

CHAPTER 1: HAZARDS AND RISK CONCEPTS

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This Report

This study provides details of the outcomes of research into the risks faced by the communities of South-East Queensland that are posed by a range of natural hazard phenomena. In this study, the acute (i.e. potentially fatal) hazards considered include tropical cyclones, east coast lows ('winter cyclones'), floods, earthquakes, landslides, severe thunderstorms, heatwaves and bushfires. The risks from some of these hazards have been assessed in more detail than others, although the extent of our attention to detail does not in all cases reflect the severity of the risk of a particular hazard. In addition, the potential impacts of climate change are also addressed. It has been developed as a primary resource for those people who have a professional or personal interest in community risk within the region and is based on more detailed reports developed specifically for use by officials of the eight local government councils included in the study area.

This regional project is the fourth in a series of case studies being undertaken under the Australian Geological Survey Organisation's (AGSO)¹ *National Geohazards Vulnerability of Urban Communities Project*, more commonly referred to as the *Cities Project*. AGSO and its research partners see this regional study as providing the foundation on which the communities of South-East Queensland can develop strategies to mitigate those risks and to cope with the impact of hazards when they occur. It builds on *Cities Project* multi-hazard risk assessment work already published on the individual Queensland centres of Cairns, Mackay and Gladstone and the Australian Capital Territory. It also draws on work being undertaken in the New South Wales centres of Newcastle and Wollongong.

Cities Project case studies clearly represent pioneering research. As such the results they present will undoubtedly change as better information, techniques and tools develop. We encourage readers to view this report as a starting point, rather than an end in itself and we welcome feedback on any aspect covered in our reports.

It must be emphasised at the outset that this report represents a broad 'reconnaissance' of the hazards and the risks that they pose. It is not intended to be used, nor should it be used, to assign measures of risk to individual properties – the scale, resolution and accuracy of the data available to us does not support such precision. **Should you wish to obtain such detailed, site-specific information regarding risk you should contact the relevant local government council.** The report should, therefore, be seen as the first step in the process of comprehensive community risk management. The next steps are essentially up to the eight councils involved and their respective communities.²

The Cities Project

The *Cities Project* was established in 1996 to undertake research directed towards the mitigation of the risks faced by Australian urban communities that are posed by a range of geohazards. **The ultimate objective is to improve the safety of communities, and consequently make them more sustainable and prosperous.** It formed a significant part of Australia's contribution to the International Decade for Natural Disaster Reduction (IDNDR) which ran through the 1990's and continues to be a focus for Commonwealth community risk research. It can also be seen as a response to the findings of the 1993 Senate Inquiry into Major Disasters and Emergencies (Senate, 1994). In its findings the Senate

¹ A list of acronyms and abbreviations used in this report is included as Appendix A.

Committee encouraged the emergency management community to modify its doctrine from one that had been traditionally dominated by attention to disaster response, to one which gives greater attention and emphasis to risk mitigation and the reduction of community vulnerability.

Such a broadly-based program of research obviously requires a multi-disciplinary approach. To enable AGSO, a research agency traditionally focused on earth science, to achieve the objectives set for the *Cities Project*, a network of operational, research and supporting partners has been developed. We have been most fortunate in attracting the commitment of partners of great quality and enthusiasm. They span a very broad range of scientific disciplines, administrative responsibilities and industry sectors. Of particular value has been the close collaboration with:

- the Bureau of Meteorology;
- the Queensland Departments of Emergency Services, Mines and Energy and Natural Resources;
- the South-East Queensland Regional Organisation of Councils (SEQROC) and the eight councils covered by this study³;
- researchers in various CSIRO Divisions, academic centres and a number of private sector agencies.

Risk Management

The concept of risk, and the practice of risk management, received a significant boost in Australia with the publication of the Australia and New Zealand Risk Management Standard in 1995 and its subsequent revision as *AS/NZS 4360:1999 Risk Management* (Standards Australia, 1999a). This generic guide provides the philosophical framework within which the *Cities Project* studies have been developed. That process is outlined in Figure 1. 1.

