CHAPTER 8: A MULTI-HAZARD RISK ASSESSMENT

Overview

Our approach in developing this multi-hazard risk assessment of Cairns has been consistent with the general risk management process outlined in *AS/NZS 4360:1995 Risk management* (see **Figure 1.1** and **Figure 1.2**) and its evolving application in the emergency (or disaster) risk management field. So far in this report we have:

- established the risk study context and process;
- identified the key risks faced by the Cairns community that are posed by range of natural hazards; and,
- analysed and characterised those risks.

In this chapter we assess (or evaluate) these risks and prioritise their significance to the Cairns community.

Our methods have also been shaped by the definition of total risk adopted in this study, namely:

> ***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…*
>
> (Fournier d'Albe, 1986)

In simplistic terms we have expressed the relationship between the various components as follows:

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

To assess overall community risk, therefore, it is necessary to bring together the assessment of each suburb's exposure to hazard impact and their contribution to overall community vulnerability to reach an assessment of that suburb's total risk and then to measure that risk against established risk criteria.

Risk Criteria

It is difficult, if not impossible, to be categorical about levels of acceptable risk. Such risk criteria vary wildly over time, from circumstance to circumstance and from the different perspectives of each individual member of the community. For example, many people will tolerate the minor levels of flooding that might occur once every five or so years, especially if it affects few properties. The community generally will be less tolerant of moderate to major flooding that causes widespread dislocation and does damage. Major levels of flooding that kill people and produce massive economic loss are typically 'unacceptable'. Whilst this seems to be an eminently reasonable approach, it is unrealistic, especially where the event is rare.

It is relatively easy and inexpensive to control, or even eliminate, the nuisance levels of flooding that most people tend to tolerate. It is, however, economically impractical, if not physically impossible, to eliminate the risk of rare but catastrophic levels of flooding. Similarly, it would be prohibitively expensive to build structures to withstand the impact of the largest possible earthquake. There is clearly an inverse relationship between risk acceptability and risk controllability. The widely adopted response to this paradox is to establish thresholds of risk that are economically viable and socially acceptable to implement. Events that exceed those thresholds are coped with, if and when they occur. In Cairns the following thresholds are either explicitly or implicitly accepted:

- for earthquake - under the criteria established in *AS 1170.4-1993*, no building should fail unless it is exposed to earthquake loads greater than those for which there is less than a 10% probability of exceedence in any 50 year period (i.e an ARI of around 500 years). More stringent construction standards are required for structures used for what we have termed 'critical facilities';
- for landslide - there are no explicit thresholds other than 'good engineering practice', though some areas proposed for development have been 'quarantined' by Cairns City Council pending further geotechnical investigation;
- for flood - planning constraints apply to new development within the area likely to be effected by a 1% flood in the Barron River delta (i.e. an ARI of 100 years);
- for destructive winds - under the criteria established in *AS 1170.2-1989*, no building should fail unless exposed to wind loads greater than those for which there is less than a 5% probability of exceedence in any 50 year period (i.e. an ARI of around 1 000 years);
- for storm tide - planning constraints apply to new development within the area subject to inundation under a notional 1% AEP storm tide (i.e. an ARI of 100 years).

This inconsistent approach to standards of 'risk acceptance' is certainly not unique to Cairns. These thresholds have largely been set by agencies outside Cains, especially those involved in establishing the various standards under the Building Code. The 1% thresholds for inundation hazards appear to have been accepted because of their widespread adoption elsewhere in Australia as 'best practice'. This latter threshold originated in Europe and has simply been adopted in some areas of Australia without being tested for its appropriateness or its universal applicability in all catchments.

These thresholds do not address the risks to structures (and consequently people) built before the introduction of the various standards or planning constraints. The vulnerability of older structures to earthquake loads has, however, recently been addressed with publication of *AS 3826-1998 Strengthening existing buildings for earthquake* (Standards Australia, 1998) and a similar standard for upgrading older buildings to meet wind loads is close to publication.

In spite of these limitations, these thresholds do provide us with a benchmark against which to assess community risk in Cairns.

Total Risk Assessments

In **Table 8.1** we have brought together the rank values of Cairns suburbs for their contribution to overall community vulnerability (from **Table 3.11**) and their rank values for exposure to earthquake (from **Table 4.8**), landslide (from **Table 5.4**), flood (from **Table 6.6**), strong winds (**Table 7.2**) and storm tide (from **Table 7.5**). Each of the exposure rankings is based on scenarios that match or exceed the threshold values described above.

By plotting each suburb's rank of contribution to overall community vulnerability against their rank of exposure to each hazard, it is possible to classify suburbs according to their total risk as follows:

A. high total risk (high exposure and high contribution to vulnerability)
B. significant total risk (high exposure and low contribution to vulnerability)
C. moderate total risk (low exposure and high contribution to vulnerability)
D. low total risk (low exposure and low contribution to vulnerability)

In this classification 'high' rank is taken to be the top 50% of ranks and 'low' is the bottom 50% of ranks as follows:

high contribution ranks 1 to 20	low contribution ranks 21 to 41
high earthquake exposure ranks 1 to 20	low earthquake exposure ranks 21 to 41
high landslide exposure ranks 1 to 14	low landslide exposure ranks 15 to 29
high flood exposure ranks 1 to 6	low flood exposure ranks 7 to 12
high storm tide exposure ranks 1 to 14	low storm tide exposure ranks 15 to 28

Suburbs with no exposure to a particular hazard have been left unranked.

Table 8.1: Ranking of Cairns suburbs according to vulnerability and hazard exposure

Suburb	Vulnerability	Earthquake	Landslide	Flood	Wind	Storm Tide
Aeroglen	24	34	13	10	33	11
Barron	41	41		1	38	27
Bayview Heights	26	6	3		1	
Bentley Park	19	19	25		17	
Brinsmead	27	25	6		21	
Cairns North	10	8			14	6
Caravonica	33	33	20	7	32	
City	15	14			36	4
Clifton Beach	30	22	22		23	14
Earlville	18	9	9		7	
Edge Hill	2	5	10		5	17
Edmonton	6	18	16		15	24
Freshwater	32	29	4	11	19	
Gordonvale	4	16	26		18	
Holloways Beach	22	12		8	12	16
Kamerunga	37	35	19	4	34	
Kamma	36	37			38	26
Kanimbla	38	36	18		35	
Kewarra Beach	23	23	26		28	21
Machans Beach	34	20		6	16	7
Manoora	5	11	21		9	9
Manunda	2	2			6	1
Mooroobool	11	3	2		3	18
Mount Peter	40	40	26		38	
Mount Sheridan	28	26	12		27	
Palm Cove	25	31	16		30	15
Parramatta Park	9	4			11	5
Portsmith	8	15			31	3
Redlynch	21	27	1	5	26	
Smithfield	16	24	6	3	24	26
Stratford	29	28	8	9	22	28
Trinity Beach	17	17	14		10	13
Trinity East	31	11	11		37	20
Trinity Park	35	30		12	29	10
Westcourt	1	1			4	2
White Rock	12	21	24		20	19
Whitfield	20	7	5		2	
Woree	7	10	22		8	22
Wright's Creek	39	39	29		38	25
Yarrabah	13	32	14		25	12

Yorkeys Knob	14	13		2	13	8

Total earthquake risk: Any earthquake of a magnitude likely to cause damage in Cairns will have an effect across all suburbs. The amount of damage, and consequently risk, will increase in direct proportion to the intensity of the event. All suburbs, therefore, have some degree of exposure. The relationship between each suburb's vulnerability contribution (i.e. the relative contribution made to overall community risk by the elements at risk in each suburb as detailed in **Chapter 3**) and its exposure to earthquake is shown in **Figure 8.1** and the spatial distribution in **Figure 8.2**.

