Developing an understanding of urban geohazard risk

Introduction
This paper provides an overview of the geohazards risk assessment philosophy and practice that has evolved through the experience gained over the first two years of the Australian Geological Survey Organisation’s (AGSO) Cities Project. It is offered as a contribution to the ongoing development of a national approach to the adaptation of AS/NZS 4360:1995 Risk management (Standards Australia, 1995) to the specific realm of emergency management.

The approach reported here is still somewhat provisional because we are still developing the information, techniques and tools needed to undertake a task as complex as assessing community risk to a multitude of hazards. There are several reasons for this ‘provisional’ status, not least of which is the need for our approach to be tested in the final step of the risk management process, namely the development of risk mitigation strategies and emergency response options at the community level. The first such application is currently being planned.

The Cities Project

The Cities Project was established in 1996 to undertake applied research directed towards the mitigation of the risks that are posed by a range of geohazards and faced by Australian urban communities. The ultimate objective of the project is to facilitate safe, sustainable and prosperous communities. To provide a realistic focus to this research, and to achieve early practical outcomes, the Cities Project is using a series of case studies based on Queensland centres to develop and test its science and techniques. Cairns is the first of these case studies, and the results of this study are used here to illustrate our approach.

Our view of geohazards is deliberately very broad and includes all earth surface processes with the potential to cause loss or harm to the community or the environment. Whilst our focus is mainly on the potentially fatal acute geohazards such as earthquake, landslide and inundation, the importance of chronic, but economically significant, geohazards such as acid sulphatesoil, coastal erosion, reactive clay and dry land salinity, is also recognised.

Such a broadly based program of research obviously demands a multi-disciplinary approach. To enable AGSO, which is a highly focused earth science research agency, to achieve the objectives set for the Cities Project, a network of operational, research and supporting partners has been developed. We have been most fortunate in attracting the support of partners of great quality and enthusiasm. They span a very broad range of scientific disciplines, administrative responsibilities and industry sectors.

Of particular value has been the close collaboration with researchers involved in the Tropical Cyclone Coastal Impacts Program (TCCIP), a multi-agency and multi-disciplinary research program coordinated by the Bureau of Meteorology. The risk assessment approaches adopted under both the Cities Project and TCCIP are essentially identical, in spite of the different hazard phenomena being addressed.

Risk management

The concept of risk, and the practice of risk management, received a significant boost in Australia with publication of AS/NZS 4360:1995. This general guide provides the philosophical framework within which Cities Project studies are developed. That process is outlined in Figure 1.

This paper deals largely with the risk identification, risk analysis and risk assessment stages of the process. The tasks of risk prioritisation and risk treatment are left to other stakeholders such as the Cairns City Council and the Queensland Government agencies that have that statutory responsibility.

What is Risk?
AS/NZS 4360:1995 (page 5) defines ‘risk’ as: ‘the chance of something happening that will have an impact upon objectives. It is measured in terms of consequences and likelihood’.

This definition is really too general for our purposes, consequently we have chosen to follow the conceptual basis developed under the Office of the United Nations Disaster Relief Coordinator (UNDRO) in 1979 and cited by Fournier d’Albe (1986) as follows:

- Natural hazard means the probability of occurrence, within a specified period of time in a given area, of a potentially damaging natural phenomenon.
- Vulnerability means the degree of loss to a given element at risk or set of such elements resulting from the occurrence of a natural phenomenon of a given magnitude.
- Elements at risk means the population, buildings and civil engineering works, economic activities, public services, utilities and infrastructure, etc., at risk in a given area.
- Specific risk means the expected degree of loss due to a particular natural phenomenon: it is a function of both natural hazard and vulnerability.
- Risk (i.e. ‘total risk’) means the expected number of lives lost, persons injured, damage to property and disruption of economic activity due to a particular natural phenomenon, and consequently the product of specific risk and elements at risk.

Total risk can thus be expressed simply in the following form:

Risk (Total) = Hazard x Vulnerability x Elements at Risk

This approach is not only elegant, it is also very practical. Given the complexity of urban communities and the degree to which the various elements at risk are interdependent, the ‘total risk’ approach is considered mandatory. Further, it also lends itself equally well to quantitative, qualitative and composite analytical approaches.

Risk mitigation (i.e. moderating the severity of a hazard impact) is the principal objective of risk management. In this...
context, risk mitigation might be seen as the process by which the uncertainties that exist in potentially hazardous situations can be minimised and public (and environmental) safety maximised. The objective is to limit the human, material, economic and environmental cost of an emergency or disaster, and is achieved through a range of strategies from hazard monitoring to the speedy restoration of the affected community after a disaster event.

It is clear that uncertainty is a key factor, indeed it can be argued that the effectiveness of risk mitigation strategies is inversely proportional to the level of uncertainty that exists. The risk management process, particularly the risk analysis and risk assessment stages is, therefore, clearly aimed at developing the best and most appropriate information with which to reduce that uncertainty.

