ERSA RISK MANAGEMENT METHODOLOGY & TERMINOLOGY

(2nd edition)

Ken Granger
Principal Disaster Risk Scientist

DEFINITIONS OF RISK

There are numerous definitions of 'risk'. The Australian and New Zealand Standard *AS/NZS 4360-2004 Risk management* (SA/SNZ, 2004a) that preceded the current standard *AS/NZS ISO 31000:2009* (SA/SNZ, 2009), for example, defined 'risk' as:

> *the chance of something happening that will have an impact upon objectives. It is measured in terms of consequences and likelihood.*

while the Queensland Department of Emergency Services provide a similar definition of 'disaster risk', namely:

> *A concept used to describe the likelihood of harmful consequences arising from the interaction of hazards, community and the environment.* (Zamecka and Buchanan, 1999)

The more recent *National emergency risk assessment guidelines* (EMA, 2010) offer the following definition:
:

> *For emergency risk assessments the effect is usually a negative deviation from the expected and is characterised by hazardous events and the likelihoods of particular consequences.*

AS/NZS ISO 31000:2009 (SA/SNZ, 2009 p1) has adopted a more abstract definition of risk as the:

> *effect of uncertainty on objectives*

To 'explain' this definition ISO has added the following notes to elaborate on their definition:

> *NOTE 1 An* ***effect*** *is a deviation from the expected — positive and/or negative.*
> *NOTE 2* ***Objectives*** *can have different aspects (such as financial, health and safety, and environmental goals) and can apply at different levels (such as strategic, organization-wide, project, product and process).*
> *NOTE 3 Risk is often characterized by reference to potential* ***events*** *and* ***consequences*** *or a combination of these.*
> *NOTE 4 Risk is often expressed in terms of a combination of the consequences of an event (including changes in circumstances) and the associated* ***likelihood*** *of occurrence.*
> *NOTE 5* ***Uncertainty*** *is the state, even partial, of deficiency of information related to, understanding or knowledge of an event, its consequence, or likelihood.*

The ISO definition would seem to suit the relatively simple 'business' risk situations rather than the broader and far more complex multi-dimensional relationships that exist with the risks posed to communities in emergencies or disasters. I consider the broader *ISO 31000-2009* definition to have diluted the important 'cause and effect' relationship that had been central to the approach employed in the earlier versions of the Standard and its operational application in the disaster risk management field since 1996. The earlier formulation continues to form the basis for ERSA disaster risk assessments.

THE ERSA APPROACH

The approach that I follow has its origins in work undertaken in the 1970s by various international agencies. Perhaps the principal way-point in that activity was the conference held by the Office of the United Nations Disaster Relief Coordinator (UNDRO) in 1979 at which definitions were developed for risk, the relationship between natural hazard, the community elements exposed and their vulnerability. Those definitions, as reported by Fournier d'Albe (1986) are 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.*

The risk relationship has been expressed in a pseudo-mathematical form as:

$$\text{Risk}_{\text{(Total)}} = \text{Hazard x Elements at risk x Vulnerability}$$

The 'likelihood' component of risk is derived largely from consideration of the hazard phenomena involved and the assessed probability of events of differing magnitude or severity occurring. It can also include measures of the 'likelihood' that those elements exposed to the hazard will be harmed, i.e. their degree of vulnerability. 'Consequences' are usually measured in terms of lives lost, people injured, the amount of damage to the environment or property and disruption to economic activity. Risk can thus be assessed in terms of the interaction between three key elements – the hazard, the community elements exposed to that hazard and their vulnerability. The relationship between these three elements is shown in Figure 1.

In the figure, the large triangle portrays each of the variables as being equal and risk being represented by the area of the triangle. The amount of total risk may be diminished by reducing the size of any one or more of the three contributing components. In the smaller (hachured) triangle the total risk has been reduced by mitigating the exposure and vulnerability components. The reduction of any of the factors to zero (e.g. by eliminating flood plain development) would consequently eliminate the risk. Conversely, any increase in one of the elements (e.g. an increase in the frequency and severity of floods due to climate change) will increase the risk.

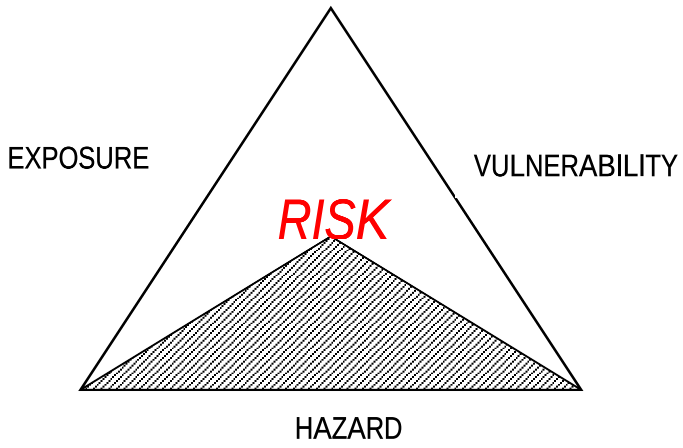

Figure 1: The risk-hazard-exposure-vulnerability relationship (based on Crichton, 1999)

It is important to note that the definition of vulnerability used in ERSA studies is consistent with that provided by EMA (2010), namely:

> *The conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards.*

Under this methodology the risk assessment and risk treatment options are developed in terms of these three components.

HAZARDS

The thresholds of complexity and seriousness of an event will tend to be dictated by the severity, spatial extent and magnitude of the hazard phenomenon involved. Hazards can range in potential seriousness from the proverbial crack in the pavement that could trip up an individual and cause injury, through to the impact on the planet of an asteroid that would end life on earth as we know it. Clearly, at one end the issue is trivial and at the other is well beyond the capacity of any one agency or coordination system to deal with.

Even with the recognised natural hazards, such as flood and earthquake, there are degrees of severity below which 'a significant and coordinated response' would not be needed. A flood that only covers a minor road for less than an hour, for example, would not require such a response, however a flood that inundated many homes and businesses would certainly require such a response. Likewise, an earthquake that caused no damage would not require a response, but an earthquake that produced widespread damage and casualties would demand a 'significant and coordinated response'.

Form 1 of Annex A in the NSW State Emergency Management Committee's implementation guide for emergency risk management studies (SEMC, 2001) contains a comprehensive checklist of hazard agents that should be considered by Local Emergency Management Committees in NSW when undertaking a disaster risk management study. That list goes well beyond consideration of the natural hazards that are covered by the Commonwealth/State Natural Disaster Relief and Recovery Arrangements (NDRRA) that are usually followed in other states and territories. Table 1 provides a simplified typology of the hazard agents that ERSA has investigated in multi-hazard disaster risk management studies.

