Issues 04

Issues in Risk Science

Natural Hazards Risk Assessment: An Australian Perspective

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Acknowledgements:

This entire paper is based on work undertaken at Risk Frontiers during the last decade. All of the staff, past and present, have contributed in numerous ways.

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In July 2003 Emeritus Professor Russell Blong retired after nine years as founding Director of Risk Frontiers at Macquarie University, Australia. After a few months of beach-combing and (rarely successful) fishing he joined the staff of Benfield in Sydney where he enjoys a range of new natural hazard risk assessment challenges.

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Executive Summary

- Nearly twenty years ago, researchers at Macquarie University in Australia, in what was later to become the insurance industry-sponsored research centre known as Risk Frontiers, began compiling databases on natural hazards and their impacts in Australia.

- Information extracted from scientific reports, government papers, existing databases, and newspaper accounts was used to produce integrated databases containing more than 5,000 hazard occurrences and information about human deaths and damage to the built environment resulting from nine natural perils - tropical cyclones, bushfires, floods, wind gusts, tornadoes, hailstorms, earthquakes, landslides and tsunami.

- Tropical cyclones and floods together account for more than 70% of known natural hazard deaths since the European colonisation of Australia in 1788. Thunderstorms, particularly lightning, and bushfires each account for 11 to 13% of deaths, indicating that the other hazards considered have produced very few human deaths, at least in the last 200 years.

- Death rates, per 100,000 population, have fallen by three orders of magnitude in the last two centuries.

- A new building damage index has been compiled allowing easy comparison of total damage to buildings from about 1,200 twentieth century events.

- Tropical cyclones, floods, thunderstorms and bushfires produced 93.6% of known building damage, suggesting that geological, as opposed to meteorological hazards, have been relatively unimportant - at least in the period since 1900.

- Just 20 out of the 1,200 events contributed 50% of the total building damage. This short list – six floods, five bushfire days, four tropical cyclones, three thunderstorms and two earthquakes – reinforces the view that natural hazards risk in Australia is not dominated by just one or two natural hazards.

- Despite the wealth of data, deciding which part of Australia is the most hazardous is not as simple as it sounds. Similarly, determining which hazard <u>will</u> be the most important in the next few decades is equally difficult.

Introduction

"Natural hazards risk assessment" - Which natural hazards? Risk to what or whom? When? Where? And over what time period?

In the mid-1980s researchers at Macquarie University began struggling with some of these questions at a time when "risk", to most users, referred not to "financial risk" but to a rather nebulous concept involving "hazard" and "vulnerability". The researchers at Macquarie focused on several questions:

1. Which natural hazard in Australia kills the most people?

2. Which natural hazard in Australia causes the most damage?

3. Which part of Australia is the most hazardous?

and:

4. Which natural hazard <u>will</u> kill the most people?

and similar questions focused on the future.

Now, nearly twenty years later, we are a lot older and a tad wiser. Whilst we can now answer these questions – with the usual fistful of academic caveats – we also know that the answers are a lot tougher than they first seemed. Australia now has an integrated database on natural perils that ranks amongst the best in the world and which, despite its limitations, would take a lot of effort and cash to emulate or improve and would most likely lead to many more intriguing issues. Its real potential is still to be fully realised.

This report briefly describes the construction of the natural hazards database and comments on issues of data quality, and then focuses on: (i) qualified answers to the questions above; (ii) ways in which the data have been and could be used; and (iii) some thoughts on where natural hazards risk assessment in Australia should head from here.

In 1994 the natural hazards researchers at Macquarie University formed the Natural Hazards Research Centre (NHRC), sponsored by the reinsurance broker Greig Fester (now Benfield), Swiss Re and QBE Insurance. In 2001 the NHRC was re-engineered as Risk Frontiers with 12 insurance industry sponsors, still including Benfield amongst a mix of direct insurers, reinsurers and reinsurance brokers (see Acknowledgements for the full list of sponsors). Inevitably, Risk Frontiers' research has developed a focus on natural hazards issues that are of interest to the re/insurance industry and this report reflects that focus.

Data Sources

The European colonization of Australia – and its written history - began at Sydney Cove in 1788. With only 20 million people spread across 7.7 million km^2, even today parts of the continent are not exactly overcrowded. As an example, Australia Post divides the country into 2,433 postcodes, each with an average population of about 8,200. The largest postcode (872 in Western Australia), had a population at the 2001 Census of 20,400; the postcode covers an area of 621,400 km^2, an area significantly larger than continental France! While it could be argued that nothing much happens, from a natural hazards point of view, in Postcode 872, that was exactly the rest of the nation's view of Canberra, the national capital – except that this view changed in January 2003.

So the written history of natural hazards and their consequences is short, barely more than a hundred years for substantial parts of the country. Numerous attempts had been made to construct summary histories of tropical cyclones or bushfires both in popular accounts and in more scientific literature. Inquiries, official reports and accounts in learned journals into the causes and consequences of the more damaging events almost inevitably add perspective with summaries of earlier damaging events. Dozens of local histories also offer valuable information.

The Australian Bureau of Meteorology (BoM) has maintained a severe weather database for some decades, focused on severe thunderstorms, defined more-or-less by international convention as thunderstorms producing wind gusts of 90 km/h or greater, tornadoes, hailstones greater than 20 mm in diameter on the ground, or flash flooding resulting from a rainfall with a 1-hour intensity exceeding that of the rainfall intensity with a 5-year recurrence interval. For the most part, the BoM database focuses on the last 50 or so years.

Similarly, the Federal government agency Geoscience Australia maintains databases on the occurrence of earthquakes, landslides and tsunami and their consequences. These databases span the entire period since European colonization. The earliest versions of the landslide and tsunami databases were compiled by Risk Frontiers for Geoscience Australia.

And then there are newspaper accounts. While a range of newspapers were examined, The Sydney Morning Herald and its forerunner The Sydney Gazette, provides an unbroken record of just over 200 years of disaster reporting, for the first hundred years and more, by correspondents, in every tin-pot settlement in the country. While parts of the paper are indexed, much of the run is not and researchers read every natural hazards-related item up to the late 1990s; the photocopied items fill nearly a dozen filing cabinet drawers.

This summary of the building blocks provides insights into the strengths and weaknesses of the Risk Frontiers database. It combines reports of nine perils and the consequences of individual events – tropical cyclones, bushfires, floods, wind gusts, tornadoes, hailstorms, earthquakes, landslides and tsunamis – in an integrated framework.

In the end we focused on the 20th century, endeavouring to make the record as complete as possible for the period 1900-1998. We recognize that narrowing the period of record might bias the results. As an extreme example, the greatest loss of life in any natural hazard impact in Australian history, about 400 people, was produced by the Bathurst Bay cyclone (Cyclone Mahina) in 1899.

Cynics, a group that certainly includes the owners of this database, can argue that any reliance on the veracity of newspaper reports casts doubt on the value of the information in a database. Cynicism is an essential attribute for researchers, but we should make sure to extend it widely. Normally one would prefer, for example, the records of deaths compiled by the Australian Bureau of Statistics (ABS) over mere newspaper accounts of deaths as a result of natural hazards. However, the ABS data don't always fall neatly into categories such as "floods" or "bushfires". The ABS also preserves privacy so that data on age, sex and the locations where deaths occurred are only occasionally provided unambiguously. Interestingly, the ABS records the date the record of the death was received, rather than the date of death.