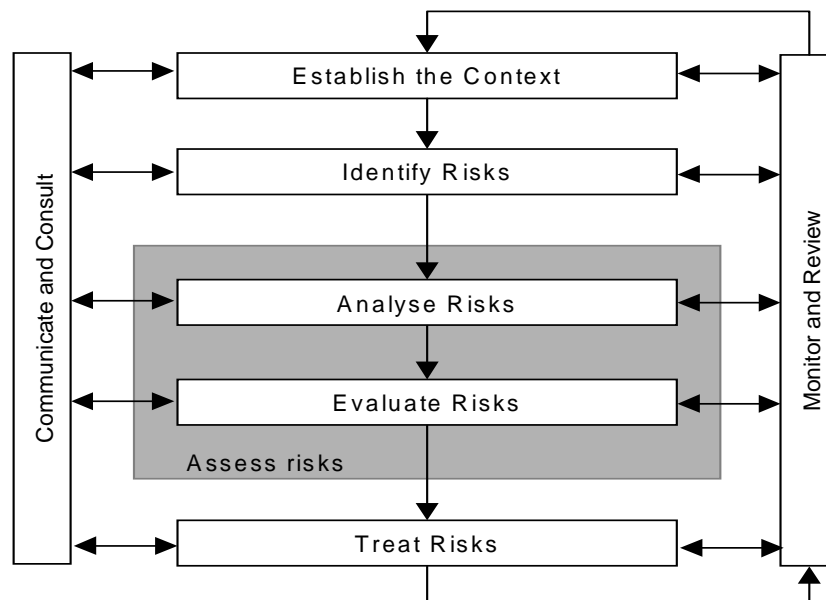


Figure 1. 1 : Risk management overview (Standards Australia, 1999a, after Fig 3.1)

³ From north to south they are Caboolture Shire, Pine Rivers Shire, Redcliffe City, Brisbane City, Ipswich City, Redland Shire, Logan City and Gold Coast City.

This study deals largely with the risk identification and risk assessment (i.e. the analyse and evaluate) stages of the process. Whilst we provide some opinion on matters relating to risk treatment, these are the responsibility of those, such as the local governments and the Queensland Government agencies, that have that statutory role.

What is Risk?

The risk management Standard defines ‘risk’ as:

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

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

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

Total risk can be expressed simply in the following pseudo-mathematical form:

$$\mathbf{Risk}_{(Total)} = \mathbf{Hazard} \times \mathbf{Elements\ at\ Risk} \times \mathbf{Vulnerability}$$

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

Our experience, however, has clearly shown that there is quite a gap between the ideal of total risk articulated in the definition and the practical reality of risk assessment. Put simply, the data does not exist by which to measure total risk across all elements at risk in complex urban communities for all hazards and for all probabilities. To overcome this problem we have resorted to the use of a series of indexes that reflect the relative level of hazard exposure and the relative level of community vulnerability. By drawing these together we have produced a ‘risk index’ which is then used to create ‘risk surface’ maps to illustrate the spatial relationship between levels of exposure and vulnerability. These are described in some detail in each of the hazard-specific chapters.

Risk mitigation (i.e. moderating the severity of a hazard impact) is the principal objective of risk management. In this context, risk mitigation might be seen as:

the process by which the uncertainties that exist in potentially hazardous situations can be minimised and public (and environmental) safety maximised. The objective is to limit the human, material, economic and environmental costs of an emergency or disaster, and is achieved through a range of strategies ranging from hazard monitoring to the speedy restoration of the affected community after a disaster event

(after Granger, 1988 and 1993).

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

The amount of total risk may be diminished by reducing the size of any one or more of the three contributing variables – the hazard, the elements exposed and their vulnerability. This can be illustrated by assuming the ‘dimension’ of each of the three variables represents the side of a triangle, with risk represented by the area of the triangle. In Figure 1. 2 the larger (yellow) triangle portrays each of the variables as being equal, whilst in the smaller (green hachure) triangle the total risk has been mitigated by the halving of both exposure and vulnerability. The reduction of any one of the three factors to zero would consequently eliminate the risk.