Table 1: A typology of hazard phenomena (after Granger, 2005)

Atmospheric	Earth	Biological	Human
tropical cyclone	landslide	human epidemic	transport accident
east coast low	earthquake	animal epidemic	industrial accident
severe storm/tornado	tsunamis	plant epidemic	structure failure
flood	subsidence		structure fire
storm tide	coastal erosion		hazardous materials
bush fire	meteorite strike		contamination/pollution
heat wave			infrastructure failure
drought			space debris re-entry
fog and frost			terrorism
climate change			

Most 'damaging natural phenomena' are very complex and can be associated with a range of harm-producing elements. A tropical cyclone, for example, may be seen as the main hazard, but it is its attendant 'damaging natural phenomena' of storm tide, coastal erosion, destructive winds, widespread rainfall, riverine flooding and numerous widespread landslides that actually produce the damage. Similarly with bushfires, the harm producing elements include flames, radiant heat, embers, smoke and strong winds.

Some hazards, such as earthquakes, are regional in nature (i.e. they are mega-hazards that have a widespread impact) whilst others are smaller in scale and impact on a relatively small area. The relationships between the scale of a hazard and their associated damaging phenomena are illustrated in Figure 2.

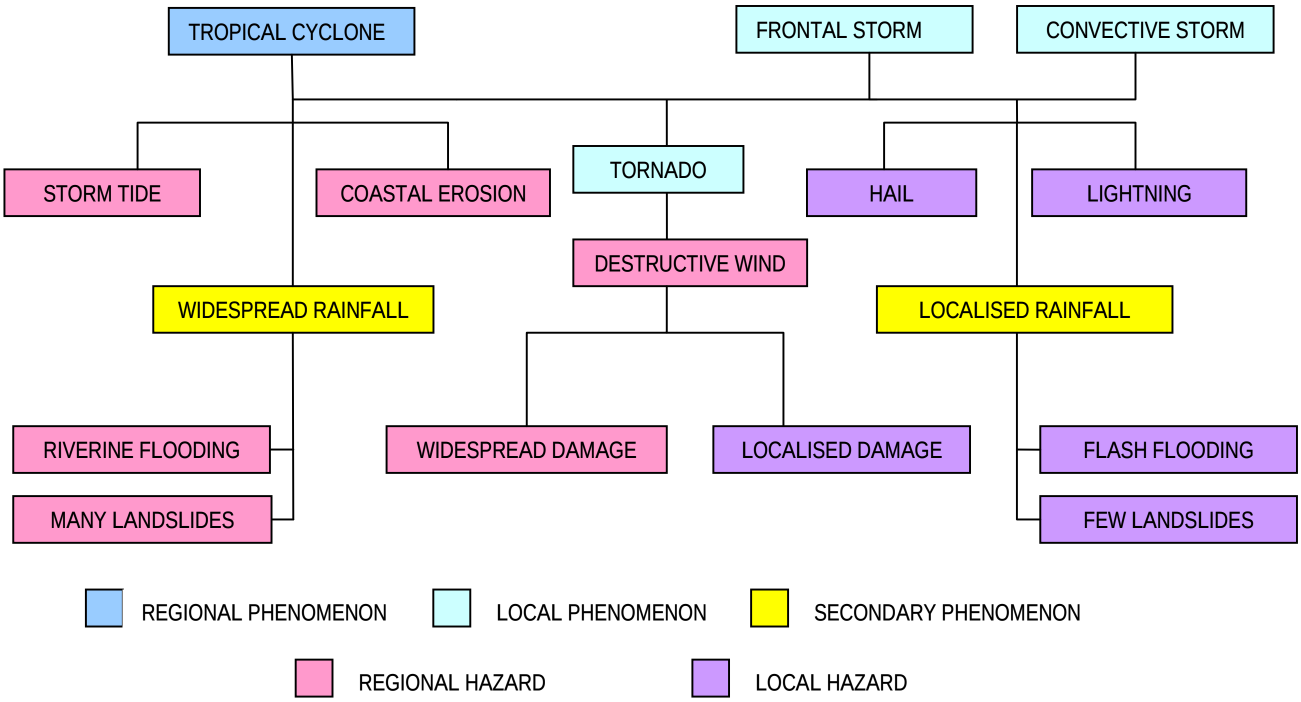

Figure 2: A typology of severe weather hazards

In a similar vein, hazards such as flood and storm tide inundation, landslides and (to some extent) bushfires are confined in their extent by factors such as terrain. Hazards such as earthquake, destructive wind, and heatwave, by comparison, have no such spatial constraints. Others, such as hail and lightning, tend to have a localised impact, but they can have an impact anywhere.

It is essential that the spatial extent of an event's impact be taken into account. For example, the horizontal and vertical extent of inundation from a given flood; the areas that have a high bushfire hazard potential; or the area that would be affected by the escape of a given quantity of hazardous materials from a storage facility under the prevailing weather conditions. The mapping of hazard extents is perhaps the most critical step in the risk analysis process because without it there is now way of identifying the community elements that are potentially exposed. It is in this function that geographic information systems (GIS) come into their own in their application as *Risk-GIS* as I have previously described (Granger, 1998):

> *There are obvious advantages 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. *As such,* Risk-GIS *provides the analytical 'engine' which drives the* Cities Project's *urban geohazard risk assessment process.* Risk-GIS *also provides a most potent form of risk communication (an aspect about which* AS/NZS 4360:1995 *is unfortunately silent) through its capacity to provide a visual representation of risk situations.*

EXPOSURE

Mapping and classifying the community elements that may be exposed to the impact of a given hazard provides the basis for a quantification of the hazard impact. To be effective that mapping should identify each developed property and infrastructure element. In addition to the location, any attribute that may be relevant to understanding the nature of its exposure should also be collected. For example, for exposure to inundation hazards the height of the floor levels in dwellings and other structures is a key attribute. The function of the developed property is also a critical attribute so its importance to the community can be assessed.

A wide range of facilities exist in all communities that are important to community safety and wellbeing before, during and after any disaster or emergency. The loss or dislocation of these critical facilities would greatly exacerbate the impact on the community. Some of these, such as hospitals, can be regarded as being 'critical infrastructure'.

Other facilities exist at which people, especially children or the elderly, may congregate or be concentrated. These include such facilities as:

- schools and other educational facilities,
- kindergartens, child care centres,
- nursing homes and senior citizen's centres
- sheltered workshops.
- retirement villages;
- caravan parks, motels and other forms of commercial accommodation;
- shopping centres;
- churches and community centres;
- social and recreational facilities such as clubs and sporting venues.

Attention should also be given to utilities including power supply, water supply, sewerage systems, road and other transport infrastructure and telecommunications. All of these can also be defined as being 'critical infrastructure'[1].

