Economic Costs of Natural Disasters in Australia

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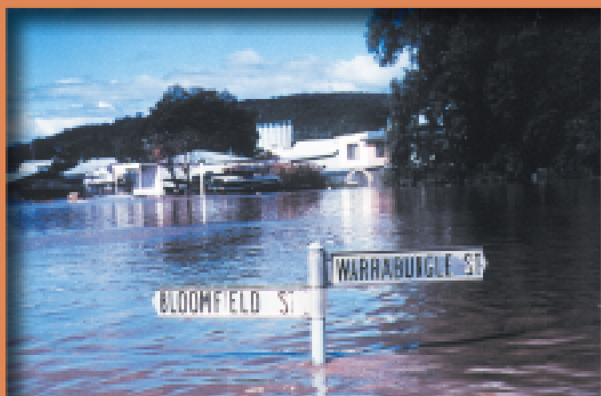
Report 103



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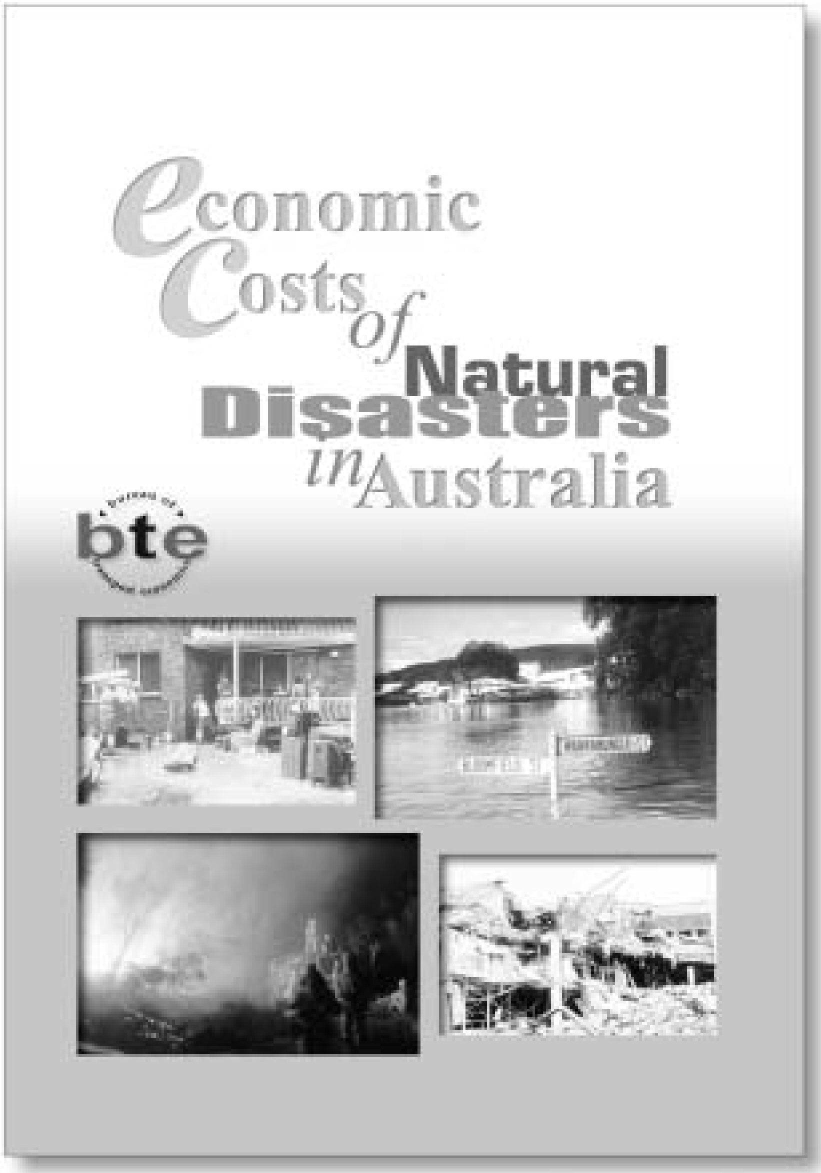

ISSN 1440-9569
ISBN 0 642 45633 Xs

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Published by Bureau of Transport Economics, GPO Box 501, Canberra ACT 2601, Australia.

Orders to AusInfo, GPO Box 84, Canberra, ACT 2601, Australia, telephone (international) +61 2 6295 4861, fax +61 2 6295 4888, freecall within Australia 132 447, internet: http://www.ausinfo.gov.au

Indemnity Statement

Desktop Publishing by Jean Penny and Thomas Smith.
Cover design by Thomas Smith.
The cover photos were provided by Emergency Management Australia (EMA).
Clockwise from top left:
Wollongong—flash flooding, clean-up by State Emergency Services (photo by Gary Pearton).
Narrabri—breaking of the banks of the Namoi River (photo by Peter Lorimer).
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Printed by Paragon Printers, Canberra.

FOREWORD

Every year Australian communities are subjected to the damaging impacts of natural disasters. Australia is well served by dedicated groups of men and women who respond quickly to these emergencies and assist generously with the recovery afterwards. Most Australians, at some time in their lives, would have had some experience of the devastating effects of severe weather and geophysical events. Yet, little is known about the economic costs of natural disasters.

This report is a first step in better understanding the costs of natural disasters in Australia. It also brings together information allowing a consistent approach to the estimation of future disaster costs.

The Disaster Mitigation Research Working Group (DMRWG), chaired by the Department of Transport and Regional Services, oversaw the research. The DMRWG represents a collaborative effort among Commonwealth and State and Territory Governments, Local Government, the Insurance Council of Australia and the New Zealand Government. The research was endorsed by the National Emergency Management Committee (NEMC).

The research team comprised Neil Gentle (Project Leader), Sharyn Kierce and Alistair Nitz. Tammy Braybrook contributed to the study at a critical stage. Joe Motha, Deputy Executive Director, provided valuable management and professional guidance to the project team.

Tony Slatyer
Executive Director
January 2001

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ACKNOWLEDGEMENTS

Thanks are due to many people and organisations who gave their time generously and contributed information and assistance.

The project team would like to thank the Territories and Regional Support Division of the Department of Transport and Regional Services for their assistance throughout the study.

Emergency Management Australia made a significant contribution. The former Director-General, Alan Hodges AM, was an enthusiastic supporter of the project from its inception. David Templeman, the current Director-General, continues to provide support. The BTE is especially grateful to Emergency Management Australia for making their database freely available to the research team. In particular, thanks to Peter May and David Winterburn for their help and support during the project.

Many people gave their time to talk with and provide information to the research team over the course of the project. In particular, the Victorian Country Fire Authority, the Australian Emergency Management Institute library and the libraries of many other organisations provided invaluable assistance.

Discussions arranged by the Queensland Department of Emergency Services with a wide range of State agencies provided the research team with an important insight into emergency management at State government level.

Mr Dingle Smith and Professor John Handmer generously contributed advice and wisdom and refereed the report. Thanks also to the many people who participated in the discussion and provided comments following the seminar on preliminary findings in August 2000.

The Disaster Mitigation Research Working Group (DMRWG) provided valuable comments and input at various stages of the project. Others who were less formally involved but nonetheless took a keen interest and shared their knowledge include Ric McRae (ACT Emergency Services Bureau) and Marion Michael-Leiba (Australian Geological Survey Organisation).

Thanks are also due to former DMRWG members for their contributions including Henry Dowler (NZ Ministry for Emergency Management), Geoff Graves (NSW State Emergency Management Committee), Greg Haughey (Department of Finance and Administration), Trevor Jones (Australian Geological Survey Organisation) and Anne Morant (Department of Finance and Administration).

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EXECUTIVE SUMMARY

Natural disasters affect every State and Territory in Australia and impinge directly on the everyday lives of residents in vulnerable communities. Although communities usually have well-developed plans for responding to natural disasters, mitigation measures have generally received less attention.

Good information on the costs of natural disasters is required to assess the effectiveness of expenditure on mitigation measures. In response to the need for better cost information, the National Emergency Management Committee endorsed the project leading to this report. The key objectives of the project were to establish the costs of natural disasters in Australia over time, to examine the trends in these costs and to develop a model for costing future disasters. A working group, (the Disaster Mitigation Research Working Group chaired by the Department of Transport and Regional Services), was established to oversee the project.

The term 'natural disaster' covers a wide variety of disaster types. For the purposes of the project, a natural disaster was classified as any emergency defined by the Commonwealth for the purposes of the Natural Disaster Relief Arrangements (NDRA) which are administered by the Department of Finance and Administration. As a result of this classification, the analysis was limited to floods, storms (including hailstorms), cyclones, tsunami, storm surges, bushfires and earthquakes. Landslides were also included, as they are included in the NDRA when they are consequential to an eligible event.

The focus of the study was on national economic costs, as a national approach was necessary to achieve the project's objectives. A local or regional approach may be more appropriate for an assessment of individual disaster mitigation measures.

AVAILABILITY OF DATA

Australian data used for the analysis were derived from a database maintained by Emergency Management Australia (EMA). Although the

BTE considers the EMA database as the best currently available in Australia for purposes of the project, it has limitations:

- The heavy reliance on media reports limits the accuracy of the database.
- Some of the earlier events that occurred in Australia, especially smaller ones, are not likely to have been recorded, as they were not reported in the media.
- The method of estimating total costs as multiples of insurance costs can lead to significant inaccuracies.
- Cost estimates contained in the database were found to have not been properly indexed to 1998 dollars. However, the low inflation levels experienced over the past three to four years would have had little impact on the cost estimates.

Although the EMA database contains records dating back to the 1800s, it is only since 1967 that reliable insurance data, on which the most reliable cost estimates in the database are based, became readily available. Therefore, for the study, records of events prior to 1967 were not included. However, care is still required, as events early in the study period may not have been reported and recorded in the database.

The analysis in the report was limited to events having an estimated total cost greater than or equal to $10 million each, excluding the costs of deaths and injuries. The BTE believes the use of this threshold does not substantially affect the conclusions reached.

FRAMEWORK FOR ESTIMATING COSTS

It was difficult to make a conclusive assessment of the trends in disaster costs due to limitations of the data. A framework for estimating the economic cost of natural disasters, which should facilitate future estimations of disaster costs, was developed. Although drawing heavily on flood literature, the framework should be suitable for use in determining the cost of all disaster types. Nevertheless, the unique character of each disaster means that the framework should only be used as a guide, rather than an exact model to determine the cost of any particular disaster.

The objective of this report was to identify the economic costs related to an event, rather than the financial cost. Economic costs are focused on the additional resources used by the Australian community as a result of a disaster. Financial analysis is concerned with the financial impact on the individual or the entity directly affected by the disaster. In estimating the economic costs of disasters, caution needs to be exercised to avoid double counting of costs and to ensure the use of appropriate economic values of assets.

Classification of losses

Generally, the method used to estimate the costs of a natural disaster is to categorise the losses into tangible and intangible losses, which are further sub-divided into direct and indirect losses. The BTE's approach was to analyse the costs in three broad categories—tangible direct, tangible indirect and intangible (comprising the direct and indirect intangible cost). Direct costs, which are the easiest to classify, are losses that result from the physical destruction or damage to buildings, infrastructure, vehicles and crops.

Indirect costs, which are more difficult to estimate, are costs incurred as a consequence of the event occurring, but not due to the direct impact. One area of contention is the costing of the disruption to business. The cost of lost business is often included in the estimated cost of a disaster. The impact of a disaster can be devastating for businesses directly affected by that disaster, and local communities can suffer as a consequence. However, when examining the impact of the disaster from a national perspective, business disruption costs typically should not be included. This is because business disruption usually involves a transfer between producers, without a significant loss in national economic efficiency. There may be occasions when the transfer between producers involves additional costs, which would be a valid indirect cost of the disaster. Business disruption costs would be included if the event affected the nation's economy through an increase in the level of imports or a decrease in exports.

The intangible cost category attempts to capture all losses not considered as a direct or indirect tangible cost. Intangible costs are typically those for which no market exists. These costs are difficult to estimate, as there is no systematic or agreed method available to measure them. The largest impact is normally found in the residential sector, which includes health effects, household disruption and loss of memorabilia. Although presently available methods are generally poor at reliably estimating many intangible costs and benefits, they should not be ignored in assessing mitigation proposals.

KEY FINDINGS

Disaster costs

- Natural disasters (with a total cost per event over $10 million) cost the Australian community $37.8 billion (including the costs of deaths and injuries) in 1999 prices over the period 1967 to 1999.
- The average annual cost of these disasters between 1967 and 1999 was $1.14 billion (including the costs of deaths and injuries). This translates to approximately $85 per year per person.
- Estimated average costs were $1.3 million for a fatality, $317 000 for a serious injury and $10 600 for a minor injury. The estimated total cost of deaths and injuries during the period 1967 to 1999 was $1.4 billion at an average cost of $41 million per year.
- The average annual cost is strongly influenced by three extreme events—Cyclone Tracy (1974), the Newcastle earthquake (1989) and the Sydney hailstorm (1999). If the costs of these three events are removed from the calculations, the average annual cost declines to $860 million. This may be a better estimate of the costs of disasters that can be expected in a year in which extreme events do not occur.

- The annual cost of disasters is highly variable. The annual cost in years in which extreme events do not occur can be as high as $2.7 billion in 1999 prices. In years in which extreme events occur, the total cost can be much higher. As a result, it is not possible to assess whether the annual cost is increasing or decreasing over time.
- There is no evidence in the data that the total cost of smaller and more frequent events (less than $10 million total cost) exceeds the total cost of large rarer events. For a selection of sample years, these smaller events are estimated to have accounted for an average of 9 per cent of total economic costs of disasters.

Numbers of disasters

- There have been 265 natural disasters costing more than $10 million each during the period 1967 to 1999.
- The total cost of most disasters is between $10 million to $50 million. More costly events are much less common. Despite the large number of events in the $10 million to $50 million

range, the sum of total costs of these events remains small (around 10 per cent of total cost) in comparison to the costs of the infrequent extreme events. (Again, it is worth bearing in mind that many smaller disasters go unrecorded).

- There is some evidence that the number of disasters per year is increasing due partly to better reporting in recent years and possibly to increasing population in vulnerable areas.

Regional findings

- New South Wales and Queensland accounted for 66 per cent of total disaster costs and 53 per cent of the total number of disasters over the period 1967 to 1999. The Northern Territory ranked third in terms of total disaster costs (13 per cent), followed by Victoria (9 per cent), Western Australia (6 per cent), South Australia (4 per cent), Tasmania (2 per cent) and the Australian Capital Territory (0.02 per cent). No events were recorded for Norfolk Island or the Indian Ocean Territories.
- Floods were the most costly of all disaster types, contributing $10.4 billion or 29 per cent of the total cost. Storms (26 per cent of total cost) and cyclones (24 per cent) caused similar levels of damage. Together, the combined cost of floods, storms and cyclones was almost 80 per cent of total disaster cost. They also accounted for 89 per cent of the total number of disasters. The costs of bushfires were a relatively small proportion of total disaster costs. However, bushfires are the most hazardous type of disaster in terms of deaths and injuries.
- The two most costly hazard types for each State and Territory are:
  - New South Wales (floods, storms);
  - Queensland (floods, tropical cyclones);
  - Victoria (floods, bushfires);
  - Western Australia (tropical cyclones, storms);
  - South Australia (floods, storms);
  - Tasmania (bushfires, floods);
  - Northern Territory (tropical cyclones, floods); and
  - Australian Capital Territory (bushfires, storms).

Findings on methods of estimation

- There is considerable variation in the methods used to estimate past disaster costs, mostly in the estimation of indirect costs.

- The use of a consistent framework for estimating cost, based on that developed in this report, can provide a better basis for assessing mitigation proposals.
- There is no simple relationship between indirect and direct costs of a disaster. Previous disaster reports indicate that, as a broad estimate, indirect costs are usually in the range of 25 to 40 per cent of direct costs.
- There are very few methods for the adequate estimation of intangible costs and more research is needed in this area.

A COMPARISON OF ESTIMATES

The BTE examined past disaster reports using the framework discussed in chapter 4 as a benchmark for the analysis. The Nyngan flood (1990), Lismore flood (1974), Cyclone Tracy (1974), Ash Wednesday Bushfires (1983) and the Edgecumbe (New Zealand) Earthquake (1988) were chosen because of the range of disaster types and their geographic distribution, and most importantly, the availability of adequate documentation. In some cases, BTE estimates were relatively close to past estimates (Nyngan, Lismore and Ash Wednesday). For others, the estimates differed widely (Cyclone Tracy and Edgecumbe). The main reason for differences between estimates was the lack of availability of indirect cost information and the different treatment of particular indirect costs, such as business disruption.

Testing the cost framework outlined in this report against five disasters represents a small sample. However, the evidence indicated that there was a wide variation in the approach to measuring the losses associated with a disaster. Care needs to be exercised in defining the boundaries of the analysis to ensure that the full effects of a disaster are estimated. The analysis of the sample also illustrates the potential errors in using a simple multiplier of insurance costs to estimate total cost.

NEXT STEPS IN DISASTER COST RESEARCH

The purpose of the framework and discussion of estimation methods was to provide a first step in attempting to develop a more consistent approach in measuring the cost of disasters in Australia. Historically, indirect costs, and particularly intangible costs, have not been well documented and incorporated into estimates of disaster costs. As a consequence of these data limitations, the conclusions derived from the data analysis must be interpreted as indicative or approximate only, and any conclusions drawn must be regarded as tentative.

Obtaining a more accurate cost estimate would require a system for the consistent collection of disaster costs in the wake of a disaster occurring. The current short time series of available data means that it is very difficult to come to grips with any trends, while any changes to basic data parameters may have considerable implications for the future ability to analyse trends. It is important that a strategy for handling this issue is devised if trends in natural disaster costs are to be reliably examined in the future.

The cost framework developed by the BTE was cross-checked against several well-documented disasters which used differing approaches. The results were not strictly comparable. As a result, the next step would be to test the cost framework outlined in the report in a variety of future disasters so that it can be refined to achieve greater agreement and consistency in costing Australian disasters.

The largest gap in the estimation of disaster costs is the inability to adequately estimate intangible costs. Evidence suggests that they are at least comparable with direct costs and possibly much larger. Research is needed to develop reliable methods to overcome this gap.

There have been few extreme disaster events in Australia, so that the understanding of their costs is poor. Knowledge of the potential costs of future extreme events can guide the development of measures to reduce their impact. The Cities Project, being implemented by the Australian Geological Survey Organisation in Queensland and Western Australia, provides an excellent tool for analysing the vulnerability of communities to natural disasters. Together with the models developed by the Cities Project of potential impacts of disasters on local communities, the methods presented in this report could provide a useful means of estimating the future costs of extreme events.

Finally, a weakness of studying past events is that the more recent increased reliance of urban communities on technology, especially computer-controlled networks, is inadequately recognised. Research is needed on how the increased reliance on technology affects the vulnerability of communities.

1

INTRODUCTION

BACKGROUND

The risk of natural disasters forms a backdrop to our everyday lives. Depending on where we live, floods, bushfires, cyclones and earthquakes are possible threats to both property and lives. Over time, communities have developed organised responses to the threats posed by natural disasters. Although preparation and response measures can mitigate their effects, natural disasters continue to occur and cause severe damage.

Much of the focus in the past has been on the community's response to disasters, with less attention given to mitigation measures. Floods are probably the best understood of natural disasters, and it is therefore no accident that mitigation of flood damage is more highly developed than for other disasters.

Current views among those who interface with disasters and those in policy-making areas are that money spent on disaster mitigation can be more than recouped in the amount saved in response and recovery afterwards. The statement that a dollar spent on mitigation is worth two dollars of response and recovery is often found in the American disaster literature, although it is difficult to trace its origin.

The increasing focus on the proactive role of mitigation has come about from a belief that the costs of natural disasters have been rising. On a global scale, the financial problems faced by a number of insurance and re-insurance companies are testament to this view. In the USA, the Federal Emergency Management Agency (FEMA) claims that from 1989 to 1993 the average annual loss in the USA from natural disasters was US$3.3 billion and that this had grown to an average annual cost of US$13 billion over the four years to 1997 (FEMA 1997). In Australia, the view also exists that major disaster events appear to be occurring more frequently (Petersen 1999, p. 11).

Natural hazard or disaster mitigation can be defined as measures taken in advance of a disaster aimed at reducing or eliminating its impact on society and the environment (EMA 1998, p. 85). The important factor is that mitigation is a long-term commitment that must generally be implemented before a disaster strikes.

Before mitigation can be adequately addressed, knowledge of the effects of natural disasters on property and people is required. Although scientific understanding of natural disasters in Australia is of a high order, very little study has been undertaken on the economic effects of disasters. The aim of this report is to take a first step in assessing information on the costs of Australian natural disasters. The report also brings together work by others on loss estimation methods. The presentation of this information will hopefully be of value to other researchers in estimating the costs of future disasters.

The research leading to this report is part of a longer-term project to look at mitigation measures in more detail. The research arose out of a need to put the value of mitigation expenditure on a sounder footing than has previously been the case.

The project received the endorsement of the joint Commonwealth, State and Territory National Emergency Management Committee in November 1999. A working group comprised of representatives of stakeholders in emergency management oversaw the research.

The objectives of the overall project are:

1. to establish more accurately the costs of natural disasters in Australia, the trends in these costs and to develop a model for costing future disasters;
2. to test the hypothesis that greater emphasis on mitigation has the potential to reduce the costs of disaster response and recovery, and so better protect communities against loss of life and damage;
3. to test the relative effectiveness and cost-benefit of various mitigation measures and develop a model for assessing mitigation proposals; and
4. to develop a picture of natural hazards and risks across Australia.

The first objective is the major focus of this report.

REPORT STRUCTURE

This introductory chapter provides the background context and outlines the scope, definitions and method employed throughout the report. Chapter 2 examines the available data that could be used to estimate the historical costs of natural disasters. It also discusses the implications of the limitations of the data for any conclusions drawn. Chapter 3 provides estimates of the costs of natural disasters from 1967 to 1999 using the data examined in chapter 2. Chapter 4 provides a guide for the future estimation of costs through the use of a consistent framework of costs and examines available estimation methods and data sources. Chapter 5 provides a comparison between the historical cost estimation (chapter 3) and framework (chapter 4), with other published disaster research. Several disaster case studies are examined in order to apply the cost framework to published reports on natural disasters. Chapter 6 summarises the key findings of the report and concludes by outlining the next steps in disaster costing research.

Appendix I examines the issue of estimating the cost of deaths and injuries in Australian disasters. Appendix II provides a point of comparison by discussing the number and costs of New Zealand disasters. Appendix III provides more technical information on the depreciated value of an asset. Appendix IV discusses the economic effects of disasters on business activity and appendix V provides information on Natural Disaster Relief Arrangements (NDRA).

SCOPE

The term ‘natural disaster’ covers a wide range of disaster types that could be considered for inclusion in the analysis. To provide a focus to the study, the BTE adopted the definition of natural disasters published by Emergency Management Australia (EMA). That is, a ‘natural disaster’ is any emergency defined by the Commonwealth for the purposes of the NDRA administered by the Department of Finance and Administration (DOFA). These are typically geological and meteorological hazards (EMA 1998, p. 90).

Hazards currently covered by the NDRA include floods, storms (including hailstorms), cyclones, tsunami, storm surges, bushfires, and earthquakes. Landslides are covered by the NDRA where they occur as a direct result of one of the eligible events.

Although the term ‘natural disaster’ is used to describe the disaster types covered by the study, not all disasters have a natural origin. For example, bushfires are often started by people. It is not always possible to ascertain how a disaster started, and in any case, the response and NDRA payments are not influenced by how a disaster started. This report also makes no such distinction.

The natural disasters of droughts and heatwaves are not covered by the NDRA and consequently were excluded from the study. Disasters of a biological or botanical nature, such as those caused by exotic flora and fauna, are beyond the scope of the project. Similarly, technological disasters are also beyond the scope of the project.

It is also worth noting that heatwaves, although not included in NDRA, are estimated to have caused more deaths than any other disaster type. The EMA (1999, p. 10) estimated that heatwaves killed 4500 people between 1803 and 1999 compared with 2500 for floods and 2200 for tropical cyclones.

At this stage, it is important to make a distinction between financial and economic costs (table 1.1). A financial analysis is concerned with the financial impact of a disaster on individuals and enterprises affected by the disaster. A financial analysis is based purely on the cash value of resources affected by the disaster. Market prices are used to value all costs and benefits. The analysis is not concerned with effects that have no market value.

Economic analysis considers the effect of a disaster on society as a whole. It is concerned with efficiency, in that the effect of the disaster on resource consumption is the major focus of the analysis. Transfer payments within the economy that have no impact on resources, such as taxes and subsidies, are ignored because they have no net impact on resource consumption nationally[1]. Similarly, a gain by one enterprise at the expense of another is not necessarily an economic cost, although there are financial effects for the enterprises concerned. An economic analysis would include effects that would not be included in a financial analysis, such as the cost of traffic delays and health effects.

Economic analysis is concerned with the broader social effects of a disaster. This is the approach used in this study as it is more consistent with government concerns in responding to disasters than a purely financial analysis.

The impact of a disaster can be devastating for businesses and communities directly affected. However, the economic analysis has a national perspective, rather than a local one, in order to develop an Australia-wide view of the costs of disasters. One consequence of a natural disaster might be that private or public enterprises lose business to competitors. Although the loss of business is a financial loss for the disaster-affected enterprise or locality, it is an economic loss only if the national economy is affected. Loss of business to a

1 This overlooks the distorting effect of taxes and subsidies and the consumption of resources in administering government programs.

TABLE 1.1 SUMMARY OF FINANCIAL AND ECONOMIC ANALYSES

Method	Scope	Objective	What is counted	Values used
Financial analysis	Single economic unit.	Net income or profit	Any change in unit's finances.	Market prices. Taxes are considered as costs and subsidies as benefits.
Economic analysis	All members of society within the chosen analysis boundary.	Economic efficiency	All impacts affecting any member of society. Distributional impacts are ignored.	Market values adjusted to reflect resource costs. Taxes and subsidies considered as transfer payments.

Source Based on Parker, Green & Thompson (1987, p. 20).

competitor within Australia is not an economic cost of the disaster, but a loss of business to a foreign competitor is. It should be noted that if there are additional costs incurred by the use of an alternative supplier, such as increased labour or transport costs, then these additional costs are economic costs of the disaster, as resources are consumed that could be used for alternative uses (Thompson & Handmer 1996, pp. 22–24). Further discussion on this issue is in chapter 4 and appendix IV.

DEFINITIONS

Standards Australia (2000, p. 2) defines a hazard as **'a source of potential harm or a situation with a potential to cause loss'**. A natural disaster occurs when a natural hazard event actually causes damage to property or harms people. The question then arises: How much damage must be caused or how many people must be harmed before a disaster is said to occur? This distinction between an 'event' and a 'disaster' is not always clear, and in fact there are different views among the specialist fields and jurisdictions across Australia about what is meant by 'event' and 'disaster'. Hazardous events are often labelled as 'accidents', 'incidents', 'emergencies' or 'disasters'. It is commonly the case that not all hazardous 'events' are classified as 'disasters'. There is usually some sort of threshold applied to events relating to their scale, the severity of damage, the number of people affected, the number of organisations involved and the ability of organisations to cope within their normal resources (EMA 1998, p. vi).

Most States and Territories have mechanisms in place that enable an official 'state of disaster' or 'state of emergency' to be declared when a natural hazard event is occurring or imminent. The declarations are usually made depending on the magnitude of the event, but the criteria used to decide whether an event requires a declaration are not always explicit. The approach also varies across jurisdictions, but these declarations generally apply to larger-scale events.

Although the mechanisms for a formal declaration of a state of disaster or state of emergency are available, they are not necessary and not commonly used for effective response to emergencies. More important is the existence of arrangements by which the activities and resources of a variety of emergency-relevant organisations (such as emergency services, government departments and local councils) can be brought together in coherent ways to carry out response and recovery activities in conjunction with the community. For each type of emergency, an agency is nominated as 'lead' or 'control' agency to take charge of response operations. All States and Territories have such arrangements. They often depend on prescribing a particular agency, such as police, as the overall coordinator for emergency response. In most States and Territories, these arrangements are supported by legislation.

Insurance companies define a disaster according to the impact an event has on insurance claims and reserves. For the insurance industry, an 'event' is not typically a 'disaster' unless it results in insurance claims in excess of $50 million. However, the industry does keep records of events with insurance payouts exceeding $10 million. Insurance industry definitions of a disaster are not comprehensive, as not all hazards are covered by insurance. A flood is an example of an event that is often not covered by insurance. Consequently, some large floods may be excluded from the analysis if the insurance industry definition were adopted.

The EMA (1998) defines a 'disaster' as a serious disruption to community life which threatens or causes death or injury in that community and / or damage to property which is beyond the day-to-day capacity of the prescribed statutory authorities and which requires special mobilisation and organisation of resources other than those normally available to those authorities (EMA 1998, p. 42).

The approach of defining a disaster on the basis of the assistance required to respond to it is a useful starting point. A State or Territory government response is invoked when resources are insufficient or local authorities cannot respond effectively. National assistance is sought when the response required is too large, or the resources too specialised, for the State or Territory Government to handle on its own. The threshold should not be set too low, as the number of events could become very large and unwieldy for analysis. However, if the threshold were set too high, a large number of significant events may be excluded from the analysis. Although a few large events dominate Australia's disaster record, it could be that the cumulative costs of smaller events exceed those of the larger events.

As a start, a disaster is defined as an emergency event that is too large or complex for emergency management agencies to respond to effectively with resources available locally or regionally. This is a conceptual definition of a disaster, but may not be particularly practical in operational terms when it comes to analysing historical data. One problem is that the database of disasters available to the BTE do not always identify what level of government support was given. So although disasters have been defined, the analysis described later in the report may include loss estimates for events that may not fall strictly within the conceptual definition. As a result, it was necessary to adopt a threshold cost as a practical measure in analysing past events. A threshold total cost of $10 million was used in the analysis presented in chapter 3. The implications of this choice of threshold are discussed in detail in chapter 2, but it is important to note that a $10 million total cost threshold means that, depending on the disaster type, events with insurance costs of just a few million dollars are included in the analysis.