Some of the perils and consequences databases are less complete than we would like. For example, the severe weather part of the database has fewer storms in the first half of the 20th century than we would expect, and we know that wind-driven hail with maximum diameters less than 20 mm (i.e. non-severe thunderstorms) that can pit motor vehicles are probably missing from the register of events. We are fairly confident that the record of human deaths in floods is substantially complete, but we are less certain that we have recorded all flood damage to buildings.

We haven't kept a record but the database took more than 20 person-years worth of effort. Certainly there are errors and omissions and perhaps some double-counting. But the database is essentially complete; conclusions drawn from the data are likely to be robust. Improving the database, say another five person-years of effort, might progress the information by a small margin, but it is unlikely to alter conclusions drawn from the information.

Deaths Due to Natural Hazards

Table 1 summarises the deaths in natural hazards recorded in the Risk Frontiers database up to 2003. The central column records the first reported death; for example there are no known deaths from earthquakes in Australia in the period 1788 to 1901. Windgust, hailstorm and lightning deaths have been combined as thunderstorm deaths; nearly all of the thunderstorm deaths have been produced by lightning strikes.

Table 1: Summary of deaths in natural hazards in Australia: 1788-2003.

Peril	First recorded Death	Number of Deaths	% Total Deaths
Earthquake	1902	16	0.3
Landslide	1842	95	1.6
Bushfire	1850	696	11.4
Thunderstorm	1824	774	12.7
Tornado	1861	52	0.9
Cyclone	1839	2163	35.5
Flood	1790	2292	37.6
Tsunami		0	0.0
Total		6088	100.0

Tropical cyclones and floods together account for more than 70% of the known deaths from natural perils, even after carefully scanning the databases to ensure there is no double-counting of victims of floods produced by tropical cyclones. In this database, you can only die once.

At the other end of the spectrum, deaths in earthquakes, landslides and tsunamis combined account for less than 2% of all deaths. This paltry total reinforces the view that Australia is a land of meteorological perils; a low-lying, ancient continent with all its sea coast remote from the active boundaries of tectonic plates is unlikely to be dominated by geological hazards.

If we delve into the totals a little further we discover, for example, that while flood deaths average 10-11 per year, one quarter of all flood deaths have occurred in just 16 separate floods and that 49% of the total flood deaths have occurred in New South Wales. Bushfire deaths have averaged about 4 per year with 50% of all deaths in just eight fires or, more accurately, on just eight days of extreme fires. Lightning deaths (that is, most of the thunderstorm deaths) average about 3.5 fatalities per year, with nearly half in NSW.

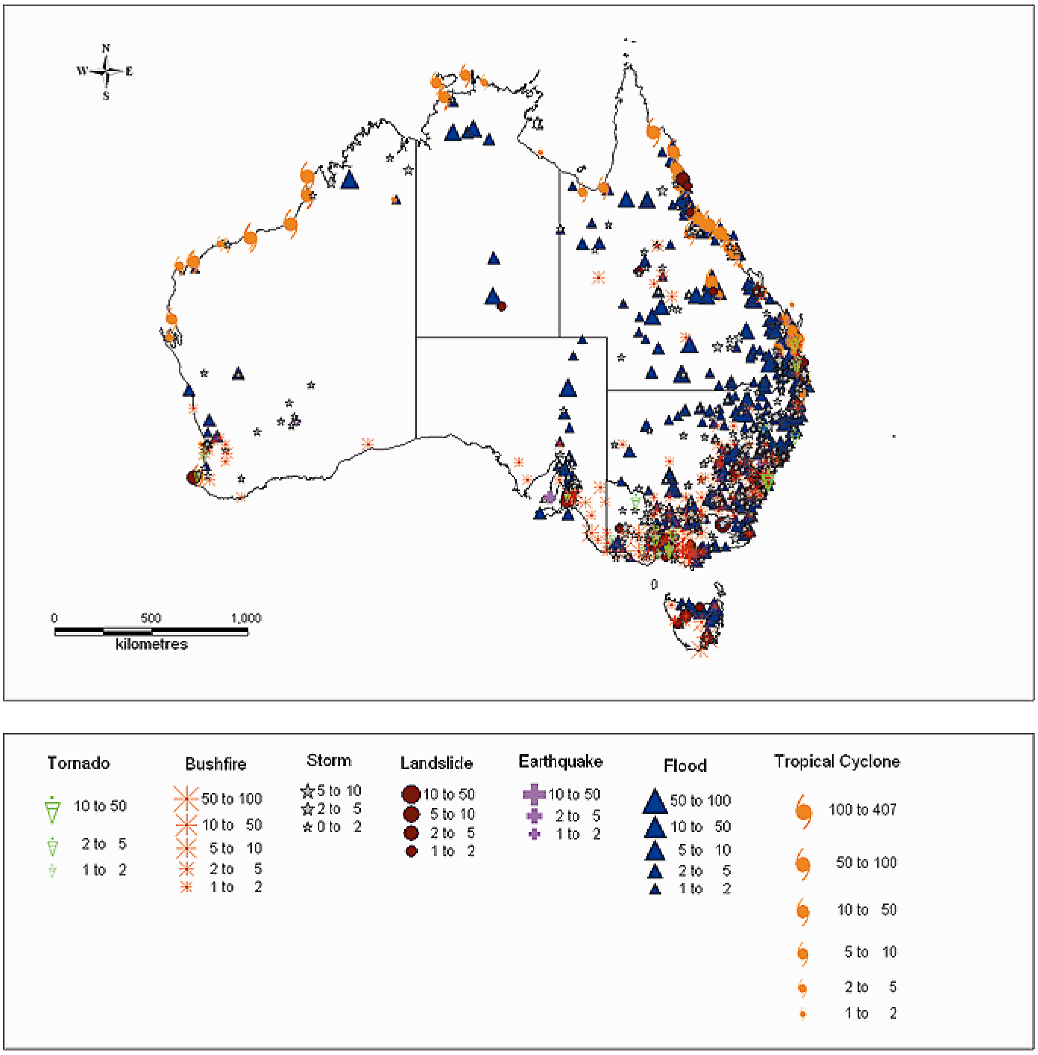

Figure 1: Locations of deaths in natural hazards in Australia.

Figure 1 provides an impression of where natural hazard deaths have occurred and whether those deaths have been isolated or multiple deaths. The vast majority of deaths have occurred in the southeast of the continent. This is not surprising as this was the first area settled and the area where most of the population currently lives.

Tropical cyclone deaths are scattered around the coast north of about 26°S; many of these were deaths at sea, particularly in boats employed in the pearl industry on the northwest coast. The few flood deaths in the southern part of the Northern Territory are scattered along the main Alice Springs – Darwin highway. These locations emphasise that there were probably even more remote deaths not recorded in the database.

While the spatial view of deaths in Figure 1 and the totals in Table 1 provide broad views of deaths in natural hazards, Figure 2 is more revealing. While the details of the figure are difficult to determine, the Y-axis shows death rates, indicating the numbers of deaths per 100,000 population at the time the death occurred.