**Risk identification**
A detailed understanding of what events have occurred in the past (including paleo events) and their effects provides the basis for understanding what could or will happen in the future, it is the key step in the risk identification process. To this end, AGSO has developed catalogues on historic earthquakes, landslides and tsunami events, whilst the Bureau of Meteorology maintains comprehensive collections on severe weather events such as cyclones. The insurance industry maintains some data on the loss associated with such events. The material accumulated by the Newcastle Region Public Library on the 1989 earthquake in that city stands out as an exemplar of the type of comprehensive historical information resource that is needed to underpin community risk assessments. Whilst there is no comparable collection yet available for Cairns, Figure 2 provides an overview of the 'risk history' of that city.

It is important to note that the earthquake of record occurred in 1896 (felt intensity of MMI 5+), the flood of record occurred in 1911 (15.39 metres gauge height) and the most significant cyclone impact on record was that of 1927 which put a storm tide of about 1 metre above high tide level through the town. In 1927 the population of Cairns was only 10% of its current level! The list does not include Australia’s first BLEVE (boiling liquid expanding vapour explosion) accident that occurred in Cairns in 1887 or the numerous bushfires that have occurred in the area.

It is perhaps little wonder that today there is a widespread belief in Cairns that they face little, if any, risk, from severe natural hazards. The myth of the 'glass wall' protection provided by the Great 'Barrier' Reef and the hinterland mountains unfortunately has great currency in Cairns.

**Risk analysis**
Phenomenon process knowledge. The focus of hazard science research is on the mechanisms that cause, create, generate or drive the hazard phenomena e.g. what causes earthquakes and what influences the transmission of their energy through different strata. This is underpinned by information relating to the background climatic, environmental, terrain, ecological and geological aspects of the site that are relevant to hazard studies, e.g. the depth and nature of the sediments and their microtremor response. Whilst there is little that can be done to eliminate or reduce the severity or frequency of these phenomena, a good understanding of what drives them enhances our ability to forecast or predict their behaviour. It is also fundamental to establishing an understanding of event probabilities.

Elements at risk and their vulnerability. This is a relatively 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 e.g. the buildings, infrastructures and people. It draws on disciplines as diverse as geography, engineering, demography, economics and psychology. It is in this aspect that the synergy between the Cities Project and TCCIP has been most effective, given that the elements at risk are common, regardless of the hazard involved. A very significant effort has been made to develop very detailed data on the principal elements at risk in the built environment of Cairns, whilst comprehensive statistics of good resolution are available from the quinquennial national census to provide at least basic measures of human vulnerability. The broad groups of elements at risk for which data have been collected in Cairns include:

- The Basic. Setting. Geographic regional data has been accumulated from a very wide range of custodians for themes including the physical environment (climate, vegetation, geology, soils, land use, topography, etc), access (external links by major road, rail, air, maritime and telecommunications infrastructures) and administrative arrangements (local government, suburb and other administrative boundaries).
- Shelter. The buildings that provide shelter to the community at home, at work and at play vary considerably in their vulnerability to different hazards. A range of information relating to their construction, including materials of the walls and roof, the shape of the roof, the height of the floor above the surrounding ground, the number of stories and the age of the building, is required. These building characteristics contribute to the relative degree of vulnerability associated with exposure to a range of hazards, as shown in Figure 3. A database containing such details on more than 33,000 individual buildings in Cairns has been developed.
- Access to shelter is also significant, so information on mobility within the community is needed. Details of the capacity and vulnerability of the road network and the availability of vehicles, for example, have been acquired, as has the location and status of designated emergency shelters or safe havens. The detailed street network is held in topological form so that the necessary

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1 Collection of this data was made possible by a grant from the Australian Coordinating Committee for the International Decade for Natural Disaster Reduction in 1995.
sary route modelling analysis can be undertaken.

Sustenance. Modern urban communities are highly reliant on their utility and service infrastructures such as water supply, sewerage, power supply and telecommunications. These so-called lifelines are significantly dependent on each other and on other logistic resources such as fuel supply (see, for example, Granger, 1997).

The community is also dependent on the availability of food supplies, clothing, medical supplies and other personal items. Information is being accumulated on all of these, as well as on the enterprises that wholesale, distribute and service these sectors (such as transport, material handling equipment and storage). All of the key facilities in Cairns have been identified in the building database and basic data on power and water supply infrastructure are available.

Security. The security of the community can be measured in terms of its health and wealth and by the forms of protection that are provided. Physically, these may be assessed by the availability of facilities such as hospitals, nursing homes, industries, commercial premises, agricultural land use, ambulance stations, fire stations, police stations and works such as levees. Also important are socio-demographic and economic issues related to the elderly, the very young, the disabled, household income, unemployment, home ownership and the resources available at the fire and police stations. Emergency plans are also a necessary route modelling analysis can be undertaken.