Defining a disaster is a difficult and somewhat controversial task. Storm damage to a few houses may be disastrous for the households involved, but from a national perspective is unlikely to be thought of as a disaster. However, designating just how many properties must be damaged or lives lost before an event constitutes a disaster is a subjective and mostly arbitrary task. **As the focus of this report is to estimate the national economic cost of disasters, the use of a $10 million total cost threshold to define a disaster is thought to capture the significant natural hazard events from an economic cost viewpoint.** If the focus of this report were deaths and injuries caused by natural hazards, a different threshold might be more appropriate. The remainder of this report uses the terms 'event' and 'disaster' interchangeably, but it is important to remember that, within the context of the report, both terms refer to events conforming to the practical definition of disasters described above.

METHOD

A major difficulty in attempting to estimate the costs of past disasters is that much of the available data were collected for reasons unrelated to the task of estimating the total costs of disasters. Possibly the most consistent set of available data is that collected by the insurance industry. Insurance data are understandably directed at estimating the total cost of claims for each event. The data therefore exclude both those who are uninsured and the costs of damage not covered by insurance. Other data cover information needed for statutory reasons such as for reimbursements under the NDRA.

There are two comprehensive databases known to the BTE that contain estimates of the damage caused by disasters—EMATrack and PerilAus.

EMATrack is a database held by Emergency Management Australia. It contains estimates of both insured and total cost for events dating back to the 1800s.

PerilAus is a spatial database covering the last 100 years developed by the Natural Hazards Research Centre (NHRC) at Macquarie University. Rather than containing actual cost estimates, this database includes a damage index. The damage index relates only to building damage, with other important forms of damage excluded, (for example, it does not include building contents, cars, machinery, aircraft or crops). The damage index has the advantage of avoiding problems associated with different repair costs between tradespeople and across jurisdictions and the possible inflation of reconstruction costs in the aftermath of a disaster. It also reduces the impact of changing building values over time.

However, as the objective of this report was to obtain a more accurate and comprehensive picture of the costs of natural disasters, the EMA database was chosen as the basis of historical analysis. The advantages of this database and reasons for choosing it are outlined in greater detail in chapter 2. A comparison of the results derived in chapter 3 using the EMA database and published analysis from PerilAus is provided in chapter 5.

The BTE used the EMA database to identify the natural events that were relevant to the study and to obtain an initial estimate of their costs. It was not possible to re-estimate the costs of every event in the database. After the relevant events were selected, the costs of deaths and injuries were added. These are generally not included in estimates of disaster costs. The BTE has some expertise in this area, having developed methods for estimating the costs of injuries and fatalities in transport accidents.

This stage of the analysis also allowed a limited assessment of the relative contribution of large events, compared with small events, to the total costs of disasters. The larger events are generally better documented than the smaller ones, thus providing a means of assessing the costs recorded in the database. The cost details in these reports also allowed a comparison of the reported costs and the costs derived using the economic cost framework outlined in chapter 4.

The database was used to answers several questions. How much have natural disasters cost Australia? Which jurisdictions have been most affected by natural disasters? What types of disasters are most common or cause the most damage in Australia? What differences exist between States and Territories in terms of the impact and type of disasters?

The limitations of the data (discussed in chapter 2) mean that some error is inevitable when examining the historical costs of natural disasters and the overall estimate of disaster costs will be subject to a substantial band of uncertainty. The data limitations also mean that trend analysis is difficult and any conclusions drawn must be regarded as tentative.

An important task in the project was to define the cost elements relevant to estimating the overall costs of disasters. Previous studies of natural disasters used a wide range of methods of categorising costs and there appears to be little uniformity in what costs should be included. This report reviews the literature, and makes some suggestions on which costs should be included and how they might be estimated. Although the cost framework developed in this report provides some assistance in reviewing past studies, its main value is to provide a starting point for examination of the costs of future disasters. The research results in this report should therefore be seen as a first step. In the future, improved data collections and better methods of estimating costs should lead to more reliable results.

2

DATA SOURCES AND LIMITATIONS

This chapter examines the data sources used to estimate the historical costs of natural disasters, presented in chapter 3. The implications of any data limitations, along with the use of a threshold cost, are also discussed.

THE AUSTRALIAN EMA DATABASE

Information on Australian natural disasters was obtained from a database held by EMA (EMATrack). The advantages and limitations of the database are set out in table 2.1 and discussed further below.

The database is unique in that it includes not only all natural hazards but also technological and human-caused disasters. The NHRC PerilAus database is the only other database that covers all natural

TABLE 2.1 EMA DATABASE—ADVANTAGES AND LIMITATIONS

Advantages	Limitations
Covers all natural hazards.	Based on media reports.
Comprehensive—includes information on the disaster name, location, date, disaster type, State or Territory, deaths, injuries, insurance cost and total estimated cost (TEC).	The better reporting and recording of disasters in more recent years limits the extent to which conclusions can be drawn about trends.
Includes data records from the 1800s to the present.	Use of ratios between insurance cost and TEC is simplistic and likely to be subject to large error bands.
The database is regularly updated and maintained.	Indexation to 1998 prices is only approximate.

Source BTE analysis.

hazards[2]. Most other hazard databases are specific to a particular disaster type. The database is also comprehensive in that it contains a large amount of quantitative and qualitative information. For the purposes of this report, the BTE examined the following data fields: disaster name, location, date, disaster type, State or Territory, deaths, injuries, insurance cost and total estimated cost (TEC).

The database has been compiled using estimates from the Insurance Council of Australia (ICA), published disaster reports and reports in newspapers and other media. The database relies heavily on media reports and therefore the consistency of the media's approach and its definition of what constitutes a newsworthy event are a major limitation. There may be little or no consistency as to which disaster events are reported by the media in terms of the extent of damage or severity of the event. As a result, the database may be missing some disasters that did not receive media attention and it may include events that do not necessarily fall within the definition of a disaster used in this report. However, on the whole, the database is believed to include most natural disasters causing significant economic costs during the time period examined.

The EMA database contains records of disasters dating back to the 1800s; however, prior to the late 1960s, the data are somewhat piecemeal. Insurance data, on which the EMA TEC data are based, have been collected reliably only since 1967. To ensure the conclusions drawn from the data are as reliable and consistent as possible, the analysis in chapter 3 predominantly relates to the 1967 to 1999 period. Even within this period, the analysis is affected by the better reporting and recording of disasters in more recent years. This is particularly the case for smaller-scale events. As a result, any upward trend in the cost or number of events needs to be viewed with some caution. This problem is common to all analyses of natural disaster trends across the world. Loster (1999), in examining trends in large natural disasters, found that there was no significant trend in the number of events occurring either globally or in Europe for the period 1987 to 1998. Global data did show a slight upward trend, but this was attributed to the increased flow of information as a result of factors like the media revolution (Loster 1999, p. 4).

The TEC in the database was derived by multiplying insurance costs by factors derived by Joy (1991) (table 2.2). The result obtained by multiplying the insurance loss by the factor is an estimate of the

2 The main reason for not choosing this database was discussed in chapter 1—the costs of disasters are expressed using a building damage index rather than the actual dollar cost of damage.

total cost (direct plus indirect costs) of the disaster. The accuracy of these factors is difficult to gauge. The factors undoubtedly contain large error bands as a result of their simplicity.

TABLE 2.2 PROPORTION OF INSURED LOSS TO TOTAL LOSS

	Proportion of insured loss to total loss	Factor
Severe Storm	35%	3
Tropical Cyclone	20%	5
Flood	10%	10
Earthquake	25%	4
Bushfire (Wildfire)	35%	3

Source Joy (1991, p. 4.).

Certainly, for some events, the factors may overestimate costs, but for others the resulting TEC may be an underestimate. A difficulty with the factors is that it is not clear what costs are included. It is known that intangible costs are not included, but there are ambiguities regarding other costs. For example, it is not known if the application of the factors covers losses to agriculture, which can be substantial. In many cases, the factors are adjusted by EMA to reflect known information about particular disasters. In any case, the cost figures contained in the EMA database are the most comprehensive and consistent available source of historical natural disaster costs in Australia.

The cost estimates contained in the database are supposedly in 1998 dollars. However, after examining the estimates in greater depth, the BTE found that there was some confusion over the year in which dollars estimates were expressed. It appears that the figures have not been properly indexed to 1998 dollars. Instead, the ICA assumed that since the mid-1990s, the ICA figures on which the database relies have remained relatively unchanged due to the low inflation experienced during this period. While this is not the optimal approach, the BTE accepted the rationale that the estimates would not change significantly. Given the considerable margins of error already inherent in the data, it was reasonable to accept the estimates as being approximately equal to those expressed in 1998 dollars.

It was not possible to re-estimate the cost of each event in the database using the framework outlined in chapter 4, as the information required to do so simply does not exist. The only possible consistent modification to the cost estimates contained in the database was to add the costs associated with deaths and injuries[3].

For the reasons outlined in chapter 1, it was decided to limit the scope of the analysis to events with a TEC greater than or equal to $10 million. The implications of this threshold choice are discussed in the following section. This cost threshold was applied before the costs of deaths and injuries were added to the data. As a result, some events that caused substantial deaths or injuries (which would exceed $10 million if the BTE estimates derived in appendix I were applied) but caused little or no physical damage to property are not included in the analysis[4]. However, this is not regarded as a major limitation, as these costs are likely to be small in proportion to the total cost figures derived in chapter 3. While the inclusion of the costs of deaths and injuries before applying the threshold might increase the costs of some disaster types, it is not likely to substantially alter the relative order of the disaster types in terms of cost.

The cost estimates contained in chapter 3 are based on the EMA database and represent the total costs of natural disasters in Australia. Although there are limitations associated with the data, the information required to correct for these limitations was not available. As a result of these limitations, the total cost estimates contained in the database and used in chapter 3 are intended to be indicative only. Accordingly, the conclusions that can be drawn from the data must be regarded as tentative. Without more accurate and reliable data, definitive conclusions are not possible. In the absence of better information, the estimates presented in chapter 3 provide some guidance for decision-making and a reference point for further work to improve the quality of the data and test the findings of this report. The relationship between the database costs, the findings of previous disaster reports and the framework are discussed in chapter 5.

NATURAL DISASTERS COSTING LESS THAN $10 MILLION

The use of a threshold disaster cost in the analysis contained in this report could bias the results in a number of ways. A significant proportion of both the number of events and their total costs could be ignored. There is a hypothesis, often debated, that a larger

3 See appendix I for details.

4 For example, a landslide in September 1996 at Gracetown in Western Australia, which killed nine people and injured three others (AGSO, pers. comm., September 2000).

number of smaller events might add up to a greater cost than the fewer large events. Particular hazard types and geographic areas could be under or over represented. Any of these biases resulting from the threshold choice would lead to inaccurate conclusions. To investigate the possibility of any biases being introduced by the $10 million TEC threshold used throughout this report, the BTE examined a number of sample years of data for events costing less than $10 million. A sample of six years (1987–1989 and 1997–1999) was taken from the EMA database. The sample years chosen are believed to be reasonably representative of natural disasters across the time frame examined in this report. The sample includes data for:

- both recent and earlier years; and
- years in which major events occurred, (for example, 1999 Sydney hailstorm), and years in which there were no major events, (for example, 1987).

Number of events, TEC and insurance cost

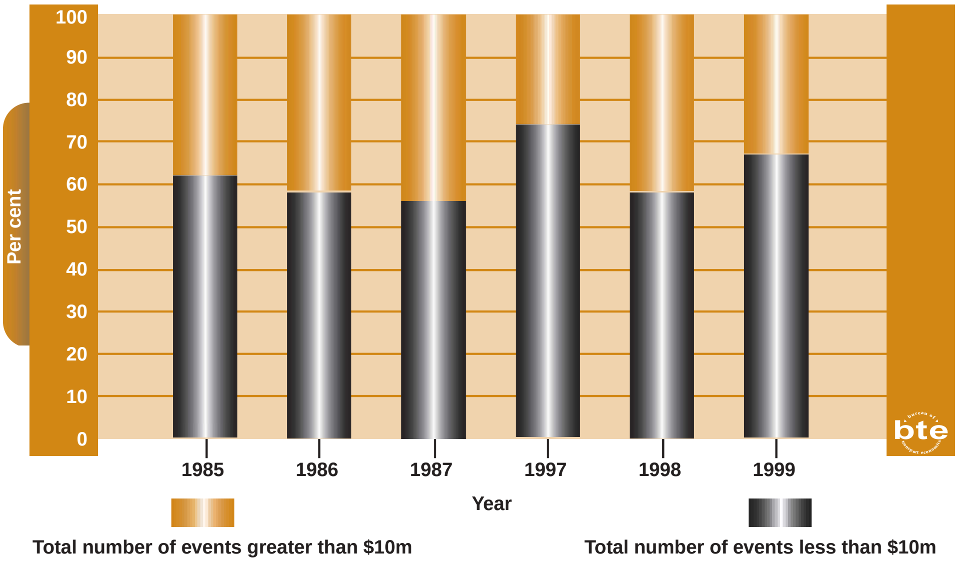
Table 2.3 shows the proportion of events costing less than $10 million in relation to the annual total number of events, TEC and insurance costs. The same information is shown graphically in figures 2.1 and 2.2.

TABLE 2.3 SAMPLE OF NATURAL DISASTERS LESS THAN $10M TEC

Year	Events <$10m TEC as a proportion of total number of events	Events <$10m TEC as a proportion of total TEC	Events <$10m TEC as a proportion of total insurance costs
		(per cent)	
1985	62	12	6
1986	58	4	4
1987	56	14	23
1997	74	16	7
1998	58	4	0
1999	67	2	0.2
Average	**62**	**9**	**7**

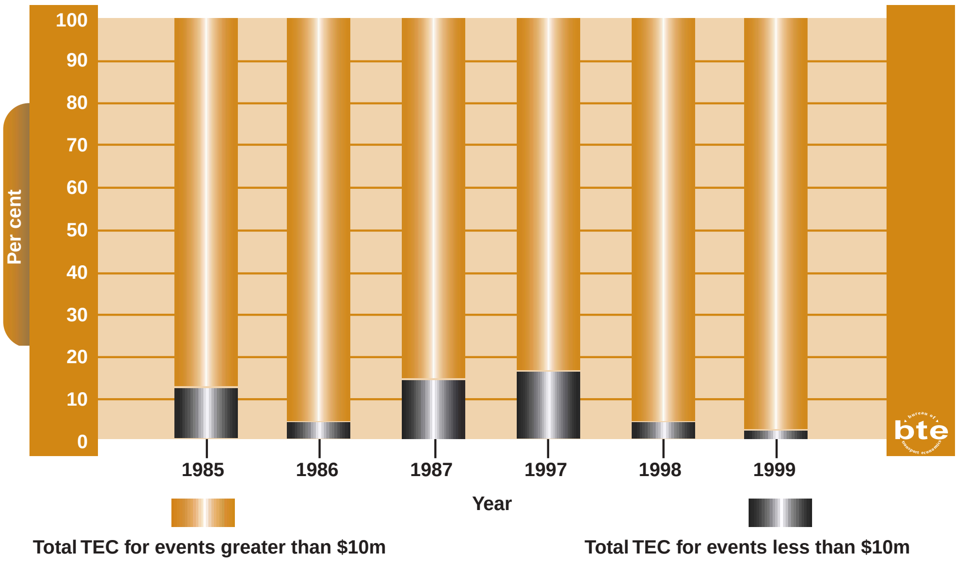
Source BTE analysis of Emergency Management Australia (EMATrack) database (unpublished).

FIGURE 2.1 $10 MILLION TOTAL ESTIMATED COST THRESHOLD—NUMBER OF EVENTS



Source BTE analysis of Emergency Management Australia (EMATrack) database (unpublished).

FIGURE 2.2 $10 MILLION TOTAL ESTIMATED COST THRESHOLD—TOTAL ESTIMATED COST



Source BTE analysis of Emergency Management Australia (EMATrack) database (unpublished).

As would be expected, the data show that events costing less than $10 million are a substantial proportion in terms of the number of events occurring (ranging from 56 to 74 per cent). On average, these events represent about 62 per cent of the number of events in the sample years. Importantly, however, for the purposes of this analysis, the data also show that while the number of events less than the threshold is typically significant, the total estimated cost associated with these events is not large in comparison with the total annual cost of natural disasters in the sample years. Events costing less than $10 million, on average, make up only around 9 per cent of the total estimated cost of natural disasters in these years. However, this proportion ranges from 2 to 16 per cent. If the costs of deaths and injuries had been added before the $10 million threshold was applied, the proportion of total cost contributed by smaller events (less than $10 million) would be less. In terms of insurance costs, the significance of events less than the threshold show greater variability, but average 7 per cent in the sample years.

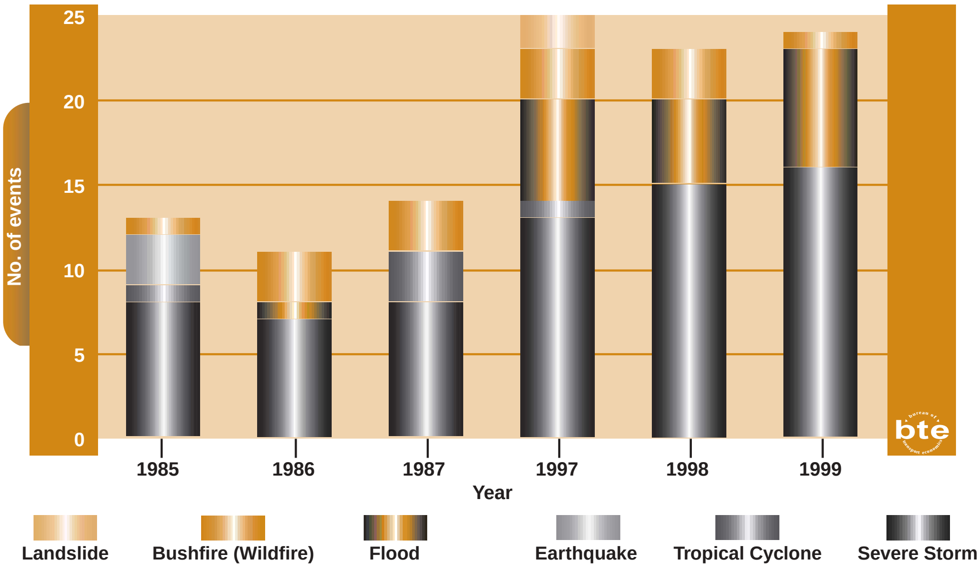
Remembering the limitations of the EMA database (in particular, the lack of reporting of smaller disasters), the hypothesis that a larger number of smaller events might add up to a greater cost than the fewer large events is not supported by the sample years of data. Within the context of the EMA database, the choice of the threshold therefore appears to be reasonably robust and adding around 10 per cent to the annual total estimated cost of natural disasters might be a reasonably approximate method to account for smaller, more frequent events. However, there is considerable debate surrounding the issue of the costs of smaller versus larger events. As a result, the BTE believes this analysis is reasonable within the confines of the EMA database used in this report, but further work would need to be done before any more generalised conclusions could be made concerning the hypothesis. The scope of this report is also an important consideration here, remembering that it is concerned with 'disasters' rather than all natural 'events' which may cause some damage.

Hazard type

Figure 2.3 illustrates the number of events, less than the threshold, according to the type of hazard. The figure shows that storms, floods and bushfires are the most common events falling short of the cost threshold. Similar disaster types (storms and floods) are also the most common for events exceeding the cost threshold. Figure 2.3 also illustrates the possibly better reporting of disaster information in more recent years, particularly for smaller events, with a significantly larger number of events less than $10 million in the 1990s than in the 1980s.

One interesting aspect of the analysis by type of hazard is the lack of data on landslides both above and below the $10 million TEC threshold. While the threshold choice appears to have a relatively

FIGURE 2.3 NUMBER OF EVENTS LESS THAN $10 MILLION TOTAL ESTIMATED COST BY HAZARD TYPE



Source BTE analysis of Emergency Management Australia (EMATrack) database (unpublished).

small impact on the total cost of disasters in the database, the absence of events such as landslides might have a larger impact if the focus were on deaths and injuries resulting from natural disasters.

Only one landslide (Thredbo in 1997[5]) satisfies the criteria for inclusion in the data set used in this report. Even without the $10 million TEC threshold, there would be only another two landslides included for the six sample years of data. The Australian Geological Survey Organisation (AGSO) maintains an Australian landslide database that indicates that there have been 47 landslides known to have caused 82 deaths and 52 injuries from 1842 until June 1999 (AGSO, pers. comm., November 1999). The database also

5 Although the Thredbo landslide is included as a natural disaster in this report, a human element was involved. The coroner investigating the disaster concluded that inadequate roadworks were the major factor in the inititation of the landslide (Hand 2000, p. 5).

shows that 56 landslides have caused damage to more than 200 buildings over the same period.

The nature of landslides as smaller, more frequent events, killing only one or two people at a time means that they are not widely reported. One of the most significant effects of landslides, and possibly the most important, is the disruption of transport when roads are affected as they frequently are. Landslides are estimated to have caused hundreds of millions of dollars worth of damage, but available data do not allow a more in-depth estimate of the costs of landslides in Australia. Simply applying the death and injury costs estimated in appendix I to the 82 deaths and 52 injuries resulting from landslides gives a cost of $111 million.

The BTE recognises the lack of landslide data as a limitation of the analysis and suggests that the inclusion of landslide cost data should be improved in the EMA database. It appears that while deaths and injuries associated with landslides are well documented, the costs of landslides are rarely quantified. The definitional issue of what constitutes a 'disaster' versus an 'event' is also relevant here. Many of the smaller, more frequent events, such as landslides, may not fit into the definition of disaster used throughout this report. Despite these problems, the BTE believes that this limitation does not pose a large problem in terms of the key focus of this report, which is the economic cost of natural disasters.

Geographic distribution

The BTE also found that events below the threshold did not differ significantly from the larger events in terms of geographic distribution. As expected, and commensurate with events greater than the threshold, New South Wales and Queensland dominate in terms of both the number and costs of events, with Western Australia and Victoria the next most affected States.

Overall, while the use of a $10 million total cost threshold may place some limitations on the analysis contained in this report, given the already indicative nature of the database, the BTE believes it does not substantially affect the conclusions reached.

3

ESTIMATING THE COSTS

This chapter uses the EMA data discussed in the previous chapter to produce estimates of the costs of natural disasters in Australia over the last 33 years. The estimates are for the direct and indirect costs. As the costs in the EMA database are based on insurance losses, these are also included as a separate item in the analysis. The intangible costs of deaths and injuries are added to the EMA estimates in the final part of the chapter. Caution needs to be exercised when interpreting the results of the analysis because of the data limitations outlined in the previous chapter.

Some estimates of New Zealand disaster costs can be found in appendix II.

COSTS OF NATURAL DISASTERS IN AUSTRALIA

The total cost of natural disasters in Australia over the period 1967 to 1999 was estimated to be $36.4 billion in 1999 prices. This translates to an average annual cost of disasters of $1.10 billion in 1999 prices. The average annual cost for the period from 1980 to 1999 was $1.13 billion in 1999 prices. While this is a substantial cost, it needs to be put into perspective: road crashes in Australia cost almost $15 billion in 1996 (BTE 2000) while aviation accidents in the same year cost $112 million (BTE 1999a).

The impact of natural disasters in Australia varies considerably from year to year (figure 3.1). A few large events dominate the overall cost for the period 1967 to 1999. These include Cyclone Tracy (1974) (12 per cent of the total cost for the period), the Newcastle Earthquake (1989) (13 per cent) and the Sydney hailstorm (1999) (6 per cent). As a result, there is no clearly identifiable trend in the total annual cost of natural disasters over the 33-year period.

These three large events clearly have a substantial effect on the annual average costs of natural disasters. If these events are ignored, the average annual costs of natural disasters is still a sizeable

$765 million in 1999 prices. This figure may be a more reliable estimate of the losses that can be expected in an average year.

The annual totals are volatile. The standard deviation, which is a measure of the variation in the annual figures, is $1474 million if the three large events are included and $618 million if the three large events are excluded from the calculations. Clearly, the three large events contribute a substantial amount to the volatility of the annual totals.

The average annual costs without the large events can be interpreted as the cost that can be expected from natural disasters in any year. However, because of the volatility of the annual cost, it is more useful to specify a range in which the annual cost is likely to fall. The average plus twice the standard deviation gives the approximate range into which 90 per cent of annual costs can be expected to fall. That is, annual costs can be expected to be up to $2000 million in years without extreme events.

The EMA data suggest that in years with extreme events, the total cost could be up to $4050 million. However, extreme events, by their nature, occur infrequently. The three that have occurred over the last 33 years are unlikely to be a useful guide to future costs of extreme events—the future costs could be much higher.

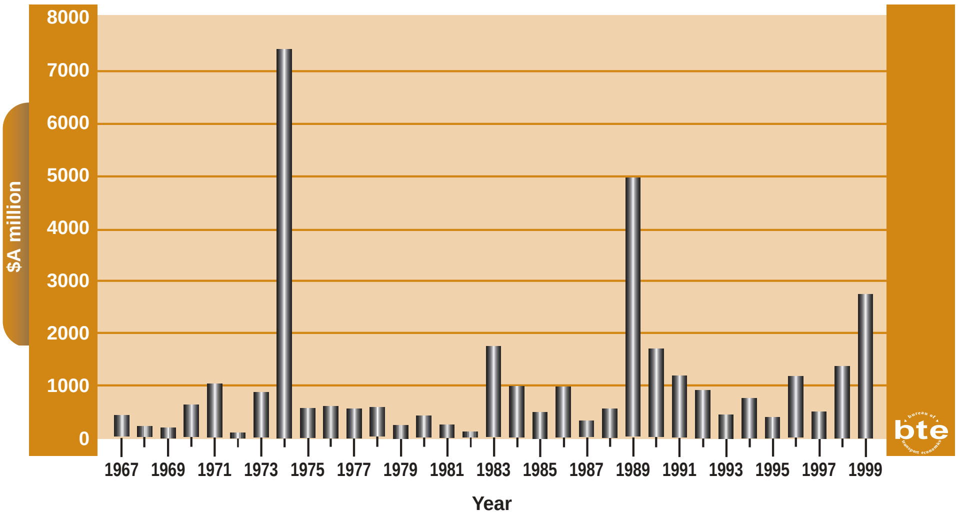
It is interesting to note that it is possible to derive an increasing or decreasing trend in costs depending on the time frame chosen. For example, it is possible to conclude that during the early 1990s (1989–1994) the cost of natural disasters was falling, while over the period from 1995 to 1999 the trend was increasing. This example serves to illustrate the need for caution when drawing conclusions from a short time series.

Although there is no statistically significant trend in the cost of disasters, there is a possibility that, as a proportion of GDP, a trend may be evident. To test this hypothesis, the BTE analysed the trend in annual disaster costs as a proportion of GDP over the period 1967 to 1999. The analysis found that, although the ratio tended to decrease over time, the trend was statistically insignificant and the statistical measure for goodness of fit[6] was negligible.

Figure 3.2 illustrates the total cost of disasters in Australia for each of the past four decades. The small total for the 1960s is probably

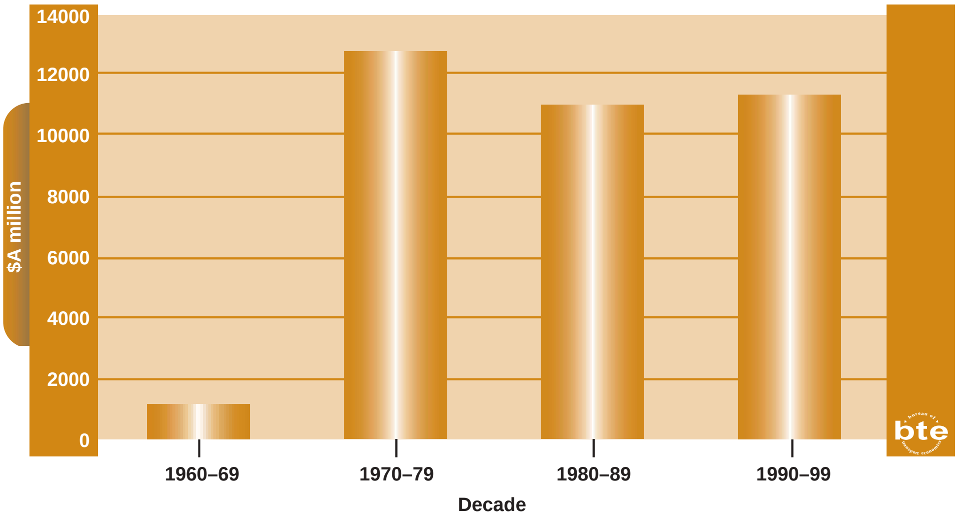
6 Goodness of fit is measured by R-squared which varies from 0 for no fit at all, to 1 when the fit is perfect. R-squared for the relationship fitted to the GDP data was 0.0037.

