest rates.

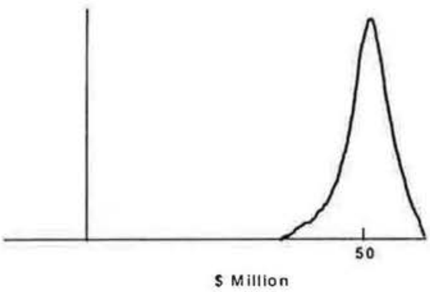

Figure 1 Expected Net Assets after Tax and before Dividend Distribution

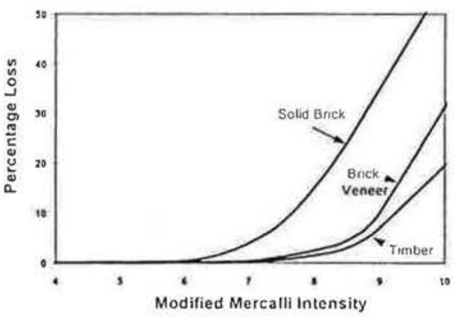

Figure 2 Vulnerability Curves

What is needed is the corresponding probability curve for catastrophe losses, which when combined with the curve in figure 1 will give an indication of the company's volatility without protection. The corresponding curve for earthquake losses will be a major component of this.

3 THE EARTHQUAKE MODEL

Losses were modelled using the Alexander Howden Australian earthquake model. This is a GIS model which, for a specified earthquake in terms of Richter magnitude, location and depth:

1) maps the estimated ground shaking intensity in terms of Modified Mercalli (MM) intensity or peak ground acceleration, including amplification due to soft soils;
2) maps an insurance company's property portfolio in terms of different building characteristics which are expected to influence the response to an earthquake, and superimposes it on the map of earthquake ground shaking intensity;
3) evaluates the anticipated losses for each building type based on the estimated ground shaking intensities and assumed vulnerability curves relating expected loss to ground shaking intensity for each building type, and combines them to produce the total expected loss.

The estimated ground shaking intensities are based on the attenuation relationships given in Gaull, Michael-Leiba and Rynn [1]. For the analysis of XYZ Home Insurance Limited's portfolio the study was undertaken in terms of MM intensities based on the recommended attenuation relationships for Southeastern Australia. The model assumes that these relate to firm ground or rock and provides for these to be increased by up to 1.5 MM units on soft soil.

The property portfolio was assumed to be a mixture of solid brick, brick veneer, and timber homes, with a higher concentration of solid brick homes in the older suburbs on soft ground than elsewhere. It was considered on a post code basis and assumed to be spread across the whole of the Sydney area encompassed by the Insurance Council of Australia (ICA) Risk Zones[2] 41, 42 and 43 roughly in proportion to post code populations.

The vulnerability curves used are shown in figure 2. They are based on the general shape of vulnerability curves used overseas - eg Applied Technology Council[3], and Coburn and Spence[4] - but the actual shapes have been derived by using them to calibrate the model against past earthquake losses in Australia.

The three earthquakes considered were the Adelaide earthquake of 28 February 1954; the Meckering earthquake of 14 October 1968; and the Newcastle earthquake of 28 December 1989. The firm ground shaking intensities were based on the isoseismal maps of the events published by the Australian Geological Survey Organisation [5,6] and modified for soft ground according to the algorithms incorporated in the model. Published information suggests the insured losses as a percentage of the insured values were of the order of 0.8% for Adelaide, 0.05-0.075 % for Meckering, and 3-4 % for Newcastle. The modelled losses using the curves in figure 2 were of this order. This does not mean that all the assumptions in the model are correct, but does suggest that in combination they are producing results in the right ball park.

Earthquake occurrence characteristics were based on those given for the Lachlan fold belt, which includes Sydney, by Gaull, Michael-Leiba and Rynn[1], with the exception that no upper limit was placed on the earthquake magnitude.

4 EARTHQUAKE LOSS PROFILE

The earthquake loss profile was evaluated by dividing the Sydney region into a grid and evaluating the loss for earthquakes of different magnitudes at the centre of each grid. Using the earthquake occurrence data, the probability of exceedance of different levels of loss was determined for each grid area. The overall loss profile was then obtained by adding these probabilities of exceedance over the whole region. The resulting curve is shown in figure 3.

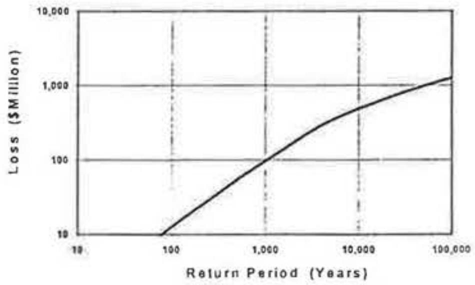

Figure 3 Earthquake Loss profile

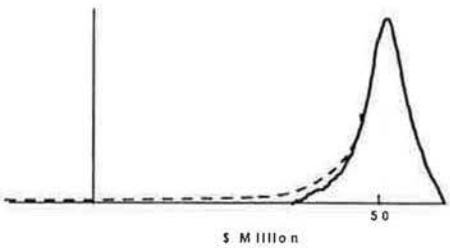

Figure 4 Effect on Expected Net Assets

The effect of this on the probable net assets at the end of the financial year, including earthquake risk, is to produce a long negative tail as shown in figure 4.

In the case of XYZ Home Insurance Limited this could bankrupt the company as the study indicates losses could be of the order of hundreds of millions of dollars, and their total net assets are only of the order of 50 million dollars. XYZ Home Insurance Limited can protect itself against this risk through reinsurance or other means of financial risk protection. The cost of this protection will of course reduce the probable net value of the company. While the earthquake risk could be fully covered, the cost of this is normally regarded as too high, and a balance is sought between the unprotected risk and the costs of risk protection. Key factors in making this decision are the risk of the net loss to the company exceeding general reserves, and the risk it will exceed total net assets. Table 1 shows the risks associated with different levels of loss protection using excess of loss reinsurance.

Table 1

Protection	Risk of Exhausting General Reserves	Risk of Exhausting Net Assets
None	0.013	0.0022
$50M XS 0	0.0017	0.001
$50M XS $5M	0.0019	0.001
$50M XS $10M	0.013	0.001
$100M XS $5M	0.0019	0.00057

5 DISCUSSION

The primary purpose of this paper is to demonstrate the use of earthquake loss modelling in the insurance industry and to stimulate discussion on the scientific information on which it is dependent. Some comments for discussion follow:

1) The loss profile curve in figure 3 is a conditional probability curve, as it purports to give the expected value of loss for an event of the given return period, not the probability of exceedance of a given value of loss, which is the way it is usually interpreted. To obtain the latter it is necessary to derive the associated family of confidence limit conditional probability curves and from these obtain the true probability of exceedance curves. It can be shown that providing the confidence limit range is not too great, using the expected loss conditional probability curve is conservative. To obtain the expected curve it is necessary to use the expected values of variables, not conservative values, with the uncertainties being incorporated in the confidence limits. Is this the basis of the information given in Gaull, Michael-Leiba and Rynn(1)?

2) The shape of the loss profile is very significant, but also dependent on not imposing limits on the likely maximum magnitude of earthquakes in the Sydney region. Are there sound scientific reasons for imposing the limits suggested in Gaull, Michael-Leiba and Rynn(1)?

3) In applying the attenuation formulae in Gaull, Michael-Leiba and Rynn(1) it has been assumed that they produce maximum ground vibration on rock or firm ground. Is this correct?

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PRELIMINARY ESTIMATES OF TSUNAMI-RISK FOR AUSTRALIA

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The Nekashizuka Award. The International Tsunami Society 1991.

ABSTRACT:

Statistics of tsunamis show that the number of tsunamis has increased in the last decade. There were 40 events of tsunamis for 1992-1997, many of them occurred in the South Pacific, Indonesia and Australia. Two important problems are studied in this paper. First, based on different numerical simulations we estimate the arrival time of tsunamis for several Australian cities (Melbourne, Brisbane, and Perth), generated by earthquakes at various locations. Second, we calculate the exceedance frequency for tsunamis on the east coast of Australia (Sydney area). In particular, the predicted tsunami height for a period of 100 year for the Sydney area is 1.3 m. Of course, this is a mean estimation for a large region. Local tsunami mapping can be achieved through the numerical simulation and seismo-techtonical analysis.

Preliminary Estimates of Tsunami-Risk for Australia

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The statistics of tsunamis show that the number of tsunamis in last decade has increased. There are 40 events of tsunamis for 1992 - 1997, many of them occurred in the South Pacific, Indonesia and Australia. For example, the killer tsunami of June 3, 1994 (local time), that took over 200 lives along the Indian Ocean coastline of Java (Indonesia) impacted the Australian coastline three to four hours later. As G.Foley reported(1), clear evidence of the tsunami was recorded on tide gauges at Broome, King Bay, Onslow and Carnarvon. The most significant impact occurred near the Northwest Cape, where the shore was exposed by a gap in the off-shore reef. The tsunami inundated a beach and car park. A surge estimated at 3 to 4 m carried hundreds of fish, crayfish, rocks and coral inland for a distance of two to three hundred meters. Of course, tsunamis occur infrequently in Australia, but we should note the previous tsunami of 1977 was more dangerous. It occurred after the Indonesian earthquake of 19 August 1977 (magnitude 8), which was felt in Western Australia up to distances of 2600 km from the source. As reported(2), the maximum ground intensity was MM V in northwest towns up to 1100 km from the epicentre, and MM III in Perth. Tsunami waves up to 6 m in height (1.5 m in Port Hedland, 2.5 m in Dampier, 0.2 m in Geraldton) were reported several hours after the earthquake. In 1883, after the volcanic eruption (Krakatou), the sea level rises to 2.5 m in Geraldton.
An examination of data from the Indonesian area, for period 1900 - 1977, suggests that about eight earthquakes of magnitude greater than 7.5 could occur in this region every 100 years, and of these, two or three might be felt in Western Australia. The same statistics is known for the east coast of Australia. For instance, the tsunami waves reached the Australian Coast (Brisbane, Evans Head, Newcastle, Sydney) after a strong earthquake (magnitude 8.6) in Chile of May 22, 1960. The tsunami took the form as the waves of different kinds (large waves, short-period surge, bore) with the runup height up to 4 - 5 m(3). Weak tsunamis in this region were recorded in 1995 and 1996 after earthquake at Loyalty Island and Chile consequently. New data of catastrophic tsunamis can be obtained by the geological methods(4,5). Characteristics of observed tsunamis in Australia are collected in the Australian Tsunami Database (AGSO) prepared recently.
Two important problems are studied in this paper. First, we estimate the arrival time of tsunamis, generated by earthquakes at various locations, for several Australian cities. Second, we calculate the exceedance (cumulative) frequency for tsunamis on the east coast of Australia (Sydney area).