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is the practice to compare the level of risk found during the assessment process with previously established risk criteria, so that it can be judged whether the risk is ‘acceptable’ or not. At first glance this may seem to be something of a ‘chicken-and-egg’ process— if you do not know what the level of risk posed by earthquake is in Cairns, for example, how can you realistically determine what level of risk is acceptable?

Levels of acceptability are, however, ‘built in’ to such things as urban planning design constraints and the Building Code, where criteria are based on ‘design’ levels. For example, under the earthquake loading code AS1170.4–1993 Earthquake Loads (Standards Australia, 1993), the ‘design level of earthquake shaking’ is one in which there is an estimated 10% probability of the ground motions being exceeded in a 50 year period i.e. the acceptability criterion is set at a 10% chance of exceedence over the nominal lifetime of a ‘typical’ building.

Not all acceptability criteria can be expressed categorically as this because they deal with human nature and the political ‘outrage’ dimension of risk management. They also vary considerably over time— the threshold of acceptability is typically much lower immediately after a hazard impact than it was immediately before the impact, hence the need for a strong feedback mechanism between establishing acceptability and the formulation of risk mitigation and response strategies.

Perhaps the ‘risk formula’ could be better expressed as:

\[
\text{Risk} \text{ (Total)} = \left(\text{Hazard} \times \text{Vulnerability} \times \text{Elements at Risk}\right) \div \text{Acceptability}
\]

Risk mitigation strategies

Whilst the Cities Project is concerned primarily with risk identification, analysis and assessment, it does have some linkage with elements of the risk mitigation process.

Monitoring and surveillance: One of the principal sources of historical hazard event information and hazard phenomenon knowledge is the extensive network of monitoring stations and remote sensing resources that have been established across Australia. For example, the Bureau of Meteorology maintains some 45 weather radar sites, 246 automatic weather stations and 3,029 stream gauging stations, whilst AGSO has access to more than 150 seismographs across the country. The Bureau also takes data from the Japanese Geostationary Meteorological Satellite 26 times a day in addition to data taken from the polar orbiting US NOAA. Whilst weather monitoring of Cairns is comprehensive and has reasonable historical depth, seismic monitoring coverage has until recently been relatively poor, with only the larger (and less frequent) events being measured by distant instruments.

Warnings and forecasts. An effective warning and forecasting system, combined with a high level of community awareness and risk appreciation, is clearly one of the most potent mechanisms by which to achieve risk mitigation. Whilst these warnings are typically taken to mean short-term warnings such as those issued by the Bureau of Meteorology for the hazards that can literally be seen coming, such as cyclones, floods and severe storms, they may also embrace the longer-term estimates of the ‘hazardousness’ of areas such as those contained in the earthquake hazard (acceleration coefficient) maps that accompany AS1170.4-1993 or by hazard maps specifically prepared for a city. They can both be significantly enhanced through the scenario analysis process.

Mitigation strategies and response options. Risk assessments are made so that strategies may be developed that ultimately will lead to the elimination, reduction, transfer or acceptance of the risks, and to ensure that the community is prepared to cope with a hazard impact. Whilst the development and implementation of these strategies lie essentially outside the remit of the Cities Project, our experience in working with emergency managers and others to date suggests that amongst the most effective strategies are:

- well maintained and appropriate information that is fundamental to risk assessment
- risk-based planning of settlement, development and key facilities (such as hospitals)
- protection plans for key facilities and lifelines
- cost-effective engineered defences such as levees and retrofit programs
- appropriate and enforced building and planning codes
- emergency management plans, resources and training based on risk assessments
- wide-spread and ongoing community awareness programs based on risk history, scenario analysis and an effective risk communication capability.

These components of the Cities Project’s understanding of the risk management process are illustrated in Figure 5.
The bottom line is that if we get all of this right, the outcome will be safer, more sustainable and more prosperous communities.

References

Disaster events calendar

- **10–13 May 1999**, Osaka, Japan 11th Congress of World Association for Disaster and Emergency Medicine (WADEM)
  Contact: Secretariat of 11th Congress of WADEM, 1-1, Tsukumodai, Suita City, Osaka, Japan 565-0862; Tel: 81-6-6834-7304; Fax: 81-6-6872-1846; e-mail: wadem11@osik33web.ne.jp

- **10–21 May 1999**, Bangkok, Thailand Third Regional Training Course on ‘Community Based Approaches to Disaster Management’ (CBDM-3). Offered by: the Asian Disaster Preparedness Center (ADPC)
  Contact: ADPC
  Asian Institute of Technology
  P.O. Box 4, Klong Luang, Pathumthani 12120, Thailand
  Tel: (+66-2) 524-5378/5354; Fax: (+66-2) 524-5360
  e-mail: adpc@ait.ac.th
  http://www.adpc.ait.ac.th/Default.html