FIGURE 3.1 ANNUAL TOTAL COST OF DISASTERS IN AUSTRALIA, 1967–1999



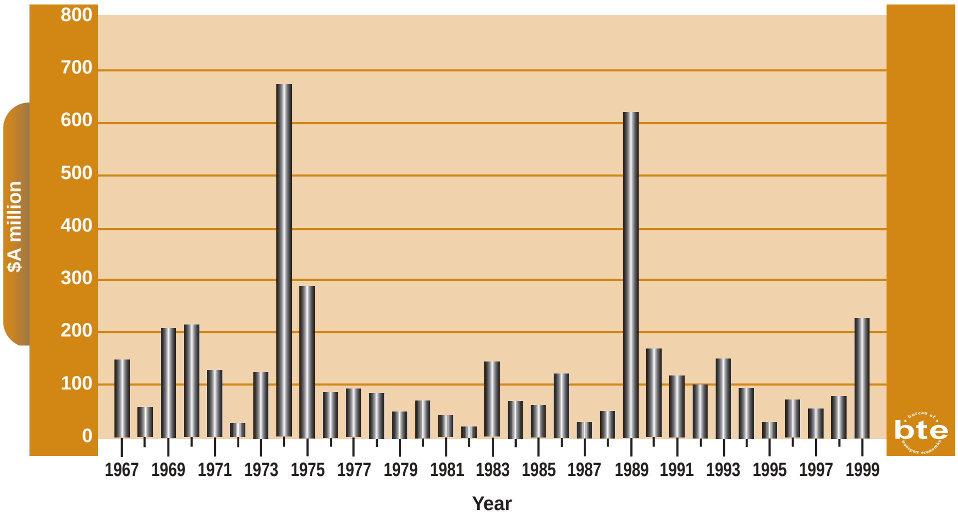
Note Estimates are in 1998 dollars.
Source BTE analysis of Emergency Management Australia (EMA Track) database (unpublished).

FIGURE 3.2 AUSTRALIAN NATURAL DISASTER COSTS BY DECADE, 1960–1999



Note Estimates are in 1998 dollars.
Source BTE analysis of Emergency Management Australia (EMA Track) database (unpublished).

FIGURE 3.3 AVERAGE COST PER EVENT, 1967–1999



Note Estimates are in 1998 dollars.
Source BTE analysis of Emergency Management Australia (EMA Track) database (unpublished).

due to poor recording of disaster events during that decade compared with more recent decades. Over the last three decades the cost of recorded disasters has shown little variation (ranging between $11 billion and $13 billion). The decade of the1970s is the most significant in terms of total costs of disasters in Australia.

The average cost of individual disasters appears to be trending slightly downwards over the period 1967 to 1999 (figure 3.3). However, the trend is not statistically significant. Although three clear spikes dominate figure 3.1, the influence of the Sydney hailstorms in 1999 was relatively less pronounced, as 10 of the 12 events in 1999 had costs of less than $100 million.

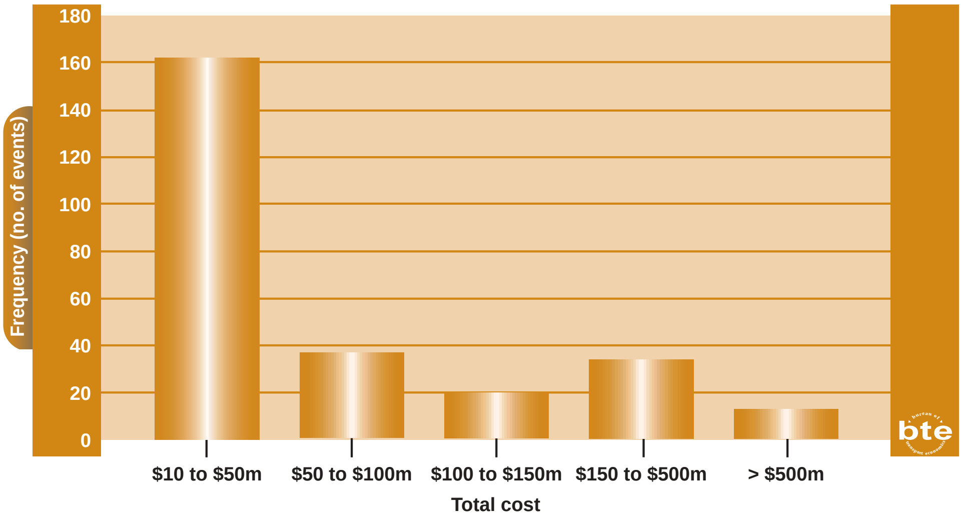
The total cost of most disasters is between $10 million to $50 million. Figure 3.4 shows that more costly events are much less common. Despite the large number of events in the $10 million to $50 million range, the sum of total costs of these events remains small (around 10 per cent of total cost) in comparison to the costs of the infrequent extreme events. (Again, it is worth bearing in mind that many smaller disasters go unrecorded).

Insurance costs

The total insurance cost of disasters between 1967 and 1999 was $9.6 billion, with an average annual cost of $290 million (figure 3.5).

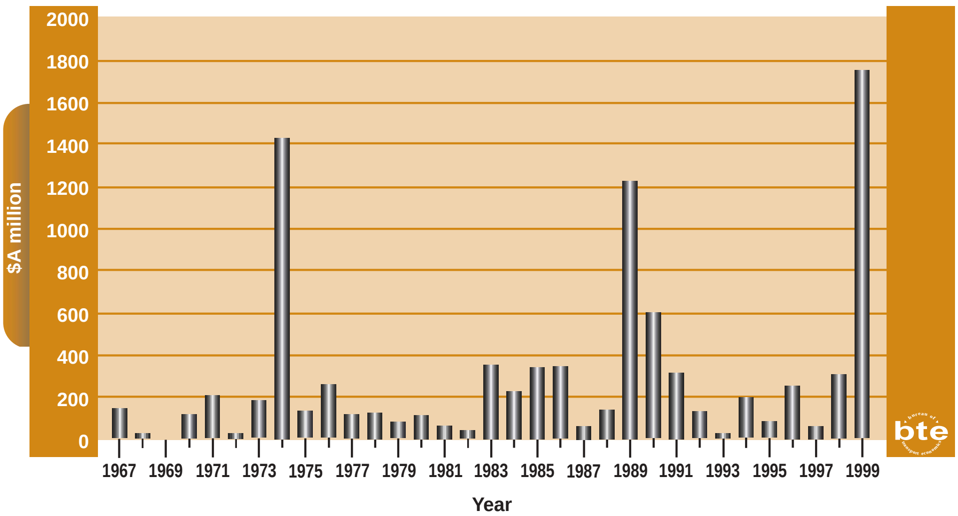
The average annual insurance cost for the period 1980 to 1999 was $334 million. This could reflect increasing costs, improved reporting standards or greater insurance coverage. Although there appears to be an upward trend in insurance costs, the trend is not

FIGURE 3.4 DISTRIBUTION OF DISASTERS (FREQUENCY) BY COST, 1967–1999



Source BTE analysis of Emergency Management Australia (EMA Track) database (unpublished).

FIGURE 3.5 ANNUAL INSURANCE COST OF DISASTERS IN AUSTRALIA, 1967–1999



Note Estimates are in 1998 dollars.
Source BTE analysis of Emergency Management Australia (EMA Track) database (unpublished).

statistically significant. The spikes that are evident in figure 3.1 also occur in figure 3.5. However, the relative size of the spikes has changed, with the 1999 Sydney hailstorm having the largest impact compared with Cyclone Tracy (1974) and the Newcastle earthquake (1989). This reflects the varying degree of insurance coverage between the different disaster types. Furthermore, a comparison between average insurance cost per event and total cost per event (figure 3.3) would result in a pronounced insurance cost spike for 1999, due to the impact of the Sydney hailstorm and high insurance costs associated with that event.

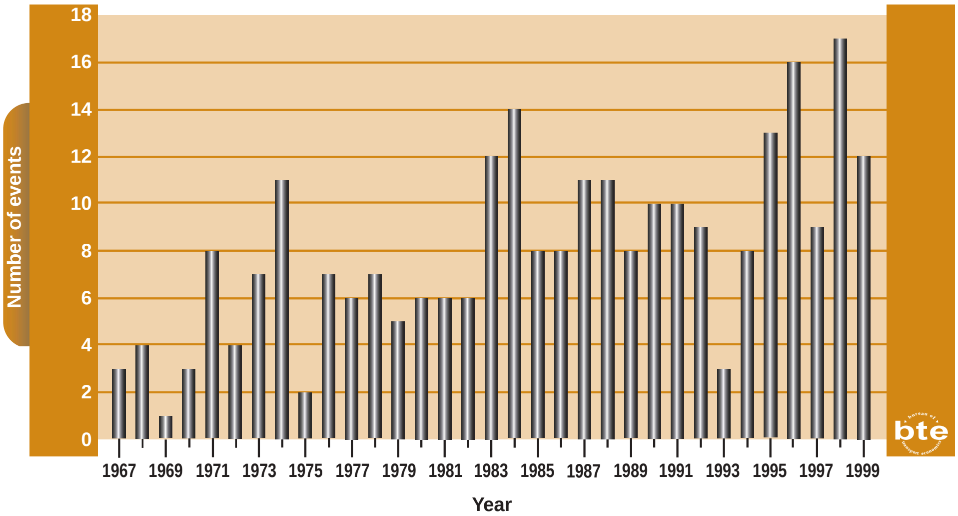
THE NUMBER OF NATURAL DISASTERS IN AUSTRALIA

The number of events counted depends on how an event is defined. For example, widespread flooding could be counted as a single event or as many events if defined in terms of towns or local government areas affected. The EMA database generally treats widespread flooding as a single event. Similarly, bushfire events such as the Ash Wednesday fires in 1983 are treated as a single event even though there were a large number of individual fires in two states.

Given these observations about the definition of an event, the EMA database has a total of 265 natural disasters with a total cost over $10 million per event recorded between 1967 and 1999. The data series shows that Australia faces approximately eight disasters with a total cost per event greater than $10 million on average each year. However, since 1980, the average number of disasters recorded has been approximately 10 events per year. Figure 3.6 also show that 1998 was the worst year, with 17 events recorded over the $10 million threshold. The upward trend evident in the figure is statistically significant. This increase could be explained by a number of factors, such as:

- an actual increase in the number of disasters in Australia;
- better reporting and recording of events, particularly smaller events, as a result of improved communications and attention from media and / or different levels of government; and / or
- a larger and more concentrated population, especially in coastal regions. It is possible that the numbers of events with the potential to cause substantial damage has not changed significantly, but the number of people in the vulnerable areas has increased. People and property are therefore more likely to be affected by natural hazards.

FIGURE 3.6 NUMBER OF NATURAL DISASTERS IN AUSTRALIA, 1967–1999



Source BTE analysis of Emergency Management Australia (EMA Track) database (unpublished).

Stratified analysis

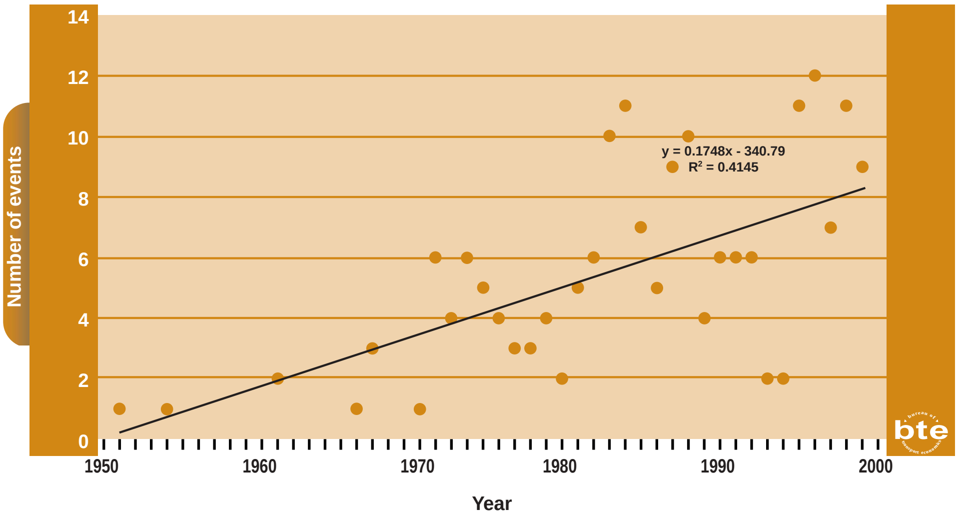
If the reporting of events is a factor in the significant increase in the number of events, it is likely that there has been improved reporting for smaller events. The BTE stratified the events into smaller subsets and examined the trend in each subset in order to identify any difference in trends. It was found that only two of these subsets were statistically significant at the 5 per cent level of significance: $10 million to $75 million and $75 million to $150 million (figures 3.7 and 3.8). However, the subset $75 million to $150 million was less significant than the $10 million to $75 million subset.

These results provide some support for the hypothesis that the smaller events were under-reported in the earlier years of the period reviewed. Although the selection of the subsets was to a large extent arbitrary, the lower cost range remained statistically significant with changes in the boundary from $75 million to $50 million and to $100 million.

Effect of population increase

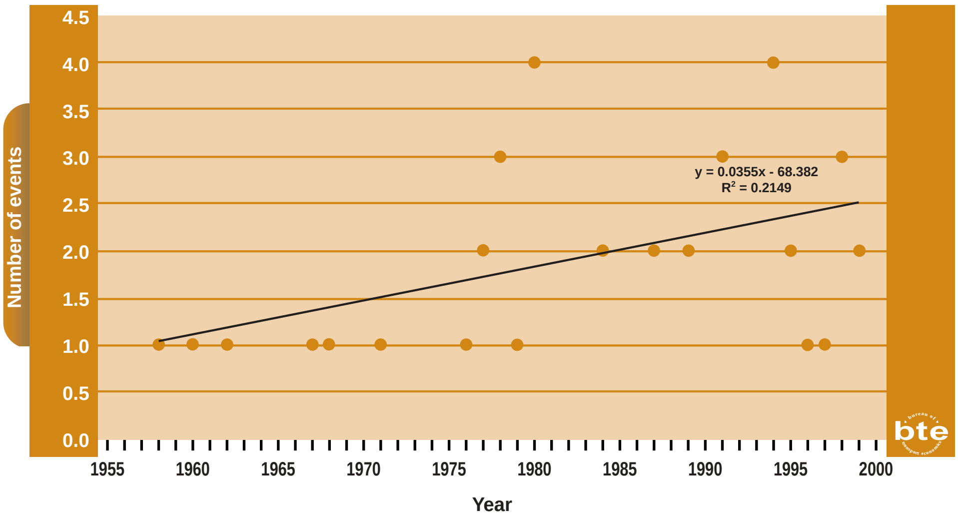
One of the factors that may contribute to an increase in the number of events recorded in Australia is the change in population. An increasing population in hazardous areas would increase the likelihood

FIGURE 3.7 NATURAL DISASTERS RECORDED IN AUSTRALIA WITH A TOTAL COST BETWEEN $10 MILLION AND $75 MILLION



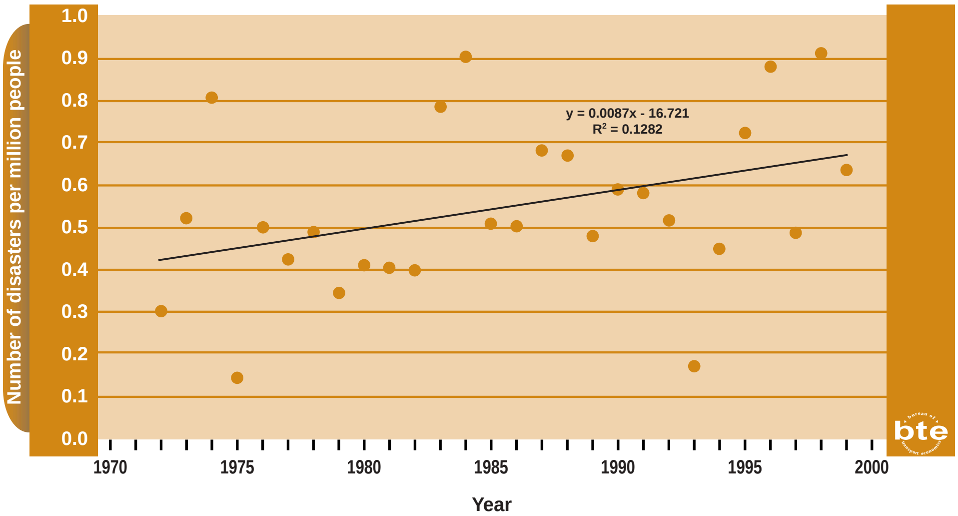
Source BTE analysis of Emergency Management Australia (EMA Track) database (unpublished).

FIGURE 3.8 NATURAL DISASTERS RECORDED IN AUSTRALIA WITH A TOTAL COST BETWEEN $75 MILLION AND $150 MILLION



Source BTE analysis of Emergency Management Australia (EMA Track) database (unpublished).

FIGURE 3.9 NUMBER OF DISASTERS PER MILLION PEOPLE, 1972–1999



Source BTE analysis of Emergency Management Australia (EMA Track) database (unpublished).

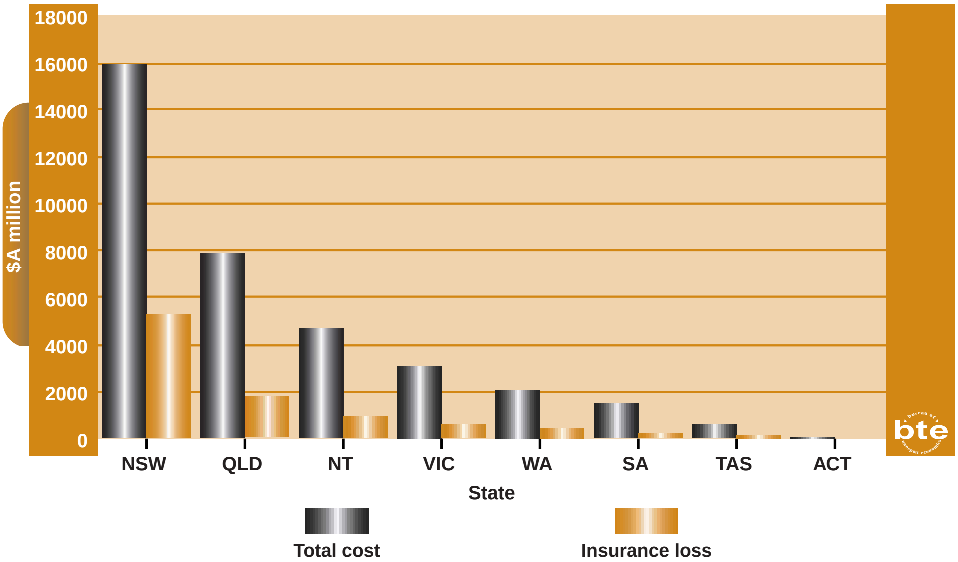
of an event causing damage and being reported. Therefore, if the percentage increase in the population is greater than the overall change in the number of events being recorded, then the actual trend in the number of events may be downwards. To test the hypothesis, the BTE examined the trend in the number of events per million people from 1972. A downward or flat curve (that is, the slope of the curve not being statistically significant) would be strong evidence that the population effect was a large part of the increase in the number of recorded disasters.

The regression analysis indicates a positive trend (figure 3.9). The number of events per million people was found to be statistically insignificant at a 5 per cent level of significance, but statistically significant at the 10 per cent level of significance. This suggests that increasing population is likely to have partly contributed to the increase in the number of reported events, but it does not provide a complete explanation.

ANALYSIS BY STATE AND TERRITORY (AUSTRALIA)

The overall cost of natural disasters in Australia and the impact on the individual States and Territories are heavily influenced by the incidence of extreme events. New South Wales and Queensland recorded the highest costs associated with disasters ($16.0 billion and $7.9 billion respectively) with their combined total representing 66 per cent of the total cost (figure 3.10). The cost of disasters in New South Wales was approximately double that of Queensland, reflecting the influence of extreme events, such as the Newcastle earthquake and the Sydney hailstorm. The influence of these few extreme events is also illustrated when comparing the number of events in the two states: the number of events in New South Wales (83) was only marginally more than Queensland (71) (figure 3.11).

FIGURE 3.10 DISASTERS COSTS BY STATE AND TERRITORY IN AUSTRALIA, 1967–1999



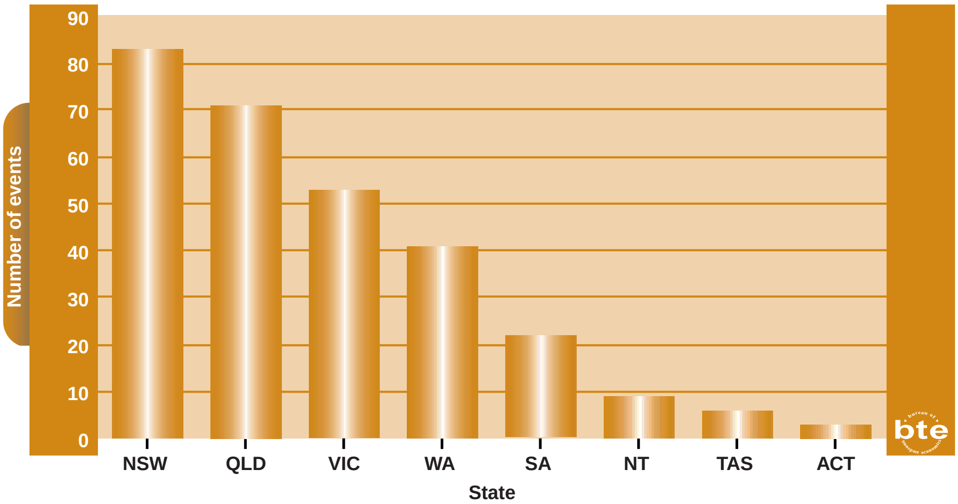
Note According to the database, there were a total of 265 disasters that struck Australia between 1967 and 1999. However, several of these events had an impact on more than one state. When the BTE separated these events and apportioned a cost to each of the States, the number of events in the database rose to 288.

Estimates are in 1998 dollars.

Source BTE analysis of Emergency Management Australia (EMATrack) database (unpublished).

Furthermore, there is a larger gap between the insurable costs in New South Wales and Queensland. In Queensland, only 23 per cent of the total cost was covered by insurance, whereas in New South Wales, 33 per cent of the total cost was covered by insurance. The difference is mostly due to the high insurance cover of the Sydney hailstorm. If the insurable cost of the Sydney hailstorm ($1.7 billion) were removed, the gap for New South Wales would be similar to that of Queensland. However, the difference between the insurance

FIGURE 3.11 NUMBER OF DISASTER EVENTS BY STATE AND TERRITORY, 1967–1999



Source BTE analysis of Emergency Management Australia (EMATrack) database (unpublished).

and total cost in the EMA database is largely determined by the ratio of insured losses to total costs as estimated by Joy (1991).

The Northern Territory recorded the third highest total cost for natural disasters (with 13 per cent of total cost) despite suffering a small number of disasters (nine). This is a result of the high cost of Cyclone Tracy ($4.2 billion of the $4.7 billion total) dominating the Northern Territory data. If the impact of Cyclone Tracy were removed, the Northern Territory would move below Tasmania in figure 3.10.

Excluding the Ash Wednesday bushfires (1983) and several large floods in the seventies and in 1995, Victoria has generally faced small to medium events (between $10 million and $60 million). As a result, Victoria ranked fourth (approximately 9 per cent) in terms of total cost of natural disasters, and third (18 per cent) in terms of the number of events. Figures 3.10 and 3.11 also show that Western Australia suffered a relatively large number of events (41 or 14 per cent of disasters recorded), but these events only account for 5.8 per cent of the total cost. This is probably because the coastline most vulnerable to cyclones is sparsely populated.

South Australia ranked sixth (4.2 per cent) in terms of cost and fifth (8 per cent) in terms of the number of events. Two significant events that affected South Australia, and in particular Adelaide, were the Adelaide Hills floods (1992) and the Ash Wednesday bushfires

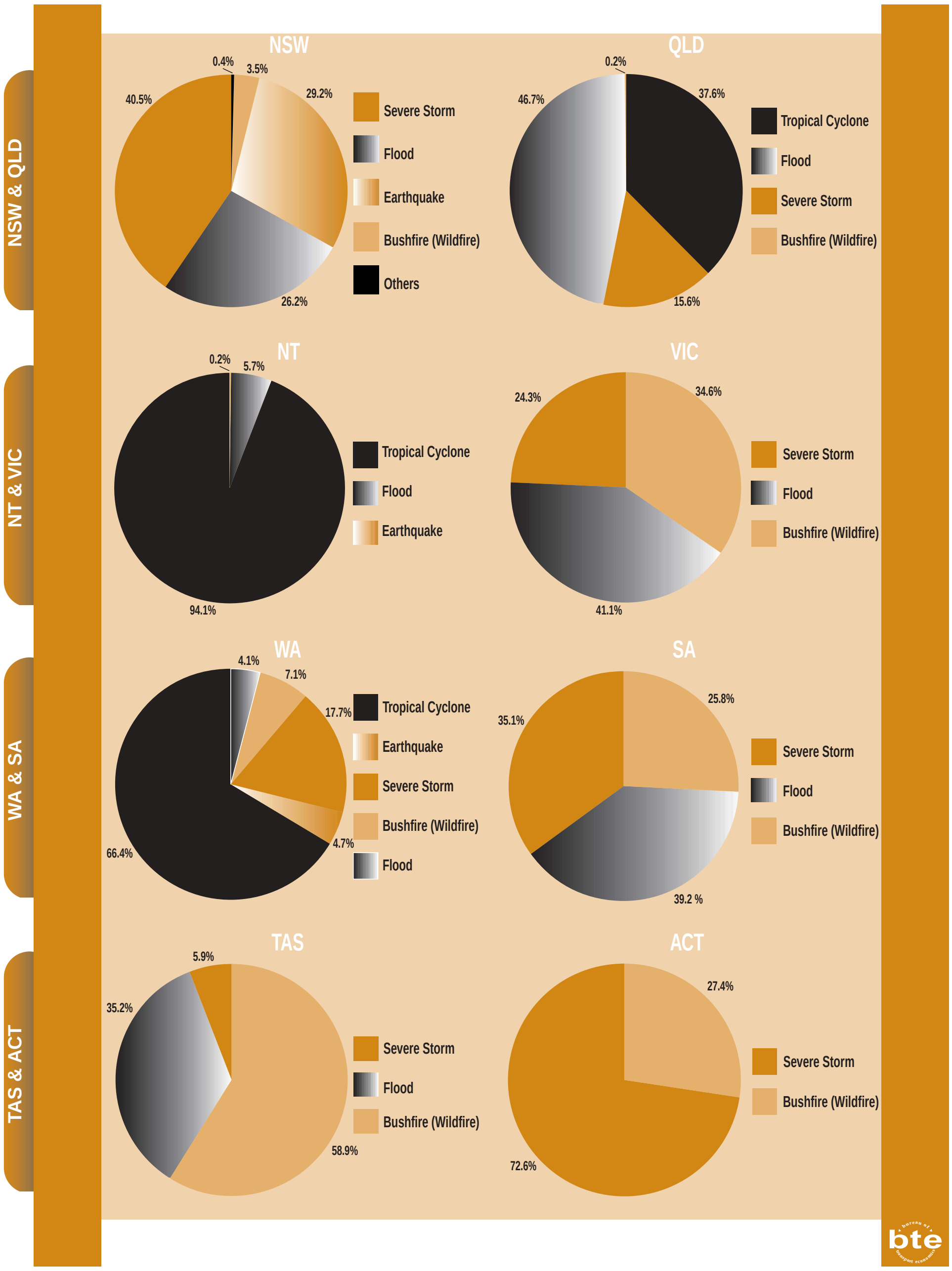
(1983). The impact of disasters in Tasmania (1.7 per cent) and Australian Capital Territory (0.02 per cent) represent a small proportion of the total costs in Australia. Furthermore, only 3 per cent of the total number of disasters recorded in Australia occurred in these two jurisdictions. No events were recorded for Norfolk Island or the Indian Ocean Territories.

The ACT had no disasters wholly within its jurisdiction that met the $10 million threshold. A proportion of the cost of disasters that straddled the ACT / New South Wales border was allocated to the ACT. Because the ACT has a small area, it has a correspondingly low probability of being in the path of a major event. If a major event, such as a severe storm, were to occur in the ACT, the damage bill could be similar to that incurred in other large cities.

Insurance costs generally accounted for between 16 and 33 per cent of the total cost of natural disasters. However, there are two factors that influence the large gap between the insurance and total cost. Firstly, the ratio of insurance to total cost is influenced by the relative coverage provided by insurance companies. For example, the limited coverage provided by insurance companies for flooding translates into a low ratio of coverage for flood prone States. Secondly, the gap is heavily influenced by the use of Joy's ratio of insurance to total losses employed in the EMA database. The only State in Australia to be affected by each of the major disaster types analysed between 1967 and 1999 was New South Wales. However, with the exception of landslides, all other disaster types over the $10 million threshold were recorded in Western Australia. The impact of extreme events has a significant effect on the proportion of total cost contributed by the different disaster types. The influence of these extreme events is evident in New South Wales (hailstorm and Newcastle earthquake) and Northern Territory (Cyclone Tracy).

Severe storms have the largest impact in New South Wales (40.5 per cent), and they also represent a large proportion of the total costs for South Australia (35.1 per cent), Victoria (24.3 per cent) and Queensland (15.6 per cent). Floods had a major impact in three states. The single biggest impact occurred in Queensland (46.7 per cent) followed by Victoria (41.1 per cent) and New South Wales (26.5 per cent). As a proportion of total cost, cyclones have the greatest impact in the Northern Territory (94.1 per cent), Western Australia (66.4 per cent) and Queensland (37.6 per cent). Finally, the impact of bushfires, as a proportion of total cost, appears to have the greatest impact on the southern states of Australia. In Victoria, South Australia and Tasmania the cost of bushfires represented more than 25 per cent of the total cost, while in

FIGURE 3.12 COSTS BY TYPE OF DISASTER AND STATE AND TERRITORY, 1967–1999



Source BTE analysis of Emergency Management Australia (EMATrack) database (unpublished).