Tsunami travel time

The propagation of tsunami waves across the ocean is studied now using mathematical models at different levels. They are described, for instance in books[6,7].All models estimate the travel time with good accuracy, and this property is used by the international and national Tsunami Warning Systems. The estimated tsunami travel time charts for the earthquakes epicentres at various locations are prepared by the Pacific Tsunami Warning Centre using hourly contour intervals and published, for example, in the Proceedings of the National Tsunami Workshop in 1994. More detail information of arrival times of tsunami (with the discretisation of 20 min) for two points of Australia (Northwest Cape, and Brisbane) is available in[8]. Based on different numerical simulations, the rough estimates of the arrival time for Melbourne, Brisbane, and Perth of various locations of possible earthquakes are summarised in Table 1.

Table 1. Estimated tsunami travel time for several cities

From:	To:		
	Melbourne	Brisbane	Perth
Macquarie Is.	3 hr	4 hr	6 hr
Vanuatu	5	3	10
Fiji	6	5	11
New Zeland	6	5	9
Papua-New Guinea	8	6	10
Indonesia	8	11	4
Philippines	11	9	9
Hawaii	13	9	17
Japan	14	11	13
Kurile Is.	15	11	14
Chile	15	16	18
Aleutians	17	14	18
Peru	18	19	21
Mexico	19	17	23
Alaska	19	15	20

Exceedance frequency for tsunamis on the east coast of Australia

The frequency estimation of tsunamis is based on the methods of extreme statistics[9,10]. Table 2 contains the known tsunami heights for Sydney area[11]. We do not include tide-gauge data of two last weak tsunamis (1995 and 1996), because they have not yet been published. The relation "earthquake magnitude - tsunami height" is shown in Fig. 1. Earthquakes with magnitudes more than 7.8 - 8.0 may effective generate tsunami waves, and this can be used by the National Tsunami Warning System. Fig. 2 shows the relation between the calculated exceedance (cumulative) frequency of tsunamis with their heights. Analytically, this dependence can be expressed as

$$f = 0.07\exp(-1.48R) \quad (1)$$

with good accuracy. Here the tsunami height R is in meters, and f is in 1/year. Thus, the predicted tsunami height for a period of 100 yr for the Sydney area is 1.3 m. Of course, this is a mean estimation for a large region. A local tsunami mapping can be achieved through the numerical simulation and seismo-techtonical analysis. Such calculation for the Russian Coast of Pacific is described in[9].

Table 2. Tsunami data for the region of Sydney

Date	Source	Magnitude	Height (m)
1868 Aug 13	Peru-Bolivia	8.0	1
1877 May 10	Chile	8.0	0.5 - 1
1922 Nov 10	Chile	8.3	0.2
1924 Jun 26	Macquarie Is	7.8	0.1
1929 Jun 17	Murchison NZ	7.6	0.1
1931 Feb 13	Hawkez Bay NZ	7.8	0.2
1931 Feb 13	Hawkez Bay NZ	7.1	0.1
1960 May 22	Chile	8.3	1 - 2
1989 May 23	Macquarie Is	8.3	0.2

Acknowledgement
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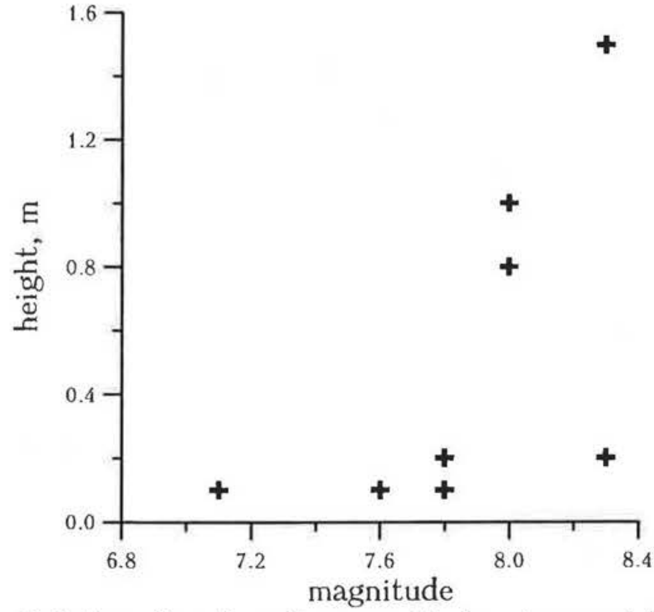

Fig. 1. Relation "earthquake magnitude - tsunami height"

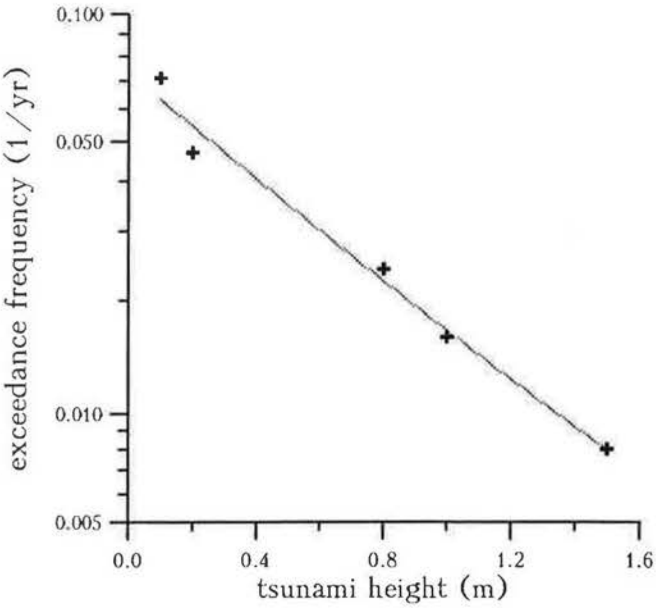

Fig. 2. Cumulative frequency for tsunamis in Sydney area

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THE GLOBAL SEISMIC HAZARD ASSESSMENT PROGRAM - GSHAP

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In late August, Gary attended the final working meeting of the International Association of Seismology and Physics of the Earth's Interior (IASPEI) Global Seismic Hazard Assessment Program (GSHAP) in Thessaloniki, Greece. This program is a significant step by the seismological community towards a unified global earthquake hazard study.

SUMMARY:

The International Association of Seismology and Physics of the Earth's Interior (IASPEI) held the final meeting for the Global Seismic Hazard Assessment Program (GSHAP) in Thessaloniki, Greece, in late August. This is the major IASPEI project for the United Nations International Decade of Natural Disaster Reduction (IDNDR), and is parallel with the WSSI program in earthquake engineering.

The quality and quantity of earthquake data vary widely over the Earth. Different magnitude scales are used in different countries. The methods used for earthquake hazard studies also vary widely. Some countries specify hazard using intensity, some use peak ground velocity or peak ground acceleration, and others use spectral measures of earthquake hazard. The aim of the GSHAP project is to provide a degree of standardisation for the earthquake data base, for the types of attenuation function used, and for the earthquake hazard computation methods used.

The closing phase of GSHAP will see:

1. collection of GSHAP seismicity data bases and the results that have been developed to date, in a uniform fashion according to specified guidelines.
2. production of earthquake hazard maps for several selected test areas in different tectonic situations, providing useful comparisons for seismic hazard studies undertaken in different situations.
3. a uniform map of global seismic hazard, not to replace the earthquake hazard maps used in individual countries, but to provide a unified overview of relative hazard.

The final years of the IDNDR will focus on the protection of megacities, moving from hazard assessment to engineering applications and risk mitigation strategies for multiple natural hazards. This includes the Risk Assessment and Diagnosis of Urban Areas against Seismic Disasters (RADIUS) initiative.

TSUNAMI OBSERVATIONS IN WESTERN AUSTRALIA

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ABSTRACT:

Tsunamis have been observed and recorded on tide gauges on the coast of north Western Australia. Although infrequent, tsunamis have the potential of causing loss of life and significant damage.

Observations from four tsunamis have been well documented, with reported waves up to 6m high. Travel times from an earthquake source to various locations vary considerably as a function of distance and water depth.

Actual travel times compare well with theoretically determined travel times. Travel times for locations of equal distance from the source vary by up to 65 minutes.

For Sunda Arc earthquake generated tsunamis, the estimated frequency on the north west coast of Western Australia is between 10 and 20 years.

INTRODUCTION

Several tsunamis (seismic sea waves) have been observed and recorded on tidal gauges on the Australian coast. None have caused significant damage. The most significant waves recorded were along the Western Australian coast following the Krakatoa volcanic explosion in 1883 (Bureau of Meteorology, 1929), and Indonesian earthquakes on 17 August 1977 (Gregson & others, 1979) and 3 June 1994 WST (UT + 8 hours).

Shallow ocean depths around New Zealand, Fiji, New Caledonia and Lord Howe ridge protect the eastern coast of Australia from tsunamis. Tsunamis from the south and west of Australia are unlikely as the earthquakes are associated with transcurrent faulting and therefore do not have the vertical earth movement needed to generate sea waves.

The section of the coast most likely to experience tsunamis is the north-west coast of Western Australia from earthquakes that occur in the Indonesian Sunda Arc. Much of the coast has a very wide continental shelf, up to 200 km wide at the 200 m bathometric contour, which prevents the waves from reaching large heights. However there are parts of the coast where the shelf narrows, particularly near the North-West Cape where the shelf is only about 10 km wide. Although infrequent, tsunamis have the potential to cause loss of life and significant damage. With the offshore development in the north-west the significance is increasing.