There is a significant degree of correlation between the two sets of rank. This can be explained in terms of the history of urbanisation in Cairns where the oldest (and most vulnerable) buildings are located on the extensive, 'soft' coastal sediments that are most likely to amplify earthquake peak ground acceleration. These are also the suburbs that contain many of the critical facilities and have significant concentrations of people, buildings and infrastructure. The more modern suburbs, in which the majority of buildings and other structures conform to the earthquake loading provisions of the Australian Building Code, are on the shallow soils or rock of the hill slopes where peak ground accelerations will be less damaging.

The grouping of suburbs (in alphabetical order) according to total risk is provided in **Table 8.2**.

Table 8.2: Level of total earthquake risk of Cairns suburbs

RISK LEVEL	SUBURBS
High total risk	Bentley Park, Cairns North, City, Earlville, Edge Hill, Edmonton, Gordonvale, Manoora, Manunda, Mooroobool, Parramatta Park, Portsmith, Trinity Beach, Westcourt, Whitfield, Woree, Yorkeys Knob
Significant total risk	Bayview Heights, Holloways Beach, Machans Beach
Moderate total risk	Smithfield, White Rock, Yarrabah
Low total risk	Aeroglen, Barron, Brinsmead, Caravonica, Clifton Beach, Freshwater, Kamerunga, Kamma, Kanimbla, Kewarra Beach, Mount Peter, Mount Sheridan, Palm Cove, Redlynch, Stratford, Trinity East, Trinity Park, Wright's Creek
No discernible risk	nil

Total landslide risk: Unlike earthquakes, which will have an effect across Cairns, landslide risk is localised. Even within the suburbs identified as having a high level of total landslide risk, the impact in any single landslide event is likely to be localised. The assessment of total risk relates, therefore, to the cumulative landslide risk over time across each suburb. The relationship between each suburb's vulnerability contribution and its exposure to landslide is shown in the scattergram (**Figure 8.3**) and their distribution in the map (**Figure 8.4**).

There is a very low degree of correlation between the two sets of rank. This can be explained by the fact that the suburbs with the greatest exposure to landslide are found mainly on the hill slopes. Such suburbs tend to be largely residential and the most recently developed areas in Cairns. As the level of development in those suburbs increases, so will the magnitude of the risk also increase. The relative level of total landslide risk is given in **Table 8.3**.