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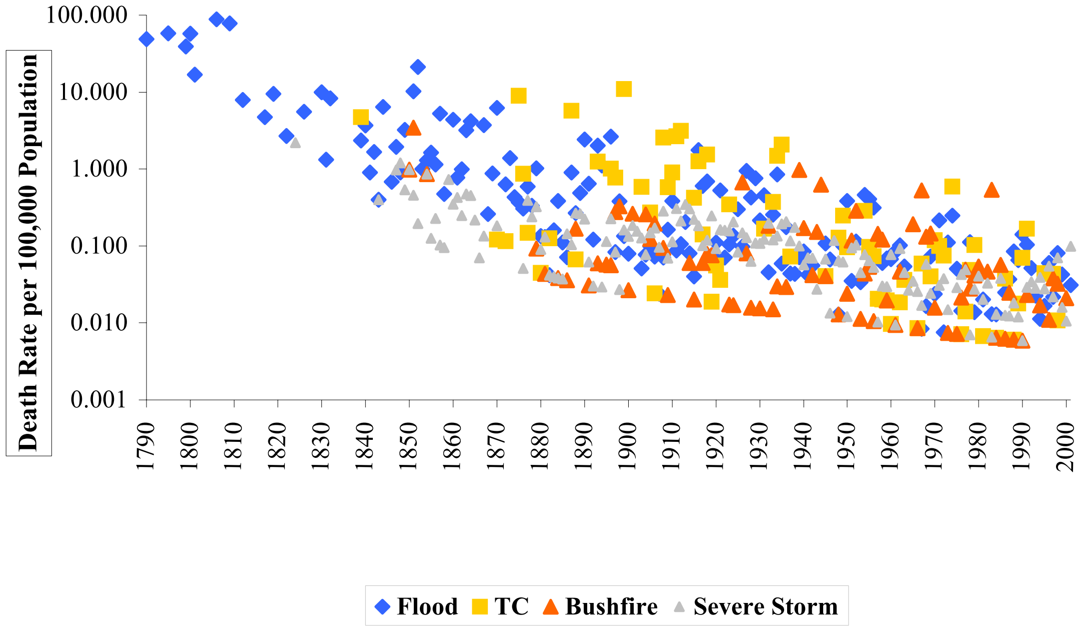

Figure 2: Deaths in natural hazards per 100,000 population, 1790-2000.

The most striking aspect of Figure 2 is the dramatic steady decline – by more than three orders of magnitude – in the death rate over the last 200 years. While the reasons for this decline undoubtedly include an improved understanding of the Australian environment, improved warnings, better emergency services, a better educated citizenry, changing lifestyles, and improved land use planning and building codes, it is not yet possible to put these "reasons" into any order of importance.

Whatever the reasons for this steady decline in the death rate, any rational view of natural hazards risk assessment needs to take this changing scene into account. Figure 2 might suggest, for example, that the long-term view of deaths in Table 1 has limited relevance to present day risk assessment.

A Building Damage Index

Natural hazards damage not only includes buildings and infrastructure but also agriculture and other economic activity. Damage other than to buildings is difficult to get a grip on – we have taken the easy path and focused on building damage which is probably the most important aspect of damage, in both economically advantaged and economically disadvantaged societies. However, our emphasis on building damage reflects the difficulty of dealing with other aspects, the woeful lack of reasonable data, and our interest in insurance issues. This implies that our third question above has been modified to: "Which natural hazard in Australia causes the most damage to buildings?"

Even simplifying the question still leaves some tough issues: How do you compare severe damage to a dozen houses to destruction of the local pub? Or hospital? We approached this issue by developing a purpose built damage index that we hope will have wide applicability (Blong, 2003).

The Risk Frontiers Damage Index reduces building damage to House Equivalents (HE); for example, 2 houses half-destroyed is equivalent to 1 house totally destroyed. Buildings other than houses are made equivalent to houses using comparisons of floor areas and per m^2 construction costs. Much of the necessary data can be found readily in construction handbooks (e.g. Rawlinsons, 1999).

For example, if we set the cost of building an average Australian house at AUD$800/m^2, and the cost of building a supermarket at AUD$1,130m^2, the cost ratio for the supermarket is about 1.4 (setting the house construction cost to 1.0). Then, if the floor area of an "average" Australian house is 180m^2 and the floor area of the supermarket is 2,000m^2, setting the replacement cost of the house to 1.0, the Replacement Ratio (RR) for the supermarket is about 16.0 [($1130x2000m^2)/($800x180m^2)= 15.7]. Thus, the cost of replacing the supermarket is roughly 16 times the cost of replacing a house (RR=16).

A tornado takes out 10 houses, the supermarket, the local pub, and half-destroys 6 more houses. With a cost ratio of 1.9 and a floor area of 1,000m^2, the RR for the pub = 11. Thus, the tornado damage amounts to 10+16+11+(0.5x6) = 40 House Equivalents.

The Damage Index is concerned only with building damage. As constructed, it ignores damage to motor vehicles, parking areas, swimming pools, gazebos, fences, barbecues and other important elements of Australian life. It also ignores building contents, though all the elements named above (plus aeroplanes, power pylons, gas pipes and fire engines) could be readily turned into House Equivalent values given sufficient time and desire. Obviously, the Index also ignores the social value or utility of the buildings as is evident from the relative replacement ratios for the supermarket and the pub.

In the tornado example above six houses were described as "half-destroyed". Often, we will want to be more sophisticated than that. Table 2 outlines a scheme relating

Damage Classes to Central Damage Values (CDV) and ranges in these values for each class.

Table 2: Central Damage Values (CDV)

Damage Class	Central Damage Value	Range
Light	0.02	0.01-0.05
Moderate	0.10	0.05-0.20
Heavy	0.40	0.20-0.60
Severe	0.75	0.60-0.90
Collapse	1.00	0.90-1.0

Table 2 shows that Heavy Damage implies damage equivalent to about 40% of the replacement value of a building. Thus for our supermarket, Heavy damage implies 40% of the Replacement Ratio (0.4x16) = 6.4 House Equivalents.

For a single building, Damage (HE) = RR x CDV.

Obviously, if we have more specific information about the cost of damage or the replacement value of the supermarket we can vary the CDV and the RR.

The single-word Damage Class descriptors in Table 2 convey only limited information. Table 3 provides more detailed information for tropical cyclone and landslide damage – those familiar with the literature will note my indebtedness to Leicester and Reardon (1976) and to Alexander (1989). Details for tornado, hail, earthquake, bushfire, flood and tsunami are listed in Blong (2003).