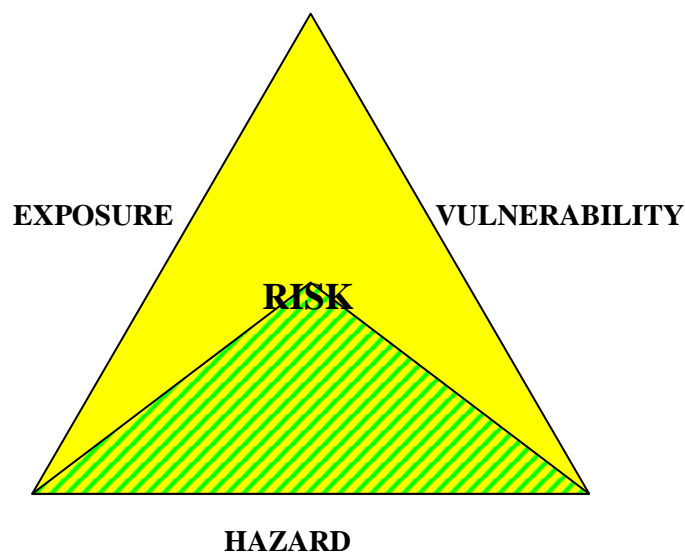


Figure 1. 2 : The risk – hazard – exposure – vulnerability relationship

Risk Identification

A detailed understanding of what events have occurred in the past (including prehistoric events) and their effects provides the basis for understanding what could or will happen in the future, i.e. it is the key step in the risk identification process. To this end, AGSO has developed catalogues on historic earthquakes, landslides and tsunami events; the Bureau of Meteorology (BoM) maintains comprehensive collections on severe weather events such as cyclones, east coast lows and floods; and the insurance industry maintains some data on the losses associated with such events. Throughout this report we provide details of the known history of hazard impacts in South-East Queensland. This

history is not only important in establishing levels of probability for future events but also to illustrate that such threats are very real.

The hazards included in this study were selected on the basis of their known history of impact in South-East Queensland both in terms of the fatalities caused and the resulting economic losses. It is worth reflecting that, between 1967 and 1999 major disasters (excluding drought) cost Australia, as a nation, on average \$1.14 billion annually (Bureau of Transport Economics, 2001) and that disaster impacts in Queensland contribute significantly to that total.

The known fatalities attributed to natural hazards, as given in Table 1.1, helps to put them into perspective.

Table 1. 1 Fatalities in Australia caused by natural hazards (based on Coates, 1996 and AGSO data)

| Natural Hazard | Period Covered | Fatalities |
|-------------------|----------------|--------------|
| Heatwaves | 1803 - 1992 | 4287 |
| Tropical cyclones | 1827 - 1989 | 1863 – 2312* |
| Floods | 1803 - 1994 | 2125 |
| Bushfires | 1827 - 1991 | 678 |
| Lightning strikes | 1803 - 1992 | 650 |
| Landslides | 1803 - 1999 | 84 |
| Earthquakes | 1803 - 1999 | 15 |

* minimum and maximum estimates which also include approximately 170 flood fatalities

The real number of fatalities is almost certainly greater than listed, given that the statistics in the table were derived largely from reports contained in the *Sydney Morning Herald* and its predecessor, the *Sydney Gazette*. Nevertheless, they confirm that we do not live in an especially benign environment.

Monitoring and surveillance: One of the principal sources of historical hazard event information and hazard phenomenon knowledge is the extensive network of monitoring stations and remote sensing resources that have been established across Australia. For example, AGSO has access to more than 150 seismographs across Australia, whilst the Bureau of Meteorology maintains some 45 weather radar sites (including one at Brisbane Airport), around 250 automatic weather stations and more than 3,000 stream gauging stations. The Bureau also takes data from the Japanese Geostationary Meteorological Satellite (GMS) 48 times a day, in addition to data taken from the polar orbiting satellites operated by United States National Oceanographic and Atmospheric Administration (NOAA).