HISTORICAL OBSERVATIONS

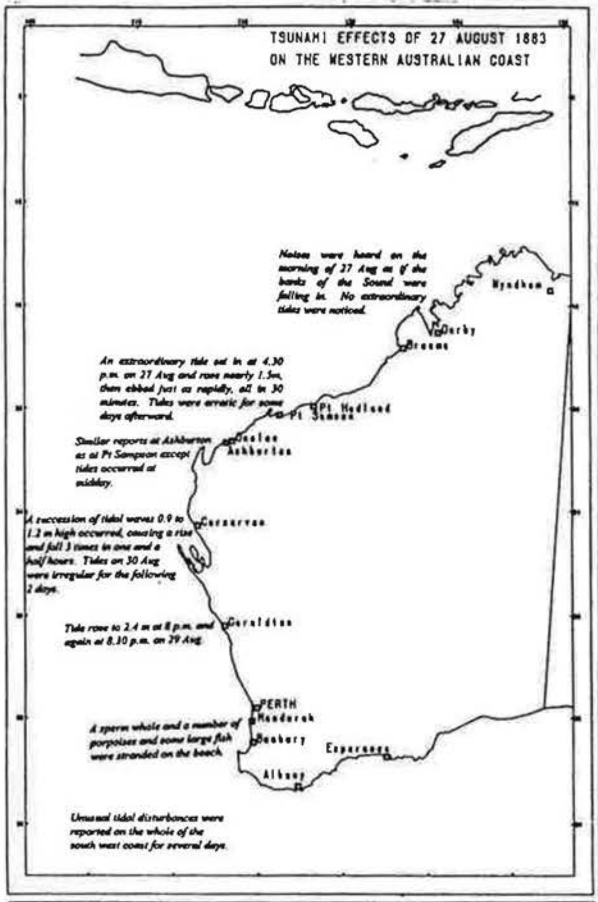
Two events have occurred at the Abrolhos Islands, 70 km west of Geraldton that may or may not be of significance with respect to the occurrence of tsunamis.

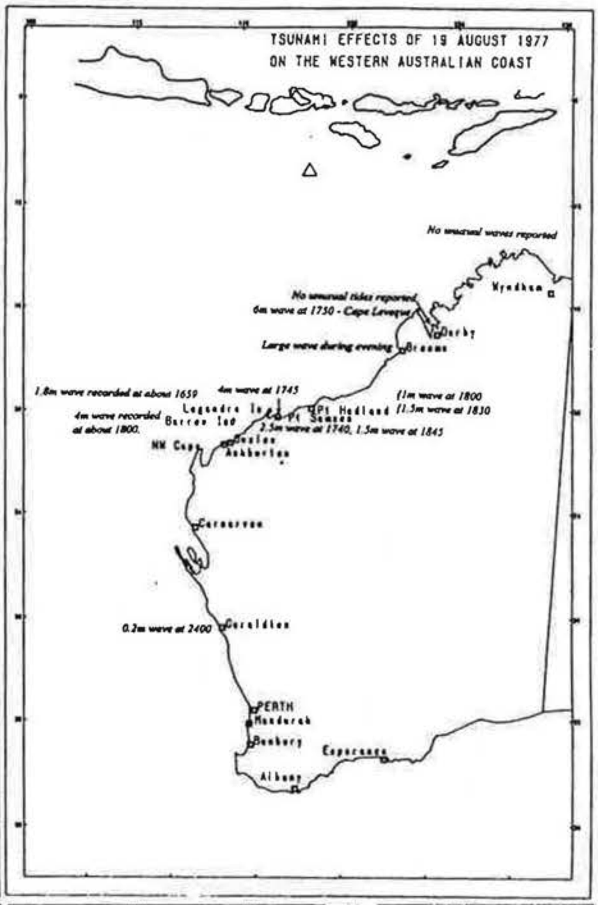
Many of the low islands are a compound of coral rubble storm ridges with elevations of less than 2m above sea level. During a sedimentological study of the islands by Curtin University (Collins & others, 1993), radiocarbon dating has indicated an erosional episode between 4000 and 2000 14C years before present. Although further work is needed to determine the origin of this destructive event, tsunamis or cyclonic storms are considered the most likely.

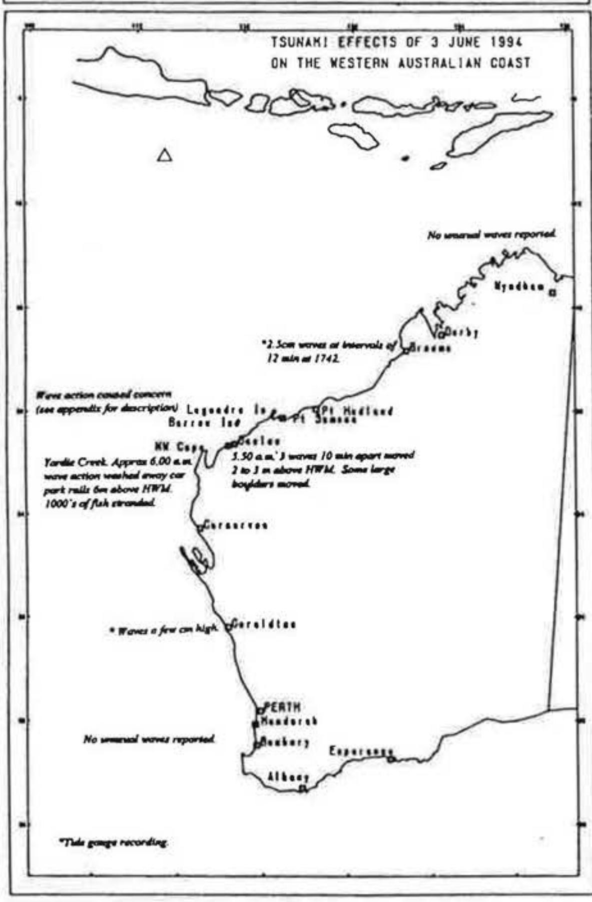
There is an unsubstantiated report of a number of Chinese workers drowning at the Abrolhos Islands about 1900. A search of earthquake catalogues could not identify an earthquake that could have been responsible for this occurrence. Recent studies in the Sandy Desert area inland from Broome, show evidence of massive tsunami effects 35 km inland (Bryant, 1996).

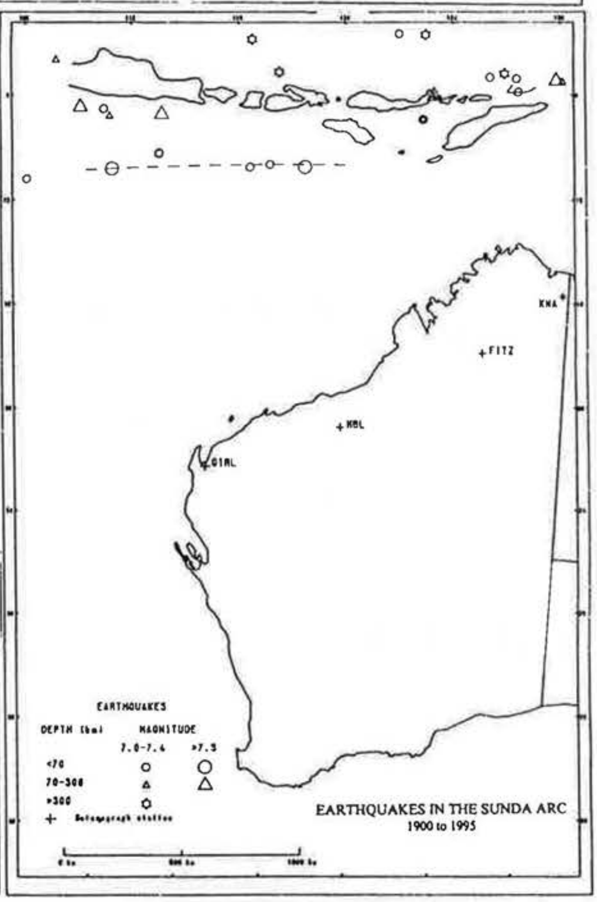
OBSERVATIONS

Four significant tsunamis have been observed along the northwest coast of Western Australia in the last 120 years. Descriptions of the observations are shown in Figure 1.


TSUNAMI EFFECTS OF 27 AUGUST 1883
ON THE WESTERN AUSTRALIAN COAST
Noises were heard on the morning of 27 Aug as if the banks of the Sound were falling in. No extraordinary tides were noticed.
Wyndham
Derby
Broome
An extraordinary tide set in at 4.30 p.m. on 27 Aug and rose nearly 1.5m, then ebbed just as rapidly, all in 30 minutes. Tides were erratic for some days afterward.
Pt Hedland
Pt Samson
Similar reports at Ashburton as at Pt Sampson except tides occurred at midday.
Onslow
Ashburton
A succession of tidal waves 0.9 to 1.2 m high occurred, causing a rise and fall 3 times in one and a half hours. Tides on 30 Aug were irregular for the following 2 days.
Carnarvon
Tide rose to 2.4 m at 8 p.m. and again at 8.30 p.m. on 29 Aug.
Geraldton
PERTH
Mandurah
A sperm whale and a number of porpoises and some large fish were stranded on the beach.
Bunbury
Esperance
Albany
Unusual tidal disturbances were reported on the whole of the south west coast for several days.


TSUNAMI EFFECTS OF 19 AUGUST 1977
ON THE WESTERN AUSTRALIAN COAST
No unusual waves reported
No unusual tides reported
6m wave at 1750 - Cape Leveque
Wyndham
Derby
Large wave during evening
Broome
1.8m wave recorded at about 1659
4m wave at 1745
Legendre Is
Barrow Isd
4m wave recorded at about 1800.
Pt Hedland
Pt Samson
(1m wave at 1800
(1.5m wave at 1830
2.5m wave at 1740, 1.5m wave at 1845
NW Cape
Onslow
Ashburton
Carnarvon
0.2m wave at 2400
Geraldton
PERTH
Mandurah
Bunbury
Esperance
Albany


TSUNAMI EFFECTS OF 3 JUNE 1994
ON THE WESTERN AUSTRALIAN COAST
No unusual waves reported.
Wyndham
Derby
*2.5cm waves at intervals of 12 min at 1742.
Broome
Wave action caused concern (see appendix for description)
Legendre Is
Barrow Isd
Pt Hedland
Pt Samson
NW Cape
Onslow
Yardie Creek. Approx 6.00 a.m. wave action washed away car park rails 6m above HWM. 1000's of fish stranded.
5.50 a.m.' 3 waves 10 min apart moved 2 to 3 m above HWM. Some large boulders moved.
Carnarvon
* Waves a few cm high.
Geraldton
PERTH
Mandurah
No unusual waves reported.
Bunbury
Esperance
Albany
*Tide gauge recording.