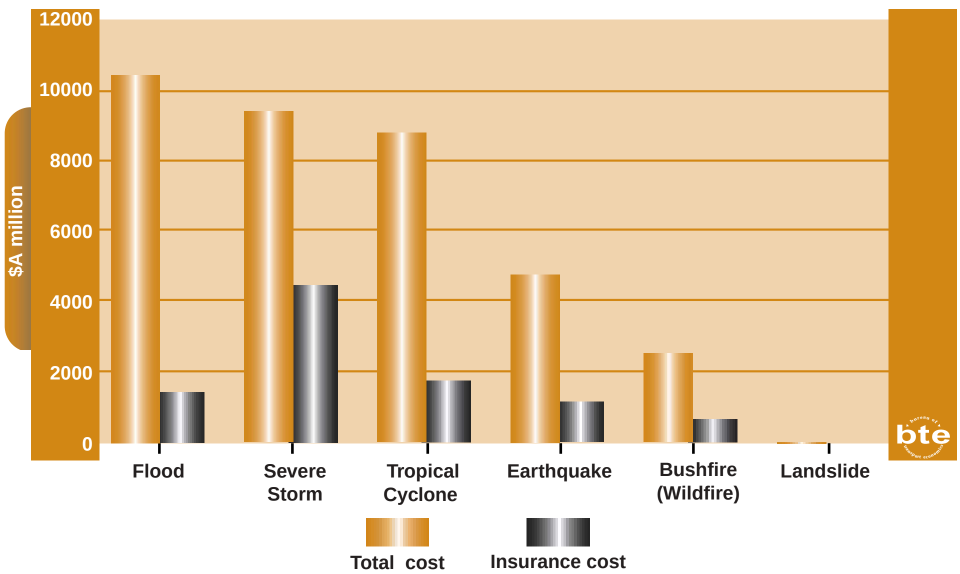
Queensland, New South Wales and Western Australia the total cost of bushfires was less than 10 per cent.

Some caution is required when interpreting the snapshot of disaster types by State and Territory (figure 3.12) due to the static nature of the analysis and the influence of extreme events. The actual breakdown of the total costs between the various disaster categories depends on the time period chosen. For example, if the analysis were completed prior to 1989, floods would have been more dominant in New South Wales because the impact of the Newcastle earthquake would not have been included. An extreme event in the future could radically change the proportions in figure 3.12.

ANALYSIS BY DISASTER TYPE

Figure 3.13 shows the breakdown of total and insurance costs by the type of natural disaster between 1967 and 1999. The figure illustrates the six most significant disaster types in terms of costs, but does not include all natural disasters that fall within the scope of this report. For example, events such as tsunami do not have a

FIGURE 3.13 TOTAL AND INSURANCE COSTS BY DISASTER TYPE, 1967–1999



Note The insurance cost of the landslide at Thredbo in 1997 has a nil entry in the database. The reason for this is that landslides in Australia are not normally covered by insurance (AGSO, pers.comm, June 1999).

Estimates are in 1998 dollars.

Source BTE analysis of Emergency Management Australia (EMATrack) database (unpublished).

TABLE 3.1 AVERAGE ANNUAL COST OF NATURAL DISASTERS BY STATE AND TERRITORY

	Average Annual Cost ($ million)						
State	Flood	Severe Storms	Cyclones	Earthquakes	Bushfires	Landslide	Total
NSW	128.4	195.8	0.5	141.2	16.8	1.2	484.1
QLD	111.7	37.3	89.8	0.0	0.4	0.0	239.2
NT	8.1	0.0	134.2	0.3	0.0	0.0	142.6
VIC	38.5	22.8	0.0	0.0	32.4	0.0	93.6
WA	2.6	11.1	41.6	3.0	4.5	0.0	62.7
SA	18.1	16.2	0.0	0.0	11.9	0.0	46.2
TAS	6.7	1.1	0.0	0.0	11.2	0.0	18.9
ACT	0.0	0.1	0.0	0.0	0.0	0.0	0.2
Total	314.0	284.4	266.2	144.5	77.2	1.2	1087.5
Proportion of total (%)	28.9	26.2	24.5	13.3	7.1	0.1	100.0

Note Figures may not add to totals due to rounding.

Source BTE analysis of Emergency Management Australia (EMATrack) database (unpublished).

significant cost compared to the disaster types examined in the following analysis.

In Australia, between 1967 and 1999 floods (29 per cent of the total cost), followed by severe storms (26 per cent) and tropical cyclones (24 per cent) have been the most costly natural disaster types (figure 3.13 and table 3.1). However, the prominence of storms is heavily influenced by the Sydney hailstorm.

Australia has been affected by a number of earthquakes, but the greatest impact was felt with the Newcastle earthquake in 1989. It accounts for approximately $4.5 billion (94 per cent) of the total cost of earthquakes. Other earthquakes in Australia have occurred in sparsely populated areas.

The costs ($2.5 billion) associated with bushfires represent a relatively small proportion (7.1 per cent) of the total disaster costs. However, as discussed later in this chapter, bushfires are the most hazardous type of disaster in terms of deaths and injuries.

Landslides, at a total cost of $40 million, were the least costly category, representing only 0.1 per cent of the total cost of disasters. The economic impact of landslides would not have been included in this analysis had the Thredbo disaster not occurred, as it was the single largest event of its type in Australia and no other landslides had costs greater than $10 million. However, as mentioned in chapter 2, landslide cost data are lacking in Australia, especially the indirect costs of transport disruption.

Figure 3.13 also illustrates to some extent the different degrees of availability of insurance across the disaster types, with insurance covering only a small proportion of the costs of floods and a larger proportion for severe storms. However, the total costs of disasters recorded in the EMA database are largely derived from ratios of total cost to insurance cost published by Joy (1991). Thus, the relationship between insurance cost and total cost reflects to a large degree, the method of constructing the database rather than actual measurement.

Among the major disaster types, severe storms were the most frequent, with 112 recorded events or approximately 42 per cent of all disasters recorded over the $10 million threshold. Floods were the next most frequent, with 77 events occurring, followed by cyclones with 46 events. Earthquakes account for only about 2 per cent of the total number of natural disasters occurring in Australia. However, because of the significance of the Newcastle earthquake, they account for approximately 13 per cent of the total cost. The top three disaster types accounted for approximately 89 per cent of all natural disasters recorded in Australia between 1967 and 1999 (figure 3.14).

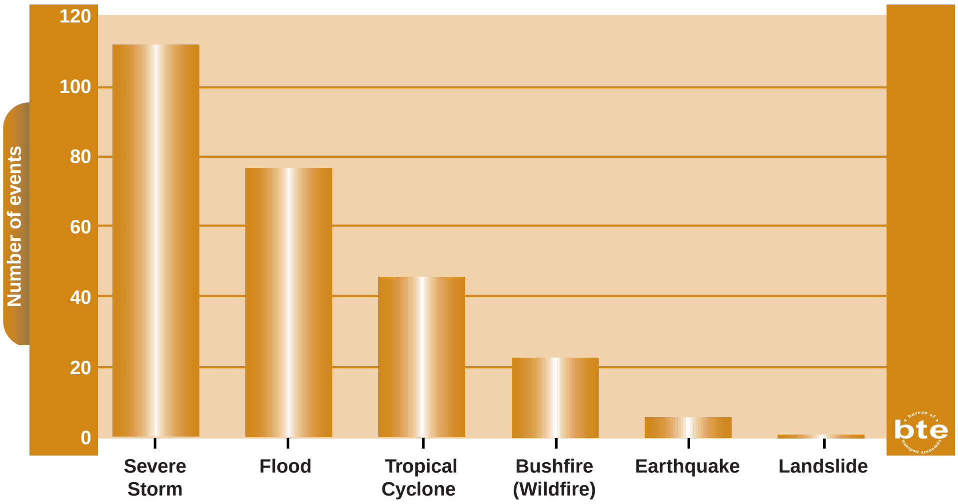
Each disaster type is now examined in more detail in order to identify any trends.

Floods

Since 1967, floods costing more than $10 million each have resulted in a total cost of $10.4 billion. The worst year was 1974, with a total cost of $2.9 billion (figure 3.15). There are no statistically significant trends in the flood costs during this period. The average annual cost of floods in Australia has been approximately $315 million since 1967.

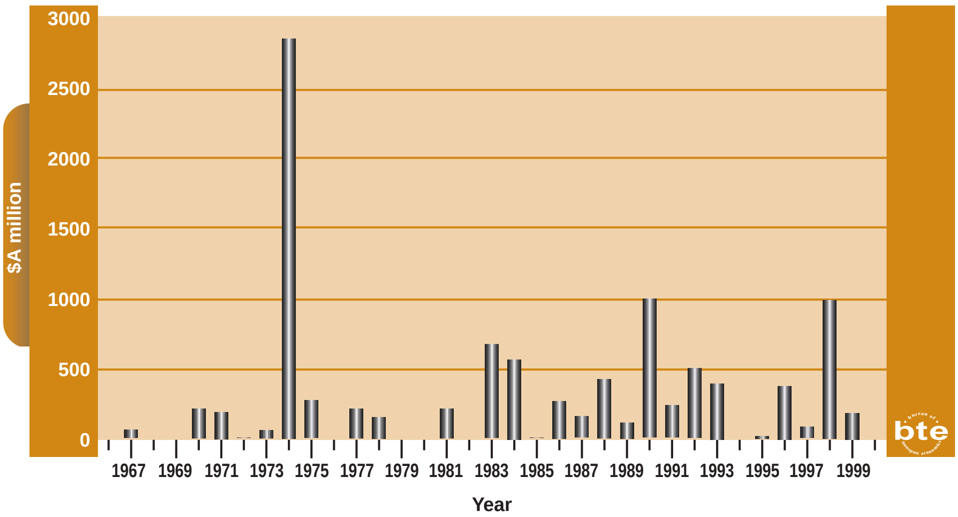
The total cost of floods by decade is illustrated in figure 3.16. The low cost of floods prior to 1970 may have been a result of the lack of reporting of smaller events. However, the 1950s had a high incidence of severe flooding and if good cost data were available, the inclusion of the 1950s data could be expected to show comparable totals to the 1970s (J. Handmer, pers. comm. October 2000). For the past three decades, the total cost of floods has

FIGURE 3.14 NUMBER OF EVENTS BY DISASTER TYPE, 1967–1999



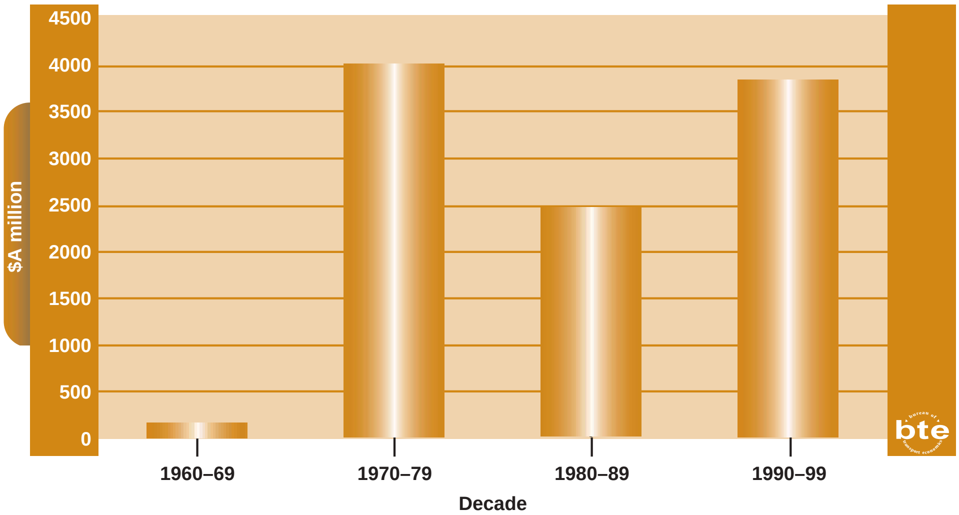
Source BTE analysis of Emergency Management Australia (EMATrack) database (unpublished).

FIGURE 3.15 ANNUAL COST OF FLOODS IN AUSTRALIA, 1967–1999



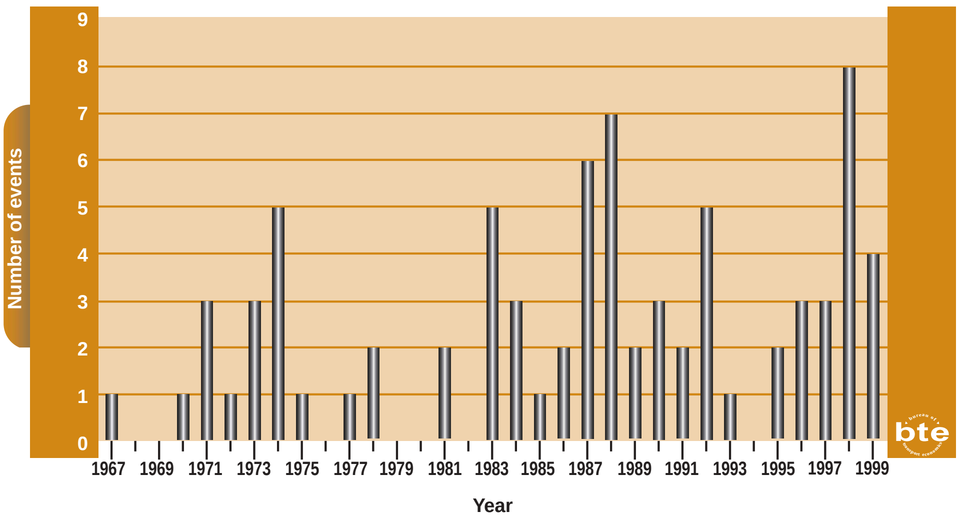
Note Estimates are in 1998 dollars.
Source BTE analysis of Emergency Management Australia (EMA Track) database (unpublished).

FIGURE 3.16 TOTAL COST OF FLOODS BY DECADE, 1960–1999



Note Estimates are in 1998 dollars.
Source BTE analysis of Emergency Management Australia (EMA Track) database (unpublished).

FIGURE 3.17 ANNUAL NUMBER OF FLOODS IN AUSTRALIA, 1967–1999



Source BTE analysis of Emergency Management Australia (EMA Track) database (unpublished).

ranged between $2.5 billion and $4 billion per decade. Flooding costs in the 1990s were at comparable levels to the 1970s.

Since 1967, the number of floods has trended upwards, with the trend being statistically significant (figure 3.17). As previously discussed, this is likely to be at least partly due to an improvement in reporting methods. During the period from 1967 to 1999, two significant floods affected Australia, on average, each year. Overall, since 1967, Australia has recorded 77 flooding events (with a cost greater than $10 million). The worst years in terms of number of events were 1988 and 1998. Although a large number of floods were recorded in 1988, the damage cost was not high in comparison with other years (less than $500 million). Whereas, in 1998, approximately $1 billion worth of damage was recorded. The damage cost of these events was still substantially less than the total cost recorded in 1974.

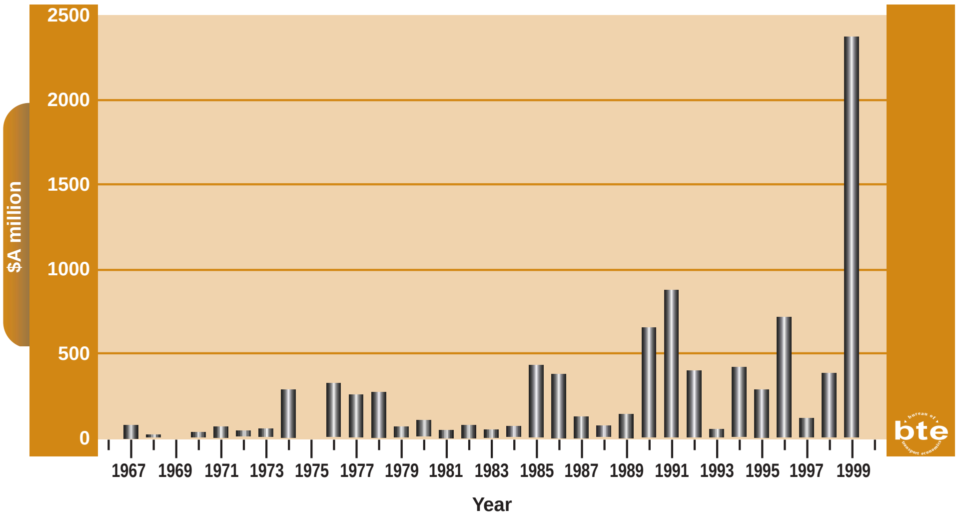
Severe storms

The cost of severe storms increased over the period between 1967 and 1999 (figure 3.18). The Sydney hailstorm that struck in April 1999 was the most damaging severe storm in Australia at a cost of $2.2 billion. It was also the single largest insurable natural disaster in Australia at a cost of $1.7 billion.

Since 1967, the total cost of severe storms has been $9.4 billion, with an average annual cost of $284 million per year. It is not known if the estimated costs include crop damage, which can be considerable, although insurance cover is not common. Although the increasing trend is statistically significant, the increase is likely to be at least partly due to improved reporting and recording of disaster events, particularly smaller and more frequent events, such as storms. Figure 3.19 emphasises this upward trend in the cost of severe storms over the last four decades. Even if the cost of the Sydney hailstorm were removed from figure 3.19, the remaining upward trend is still statistically significant. One of the possible reasons for a rise in the cost of severe storms is an increase in community exposure to storms with rising population densities in coastal areas.

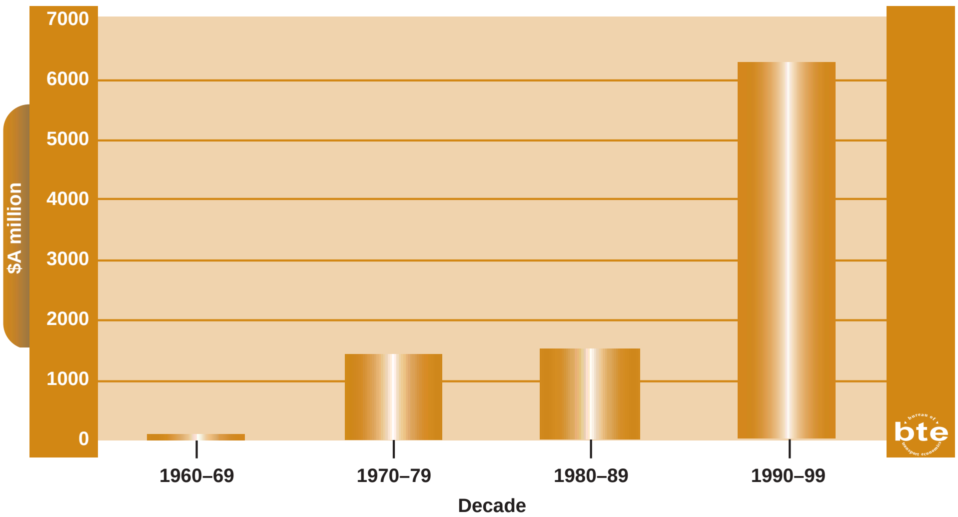
Since 1967, 112 severe storms each causing more than $10 million in damages have been recorded (figure 3.20). This represents an average of 3.4 events per year. Since 1980, the number of storms (causing damage over $10 million), has increased to an annual average of 4.4 from 2.3 in the 1970s. Although this trend may reflect better reporting, increased community exposure is possibly a more important factor.

FIGURE 3.18 ANNUAL COST OF SEVERE STORMS IN AUSTRALIA, 1967–1999



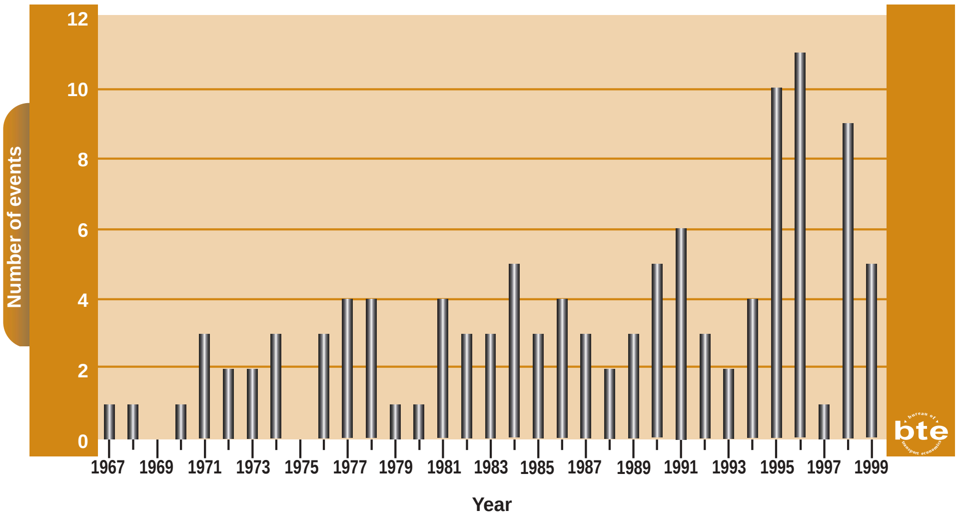
Note Estimates are in 1998 dollars.
Source BTE analysis of Emergency Management Australia (EMA Track) database (unpublished).

FIGURE 3.19 TOTAL COST OF SEVERE STORMS BY DECADE, 1960–1999



Note Estimates are in 1998 dollars.
Source BTE analysis of Emergency Management Australia (EMA Track) database (unpublished).

FIGURE 3.20 ANNUAL NUMBER OF SEVERE STORMS IN AUSTRALIA, 1967–1999



Source BTE analysis of Emergency Management Australia (EMA Track) database (unpublished).

Tropical Cyclones

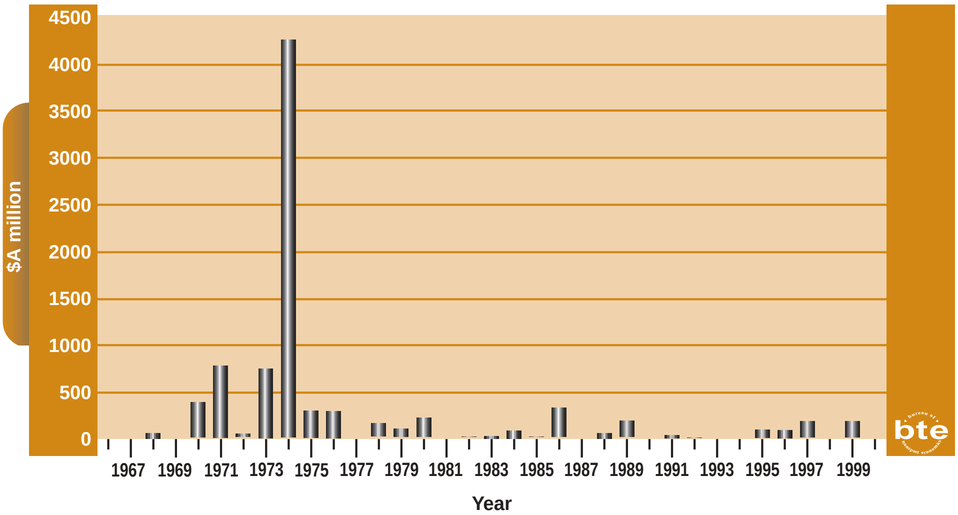
There is some ambiguity about what is included in damage attributed to tropical cyclones. Clearly, there is wind damage; but floods, both local and regional, are frequently associated with cyclones and occasionally storm surges. It may not always be possible to identify the separate damage costs. Cyclone Rona, which crossed the Queensland coast in February 1999, is one example where the data in EMATrack does have separate entries for wind and flood damage.

The annual cost of cyclones is dominated by events in 1974, as shown by figure 3.21. Since 1967, the total cost of cyclones has been $8.8 billion, averaging $266 million per year. This is considerably more than the average annual cost over the past 20 years ($80 million). Possible reasons for the lower costs during the last two decades include:

- the number of cyclones actually occurring may have fallen;
- better building codes and standards, so that cyclones are less damaging when they do hit populated areas; and
- vulnerable communities have been lucky in that severe cyclones have missed them.

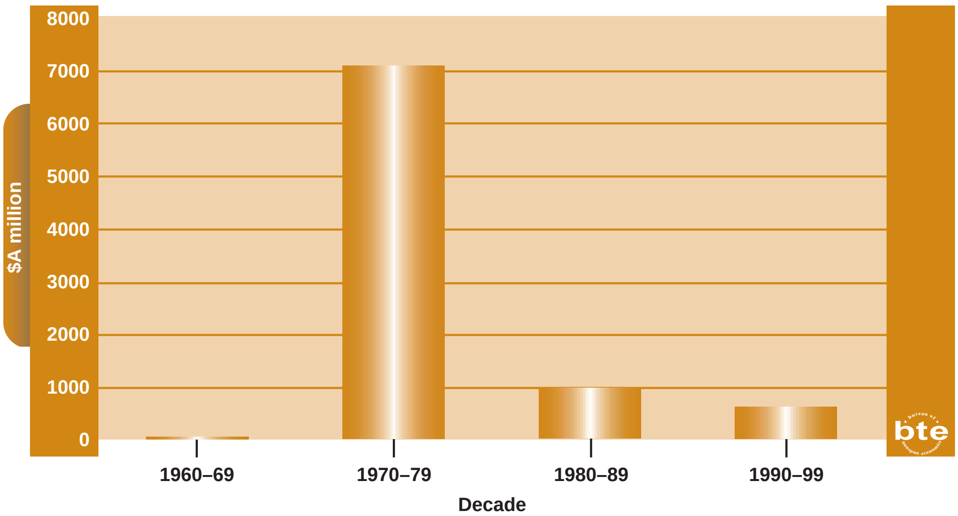
Figure 3.22 further illustrates the downward trend in the total cost of tropical cyclones, with the 1970s dominated by Cyclone Tracy

FIGURE 3.21 ANNUAL COST OF CYCLONES IN AUSTRALIA, 1967–1999



Note Estimates are in 1998 dollars.
Source BTE analysis of Emergency Management Australia (EMA Track) database (unpublished).

FIGURE 3.22 TOTAL COST OF CYCLONES BY DECADE, 1960–1999



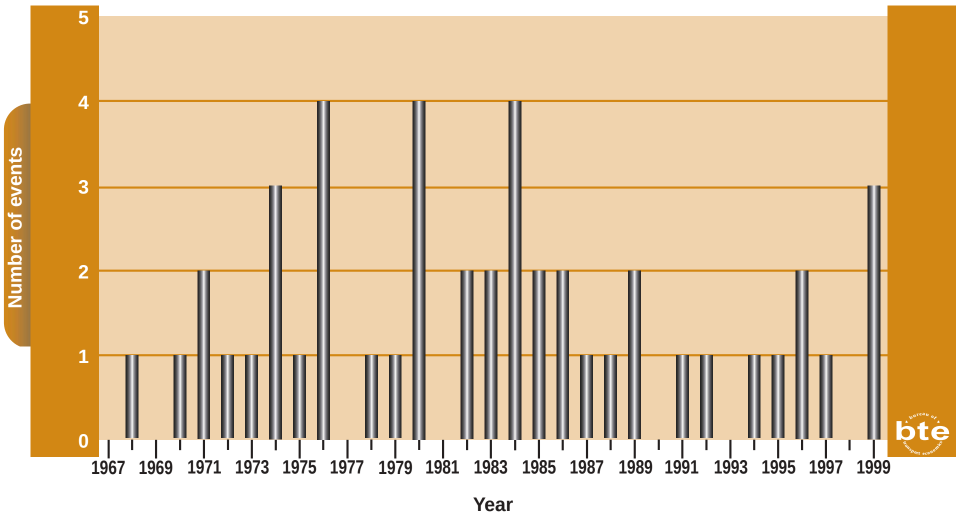
Note Estimates are in 1998 dollars.
Source BTE analysis of Emergency Management Australia (EMA Track) database (unpublished).

(1974) which caused damage to Darwin, although a number of other severe cyclones struck Australia during this period. These include Cyclone Madge in 1973 and Althea in 1971. Removal of the effect of Cyclone Tracy would still result in the costs trending downwards due to the number of other significant events that occurred during the 1970s.

Since 1967, 46 cyclones causing more than $10 million damage have been recorded in Australia. The number of cyclones causing more than $10 million damage in any one-year peaked at four, which occurred in 1976, 1980 and 1984. There is no identifiable trend in the data (figure 3.23). Similarly, the data for all cyclones crossing the coast (that is, including those causing damage less than $10 million), show no statistically significant trend. On average, at least one cyclone causing significant damage crosses the Australian coast every year, suggesting that part of the explanation for the downward cost trend is luck. No severe cyclone has struck a major population centre since 1974.

Research has shown that cyclone activity on the eastern coast of Australia is strongly related to the value of the Southern Oscillation Index (SOI). During La Niña periods (SOI greater than 5) cyclones are more frequent than during El Niño periods (SOI less than -5). Of the 51 severe cyclones occurring since 1876, 36 coincided with

FIGURE 3.23 ANNUAL NUMBER OF CYCLONES CAUSING MORE THAN $10 MILLION DAMAGE IN AUSTRALIA, 1967–1999



Source BTE analysis of Emergency Management Australia (EMA Track) database (unpublished).

a positive SOI (pers.comm, Jeff Callaghan, Bureau of Meteorology, Queensland, 17 November 2000).

For the 20 years prior to 1977, the SOI was mostly positive, and mostly negative for the following 20 years. For the first ten years of the analysis period, the SOI was mostly positive and associated with the likelihood of more frequent and severe cyclones on the eastern seaboard. During the latter part of the analysis period, eastern coast cyclones were less likely to be severe. Therefore, the downward trend in cyclone damage costs may be a reflection of the trend in the SOI (pers.comm, Jeff Callaghan, Bureau of Meteorology, Queensland, 17 November 2000). If so, a return to mostly positive SOI conditions over several years could see a reversal of the downward trend in cyclone damage costs.

Earthquakes

Damaging earthquakes are not a common phenomenon in Australia. Given that there are so few earthquakes in Australia, it is not useful to attempt a trend analysis. Since 1967, the total cost of earthquakes has been $4.8 billion (figure 3.24). However, 94 per cent of the total cost is attributable to the Newcastle earthquake.