Risk Analysis

AS/NZS 4360:1999 (p. 3) defines ‘risk analysis’ as:

a systematic use of available information to determine how often specified events may occur and the magnitude of their likely consequences.

We have identified three distinct aspects of this process.

Phenomenon process knowledge: The focus of hazard science research is on the mechanisms that cause, create, generate or drive the hazard phenomena, e.g. what causes earthquakes and what influences the transmission of their energy through various geological strata. This is underpinned by information relating to the background climatic, environmental, terrain, ecological and geological aspects of the site that are relevant to hazard studies, e.g. the depth and nature of the sediments and their likely behaviour under earthquake shaking. Whilst there is little that can be done to eliminate or reduce

the severity or frequency of these phenomena, a good understanding of what drives them enhances our ability to forecast or predict their behaviour. It is also fundamental to establishing an understanding of event probabilities.

Elements at risk and their vulnerability: This is a relatively new area of study and is focused on developing an understanding of the vulnerability of the wide range of elements that are at risk within the community, i.e. the people and their physical and social infrastructures. It involves disciplines as diverse as geography, demography, psychology, economics and engineering.

A significant effort has been made to develop very detailed data on the principal elements at risk in the built environment of South-East Queensland, whilst comprehensive statistics of good resolution are available from the quinquennial national censuses to provide at least basic measures of human vulnerability. For convenience we have grouped these elements at risk into the five broad groups we refer to as the “five esses”. The data which have been collected over South-East Queensland include:

The Setting. Basic regional data were accumulated from a very wide range of custodians for themes including:

- the physical environment (climate, vegetation, geology, soils, land use, topography, elevation);
- access (external links by major road, rail, air, marine and telecommunications infrastructures);
- administrative arrangements (local government, suburb and other administrative boundaries); and,
- population and its distribution.

Shelter. The buildings that provide shelter to the community at home, work and play vary considerably in their vulnerability to different hazards. The degree to which different building characteristics contribute to the relative degree of vulnerability associated with exposure to a range of hazards is shown in Table 1. 2

Table 1. 2 Relative contribution of building characteristics to vulnerability

| CHARACTERISTIC | FLOOD | WIND | HAIL | FIRE | QUAKE |
|-------------------------------------|-------|-------|-------|-------|-------|
| Building age | *** | ***** | *** | ***** | ***** |
| Floor height or vertical regularity | ***** | * | | **** | ***** |
| Wall material | *** | *** | ***** | **** | **** |
| Roof material | | **** | ***** | **** | *** |
| Roof pitch | | **** | ** | * | |
| Large unprotected windows | ** | ***** | **** | ***** | ** |
| Unlined eaves | | *** | | ***** | |
| Number of stories | **** | ** | | * | ***** |
| Plan regularity | ** | *** | | ** | ***** |
| Topography | ***** | **** | | **** | *** |

In Table 1. 2 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.

In the first three *Cities Project* case studies, comprehensive structural data were developed on virtually every building. In the South-East Queensland study, however, such an effort was clearly impractical given that there are more than 1 million individual buildings. None-the-less, descriptions of the ‘typical’ residential and commercial structures in each council area have been developed. Information on the location, function and the approximate vintage of some 685 090 individual developed properties in the

study area was developed, based largely on material provided by the respective local government councils augmented by field work and other documentary sources such as the UBD Refidex.

Access to shelter is also significant, so information on mobility within the community is needed. Details of the road network, for example, were accumulated.

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

The community is also dependent on the supply of food, clothing, medicine and other personal items. Information was accumulated on all of these, as well as on the industries that wholesale, distribute and service these sectors (such as transport, material handling equipment and storage). Most (if not all) of the key logistic facilities in South-East Queensland were identified in the property database. Basic data on the key elements of the power and water supply, telecommunications and sewerage infrastructures were also obtained.