Table 3: Damage descriptions for specified Central Damage Values

PERIL	CDV				
	0.02 Light	0.10 Moderate	0.40 Heavy	0.75 Severe	1.00 Collapse
Tropical cyclone	Negligible – missile damage to cladding or windows	Loss of half roof sheeting	Loss of roof structure + some damage to walls	Loss of all walls	Loss of walls, floor and some support piers on elevated houses
Landslide	Hairline cracks (<0.1mm) in walls or structural members	Minor settlement of foundations	Walls out of perpendicular by several degrees; floors inclined; or heaved; open cracks in walls	Structure grossly distorted; partition walls and brick infill at least partly collapsed; footings lose bearing; service pipes disrupted	Partial/total collapse

We can now express damage as:

Damage (HE) = No of Buildings x RR x CDV

In the tropical cyclone that struck Endsnigh in 1998, 40 houses suffered Moderate wind damage, 60 houses Severe damage, a grandstand (RR=10) totally Collapsed, and a Motel suffered Heavy damage. Thus:

Damage (HE) = [40x1.0x0.1]+[60x1.0x0.75]+[1x10.0x1.0]+[1x7.0x0.4]

= 4+45+10+2.8 = 61.8 House Equivalents

The same tropical cyclone caused landsliding in the suburb of Slippery Slope, destroying 12 houses, while a debris flow entered a single-storey office block (RR=6, CDV=0.3):

Damage (HE) = [12x1.0x1.0]+[1x6.0x0.3] = 13.8 HE

The same tropical cyclone produced flooding in Gurgle, another Endsnigh suburb, with water entering 180 houses (CDV=0.1), floating debris Severely damaging a 1000m^2 warehouse (RR=4.2), producing Heavy damage to a suburban police station (RR=2.1) and destroying 5 adjacent small retail outlets (RR=0.5):

Damage (HE) = [180x1.0x0.1]+[1x4.2x0.75]+[1x2.1x0.4]+[5x0.5x1.0]

= 24.5 HE

Thus the total damage produced in Endsnigh by the cyclone is 100.1 HE, cunningly allowing the House Equivalents shown in Table 4 to also serve as percentages. We can note that more than 60% of the total building damage was produced by the cyclonic winds and that nearly 80% of the total damage was to residential buildings.

Table 4: 1998 Endsnigh tropical cyclone damage summary – House Equivalents

	Wind	Landslide	Flood	Total
Residential	49.0	12.0	18.0	79.0
Commercial	2.8	1.8	5.65	10.3
Govt./Public	10	-	0.9	10.9
Total	61.8	13.8	24.5	100.1

Table 4 characterises some of the real benefits of considering building damage in this way. We have a good understanding of the components of damage in the 1998 Endsnigh cyclone. We can compare total damage and the components with earlier cyclones that struck Endsnigh and with the consequences of cyclones that have struck other parts of this great country.

We can also compare the consequences of cyclones with the consequences (for buildings) of other natural perils. Now we have the basis for a reasonably rational natural hazards risk assessment.

20th Century Building Damage

The Risk Frontiers natural hazards database contains every known natural hazard event in Australia for the period 1900 to 1998. More than 5,000 events are included in the database and spatially referenced to a database of more than 10,000 locations. For about 1,200 of these events some information is available about building damage. For each of these events an estimate of Damage in House Equivalents has been made. For the period 1900 to 2003, total building damage expressed as House Equivalents is about 46,500; that is, total damage to buildings is equivalent to the total destruction of 46,500 houses. Figure 3 summarises the estimates, with the results expressed as the proportion of known building damage attributable to each natural peril.

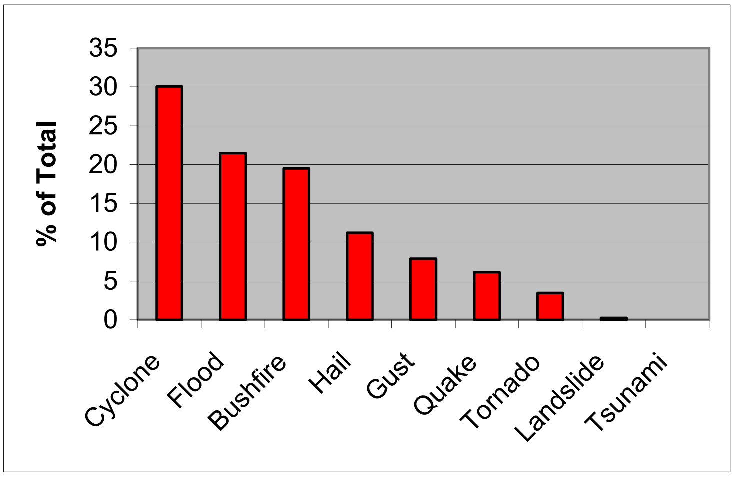

Figure 3: Proportion of total building damage (1900 – 2003) attributed to each of nine natural perils (after Chen, 2004).

These data confirm that tropical cyclones and floods are the most significant natural hazards in Australia in terms of building damage and, as we saw earlier, in terms of human deaths. While bushfires occupy third place in Figure 3, this view is challenged in Figure 4 where damage from wind gusts (other than those associated with tropical cyclones), tornadoes and hailstorm damage are combined as severe storm damage.

Figure 4 suggests that thunderstorm damage to buildings is second only to that caused by tropical cyclones. The exact order of the “big 4” raises questions about the completeness of each of the databases – a discussion that it is not profitable to delve into other than to remind the reader of the comments in an earlier section about the completeness of the flood and thunderstorm portions.

In Figure 4 the four meteorological perils account for 93.6% of the total damage to buildings. Startling as this total might seem, it is the very small contribution made by the geological hazards – earthquake, landslide and tsunami – that is even more surprising. It is a sad admission for this geomorphologist to make, but the death data and the building damage data suggest that geological hazards (shouldn't that be geomorphological hazards?) don't count for much in Australia.

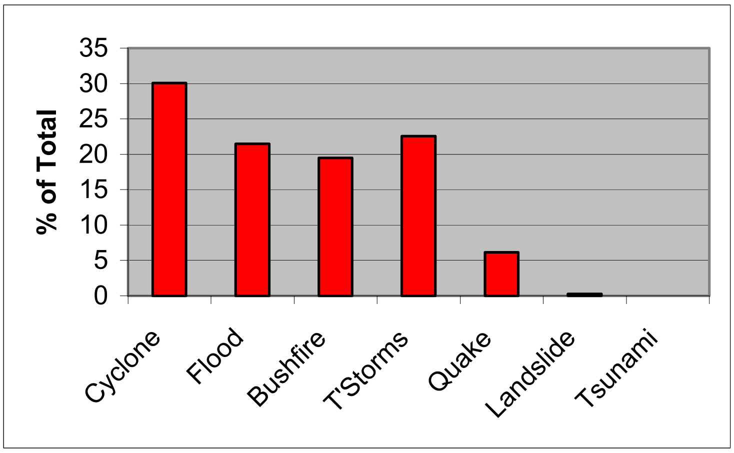

Figure 4: Proportion of total building damage (1900 – 2003) attributed to each of seven natural perils (data after Chen, 2004).

Alternative Perspectives on Damage

As recognized earlier, building damage is just a fraction of the total damage picture - albeit the most important one. Nevertheless, we need to recognize that property other than buildings are often damaged. Consideration of an insurance view provides further insights to natural hazards-related damage in Australia.

The Insurance Disaster Response Organisation (IDRO) maintains a website [http://www.idro.com.au] which sets out insurance payments on natural disasters in Australia since 1967. At the time of writing these data are in need of a substantial overhaul, but they do provide some clues to insured damage. Table 5 lists the nine largest insured losses in the last 38 years, all expressed in 2003 Australian dollars.

The most interesting feature of this list is the range of natural hazards included: three hailstorms, two bushfires, an earthquake, a flood, a tropical cyclone and a windstorm. This table also suggests that it is hailstorms that have caused the most insured damage in Australia. In fact, for all natural disaster losses for which insurance payments are available, hailstorms contributed 34% of the total with tropical cyclones in second place with a mere 18% of the total. As the Sydney windstorm of January 1991 was a severe thunderstorm with relatively little damage caused by hail, lightning or flash flooding, we should recognize that 34% under-represents the thunderstorm proportion.