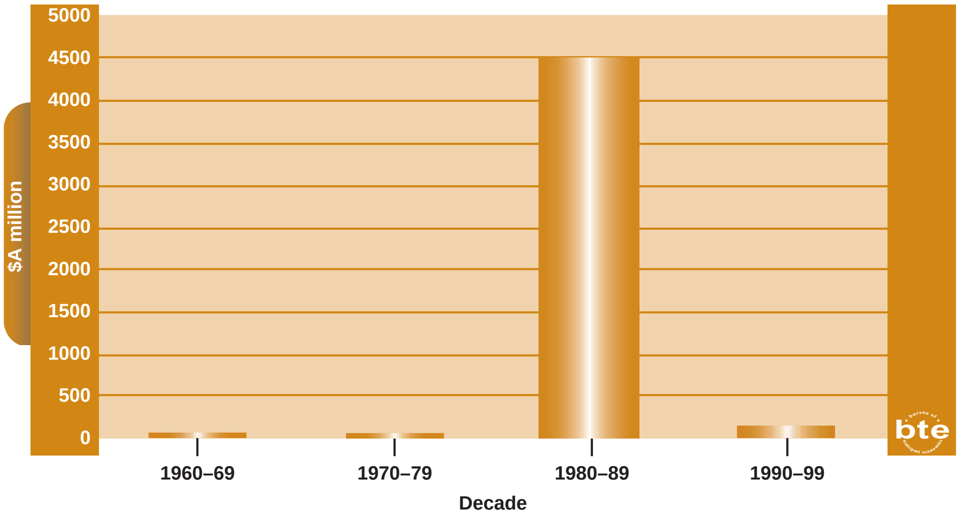
Overall, the cost of earthquakes represents a relatively small proportion of the total cost of disasters (13 per cent), with the exception of the 1980s, when the Newcastle Earthquake accounted for a large proportion (41 per cent) of overall disaster costs. With the data being dominated by one extreme event, the average cost and number of events do not provide any meaningful insight.

Bushfires

Figure 3.25 illustrates the total costs of bushfires in Australia between 1967 and 1999. The total cost of bushfires causing damage greater than $10 million in Australia is estimated to have been $2.5 billion. It is not clear if the bushfire damage costs in EMATrack includes damage to forestry. Damage to plantation timber was a significant component of the costs of the Ash Wednesday bushfires in 1983.

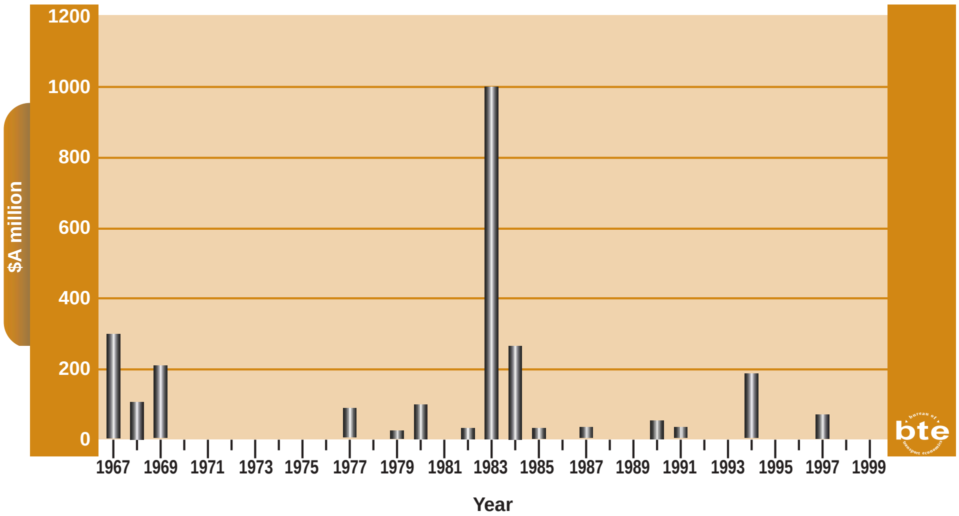
Although the cost of bushfires are small in proportion to other events, they are the fourth most frequent disaster type causing damage more than the $10 million threshold, while being the third most frequent disaster type causing damage less than $10 million. Each year, bushfires, on average, cost $77 million. The effect of the Ash Wednesday (1983) bushfires in Victoria and South Australia dominate figure 3.25.

FIGURE 3.24 TOTAL COST OF EARTHQUAKES BY DECADE, 1960–1999



Note Estimates are in 1998 dollars.
Source BTE analysis of Emergency Management Australia (EMA Track) database (unpublished).

FIGURE 3.25 ANNUAL COST OF BUSHFIRES IN AUSTRALIA, 1967–1999

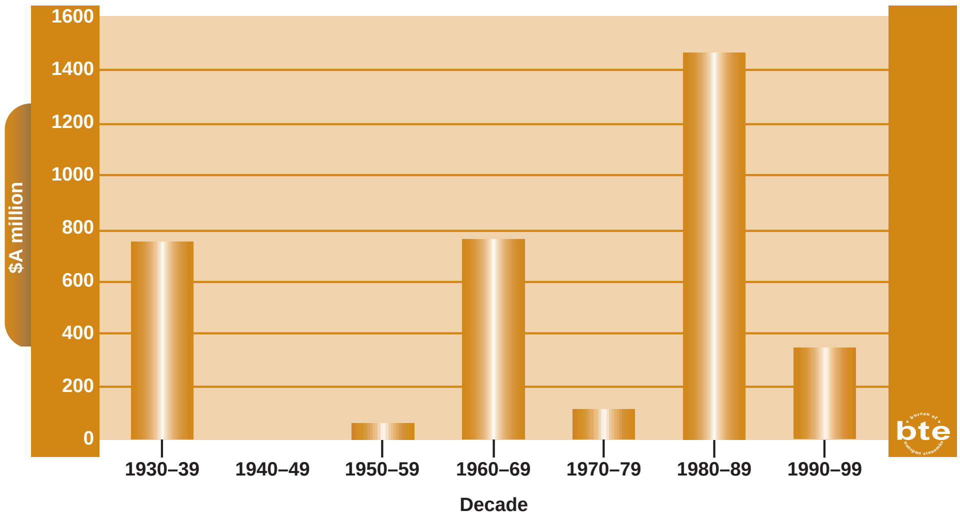


Note Estimates are in 1998 dollars.
Source BTE analysis of Emergency Management Australia (EMA Track) database (unpublished).

The timeframe used in the decade analysis (figure 3.26) has been extended to incorporate data from the 1930s because of the Black Friday bushfires in regional Victoria, which caused roughly $750 million in damage. This event was one of the largest bushfires in Australian history. Figure 3.26 also illustrates the periodic nature of bushfires. Since the 1960s, there appears to be a pattern to the cost of bushfires in Australia. Figure 3.26 shows that periods with high bushfire costs are typically followed by a period with lower bushfire activity and lower cost. Prolonged dry spells are more conducive to the occurrence of bushfires. Once an area has been burnt, there is a reduced chance of a fire in the same area until flammable material is replenished. Bushfires therefore tend to occur in cycles.

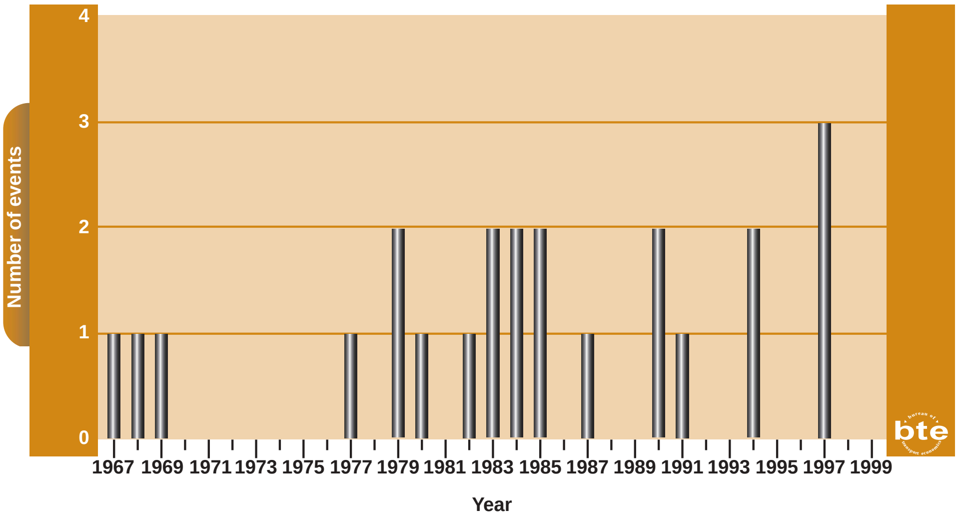
Figure 3.27 shows the numbers of bushfires annually in Australia between 1967 and 1999. Since 1967, Australia has been affected by 23 bushfires above the threshold of $10 million, which is on average about one bushfire per year. There are also periods where Australia has not been affected by any large bushfires, (1970–76, 1995–96), greater than the $10 million threshold, further emphasising the periodic nature of bushfires.

FIGURE 3.26 TOTAL COST OF BUSHFIRES BY DECADE, 1930–1999



Note Estimates are in 1998 dollars.
Source BTE analysis of Emergency Management Australia (EMA Track) database (unpublished).

FIGURE 3.27 ANNUAL NUMBER OF BUSHFIRES IN AUSTRALIA, 1967–1999



Source BTE analysis of Emergency Management Australia (EMA Track) database (unpublished).

COST OF FATALITIES AND INJURIES (AUSTRALIA)

In the analysis presented so far, the Australian EMA data were adopted without alteration. In this section, the costs of deaths and injuries are added to produce a total cost estimate for natural disasters in Australia. Deaths and injuries were the only intangible impact of disasters able to be consistently estimated and incorporated into the EMA data.

Although the BTE used EMATrack as its data source for deaths and injuries, EMATrack is not the only source of such information. The Natural Hazards Research Centre is noted for its excellent database of fatalities caused by natural hazards.

Adapting the method used in BTE (2000), the BTE derived average values of $1.3 million as the cost of a natural disaster fatality, $317 000 for a serious injury and $10 600 for a minor injury (see appendix I for details).

To apply these estimates, data on the number of deaths and injuries and the extent of those injuries are needed for each disaster over the relevant time period. The EMA database contains estimates of the number of fatalities and injuries by event for the period 1918 to 1999. For many events in the database, no information is contained in these fields. The database also does not separate serious from minor injuries.

Another source of data is the Australian Institute of Health and Welfare (AIHW) morbidity database, which contains more detailed injury information. However, its coverage of injuries caused by natural disasters is somewhat limited and therefore not particularly suitable.

As a result of the data limitations, the BTE took the approach of applying the estimates derived in appendix I to the death and injury data contained in the EMA database to produce estimates of the cost of deaths and injuries by year for the period 1967 to 1999 (figure 3.31). The BTE assumed a 1:3 ratio between serious and minor injuries for those events where no distinction was made regarding the extent of injuries. This assumption was based on data for a selection of events for which serious and minor injury information was available[7].

Figures 3.28 and 3.29 show the number of deaths and injuries recorded in the database for the period 1967 to 1999. The 1983 Ash Wednesday bushfires, followed by Cyclone Tracy, the Brisbane floods in 1974 and the Tasmanian bushfires of 1967 are Australia's largest natural disasters in terms of deaths and injuries during the period.

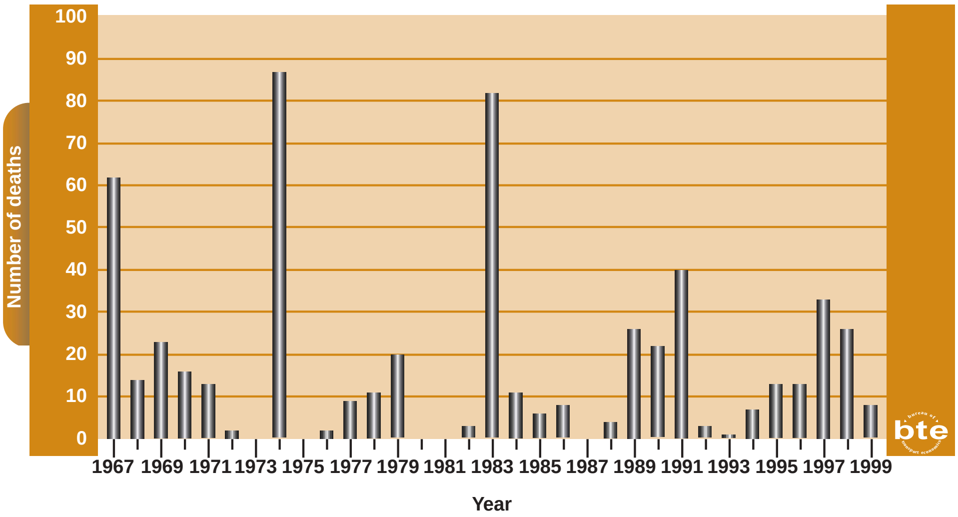
Figure 3.30 illustrates the number of deaths as a result of natural disasters by decade since the 1960s. The figure shows that while the 1990s suffered the largest number of deaths over the last four decades, there has been little variation in these numbers since the 1970s.

Applying the monetary values of deaths and injuries estimated in appendix I to the data gives a total cost of deaths and injuries during the period 1967 to 1999 of $1.4 billion (figure 3.31). This translates to an average annual cost of deaths and injuries of $41 million. Figure 3.32 shows the costs of deaths and injuries over the last four decades. The 1980s were the worst decade due to the Ash Wednesday bushfires, which killed 76 people and injured in excess of 2500 people.

During the period 1967 to 1999, bushfires have been Australia's most dangerous natural hazard in terms of risk to human life (table 3.2). Deaths and injuries account for approximately 20 per cent of the total cost of bushfires. Since 1967, bushfire deaths accounted for 39 per cent of the natural disaster fatalities analysed in this

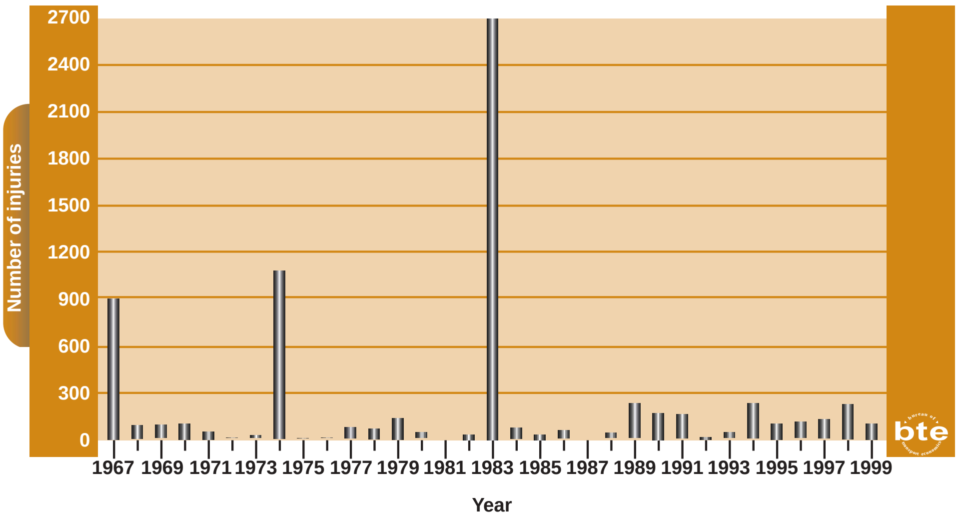
7 It is not certain whether the definition of what comprised serious and minor injuries was the same as that used in BTE (2000).

FIGURE 3.28 NUMBER OF NATURAL DISASTER DEATHS, 1967–1999



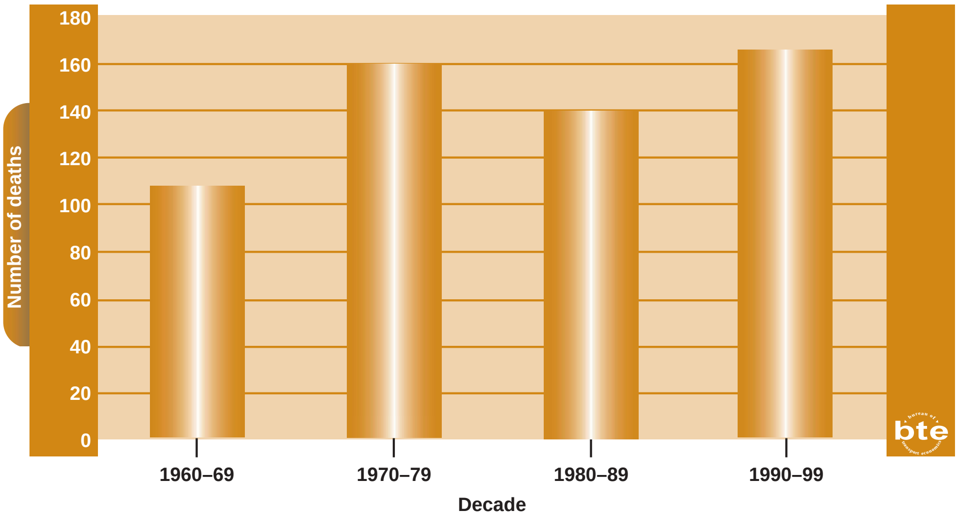
Source BTE analysis of Emergency Management Australia (EMA Track) database (unpublished).

FIGURE 3.29 NUMBER OF NATURAL DISASTER INJURIES, 1967–1999



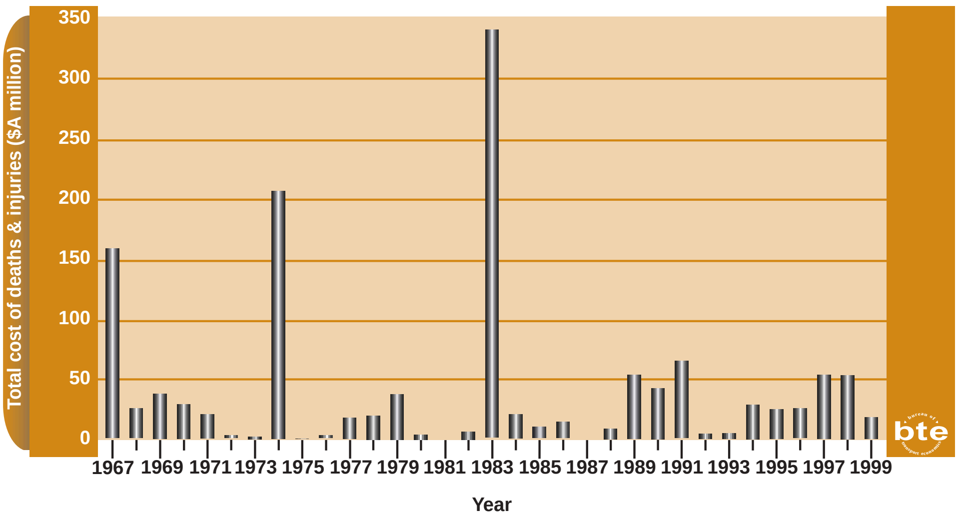
Source BTE analysis of Emergency Management Australia (EMA Track) database (unpublished).

FIGURE 3.30 NUMBER OF DEATHS BY DECADE, 1960–1999



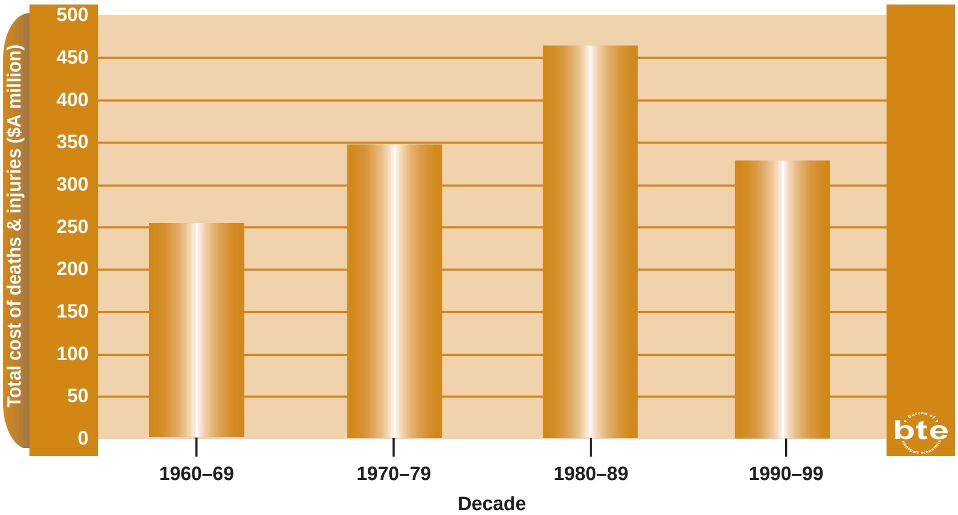
Source BTE analysis of Emergency Management Australia (EMA Track) database (unpublished).

FIGURE 3.31 COST OF DEATHS AND INJURIES, 1967–1999



Source BTE analysis of Emergency Management Australia (EMA Track) database (unpublished).

FIGURE 3.32 COST OF DEATHS AND INJURIES BY DECADE, 1960–1999



Source BTE analysis of Emergency Management Australia (EMA Track) database (unpublished).

report. Bushfires also accounted for over half (57 per cent) of the total injuries caused by natural disasters. However, the use of the $10 million total estimated cost threshold in this analysis may influence the results. There may be events that regularly cause deaths and injuries to a small number of people and therefore fall below the cost threshold. Landslides may fall into this category.

There also appears to have been a change over time in the hazard type causing the most deaths and injuries in Australia. If the time series is extended back to the early 1800s, deaths and injuries due to floods, cyclones and storms exceeded those due to bushfires[8] (EMA 1999, p. 10). Whether this change reflects increasingly successful mitigation activity or simply a change in the hazards impacting Australia is difficult to say. This sort of analysis is beyond the economic focus of this report.

The objective of including cost estimates for deaths and injuries in this report is to provide ‘ballpark’ lower bound estimates to improve the comprehensiveness and understanding of the true cost of natural disasters in Australia. Some recognition of these costs is important; even an absolute lower bound estimate is arguably better than using no cost at all. Quantifying these costs allows them to be included in

8 According to the database, since the early 1800s heatwaves (which lie outside the definition of natural disasters covered by this report) have been the worst natural disaster in terms of risk to human life.

analyses of costs and benefits and therefore more explicitly considered in decision-making. While the strict correctness of the simplistic approach taken here (to use the estimates from a road crash cost study) can be questioned, it is nonetheless a first step towards more accurate and comprehensive costing of the impact of natural disasters in Australia.

TABLE 3.2 DEATHS & INJURIES BY HAZARD TYPE, 1967–1999

Type	Dead	Injured	Total cost of deaths & injuries ($ million)
Bushfire (Wildfire)	223	4 185	654
Tropical Cyclone	154	958	283
Flood	99	1 019	216
Severe Storm	58	942	154
Landslide	18	1	24
Earthquake	13	191	33
Total	565	7 296	1 364

Source BTE analysis of Emergency Management Australia (EMATrack) database (unpublished).

TOTAL COST OF NATURAL DISASTERS IN AUSTRALIA

Adding the cost of deaths and injuries to the total cost estimated earlier in this chapter ($36.4 billion) gives a total estimated cost of natural disasters of $37.8 billion in 1999 prices for the period 1967 to 1999 or approximately $85 per person. This translates to an average annual total cost of natural disasters (including deaths and injuries) of $1.14 billion since 1967 (or $1.17 billion since 1980) with a standard deviation of $1.51 billion in 1999 prices.

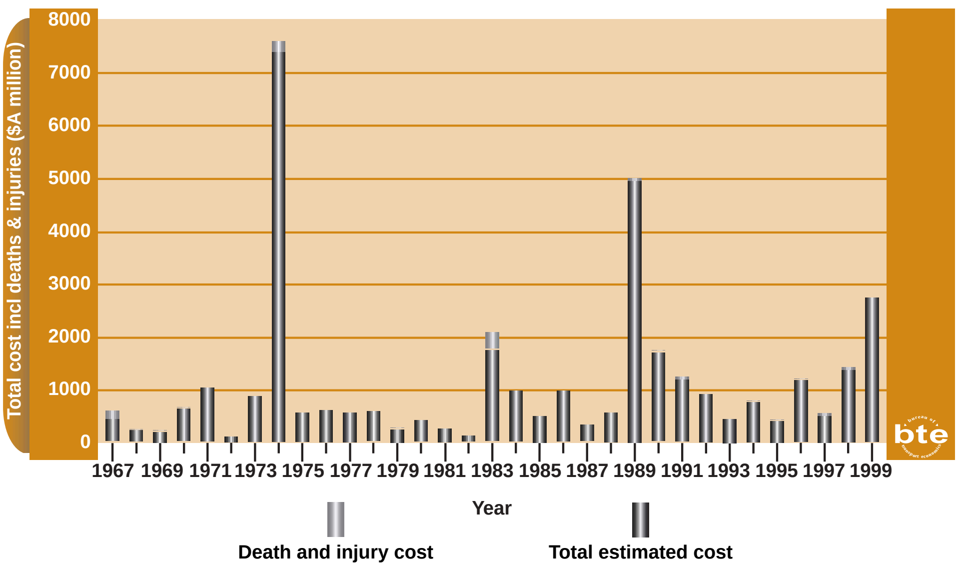
To put these figures into context, two studies by the BTE in recent years shed further light on the significance of the average annual cost of natural disasters in Australia. As mentioned earlier, BTE (2000) estimated that the cost of road crashes during 1996 was $15 billion and involved 1970 fatalities. A similar BTE study on the cost of aviation accidents in Australia found that aviation accidents in 1996 cost approximately $112 million (BTE 1999a). While this is a limited and somewhat arbitrary comparison, it does serve to illustrate that while disasters are not the biggest cost burden, they are certainly not insignificant.

If the average annual cost is calculated, ignoring the three major events of Cyclone Tracy (1974), Newcastle earthquake (1989) and Sydney hailstorm (1999), the average annual cost, inclusive of deaths and injuries, is $860 million in 1999 prices with a standard deviation of $909 million. In a year without extreme events, the total cost of natural disasters could be up to $2.68 billion, if deaths and injuries are included in the cost estimates.

Figure 3.33 illustrates the total cost of natural disasters (including deaths and injuries) by year over the period 1967 to 1999. The significance of death and injury costs is not evident from this figure. However, the proportion of death and injury costs, in total disaster costs, ranges from less than 1 per cent to around a quarter of the total cost per event. On average, death and injury costs account for around 4 per cent of the total disaster costs for the period 1967–1999.

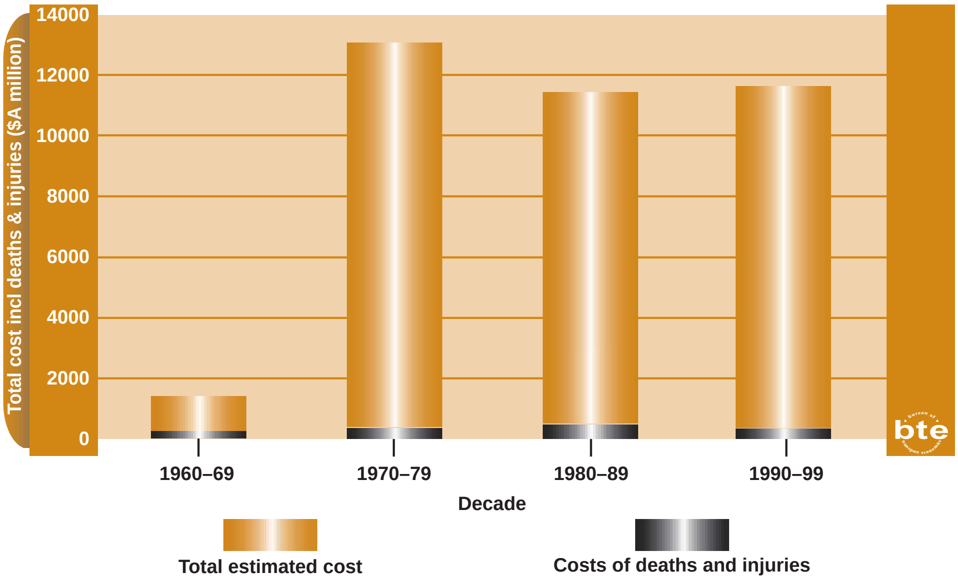
When the costs of deaths and injuries are added, the 1970s still remain the most costly decade for natural disasters. The relative magnitude of the 1980s and 1990s does not change significantly (figure 3.34).

FIGURE 3.33 TOTAL COST OF NATURAL DISASTERS, 1967–1999



Source BTE analysis of Emergency Management Australia (EMA Track) database (unpublished).

FIGURE 3.34 TOTAL COST OF NATURAL DISASTERS BY DECADE, 1960–1999



Source BTE analysis of Emergency Management Australia (EMA Track) database (unpublished).

SUMMARY

This analysis of the best currently available data shows that the total cost of natural disasters in Australia between 1967 and 1999 (in 1999 prices) was approximately $36.4 billion, which increases to $37.8 billion (or approximately $85 per person) once deaths and injuries are integrated into the data. The equivalent average annual cost is approximately $1.14 billion in 1999 prices over the 33-year time period. This annual cost, although small compared to Australia's GDP or Australia's annual road crash cost, is not insignificant.

Extreme events contribute a substantial proportion of annual disaster costs. If the three extreme events, Cyclone Tracy, the Newcastle Earthquake and the Sydney hailstorm, experienced over the 33-year time period are excluded, the average annual cost decreases to $860 million in 1999 prices (including deaths and injuries). The average annual cost, excluding the three extreme events, may be a better measure of the actual cost that can be expected in any year.

The annual cost of disasters exhibits considerable volatility. The standard deviation is a statistical measure of the variation in the data. The average cost plus twice the standard deviation is a measure of the maximum cost that could be expected in any year. Taking the standard deviation into account, annual disaster costs could be as high as $2.68 billion in years in which no extreme events occur. Because of the few extreme events occurring in Australia, the upper limit calculated from past data for years in which extreme events have occurred is a poor guide to future costs. Future extreme events are likely to be very different from past events.