In its disaster risk assessments ERSA employs the following functional classifications for the built environment:

Business: commercial and professional facilities including shops and offices – some of these are considered to be 'critical infrastructure' or critical facilities;
Community: a wide range of community facilities including churches, halls, libraries and museums, many of these are sensitive facilities;
Doctors, hospitals, etc: all health facilities including hospitals, nursing homes, medical centres, clinics, dentists and so on – major facilities in this group are critical facilities, others are sensitive facilities;
Education: all education facilities including schools, TAFE, universities, kindergartens and child care facilities – all are sensitive facilities;
Government: facilities including offices, depots, etc used by all levels of government – some of these are critical facilities;
Industry: manufacturing and processing industries such as steel works, cement plants, fabrication plants, etc – some of these are critical facilities;
Logistic: bulk supplies of fuel, gas and food including supermarkets, cold stores and service stations – most of these are critical facilities;
Public safety: police, fire, ambulance, SES, and defence facilities – all of these are critical facilities;
Recreation: sporting clubs, grandstands, etc, most of which are sensitive facilities;
Residential: all private residential dwellings including detached houses, flats, town houses, retirement village units and so on;
Storage and transport: features that support road, rail, and sea transport and storage (e.g. warehouses) – many of these are critical facilities;
Telecommunications: facilities that support radio, telephone and TV communications – all of these are critical facilities;
Utilities: electric power generation, distribution and service facilities – all of these are critical facilities;
Water: water supply and sewerage utilities - above ground storage, treatment, pumping, etc but not including in-ground pipe networks – all of these are critical facilities

VULNERABILITY

Vulnerability should always be considered holistically, rather than on a hazard-by-hazard basis. This is because there is very little differentiation between the things that make structures, lifelines and people susceptible to the impact of different hazards.

Built Environment

Buildings: Because buildings are the most common form of protection for people and because much of the economy and community governance is conducted within buildings, the characteristics of buildings that make them more or less susceptible to damage or destruction deserves particular attention. The degree to which different building characteristics are relevant to the more important hazards is summarised in Table 2. In this

[1] 'Critical infrastructure' is defined by the Commonwealth Government to be 'those physical facilities, supply chains, information technologies and communications networks which, if destroyed, degraded or rendered unavailable for an extended period, will significantly impact on social or economic well-being of the nation or affect Australia's ability to conduct national defence and ensure national security.' (Engineers Australia, 2003).

table, the number of stars reflect the significance of each attribute's contribution to building vulnerability, where the greater the number of stars, the greater the relative contribution of an attribute to building vulnerability.

Table 2: Relative contribution of building characteristics to building vulnerability (after Granger, 2001)

CHARACTERISTIC	WIND	HAIL	FLOOD	FIRE	SLIDE	QUAKE
Building age	*****	***	***	*****	**	****
Floor height or vertical regularity	*		*****	****	*	*****
Wall material	***	*****	***	****	***	****
Roof material	****	*****		****		***
Roof pitch	****	***		*		
Large unprotected windows	*****	****	**	*****	**	***
Unlined eaves	***			*****		
Number of storeys	**		****	*	*	*****
Plan regularity	***		**	***	**	*****
Topography	****		*****	****	*****	***
Interior fittings and furniture			****	*****		

The Building Code of Australia is based on a number of standards designed to maximise the structural integrity of all buildings. Of particular significance are the standards that set design and construction parameters for severe wind and earthquake loads. A standard for construction in bushfire-prone areas has also been published. There is no comparable standard for construction in landslide-prone areas or for inundation hazards.

Residential buildings constructed before 1985 will not have been explicitly designed to the wind resistant standards laid down in AS 1170.2 (wind) or AS 1170.4 (earthquake) loading standards of the Building Code; nor will those built before 1993 necessarily have taken into account the provisions of AS 3959 (bushfire-prone areas). Non-residential buildings constructed since 1976 will have been built to the wind loading code which will provide them with a high degree of resilience to earthquake loads.

<u>Roads</u>: Road pavements are very resilient to most hazards though they may be damaged by landslides, floods and severe earthquakes. They may be blocked by landslide debris, fallen trees (during bushfires or severe winds) and bushfire smoke. The most vulnerable points tend to be bridges and other choke points such as deep cuttings.

<u>Railways</u>: Railway permanent ways are generally resilient to most hazards though rails and points may be affected by extreme heatwave conditions causing rail services to be slowed considerably. They may also be buckled by the more severe earthquakes and blocked by landslide debris or affected by embankment fill failures. Signalling and control equipment relies on electricity as do most trains that operate on the main northern line. As with roads, the most vulnerable points are bridges, cuttings, embankments and overpasses.

<u>Airfields</u>: The pavement of larger airfields is largely resilient to most hazards but may be blocked by flood waters (including storm tide) and debris from damaged buildings. Support facilities such as terminals and fuel systems could be damaged by destructive wind, earthquake and inundation hazards. Airfields will probably be closed in the face of a severe tropical cyclone or severe thunderstorms where high winds make flying operations too dangerous.

<u>Ports</u>: Port facilities are vulnerable to damage from high seas and will probably be closed in the face of an approaching severe cyclone. On-shore port facilities are susceptible to damage by destructive winds and earthquake. Tall structures such as container cranes are especially vulnerable to being toppled. Given that most port facilities are built largely on filled estuarine deposits, the risk of liquefaction during an earthquake should be taken into account.

Power supply: The reticulation infrastructure is quite susceptible to fire and heat damage. Most of the poles that carry the lower voltage reticulation in Australia are wood and can burn out; the copper or aluminium cables that carry the power can melt, or at least stretch significantly, at relatively low fire temperatures, or be broken by high winds and falling branches; electronic control equipment is susceptible to high temperatures. Power poles can also be displaced or toppled by earthquakes or landslides. High voltage transmission lines are susceptible to failure in dense bushfire smoke which permits the line to arc to the ground through the smoke. Ground-mounted transformers will be vulnerable to inundation hazards.

If power is lost, the knock-on effect to other lifeline infrastructures, especially water supply, sewerage systems and telecommunications, can be great. Gravity feed water supply would continue to operate until their reservoirs were empty or power supply (either mains or stand-by generators) to the pumps is resumed.

Water supply and sewerage: Most urban properties have access to reticulated supply, however, in most rural areas supply (including fire-fighting water) is from rainwater catchment tanks, dams or swimming pools. In-ground pipe networks are susceptible to damage during earthquakes and landslides, especially those older segments made of brittle material such as AC or cast iron. Above ground pipes can also be affected by landslides and probably earthquakes. Pumping equipment is dependent on the power supply.

Pumping stations for both water supply and sewerage systems are susceptible to damage if inundated or subject to high levels of radiant heat in bushfires.