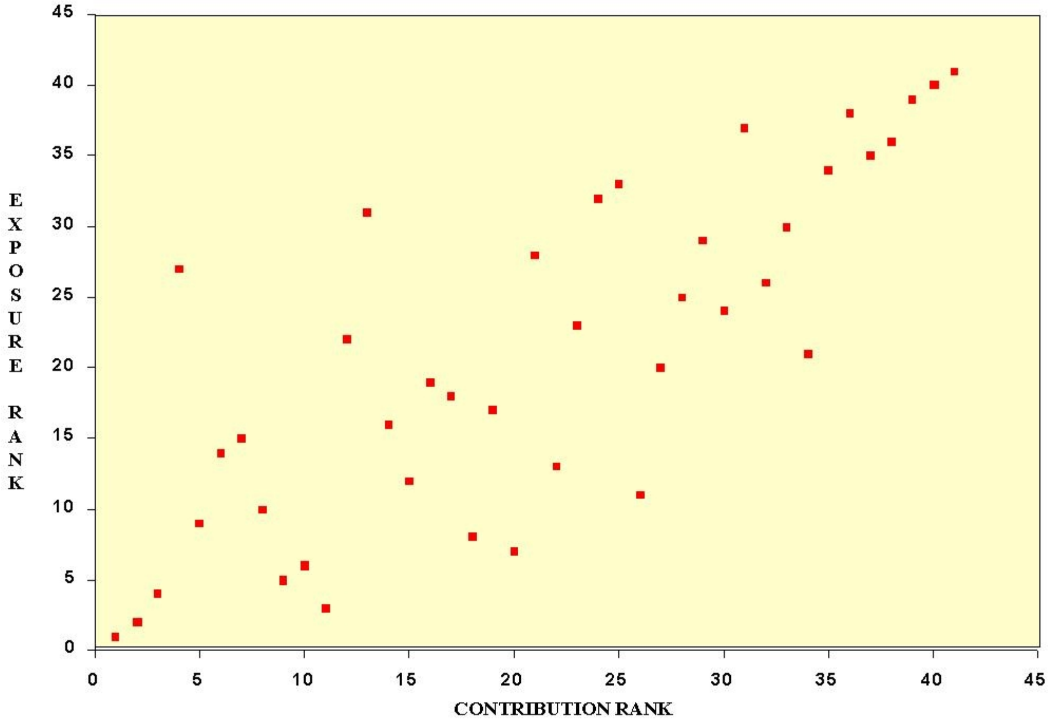

Figure 8.1: Earthquake total risk relationship

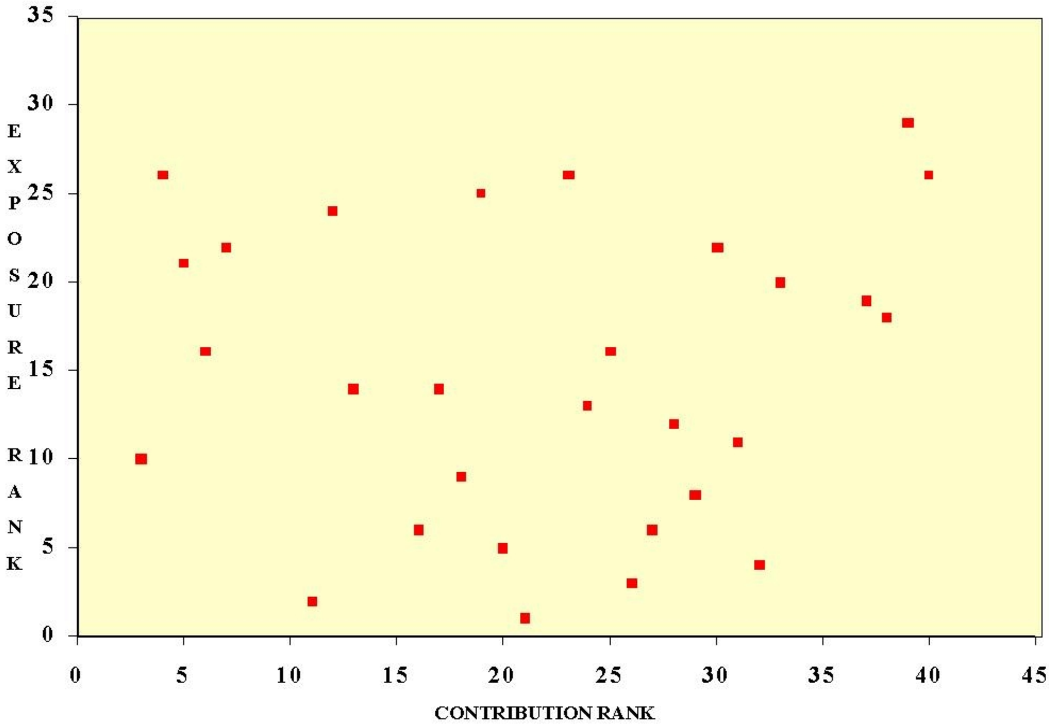

Figure 8.3: Landslide total risk relationship

Table 8.3: Level of total landslide risk of Cairns suburbs

RISK LEVEL	SUBURBS
High total risk	Earlville, Edge Hill, Mooroobool, Smithfield, Trinity Beach, Whitfield, Yarrabah
Significant total risk	Aeroglen, Bayview Heights, Brinsmead, Freshwater, Mount Sheridan, Redlynch, Stratford, Trinity East
Moderate total risk	Bentley Park, Edmonton, Gordonvale, Manoora, White Rock, Woree
Low total risk	Caravonica, Clifton Beach, Kamerunga, Kanimbla, Kewarra Beach, Mount Peter, Palm Cove, Wright's Creek
No discernible risk	Barron, Cairns North, City, Holloways Beach, Kamma, Machans Beach, Manunda, Parramatta Park, Portsmith, Trinity Park, Westcourt, Yorkeys Knob

Total Barron River flood risk: The total flood risk, based on an event with a 1% AEP (ARI of 100 years) in the Barron River, presents a further variation. Whilst flooding in the Barron River delta will affect less than one third of all Cairns suburbs, in most flood events all delta suburbs will be affected to some degree. In spite of the spatially confined nature of the threat, the scattergram (**Figure 8.5**) shows a degree of correlation between the exposure of suburbs to flood and their contribution to community vulnerability. The fact that the scatter commences well to the right of the diagram (i.e. into the low contribution ranks) can be interpreted to indicate that there has been limited overall development, other than agriculture, in the more flood prone areas of the delta.

The spatial distribution is shown in **Figure 8.6** and the listing of suburbs according to the level of total risk is provided in **Table 8.4**. It is emphasised that this assessment relates only to the Barron River. When data relating to the flood exposure in the other Cairns catchments (MacAlister Range, Trinity Inlet, Mulgrave River and Yarrabah) become available it will be possible to produce an overall total flood risk assessment. Flash flooding in the other catchments, especially the streams that flow into Trinity Inlet, is a potentially significant problem. Not only are there significantly more properties exposed to urban drainage surcharge in the downtown area than there are on the Barron delta, but also the risk to life is significant because of the rapid onset of flash floods and the propensity for careless or foolish behaviour by some people in and around floodwaters.

Table 8.4: Level of total Barron River flood risk of Cairns suburbs

RISK LEVEL	SUBURBS
High total risk	Smithfield, Yorkeys Knob
Significant total risk	Barron, Kamerunga, Machans Beach, Redlynch
Moderate total risk	nil
Low total risk	Aeroglen, Caravonica, Freshwater, Holloways Beach, Stratford, Trinity Park
No discernible risk	Bayview Heights, Bentley Park, Brinsmead, Cairns North, City, Clifton Beach, Earlville, Edge Hill, Edmonton, Gordonvale, Kamma, Kanimbla, Kewarra Beach, Manoora, Manunda, Mooroobool, Mount Peter, Mount Sheridan, Palm Cove, Parramatta Park, Portsmith, Trinity Beach, Trinity East, Westcourt, White Rock, Whitfield, Woree, Wright's Creek, Yarrabah

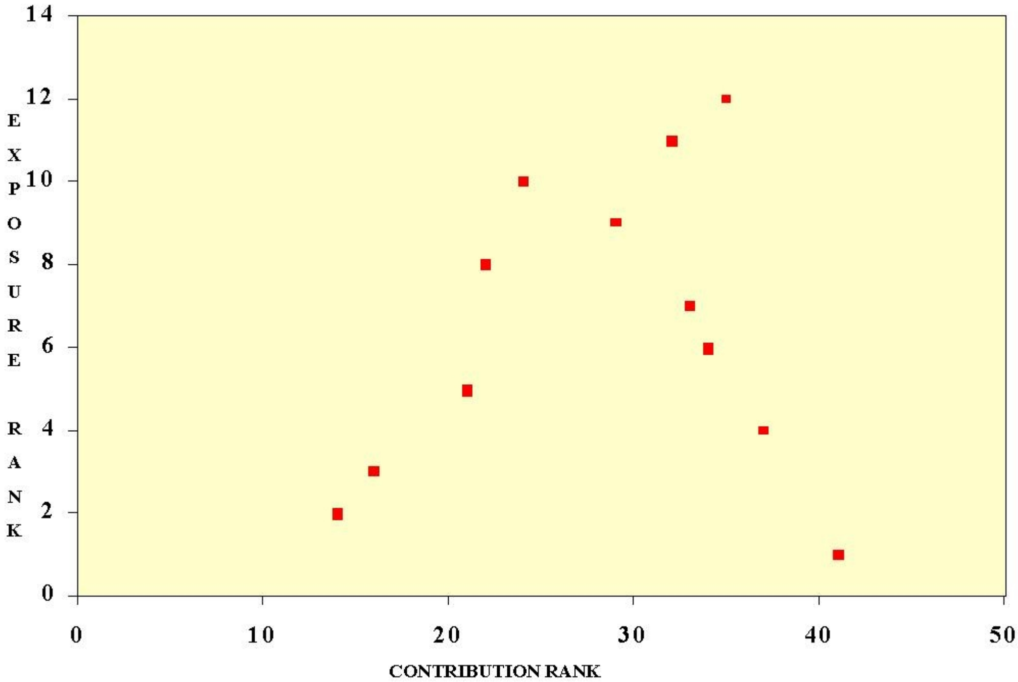

Figure 8.5: Barron River flood total risk relationship

Destructive wind total risk: Whilst there is a reasonable degree of correlation between exposure and vulnerability contribution shown in the scattergram (**Figure 8.7**), it is certainly weaker than for either earthquake or storm tide. This may be explained by the fact that the highest exposure levels are for suburbs on the hill slopes that have older buildings followed by the older buildings on the flat country. The spatial distribution is shown in **Figure 8.8** and the suburbs are listed by total risk in **Table 8.5**.