There is some evidence pointing toward an increasing number of disaster events occurring in Australia since 1967. Similar evidence was also found using the limited New Zealand data (appendix II). However, caution needs to be exercised in the interpretation of this trend, as it is influenced by two factors. These factors are better reporting and recording of events in more recent times and a gradually increasing population, especially in the coastal areas which are more prone to storms.

The impact of natural disasters on Australian States and Territories varied in terms of damage cost and the type of disasters most commonly occurring. The most damage occurred in the eastern seaboard States, particularly in New South Wales and Queensland, which accounted for 66 per cent of Australia's total cost and 53 per cent of the total number of disasters. However, State and Territory rankings are heavily influenced by the incidence of extreme events. The rankings could change when Australia experiences more of these extreme events.

Australia, due to geographic location and geological composition, faces a wide variety of natural disaster threats. However, three of these potential threats—floods, severe storms and cyclones—accounted for approximately 80 per cent of Australia's total costs and 89 per cent of the total number of events between 1967 and 1999. These proportions change only slightly with the inclusion of deaths and injuries, with the most significant change occurring in the case of bushfires, the most hazardous disaster type in terms of human life.

The interpretation and the conclusions derived from the data provided are by no means conclusive because of the problems and limitations of the database. Evidence seems to point towards a continuing improvement in the reporting and recording of small natural disasters in Australia. Therefore, the reader needs to be aware of these potential influences and exercise caution when interpreting results.

4

FRAMEWORK FOR ESTIMATING COSTS

The previous chapters discussed the costs of past natural disasters. Shortcomings in the data mean that only broad conclusions can be drawn with respect to trends in disaster costs and number of disasters. This chapter takes a future orientation and considers how disaster costs can be both categorised and estimated to produce consistent results. This is done by developing a framework for estimating the economic costs of natural disasters. The framework includes costs for which data are not available for past disasters, but which may become available for future ones.

Although the framework is designed to aid in the estimation of costs for all types of natural disaster, the data sources used in illustrating estimation methods are drawn mostly from the literature on floods. This is simply because the flood literature is more highly developed than that of other disaster types. The chapter also draws substantially on the Rapid Appraisal Method (RAM) developed by Read Sturgess & Associates (2000) for the Victorian Department of Natural Resources and Environment.

This chapter attempts to cover the major elements of disaster costs. However, each disaster has unique characteristics. Consequently, a general framework of the type presented here will inevitably omit some categories of costs that become evident during the analysis of specific disasters. The framework should therefore be considered as a guide, and not a total prescription of the costs that should be estimated.

GENERAL PRINCIPLES

There are a number of important principles that should be followed to avoid major errors in the estimation of losses. The more important of these principles are discussed in the following paragraphs.

Measure economic and not financial costs

An objective of this report, and of disaster costing in general, is to estimate the impact of disasters on society as a whole. In contrast, a financial analysis is concerned with the financial impact on the individual or entity undertaking the analysis. For example, a business subject to flooding would, in a financial analysis, be concerned with the net effect of a flood after taking account of any government assistance and insurance payouts that might be received. An economic analysis is not concerned with these transfer payments, but is concerned with the impact on resources available to society. Chapter 1 has more information on the difference between financial and economic analysis.

Measure loss with and without the disaster

There is often a tendency to measure the loss on a basis of before and after the event. Regional economies are rarely static. They are more likely to be experiencing economic trends that may be developing over a lengthy period of time. Concentration of loss measurement on a 'before and after' basis can easily overlook these trends and attribute the effects of longer-term trends to the effect of the disaster (Commission on Engineering and Technical Issues 1992, p. 105, Thompson & Handmer 1996, p. 50).

In addition to long-term trends, other factors, (largely unknowable), could affect loss measurement. It is therefore likely that a 'before and after' analysis would overstate the cost of a disaster to some (unmeasurable) extent.

Identifying trends that would have occurred in the absence of any disaster should allow the analyst to avoid the problem.

Do not double count

It is very easy to make the mistake of double counting disaster losses. A common problem is to ignore the interactions between different economic agents affected by a disaster.

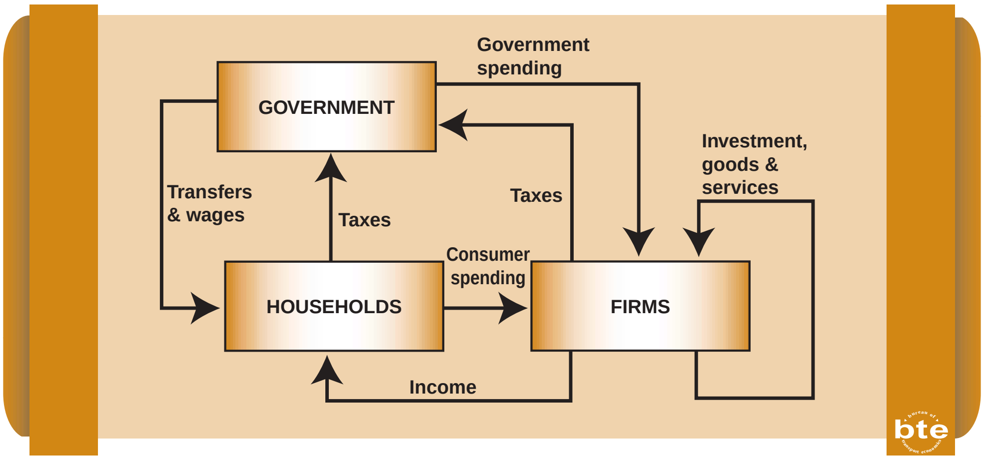
Expenditures versus incomes

In its simplest form, a regional economy can be described in terms of the three sectors shown in figure 4.1. Producers continue production as long as there are demands for their output. In producing output, producers employ labour, pay dividends to shareholders, interest to lenders and taxes to governments.

Households earn income from firms, and receive payments from governments.

Households also pay taxes to governments and purchase goods and services from firms. Governments use taxes to finance their own spending (Commission on Engineering and Technical Issues 1992, p. 105).

FIGURE 4.1 FLOW OF PAYMENTS IN A SIMPLE THREE-SECTOR ECONOMY



Source Based on Commission on Engineering and Technical Issues (1992, p.102).

An important principle that can be derived from the diagram is that each transaction represents one party's expenditure and another party's income. In estimating disaster losses, only one side of the transaction should be counted.

For example, the price of a firm's products reflects the costs of production, such as wages, interest payments and profits. To count lost sales as a loss, as well as lost expenditure on salaries and dividends, is a double counting of the loss. The correct approach is to use lost value added[9] as the loss.

9 Value added is 'the difference between the total revenue of a firm, and the cost of bought-in materials, services and components' (Bannock, Baxter & Davis 1998, p. 425).

Assets versus flows

According to economic theory, the value of an asset is equal to the present value of the future stream of goods and services the asset can produce. If a durable asset is damaged or destroyed during a disaster, then it would involve double counting to include both lost value added and reduction in asset value.

Thompson and Handmer (1996, p. 57) recommend that if the asset is repaired, the costs of repairs can be taken as the value of the loss. This is based on the assumption that the repairs result in the repaired asset having the same life and production potential as it originally had. Not all damaged assets will be repaired because some owners would believe that the cost of the repairs exceeds the value of the gains from the repairs. The recommendation will therefore overstate the value of the loss, but the error is not thought to be significant (Thompson & Handmer 1996, p. 57).

If the asset is to be replaced, the theoretically correct approach is to measure the change in the present value of the anticipated capital outlays, with and without the disaster (Howe et al. 1991, p. 23). Thompson and Handmer (1996, p. 57) and Parker, Green and Thompson (1987, p. 37) recognising the difficulty in making the necessary estimates, recommend that the loss be calculated as the average remaining value of the asset and that this can be taken as 50 per cent of its new market value. If there are many assets to be replaced as a result of the disaster, the assumption of a 50 per cent remaining asset life is reasonable. But if the asset is half way through its expected life, how accurate is it to assume that the loss is 50 per cent of its new market value? Some assets like cars depreciate in value in the early years much faster than physical condition. On the other hand, houses can depreciate at various rates over time. These different depreciation rates can influence the value of an asset that is half way through its life.

However, even if an asset depreciates linearly with time, its value halfway through its economic life may not equal 50 per cent of its new value. For short-lived assets, the assumption that the remaining life is 50 per cent of the replacement value gives reasonable results. However, for long-lived assets, this approach will understate the loss, even for assets that are exactly half way through their expected life.

For assets with an expected life of 10 or less years, assuming that the loss is equal to 50 per cent of the new market value will not introduce serious errors for low discount rates. For assets with longer lives, a closer look is warranted. For example, for an asset with an expected life of 30 years, it would be more reasonable to take the loss as 75 per cent of the new market value for a discount rate of 7 per cent (see appendix III).

Typically, insurance policies provide for full replacement costs of assets that are total losses. It is clear that unless the asset is close to the beginning of its expected life, the insurance payout will significantly overstate the economic value of the loss. If the assumption that assets destroyed in a disaster are half way through their economic life is a reasonable reflection of reality, then insurance payout figures will overstate the economic cost by up to 100 per cent. However, where repairs are carried out, the insurance payout will more closely reflect actual economic loss.

Do not include land

According to Cochrane (Commission on Engineering and Technical Issues 1992, p. 105), occasionally a change in the total price of a house and land has been used as an estimate of loss. However, the land clearly still has value after a disaster. If the price of the land declines subsequent to a disaster, the change is more likely to be a result of more accurate knowledge of the risks of building on that site.

There may be occasions when the land itself suffers direct damage due to a disaster. For example, a flood may cause erosion or land slippage. The cost of restoring the land to its former condition would then be a cost of the disaster.

CLASSIFICATION OF LOSSES

There are several methods of classifying the losses resulting from natural disasters. The usual method is to divide the losses into two categories: tangible (those with a market value) and intangible (those with no market value). Losses are usually further subdivided into direct and indirect losses (table 4.1).

A useful means of considering the difference between direct and indirect losses is to define direct losses as those that result from the physical destruction or damage to buildings, infrastructure, vehicles and crops. Indirect losses are due to the consequences of the damage and destruction (National Research Council 1999, p. 35). Within these broad categories of costs there are a number of sub-categories that form the basis of the discussion in this chapter (figure 4.2). In figure 4.2, direct and indirect intangible costs have been combined, leaving three main categories, (direct, indirect and intangible), compared with the four in table 4.1.

Direct tangible costs

Direct damage can cover a wide range of impacts. Typically damage to buildings can be classified as:

- structural damage to foundations, walls, floors, roofs, doors, in-built furniture, windows etc.;
- contents damage to carpets, furniture etc.; and
- external damage, for example, to swimming pools and motor vehicles.

The Youth and Community Services' component of a detailed residential damage survey conducted after the 1986 Toongabbie Creek floods, (based on average relief payments to properties

TABLE 4.1 CLASSIFICATION OF DISASTER LOSSES

	Type of loss	
Measurement	Direct	Indirect
Tangible (market values)	Damage to infrastructure, buildings and contents, vehicles boats, etc.	Loss of production, emergency response and relief, and clean-up costs.
Intangible (non-market values)	Death and injury, loss of items of cultural significance and personal memorabilia.	Inconvenience and disruption, especially to schooling and social life.
		Stress induced ill-health and mortality.

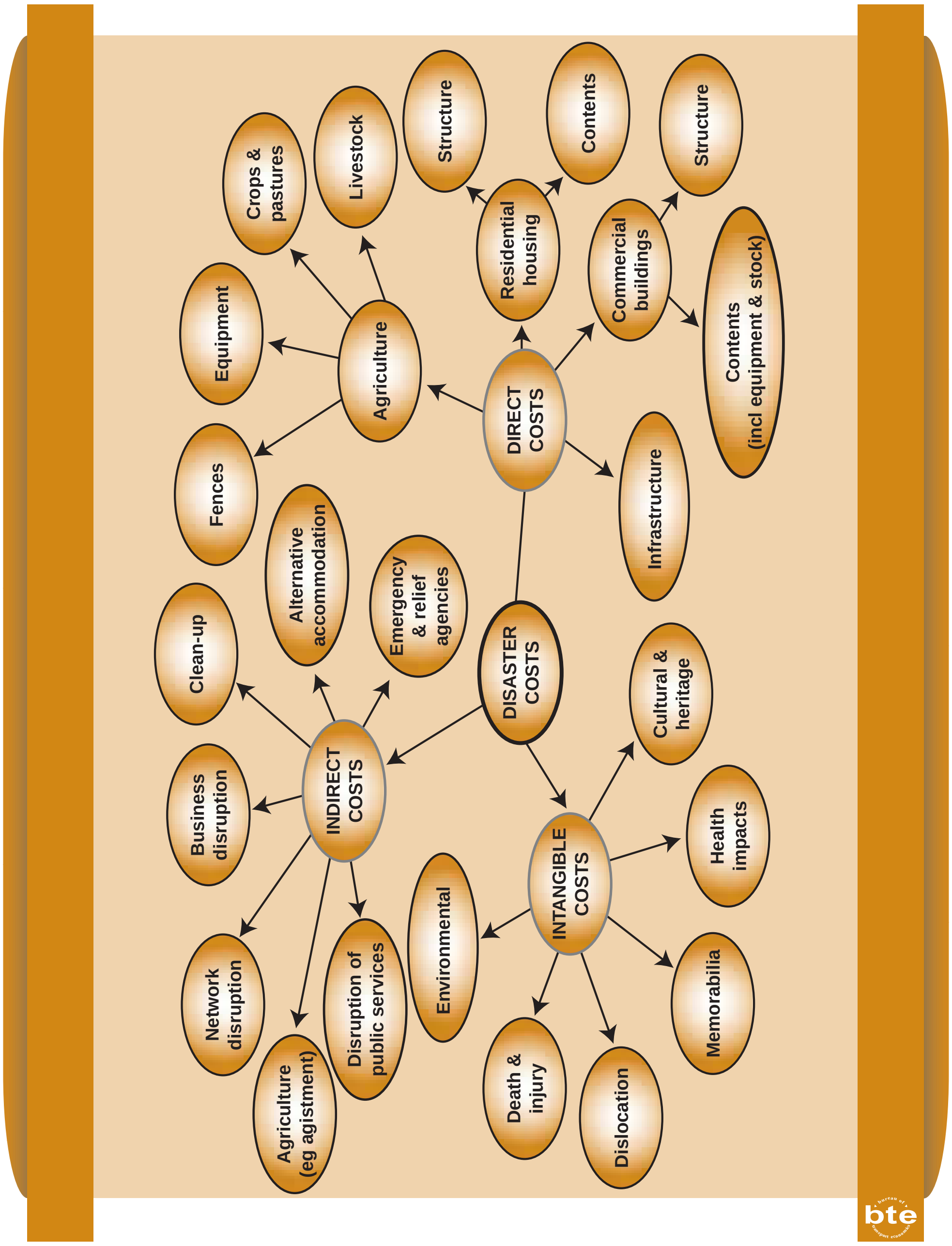
Source Smith et al. (1995, p. 21).

suffering overfloor flooding), showed that structural damage comprised around 20 per cent of average residential damage and contents damage the remaining 80 per cent. Floor coverings alone contributed in excess of 20 per cent to total costs (Smith et al. 1990b). In the April 1999 Sydney hailstorm, the most common direct damage was to roofs (broken tiles) and motor vehicles (NHRC 1999a).

Although damage to buildings may be the largest component of direct damage, damage to infrastructure and agriculture can also be substantial.

Direct damage is the most amenable to estimation and certainly the most obvious. Nevertheless, caution is needed in estimating direct damage costs. Insurance companies in Australia generally insure for the replacement value of the asset. As seen earlier, the economic value is less than this, depending on the age of the asset and its economic life.

FIGURE 4.2 OUTLINE OF COST FRAMEWORK



Source BTE analysis.

Damage to residential and commercial buildings

The estimation of flood damage to buildings is usually based on the use of stage-damage curves (discussed below), either developed from survey data or curves already existing in computer models. There are similar approaches to estimating the potential damage from wind and earthquakes. Damage to buildings can be related to wind speed and to the intensity of earthquakes (Commission on Engineering and Technical Issues 1992, pp. 36–48).

Stage-damage curves

A stage-damage curve (figure 4.3) gives a relationship between depth of over-floor flooding and potential damage costs for properties having similar structures and contents. The method is widely accepted in Australia, the United Kingdom and the United States (Thompson & Handmer 1996, p. 56).

There are two types of stage-damage curves, one type is based on actual damage costs and the other is based on 'synthetic' costs. The synthetic cost stage-damage curves are mostly used for the prediction of flood costs such as in benefit-cost analyses.

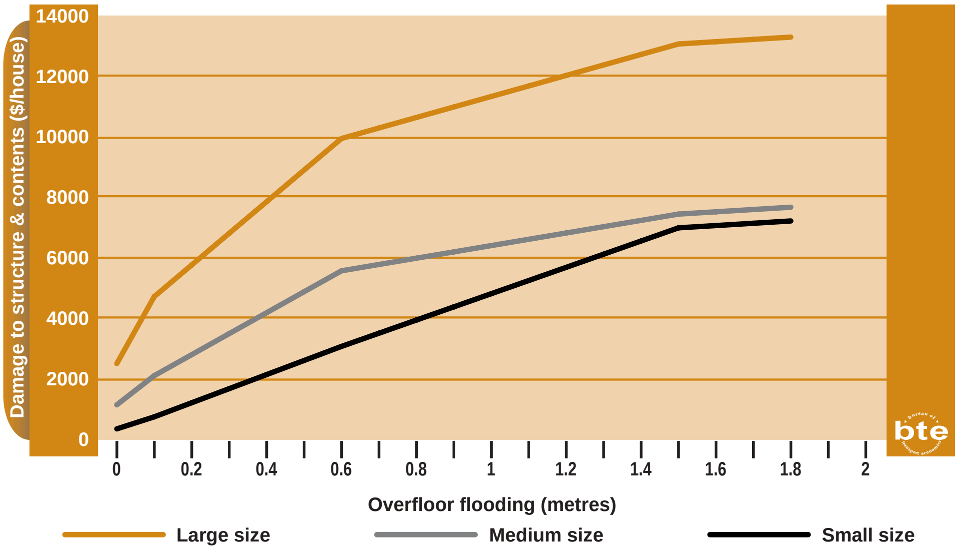
The development of residential synthetic cost stage-damage curves has the following steps (Smith 1994):

- In the area of study, representative classes of houses are selected, usually based on size, (for example, small, medium and large).
- A sample of houses is selected in each dwelling class. In each room type of the selected houses, contents are checked and value noted. Information on the height above floor level can also be noted or heights can be taken as the same in all dwellings. Preferably, a qualified quantity surveyor or valuer should undertake this step.
- Values are averaged across each sample for each class of house and the stage-damage curves constructed.

The stage-damage curves constructed by the synthetic cost method are for potential damage, not actual damage. A similar approach can be used for constructing actual cost stage-damage curves soon after a flood (Smith 1994).

In Australia, a computer package, (ANUFLOOD), developed in 1983 at the Centre for Resource and Environmental Studies (CRES), is widely used for estimating damage costs for floods. Several consultants have the package or derivatives of it.

FIGURE 4.3 TYPICAL STAGE-DAMAGE CURVE



Source Based on Smith et al. (1995, p.22).

ANUFLOOD has in-built default stage-damage curves that are averages of curves developed from past floods. The curves need to be modified to ensure they are representative of the area being studied. Unfortunately, this is not always done.

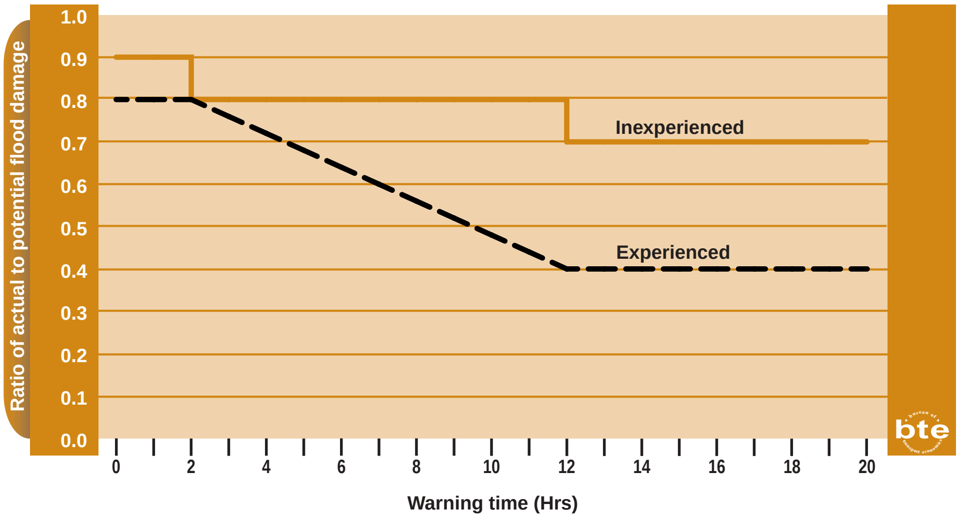
A similar method can be used for commercial properties. However, because there are usually few industrial properties, and because there is usually much more variability in size and function, stage-damage curves for large industrial plants are generally considered inappropriate (Smith 1994). Catchment Management Unit (1990, pp. 61–69) and Smith (1994) give good descriptions of the use of stage-damage curves in estimating damage costs.

Actual and potential damage

As noted above, synthetic cost stage-damage curves estimate potential damage and not actual damage. In-built stage-damage curves in ANUFLOOD and its derivatives are usually based on synthetic costs. If synthetic cost curves are used, an allowance needs to be made to estimate actual damage costs from the potential costs derived from the synthetic cost curves.

The difference between actual and potential damage depends on factors such as previous disaster experience and amount of prior

FIGURE 4.4 EFFECT OF EXPERIENCE AND WARNING TIME ON ACTUAL FLOOD DAMAGE



Source Read Sturgess and Associates (2000, p. 22).

warning. The more warning, the better the preparation and more community experience with disasters, the lower the ratio of actual to potential damage. Removing portable and valuable possessions out of the danger zone can significantly reduce damage. For example, for a well prepared community subject to frequent flooding and approximately 10 hours warning, actual damage can be reduced by up to 60 per cent of potential damage (Smith et al.1995, figure 3.2).

Read Sturgess and Associates (2000, p. 22) have developed a relationship between warning time and community flood experience using damage data from eleven Australian floods (figure 4.4). The relationship in figure 4.4 could be used with an estimate of potential costs to derive an estimate of actual damage costs. For other disaster types, experience and prior warning could also result in less damage, but there does not appear to be any information available on the likely effect.

Surveys and insurance data

Surveys of disaster victims are often used to establish the costs they have incurred. A sample of households and businesses may be surveyed and the results generalised to all those affected by the disaster. For large floods, stage-damage curves for actual costs can be developed from the survey data (Thompson & Handmer 1996, p. 54).

Surveys can be used to assess direct damage for other disaster types. Insurance data are generally more comprehensive for disasters other than floods, principally because of the lack of availability of flood insurance. Insurance payout figures can provide a good guide to direct damage costs for those non-flood disasters, but the issue of overstatement of economic costs covered earlier in this chapter, needs to be taken into account. Not everyone is covered

TABLE 4.2 POTENTIAL DIRECT STAGE-DAMAGE CURVES FOR COMMERCIAL PROPERTIES

	Value class[a]				
Over-floor depth (m)	1	2	3	4	5
Floor area < 186m^2			($)		
0.00	0	0	0	0	0
0.25	1 985	3 970	7 939	15 878	31 756
0.75	4 962	9 924	19 848	39 695	79 391
1.25	7 443	14 885	29 771	59 543	119 086
1.75	8 270	16 540	33 079	66 159	132 318
2.00	8 765	17 532	35 064	70 128	140 257
Floor area 186m^2 to 650m^2			($)		
0.00	0	0	0	0	0
0.25	6 286	12 570	25 140	50 281	100 561
0.75	15 217	30 433	60 866	121 732	243 464
1.25	23 156	46 311	92 622	185 245	370 489
1.75	25 636	51 273	102 546	205 092	410 184
2.00	27 290	54 581	109 162	218 324	436 648
Floor area > 650m^2			($/m^2)		
0.00	0	0	0	0	0
0.25	3	7	14	28	57
0.75	18	37	74	142	286
1.25	37	75	150	300	599
1.75	61	123	246	492	984
2.00	74	147	294	588	1 176

Note Values are updated to 1999 prices using the CPI.

a Value class relates to the enterprise's susceptibility to flood damage with 1 = very low and 5 = very high.

Source Smith (1994).

by insurance and the degree of coverage would need to be taken into account. The damage covered by insurance data should also be considered. Insurance data for residences can cover both structures and contents. For businesses, the payout figures may include business disruption as well as damage to buildings and contents.

The survey method gives an estimate of the damage that is accurate to the extent that the survey itself will allow. For example, strategic response bias is probable if respondents believe that they may receive compensation, or more resources are likely to be expended in disaster recovery. Damages may be overstated in such circumstances. The accuracy of the survey only applies to the event for which it is initially used. Extrapolation to other disasters may not give comparable accuracy.

Approximation methods

If it is not possible to adequately survey damaged properties or to use ANUFLOOD or its equivalent, Read Sturgess and Associates (2000, p. 18) recommend using an average value of $20 500 (in 1999 prices) for all buildings inundated by a flood, except for large non-residential buildings[10]. It should be noted that the Read Sturgess and Associates recommendations are based on Victorian data and may not necessarily be representative of damage to properties in other jurisdictions.

Damage costs of large non-residential buildings are best estimated by means of a survey. Where it is not feasible to undertake a survey, the stage-damage curve information shown in table 4.2 is a good alternative for commercial buildings. For industrial buildings, if a survey is not possible, the data in table 4.2 for floor areas greater than 650 m^2 and the relevant value class could be used as a last resort.

There are few comparable data sources to simplify the estimation of direct damage costs due to other disaster types. One possible source for damage due to bushfires is the coroner's report of the 1994 Sydney bushfires (NSW Coroner 1994), which included estimated damage costs to 585 residential properties. Although it was not always clear from the data, the BTE categorised all of the properties as damaged or total losses. The estimated average value of each

10 The damage estimate of $20 500 'includes external, internal contents and structural damages and should be applied to all inundated properties including those inundated above and below floor level' (Read Sturgess and Associates 2000, p. 18).

residential property suffering a total loss was $217 300 ($244 000 in 1999 prices). The total loss estimates need to be adjusted to allow for the difference between replacement values and economic values as discussed earlier in this chapter. The adjustment gives an estimated value of average economic loss of $183 000 per destroyed house.

An alternative approach is to estimate the cost of constructing a new house and to allow for the destruction of the contents unable to be saved. The BTE developed an indicative cost estimate of a 140 square metre brick veneer house as $160 000, based on a building cost of $1000 per square metre[11] plus $20 000 for a separate garage, other structures, and heating or cooling systems. Taking the depreciated value as 75 per cent of the new building price and allowing $60 000 for contents, gives a total indicative value of $180 000 for the economic loss of a destroyed house.

The average cost of damage to houses not suffering a total loss in the 1994 Sydney bushfire was $25 800 ($29 000 in 1999 prices). The reported losses included damage to motor vehicles, house contents, sheds and fences. It was not possible from the data to separate out the different cost components. Some of the damage reported will be for items that are replaced and not repaired, such as washing machines and entertainment equipment. The average reported damage cost will therefore overstate the economic cost of the damage, but the extent of the overstatement cannot be estimated using the available data.

There was considerable variation in the value of total losses depending on the location of the bushfire. Although applying a simple average for total loss derived from the Sydney bushfires of 1994 has its limitations, the derivation of a similar figure using new building costs gives some confidence in the estimate. In contrast, the average damage per property (excluding total losses) is much more consistent across locations and the average value reported above is considered reasonable if no other information is available.

Damage to infrastructure

Infrastructure is vulnerable to all types of disasters. Floods frequently damage railways, roads and bridges, but other infrastructure such as water supplies and sewerage systems are also susceptible to flood damage. Bushfires are more likely to damage electricity and telecommunications systems than other infrastructure.

11 Based on building costs in the NRMA form Calculation Guide—Buildings.

Apart from the initial damage to roads caused by floods, inundated roads also suffer accelerated deterioration due to the effect of water intrusion under the pavement. The Rapid Appraisal Method (Read Sturgess and Associates 2000) suggests the values in table 4.3 for flood damaged roads in Victoria, which also allows for the accelerated depreciation.

Funding for restoration of publicly-owned infrastructure is available from National Disaster Relief Arrangements (NDRA) funds (appendix V). State and Territory Treasury departments collect the required data before a claim is lodged with the Commonwealth Department of Finance and Administration. Therefore, State and Territory Treasury Departments may be the best source of

TABLE 4.3 COST OF REPAIRING FLOOD INDUNDATED ROADS

($ / km)

	Initial repairs	Cost of accelerated deterioration	Bridge repairs	Total cost
Major sealed roads	32 000	16 000	11 000	59 000
Minor sealed roads	10 000	5 000	3 500	18 500
Unsealed roads	4 500	2 250	1 600	8 350

Note Values are in 1999 dollars

Source Read Sturgess & Associates (2000, p. 31).

information on the cost of restoration of publicly-owned infrastructure. For infrastructure not publicly owned, the analyst is dependent on the infrastructure owner to provide the relevant data.

Damage to agriculture

Natural disasters affect agriculture through damage to crops and pastures, fences and other structures, and livestock. Surveys are the most reliable method of estimating damage to agriculture. However, if surveys are not feasible, the Rapid Appraisal Method (Read Sturgess and Associates 2000) provides guidance on likely flood damage costs to Victorian agriculture.

Damage to agriculture can be substantial and is often not covered by insurance. For example, Yeo (2000) estimated that winter wheat and barley sustained damage of $65 million out of a total estimated damage cost of $265 million following floods in north western New South Wales in 1998. Loss of farm income due to a natural disaster can affect the economies of country towns. For example, the

Australian Bureau of Agriculture and Resource Economics (ABARE 2000) estimates that farm expenditure represents at least a third of the economies of towns with less than 1000 people. Disasters that reduce farm expenditure can therefore have a major effect on the economies of small towns.