KNA
FITZ
MBL
GIRL
EARTHQUAKES
DEPTH (km)
MAGNITUDE
7.0-7.4
>7.5
<70
70-300
>300
EARTHQUAKES IN THE SUNDA ARC
1900 to 1995

1883, August 27. A tsunami followed the massive volcanic explosion at Krakatoa (6.07° S, 105.24° E). Large waves and irregular tides were observed for several days on the Western Australia coast between Geraldton and Derby. An estimated 36,000 people were killed in Indonesia as a result of the eruption.
1885, January 5. Geraldton experienced a subsidence of the sea of one metre at 2225 (WST) following an earthquake. The Australian earthquake catalogue lists an earthquake of magnitude Ms 6.5 at 29° S and 114° E at 2020 WST on 5 January.
1977, August 19. Seismic sea waves were observed and recorded on tide gauges between Derby and Geraldton over several hours with unusual tides over the next day. The tsunami followed a magnitude Ms 7.9 earthquakes located at 11.09° S and 118.46° E which occurred at 1408 WST.
1994, June 3. At 0220 (WST) a magnitude Ms 7.2 earthquake located at 10.477° S and 112.835° E resulted in a tsunami which was observed between North West Cape and Onslow. The recordings were also obtained on tide gauges along the coast. The tide was low at the time the tsunami arrived along the coast.

INSTRUMENTAL RECORDINGS

The tsunamis on 19 August 1977 and 3 June 1994 were recorded on tide gauges at various locations on the Western Australian coast. Brief descriptions of the recordings are given in Figure 1.

TSUNAMI TRAVEL TIMES

The travel time from the earthquake source to various locations varied considerably and is a function of both distance and water depth between the source and point of observation. Water depth can have a significant effect on the travel time to locations at similar distances. The velocity of the sea waves is related to the depth of water, with velocities of up to 1000 km/hr reached over deep ocean.

Tanahashi, 1963 estimates the velocity of a tsunami wave using the formula: $v = (gh)^{1/2}$ where v = velocity km/hr h = depth of water in metres g = acceleration due to gravity 9.8 m/sec^2. The average velocity was calculated between contours of water depth and the approximate travel time between contours determined. Hence the total travel time between the origin of the earthquake on 3 June 1994 and arrival at different locations along the coast could be calculated. Figure 2 graphically shows the changes in water depth and velocity of the sea wave between the earthquake epicentre and Onslow. There was good agreement, within 10 minutes, between the theoretical (0602 WST) and the observed arrival time (0550 WST).

Although the travel time generally increases with distance it is also affected by the water depths over which the tsunami travels. This is evident in the case of Legendre Is and the Griffin Venture where travel times were 46 minutes and 65 minutes respectively, shorter than other locations at the same distance.

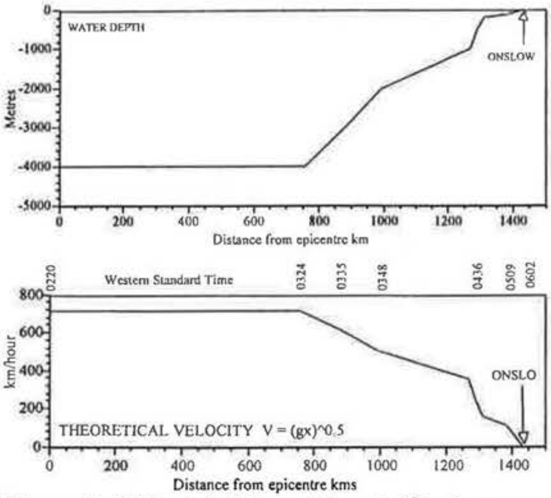


Figure 2. Calculated travel time to Onslow

Using the same method there was good agreement between the theoretical and observed travel times at other locations. The same method has been used to calculate the theoretical travel time between a set of hypothetical earthquakes at 1 degree intervals of longitude on latitude 11°S and several locations on the north-west coast of Western Australia. For earthquakes between 112.0° E and 114.0° E and within one degree north or south of latitude 11° S the epicentre is in deep water, 4000 to 6000 m. The travel time will vary within ± 6 minutes.

For earthquakes west of 112.0° E, travel times will increase by approximately 6 minutes per degree as the epicentres will be that much further from the north west coast. The travel time to off-shore installations such as the Griffin Venture will be considerably shorter because the proportion of the travel path through shallow water, and hence slow velocities is significantly reduced. In the case of the Griffin Venture the travel time is approximately 70 minutes less than that to Onslow, even though the distance to the epicentre is only 40 km shorter and the travel paths are similar.

TSUNAMI GENERATING SOURCE

Four sources that could generate tsunamis that could impinge on the West Australian coast are: (a) Massive volcanic eruptions (b) Earthquakes offshore Western Australia (c) Massive sub-marine landslides (d) Earthquakes in the Indonesian Sunda Arc. The latter is the most likely source of tsunamis affecting the north west coast of Western Australia.

For a tsunami of significance to be generated, an earthquake needs to be shallow in depth (generally less than 70 km), magnitude of 7 or more and located on the southern side of the Indonesian Islands. Earthquakes of magnitude 7 in the Sunda Arc since 1900 are shown in Figure 1. Only 19 of these earthquakes fit these criteria and of these, 10 had magnitudes equal to or greater than the earthquake on 3 June 1994 and five had magnitudes of 7.5 or more.

In a study on statistics of tsunamis in Indonesia, Nakamurs lists six earthquakes that fit the above criteria in the period 1800 to 1900.

Based on the frequency of large earthquakes of shallow depth occurring south of the Indonesian Islands it would be reasonable to expect effects from tsunamis on the average of every 10 to 20 years along the north west coast of Western Australia. The extent of the effects and danger will depend on the state of the tide at the expected arrival time of the tsunami. The danger to the coast will be higher at high tide.

CONCLUSIONS

The following conclusions are drawn:

(a) Tsunamis, although infrequent, occur along the coast of Western Australia, particularly the north-west.
(b) With increased industrial development both on-shore and off-shore, the tsunami hazard is more significant.
(c) The most likely source of tsunamis is from large earthquakes in the Sunda Arc region with a frequency of one every 10 to 20 years.
(d) The travel time from the source to coast will vary considerably being both a function of distance and depth of ocean. In some cases it can be as little as 2 hours.

(e) The wave height will vary depending on the rate of shallowing of the sea floor, coastal features such as reefs and the state of the tide.
(f) The possibility of large submarine landslides should not be ignored, however there is no documented evidence of their frequency of occurrence.

More detailed studies are required to determine the effects of coastal features and the areas where the shelf width is narrow, to determine vulnerable areas.

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EARTHQUAKE VULNERABILITY ANALYSIS OF GLADSTONE, QUEENSLAND: PRELIMINARY RESULTS

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AUTHOR:

Trevor Jones is Manager of the AGSO Cities Project which aims to assess and reduce the vulnerability of Australian urban communities to geological hazards. He has extensive experience in earthquake hazard assessment in Australia and the Southwest Pacific.

Ken Granger is Director of the AGSO Cities Project. He is a leading creator and proponent of GIS-based decision support tools which aid the mitigation of risk from natural and cultural hazards. Ken has extensive experience in the management and analysis of spatial data.

Long-Qing Cao is a scientist in the AGSO Cities Project and is a PhD candidate in geochemistry at the University of New England. He has developed computer programs to model and display GIS-based urban earthquake hazard zonations.

Jack Rynn is Director of Research, CERA. He has a long history of involvement with earthquake hazard issues and is known internationally for his commitment to the reduction of earthquake risk.

Steven Houston is a student of Civil Engineering at Central Queensland University. He has been instrumental in collecting and analysing geotechnical data for the Gladstone earthquake vulnerability study and has developed GIS databases for Gladstone City Council.

ABSTRACT:

In 1997 an earthquake vulnerability analysis was undertaken of Gladstone, Boyne Island and Tannum Sands in Central Queensland. The region has the highest assessed earthquake hazard in Queensland, and disruption of major local industry by future earthquakes would have national and international impact. We present preliminary results.

Geotechnical data and recordings of ambient ground noise at approximately 240 sites were used to prepare hazard maps. Major industries and residential areas are founded mostly on rock. Large areas of low-lying estuarine sediments of the Calliope River and Auckland Creek have been infilled for light industrial and other uses. The ground noise data showed a strong association between potentially enhanced ground shaking and areas of Quaternary sediments and landfills, particularly for vibration frequencies which may affect 'medium-rise' (4-9 storeys) and 'high-rise' (10+ storeys) buildings. Detailed information was collected on about 5,000 buildings and basic information on another 7,000. These data were integrated with the hazard information in a GIS tool to perform vulnerability analyses for scenario events.

INTRODUCTION

In 1997 an earthquake vulnerability analysis was undertaken of Gladstone, Boyne Island and Tannum Sands at the request of Gladstone City Council and Calliope Shire Council. The study was an activity of the AGSO Cities Project (National Geohazards Vulnerability of Urban Communities Project). We present preliminary results of the study.

The Gladstone and Boyne-Tannum area is a hub of major industrial activity in Central Queensland. Industries includes the Boyne Island aluminium smelter, the Queensland Alumina processing plant, ICI and Ticor chemical plants and the Queensland Cement Limited plant. These industries are serviced by the seaport infrastructure of the Gladstone Port Authority and by the NRG thermal power station. The port also services inland Central Queensland and is a major coal exporter. Major industrial and port expansion is planned, largely to the northwest of Gladstone.

The Gladstone region is estimated to have the highest earthquake hazard of Queensland (Standards Australia, 1993). This estimate is based on the historical seismicity which includes Queensland's largest known earthquake, the 1918 ML 6.3 event, approximately 120 km offshore from Gladstone, four moderate (ML 5.2 to ML 5.9) events from 1883 to 1935 in the Gayndah area approximately 200 km south of Gladstone, and an ML 5.2 event near Heron Island, approximately 160 km from Gladstone, in 1978. None of these events caused significant damage at Gladstone.