Table 8.5: Level of total destructive wind risk of Cairns suburbs

RISK LEVEL	SUBURBS
High total risk	Bentley Park, Cairns North, Earlville, Edge Hill, Edmonton, Gordonvale, Manoora, Manunda, Mooroobool, Parramatta Park, Trinity Beach, Westcourt, White Rock, Whitfield, Woree, Yorkeys Knob
Significant total risk	Bayview Heights, Freshwater, Holloways Beach, Machans Beach
Moderate total risk	City, Portsmith, Smithfield, Yarrabah
Low total risk	Aeroglen, Barron, Brinsmead, Caravonica, Clifton Beach, Kamerunga, Kamma, Kanimbla, Kewarra Beach, Mount Peter, Mount Sheridan, Palm Cove, Redlynch, Stratford, Trinity East, Trinity Park, Wright's Creek
No discernible risk	nil

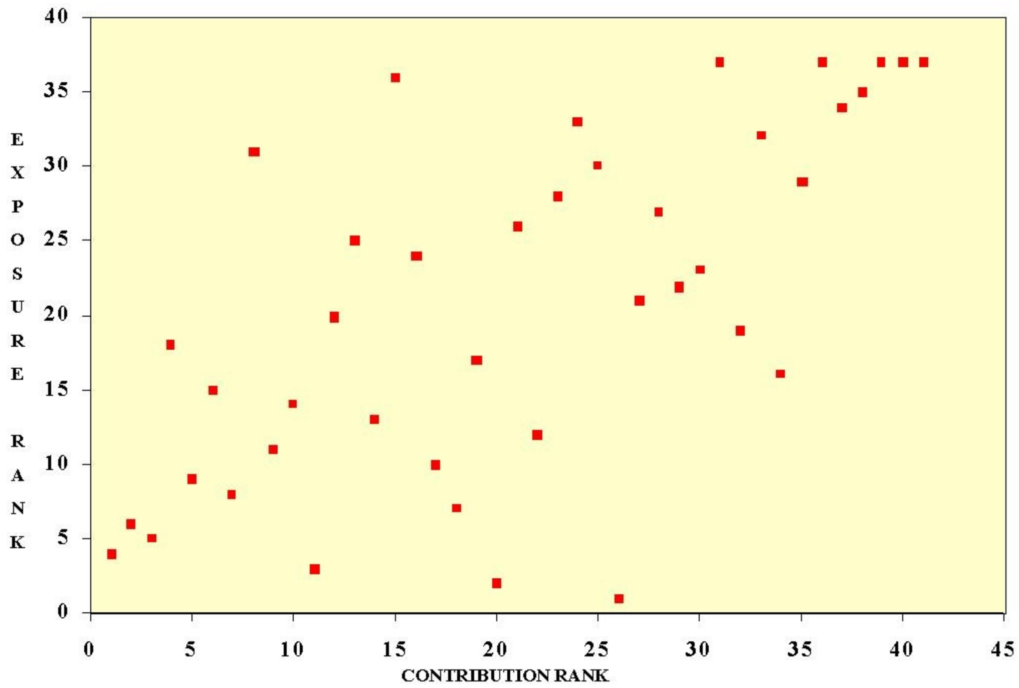

Figure 8.7: Destructive wind total risk relationship

Total storm tide risk: The total storm tide risk, based on an event with an AEP of 1% (ARI of 100 years), reflects both the history of Cairns settlement and the confining aspects of terrain. As such it contains elements of both the earthquake total risk and the Barron River flood total risk assessments.

The scattergram (**Figure 8.9**) shows a degree of correlation between exposure rank and contribution rank. This reflects the way in which both factors diminish away from the CBD on the low-lying inner area. The spatial distribution, shown in Figure 8.10, clearly reflects the coastal focus of the storm tide threat. **Table 8.6** lists the suburbs of Cairns according to their total storm tide risk.

Table 8.6: Level of storm tide risk of Cairns suburbs

RISK LEVEL	SUBURBS
High total risk	Cairns North, City, Manoora, Manunda, Parramatta Park, Portsmith, Trinity Beach, Westcourt, Yarrabah, Yorkeys Knob
Significant total risk	Aeroglen, Clifton Beach, Machans Beach, Trinity Park, ,
Moderate total risk	Edge Hill, Edmonton, Mooroobool, Smithfield, White Rock, Woree
Low total risk	Barron, Holloways Beach, Kamma, Kewarra Beach, Palm Cove, Stratford, Trinity East, Wright's Creek
No discernible risk	Bayview Heights, Bentley Park, Brinsmead, Caravonica, Earlville, Freshwater, Gordonvale, Kamerunga, Kanimbla, Mount Peter, Mount Sheridan, Redlynch, Whitfield

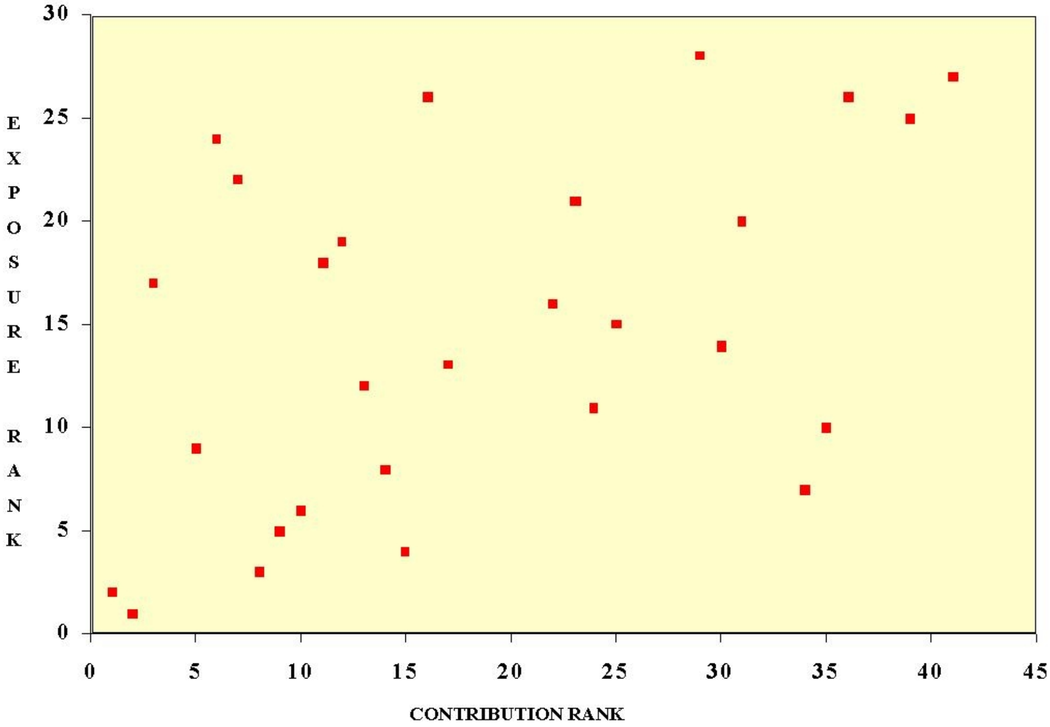

Figure 8.9: Storm tide total risk relationship

Total cyclone risk: Given that cyclones are compound hazards which bring with them (in severe cases) destructive winds, storm tide, flood and landslide, it is appropriate to consider the cumulative total risk represented by a severe cyclone impact. To do this we have taking the highest total risk value for each suburb identified in **Table 8.3** (landslide), **Table 8.4** (flood), **Table 8.5** (destructive wind) and **Table 8.6** (storm tide). **Table 8.7** lists the suburbs according to their overall total cyclone risk and the distribution is shown in **Figure 8.11**.