Table 5: The nine largest insured losses, 1967-2004 [www.idro.com.au].

Event	Date	Insured Loss (AUD$million)
Sydney hailstorm, NSW	April, 1999	1700
Newcastle earthquake, NSW	December, 1989	1124
Cyclone Tracy, Darwin, NT	December, 1974	837
Sydney hailstorm, NSW	March, 1990	384
Canberra fires, ACT	January, 2003	350
Brisbane floods, QLD	January, 1974	328
VIC and SA bushfires	February, 1983	324
Brisbane hailstorm, QLD	January, 1985	299
Sydney windstorm, NSW	January, 1991	226

The differences between the IDRO list and the Risk Frontiers' Building Damage estimates can be attributed to, *inter alia*:

- The shorter IDRO record
- The IDRO lower cutoff of AUD$1 million and AUD$10 million (it varies), misses smaller loss events
- Flood losses (and landslide losses) are seldom insured in Australia
- Insured hailstorm losses include motor vehicles (and, to a lesser extent, crops)

A breakdown of the proportions contributed by the various insurance classes to the losses in Table 5 is available for only a few events, so that comparisons with the Risk Frontiers' data are not simple. However, for example, residential building and contents, motor vehicles, and commercial buildings and contents each contributed between one-third and one-quarter of the insured losses in the 14 April, 1999 Sydney hailstorm.

Table 6 lists the 20 events that contributed the most to the House Equivalent damage in the Risk Frontiers' database for the period 1900-2003. The list includes six floods, five bushfires (really bushfire days), four tropical cyclones, three thunderstorms and two earthquakes. This mix reinforces the view that natural hazards risk in Australia is not dominated by just one or two hazards.

Seven of the 20 events in the list occurred before the insurance record began in 1967.

Although smaller events post-1998 have not been included in the sum, the 20 events listed in Table 6 contributed just over 50% of the total HE recorded in the 1,200 events in the Risk Frontiers' database. As with the death database, a few events dominate the total record.

Table 6: Events ranked by HE (1900-2003)

Event	Date
Cyclone Tracy, Darwin, NT	December 1974
Ash Wednesday bushfires, VIC & SA	February 1983
Sydney hailstorm, NSW	April 1999
Newcastle earthquake, NSW	December 1989
Katherine floods, NT	January 1998
Hobart bushfires, TAS	February 1967
Hunter R and other NSW floods	February, 1955
Brisbane floods, QLD	January 1974
NE Victorian floods, VIC	Sept-Oct 1993
Black Friday fires, VIC & NSW	January 1939
Adelaide earthquake, SA	February 1954
Cyclone Althea, Townsville, QLD	December 1971
Victorian bushfires, VIC	January 1944
Cyclone Leonta, QLD	March 1903
Canberra bushfires, ACT	January 2003
Un-named cyclone, Capricorn coast, QLD	January 1918
Sydney hailstorm, NSW	March 1990
Brisbane thunderstorm, QLD	January 1985
Floods, NSW & QLD	April 1990
Macleay & Clarence R floods, NSW	June 1950

Spatial Variation in Damage

The question "Which part of Australia is the most hazardous?" can be answered in many ways, but lets begin at the state level using the HE damage estimates. In Figure 5 Tsunami damage (grand total = 0) has been excluded to simplify the diagram, and at the scale of reproduction it is not possible to show Landslide damage clearly (only significant in New South Wales and Tasmania). NSW, Queensland and the Northern Territory are the states where it all happens and nothing much ever happens in the Australian Capital Territory (Canberra, and the location of the Federal Parliament). While, Figure 5 only includes data up to 1998, allowance has been made for the January 2003 Canberra bushfires in which more than 500 homes where destroyed, and for the 14 April 1999 hailstorm in Sydney, the largest insured loss event in Australian history. These adjustments mean that some minor details of the pattern in Figure 5 may be incorrect but the broad picture is a realistic representation.

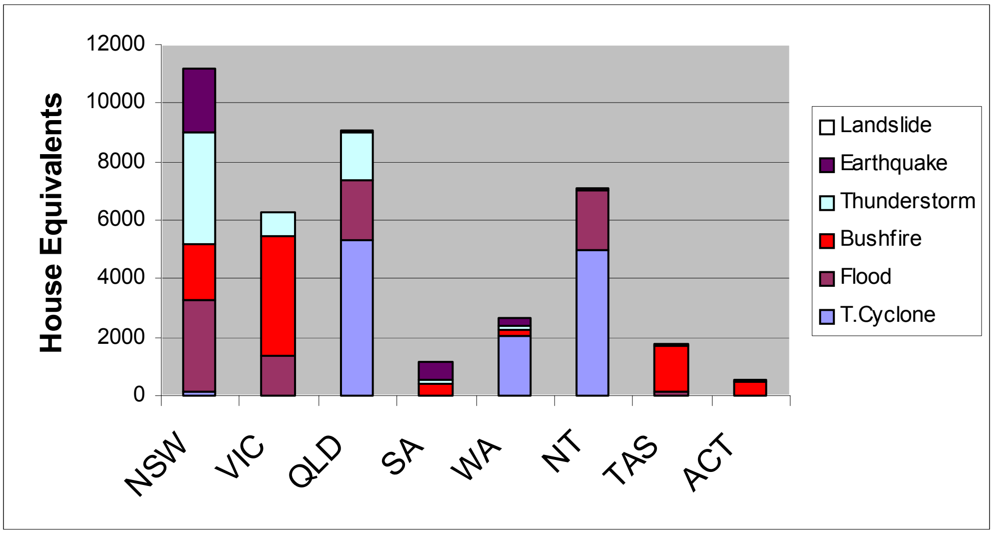

Figure 5: House Equivalent damage estimates based on 1900-1998 data with adjustments for the 2003 Canberra bushfires and the 1999 Sydney hailstorm.

Figure 5 also shows the varying impact of each natural hazard from state to state. NSW has experienced a reasonably even mix of damage from flood, bushfire, thunderstorm and earthquake, whereas damage in Victoria has been much more dominated by bushfire and in Queensland, Western Australia and the Northern Territory by tropical cyclones. The Tasmanian and ACT experiences have been dominated by the 1967 Hobart bushfires and the 2003 Canberra bushfires respectively.

As Mark Twain once noted (1883): "There is something fascinating about science. One gets such wholesome returns of conjecture, out of such a trifling investment of fact". So here we go.

New South Wales is the most populous state – it has the most buildings and so we might expect the most damage there. On the other hand, Western Australia has an enormous land area … So which state is the most hazardous when we estimate damage per 100,000 population or per unit area?

Figure 6 suggests that the Northern Territory is easily the most hazardous state or territory in Australia on a unit population basis. However, we should recognize that the head count is based on just the 2001 Census and does not reflect the changes over the century in which the damage has accumulated. This approach probably underestimates the HE per unit population for the Northern Territory and, possibly, for other states where population increase has been more dramatic in recent decades.