Urban areas underlain by unconsolidated sediments and landfills are known to have been the sites of maximum damage during strong earthquakes. In Gladstone, Quaternary sediments are deposited in at least two environments. The first comprises the tidal flats of the Calliope River and Auckland Creek estuaries, and the second is the middle and upper reaches of Auckland Creek where colluvial and alluvial sediments are deposited. Sediments originate from the weathering of the Palaeozoic mudstones, arenites and cherts of the Wandilla Formation (Donchak and Holmes, 1991).

Large areas of low-lying estuarine sediments of the Calliope River and Auckland Creek have been, and are being, infilled with a variety of materials for light industrial and other uses.

Disruption of major industry in the Gladstone and Boyne-Tannum area by future earthquakes would have national and international impact. For this reason, the mitigation of risks posed by earthquake activity in the area is important.

DATA COLLECTION AND PROCESSING

Geological and geotechnical data, recordings of very weak seismic motion, and information on the building stock, infrastructure and the historic effects of earthquakes were collected.

Recordings of ambient ground noise (microtremors) at approximately 240 sites with nominal half-km spacing were processed using the method of Nakamura (1989). Data were recorded for 400 seconds, with 100 Hz sampling, at each site using 1 Hz Mark Products L4C-3D seismometers and Kelunji digital seismographs. These data were cut to 40-second time windows for processing.

New techniques developed by AGSO were used to prepare hazard maps pertaining to three building heights: high-rise (10+ storeys with corresponding resonant frequencies in the range 0.25 to 1.5 Hz); medium-rise (4-9 storeys with corresponding resonant frequencies in the range 1.25 to 3.75 Hz); and low-rise (1-3 storeys with corresponding resonant frequencies in the range 3 to 10 Hz).

Information on more than 20 parameters describing about 5,000 individual buildings was collected. The parameters include the type of cladding, building height, roof material and pitch, gable type, window size and building foundation. More basic information on the remaining 7,000 buildings was also accumulated.

All data were incorporated in a GIS to perform vulnerability analyses for scenario events.

RESULTS, DISCUSSION AND CONCLUSIONS

Very good agreement was observed between the mapped areas of *soft* tidal estuarine sediments, in some cases overlain by landfills, and areas where the microtremor data indicated potentially enhanced, resonant, ground shaking for medium-rise and high-rise buildings. At present few buildings or industrial structures of four or more storeys or similar dimension are situated on the estuarine sediments in Gladstone.

Ground shaking with possible resonant effects pertaining to low-rise buildings was indicated in some areas underlain by Quaternary alluvium. Where industries and residential areas are founded on the Wandilla Formation, as is mostly the case, enhanced ground shaking in future earthquakes is not expected except where residual soil thicknesses exceed several metres.

The methodologies, linkages and data developed in the Gladstone earthquake vulnerability study could be applied successfully to the areas northwest of Gladstone as part of the planning process for the future industrial and urban expansion.

The microtremor technique we employed in Gladstone highlighted areas where the earthquake hazard is described in more detail, and may be higher or lower, than that inferred from a simple assessment of surface geology. This microtremor technique alone can provide useful hazard information for Australian urban areas in which geological and geotechnical data are absent or inadequate.

Incorporation of detailed geological and especially geotechnical data is essential to develop quantification of the localised hazard.

ACKNOWLEDGEMENTS

We thank the many local government, state government, industry, infrastructure and geotechnical engineering organisations who contributed greatly to this study. These include Gladstone City Council, Calliope Shire Council, Gladstone Port Authority, Queensland Alumina, NRG Power Station, Queensland Cement Ltd, Boyne Smelter and Connell Wagner. Cvetan Sinadinovski provided computer programs. Greg Scott developed the GIS.

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TOWARDS UNDERSTANDING COMMUNITY RISK: THE AGSO CITIES PROJECT

KEN GRANGER
DIRECTOR, AGSO CITIES PROJECT

AUTHOR:

Ken Granger is the foundation Director of the AGSO National Geohazards Vulnerability of Urban Communities Project (better known as the Cities Project) which is now entering its second year of activity. He has almost thirty years experience in the emergency management and defence fields. He is widely recognised as a pioneer in the application of GIS to support public safety agencies. He holds a Bachelor of Applied Science in Applied Geography (CCAE) and Master of Arts (AUN).

ABSTRACT:

The Australian Geological Survey Organisation (AGSO) has a well established reputation for its work in earthquake monitoring and analysis, in volcanic hazard research, and in fields of geoscience that relate to a wide range of more chronic geohazards such as salinity and acid sulphate soils. The establishing of the Cities Project (the National Geohazards Vulnerability of Urban Communities Project), however, has extended this emphasis on hazard science to the new field of risk science. A series of pilot projects, with an emphasis on earthquake and landslide risks, is being used to develop and test methodologies, identify research needs and to form operational, research and supporting partnerships.

The greatest challenge for AGSO introduced by the Cities Project, has been the need to develop information and analytical techniques to assess the vulnerability of a wide range of elements-at-risk from the impact of geohazard events. The elements-at-risk include buildings; utility infrastructure; logistic support infrastructure; economic and health facilities; public safety services; and individuals and groups of people. GIS are being employed to support the integration and modelling of data and to provide decision support for a range of public safety activities.

TOWARDS UNDERSTANDING COMMUNITY RISK - THE AGSO CITIES PROJECT

Ken Granger
Director, AGSO Cities Project
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BACKGROUND

The Australian Geological Survey Organisation (AGSO) has a well established reputation for its work in earthquake monitoring and analysis, in volcanic hazard research, and in fields of geoscience that relate to a wide range of more chronic geohazards such as salinity and acid sulphate soils. The establishing of the Cities Project (the National Geohazards Vulnerability of Urban Communities Project), however, has extended this emphasis on hazard science to the new field of risk science. A series of pilot projects, with an emphasis on earthquake and landslide risks, is being used to develop and test methodologies, identify research needs and to form operational, research and supporting partnerships.

RISK ANALYSIS

The *Risk Management* approach outlined in AS/NZS 4360:1995[1] provides the philosophical base for this research. At the heart of this approach is the recognition that risk is the outcome of the interaction of a hazard event and the elements at risk and their degree of vulnerability to such an impact. This relationship is invariably modified by the degree to which the risk outcome is acceptable to the community involved. Thus we can express the relationship in the following form:

$$\textbf{Risk} = (\textbf{Hazard} \times \textbf{Elements at Risk} \times \textbf{Vulnerability})^{\text{Acceptability}}$$

From this base, a generic approach to the analysis of risk from natural hazards is evolving. This process is illustrated in Figure 1.

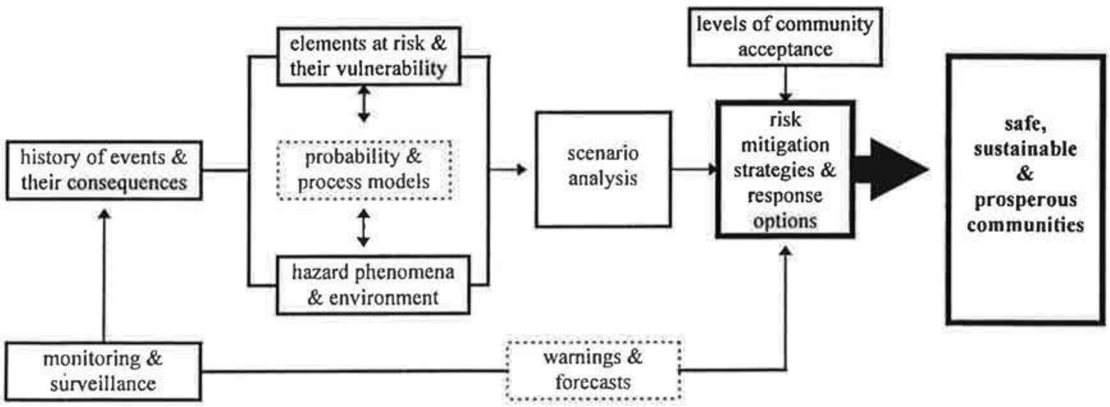

Figure 1: Cities Project generic risk analysis process

Historical knowledge: a detailed understanding of what events have occurred in the past (including paleo-events) and their effects provides the base for understanding what could/will happen in the future.

Monitoring and surveillance: one of the principal sources of historical event information is the extensive network of seismic and other monitoring stations and remote sensing resources.

Phenomenon process knowledge: the focus of hazard science research is on the mechanisms that cause, create, generate or drive the hazard phenomena, eg what causes earthquakes and how their energy is transmitted through various strata. This is underpinned by foundation information relating to the background climatic, environmental, terrain, ecological and geological aspects of the site that are relevant to hazard studies, eg the depth and nature of the sediments and their microtremor response.

Elements at risk and their vulnerability: this is a new area of study and is focused on developing an understanding of the vulnerability of a wide range of the elements that are at risk within the community eg the buildings, lifeline infrastructures and people.

Synthesis and modelling: given that our knowledge of hazard phenomena and the processes that drive them are imperfect, it is necessary to develop appropriate models (process, spatial and temporal) to fill the gap eg the various models of bushfire spread or flood behaviour. A key aspect of these models is an understanding of the probability of events of particular severity occurring. The synthesis of data and the mapping of the relationships between the hazard phenomena and the elements at risk is also an important process in this stage.

Scenario analysis: this is an emerging technique that contributes to 'future memory', an understanding of 'what will happen when...'. The output embraces forecasts of economic loss (eg PML calculations), estimates of potential casualties or assessments of the risk of secondary or consequential hazard impacts such as the spread of fire or the release of hazardous materials following an earthquake.

Acceptability: it is in this area that the science of risk analysis comes face-to-face with human nature and the political 'outrage' dimension of risk management. A key element in determining limits of acceptability rests with effective risk communication and public policy development.

Warnings and forecasts: the most potent mechanism by which to achieve risk mitigation is an effective warning and forecasting system. These are well advanced for hazards such as floods and cyclones but are less well developed for landslides and earthquakes.

Mitigation strategies and response options: the ultimate objective of risk analysis is to develop strategies that will lead to the elimination, reduction, transfer or acceptance of the risk and to ensure that the community is prepared and able to cope with a hazard impact. Included here are strategies such as building codes and urban planning schema.

The outcome of all of this is safer, more sustainable and more prosperous communities.

The greatest challenge for AGSO introduced by the Cities Project, has been the need to develop information and analytical techniques to assess the vulnerability of a wide range of elements-at-risk from the impact of geohazard events. The elements-at-risk include buildings; utility infrastructure; logistic support infrastructure; economic and health facilities; public safety services; and individuals and groups of people. This work is involving collaboration with a very wide range of disciplines including geography, engineering, economics, logistics, public policy, psychology and a range of social sciences.