NDRA assistance is available to primary producers for losses resulting from certain natural disasters. The assistance is in the form of concessional loans and freight subsidies. Eligibility and the size of the loans are the subject of various conditions (appendix V) with the result that NDRA payments are not a good measure of the damage sustained.

Crops

The cost of crop damage depends on the type of crop and the time of year of the disaster. For example, a flood before a crop is planted may have little cost, but a flood after planting can lead to total crop loss. As for other production, the economic loss is the value added forgone. Some inputs will not be required if a crop is lost. Costs, such as for harvesting and transport, are no longer incurred and will represent an offset to the value of the lost crop. Read Sturgess

TABLE 4.4 REPRESENTATIVE COSTS OF DAMAGE TO PASTURE

($ / Ha)

	Inundation time	
Pasture type	Less than 5 to 7 days	More than 5 to 7 days
Dryland	0	30
Irrigated	90	370

Source Read Sturgess & Associates (2000, pp. 23–24).

TABLE 4.5 SUGGESTED LIVESTOCK VALUES

($ / head)

	Dairy	Beef	Sheep for wool production	Sheep for lamb production
High	650	480	33	50
Average	560	410	27	45
Low	460	340	23	35

Note Carcass disposal costs of $6 to $10 for sheep and $40 to $80 for cattle should be added to the values in the body of the table.

Source Read Sturgess and Associates (2000, p. 25).

and Associates (2000, pp. 27–28) provide examples of how crop damage varies with time of year and crop type for Victorian agriculture. For some crop types, such as grapes, cereal crops and pastures, stage-damage curves have been developed that provide estimates of damage as a function of flood depth. However, the curves have not been published (pers. comm. Peter Brown, Hassall & Associates, 22 September 2000).

Because of the dependence of damage costs on the time of year of the natural disaster, it is not possible to derive an average damage cost that is relevant to all disasters. Each disaster and crop would need to be considered individually.

Pastures

According to Read Sturgess and Associates (2000, pp. 23–24), the critical period for pasture inundation is five to seven days. After this period of inundation, plant death is likely to occur. The response by farmers therefore depends on the time the pasture is inundated and whether the pasture is dryland or irrigated. Long-term negative effects on agriculture, such as an increase in insect pests and noxious weeds following a flood, were noted by Smith et al. (1979, pp. 118–119).

If it is not possible to obtain costs from a survey, then costs suggested by Read Sturgess and Associates for Victorian agriculture provide a good guide (table 4.4).

Fences

Damage to fences can represent a significant cost to agricultural producers. For example, an estimated 15 900 kilometres of fencing were destroyed during the Ash Wednesday bushfires in 1983 (Healey, Jarrett, and McKay 1985, p. 4). A recent estimate of the cost of repairing damaged fences is that provided by Read Sturgess and Associates (2000, p. 29) of $5000 per kilometre.

Livestock

Livestock losses are usually low for most disasters, as producers mostly receive adequate warning to remove stock to safer areas. However, there have been some notable exceptions where stock losses have been high. For example, during the Ash Wednesday fires, an estimated 265 900 sheep and 16 700 cattle were killed (Healey, Jarrett, and McKay 1985, p. 4). During the East Gippsland flood of 1998, 30 000 sheep and 7000 cattle were lost. Prices of livestock can vary significantly from season to season. However, the prices in table 4.5 are those suggested by Read Sturgess and Associates (2000, p. 25) as representative of 1999 prices.

Indirect tangible costs

Indirect costs are those that are incurred as a consequence of the event, but are not due to the direct impact. The costs of emergency services and volunteers in responding to the emergency are typical costs. The cost of cleaning up after the disaster is another obvious indirect cost. Disruption to transport services can be a substantial indirect cost.

Indirect costs, by their very nature, are much more difficult to estimate than direct costs. For example, damage to a bridge in a flood is directly observable, but the extra travel costs of travellers forced to travel longer distances and the cost of delay to those unable to proceed, are much harder to measure and estimate. Indirect costs can include a wide range of disaster consequences. One classification is given by Thompson and Handmer (1996, p. 58) (table 4.6).

There is some overseas evidence that indirect costs increase as a proportion of total disaster costs with the size of the disaster (National Research Council 1999, p. 35). Australian data is too limited to make any comparable assessment.

Kates (1965) is often quoted as suggesting that the indirect damage costs for commercial buildings is 37 per cent of the direct damage costs and 45 per cent for industrial buildings. Kates categorised clean-up costs as direct costs. Smith et al. (1979, pp. 69, 78), estimated the indirect costs, (including clean-up costs), of the 1974 Lismore flood as 27 per cent of the direct damage costs for commercial and 52 per cent for industrial buildings. When the Smith et al. estimates were adjusted to be comparable to the Kates categorisation, commercial indirect costs were 18.5 per cent of direct costs and industrial indirect costs were 36 per cent of direct costs. Smith et al. argued that the lower figure for Lismore was, in part, due to the previous flood experience of the Lismore commercial and industrial sectors.

SMEC (1975, p. 39) used Kates proportion for consistency with other Queensland studies, but estimated 35 per cent for commercial buildings and 65 per cent for industrial buildings. Smith et al. (1990a, p. 48) assumed indirect damage as 55 per cent of direct damage costs for commercial and industrial properties, but the Smith et al. (1990a) estimates did not include clean-up costs which were included in direct costs.

TABLE 4.6 CLASSIFICATION OF INDIRECT TANGIBLE LOSSES

Loss category	Examples
Disruption of business	• Manufacturing production • Retail, distribution, office • Leisure services
Disruption of networks	• Communications – Road traffic – Other traffic • Public utilities – Water supply – Sewerage and sewerage treatment – Gas – Electricity – Telecommunications • Computer control systems
Disruption of public services	
Disruption of households	• Additional heating / drying out costs • Other miscellaneous costs
Emergency service costs	• Local government • Police • Fire brigades • Ambulance services • Flood defence agencies • Military aid • Voluntary services

Source Thompson & Handmer (1996, p. 58).

Read Sturgess and Associates (2000, p. 32) estimated that indirect damage costs of the 1993 Benalla flood were 27 per cent of the direct costs and 35 per cent of the direct costs of the 1998 East Gippsland flood. The estimates correctly excluded trade lost during the inundation, but did include the costs of forgone tourism. Tourism should also be excluded from the direct cost estimates, because tourism, like any other business activity, can be deferred or transferred to another location within Australia. When this correction is made, the indirect costs remain unchanged at 27 per cent for the Benalla flood and reduce to 26 per cent for the East Gippsland flood. Other estimates of indirect costs as a proportion of direct costs included 33 per cent for the Nyngan flood and 28 per cent for the 1974 Lismore flood.

Clearly, there is no simple relationship between direct and indirect damage costs. The sample presented in this chapter indicates that the proportion is likely to be in the range of 25 per cent to 40 per cent for floods. There are no good estimates available for other disaster types for Australian conditions.

Disruption of business

Natural disasters can cause serious disruption to affected businesses. Businesses may not be able to operate during the event, and for some time afterwards, while the premises are being cleaned and equipment repaired. Business lost during this period can have devastating financial consequences and in some cases the business may not recover at all.

Loss of production of goods and services

The cost of lost business is often included in the estimated cost of a disaster. For example, Smith et al. (1979, p. 70), estimated that for the Lismore flood, loss of business confidence and loss of trading profit and production accounted for 67 per cent of commercial indirect costs and 71 per cent of industrial indirect costs. But how relevant is the loss of business disruption to national economic costs?

When an economic event occurs (such as flood damage to commercial premises) there is not just one effect, but a series of effects. The principle can be illustrated by a simple example first given by Bastiat in an 1850 essay (Bastiat 1850).

FIGURE 4.5 BASTIAT'S BROKEN WINDOW EXAMPLE

Source Anthony Casey (pers. comm. 14 September 2000).

Bastiat takes the example of a person (he calls him James Goodfellow) who has a window broken in his house. As a result of the broken window, a glazier gains business. In Bastiat's terms, what is seen is the benefit to society of the business activity of the glazier. What is not seen is that the money spent on fixing the window would otherwise have been spent on shoes or books. If the window had not been broken, the shoe industry or some other industry would have received the stimulus of the expenditure. If the window is broken, James finishes up where he started—he has the enjoyment of the window. However, if the window were not broken he would have had the enjoyment of a pair of shoes as well as the window. Industry in general receives no benefit from the broken window—the gains received by the glazier are offset by the losses to other businesses. The net effect is that James has lost the value of the broken window. The effect is illustrated in simple terms in figure 4.5.

If the broken window represents a flooded house and the glazier represents the reconstruction industry, the example illustrates that the net effect on business activity is small. If the analogy is extended a bit further and it is now assumed that James not only has a broken window, but also is unable to continue his business of, say, selling books until the window is fixed, then the glazier in figure 4.5 would also represent other booksellers. The other booksellers would gain from James' loss, but other businesses would enjoy even less of James' patronage. Again, the net effect is the loss of a window to James, and no change in overall business activity.

Appendix IV looks at the same issue from a more technical perspective and arrives at a similar conclusion. Of course, the real world is more complex. If the company gaining business as a result of the disaster incurs additional costs, such as higher transport costs or additional overtime, then these would be a cost attributable to the disaster.

A further example might help to illustrate the point. Consider a vineyard that is affected by flood and is unable to supply grapes to the market. Suppose that a nearby winemaker normally uses the grapes from the flooded vineyard. The grower loses the market value of the grapes, less harvesting and transport costs no longer required, and these losses are a direct cost of the flood. The wine maker must now source grapes from other growers, who in turn increase their prices in response to the increased demand they now face. The increased price benefits other grape growers at the expense of the winemaker and the grower affected by the flood. It will be seen in appendix IV that the net effect is a transfer of welfare from consumers (including the winemaker) to other grape producers.

Whether business disruption costs should be included depends on the perspective that is taken. A local perspective would include business disruption costs if the lost business went to companies outside the local area. The BTE has taken a national perspective, so it is only if the lost business was lost to increased imports or reduced exports that business disruption costs would be included. Disruption to agricultural production may fall into this category, as a large segment of agricultural output is for export.

If business disruption costs are to be included, the value of the loss is the value added forgone and not the value of lost sales. Value added can be measured as the sum of the labour input (including management), profits, interest and rents. If the resources not used during the period of lost production are able to be employed elsewhere, then the value of the loss is the difference between the lost value added and the value of the alternative use of the resources. For example, employees are often involved in the clean-up of flooded commercial and industrial buildings.

If production is not lost but merely interrupted, then the value of the loss is the cost of deferring production. The cost of delay is very much less than the cost of production that is not made up. For example, if twelve months production is lost, the present value, (using a 5 per cent discount rate), of the loss is $11.69 per dollar of lost monthly production. If production is delayed for twelve months and made up by doubling production for the next twelve months, the loss is only 56 cents per dollar of delayed monthly production (Howe et al. 1991, p. 20).

The value of lost stock, including work in progress and input materials, are not included in the cost of lost production as these would be counted in the direct tangible costs.

Clean-up cost for commercial and industrial premises

In the 1974 Lismore floods, very few commercial or industrial enterprises engaged contract cleaners for the clean-up of their premises. Staff of the enterprises were mostly used for cleaning up, with some casual staff also employed (Smith et al. 1979). The results of the analysis of the Lismore floods are shown in table 4.7. The Lismore estimates indicate that the clean-up costs and associated costs of removal and storage represent about 9 per cent of direct damage costs for commercial buildings and 15 per cent of direct damage costs for industrial buildings[12].

Estimates of the clean-up costs for commercial establishments following the 1990 Nyngan floods were based on the following assumptions (Catchment Management Unit 1990, p. 27):

- On average, four people working for five days (or 20 person-days) at 8hrs / day were required to clean-up each commercial establishment.
- At $10 / hr this is equal to $1600 per establishment.
- Another $400 was assumed spent on cleaning materials.
- Total clean-up cost per establishment was therefore $2000 ($2436 in June 1999 prices).

TABLE 4.7 CLEAN-UP TIME AND COSTS FOR THE 1974 LISMORE FLOODS

	Clean-up time (days)	Clean-up costs ($) [a]
Commercial		
Small (< 186 m^2)	1.95	660
Medium (< 186 – 650m^2)	3.20	2640
Large (> 650 m^2)	2.94	5270
Average	2.6	2110
Industrial	2.5	8120

a Costs are in June 1999 dollars. Original figures were in 1974 dollars and updated using the CPI.

Source Smith et al. (1979, pp. 63–72).

Smith et al. (1990a, p. 48) estimated clean-up costs following the Sydney 1986 floods as 11 person-days per property for smaller commercial and industrial premises. Individual estimates using a survey were used for the larger enterprises. The estimate of 11 person-days is significantly less than the estimate for Nyngan, but if the larger premises were included, the average cost is likely to more closely approximate the estimates for both Lismore and Nyngan.

12 These proportions can be derived using information presented earlier in the chapter. Total indirect costs are 27 per cent and 52 per cent of direct costs for commercial and industrial buildings respectively and loss of production and business confidence are 67 per cent of total indirect costs for commercial buildings and 71 per cent of indirect costs for industrial buildings.

The estimates for both the Lismore and Nyngan floods are close in terms of 1999 dollars. If it is not feasible to undertake a survey, an estimate of $2400 per commercial establishment appears reasonable for flooded areas with a similar range of commercial enterprises as Lismore and Nyngan.

Clean-up costs for industrial establishments tend to be more difficult to estimate because of the greater variability in size and type of production facilities. Using the Lismore estimate for other floods would be unlikely to produce an accurate result. If a survey is not practical, a ratio of direct damage costs might be considered.

Clean-up costs for public buildings

An estimate of clean-up costs for public buildings in Nyngan was $8240 per property, including the value of volunteer labour (Catchment Management Unit 1990, p. 30). In June 1999 prices, this is equivalent to $10 040 per property. Clean-up costs for public buildings for other floods or other disaster types were not available in the sources available to the BTE.

TABLE 4.8 PARAMETERS FOR ESTIMATING ROAD TRANSPORT DELAY COSTS

	Cars		Trucks	
	Non-business	Business	Rigid	Artic
$ / person-hr	7.61	24.36	15.70	16.69
Occupancy	1.70	1.30	na	na
No. pallets	na	na	12	16
$ / pallet-hr (non-urban)	na	na	0.70	0.70
$ / pallet-hr (urban)	na	na	1.30	1.30
Proportion (%)	70	30	50	50
$ / vehicle-hr	12.94	31.67	24.10	27.89
$ / vehicle-hr (unladen)	na	na	15.70	16.69

Source FDF Management (1998), BTE Road Infrastructure Assessment Model (RIAM).

Disruption of networks

Transport networks

The most common source of indirect costs from network disruption is due to delays to road traffic following a natural disaster. Road traffic delays are mostly ignored in the measurement of disaster costs, possibly because they are difficult to estimate after the event.

According to Parker, Green and Thompson (1987, p. 73), unless traffic volumes exceed around 4000 vehicles per day in both directions and capacity of the alternative routes is relatively low, traffic disruption costs are likely to be low.

Most rural roads in Australia would not have traffic volumes of this magnitude. Even though traffic volumes on most rural roads in Australia tend to be low, traffic disruption costs can still be significant. Diversions in rural areas over alternative routes can require very large additional travel times and distance travelled. If alternative routes are not taken, waiting times on flooded roads can be long.

Road network disruption costs have two basic components—additional operating costs of the vehicle and the opportunity costs[13] of the delay to vehicle occupants and freight. The additional motoring costs are the additional fuel, oil and maintenance costs incurred in travelling further or at a less efficient speed. It is important to estimate these costs net of taxation. Taxes, such as excise on fuel, are transfer payments, and do not measure the underlying economic cost of the loss due to the additional distance travelled (Parker, Green and Thompson 1987, p. 71). Disruption costs to public transport networks can be estimated in a similar way to road transport costs.

The more common case in non-urban roads is the delay due to vehicles not being able to move at all because of blocked highways. Suggested parameters for estimating the cost of delays are in table 4.8. The parameters are for estimating economic costs. Financial costs to vehicle operators would also include the capital costs of the vehicles.

The following example, illustrating the costs involved, is based on flooding of the Bruce Highway at Tully in early 2000. The total number of vehicles delayed was 150 cars and 140 trucks, each of which was delayed by 105 hours. The total cost of the delays was $638 000. The estimate is a lower bound as it is not known how many drivers waited elsewhere for flood waters to subside and how

13 Economists define opportunity cost as ‘the value of that which must be given up to acquire or achieve something’. For example, if a self-employed person makes a profit of $40 000 per year, but is able to earn $60 000 per year working for someone else, then the opportunity cost of his time is $60 000 per year (Bannock, Baxter & Davis 1998, pp. 304-305).

many used alternative routes to reach their destinations (Queensland Department of Emergency Services, pers. comm. 20 October 2000).

Disruption of computer control systems

If, as a result of a natural disaster, a computer system ceases to function, the repercussions can be substantial. Computer systems have become an integral part of the operations of modern society. They are used to manage networks and production processes among many other applications. In a road network with high traffic volumes, a loss of a computer control system could lead to wide spread congestion. A loss of control of production processes could lead to substantial loss in the value of production. The potential impacts of damaged computer control systems are wide-ranging and would need to be considered separately for each disaster.

Other network disruptions

The loss of utility services within a disaster area is unlikely to add to the indirect costs estimated for other sources. It is only if the loss of a utility (for example, electricity supply) is likely to extend the time of the disruption to business, would the loss of utility services add to disruption costs. Loss of electricity and telecommunications can reduce the efficiency of the response to a disaster, but these costs are unlikely to be large or easily estimated.

In some circumstances, consumers outside the disaster area could lose service from the utility. For example, electricity distribution systems to a group of consumers could be disrupted due to damage caused by a bushfire that had no direct effect on them. The costs of the disruption to such groups, if any, would be a legitimate cost of the bushfire.

However, electricity and telecommunications networks frequently have considerable redundancy built into them. For most locations, disruptions outside a disaster area are likely to be of relatively short duration and can be ignored in disaster cost estimation.

Disruption of public services

Public services present some difficulties. Although cost recovery is becoming more common for the supply of government services, many government functions are of an administrative nature and are not easily valued. Governments place a value on the services they provide of at least the cost of their provision, otherwise they would not provide them. Consequently, the general approach is to value the indirect cost of the loss of government services at the cost of provision.

Many public services such as education, health, defence, art galleries and museums, have externalities associated with them to some degree. That is, the provision of the service brings benefits to society in addition to the direct beneficiaries of the service. For these externalities, the economic costs of service disruption are largely intangible (Parker, Green and Thompson 1987, p. 94).

Education

An indirect cost following a disaster can occur if education cannot be provided at the normal location but can be provided elsewhere at the cost of transporting students between the two locations. The indirect costs would then be the transport costs. This would place a lower bound on the cost, as there would also be an opportunity cost of the time involved in travelling.

Health care

Apart from the direct damage to health care facilities, the main sources of indirect costs are:

- deferral of procedures;
- lower quality of care to patients, due to damaged facilities; and
- costs of transfer to other facilities.

Deferral of procedures can involve additional costs for the hospital, as overtime may be required. However, the additional costs in the overall costs of a disaster are unlikely to be large. The largest component of the deferral cost will be to the patients waiting for the procedure. They would experience a loss of quality of life during the deferral period, the cost of which falls into the category of intangible costs.

In some circumstances, it may be necessary to transfer patients to another facility. The transport costs could then be estimated as an indirect cost of the disaster.

Libraries, art galleries and museums

The direct damages are potentially far larger than indirect costs for libraries, museums and art galleries. Demand can usually be deferred or transferred to another facility, leaving the indirect costs small (Parker, Green and Thompson, 1987, p. 96).

FIGURE 4.6 RESIDENTIAL CLEAN-UP TIME AS A FUNCTION OF FLOOD DEPTH

Source SMEC (1975, p.48).

Disruption of households

Disruption costs faced by households are largely intangible costs. The major indirect costs that are, in principle, capable of being estimated are the increased transport costs in travelling to and from work, costs of alternative accommodation and clean-up costs. Increased travelling costs are included in the costs of disruption to road and public transport networks and should not be included in household costs.

Alternative accommodation

For floods, the time that people need alternative accommodation is usually short-term and mostly with friends and relatives living close to the flood area. Accommodation with friends and relatives is usually freely given. Smith et al. (1979, p. 55) assigned a value of $5 per person per night (in 1974 prices; $26 in June 1999 prices). They also allowed a nominal cost of $10 per household ($53 in June 1999 prices) for the cost of moving goods from the house in preparation for the flood. Corresponding estimates for other disaster types were not available in the sources examined by the BTE.

Clean-up costs

Clean-up costs are a considerable cost to households following a natural disaster. The available information is confined largely to floods. However, estimates of clean-up times for Australian floods vary considerably.

The Snowy Mountains Engineering Corporation (SMEC) developed the following relationship to estimate clean-up times for the 1974 Brisbane flood, which is also depicted in figure 4.6:

$$C = 16.5\ln(F / 0.023)$$

Where:

C = clean-up time in person-days per house
F = flood depth over floor level in metres

The average clean-up time for the Lismore floods of 1974 was estimated to be 7.5 person-days (Smith et al. 1979, p. 53). This estimate is far less than that estimated by SMEC (1975). Smith et al. attribute the difference, in part, to limitations in the questionnaire they used. They conclude that their result was an underestimate.

The Catchment Management Unit of New South Wales (1990, p. 23) used a clean-up time of 26 person-days for the 1990 Nyngan floods. This estimate was based on an earlier estimate for the Georges River flood in Sydney in 1986. Using a sample of over-floor flooding contained in the Nyngan report, the SMEC equation gave an estimated average clean-up time of 52 person-days per house, or twice the Nyngan estimate.

The SMEC curve is probably more suited to estimating clean-up times when the affected households have little prior experience of floods, as was the case for the Brisbane 1974 floods. The SMEC curve would be likely to overestimate clean-up costs for those areas with experience of floods and may even overestimate the time for inexperienced communities. The large range in the estimates suggests that more research is needed. A rough estimate of 20 person-days is considered a reasonable estimate in the absence of better information.

A possible reason for the wide range in the estimates could be due to varying definitions of clean-up costs. Clean-up costs could simply be the removal of mud and stains from flooded houses giving low estimates or could include the disassembly and cleaning of appliances giving a much higher estimate of costs.

The appropriate economic principle for estimating the value of labour used in residential clean-up activities is the opportunity cost of the people involved. For employed people, this is the wage rate they could have earned in their normal employment. The opportunity cost of people not normally employed is more difficult to estimate. SMEC got around this issue by arbitrarily assigning 50 per cent of average weekly earnings to all labour used for flood clean-up. There appears to be an implied assumption that value of the labour provided by unemployed people was zero.

Smith et al. (1979, p. 54) used average weekly earnings for all clean-up labour. The Department of Water Resources (Catchment Management Unit 1990, p. 23) used $10 per hour, which was the rate assumed for unskilled labour.

In principle, the appropriate rate is the wage rate the householders can earn while employed. The same wage rate should be used whether the householder is employed or not. Average weekly earnings can vary with age and sex. However, such information is usually not available for householders involved in clean-up operations. In that case, average weekly earnings would be a reasonable wage rate to use. Such an approach is consistent with the value placed on the labour forgone by accident victims in BTE estimates of the cost of transport accidents (for example, see BTE 2000).

Materials used in cleaning up can represent a significant cost. SMEC (1975) did not estimate material costs. Smith et al. (1979, p. 54) estimated the non-labour cost to be $17.50 ($92 in 1999 prices) per household for the Lismore floods. The Smith et al. estimate included houses that had over-ground, but no over-floor flooding. Smith et al. remarked that the estimate seemed remarkably low. They attributed the low estimate to a common tendency for respondents to surveys to under-estimate clean-up costs. The Catchment Management Unit (1990) estimated the cost to be $480 ($795 in 1999 prices) per household in the Nyngan flood, which was based on the value of cleaning materials donated and an assumption of extra costs incurred by householders. The massive difference between the two estimates suggests that, in the absence of better information gained from surveys, a figure in between would be a reasonable estimate. The value of donated materials used in the Nyngan clean-up was $330 in 1999 prices and would form a useful guide for materials costs.

Response costs

Response involves dealing with the disaster agent (such as fire or flood) plus rescue and relief of persons. The main agencies involved are the emergency services and departments of community services. Other agencies, such as councils, also can be deeply involved and incur expenditure. Relief is an aspect of response concerned with the immediate welfare of evacuees. Emergency services are involved in relief, but voluntary organisations, such as the Salvation Army and the Red Cross, play a major role.

Response costs can be significant, but are usually not well documented. The appropriate economic principle is to assess the marginal cost incurred in responding to a disaster. Information recorded for purposes of NDRA funding of costs incurred by State and Territory emergency services is mostly consistent with this principle. The main exception is that the cost of overtime payments to staff of emergency services is not normally covered, so NDRA data will understate the cost to some extent. Typical NDRA guidelines for counter-disaster operations are included in appendix V.

State and Territory Governments collect this information for purposes of claiming against NDRA funds and it may be available from them for use in estimating the costs of disasters. Data kept by the Commonwealth Department of Finance and Administration are largely aggregated and data on assistance payments for individual disasters are not readily available.

Response to natural disasters depends to a very large extent on the effort and time of volunteers. For example, volunteers contributed over $2 million worth of labour in the response to the Nyngan floods, or about 8 per cent of the estimated direct costs of the floods. Recording of volunteer effort for other disasters is generally not as extensive as for the Nyngan flood and is clearly understated in many disaster reports.

Generally, the correct approach is to value volunteer labour at its opportunity cost. Usually, it is not feasible to obtain information on the usual occupation of volunteers. In the absence of employment information, the appropriate value for volunteer labour is average weekly earnings.

Intangible costs

Intangible costs are often described as a ‘catch all’ that includes all those costs that are very difficult to estimate, for which there is no agreed method of estimation and for which there is no market to provide a benchmark (Thompson and Handmer 1996, p. 11). In the residential sector, intangible costs cover health effects, household disruption and loss of memorabilia. The residential sector has, by far, attracted the most work on intangible costs of disasters. Intangible costs faced by the commercial and manufacturing sectors are generally less than for the residential sector. The most important of the commercial and manufacturing intangible costs are those due to loss of confidence and future contracts. If a national perspective is taken, these losses will be compensated by additional business gained elsewhere in the economy and the national loss will be small.

Loss of public services can also produce intangible losses. For example, if a school is unable to open at a critical period so that students are unable to adequately prepare for exams, the loss to the students can be far in excess of the cost of a few days absence from school. Other possible intangible losses are environmental damage and loss of heritage assets.

How important are intangible costs?

Available estimates of intangible costs suggest that they are very substantial. A frequently quoted example is that of the Buffalo Creek flood of 1972, which resulted from the collapse of a dam at a coal mine. There were 125 people killed (Erikson 1976). Almost all of the survivors suffered psychological problems and 625 of them sued the company. Stern (1976) estimated the losses to households using the schedule of compensation and trauma scale resulting from the court case. In a conceptually similar study, Allee et al. (1980) constructed a scale of trauma suffered by residents in Tug Fork in the United States and estimated the costs by use of the Veteran's Administration Compensation Scheme. Both studies gave an estimate of loss approximately double the direct damage suffered by the households.

In the UK, flood-affected residents were interviewed after a number of floods. They were asked to compare the different impacts of the flood in terms of their relative severity (Parker, Green and Thompson 1987, p. 104). Stress and loss of memorabilia generally ranked above the impact of damage to house and contents (table 4.9). For many people, the effect of having their gardens damaged is similar to the loss of memorabilia. Yeo (2000) reported that a number of respondents to National Hazard Research Centre surveys were sad at the degraded state of their gardens following floods in 1998.

One of the most comprehensive studies of the health effects of floods was that by Chamberlain, Hartshorn et al. (1981) of the 1974 Brisbane flood. The Chamberlain, Hartshorn et al. (1981) report showed that 14 months after the flood, 23 per cent of respondents to a survey had still not recovered from the effects of the experience. Anecdotal evidence of other disasters indicates that the emotional and psychological effects can last for decades.

TABLE 4.9 HOUSEHOLD ASSESSMENT OF THE RELATIVE SEVERITY OF THE DIFFERENT IMPACTS OF FLOODING[a]

Impact	Swalecliffe	Uphill	Southgate	Gillingham	Loughton
Damage to house structure	5.0	5.0	3.0	6.0	5.0
Damage to replaceable contents	9.0	7.0	0.0	7.0	5.5
Loss of memorabilia	10.0	7.0	na	na	6.0
Health effects	7.5	5.0	2.0	6.5	0.0
Stress	10.0	b	6.5	10.0	6.0
Evacuation	10.0	6.0	na	5.0	8.0
Disruption	10.0	10.0	6.0	9.0	8.0
Worry	10.0	2.0	8.0	10.0	6.0
No. of households interviewed	48	101	58	11	61

a The scores are the median scores of those households reporting an impact. The scale is from 0 (not affected) to 10 (most seriously affected).

b not asked.

na No households suffered impact.

Source Parker, Green and Thompson (1987, table 9.7 p. 104).

These few cases illustrate that there is little doubt that intangible costs faced by households as a result of flooding are very important. There is little information available about the intangible costs of disasters other than flooding, but there is no reason to doubt that the intangible costs would also be high for them.

Why estimate intangible costs?

If intangible costs are so difficult to estimate, it is a fair question to ask why not just estimate their impacts without putting a monetary value on them? Many workers in the field of estimating disaster costs adopt this course of action (Smith, Handmer and Martin 1980, p. 50). For example, Smith et al. (1979) estimated days lost by households due to disruption and days of illness for residents affected by the Lismore floods in 1974, but placed no monetary value on the intangible impacts.