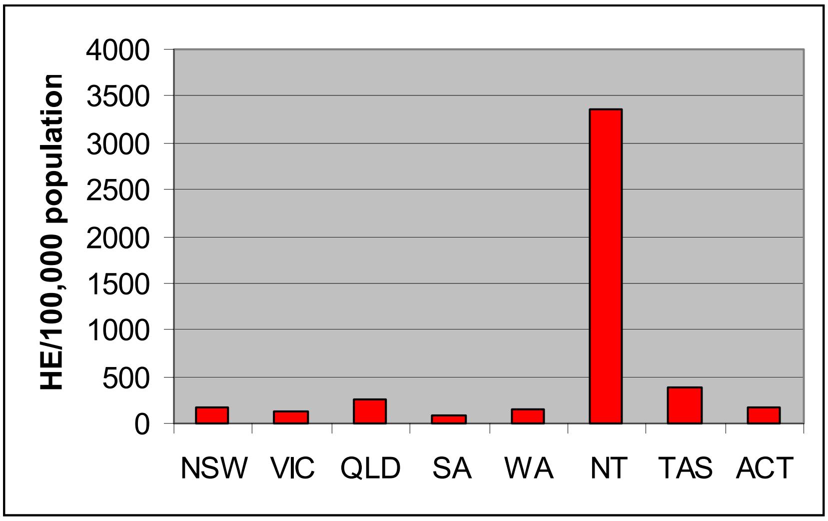

Figure 6: House Equivalents destroyed per 100,000 population. The same caveats on the data apply as on Figure 5.

Figure 7 illustrates that the picture is entirely different when the risk assessment is based on HE per unit area. Who said nothing ever happens in Canberra?

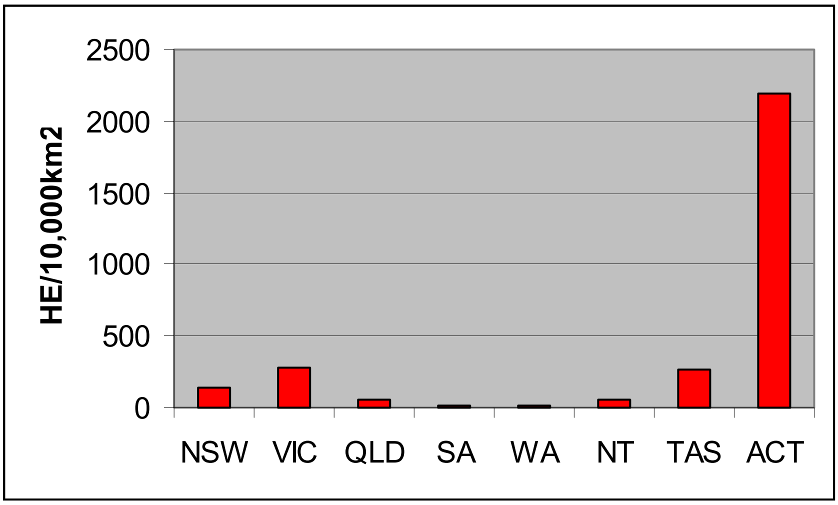

Figure 7: House Equivalents destroyed per 10,000 km2 area. The same caveats on the data apply as on Figure 5.

A More Refined View

Obviously, defining the most hazardous part of Australia just on a state-by-state basis doesn't tell us very much – though we can see from Figures 5-7 that the answer might not be as simple as we first thought. We could resolve the available data at a larger scale but with only around 5,000 events in the database spread over 100-200 years and more than 10,000 locations, it is not surprising that data are a bit thin in many areas. We used these "actual" natural hazards consequences in our map construction, but we decided that they should only count 30% towards our final map. For the other 70% we tried a different tack.

We began by choosing the best single-hazard potential maps we could find for Australia. Many of these came from the Natural Hazards Potential Map of the Circum-Pacific Region – Southwest Quadrant (Johnson et al., 1994), but we created our own maps for tornadoes, landslides and floods, and for each of these we also introduced buffer zones of varying dimensions and intensities. The maps were digitized and converted to a common co-ordinate system.

Maps of natural hazards risk usually consider only one hazard and often use rating systems such as Severe, Moderate, Low, and Don't Worry. Trying to compare an earthquake risk map at a scale of 1:1,000,000 using such a scale with a tropical cyclone map at 1:2,000,000 that rates 10% probability of exceedance gust wind speeds as >30m/s, 31-40m/s, 41-50m/s and so on, is like comparing oranges and wheelbarrows.

We then converted the hazard potential terms such as Low, High etc to fuzzy numbers and crisp numbers using the methodologies of Chen and Hwang (1992). Effectively, this methodology allows the oranges and wheelbarrows to be added (or multiplied) together. As our maps are in a GIS, we now have a potential risk rating for each hazard for each 2 km by 2 km cell – 1,907,377 cells for Australia.

Combining maps of individual hazards potential still requires decisions about the relative importance of each hazard. As our interest was, primarily, in potential building damage we have combined the maps using relative weightings similar to those suggested by Figure 3. We used a Weighted Linear Combination (WLC) method as it is the most-widely used and the best known of the Multi-Criteria Evaluation methods. These maps counted 70% towards our final product.

Figure 8 illustrates one of the integrated natural hazards maps. This is a risk map in the sense that it combines a 30% weighting on past vulnerability to natural hazard impacts with a 70% weighting on hazard potential. Here, the scale has been divided into six equal divisions. Given the methodology, we can produce integrated natural hazard risk maps at postcode, local government area, insurance CRESTA zones, state or any other divisions, using any number of categories.

Figure 8 shows a number of small red dots in the south east of the country (resulting mainly from a smearing of past tornado impacts) and a larger pink area on the northwest coast where the strongest tropical cyclone winds are expected. Vast areas on the SA-WA border, on the SA-NSW-QLD border and in northern interior Queensland have the lowest natural hazards risk.

Readers who appreciated Mark Twain's view of science quoted earlier will probably have read Darrell Huff's valuable little book "How to lie with statistics". Equally fascinating is Mark Monmier's delightful "How to lie with maps". Compare Figures 8 and 9. Both maps use the same data and the same 2 km x 2 km resolution; Figure 8 uses six equal divisions on the risk scale, whereas Figure 9 divides the country into six categories so that the total area in each category is the same.