RISK-GIS

Regardless of the scale and nature of the risk event, the reduction of the uncertainty associated with disasters is dependant largely on the availability of appropriate information. Spatial information is at the forefront in the information needed, because at least 80% of all decisions made in the risk management process have a spatial content. It is also clear that the demand for information is spread throughout the process, rather than concentrated in the heat of the response stage. One of the clear advantages in adopting the more holistic *Risk Management* approach is that the vast majority of data needed to prevent, prepare for, respond to and recover from a disaster can be accumulated, tested, validated and used **before** the disaster event becomes a reality. That is to say, the information (and the various risk management processes it supports) becomes sustainable.

Over the past decade, geographic information systems (GIS) have been used increasingly as tools to provide information to address specific aspects of the risk management problem, especially in hazard mapping and modelling for phenomena such as bushfires or flood and storm tide inundation. There are clear advantages, however, in developing a fusion between a philosophy of risk management and the power of GIS as a decision support tool, hence *Risk-GIS* as it has been christened in the Cities Project. It has as its philosophical roots the risk management approach outlined above, and the view of GIS embodied in Dave Cowan's[(2)] definition as 'a decision support system involving the integration of spatially referenced data in a problem solving environment'.

In this context, the 'problem solving environment' is risk management.

The risk management process imposes a significant demand for a wide range of information products. To cater for this eclectic demand, *Risk-GIS* must be structured to cope with a wide range of external inputs, internal operations and output to a wide range of external consumers. Figure 2 summarises the key structural elements of *Risk-GIS*.

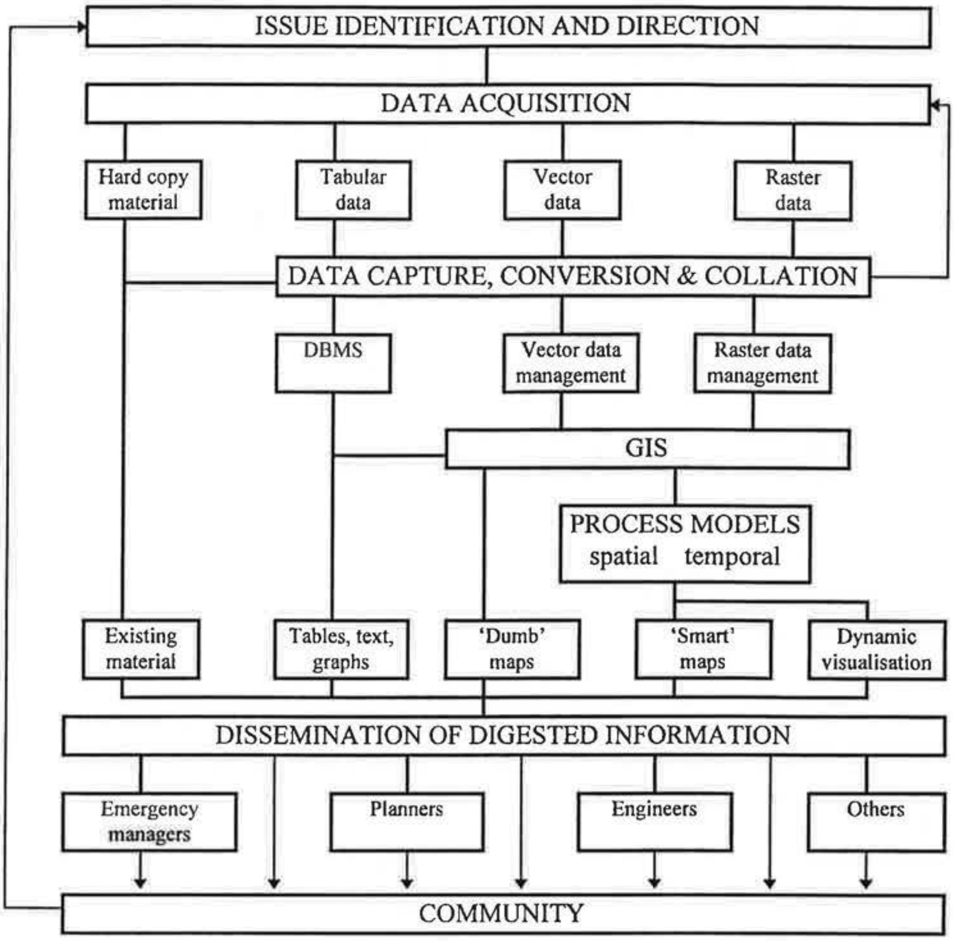

Figure 2: *Risk-GIS* structural elements

RESULTS

The results of research under the Cities Project are adding considerably to our knowledge of the risks faced by our urban communities. The contribution of *Risk-GIS* to this process goes well beyond its technology and its capacity to manipulate data. At this stage, however, it has yet to eliminate or even significantly reduce either the uncertainty or the ignorance that existed when this program commenced. However, in its application thus far, *Risk-GIS* has begun to fostered a 'sober cautiousness' when it comes to matters relating to the risks faced by urban communities in Australia.

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PROGRESS ON THE DEVELOPMENT OF A JOINT AUSTRALIAN/NEW ZEALAND EARTHQUAKE LOADING STANDARD

ANDREW KING, STRUCTURAL GROUP LEADER, BRANZ

AUTHOR:

Mr King is Chairman of the Joint New Zealand and Australia Earthquake Design Standards Committee, BD6/4. He is involved with the development of several national, regional and international structural standards. He is the Structural Engineering Section Manager at BRANZ in Wellington. He is the current President of the New Zealand National Society for Earthquake Engineering.

ABSTRACT:

The process of developing a Joint Earthquake Design Standard for New Zealand and Australia has progressed over the past year. Ten specialist working groups have beem formed each with specific tasks upon which to focus. The key issues within each task area have been identified and a plan developed to progress the resolution of those issues. This paper summaries the direction these working groups are heading on, the key issues they have identified and their proposed work plans and delivery schedules.

SEISMOLOGY & GEOTECHNICAL ISSUES (WGS 1, 2 & 3)

Kevin McCue *AGSO*	Gary Gibson *RMIT*	Graham McVerry & David Dowrick *IGNS*
Mick Pender *U. of Auckland*	John Berrill *U. of Canterbury*	Trevor Matuschka *Engineering Geology Ltd*

These working groups are charged with developing a suite of elastic ground response spectra to reflect the characteristics of earthquake induced ground motion for each region (WG1), a seismic zonation system to reflect the regional seismicity (WG2). The modifying influences of near-surface soil conditions are to be included (WG3). Their collective output is to prescribe the appropriate elastic response spectra to be established for a specific site.

Issues which have been identified include

- The differences of interplate and intraplate earthquakes both with regard to the event magnitude and the attenuation characteristics.
- Although the codified resulting presentation is expected to be similar, the basis of derivation of the pseudo elastic response spectra will differ between New Zealand and Australia to reflect both the difference in intraplate and interplate events and also the lack of measured near field response data.

For Australia:

- the Newmark and Hall method of construction will be used to develop the acceleration and velocity spectra for the nominated 500 year return period event.
- Some magnitude band amplification factoring of a typical 'Australia-type' spectra is expected to be used to scale out to the 2500 year return period ground motion.

For New Zealand:

- Work is well advanced on refining the attenuation model to include consideration of the source depth, the fault mechanism and tectonic type of earthquake. It will form the basis for developing the basic elastic pseudo response spectra. Some magnitude-dependent weighting (rather than a uniform hazard approach) is likely to be applied in the hazard estimates to reflect the greater duration and damage potential of larger magnitude earthquakes.
- The New Zealand hazard results will be presented in terms of 5% damped elastic acceleration response spectra and compatible displacement spectra.
- The presentational style for inclusion within the standard is expected to be a parametric form of spectra, with ordinates being derived from the zone factors for different periods (say a map for zone factors to provide ordinates for 0 (ie PGA), 0.2 and 1.0 or 1.5 sec period responses). Scale factors for differing soil conditions are anticipated although additional zone maps are an alternative.
- Design data for the 2500 year return period event (ie the 'survival' limit state) is to be included.
- 'Serviceability' intensity motion is required for New Zealand. The current NZ procedure of a uniform scale factor being applied ($1/6^{th}$) is an open question and needs further consideration. Guidance as to the appropriate return period for such events is an issue to be referred to the overview General Loadings Committee.
- The timetable agreed is for indicative spectral shapes to be available by mid October 1997 with the final results by April 1998.

DESIGN LEVELS (WG4)

Lam Pham *CSIRO*	John Woodside *Connell Wagner*	Bob Potter *Cement & Concrete Assn.*
Ian Billings *Beca Consultants*	John Wilson *Melbourne Uni*	

The task is to prescribe the levels of design which can be used to attain the required performance objectives prescribed in the national building codes. Designers are free to use the method of design most appropriate for the given site, occupancy class and building form (materials and geometry). In low seismicity areas with regular buildings which inherently possess some ductility, the appropriate method of design may be to provide an adequate lateral load path and detail accordingly. In areas of greater seismicity or where either the building form or geometry is such that irregular dynamic response is expected, then detailed seismic analysis and design detailing will be needed. For key facilities which are expected to continue to operate after a major event, then active base isolation or dynamic control techniques can be expected.

The group agreed first to review other modern standards (UBC, Eurocode, JAI specifications, Canadian Standard) and to compare their collective approach to this issue with that employed within AS 1170.4.

INELASTIC STRUCTURAL RESPONSE (WG5)

Rob Jury *Beca Consultants*	Charles Clifton *HERA*	Lou Robinson *Hadley Robinson*	Lam Pham *CSIRO*
Mike Griffith *Adelaide Uni.*	Gerhard Horoschun *Aus Construction Services*	Phillip Sanders *Steel Reinforcing Inst.*	John Wilson *Melbourne Uni*

The task is to provide the means of translating the elastic pseudo response spectra (delivered by WG 1,2 &3) into a suite of response spectra suitable for the design of buildings of different form and materials. The current preference appears to be to adopt the μ factor approach with some allowance for the influence of long duration shaking. The need to relate the elastic spectra reduction factor to test derived data was acknowledged, particularly when new structural materials or unusual combinations of structural form were being considered. A more detailed review of ATC 19 (the UBC 'R factor' approach), EC8, the Japanese requirements and the Canadian Code is to be undertaken as a first step (by the end of September '97). Commentary and code clause recommendations are scheduled to be developed by March '98.