In rural areas concrete, metal and some fibreglass tanks are quite resilient to high temperatures, however, PVC tanks can lose their rigidity and melt if exposed to the levels of heat associated with bushfires. The use of PVC piping to carry water from tanks to the building can also be a problem, especially if it is exposed above ground level. In most areas where water supply is provided by tanks, water pumps are electric-powered and the loss of power during a fire can cut off the water supply. The availability of a petrol or diesel-powered backup pumping capacity greatly increases the ability to fight a fire.

Telecommunications: The above-ground telecommunications infrastructure has similar vulnerabilities to those of the power supply network. In addition, dense smoke can block line-of-sight frequencies (UHF and VHF) which in turn will disrupt mobile phone and radio communications (including SCADA systems). These systems are also very heavily power-dependant.

Telstra land-line infrastructure is all underground reticulation. The system is therefore designed and installed to be robust against the ingress of water. The pit and conduit system is regularly inundated with water as part of the natural stormwater dissipation. The cable connection pillars, which are located above ground, are also sealed and positively pressurised to prevent the ingress of water. In-ground cables, especially optical fibre cable, is susceptible to damage by earth movements such as that experienced in earthquakes and landslides or where they a placed in highly reactive soils such as shrink-swell clays. Optical fibre cable, for example, will need to be replaced if it is stretched by only a few millimetres.

The weak links in the network are Telstra RIMs and exchanges. The RIMs are electronic devices installed in suburban areas in a weatherproofing housing. These housings are not designed for submersion. The loss of the RIM or exchange will cause a loss of all communications connected to the exchange. This will affect a large area of the population and rectification will not be possible until the water levels return to normal.

It should also be noted that mobile phone base stations may be out of service due to high winds, therefore the use of mobile phones should not be relied upon during emergencies.

Internet connectivity is totally reliant on the telecommunications system be it via wireless or landline connection.

Logistic Facilities: Large metal liquid storage tanks (e.g. bulk fuel tanks) are susceptible to damage caused by the liquid inside the tank sloshing from side to side under earthquake loads, thus placing stresses on the tank walls. Damage or failure, often referred to as 'elephant's foot failure', can result. Pipe connections to the tank can also suffer damage or be sheared off by differential movement. Domestic water tanks, particularly the traditional corrugated iron types, are also very susceptible to similar damage.

In-ground bulk fuel tanks are also susceptible during floods if they are not full. They have been known to 'float' in their pits and rupture pipelines.

Major bulk storage facilities for grain, sugar and other carbon-based substances are highly susceptible to 'grain dust explosions' when fine particles or organic material are in suspension in the air and an ignition source (even static electricity) occurs.

Infrastructure Interdependence As indicated in the discussion on power supply, there is a significant degree of interdependence between the various utility infrastructures. Table 3 indicates the nature of this interdependence. In this table, the loss of the lifeline in the left-hand column will have an impact on the lifelines across the row to a significant (S), moderate (M) or minor (blank) degree.

Table 3: Interdependence of lifeline assets (after Granger, 1997)

	POWER	WATER	SEWER	COMMS	ROAD	RAIL	AFLD	PORT	FUEL
POWER		S	S	S	M	M	S	M	S
WATER	M		S					M	
SEWER		S						M	
COMMS	S	S	S		M	S	S	S	
ROAD	M	M	M	M		M	S	S	S
RAIL					M			S	S
AFLD									
PORT									S
FUEL	S				S	S	S	S	

People

The degree to which people are likely to be affected by exposure to hazards depends on a wide range of factors. These are the factors that dictate the vulnerability of those elements exposed to hazard impact. ERSA has developed a vulnerability index based on 14 characteristics available at the Census Collectors District (CCD) level from the 2006 national census. These have been chosen to reflect four main aspects of population vulnerability: physical, socio-economic; mobility and awareness.

Physical vulnerability: The very young (children under 5 years) and the elderly (65 years and over) are the main groups that are likely to be susceptible to disaster impact. Elderly folk who are living alone are especially vulnerable. People with disabilities are also likely to be more vulnerable than able bodied folk.

Social and economic vulnerability: The capacity to recover from the impact of any disaster is closely related to socio-economic wellbeing. Less advantaged households, for example, will tend to be in rented accommodation; have no, or inadequate, insurance; and have difficulty replacing any losses. They will also be more likely to become unemployment should the businesses in which they work suffer damage in the event. Less tangible

Mobility vulnerability: Where an evacuation or relocation is required people with limited mobility or groups that would require assistance with moving are more vulnerable that those who have independent transport and/or are not able to move rapidly.

Awareness vulnerability: The emergency adage holds that "an aware community is a prepared community" so those who have limited ability to understand emergency messages or who have limited access to technologies such as the internet are at a distinct disadvantage over those that do.

Figure 3 outlines the community vulnerability model used.