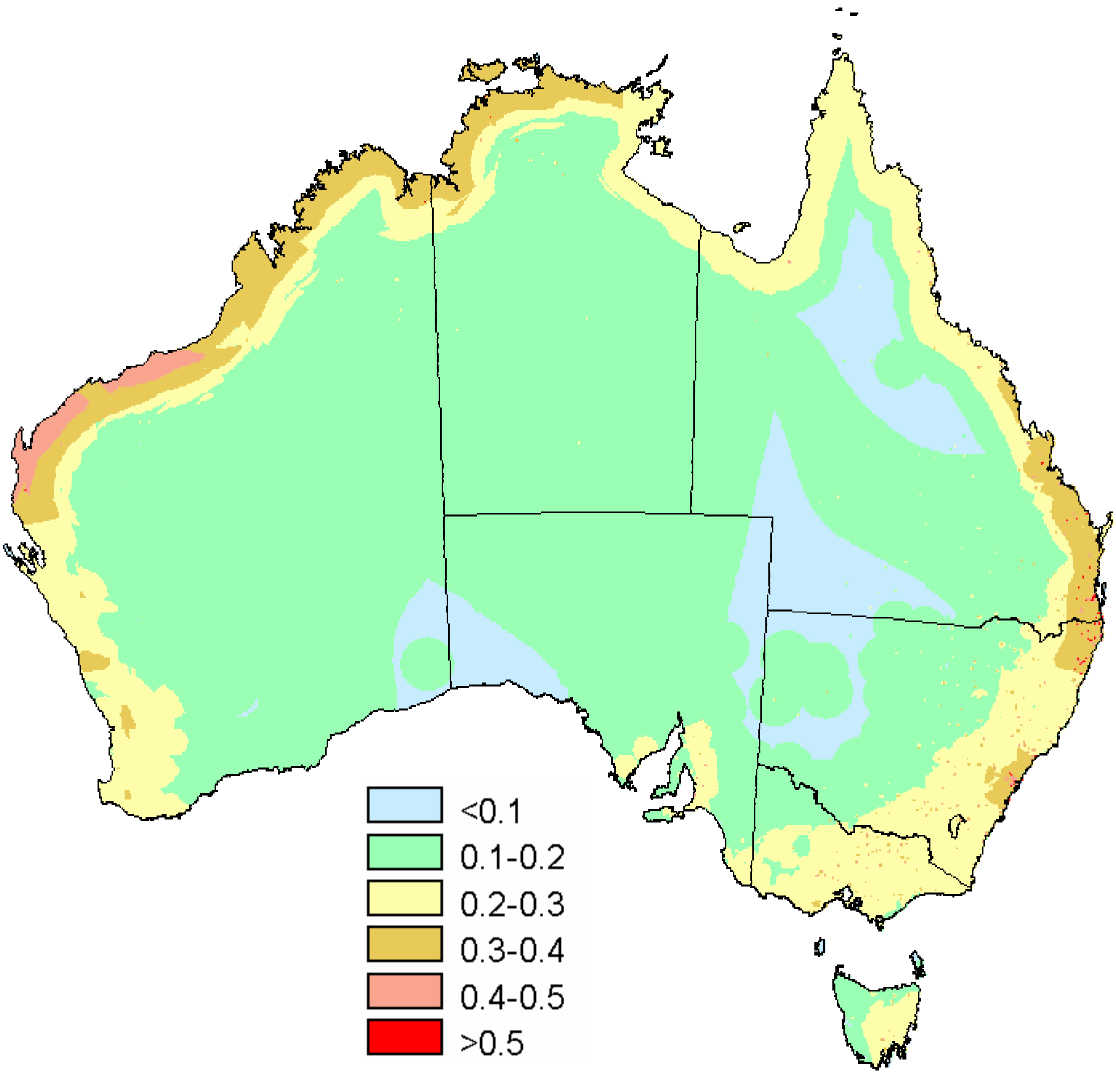

Figure 8: Integrated natural hazards risk map for Australia, using six equal divisions.

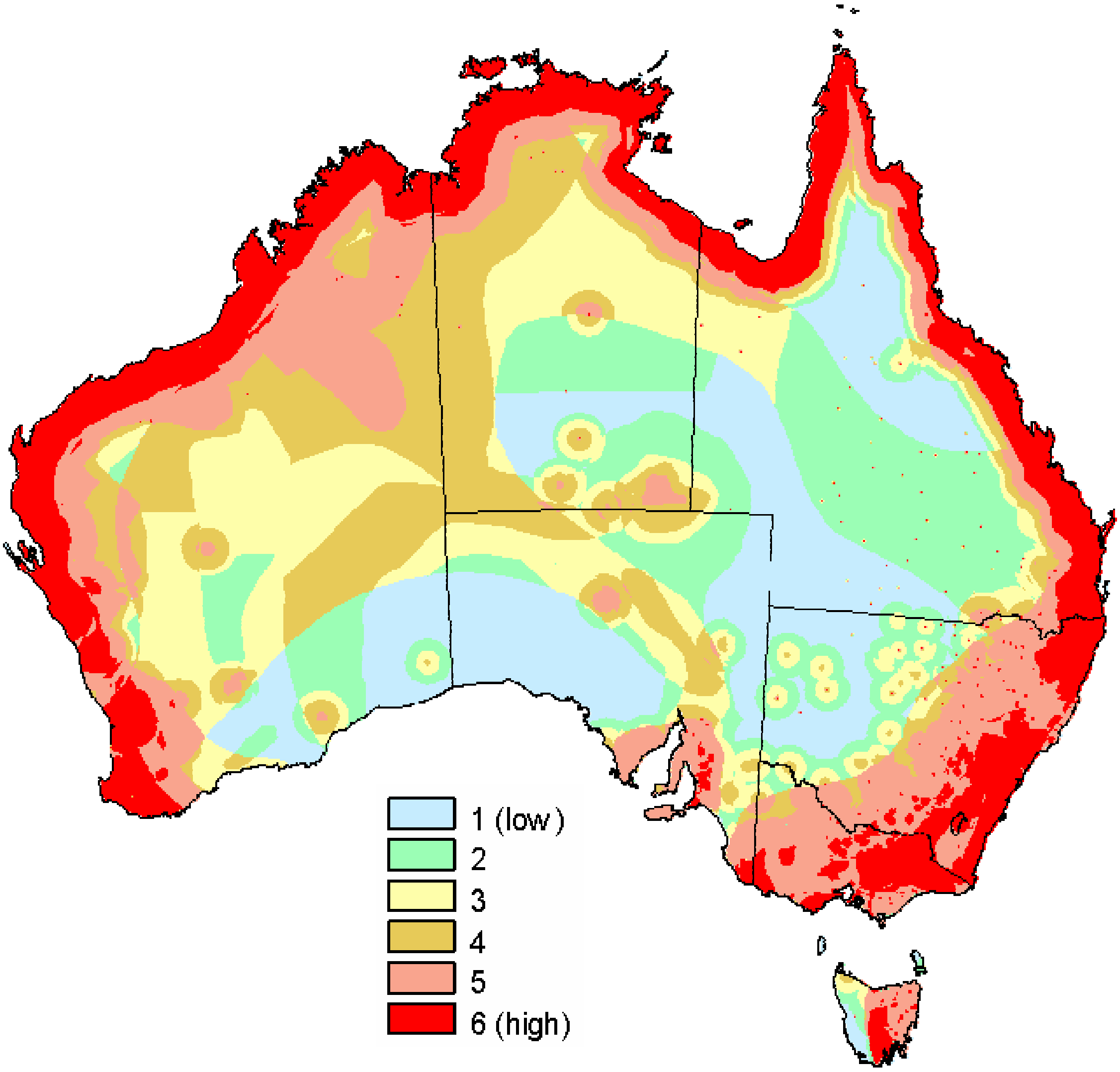

Figure 9: Integrated natural hazards risk map of Australia using six categories with equal areas.

Discussion

It is evident that the answers to the questions with which we began are not simple. We can say that the record of human deaths and building damage is dominated by tropical cyclones and floods. We can be confident that we have captured enough of the sparse record that a few more years digging through historical accounts will not change that conclusion in any significant way. It is also clear that geological hazards have been supremely unimportant during the couple of hundred years of European supremacy.

However, just 20 of the 1,200 events (i.e., 1.7% of the events) in the building damage database contributed about 50% of the total damage. Similarly, just a handful of events have contributed a substantial proportion of the death total. We have also noted the diversity of perils that produced the large death tolls and the most damaging events.