Table 8.7: Level of total cyclone risk of Cairns suburbs

RISK LEVEL	SUBURBS
High total risk	Bentley Park, Cairns North, City, Earlville, Edge Hill, Edmonton, Gordonvale, Manoora, Manunda, Mooroobool, Parramatta Park, Portsmith, Smithfield, Trinity Beach, Westcourt, White Rock, Whitfield, Woree, Yarrabah, Yorkeys Knob
Significant total risk	Aeroglen, Barron, Bayview Heights, Brinsmead, Clifton Beach, Freshwater, Holloways Beach, Kamerunga, Machans Beach, Mount Sheridan, Redlynch, Stratford, Trinity East, Trinity Park
Moderate total risk	nil
Low total risk	Caravonica, Kamma, Kanimbla, Kewarra Beach, Mount Peter, Palm Cove, Wright’s Creek
No discernible risk	nil

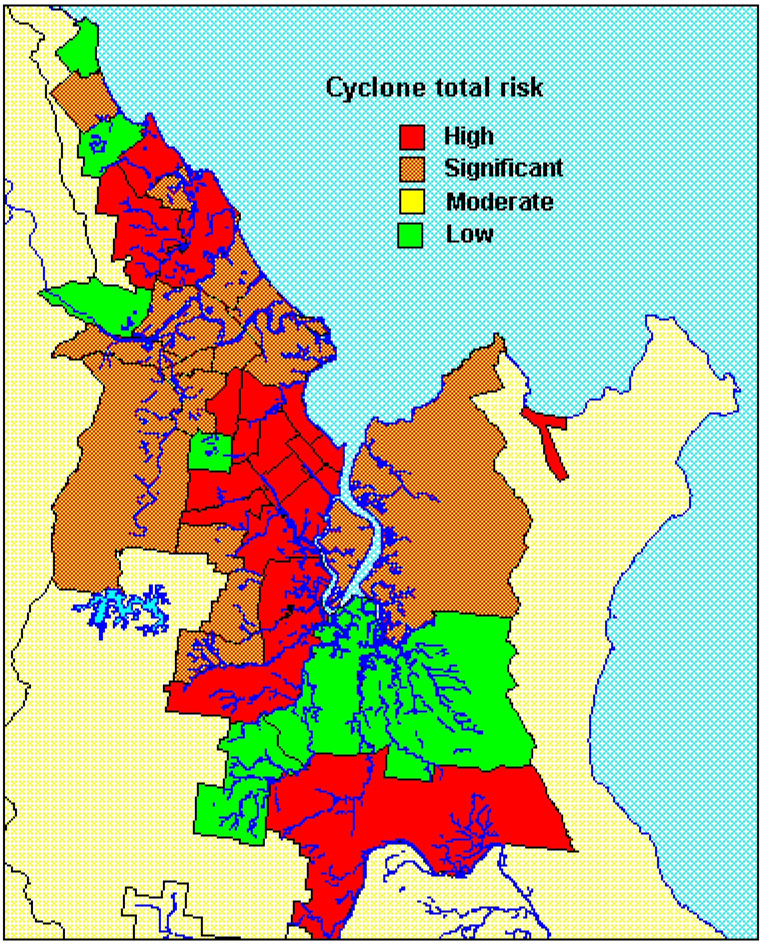

Figure 8.11: Distribution of cyclone total risk

The roughly concentric zonation, centred on the CBD/port area, reinforces the impression gained throughout this study that, in Cairns at least, there is a very strong correlation between the suburbs that contribute most to the overall vulnerability of the community and the degree to which they are exposed to the most significant hazard phenomena. The secondary core risk areas on the northern beaches, at Yarrabah and at Gordonvale reflects the significance of those communities as distinct from the central Cairns community. It is likely, as Cairns grows more to the south, that a similar concentric zonation will develop around the centre that evolves to be the service centre for the southern community. The similarity of the distribution of total risk for cyclones to the distribution of total risk for earthquakes (**Figure 8.2**) is also of significance.

Risk Evaluation and Prioritisation

Several methodologies have been described in the literature for evaluating and prioritising risk as the first step towards establishing treatment strategies and priorities. The method that has gained wide recognition amongst Australian emergency managers is the 'SMAUG' approach based on the work of Kepner and Tregoe (1981). In this instance, SMAUG is not J.R.R. Tolkien's dreaded dragon, but an acronym standing for:

Seriousness, **M**anageability, **A**cceptability, **U**rgency and **G**rowth

The method involves rating each risk in relation to these criteria as being high, medium or low (see, for example, the discussion of this approach in Salter, 1997). The risk management standard (*AS/NZS 4360:1995*) provides a similar approach based on a matrix to qualitatively rate risk likelihood against its consequences (see Standards Australia, 1995 Appendix D).

Whilst both of these approaches provide a useful method for reaching a qualitative evaluation of risk, especially for a single hazard, they are rather limited and cumbersome in their application to multi-hazard risk evaluation and prioritisation. The semi-quantitative approach that we have adopted in this study, by contrast, provides a more subjective means of identifying the risks that pose the greatest threat to the total community. It also provides a means for identifying the risks that pose the greatest threat to individual suburbs (even neighbourhoods and individual buildings) within the community.

There is no doubt that tropical cyclones pose the greatest threat to Cairns and that **the destructive winds that accompany cyclones pose the greatest level of risk**. Not only do they have a high frequency of occurrence, they also have a wide-spread impact across the entire community. Cairns has come within the radius of destructive winds at least 21 times since 1876 and has suffered severe damage and dislocation as a result. Locally developed design practice aimed at making buildings more resilient to strong winds came into use in the 1950s and were enhanced and formalised with the introduction of national building construction standards in 1975 for major buildings, and 1982 for domestic structures. These have proved to be an effective form of mitigation. Very few buildings constructed since 1975 have suffered more than minor damage by winds in the 10 cyclones that have had an effect on Cairns since that time, though substantial damage has been done to older buildings, unapproved structures (such as patios and sheds) as well as to vegetation and power lines. Even the best constructed modern building, however, is still at significant risk of damage from trees brought down by winds and from wind-blown debris. There is little, however, that can be done to reduce the risk of wind damage to sugar cane or tree crops such as banana and pawpaw which produces significant economic loss.

Given the capacity of the cyclone monitoring and warning system operated by the Bureau of Meteorology there is now virtually no chance of the Cairns community being caught by surprise by a cyclone impact. Thanks to the annual community awareness campaign mounted jointly by the Bureau, the Queensland Department of Emergency Services and Cairns City Council, there is a high level of community awareness of the risk and how to cope with it. The level of awareness has been reinforced by the community's experience of two relatively minor cyclone emergencies in the past three seasons. The risk to life from destructive cyclone winds, therefore, should be small and confined to the foolhardy, who ignore the warnings and advice, or those who do not hear or understand the warnings.

Of the other hazard phenomena generated by cyclones, **storm tide clearly ranks second**. Destructive storm tides have been relatively rare events in Cairns history (only three or four instances over the past 123 years). There is absolutely no doubt, however, that they hold the greatest potential to cause major loss of life and to wreak widespread and massive damage. Their potential for destruction is derived largely from the large numbers of people, buildings and critical facilities that are located within the area in which storm tide impact would be greatest. All of this development pre-dates the introduction of planning constraints aimed at reducing storm tide risk, consequently it provides a substantial residual risk that will need to be addressed by other mitigation strategies.

A significant storm tide would invariably have major environmental impacts. These could include significant coastal erosion and/or deposition that would in turn pose a threat to beachside suburbs such as Holloways Beach, Machans Beach, Yarrabah and Yorkeys Knob. The secondary risk of contamination by salt water and by the impact of the storm tide on facilities such as sewerage treatment works and major agricultural chemical warehouses should also be taken into account.