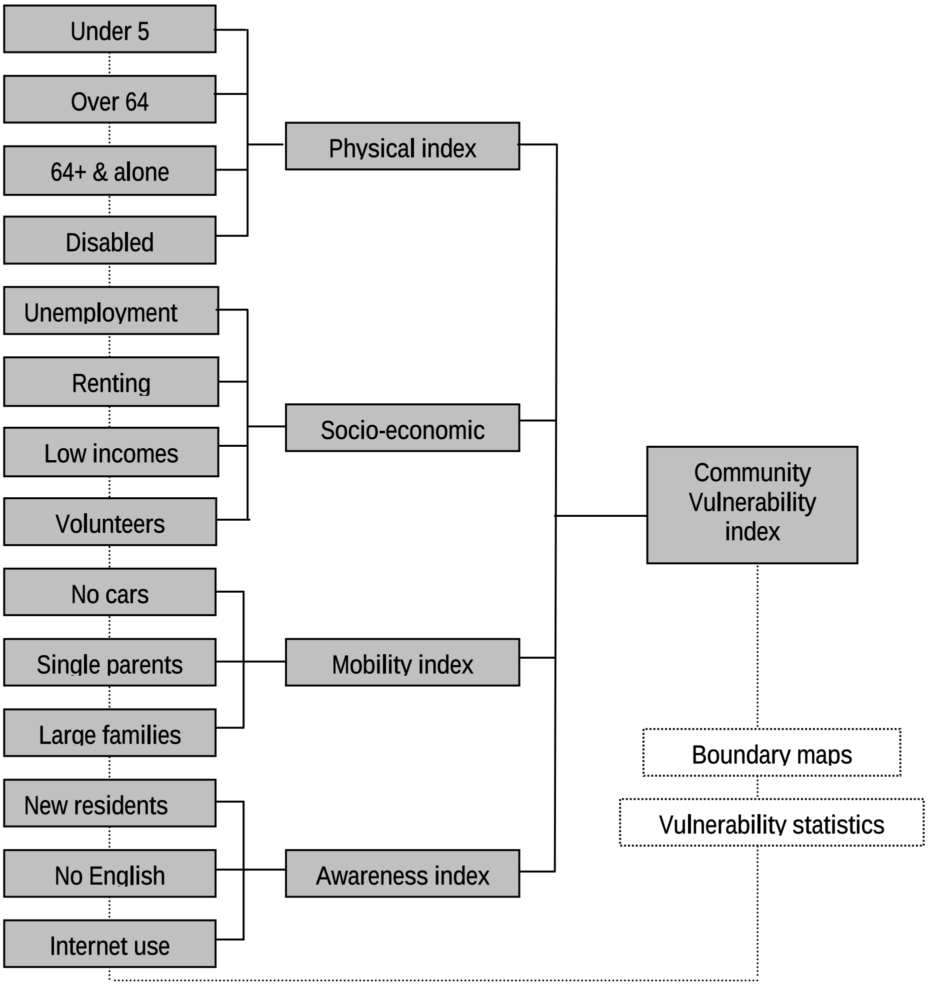

Figure 3: Community vulnerability model

PROBABILITY

In definitions of risk, terms such as 'chance', 'likelihood', 'frequency' and 'probability' routinely appear. The mathematical concept of probability is not widely understood, nor is the language of probability. The allocation of event probabilities is an area of particular uncertainty and a potential source of confusion.

A common description of event probability is the so-called 'return period' of a particular phenomenon, typically given in a form such as 'a one-in-one hundred year flood'. Not only are such figures typically based on less than 100 years of record, they are frequently misunderstood, misinterpreted and/or misused. A description of a recent event as a 'one-in-a-hundred-year event', for example, is commonly interpreted (wrongly) to indicate that there will not be another such event for another 100 years.

Disaster management professionals prefer to use the terms 'average recurrence interval' (ARI) or 'annual exceedence probability' (AEP) which are expressed mathematically and are thus less ambiguous. Table 4 is provided to illustrate probabilities related to the chance of one or more events of a given magnitude occurring in a given time frame. In this table, an event with a given ARI occurring in a specific time frame is compared with the betting odds (given in parenthesis) that most punters are familiar with.

Table 4: Probability of one or more events in a specific period (Granger & Hayne, 2001 p1.11)

Period in which event might occur (years)	50 year ARI (2.0% AEP)	100 year ARI (1.0% AEP)	200 year ARI (0.5% AEP)	500 year ARI (0.2% AEP)	1000 year ARI (0.01% AEP)
5	10% (10 to 1)	5% (20 to 1)	2% (50 to 1)	1% (100 to 1)	0.5% (200 to 1)
10	18% (5 to 1)	10% (10 to 1)	5% (20 to 1)	2% (50 to 1)	1% (100 to 1)
25	39% (2 to 1)	22% (5 to 1)	12% (10 to 1)	5% (20 to 1)	2% (50 to 1)
50	63% (2 to 1 on)	39% (2 to 1)	22% (5 to 1)	10% (10 to 1)	5% (20 to 1)
100	86% (7 to 1 on)	63% (2 to 1 on)	39% (2 to 1)	18% (5 to 1)	10% (10 to 1)
200	98% (near certain)	86% (7 to 1 on)	63% (2 to 1 on)	33% (3 to 1)	18% (5 to 1)
500	99.999% (certain)	99% (near certain)	92% (near certain)	63% (2 to 1 on)	39% (2 to 1)

The 1974 Brisbane flood is said to have had an ARI of around 75 to 80 years (an AEP of 1.3%) and 2011 floods having an ARI of greater than 100 years (an AEP of <1.0%). When the use of the more precise definition of probability is not available it is common practice to use qualitative terms such as 'frequent' or 'rare'. Table 5 provides definitions of these terms as they are applied in ERSA studies.

Table 5: Definitions of frequency (likelihood) used

FREQUENCY	DESCRIPTION
Frequent	Can occur as often or more frequently than once in any five year period (e.g. ARI of 1 to 5 years) on average - i.e. an event that is experienced many times in a lifetime
Occasional	lay be experienced or exceeded once in 20 years (e.g. ARI of 10 to 20 years) on average - i.e. and event that is experienced about once in a generation
Rare	May only be experienced or exceeded once in 100 years (e.g. ARI of 50 to 100 years) on average - i.e. an event that is experienced about once in a lifetime
Very rare	May only be experienced or exceeded once in 250 or more years (e.g. ARI of 200 to 300 years) on average
Extremely rare	May only be experienced or exceeded once in 500 or more years (e.g. ARI of 500 to more than 1000 years) on average

CONSEQUENCES

The terminology applied by ERSA to the consequences (i.e. seriousness) of a hazard impact has been taken from Table 2 of the NSW State Emergency Management Committee (SEMC) implementation guide for emergency risk management studies (SEMC, 2001).

Table 6: Definitions of seriousness (consequences)

DESCRIPTOR	HUMAN LIFE AND HEALTH	PROPERTY, FINANCIAL, ENVIRONMENTAL
Insignificant	No injuries or fatalities Small number or no people are displaced and only for short duration. Little or no personal support required (support not monetary or material).	Inconsequential or no damage. Little or no disruption to community. No measurable impact on environment. Little or no financial loss.
Minor	Small number of injuries but no fatalities. First aid treatment required. Some displacement of people (less than 24 hrs). Some personal support required. Some disruption (less than 24 hours).	Some damage. Small impact on environment with no lasting effects. Some financial loss.
Moderate	Medical treatment required but no fatalities. Some hospitalisation. Localised displacement of people who return within 24 hours. Personal support satisfied through local arrangements.	Localised damage that is rectified by routine arrangements. Normal community functioning with some inconvenience. Some impact on environment with no long-term effect or small impact on environment with long-term effect. Significant financial loss.
Major	Fatalities. Extensive injuries, significant hospitalisation. Large number displaced (more than 24 hours duration). External resources required for personal support.	Significant damage that requires external resources. Community only partially functioning, some services unavailable. Some impact on environment with long-term effects. Significant financial loss – some financial assistance required.
Catastrophic	Significant fatalities. Large number of severe injuries. Extended and large numbers requiring hospitalisation. General and widespread displacement for extended duration.	Extensive damage. Extensive personal support. Community unable to function without significant support. Significant impact on environment and/or permanent damage.

RATING RISK

Perhaps the simplest approach to rating risk is by using a likelihood/consequence matrix. This approach was suggested in Zamecka and Buchanan (1999) employing the following matrix (Table 7) which was taken directly from the 1999 edition of *AS/NZS 4360*. A similar approach has been adopted in the *National emergency risk assessment guideline* (NERAG) though the levels of likelihood used in the NERAG have been expanded to seven as shown in Table 8.