STRUCTURAL REGULARITY CONTROLS (WG6)

John Wilson *Melbourne Uni*	Nelson Lam *Melbourne Uni*	Peter Moss *U of Canterbury*	Richard Fenwick *U of Auckland*

The task is to provide appropriate controls and guidance to preclude the use of simplified design procedures when buildings have significant horizontal or vertical irregularity. It is acknowledged that the assumed first mode dominance, implicit in the equivalent static design method of load distribution is inappropriate when the structure has disparate structural stiffness between adjacent storeys (ie is vertically irregular). In these cases modal analysis will be required to more realistically distribute the lateral base shear over the height of the building (ie the first mode response no longer dominates). The implication of post elastic building response needs to be considered.

Buildings which are highly irregular in plan bring into question common assumptions about load sharing between adjacent lines of resistance and the assumptions commonly made regarding the link diaphragms. The presence of such irregularities will often require 3 dimensional analysis with emphasis on the allocation of lateral load between frames and care in the design and detailing of link elements. The means used to provide this control in other modern earthquake design codes (UBC '97; NEHRP, EC8, Canada and Japan) are to be reviewed.

Torsional effects have traditionally been allowed for by introducing a nominal eccentricity at each floor. A treatise (authored by Prof Paulay) outlining a new approach in which element demands resulting from torsional effects following the onset of inelastic behaviour can be controlled by design has been distributed for consideration by the working group.

METHODS OF ANALYSIS (WG7)

Geoff Sidwell *Connell Wagner*	Lou Robinson *Hadley & Robinson*	Max Irvine *Structures & Structural Dynamics*	Athol Carr *U of Canterbury.*

The task is to develop guidelines for designers on the appropriate methods of analysis for buildings. The preference for a simple equivalent static design approach needs to be balanced against the more sophisticated multi-modal or time history analysis approaches. It is expected to remain at the discretion of the designer to select the appropriate method of analysis. The simpler procedures will usually result in a greater level of conservatism. More sophisticated analysis, together with the inclusion of the effects of secondary elements within the analysis tends to reduce the level of redundancy present. Thus the justification for using structural performance factor reduction factors, the need to relate the base shear derived from modal analysis to that derived using the equivalent static design, and the means of selecting and scaling ground motion records to coincide with the published elastic response spectra are under review.

DEFORMATION CONTROL (WG8)

Peter Moss *U of Canterbury*	Richard Fenwick *U of Auckland*	Lam Pham *CSIRO*
Mike Griffith *Adelaide Uni.*	John Woodside *Connell Wagner*	

This working group is focusing on determining appropriate deformation controls to preclude the premature onset of non-structural damage under serviceability intensity events and unacceptable second order effects (such as P-Δ induced instability) under ultimate conditions. With the low long period response spectra being used for design, P-Δ effects are becoming more significant. Guidance will be required as to what maximum inter-storey deformation would be acceptable under both serviceability and ultimate limit state conditions. Methods of adjusting deformation derived using elastic response and material properties to match the inelastic deformations will need to be addressed. These controls have application to all loading conditions and may be included in the General Design section of the Standard. The need to control post-elastic deformation and to require adequate detailing for ductility remains an earthquake related issue. These effects are unlikely to need consideration in moderate or low seismicity regions.

DESIGN OF BUILDING PARTS (WG9)

John Hare *Holmes Consulting*	Trevor Robertson *Kingston Morrison*	Barry Davidson *U of Auckland*
Nelson Lam *Melbourne Uni.*	Gerhard Horoschun *Aus Construction Services*	

The task is to develop a simple rational methodology by which parts and components within buildings can be designed. The working group has proposed two tiers of design. A simple (more conservative) design approach may be possible for parts and components housed within regular medium rise buildings, low-rise buildings or within the lower part of high-rise buildings where the structural amplification component of the excitation is small. A more complex approach may be justified for other elements where the structural response is expected to significantly contribute to the dynamic excitation of the 'Part'. The working group have recognised that it may be preferable to develop different design procedures for different types of 'Parts' and have suggested they be classified as non-structural components (eg suspended ceilings, parapets, cladding, equipment); secondary structural components (eg lift machine rooms, penthouses, lightweight internal structures); Planar component loaded out of plane (eg tilt-slab walls); Horizontal link elements (eg diaphragms, floor systems). The performance expectations from building components and parts has also been identified as an issue which needs clarification. This is likely to be forwarded to the main BD6 committee (or higher) for a determination.

DISPLACEMENT-BASED DESIGN (WG10)

Nigel Priestley *U of Cal San Diego*	Lou Robinson *Hadley Robinson*	Mike Griffith *Adelaide Uni.*

The task is to develop a simple, rational design procedure for determining the basic required member strengths and stiffness based on direct displacement considerations. This is a relatively new procedure whereby structures are detailed to achieve a specified displacement under a design level earthquake. By limiting the acceptable member strain, it is possible to provide a uniform risk against the onset of damage or collapse. It is envisaged that this approach will be introduced as an alternative design procedure, perhaps as an appendix to the Standard. The need for consistency of ground motion data is acknowledged (and WG 1-3 are aware of this need). The group proposes to develop the necessary relationships between the structural ductility factor, the materials and the equivalent viscous damping. The need to relate the design limit states to serviceability, damage control and survival limits has been identified. It is expected that the direct-displacement design approach will primarily be used to size flexural plastic hinges. Capacity design procedures will be used to determine strength of capacity protected sections.

ASSESSING THE VULNERABILITY OF PEOPLE TO NATURAL HAZARDS: ANALYSIS OF CENSUS, INFRASTRUCTURAL AND HOUSEHOLD DATABASES

DAVID KING, BA, CERT. ED., PH.D

AUTHOR:

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ABSTRACT:

Natural hazards only become disasters when they impact upon people. As a consequence of improved monitoring and warnings, loss of life from natural hazards has diminished during this century, while at the same time loss of livelihood and property have dramatically increased. This expansion in the physical impact is a consequence of rapid urban growth in hazard zones and the increasing complexity of our cities. People are unequally impacted, not just in relation to their physical location, but also according to their personal characteristics. Communities and structures that are vulnerable to natural hazards may be classified from databases and mapped using Geographical Information Systems. Using GIS we can summarise characteristics from census data in order to estimate communities that are socio-economically vulnerable to hazard. We are also able to assess socio-economic and demographic vulnerability in relation to physical infrastructure and building type. Limitations to the use of such databases are presented and discussed.

Paper No. 31

Assessing the Vulnerability of People to Natural Hazards: Analysis of Census, Infrastructural and Household Databases

David King, School of Tropical Environment Studies and Geography James Cook University

Risk and Vulnerability

As a natural disaster is the consequence of a natural hazard impacting on a community, an understanding of the vulnerability of people and their communities is as important as understanding the processes of the hazard. Research that is summarised in this paper was carried out in relation to the community vulnerability to cyclones, although a part of the Townsville analysis was prompted by a need to assess socio-economic characteristics and housing type in relation to a dengue fever epidemic. The use of population and housing characteristics to assess vulnerability may in fact be applied to any kind of hazard. However a mapping of characteristics for vulnerability to storm surge or cyclones is not necessarily the same map as vulnerability to dengue fever. The same method and its limitations may equally be applied to earthquakes or landslides, but will probably rank building vulnerability differently from a cyclone ranking.

The basic hypotheses of vulnerability assessment are that certain sections of the population are more vulnerable to natural hazards on account of their demographic, social and economic characteristics, and that certain types of buildings are more vulnerable on account of their construction and materials. Individual vulnerability varies enormously and transcends population classifications. It has been shown [1] that the greatest death rate has been amongst active males, rather than such obviously vulnerable groups as the aged and children. However, in a major disaster it is recognised by many writers, such as Granger[2], Keys[3], Anson[4] and Blaikie[5], that the very young, the very old, the disabled, single parent families, new immigrants, low income earners etc. may require greater assistance, a concentration of emergency service resources, and intervention in evacuation and re-housing.

Another dimension of vulnerability is the built environment[6]. According to the type of hazard, certain types of structures may be identified as more or less vulnerable. In the case of cyclones we identify timber and fibro buildings as vulnerable to cyclones (the same type of building also applies to dengue, as in conjunction with the age of the house, this style is more frequently unscreened), and low set housing, as well as timber and fibro as especially vulnerable to storm surge.

Population and Infrastructural Databases

The main problems of identifying vulnerability based on population characteristics and building type lies with the nature of the data. Two infrastructural databases have been used in this study. A survey of all of the buildings in Cairns was compiled by Granger for the Queensland Department of Emergency Services, and a survey of 13,000 houses in Townsville was carried out by the Cyclone Testing Station of James Cook University as a TCCIP project (it covers about 40% of residential buildings drawn proportionately from each suburb). These surveys are not identical owing to the different priorities of each, but they give an extremely full picture of each town showing the precise location of buildings relative to known hazard zones (the Cairns database contains elevation data for each house, as well as the location of the storm surge zones and landslide sites).

The problems with both the Cairns and Townsville databases (and similar data for Mackay) are the initial cost of gathering data for every structure, and the costs of upgrading and maintaining the databases. The maintenance cost will most likely fall on the city council. Peripheral high growth laissez faire councils, like Thuringowa and Pioneer may be less likely to participate in vulnerability mapping and database collection and maintenance.