Whilst earthquake is not widely recognised as a significant threat to Cairns, our research and the known record of seismic activity along the entire east coast of Australia leads us to conclude that **strong earthquake poses the third greatest risk to the Cairns community**. This risk is largely derived from the geology of the region. Much of Cairns is built on thick sediments. In addition, the sediments that underlie much of the downtown area are classed as 'soft'. All these sediments are likely to significantly amplify strong ground motions, even from relatively distant earthquakes. Much of the major construction boom in Cairns took place after the publication of the first Australian earthquake loadings standard in 1979. However, this standard was not used widely in Queensland and, unlike its 1993 successor, did not cover domestic buildings. None-the-less, many Cairns buildings are earthquake-resistant to a degree, having been designed to comply with wind loading standards from around the late 1950s for engineered buildings and 1982 for domestic buildings.

Except in the event of a very strong earthquake we would not expect significant loss of life. Given the experience of the relatively moderate 1989 Newcastle earthquake (Richter magnitude 5.6), however, the catastrophic failure of one or more major buildings in the CBD, because of inappropriate design, poor construction and/or poor condition, can not be ruled out.

The economic risk posed by earthquake in Cairns is substantial, especially in the older parts of the city. The risk to the most vulnerable types of buildings in Cairns is compounded because they are located overwhelmingly on the two least favourable ground conditions – Site Class C and Site Class D. In any future earthquake affecting Cairns, the most pronounced direct damage may occur to these buildings because of their construction type, their condition, and their location. The older and more brittle underground utilities, such as water and sewerage reticulation networks, are especially susceptible to damage. Strong earthquakes also have the potential to create secondary risks such as the spread of fire in the older suburban and commercial areas and the loss of containment of hazardous materials in bulk storage areas such as fuel depots and service stations, although we consider these secondary risks to be low.

As a contrast, the modern, cyclone-resistant building stock in Cairns would perform better in earthquakes than the buildings in many Australian cities where significant proportions are older and constructed of unreinforced masonry. This cyclone-resistant stock comprises about two-thirds of the total number of buildings in Cairns.

Flooding of the Barron River delta is the fourth ranked risk for Cairns. Whilst major flooding in the Barron is clearly more frequent than damaging earthquakes we have ranked the flooding risk behind earthquake risk to the total Cairns community because flooding is confined to a small area, the bulk of which is occupied by agriculture. A damaging earthquake, though rare, will have an impact on the entire community, hence the higher rank we have assigned.

Major flood levels on the Barron River delta have been reached 7 times since 1911 giving an ARI over the past 88 years of around 12 years. Even though planning constraints for development in the flood-prone areas of the delta were not introduced until the early 1990s, land use is predominantly agricultural. Urban areas in Caravonica, Holloways Beach, Machans Beach, Redlynch and Yorkeys Knob together with the road network which links the northern beach suburbs to the city centre are all susceptible to inundation. Flooding is, however, generally of short duration and the warning systems operated by the Bureau of Meteorology provide sufficient time for residents to take steps to protect their property and for emergency services to conduct evacuations if that course of action is indicated.

An extreme flood, such as that experienced in 1911, or the unlikely event of the failure of either the Tinaroo or Copperload Falls Dams, would certainly result in the loss of buildings and could see the course of the Barron River change. The risk of fatalities in such events is significant, especially where people ignore warnings to evacuate, or indulge in stupid behaviour such as 'surfing' in the floodwaters or attempting to negotiate flooded roads.

Under such a scenario the Cairns International Airport and the facilities that surround it would also be at significant risk because the levees that protect them would be overtopped. Relief and recovery operations into Cairns would be significantly dislocated by the loss of the airfield. Significant environmental harm would be caused by contamination from facilities such as the sewerage treatment works, the waste chemical treatment facility and the airport bulk fuel stores that would also be inundated.

Landslide and flash flooding share the fifth place in terms of risk priority. Whilst these closely related hazards occur fairly frequently in Cairns, in developed localities they tend to affect only small areas and are a problem for only short periods. The experience of the massive 1951 Ellis beach debris flows, however, is a clear indicator of what can happen along the Cairns escarpment in extreme circumstances. Our information, however, does not permit us to know with any certainty just how rare or extreme that event was.

Even at the smallest scale, either phenomenon can be lethal because of their rapid onset and the lack or warning. Both flash flooding and debris flows in the upper Freshwater Creek valley hold the potential to disrupt the Cairns water supply by damaging the intake and pipeline.

Risk Mitigation Options

The development and implementation of risk mitigation strategies for Cairns lie outside the remit of the *Cities Project*. Our experience in working with emergency managers and others, in Cairns and elsewhere, has, however, given us some insight into key aspects of risk mitigation that are offered here as observations, rather than as suggestions, let alone recommendations.

Risk management culture: At a philosophical level at least, one of the most potent forms of risk mitigation is the development and nurturing of a strong risk management culture across the community. It has, for example, been frequently observed that emergency risk management is most effective where it is an integral part of overall community risk management. Similarly, disaster planning is most effective where it is managed as an integral part of total community planning. In the vast majority of cases, however, these processes and activities tend to be divorced from the mainstream of community governance, even within organisations that are clearly committed to public safety, as is Cairns City Council. The compartmentation and isolation of emergency risk management from the mainstream can best be attributed to the lack of a broad culture of risk management.

Risk management in organisations like Cairns City Council is still at an early stage of development. Whilst the philosophy and practice has taken root in areas such as finance, it has yet to penetrate all areas of Council. A mature risk management culture will see the decisions made by the executive, administrative, public health, planning, environmental, engineering, fiscal, legal and emergency management elements become more integrated, consistent and coordinated. The outcome would see the interdependencies of strategic decisions in each of those areas acknowledged and their consequences taken into account in a more transparent and seamless process. Such an approach would also tend to widen the planning timeframe from the current two or three year, electorally constrained, horizon, to one of 10, 20 or even 50 years.

Risk information: For a comprehensive risk management culture to flourish, it is necessary for it to be underpinned by a strong and effective information infrastructure. We see the development of such an infrastructure as being the most fundamental of all risk mitigation strategies. It is also one of the most cost effective strategies given that most of the information required is already collected, maintained and used by Cairns City Council and the other authorities that have a role in community risk management. This aspect is considered in detail in a report on the *Cities Project's* experience of implementing key aspects of the Australian Spatial Data Infrastructure (ASDI) in the Cairns case study (Granger, 1998 – included elsewhere on this CD-ROM).

Whilst much of the basic information required for risk management, such as street layout, property information, land use and demographic aspects, is already available, there are several themes that we have found to be poorly addressed. Three themes stand out:

- historical information: whilst the Bureau of Meteorology, QUAKES and AGSO maintain their own information on hazard history; and the Historical Society of Cairns, the Cairns City Library, the *Cairns Post* and the Centre for Disaster Studies at JCU each maintain collections on the community experience of disaster, there is no consolidated index or coordination of information about the Cairns history of disasters and their impact on the community;

- modern event experience: whilst there have been some *ad hoc* efforts made in recent years to collect detailed information about particular episodes, such as Cyclones *Justin* and *Rona* (largely as a part of TCCIP research), such activity is yet to be regarded, or funded, as an essential aspect of risk management. Much of this information, such as the recording of earthquake aftershocks, is highly perishable – if it is not collected during the event it will be lost forever. Without such detail of real events it is not possible to reduce the uncertainty that exists in our models and basic information. The requirement to collect key event information needs to be entrenched in the doctrine of disaster response, with appropriate resources identified in disaster plans and made available to undertake the collection and management of that information;

- technical information: much background technical information is being routinely collected by commercial consultancies to meet the requirements of various standards such as the Australian Building Code. The collection and analysis of geotechnical information on which to base the design of building foundations is a case in point. This information is of great significance to improving the accuracy and relevance of risk assessments. Whilst there are obvious commercial (and possibly legal) sensitivities concerning such information, its value to the wider aspects of community safety is not being realised because there is no central inventory of the existence of such information – let alone an archive of the detail.