Table 7: Risk rating matrix adopted by Queensland DES (Zamecka and Buchanan, 1999)

LIKELIHOOD	CONSEQUENCES				
	Insignificant	Minor	Moderate	Major	Catastrophic
Almost certain	High	High	Extreme	Extreme	Extreme
Likely	Moderate	High	High	Extreme	Extreme
Possibly	Low	Moderate	High	Extreme	Extreme
Unlikely	Low	Low	Moderate	High	Extreme
Rare	Low	Low	Moderate	High	High

Table 8: Qualitative risk rating matrix used in NERAG (EMA, 2010)

LIKELIHOOD	CONSEQUENCES				
	Insignificant	Minor	Moderate	Major	Catastrophic
Almost certain	Medium	Medium	High	Extreme	Extreme
Likely	Low	Medium	High	High	Extreme
Possibly	Low	Low	Medium	High	High
Unlikely	Low	Low	Medium	Medium	High
Rare	Low	Low	Low	Medium	Medium
Very Rare	Low	Low	Low	Low	Medium
Almost incredible	Low	Low	Low	Low	Low

The risk ratings suggested in the 1999 edition of AS/NZS 4360 and NERAG are considered to be too high when applied to the disaster risk management process. For example, if the consequences of an event are insignificant (i.e. simply an inconvenience) in my view the risk is no greater whether the event is rare or frequent, conversely if the consequences are catastrophic the frequency of impact becomes irrelevant. It is worth noting that the guideline to the 2004 edition of the Standard (SA/SNZ, 2004b) produced a new and less 'extreme' risk rating matrix. That matrix was accompanied by the following note:

> *The relationship between consequence and likelihood will differ for each application: the level of risk assigned to each cell needs to reflect that.*

ERSA has developed the relationships shown in Table 9 as being more appropriate.

Table 9: Risk rating matrix employed by ERSA

FREQUENCY	CONSEQUENCES				
	Insignificant	Minor	Moderate	Major	Catastrophic
Frequent	Low	Moderate	High	Extreme	Extreme
Occasional	Low	Moderate	High	Extreme	Extreme
Rare	Low	Moderate	Moderate	High	Extreme
Very rare	Low	Low	Moderate	High	Extreme
Extremely rare	Low	Low	Moderate	High	Extreme

In the risk assessment guide produced to accompany AS/NZS ISO 31000:2009 (IEC/ISO, 2009) the following relative strengths and limitations of the consequence/frequency matrix approach are described:

> *Strengths:*
> *• relatively easy to use;*
> *• provides a rapid ranking of risks into different significance levels.*
>
> *Limitations:*
> *• a matrix should be designed to be appropriate for the circumstances so it may be difficult to have a common system applying across a range of circumstances relevant to an organization;*

• it is difficult to define the scales unambiguously;
• use is very subjective and there tends to be significant variation between raters;
• risks cannot be aggregated (i.e. one cannot define that a particular number of low risks or a low risk identified a particular number of times is equivalent to a medium risk);
• it is difficult to combine or compare the level of risk for different categories of consequences.

Results will depend of the level of detail of the analysis, i.e. the more detailed the analysis, the higher the number of scenarios, each with a lower probability. This will underestimate the actual level of risk. The way in which scenarios are grouped together in describing risk should be consistent and defined at the start of the study.

ERSA has also developed, and prefers to employ, a risk index approach to rating risk. That approach extends the analysis beyond the consequence/frequency approach to assign ratings against the following components that contribute to total risk:

- Frequency – (the same as 'likelihood') events that occur frequently are scored more highly than those that rarely occur;
- Seriousness – (essentially the same as 'consequences') events that have the potential for causing significant numbers of casualties and/or significant economic loss are scored more highly than those that produce few casualties or little loss;
- Manageability – those hazards that are difficult to control or manage by existing techniques, resources and warning systems are scored more highly than those that are more easy to manage;
- Awareness – hazards for which community understanding and awareness before the event have not led to active steps being taken to reduce those risks are scored more highly than those for which risk reduction efforts have already been made. There are elements of voluntary versus involuntary risks in this assessment as well;
- Urgency – hazards that need to be addressed with some urgency because of a lack of preparedness, for example, are scored more highly than those that do not demand the implementation of risk reduction action so rapidly;
- Growth – hazards for which the risk is likely to grow either because the hazard could become more frequent or severe; or there is likely to be an increase in the number of community elements exposed; or there will be an increase in the vulnerability of those elements are scored more highly than those hazards that pose a more constant level of risk
- Outrage –the political dimension of risk is important because after the impact of an emergency, community outrage at what is perceived to have been a lack of preparedness or an inadequate response can generate unrealistic and unreasonable political demands rather than addressing the reality of community safety needs. Such hazards are scored more highly than those that tend to be seen as either voluntary risks or as being 'acts of God'.

By allocating scores to each component it is possible to produce a semi-quantitative risk index that identifies the risks posed by the various hazards or hazard scenarios in priority order. An example of a multi-hazard risk index developed from this approach is given in Table 10.

It is worth noting that the New Zealand Civil Defence equivalent of NERAG, produced in 2002 (MCDEM, 2002) stipulated the SMUG (Seriousness, Manageability, Urgency, Growth) model for risk assessment because:

> *The tool was to provide CDEM* [Civil Defence Emergency Management] *Groups with a mechanism for a more detailed risk analysis process than a simple likelihood and consequence assessment as described in the Australian and New Zealand Risk Management Standard (AS/NZS 4360:1999).* (Cunningham, 2006)

Table 10: Scoring guide for relative contribution of risk

RISK CHARACTERISTIC	SCORE				
	5	4	3	2	1
Frequency	Frequent	Occasional	Rare	Very rare	Extremely rare
Seriousness	Catastrophic	Major	Moderate	Minor	Insignificant
Manageability	Unmanageable	Difficult	Manageable	Easy	Very easy
Awareness	Total ignorance	Poor	Moderate	Reasonable	Widely known
Urgency	Most urgent	Very urgent	Urgent	Priority	Low priority
Growth	Extreme	High	Moderate	Low	Very low
Outrage	Extreme	High	Moderate	Low	Very low

IEC/ISO (2009) describes the relative strengths and limitations of the risk index approach as follows:

> *Strengths:*
> *• indices can provide a good tool for ranking different risks;*
> *• they allow multiple factors which affect the level of risk to be incorporated into a single numerical score for the level of risk.*
>
> *Limitations:*
> *• if the process (model) and its output are not well validated, the results may be meaningless. The fact that the output is a numerical value for risk may be misinterpreted and misused, for example in subsequent cost/benefit analysis;*
> *• in many situations where indices are used, there is no fundamental model to define whether the individual scales for risk factors are linear, logarithmic or of some other form, and no model to define how factors should be combined. In these situations, the rating is inherently unreliable and validation against real data is particularly important.*

The definitions of terms used for frequency and severity have been included above. The suggested definitions and/or scoring approach for the other five variables are as follows.