Security. The security of the community can be measured in terms of its health and wealth and by the forms of protection that are provided. Physically, these may be assessed by the availability of hospitals, medical centres, nursing homes, industries, commercial premises, ambulance stations, fire stations, police stations and works such as flood detention basins and levees. Also important are socio-demographic and economic statistics related to the elderly, the very young, the disabled, household income, unemployment, home ownership and the resources available at the fire and police stations. Emergency plans are also a key component of community security.

Society. Here we find some of the more intangible measures such as language, ethnicity, religion, nationality, community and welfare groups, education, awareness, meeting places, cultural activities and so on that contribute significantly to the community's social cohesion. Some of these may be measured in terms of the facilities that they use, such as churches, schools and sporting clubs, however, the more meaningful measures relate specifically to the individuals, families and households that make up the community.

Extensive use has been made of the detailed data from the 1996 National Census published in the *CData96* product (ABS, 1998a) to flesh out our understanding of the social, demographic and economic dimensions of vulnerability under both the 'security' and 'society' components.

Synthesis and modelling: Clearly, the range and variety of information needed to fuel a comprehensive risk analysis is enormous. Whilst there are many sources now available from which such information can be captured or derived, much of it with the essential spatial and temporal attributes needed, there remain important gaps. Our knowledge of hazard phenomena and the processes that drive them, for example, are far from perfect. The behaviour of some hazards, such as floods, have an established body of modelling research behind them, whilst models of the behaviour of other phenomena, such as cyclones and earthquakes are, as yet, still evolving. It is necessary, therefore, to develop appropriate models to fill the knowledge gaps.

A key aspect of these models is an understanding of the probability of recurrence of events of particular severity and the levels of uncertainty that exist in both the data employed and the models themselves. **Given these uncertainties, we remain cautious about presenting our findings as anything more than indications of what the future may hold.**

Risk Evaluation

AS/NZS 4360:1999 (p. 3) defines 'risk evaluation' as:

the process used to determine risk management priorities by evaluating and comparing the level of risk against predetermined standards, target risk levels or other criteria.

We see two key components of this.

Scenario analysis: This is an emerging technique that contributes to 'future memory', an understanding of *what will happen when...* The output embraces forecasts or estimates of community risk including economic loss and potential casualties, or assessments of the impact of secondary or consequential hazards, such as the spread of fire or the release of hazardous materials following an earthquake. It also provides essential input to both the development of risk treatment strategies and to framing long-term forecasts or estimates.

In an effort to address the diverse range of applications to which the output from risk scenarios may be put, we have adopted the practice of running a range of scenarios. These typically extend from the relatively small and more frequently occurring events, to those in the so-called 'maximum probable' or 'maximum credible' range.

Acceptability: In the approach to risk assessment set out in AS/NZS 4360:1999, it is the practice to compare the level of risk found during the assessment process with previously established risk criteria, so that it can be judged whether the risk is 'acceptable' (or at least tolerable) or not. At first glance this may seem to be something of a chicken-and-egg process - if you do not know what the level of risk posed by earthquake is in South-East Queensland, for example, how can you realistically determine what level of risk is acceptable?

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

The acceptability factor is central to the process of risk prioritisation. This is the first step in the allocation of resources to risk mitigation, especially if considered in a multi-hazard context. We are beginning to address the complex issue of comparing the risks posed by hazards with greatly different impact potential. In South-East Queensland, for example, there is a strong spatial correlation between the areas that are most at risk from flooding and those in which sediments are most likely to maximise earthquake impact. Additionally, the impact on the South-East Queensland community of a cyclone hazard with an average recurrence interval (ARI) of once in 150 years is likely to be more severe than the impact of the shaking associated with an earthquake with an ARI of 150 years. The maximum credible earthquake event could, however, have a greater potential for catastrophe, than the maximum credible cyclone.