There has been significant public investment in the development of systems to monitor hazard phenomena and to provide warnings of an impending impact. This important investment has not, however, been matched by the level of investment in information that enables the warnings or risk forecasts to be translated into information of relevance to members of the community. There is clearly a need for a greater level of investment in risk information.

Monitoring and warning systems: For all of the hazards considered in this study, with the exception of earthquake, warnings of impending impact are already provided. Whilst there is some scope to improve their timeliness and accuracy, their value will only be increased when individuals are able to relate warning information to their own circumstances and translate it into risk reduction action. To achieve this it is necessary to increase public awareness by combining appropriate risk information and warning information.

A report produced by the Institution of Engineers, Australia (Institution of Engineers, 1993) provides a useful hypothetical example of the benefits of this approach in the following terms:

Flood warning systems now feature real time data collection networks linked to computer based flood models. These systems not only identify and track floods down a river but also enable emergency services to quickly assess the impact of various scenarios of increased or decreased rainfall, changing tidal conditions in the lower reaches of the river and varying tailwater effects at the river mouth due to storm surge and wave setup. Based on these scenarios, authorities can take more effective action to save lives and minimise damage to property. Even in a catchment with only one thousand flood prone homes, accurate advanced information on flood levels which enables residents to move contents and motor vehicles to locations above flood waters can result in a saving of $10,000 per household. ***This $10M savings is a direct benefit to the community every time such a flood occurs.***

(emphasis in original)

Community awareness: It is widely recognised by emergency managers that an aware community is a prepared community. To put the reverse argument, all of the investments in risk information, warning systems, risk science and emergency planning is completely wasted unless they also influence the community to adopt risk reduction strategies. An effective strategy of risk communication is, therefore, essential.

A considerable literature on risk communication has emerged over the past decade or so (see, for example, the review by Marra, 1998). One of the most coherent examples we have encountered is that promoted by the US Environmental Protection Agency (EPA). Their approach devolves from the basic tenet that, in a democracy, people and communities have a right to participate in decisions that affect their lives, their property, and the things they value. The EPA approach is based on the following 'seven cardinal rules' (word in italics are quoted from EPA, 1988):

Rule 1 – accept and involve the public as a legitimate partner: *the goal of risk communication in a democracy should be to produce an informed public that is involved, interested, reasonable, thoughtful, solution-oriented, and collaborative; it should not be to diffuse public concerns or replace action.*

Rule 2 – plan carefully and evaluate your efforts: *there is no such entity as "the public"; instead, there are many publics, each with its own interests, needs, concerns, priorities, preferences, and organisations.*

Rule 3 – listen to the public's specific concerns: *people in the community are often more concerned about such issues as trust, credibility, competence, control, voluntariness, fairness, caring, and compassion than about mortality statistics and the details of quantitative risk assessment.*

Rule 4 – be honest, frank and open: *trust and credibility are difficult to obtain. Once lost they are almost impossible to regain completely.*

Rule 5 – coordinate and collaborate with other credible sources: *few things make risk communication more difficult than conflicts or public disagreements with other credible sources.*

Rule 6 – meet the needs of the media: *the media are frequently more interested in politics than in risk; more interested in simplicity than in complexity; more interested in danger than in safety.*

Rule 7 – speak clearly and with compassion: *tell people what you cannot do; promise only what you can do, and be sure to do what you promise.*

Governments, at any level, can only hope to reduce risk if their risk reduction strategies are accepted and supported by the community. Risk communication is the most democratic way of achieving that support.

Efforts to inform the community about risks are not always viewed with the same passion and altruistic values as those held by risk communicators. They are often met with opposition from small, but influential, sectors. The most common negative reactions relate to the belief that such information will have a negative impact on real estate values and/or will scare away tourists. Whilst there has been only limited research into the overall economic impact of risk communication, the anecdotal information that we have seen indicates that such negative beliefs are wrong. They do, none-the-less, excite levels of passion and political 'outrage' that typically leads to the dilution, if not termination, of public awareness efforts.

Building and planning codes: Building codes and planning regulations are rightly seen as being very effective strategies for risk mitigation. The simplest way to reduce risk is obviously to prevent development in areas that are prone to regular and/or significant hazard impact such as floods. Such an approach has already been adopted in Cairns with the Council's Flood Immunity Policy.

If planning constraints are not a viable option (as is the case with destructive winds and earthquakes), the best option is to ensure that the buildings and infrastructure that provide the community with shelter, sustenance, security and social viability are built to withstand reasonable degrees of hazard impact.

Cairns City Council enforces the provisions of the Australian Building Code, which establish minimum standards for construction to safely withstand established levels of earthquake and wind risk. Whilst these standards minimise the risk to new buildings, standards have also been, or are in the process of being, developed to 'retrofit' older buildings to similar levels of safety against earthquake and wind loads. Preliminary consideration is also being given to the development of comparable standards for design and construction in areas prone to landslide and to inundation hazards such as flood and storm tide.

Queensland's *Integrated Planning Act* (IPA), which came into force in 1998, also has the potential to be used to reduce community risk. This legislation enables local governments to include, within their urban planning schemes, specific constraints on development that are aimed at managing risk. The IPA does not establish levels of constraint for different hazards, such as an ARI of 100 years as the State-wide constraint for development in floodplains, but leaves the setting of such thresholds to the individual local government. The Cairns City Council has a Flood Immunity Policy for new development. It requires immunity to the 100 year ARI flood/storm tide event for fill levels for buildings, 150 mm above the 100 year ARI immunity for the floor level of residential, tourist and special facilities, and immunity to the 100 year ARI flood event for the floor level of commercial and industrial buildings.

The IPA also contains provisions that will enable councils to change past planning decisions that did not take into account public safety issues. A land use approved under a previous planning scheme can, for example, now be changed without compensation to the owner, but only after the owner has been allowed two years to substantially commence a previous use redevelopment.

To be effective, however, planning policy must take both a long-term view (preferably with at least a 20-year horizon) and a holistic perspective. The importance of these issues can be seen in the following Cairns examples:

- with the centre of gravity of Cairns population consistently moving south towards Gordonvale, sites for the redevelopment of critical facilities such as hospitals, nursing homes, bulk fuel supply depots, cold stores and telecommunications hubs should be identified and set aside as soon as possible. Such developments should take into account the likely future needs of the community, as well as making provision to satisfy the needs of the current community. Encouragement should be given to the redevelopment of critical facilities, especially those in suburbs such as Cairns North, City and Portsmith, on less hazard prone sites, as they reach the end of their current operational life;

- were the development of the Trinity East area to proceed as proposed, with the area being filled to at least 3.40 m above AHD to withstand inundation events to that level, careful modelling of the affect that such a change would have on storm tide levels in suburbs such as City, Parramatta Park and Portsmith should be required. With the experience of the effect on flood levels on the Machans Beach side of the Barron River produced by the construction of levees to protect the airport in 1988 as a guide, consideration of impacts beyond the Trinity East development should be mandatory.