MANAGEABILITY

In MCDEM (2002) 'manageability' is defined as follows:

> *Manageability – the relative ability to reduce the risk (through managing the hazard or the community or both). CDEM Group planning is all about addressing the hard issues - the risks that are hardest to manage, which usually have the lowest effort being expended upon them. They should rate high in relative importance.*

It is, in effect, an evaluation of the effectiveness of the PPRR approach (referred to in NZ as the 4Rs) and is elaborated in MCDEM (2002) as follows:

> *Manageability includes both a measure of how **difficult** a hazard's risks are to address and a measure of the level of cross-sector management **effort** being applied to hazards across the 4Rs* [i.e. PPRR] *directly or indirectly assisting in reducing risk. The level of difficulty may, in some cases, be inversely proportional to the management effort, particularly where a hazard appears too big to address and therefore little effort is being applied. Conversely, a lot of effort may be expended upon a relatively easily managed hazard.*

There are nine combinations of difficulty and effort if each is assigned a three level weighting (h/m/l), which can be grouped into a five level rating system as shown:

Management Difficulty	*Current Effort (4Rs)*	*Rating*	ERSA Rating
Low	*High*	*1*	Very easy
Low	*Medium*	*2*	Easy
Medium	*High*		
Medium	*Medium*	*3*	Manageable
High	*High*		
Low	*Low*	*4*	Difficult
Medium	*Low*		
High	*Medium*		
High	*Low*	*5*	Unmanageable

ERSA follows this scoring model with the ratings shown in the last column of the table.

AWARENESS

Awareness can be defined as a person's perception and cognitive reaction to a condition or an event – it does not necessarily imply understanding. In disaster risk management, awareness typically implies that a person understands that a hazard impact may be imminent and that they understand what that means in terms of their own situation. In an disaster management sense, awareness implies that the local disaster management organisation is aware of the risks associated with a given hazard phenomenon and have plans and resources in place to respond to such an eventuality. The criteria used to rate awareness are described in Table 11.

Table 11: ERSA definitions of awareness

DESCRIPTOR	MEANING
Widely known	The community has good knowledge and understanding of the risks posed by a given hazard event either through direct recent experience or from an effective education program. Disaster managers have either recently coped with such an event or have recently exercised such a scenario. Warning times are generally greater than 48 hours or are long enough for the great majority of people to take effective action.
Reasonable	The community has reasonable knowledge of the likely effects of an impending hazard event either through previous experience (say in the past 5 years) or have been made aware through an effective education program. Disaster managers have plans in place to manage such a situation but may not have had experience of an actual event or exercise a similar scenario for at least 5 years. Warning times are generally greater than 24 hours or are long enough for most people to take effective action.
Moderate	Community knowledge is patchy with newer residents having a lower level of awareness than longer-term residents that had experienced a similar event within the past 10 to 20 years or so. Disaster managers have plans in place to manage such a scenario but few personnel have actually managed or exercised such an event in the past 10 to 20 years. Warning times are generally greater than an hour or are not long enough for most people to take effective action.
Poor	A generally low level of awareness because such an event has not happened in their experience and that there has been little public information made available on the risks posed by such an event. Disaster managers may not have plans in place for such an event or have exercised such a scenario in their careers. Warning times are rarely more than a few minutes or too short for the great majority of people to take effective action.
Total ignorance	No knowledge of such a risk other that in the scientific literature – the truly unprecedented even. There is no warning or the warning was either too short for anyone to take action or its relevance not understood by the community.

It should be noted that there is a relationship between the frequency of an event's recurrence and the level of awareness.

URGENCY

MCDEM (2002) uses 'urgency' in place of 'frequency' or 'likelihood'. In the ERSA use of the term it relates to how quickly action needs to be taken to reduce or eliminate the risk. It can be related to the level of criticality that the risk represents. The criteria suggested by ERSA are given in Table 12.

Table 12: ERSA definitions of urgency

DESCRIPTOR	MEANING
Low priority	Little action required other than monitoring the situation.
Priority	Action required using existing resources within the next 3 to 4 years
Urgent	Action required using existing resources within the next 12 months or before the onset of the next hazard season
Very urgent	Action required using all available resources within the next six months or less and/or before the onset of the next hazard season
Most urgent	Action required using all available resources within days or weeks

GROWTH

The growth of risk is impacted by changes in each of the three dimension – the hazard phenomenon; the elements exposed to that hazard event and the vulnerability of those elements to such an impact. These elements are used in MCDEM (2002) as follows, noting that the term 'community exposure' in the table should be seen as combining physical exposure and vulnerability.

> *There are nine combinations of probability rise and community exposure if each is assigned a three level weighting (h/m/l), which can be grouped into a five level rating system as shown:*

Event probability rise	*Changing community exposure*	*Rating*	ERSA rating
Low	*Low*	*1*	Very low
Low	*Medium*	*2*	Low
Medium	*Low*		
Medium	*Medium*	*3*	Moderate
Low	*High*		
Medium	*High*	*4*	High
High	*Low*		
High	*Medium*		
High	*High*	*5*	Extreme

OUTRAGE

The community response to a disaster experience is usually expressed in terms of how empowered they felt in coping with the event and whether they felt that 'someone' was to blame. Typically this involves people's assessment of their level of personal control or trust of those in and their level of familiarity with the event. This is an area in which the risk communicator Peter M. Sandman (www.psandman.com) has been the pioneer. Sandman identifies 12 components of outrage, each expressed as a continuum, as follows:

Voluntary versus coerced
Natural versus industrial
Familiar versus not familiar
Not memorable versus memorable
Not dreaded versus dreaded
Chronic versus catastrophic
Knowable versus unknowable
Individually controlled versus controlled by others
Fair versus unfair
Morally irrelevant versus morally relevant
Trustworthy sources versus untrustworthy sources
Responsive process versus unresponsive processes

Some of these components clearly overlap with other criteria used here by ERSA, such as awareness, however it is the psychological and political way in which the community responds to these components that determines the contribution of outrage to the perception or impact of the disaster. Outrage is a multiplier of risk, as Sandman expresses it:

Risk = Hazard + outrage.

Given the complex inter-relationships between these components, outrage is perhaps best 'measured' in terms of the outcomes of that response. Table 13 provides a description of outcomes that are indicative of the level of outrage experienced or created by a disaster event.