Thus, while we have a fairly good idea of the past it is less easy to say which peril will be the most deadly or the most damaging in the future. We could argue that the overwhelming dominance of meteorological events will continue, but a single earthquake or a tsunami could make a substantial dent in the patterns of the past.

The range of perils that could produce a substantial single-event death toll (say, >>100 deaths) include tropical cyclone, flood, earthquake, tsunami, and bushfire. Notwithstanding this possibility, most years produce a few deaths in floods, bushfires, and thunderstorms. Most commonly, those killed are young males – sometimes because it is firefighters who are killed, but more often because it is young males who try to drive across flooded rivers or who play golf while there is lightning around. While the dramatic decline in the death rate (Figure 2) is encouraging, the details of the death statistics identify the audience for any targeted campaign aimed at further reduction.

Before we bask too long in the warm inner glow of confidence that our assessment of natural hazards deaths is spot on we need to reflect on the perils that we might have left out of the list in Table 1. In fact, while we have made only a reasonable effort to count them, as opposed to the determined effort we have made to count the deaths from perils listed in Table 1, heatwaves have killed at least 4,287 people since European settlement began; i.e. more than any other single hazard and about 70% as many as all other hazards combined. Moreover, past heatwaves have preferentially killed the elderly, in contrast to the bushfires, floods, and thunderstorms mentioned above. Maybe we need to rethink that targeted campaign as well.

While we are still basking in that inner glow we should note that drought kills no one and damages few buildings in Australia yet it is easily the most costly natural hazard in economic terms – one estimate of the cost of the El Niño-induced drought in 1983 suggests it produced losses greater than the total of all the insured losses listed in Table 5. Drought resides in a different part of the Australian psyche – the focus is rural rather than urban, inland rather than coastal, agricultural rather than service-based in its direct impacts.

While each state has a State Emergency Service and the feds have Emergency Management Australia (EMA – in the Attorney-General's department) and the Department of Transport and Emergency Services (busily capturing the hazard mitigation agenda from EMA) to deal with the Prevention, Preparedness, Response and Recovery of the rapid onset hazards, slow-onset drought is dealt with elsewhere in the bureaucracy.

As the current drought – endemic for much of the last 15 years – tightens its grip on the dwindling water supplies of the urban majority this dichotomy might change. Moreover, any nexus between drought, water supply, El Niño, and climate change might encourage serious reconsideration of Australia's negative position on ratification of the Kyoto Protocol.

Whether the Risk Frontiers' database shows evidence of the impact of climate change on natural hazards magnitude, frequency or consequence is not clear. No hypothesis has been tested – likely, the data are not of sufficient quality. If we can characterize the poles of the debate with Munich Re's assertions that the role of climate change is clear in the climbing global insurance losses of the last 35 years on the one hand and van der Vink et al.'s (1998) explanation of trends in U.S. losses through population movements and property values on the other, my personal view lies closer to the latter.

In any case, for Australia, explication is complicated by links between El Niño and climate change. Drought and bushfire increase in El Niño periods. Flood and tropical cyclone frequency decrease. A link with hail fall frequency has been identified but is not simple. With the four hazards we identified earlier as the most important in terms of deaths and building damage all linked to the El Niño cycle, we are a long way from adding climate change to a convincing natural hazards risk assessment.

The near-total destruction of dwellings in Darwin by Cyclone Tracy on Christmas Eve, 1974 produced at least one positive – the development of one of the world's best wind loading codes for residential (and other) buildings. Damage to buildings in the 1989 Newcastle earthquake led to the further strengthening of the earthquake loading code and its application to dwellings in some circumstances. Most urban areas have quite stringent controls on the types of buildings that can be constructed and their layout in bushfire-prone areas. Similarly, local governments control suburban development on floodplains – some allow almost no buildings below the Average Recurrence Interval (ARI) 100-year flood line; others have been less cautious.

These building codes and land use planning controls suggest that building damage, or at least building damage per 100,000 population, should continue to decrease. The risk assessment process has not proceeded far enough to demonstrate that this is so; the varying dates at which controls have been implemented in local areas, and the relatively low frequency of hazard impacts at a site suggest the task might be too difficult.

Nonetheless, two issues stand out. Firstly, there are no controls, or even "recommendations" concerning suitable roofing materials for hail-prone areas such as Sydney and Brisbane where the vast majority of roofs are clay tile or, increasingly, concrete tile. Wind-driven hailstones >4 cm in diameter can penetrate these materials (and slate and fiber-cement roofing), leading to water damage to ceilings and building interiors. Surprisingly, research into the hail resistance of the commonly-used Australian roofing materials has hardly begun. This is even more surprising as it now seems clear that hail is the most important natural hazard in terms of building damage in these cities in the 1-100 year (possibly 1-200 year) time frame.

Secondly, a recent re-survey of major Australian flood damage studies indicates all too clearly that about one-quarter of all residential building damage (excluding building contents) produced by flood is damage to built-in furniture – kitchen cupboards, built-in wardrobes, and bathroom vanity units. Usually, these units are constructed from non-waterproof chip-board that swells when wet. Should built-in furniture in dwellings on floodplains be constructed from something more resilient? Given the cycle of replacement of kitchen cupboards in an affluent society would more resilient materials be more cost-effective in houses located below, say, the ARI-75 year flood?

With the recognition that we have done a lot to mitigate damage to houses in cyclone, bushfire and, even, earthquake-prone areas, why have we done so little in relation to floods and thunderstorms? Isn't the risk assessment evidence in Figure 4, for example, clear enough?

Conclusion

A lengthy expensive effort would be required to significantly improve the meticulous record of natural hazard impacts and consequences in the Risk Frontiers' database. Furthermore, it is doubtful that the additional effort would place the answers to the questions raised in the Introduction on a much firmer footing. Floods and cyclones will remain the country's most deadly natural hazards for decades to come – unless we count deaths in heatwaves. We can be less certain of the rank order of floods, cyclones, thunderstorms and bushfires in producing building damage – and the order could be changed by a single event before this publication appears. Earthquake, or even tsunami, could be promoted into the big league – the historical evidence suggests otherwise, but the record is short and we shouldn't be overconfident.

In terms of building damage (house equivalents destroyed), NSW is the most hazardous state in the country, but if we rephrase the questions slightly the answer could be ACT or the Northern Territory. We could refine the question and produce the answers to the question based on local government areas, or postcodes, or 4 km^2 cells, but we need to ask whether the data would really support the answers.

The same set of questions, but focused on the future, are much tougher. The past and the present might provide pointers to the future, but we can't be too confident. The myriad of impacts is dominated by a few extreme events. And, the population of Australia is ageing, drifting to the coast, and migrating toward the winterless north, all under the aegis of climate change that may, or may not, see a greater domination by the El Niño regime.

The flaws, or potential flaws, in Risk Frontiers' efforts at integrated natural hazards risk assessment have not been hidden here. The focus is relatively narrow – just deaths and building damage. We don't yet understand the past impact of natural hazards on infrastructure or agriculture. It is clear that hazards such as drought and heatwaves should have been (and should be) considered more carefully.

Nonetheless, the emphasis on integrated risk assessment is an important one. Very few, if any, other countries have such a sound assessment of the impacts of natural hazards, integrated into a single database. We might not have all the answers, but we do have a sound platform from which to pose even tougher questions.

Further Reading

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Cover Image: Canberra Bush Fire - Professor John McAneney, Risk Frontiers