  Contact: National Building Protection Council 6300 Park of Commerce Boulevard P.O. Box 3051, Boca Raton, FL 33487-8229 Tel: (561) 988-0932; Fax: (561) 241-1247
  e-mail: nbpc@nbpc.org
  http://www.promit.com

- **19–21 May 1999**, Cape Town, South Africa
  Emergency Services Africa ’99
  Contact: Conference Secretary Suite 157, Postnet X3036, Paarl Republic of South Africa 7620
  Tel: +27 21 590 1702; fax: +27 21 872 1404
  e-mail: zacks@mweb.co.za

- **24–25 May 1999**, Sydney, Landmark Parkroyal
  Emergency Response Planning for Y2K: A national forum for all stakeholders involved in developing Emergency Response Plans for Y2K
  Includes two early evening workshops
  Developing and implementing detailed plans to ensure provision of essential services over key Y2K impact dates.
  Featuring Senator The Hon Eric Abetz and Alan Hodges, Director General, EMA.

- **25–27 May 1999**, Honolulu, Hawaii
  Tsunami Symposium
  Sponsor: Tsunami Society
  Contact: Tsunami Society
  P.O. Box 25218, Honolulu, HI 96825
  or call the symposium chairperson
  George Curtis (808) 963-6670
  1–5 June 1999, San Jose, Costa Rica
  Hemispheric International Decade for Natural Disaster Reduction (IDNDR) Meeting for the Americas: Towards a Reduction in the Impact of Disasters in the 21st Century
  Contact: Helena Molin Valdes
  IDNDR Regional Office for Latin America and the Caribbean
  c/o Pan American Health Organization P.O. Box 3745-1000, San Jose, Costa Rica
  Tel: (506) 257-3141; fax: (506) 257-2139
  e-mail: undpos@nu.or.cr

- **8–11 June 1999**, Delft, The Netherlands
  Sixth Annual Conference of the International Emergency Management Society - TIEMS ’99: ‘Contingencies, Emergency, Crisis, and Disaster Management: Defining the Agenda for the Third Millennium’
  Contact: TIEMS, SEPA
  TU Delft, P.O. Box 5015, 2600 GA Delft
  The Netherlands
  Express Mail:
  TIEMS, SEPA
  Jaffalan 5, 2628 BX Delft, The Netherlands
  Tel: +31 15 278 31 48; Fax: +31 15 278 33 22
  e-mail: tiems@sepa.tudelft.nl
  WWW: http://www.sepa.tudelft.nl/tiemss.htm

- **14–16 June 1999**, Amsterdam, The Netherlands
  International Conference on Disaster Management and Medical Relief (DMMR)
  Contact: DM MR Conference Secretariat
  Steven Lohman
  Netherlands Ministry of the Interior and Kingdom Relations
  Tel: +31 70 302 7011; fax: +31 70 302 1444
  e-mail: dmmr@minbiza.nl

- **20–23 June 1999**, Hamilton, Ontario, Canada
  Ninth World Conference on Disaster Management: ‘Real Events … Real Leaders … Real Solutions’
  Contact: Canadian Centre for Emergency Preparedness
  P.O. Box 2011
  Hamilton, Ontario, Canada L8N 3R5
  Tel: 1-800-965-4608, (905) 546-3911
  e-mail: info@wcdm.org
  http://www.wcdm.org

- **6–9 July 1999**, Albury, NSW, Australia
  Bushfire 99
  Theme: ‘Flammable Australia- the fire regimes and biodiversity of a continent’
  Co-convenors: School of Environmental and Information Sciences, Charles Sturt University,CSIRO and NSW NPWS
  Contact: Bushfire 99, Charles Sturt University
  P.O. Box 789, Albury, NSW 2640
  Tel: 02 6051 9718; fax: 02 6051 9897
  e-mail: bushfire99@life.csu.edu.au

- **8–9 July 1999**, Brisbane, Australia
  Water 99 Joint Congress
  25th Hydrology and Water Resources Symposium and 2nd International Conference on Water Resources and Environment Research
  Sponsors: Department of Natural Resources, Queensland, Australia, World Meteorological Organisation, UNESCO and others.
  Contact: Water 99 Joint Congress
  P.O. Box 1280 Milton, Queensland 4064, Australia
  Tel: (+61 7) 3369 0477; fax: (+61 7) 3369 1512
  e-mail: hyd99@im.com.au

- **27 July–26 August 1999**, Swindon, Wiltshire
  12th International Disaster Management Course
  Cranfield Disaster Management Centre
  Contact: The Administrator, Disaster Management Centre
  Cranfield University, RMCS, Shrivenham, Swindon, Wiltshire, SN6 8LA
  Tel: 01793 785287
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