Table 13: ERSA definitions of outrage

DESCRIPTOR	MEANING
Very low	Little if any public criticism or comment on the role of those perceived to be 'responsible' for the event and its management.
Low	Limited public comment, usually motivated by personal grievances, with the role of those responsible for the event and/or the response to it. Complaints and calls for action usually confined to a local media.
Moderate	Widespread media commentary and criticism of the way in which the event occurred and/or was managed prompting a response from authorities to investigate the situation. A small number of individual legal claims mounted. Complaints and calls for action usually confined to a regional or state media.
High	Widespread demands for an official and independent inquiry into the disaster and its management. Calls for 'heads to roll'. Class action legal claims mounted. Complaints and calls for action usually extend to the national media.
Extreme	Judicial inquiries established. Senior executives stood down and/or criminally prosecuted. Public support for government (at all levels) severely eroded with electoral consequences. Major public compensation payouts. Issues widely covered in the national and international media.

ASSIGNING SCORES

The allocation of scores to each of the seven characteristics is largely intuitive and based on the analysts experience and background. There is no reason, other than convenience and simplicity, for using a simple five-point scale for each characteristic. Some users may wish to apply different weights to the different criteria, for example scoring frequency out of 10 rather than five and seriousness out of 20 rather than five. That is a subjective judgement and is done should be justified, or at least explained, in the analysis.

It has been my experience that by workshopping the allocation of scores with the client group is a useful strategy given that it gives the ‘buy-in’ to the risk analysis process and provides the significant local perspective to the process.

RESILIENCE AND SUSTAINABILITY

Much of the disaster/emergency management literature in the past five years or so has placed an emphasis on community ‘resilience’ rather than ‘safety’. This term is frequently used interchangeably with, or overlapping with concepts of, ‘sustainability’.

There is a rich and growing literature on sustainability. While much of this literature is clearly focused on environmental or economic sustainability, there is a growing experience in adopting a more holistic view of community sustainability. Some definitions that have been proposed include:

> *A sustainable community is far-seeing enough, flexible enough, and wise enough to maintain its natural, economic, social, and political support systems.*

By this definition it is clear that sustainability (or resilience) is multi-dimensional. In all 16 dimensions have been identified and applied in work done by ERSA (e.g. Leake, Granger and Kirby, 2010), though not all are necessarily applicable in every community risk study. They are:

- The environment
- Population
- Water consumption
- Food production
- Use of raw materials and energy
- Transportation
- Communications
- Housing
- Economy
- Social equity and justice
- Governance and participation
- Education
- Health
- Spirituality
- Cultural identity and heritage
- Information, knowledge and wisdom

RESPONDING TO RISK

AS/NZS 4360-2004 identifies four broad options for risk treatment:

- eliminate the risk – whilst this is the theoretical ideal, this option is very difficult to achieve in practice because it would require one or more of the risk elements (hazard, exposure, vulnerability) to be reduced to zero;
- reduce the risk – this is typically the most practical option, however, it inevitably involves setting thresholds beyond which risk reduction is deemed to be either impractical or uneconomic (the 'as low as reasonably practical - ALARP - approach). This involves the difficult and often contentious task of establishing what the community considers to be a level of 'acceptable' or 'tolerable' risk;
- transfer the risk – administratively, this is frequently done by a higher level of government passing responsibility to the next level down the line, or governments passing responsibility to individual property owners. When available, insurance is the most common strategy employed to transfer financial risk;
- accept the risk – where it is not possible to eliminate, reduce further, or fully transfer the risk, the residual risk is simply accepted or tolerated. Acceptance typically relates to those risks that are either relatively common, but their impact is more of an inconvenience than a significant threat (i.e. not worth worrying about); or those that may have a devastating impact but their occurrence is extremely rare (i.e. impossible to control or manage).

To some extent the risk treatment options described in SA/SNZ (2009) paraphrase these options as follows:

> *Risk treatment options are not necessarily mutually exclusive or appropriate in all circumstances. The options can include the following:*
>
> > *a) avoiding the risk by deciding not to start or continue with the activity that gives rise to the risk;*
> > *b) taking or increasing the risk in order to pursue an opportunity;*
> > *c) removing the risk source;*
> > *d) changing the likelihood;*
> > *e) changing the consequences;*
> > *f) sharing the risk with another party or parties (including contracts and risk financing); and*
> > *g) retaining the risk by informed decision.*

CONCLUSIONS

Disaster risk management is the essential prerequisite for genuine community safety. Without an appropriate and detailed risk management study it is not possible for communities to be safe, sustainable and resilient. The approach employed by me in work undertaken by ERSA has been developed over 20 years of direct involvement in disaster management and has been tested many times by disaster managers on the ground.

REFERENCES

Crichton D., 1999: 'The risk triangle', in J. Ingleton (ed), *Natural disaster management*, Tudor Rose, London.

EMA, 2010: *National emergency risk assessment guidelines,* Emergency Management Australia, Canberra.

Fournier d'Albe E.M., 1986: 'Introduction: Reducing vulnerability to nature's violent forces: cooperation between scientist and citizen' in Maybury, R.H. (ed.) *Violent forces of nature,* pp. 1-6, Lomond Publications, Maryland.

Granger K., 1998: 'Developing an understanding of urban geohazard risk', *Australian Journal of Emergency Management*, Vol 13, No 4, Emergency Management Australia, Mt Macedon.

Granger K., 2005: *Safe, sustainable and secure communities: a geographer's perspective*, Geographic Monograph, Royal Geographical Society of Queensland, Brisbane.

Granger K. and Hayne M. (eds), 2001: *Natural hazards and the risks they pose to South-East Queensland*, Record 2001-29, Australian Geological Survey organisation, Canberra.

IEC/ISO, 2009: *IEC/ISO 31010:2009 Risk management - risk assessment techniques*, International Electrotechnical Commission and International Standards Organisation, Geneva.

Leake J., Granger K. and Kirby T., 2010: *An independent review of the recovery from the impact of Tropical Cyclone Nargis with guidelines for the future,* consultant report to United Nations Development Program Delta Working Groups by the Institute for International Development, Adelaide.

SA/SNZ, 2004a: *Australia New Zealand Standard AS/NZS 4360:2004 Risk management,* Standards Australia, Homebush, and Standards New Zealand, Wellington.

SA/SNZ, 2004b: *HB436 Risk management guidelines: companion to AS/NZS 4360:2004*, Standards Australia, Homebush, and Standards New Zealand, Wellington.

SA/SNZ, 2009: *AS/NZS ISO 31000:2009 Risk management - principles and guidelines*, Standards Australia, Homebush, and Standards New Zealand, Wellington.

SEMC, 2001: *NSW State Emergency Management Committee implementation guide for emergency management committees*, NSW State Emergency Management Committee, Sydney.

Zamecka A. and Buchanan G., 1999: *Disaster risk management*, Department of Emergency Services, Brisbane.