Emergency management: The emergency management process is based on consideration of the prevention, preparedness, response and recovery phases of disasters (known as PPRR). Under the adaptation of *AS/NZS 4360:1995* to emergency risk management, these traditional components of emergency management can be seen as risk treatment options. The emphasis is on the treatment of residual risks (i.e. the risks that can not be eliminated or reduced by other means), especially in the preparedness, response and recovery planning phases. Most mitigation options, however, clearly focus on prevention.

The preparedness phase emphasises disaster planning, community awareness, training and exercising and the provision of appropriate resources such as communications equipment (see EMA, 1993). It is important, therefore, for emergency planning to be based on sound risk assessments and realistic risk scenarios, otherwise plans may be inappropriate, awareness will be inadequate, training and exercises will not be based on realistic scenarios and resources may not be appropriate. Evacuation planning provides a good example. If such plans are based on an assessment that badly underestimates the numbers of people at risk and the timing for an evacuation, many people could be placed in serious jeopardy by reacting with too few resources, too late. Conversely, if the estimates are too conservative, large numbers of people who did not need to be evacuated could easily overwhelm evacuation resources and shelters. One extreme is probably as dangerous as the other is.

The detailed information and decision support tools developed in this study can be used to produce threat-specific plans on which to base all aspects of the preparedness phase. They enable, for example, the development of disaster response and recovery plans for specific levels of cyclone or flood risk, well in advance of any event, and to use the scenarios on which they are based to run realistic exercises and training serials.

The risk scenarios also provide a capacity to model and forecast impact consequences so that the response phase can be managed more effectively. The same modelling is also appropriate for rehearsing and planning for the recovery phase. There are examples in the literature of GIS being used to model the impact of a damaging earthquake and to forecast the requirements for short term and long term post-event shelter. Similarly it is possible to model the physical impact on lifelines and the consequences of their loss on the community.

Use of the scenario analysis technique develops ‘future memory’; i.e. disaster responders develop an understanding of what will happen when such an eventuality occurs so that their actions are based on ‘experience’ when it eventually does happen. This process could be reinforced by the development of role-play simulation ‘games’, such as *SimCity*, designed around Cairns and other real urban centres.

Critical facility protection: The loss of critical facilities such as the hospitals, the airport, cold stores, fuel depots and emergency service facilities, will greatly magnify the impact of disaster on the community. Whilst such facilities remain exposed to disaster impact, plans to protect them are called for. Such protection may be as simple as ensuring the priority allocation of sandbags to the facility. It may be as routine as ensuring that the facility has an adequate uninteruptable power supply (UPS) or a stand-by generator to cover the loss of reticulated power supply. Or it may embrace costly structural defences such as the constructing permanent protective berms or levees and the development of redundant capacity at other facilities that could cope with the potential loss of one component in a critical system.

Such mitigation efforts are targeted to maximise community protection with a minimum of effort and cost.

Engineered defences: The classic response to risk mitigation has been to turn to structural defences such as levees, dams, flood detention basins and fill. There is a view, however, that:

- they are invariably expensive;
- they frequently fail to provide the levels of protection that are attributed to them because of inadequate design or poor maintenance;
- they foster a false sense of security in the community that they are supposed to protect, with the result that when they fail, the community is exposed to a much greater degree of loss; and,
- a defence against one hazard may exacerbate the risk posed by another hazard. For example, to place extensive fill in an area to reduce an inundation risk could, unless adequately engineered, increase the risk of earthquake damage through enhanced shaking or permanent ground displacement.

There is an increasing tendency to emphasise non-structural mitigation measures (such as those discussed above) and to regard structural defences as the mitigation strategy of last resort. Where structural mitigation is being considered, however, the risk assessment methodology we have employed in this study provides the basis on which to undertake a cost-benefit study. The risk assessment approach also enables proposed mitigation strategies to be modelled and their effects tested against the risk reduction criteria that they aim to meet.

Conclusion: Is Cairns a Risky Place?

For an isolated city of more than 120 000 people located in the wet tropics, Cairns has a relatively low level of risk exposure to all hazards within the 1% annual exceedence probability range (i.e. an ARI of 100 years or less). Whilst events within this range will cause some loss **and put lives at risk**, the warning systems and other mitigation strategies already in place should keep loss of life to virtually zero and economic loss to nuisance, or at least tolerable, levels **so long as the population is aware and prepared**. There are also cost effective steps that can be taken to reduce the current level of risk even further.

Importantly, there have been no fatalities directly attributable to the impact of a natural hazard in the Cairns community in the past two decades, in spite of this being a period of very rapid population growth. This record can, in part, be attributed to the fact that there were no significant earthquakes and very few major cyclone or flood impacts during that time. It can also be attributed, in part, to the implementation of hazard-based planning constraints, the introduction of building codes and an effective local emergency management capability. These risk mitigation strategies have minimised the exposure of new developments to hazards and maximised resilience of structures to the more common hazard impacts. **Overall, we would assess Cairns as having an tolerable level of risk exposure to the more frequently occurring hazards.** It should also be recognised that the climate of the region that is the source of these hazards is also the source of the community's wealth in tourism and agriculture**.** A tolerably low level of risk, in exchange for community wealth, is perhaps not such a bad deal!

The Cairns community does, none the less, have a very high level of residual risk exposure to the less frequent and more severe events, especially strong earthquakes, severe cyclones and major debris flows. Events with an AEP of 0.2% or less (an ARI of 500 years or more) will inevitably cause significant economic harm and some (and potentially significant) loss of life. In these rarer and more extreme events, the loss of critical facilities, especially in Cairns North, City, Parramatta Park and Portsmith, will add to the magnitude of the risk posed directly by the hazard event itself. These secondary risks are likely to have an effect for a considerable period of time after the initial impact. The community will consequently be faced with a long recovery and restoration period. This is especially significant given the Cairns community's isolation and its heavy reliance on disaster-sensitive industries such as tourism and agriculture.

It is clearly not possible, economic or rational to attempt to eliminate all risk. It is, however, feasible and economic to reduce the residual risk to even the most extreme event over time by implementing long-term planning strategies (such as the relocation of critical facilities) and by maintaining a vigorous campaign of community awareness and involvement in the community risk management process. The sooner that process is started, the sooner the risk will be reduced to an even more acceptable level.

Where to From Here?

At the beginning of this provisional multi-hazard risk assessment of Cairns we stated that it was 'a starting point, rather than an end in itself'. We restate this view at its conclusion.

There is much that can be done to improve the assessment. We have, for example, deliberately avoided making economic assessments of potential loss because we lack the necessary expertise, models and data on which to base such an assessment. We are confident, however, that to add a soundly based economic dimension to the assessment would be a relatively minor undertaking.

A lack of data has limited our consideration of the risks to lifelines such as power and water supply and their interdependencies. We are confident that those data will become available in the near future and when they do, this study should be updated and its assessments re-evaluated.

Turning the information and the risk assessments provided here into risk mitigation strategies is a task for others, particularly Cairns City Council and the Cairns community. It is also up to them to keep the information base we have established up to date. If it is not kept current it will rapidly move from being an asset to being a liability.

We are greatly encouraged by the action that has already become evident in the city and elsewhere. There is also a strong level of commitment to risk management beginning to emerge. We are confident that Cairns is well on the way to becoming a much safer, and consequently more sustainable and prosperous community.