The ultimate responsibility for determining what levels of risk are acceptable or tolerable rests with the each community and those State and local government agencies responsible for risk management.

Risk Mitigation Strategies

Whilst the role of AGSO and the *Cities Project* is concerned primarily with risk identification and assessment, the following processes provide some insight into the risk mitigation process.

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

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

- a strong risk management culture;
- well maintained and appropriate information about risk, linked to comprehensive monitoring and warning systems;
- wide-spread and ongoing community awareness programs based on risk history, scenario analysis and an effective risk communication capability;
- emergency management plans, resources, training and decision support tools based on risk assessments;
- risk-based planning of settlement, development and the siting of key facilities (such as hospitals);
- protection plans for key facilities and lifelines;
- appropriate and enforced building and planning codes; and,
- cost-effective engineered defences such as levees and retrofit programs.

Guidelines have been developed by the Queensland Department of Emergency Services (Zamecka and Buchanan, 1999) for use by local government councils in developing and implementing risk mitigation activities. These should be consulted in conjunction with the risk assessments contained in this study.

Community Risk Thresholds

A key component in each of these stages of risk management is the various frames of reference that exist in the community. These are the standards to which the community, or significant elements of it, subscribe in determining and sanctioning behaviour or attitudes. These standards vary according to the extent of past experience, especially of major disasters, and the specific interests of the particular community element involved. A developer, for example, has a significantly different frame of reference, and consequently risk acceptance thresholds, to those of an emergency manager or an environmentalist. An understanding of these frames of reference, and the thresholds they produce, is particularly relevant in establishing community levels of risk acceptance.

Not all acceptability criteria can be expressed as categorically as those outlined in the Building Code because they deal with human nature and the political *outrage* dimension of risk management. There is a considerably higher level of acceptance of risks that are ‘voluntary’, i.e. those willingly undertaken by individuals, such as air travel or smoking, than there is to those that are seen as being ‘involuntary’, many of which carry a significantly lower risk. For example, in NSW, the chances of a fatality occurring from smoking 20 cigarettes a day has been calculated as being 5000 per million people per year and for travel by motor vehicle as 145 chances per million people per year. By contrast, the chances of fatality from ‘cataclysmic storms and storm floods’ is calculated as 0.2 chances per million per year and lightning strike as 0.1 per million people per year (Higson, 1989).

The levels of risk acceptance can also vary considerably over time. The threshold of acceptance is typically much lower immediately after a hazard impact, for example, than it was immediately before the impact.

The existence of these conflicting frames of reference reinforces the need for a strong feedback mechanism between establishing acceptability and formulating risk mitigation and response strategies. In developing risk management options and strategies, the competing value systems and expectations of these various frames of reference need to be taken into account.

The key components of the *Cities Project’s* understanding of the risk management process are illustrated in Figure 1. 3.