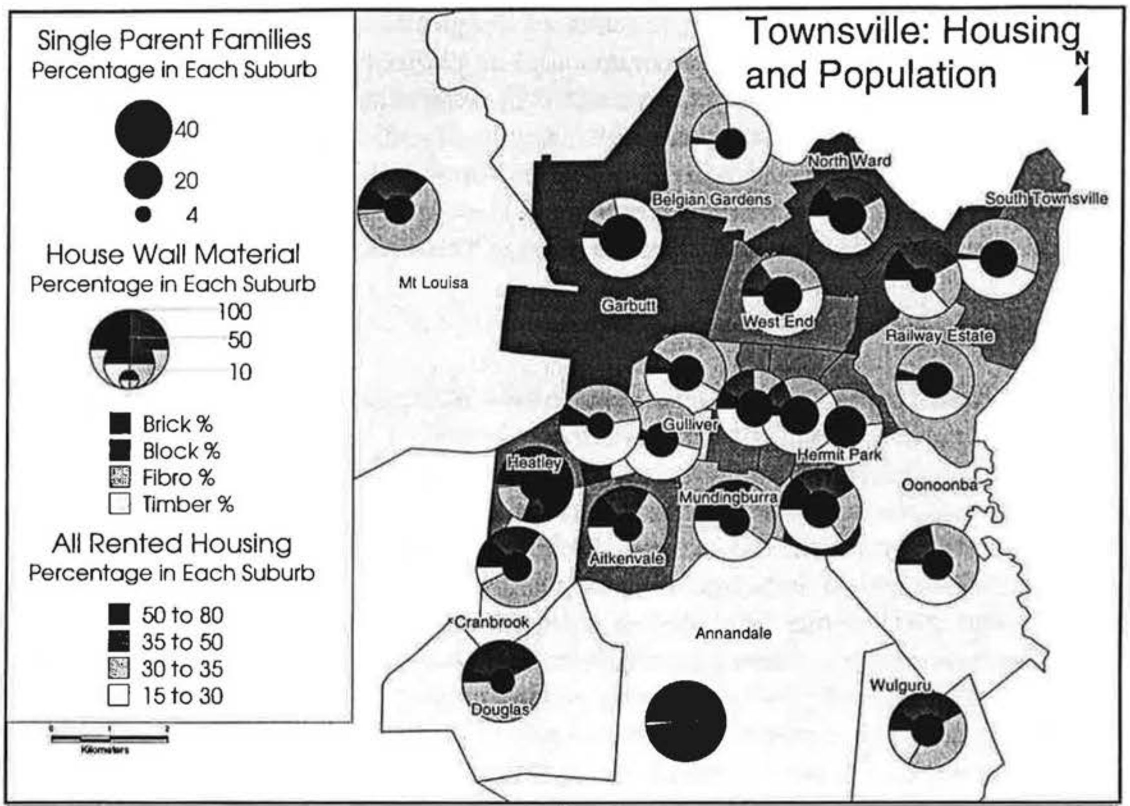
Population characteristics are derived from the national census. There are three sets of problems with this database: ageing of the data, aggregation of population at the level of the Collector District, variability of the CD populations, and the associated statistical problems of grouping variables into composite vulnerability indicators. Ageing of the data is exacerbated in rapid growth locations, which includes most of coastal Queensland. The data are already a year old before we are able to begin analysing the census, and will be almost two years old by the time is it processed for emergency management use. We will then use that data until the next census is fully processed, first by the Australian Bureau of Statistics, then the end user, for up to 7 years after the census was conducted.

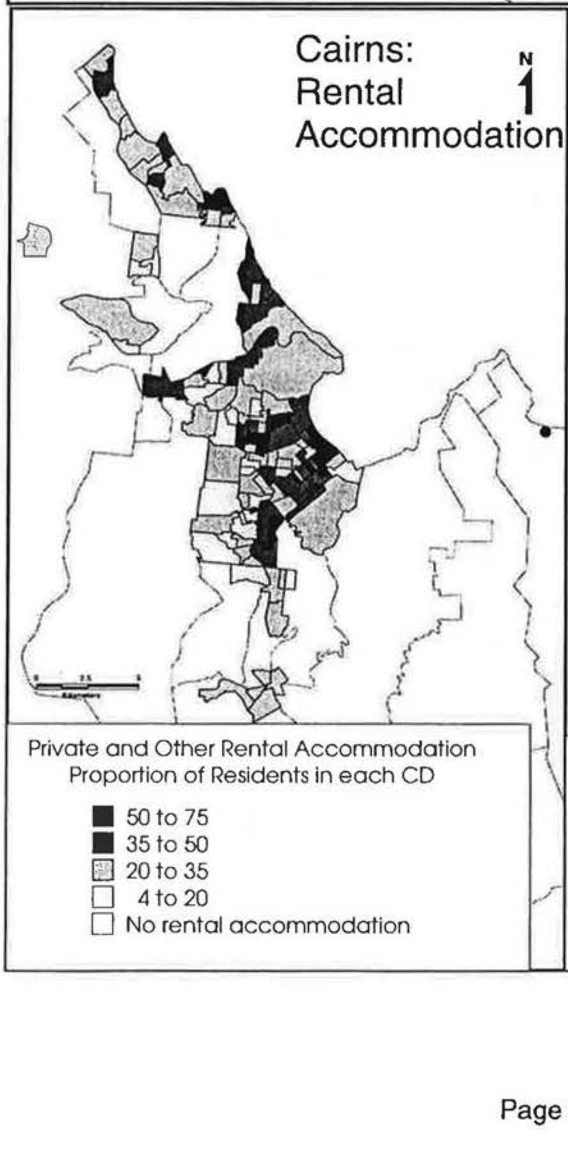
The Collector District is an area of a few streets, or an identifiable rural community, of around 200 households; the workload of one census collector. In reality the number of households varies significantly from 200, and the mean of just under 3 persons a household also varies widely. Thus CD's may range from a few dozen to over 1,000 people. The data for all of these individuals is then aggregated to a single value for each CD. This alone creates statistical difficulties when using multivariate analytical methods. It creates even more difficulties when attempting to combine population and building characteristics. Anyway it necessitates the aggregation of individual building data to a single set of statistics for each CD, thus losing much of the precision of the infrastructural surveys.

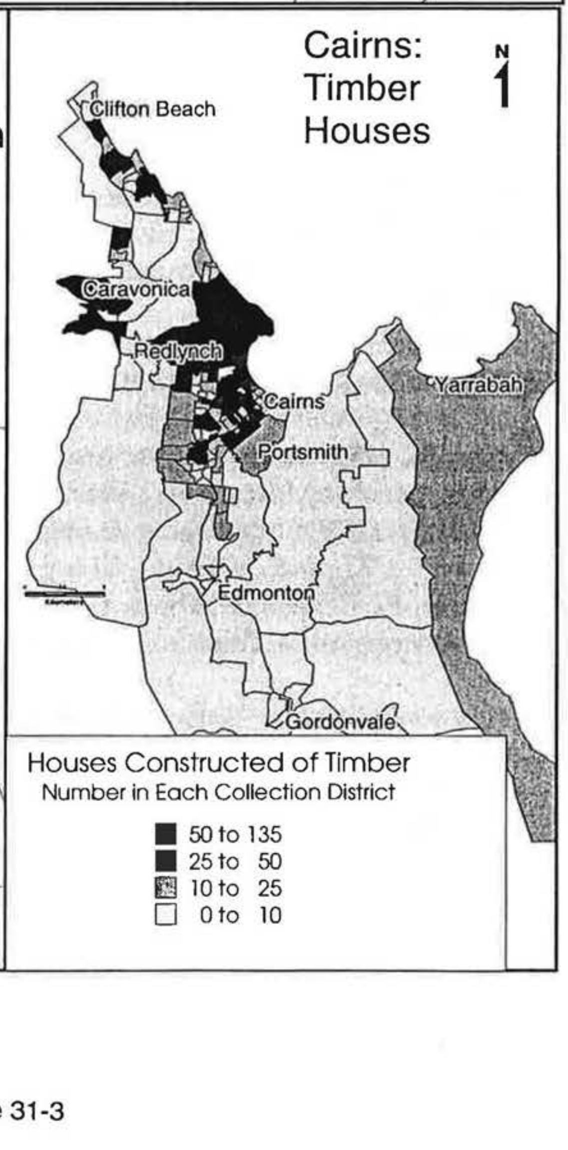
Vulnerability Mapping

Despite these difficulties databases allow an enormous variety of maps of vulnerability, ranging from individual building materials to numbers of people in each CD under a range of criteria, such as the over 75 year olds living alone, single parents with small children, car less households and non English speakers and so on. Individual characteristics of vulnerability can be mapped effectively and are undoubtedly useful to planners and emergency managers. These are illustrated by the two maps of Cairns and the composite map of Townsville.

Statistical limitations place constraints on the use of factor analysis or principal components analysis. The accuracy of composite vulnerability maps is compromised because the vulnerability ranking may be varied significantly by substituting alternative


Townsville: Housing and Population
N
Single Parent Families
Percentage in Each Suburb
40
20
4
House Wall Material
Percentage in Each Suburb
100
50
10
Brick %
Block %
Fibro %
Timber %
All Rented Housing
Percentage in Each Suburb
50 to 80
35 to 50
30 to 35
15 to 30
Mt Louisa
Belgian Gardens
North Ward
South Townsville
Garbutt
West End
Railway Estate
Gulliver
Hermit Park
Heatley
Mundingburra
Oonoonba
Aitkenvale
Cranbrook
Annandale
Douglas
Wulguru


Cairns: Rental Accommodation
N
Private and Other Rental Accommodation
Proportion of Residents in each CD
50 to 75
35 to 50
20 to 35
4 to 20
No rental accommodation


Cairns: Timber Houses
N
Clifton Beach
Caravonica
Redlynch
Cairns
Yarrabah
Portsmith
Edmonton
Gordonvale
Houses Constructed of Timber
Number in Each Collection District
50 to 135
25 to 50
10 to 25
0 to 10

socio-economic variables. However, a series of composite maps of Cairns based on factor analysis scores, shows certain communities as consistently more vulnerable than others. Correlation analyses in both Cairns and Townsville showed relationships between such characteristics as unemployed, low income, lower education levels, rental accommodation, single parent families, lack of motor transport and older style timber and fibro dwellings. The relationships were stronger in Townsville than in Cairns. These are indicated in the map of housing and population in Townsville.

The Community Dimension

Alongside socio-economic and the built environment characteristics of vulnerability, the third dimension of vulnerability, or rather resilience, is community strength and networks[7],[8],[9]. Planning students who carried out qualitative analyses of two vulnerable Cairns communities in November 1996 showed extreme variability between two similarly ranked communities in the cyclone surge zone. One area, Portsmith, was a zone in transition with a heterogeneous population and weak community structure. Machans Beach, on the other hand, had an extremely strong community spirit, networks and organisations although there was evidence of a generational split. From these case studies, a basic conclusion of all community vulnerability analysis is that while databases may point to areas of greater need and intervention in a crisis, local knowledge of people and of community groups and networks may continue to be of primary importance. GIS is not a substitute for local knowledge.

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