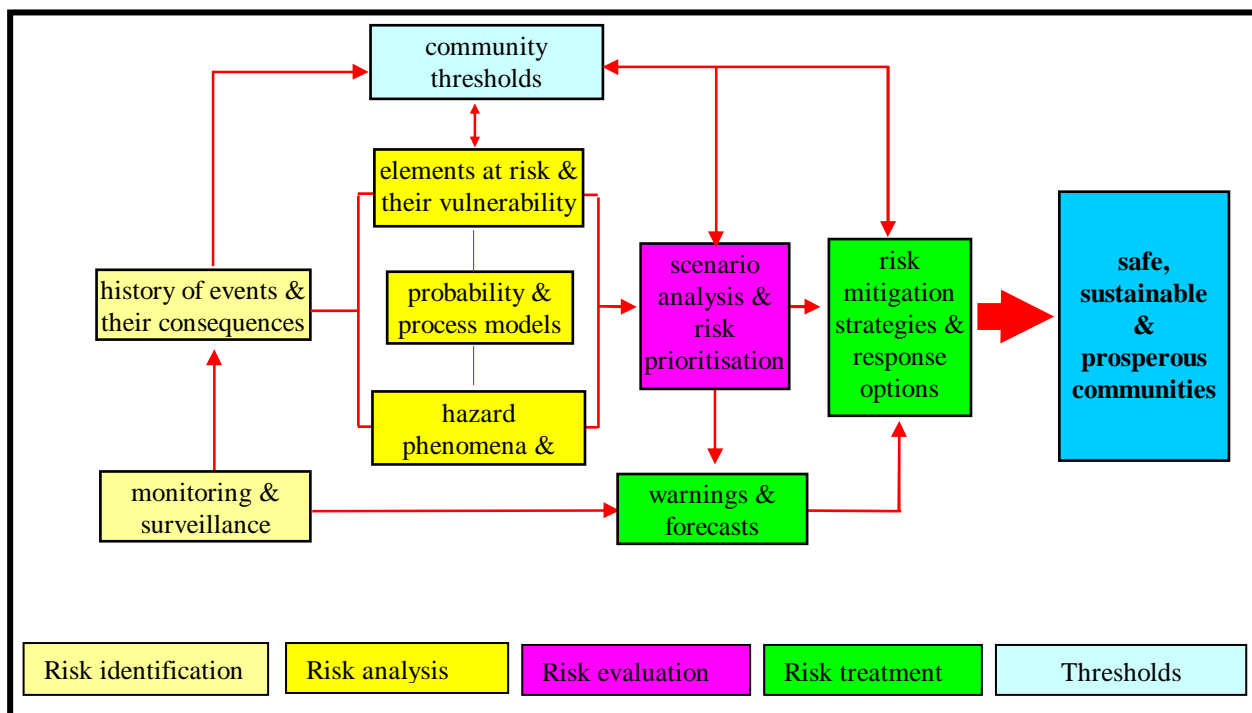


Figure 1. 3 : Cities Project interpretation of the risk management process

The bottom line is that if we get all of this right, the outcome will be safer, more sustainable and more prosperous communities.

Confidence, Uncertainty and Probability

The analysis of issues as complex as community risk is highly dependent on the accuracy, currency and appropriateness of the data that it employs. Every effort has been made to ensure that the best available data have been used in the various analyses included in this study. For the most part, the results of modelling and other forms of analysis have been subjectively examined for ‘reality’ against the experience of the authors, officials in each of the eight local government councils and a good number of external reviewers with appropriate local knowledge and experience.

The allocation of event probabilities is an area of particular uncertainty. For example, 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, but also it has been widely reported that such an expression of probability is prone to be misinterpreted and misused. Description of an event as a ‘1:100 year event’ is frequently taken (wrongly) to indicate that there will not be another such event for another 100 years.

We prefer the terms ‘average recurrence interval’ (ARI) and ‘annual exceedence probability’ (AEP) which we consider less ambiguous. A typical ARI statement would be:

on the basis of the existing record, a flood measuring 11 m or more on the reference gauge occurs, on average, once every 25 years.

A comparable AEP statement (for the same event) would be:

there is a 4% probability of a flood of 11 m or more occurring in any given year.

To put the issue of probability in a more familiar context we have produced Table 1. 3 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 1. 3 Probability of one or more events in a specific period (Leiba, pers. com., 2000)

| 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) |

Similar information is shown graphically in Figure 1. 4.

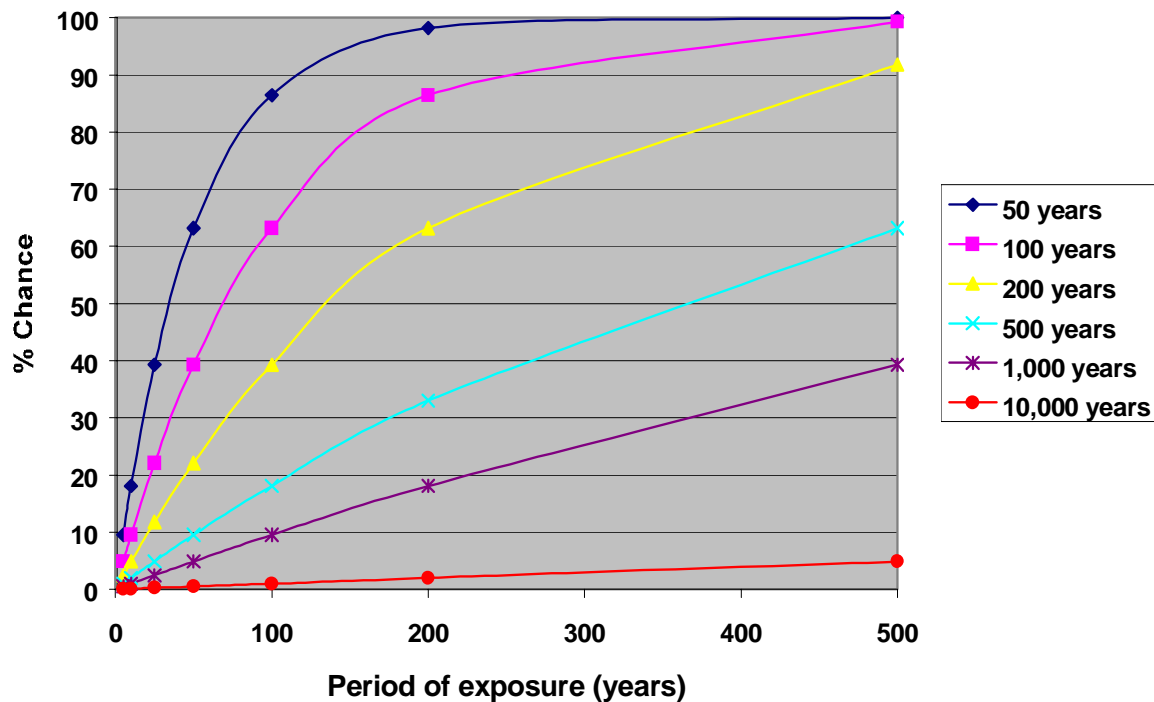


Figure 1. 4 Chance of one or more events with a given ARI occurring in a given time frame

With this approach, it is much easier to see that the short term risk of a developer or elected official, whose exposure is typically from three to five years, is considerably less than that of a householder or company (say 25 to 50 year exposure) or individual (perhaps a 100 year exposure).

Whilst such statements may be made about the probabilities of events occurring, they are frequently based on an incomplete and, often, statistically inadequate record. This is certainly the case in South-East Queensland. The record of earthquakes, floods and cyclones extends over, at best, 150 years. For the first 100 years or so of that time there was minimal instrumental measurement except for floods. Many of the smaller or more distant earthquake events before about 1970, for example, have undoubtedly gone undetected and unreported.

We realise that uncertainty can create difficulties for public officials in their dealings with developers and others. Childes and others (1996), for example, document the difficulties experienced by Redcliffe City Council, between 1987 and 1996, in relation to establishing new planning constraints to take account of scientific estimates of sea level rise associated with climate change. Council adopted the 'mid-point' of the range of sea level rise nominated over a given time-scale adopted by the Queensland State Government. A developer, however, challenged them, using a more conservative estimate published by different scientists. They conclude their study in the following terms:

The uncertainty inherent in a range of scenarios set at the international or national levels by researchers or other authorities is critical to those dealing with developers and consultants directly at the local government level. Professional engineers and planners rely on the range quoted (and therefore the uncertainty) to argue the case for caution against pressures from developers and architects to relax regulations to lower floor heights and kerb and channel levels for new building projects. In the absence of clear legislative guidelines for planning at the national/state level, the Council has only been able to stand firm on its raised

development heights in recent years because of available published scenarios in the scientific literature, set at international conferences, that support their pro-active stance.

The absence of what might be termed ‘absolute knowledge’ in this report should not be seen as invalidating the assessments made. Rather, it should be seen as a challenge for the next iteration of the risk management process.