Even though there is an acknowledgment of the importance of intangible costs, the absence of an estimate of costs often means they are discounted in the evaluation of mitigation proposals. In that case, the analyst is implicitly assuming the intangible costs are low, if not zero. Even if they are not discounted, the process of weighting the importance of different impacts involves some form of relative valuation. Therefore, there seem to be advantages in attempting to place an estimate on the intangible costs to the extent possible.

Although it is desirable to estimate intangible costs, in practice it may not be feasible to estimate many of the cost categories. Estimating costs when the method of estimation is not well developed, or the data are unreliable, may lead to results that are no better than guesses. Estimates of intangible costs are best limited to those costs for which the data and method are both capable of producing defensible results. Unfortunately, there will still remain a large body of costs for which estimation is not feasible.

The substantial size of intangible costs suggests that they should not be ignored simply because they cannot be estimated. This is especially important in considering the benefits of proposed mitigation measures. The exclusion of intangible benefits can lead to a significant understatement of the benefits. Although the costs cannot be adequately quantified, the analysis would benefit from an examination of the intangible impacts avoided by the proposed scheme.

Multi-criteria analysis is a useful method of incorporating intangible costs and benefits into the analysis. The two major techniques of multi-criteria analysis are the planning balance sheet (PBS) and the goals achievement matrix (GAM). BTE (1999b, chapter 13), has a brief description of both PBS and GAM.

In PBS, major groups within the community are identified and their objectives specified. Costs and benefits of the project are assessed against the objectives of each identified group. For a description of the use of PBS in the assessment of a transport project see Alexander (1978).

In GAM, the major focus is on selected socio-economic objectives rather than community groups. Each impact is given a score and the total score for each impact is weighted relative to other impacts. The scores for all impacts are added together to give a total score for the proposal. Scores for each option can then be compared. For an example of GAM applied to a hypothetical project, see Victorian Department of Treasury and Finance (1996).

Multi-criteria methods have the potential to take into account those costs or benefits that cannot be quantified. The methods should not be used as an alternative to benefit-cost analysis, but rather as an adjunct to it.

Methods of estimation

The methods of estimating intangible costs discussed in the literature typically refer to environmental costs and the loss of cultural and heritage assets. Typical methods are:

- travel cost method (essentially a regression of visitor rates to a site against visitor origin and visit cost and other explanatory variables);

- hedonic price method (based on the assumption that house prices reflect the risks inherent in living at that location);
- contingent valuation method (a social survey is used to estimate respondents' value of a particular good); and
- least cost alternative method (estimates the opportunity cost of using other inputs to provide the same quantity of goods).

These methods have their good and bad points. A summary of their attributes may be found in Thompson and Handmer (1996) or Howe et al. (1991). Generally, the methods can be expensive to implement and may give results of uncertain reliability.

Environmental, cultural and heritage losses

Environmental, cultural and heritage losses tend to be minor costs in most natural disasters. Environmental damage caused by natural disasters can be interpreted as being part of the natural cycle of events that have moulded the natural environment over the ages. Disruption of human activity and business might occur as a result of environmental damage, but the costs of these can be estimated under other categories of costs. If this interpretation is correct, then the cost of the damage to the environment itself can be ignored, as is usually the case.

In some floods it is not clear that this interpretation is correct. There are occasions when mitigation measures may increase the damage to the environment. For example, levee banks designed to protect property from flood damage can alter downstream flows that lead to increased environmental damage. In these examples, a case could be made for including the excess environmental costs due to human activity in the damage estimates for the flood. However, methods for estimating these excess costs are not readily available.

Where the losses to cultural and heritage assets are thought to be significant, the appropriate estimation method would depend on the particular disaster and asset damaged.

Value of life

Placing a value on human life is a contentious undertaking. Estimates of disaster losses usually exclude the costs of human life and medical costs. Generally, the reason for not including a value of a life is based on the observation that individuals would, if asked, assess the value of their own lives as being priceless. However, decisions are frequently made that imply a trade-off between expenditure on safety and risks of human fatalities and injuries. For example, decisions are made about how much money should be spent on reducing the risk of accidents that could involve fatalities. Aircraft are designed to balance the costs of safer travel against better financial performance. Such decisions include implicit valuations on human life. Costs of human life are routinely included in estimates of transport accidents and there are good reasons for including them in estimates of disaster costs. These issues are developed further in appendix I.

Adapting the method used in BTE (2000), the BTE derived average values, (in 1998 dollars), of $1.3 million as the cost of a natural disaster fatality, $317 000 for a serious injury and $10 600 for a minor injury (see appendix I for details).

Health and disruption impacts

The effects of floods and other natural disasters can be devastating on those most affected by them. It is widely recognised that people suffering from stress caused by such life-changing events can experience physical and emotional difficulties. The degree of the physical or emotional response depends on the nature of the disaster, the warning received and the person.

Bennett (1970) undertook a much quoted study of the health effects of a flood in Bristol in 1968. The results of the study included the finding that:

> Surgery attendances rose by 53 per cent, referrals to hospital and hospital admissions more than doubled. In all respects the men appeared less able to cope with the experience of disaster than the women did.

Australian studies also found significant health effects of natural disasters. Representative studies that included an examination of health effects include:

- Abrahams et al. (1974) study of the 1974 Brisbane flood;
- Smith et al. (1979) and Smith, Handmer and Martin (1980) study of the 1974 Lismore flood;
- Chamberlain and Hartshorn et al. (1981) study of the social effects of the 1974 Brisbane flood;
- Chamberlain and Doube et al. (1981) study of the social effects of the 1974 Cyclone Tracy;
- Mental Health Research and Evaluation Centre (1985) study of the 1983 Ash Wednesday bushfires; and
- Smith et al. (1990a,b) study of the 1986 Sydney floods.

Studies of health impacts of natural disasters are generally limited to estimates of the proportion of the disaster-affected population that was adversely affected and the number of the days of consequent debilitation. The next step of placing a monetary cost on the number of days lost through debilitation is usually not taken. An appropriate method would be to use an opportunity cost of the lost time.

Health impacts are usually measured by means of surveys. There is no alternative if an accurate estimate is required. The surveys almost always ask the respondent to self-report on adverse health effects. Although self-reporting can be criticised, the evidence in the previously mentioned reports seems to suggest that the method is reliable.

Household disruption can be a major disaster cost and is also best measured by means of a survey. Disruption to businesses can also be significant, but total costs of business disruption are usually less than total residential disruption costs and are negligible from a national perspective.

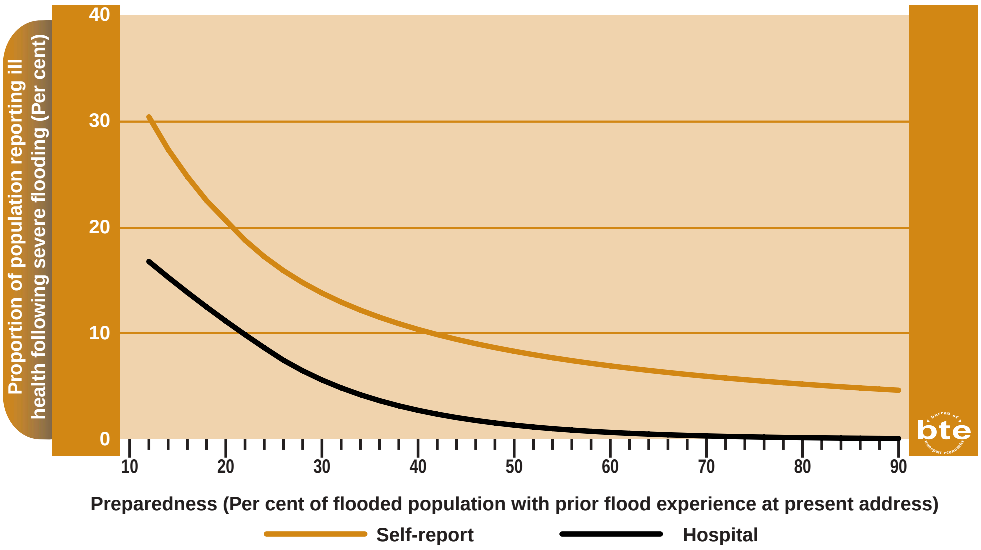
Approximation method for estimating health impacts

People with prior experience of floods are usually better able to cope with the stress induced by floods. Those studies that have estimated the impact of floods on health generally support this view. Handmer, Lustig and Smith (1986) published curves that represent the approximate relationship between prior experience and health impacts (figure 4.7). The curves in figure 4.7 provide a simple way of estimating the number of people suffering adverse health effects without the need for a comprehensive survey. Information would be required on the proportion of the population with prior flood experience and this may require a survey, but it would be simpler and less expensive than one that sought specific information on health.

However, the relationships in figure 4.7 are based on very few data points and as such will have wide confidence limits. Estimates based on them are likely to contain significant errors and consequently the curves should be used only as a last resort.

The methods of estimating health impacts mostly quantify the physical effects and length of time those affected are debilitated. The psychological effects are frequently extensive and long lasting. If at all possible, they should be included in disaster reports. Parker, Green and Thompson (1987, p. 107) describe an exploratory method that relates the perceived relative effect of the psychological impacts to the direct damage costs.

FIGURE 4.7 HEALTH IMPACT OF FLOODS AS A FUNCTION OF PRIOR FLOOD EXPERIENCE



Source Based on Handmer, Lustig and Smith (1986).

SUMMARY

Tables 4.10 and 4.11 summarise the suggested approach to estimating natural disaster costs. The tables illustrate the major points in the text. However, as noted in the introduction to this chapter, the categories are not intended to cover every conceivable cost category. Nor will every category apply to every disaster. Each disaster is unique. The analyst will need to decide on the basis of the nature of the event being investigated and the availability of data, which categories to include.

The chapter provides information on appropriate methods for estimating costs and some approximate methods where more accurate (and more costly) methods may not be feasible. The suggested methods may not cover the full range of possibilities and should therefore be interpreted as a guide.

This chapter has taken a national perspective, as this is the appropriate approach to achieve the objectives set out in chapter 1. The methods discussed in the chapter are also appropriate for estimating the benefits of mitigation proposals with one possible exception. Mitigation schemes are usually designed to provide local rather than national benefits. It may then be appropriate to estimate the benefits (that is, losses avoided) from a local rather than a national perspective. It should be noted that the locally-based estimation would ignore effects outside the local region. That is, the business disruption losses within the region may not be totally offset by gains elsewhere. As a consequence, if losses from all disasters were estimated on a local basis and then summed, the total would exceed that derived by taking a national perspective as was done in this report.

TABLE 4.10 SUMMARY OF DISASTER COST ESTIMATION—DIRECT COSTS

Cost category	Estimation principle	Data sources
Direct costs		
Residential buildings – structures and contents[a]	Depreciated economic value	1. Survey 2. Stage-damage curves for floods 3. Adjusted insurance claims 4. $20 500 per flood damaged residential building (Read Sturgess & Associates 2000) 5. $23 200 per bushfire damaged building[b] (BTE estimate based on NSW Coroner (1994))
Commercial & industrial buildings – structures and contents	Depreciated economic value	1. Survey 2. Average unit cost based on floor area and susceptibility to floods (table 4.2) 3. Adjusted insurance claims
Public buildings – structures and contents	Depreciated economic value	1. Survey 2. Adjusted insurance claims
Infrastructure	Cost of restoration	1. NDRA 2. Unit costs (table 4.3)
Crops	Market value less input costs avoided	1. Survey
Pastures	Cost of restoration	1. Survey 2. Average unit costs (table 4.4)
Fences	Cost of repairs	1. Survey 2. Unit costs ($5000 / km (Read Sturgess and Associates (2000))
Livestock	Market value	1. Survey 2. Representative values (table 4.5)

a Some methods give an estimate of potential flood damage. Actual damage is generally less than potential damage depending on the extent of warning given and the prior flood experience of the community (figure 4.4).

b The average bushfire damage estimate is only for damaged houses and does not include houses that are totally destroyed.

Source See preceding text.

TABLE 4.11 SUMMARY OF DISASTER COST ESTIMATION—INDIRECT AND INTANGIBLE COSTS

Cost category	Estimation principle	Data sources
Indirect costs		
Business disruption	Loss of value added (usually not estimated if a national perspective is taken)	1. Survey
Loss of public services	Cost of provision	1. Service providers
Non-residential clean-up	Cost of materials plus opportunity cost of labour used	1. Survey 2. table 4.7 for commercial buildings 3. $10 000 for public buildings
Residential clean-up	Cost of materials plus opportunity cost of labour used	1. Survey 2. $330 per household for materials and AWE for household labour (20 person days)[a]
Household alternative accommodation	Additional costs of accommodation plus any transport costs	1. Survey 2. $53 per person plus $26 per person-night
Agriculture	Costs such as fodder, agistment, loss of productivity due to pests	1. Survey
Transport networks	Increased vehicle operating costs. Value of time for delayed people and freight	1. Survey to estimate vehicle-hours of delay 2. Unit costs from table 4.8
Disaster response and relief	Marginal costs incurred by relevant agencies. Opportunity costs of volunteer labour.	1. NDRA 2. Survey of volunteer organisations
Intangible costs		
Fatalities	Human capital approach	$1.3 million (appendix I)
Injuries	Human capital approach	$317 000 for a serious injury and $10 600 for a minor injury (appendix I)
Health effects	Days of debilitation X AWE	1. Survey 2. Average proportion affected
Environmental damage, memorabilia & cultural heritage	Ideally one of: 1. Travel cost method 2. Hedonic prices 3. Contingent valuation 4. Least cost alternative Otherwise proportion of direct costs	Survey if one of the analytic methods is used.

a There is considerable variation in material costs and clean-up times reported in the literature. The values suggested here are representative of the reported values.

Source See preceding text.

5

A COMPARISON

In this chapter the framework for estimating the cost of natural disasters developed in chapter 4 is applied to data contained in published reports of past natural disasters. A comparison of the cost estimates contained in chapter 3, using the EMA database, with these reports and other existing research on the costs of natural disasters in Australia is also included.

A LOOK AT PREVIOUS DISASTER REPORTS

Reports of previous disasters provide useful insights into the consistency and comprehensiveness of the cost estimates of those earlier disasters. The framework developed in chapter 4 provides the benchmark for analysing the reports. Five disasters were selected for this analysis. The disasters were selected, firstly on the basis that there was adequate documentation to allow matching of the cost estimates with the cost framework, and secondly, that they represented a range of disaster types and had a reasonable geographic distribution. The disasters analysed were:

- Nyngan Flood, New South Wales (1990);
- Lismore Flood, New South Wales (1974);
- Cyclone Tracy, Northern Territory (1974);
- Ash Wednesday Bushfire, Victoria and South Australia (1983); and
- Edgecumbe Earthquake, New Zealand (1987).

Nyngan Flood (1990)

Nyngan was flooded in April 1990 following record rainfalls in the catchment of the Bogan River. Sandbag levees, laid along the permanent levees, failed and this led to extensive flooding of the town. The Catchment Management Unit of the New South Wales Department of Water Resources published a report on the costs of the flood (1990). The damage costs included in the report were estimated by Water Studies, a consultant engaged by the Department of Water Resources.

The BTE used the data in the Nyngan report (Catchment Management Unit 1990) to estimate the cost components illustrated in tables 4.10 and 4.11. The Catchment Management Unit (1990) estimated the cost of the Nyngan flood at $57.8 million in 1999 prices. The BTE estimate of $46.4 million in 1999 prices was significantly lower. The difference was mostly due to the exclusion of business and household disruption costs from the BTE estimates (table 5.1). Trade lost during the flood had the potential for being transferred or deferred with minimal national economic loss. Loss of rental income for the Department of Housing was excluded for the same reason—accommodation was still required by the tenants and this cost was picked up in the costs of alternative accommodation.

Household income lost during the flood is excluded from household disruption, but the opportunity cost of the lost wages is included in the costs of household clean up. To count lost income, as well as the value of the labour those same employees used in cleaning-up their houses or other volunteer activities, would be to count the labour cost twice.

The direct damage costs for the residential damage overstates the costs to some extent. The costs of durable items destroyed in the flood were taken as their replacement costs rather than their depreciated values (Catchment Management Unit 1990, p. 3). In chapter 4 it was noted that a common approach is to assume the item is half way through its economic life and to assign a value appropriate to this age.

In the Nyngan report, infrastructure and disaster response costs, (excluding volunteers), were included in public authority costs. In table 5.1 these have been allocated according to the scheme in tables 4.10 and 4.11.

Agricultural damage was not investigated in the study leading to the Nyngan report. This was not because there was no agricultural damage, but because the focus of the study was on the Nyngan urban area. This raises the important point that in estimating disaster losses, care should be taken in establishing the boundaries of the study to ensure that the estimation process captures all of the losses.

Some of the labour costs included in indirect costs overstate the economic costs. The Nyngan report, in some cases, does not

TABLE 5.1 ESTIMATED COSTS OF THE NYNGAN FLOOD, 1990

($'000)[a]

Cost category	Estimated cost
Direct costs	
Residential structures and contents	16 553
Commercial & industrial building structures and contents	3 861
Public buildings—structures & contents	4 747
Infrastructure[b]	9 665
Crops	
Pastures	
Fences	
Livestock	
Sub-total	34 825
Indirect costs	
Business disruption	0
Loss of public services	999
Business clean-up	231
Household clean-up	2 144
Public buildings clean-up	365
Household alternative accommodation	2 399
Agriculture	0
Transport networks	0
Disaster response & relief (excluding volunteers)[b]	4 832
Volunteer contribution to disaster response and relief	572
Sub-total [c]	11 543
Intangible costs	
Fatalities	
Injuries	
Health effects	
Environmental damage, memorabilia & cultural heritage	
Sub-total	
TOTAL	46 368

a 1999 prices
b Included in public authorities in Nyngan report (Catchment Management Unit 1990)
c Indirect costs are 33 per cent of direct costs.
Source BTE estimates based on Catchment Management Unit (1990).

distinguish between salaries that would have been paid in the absence of the disaster and the additional labour costs such as overtime and the costs of casual staff that were incurred as a direct result of the disaster. Where a distinction could be made, a correction to the results was made.

It was not possible to compare the BTE estimates with those in the EMA database, as the EMA database aggregated the Nyngan flood costs with those of the more general flooding that occurred at that time.

Lismore flood (1974)

Lismore, located on the Richmond River in Northern New South Wales, is one of the most flood-prone towns in New South Wales. The Northern Rivers College of Advanced Education and the Centre for Resource and Environmental Studies of the Australian National University investigated the flood damage due to the 1974 flood. The report on the investigation assessed both urban and rural flood damage in the Richmond River valley due to the 1974 flood (Smith et al. 1979).

The BTE estimate of the total cost of the Lismore flood was $84.1 million in 1999 prices, which is less than the total of $89.4 million in the report. The major reason for the difference is the exclusion of lost business from the BTE estimate.

The BTE also had a different allocation of direct and indirect costs. For example, a major cost item estimated in the report is the premature sale of stock. In the BTE framework, this would be an indirect cost. Unfortunately, the report by Smith et al. (1979) does not indicate how the premature sale loss was estimated.

The report did not include an estimate of the cost of disaster response or volunteer efforts. Essentially, the omission was because the report's primary purpose was to estimate damage costs, and possibly because the data were not readily available in the period after July 1977 when the study commenced.

The indirect costs were 28 per cent of the direct costs (table 5.2). The ratio would have been higher if disaster response and volunteer costs had been included.

For the most part, the report was reasonably consistent with the framework set out in chapter 4. Some differences in the allocation of costs, direct or indirect, were evident and these are reflected in table 5.2. It has not been possible to compare the costs, shown in table 5.2, with the costs in the EMA database, as the costs of the 1974 floods in the Richmond River are combined with the more

TABLE 5.2 ESTIMATED COSTS OF LISMORE FLOOD, 1974

($'000)[a]

Cost category	Estimated cost
Direct costs	
Residential structures and contents	8 668
Commercial & industrial building structures and contents	22 607
Public buildings—structures & contents	612
Vehicles	0
Infrastructure	1 366
Agriculture	32 418
Crops	
Pastures	
Fences	
Livestock	
Sub-total	65 671
Indirect costs[b]	
Business disruption	
Loss of public services	
Business clean-up	1 857
Household clean-up	2 420
Public buildings clean-up	
Household alternative accommodation	466
Agriculture	13 697
Transport networks	
Disaster response & relief (excluding volunteers)	
Volunteer contribution to disaster relief	
Sub-total	18 440
Intangible costs	
Fatalities	
Injuries	
Health effects	
Environmental damage, memorabilia & cultural heritage	
Sub-total	
TOTAL	84 111

a 1999 prices.
b Indirect costs are 28 per cent of direct costs.
Source BTE estimates based on Smith et al. (1979).

widespread flooding that occurred throughout north eastern New South Wales and south eastern Queensland.

Cyclone Tracy (1974)

Cyclone Tracy was the most damaging cyclone in modern Australian history. Darwin was almost totally destroyed and most of the town's population was evacuated. Despite the enormity of the disaster, the BTE was unable to locate a single document that attempted to estimate the total costs of the disaster. The BTE estimated the overall costs using a wide range of sources. The use of many sources inevitably leads to errors, as the assumptions were not always clear with the result that consistency across sources is doubtful. Furthermore, some key pieces of information were no longer available, so the BTE had to make many rather crude assumptions to allow reasonable estimation.

Direct costs

The Department of Housing and Construction (1975) estimated that 5000 houses were destroyed and a further 5000 were severely damaged. The estimated replacement costs of the destroyed houses were $35 000 per house in 1974 prices and the cost of repairing the damaged houses was 50 per cent of the replacement cost. The BTE updated the estimated costs of both destroyed and damaged houses to 1999 prices using the consumer price index (CPI). As a cross check, the 1999 costs of damaged houses were compared with the BTE estimated costs of repairing houses suffering major damage following the 1994 New South Wales bushfires (NSW Coroner 1994). Both estimates were very close to $70 000.

The residential costs also include damage to flats and bulk accommodation, which were estimated to have cost $18 million in 1974 prices (Department of Housing & Construction 1975, p. 55).

Government buildings were estimated to have had damage costs of $12.4 million in 1974 prices ($65.4 million in 1999 prices). No estimate was available of the damage costs related to commercial or industrial buildings. In the absence of better information, the BTE set the level of commercial and industrial building damage as equal to the damage to public buildings (table 5.3).

The Department of Housing and Construction report contained an estimate of the cost of restoring electrical reticulation ($8 million in 1974 prices) but had no estimates for other infrastructure. It is known that telecommunications, water and sewerage systems were also severely damaged. The BTE allowed for the damage to these other components of the infrastructure by setting each of telecommunications and water and sewerage to be equal to the costs of restoring electrical reticulation. The 1974 cost of the total infrastructure damage was set at $25 million in 1974 prices ($132 million in 1999 prices) or approximately three times the cost of damage to electrical reticulation.

No information was available on the number of vehicles damaged, although the number must have been large.

Indirect costs

Very little information was available on indirect costs. The information that was available allowed some estimates to be made of alternative accommodation and disaster response costs.

Alternative accommodation

Following the cyclone, 35 362 people were evacuated from Darwin out of a total population of about 45 000. Of these, 25 628 left by air and 9734 left by road (Director-General Natural Disasters Organisation 1975, p. 33). It was not until September 1975 that the first house was rebuilt in Darwin, and it was not until the middle of 1978 that Darwin could again house its pre-Tracy population (Northern Territory Library and Information Service 2000a).

The 35 000 people that were evacuated needed alternative accommodation, but it is not known for how long the accommodation was required. The fact that no new houses were constructed for nine months suggests that alternative accommodation was required for at least this length of time. The cost of alternative accommodation for those evacuated was therefore calculated on the basis of being required for nine months. The cost was calculated at $5 per night in 1974 prices (Smith et al. 1979).

In Darwin itself, the remaining 10 000 people also needed accommodation. In addition, a further 20 000 additional people arrived in Darwin by May 1975 to assist in the reconstruction of Darwin. Emergency accommodation for these people consisted of 1700 demountable dwellings and caravans brought to Darwin and the liner Patris with accommodation for 900 people. The Patris provided emergency accommodation for nine months (Northern Territory Library and Information Service 2000a). The cost of the demountable dwellings was assumed to be $5 per night for 270 nights and the Patris was estimated to cost $7000 per day in 1974 prices. The total estimated cost of alternative accommodation based on these assumptions was $320.3 million in 1999 prices.

TABLE 5.3 ESTIMATED COSTS OF CYCLONE TRACY, 1974

($'000)[a]

Cost category	Estimated cost
Direct costs	
Residential structures and contents	1 144 909
Commercial & industrial building structures and contents	65 382
Public buildings—structures & contents	65 382
Vehicles	
Infrastructure	131 818
Agriculture	
Crops	
Pastures	
Fences	
Livestock	
Sub-total	1 407 491
Indirect costs[b]	
Business disruption	
Loss of public services	
Business clean-up	
Household clean-up	
Public buildings clean-up	
Household alternative accommodation	320 318
Agriculture	
Transport networks	
Disaster response & relief (excluding volunteers)	23 918
Volunteer contribution to disaster relief	70 970
Sub-total	415 206
Intangible costs	
Fatalities	84 500
Injuries	58 731
Health effects	
Environmental damage, memorabilia & cultural heritage	
Sub-total	143 231
TOTAL	1 965 928

a Costs are in 1999 prices.

b Indirect costs are 29 per cent of direct costs.

Source Department of Housing and Construction (1975), Director-General Natural Disasters Organisation (1975), Gurd, Bromwich & Quinn (1975), Northern Territory Library and Information Service (2000a,b,c), O'Shea (1975).

Disaster response

A major cost of the disaster response was the cost of evacuating 35 000 people. Of these, 15 950 were evacuated by civilian aircraft, 9678 by military aircraft and the remainder by road. Data were not available on what types of aircraft were used or where each person went. To estimate indicative figures of the evacuation cost, the BTE assumed that all evacuations by air were to Sydney and road evacuations were to Adelaide. Evacuations by military and civilian aircraft were assumed to be by C130 and B727 aircraft respectively. The same aircraft were also assumed to bring emergency workers to Darwin. Road evacuations were assumed to be in Ford Falcon sedans.

The Government of the day also agreed to pay for evacuees to return to Darwin when it was safe to do so (Director-General Natural Disasters Organisation 1975, p. 34). However, not all evacuees returned. It is known that by 1980, 60 per cent of those who were on the electoral role in 1974 were no longer in Darwin (Northern Territory Library and Information Service 2000c). Many of those who were no longer in Darwin would not have remained even if there had been no cyclone. Darwin, prior to the cyclone was regarded as a place for short-term postings, usually for about two years (Northern Territory Library and Information Service 2000c). Some of those who did not return after the cyclone may have been near the end of their posting in any case. The cost of the return travel was therefore based on the assumption that 25 per cent did not return for reasons connected with the cyclone.

Operating costs of B727s were estimated using the BTE computer package Aerocost2. Operating costs of C130s were based on advice from the Department of Defence and car operating costs were those estimated by the NRMA as at June 1999. Based on these assessments, the BTE estimated the cost of the evacuation to be $23.9 million (table 5.3).

The early response to the cyclone depended to a large extent on the contribution of volunteers. Those residents remaining after the evacuation (10 500) were generally involved in disaster response activities and could therefore be considered as volunteers. It was assumed that this volunteer activity lasted for eight weeks. After that, activities would be directed to reconstruction, the cost of which would be covered by the direct damage cost.

A large, but unknown, number of volunteers manned reception centres in all State and ACT reception centres for evacuees. As a rough guide, it was assumed that these equalled the number of volunteers in Darwin and that their work was completed after one week. Volunteer labour was costed as being equal to average weekly earnings. The total value of volunteer labour was estimated to be $71 million in 1999 prices (table 5.3).

Intangible costs

The only intangible costs able to be estimated were those attributable to deaths and injuries. As a result of the cyclone, 65 people died and 145 people were admitted to hospital. Two of the hospital admissions subsequently died and are included among the fatalities. In this analysis, the remaining 143 admissions were considered as being seriously injured. A further 500 were treated at the hospital, but not admitted. They were considered as having minor injuries (Gurd, Bromwich and Quinn 1975). About 90 per cent of the population required first aid of some kind (O'Shea 1975). The BTE assumed that the cost of first aid was $200 per person in 1999 prices. The total cost of injuries was estimated to be $58.7 million and fatalities were estimated to cost a further $84.5 million (table 5.4).

The BTE estimate of the total cost of Cyclone Tracy is $1.97 billion (table 5.3). This is far short of the $4.2 billion estimate contained in the EMA database. Part of the reason could be the low estimate of indirect costs (29 per cent of direct costs) in the BTE calculations. For a disaster of the magnitude of Cyclone Tracy, it could be expected that the indirect costs would be a much higher proportion of direct costs. One cost that has not been included is the value of the materials brought to Darwin to assist in the response. Over 1000 tonnes of equipment were transported to Darwin by Defence aircraft in the first week after the cyclone (Director-General Natural Disasters Organisation 1975, p. 57). The total cost of the equipment and the other undocumented supplies would have been large.

Even though the BTE analysis has included an estimate of the costs of deaths and injuries, intangible costs are most likely to be very much understated. In a major disaster such as Cyclone Tracy where many homes are destroyed, the psychological effects can last for years. The evacuation of Darwin and the consequential separation of family members was the most important direct contributor to stress for those suffering psychological effects in the aftermath of the cyclone (Chamberlain, Doube et al.1981, p. 147). The number of people suffering long term effects is unknown. The costs, although impossible to estimate this far removed from the event, would be substantial.

However, even if a better estimate of indirect costs gave indirect costs as 50 per cent of direct costs, a large discrepancy between the two estimates would remain. The EMA estimate is based on a

TABLE 5.4 ESTIMATED COST OF DEATHS AND INJURIES, CYCLONE TRACY

	Number	Unit cost ($'000)	Total ($'000)
Fatalities	65	1 300	84 500
Injuries			
Serious injuries	143	317	45 331
Minor injuries	500	10.6	5 300
Required first aid	40 500	0.2	8 100
Total injury cost	41 143		58 731

Source BTE analysis based on Gurd, Bromwich and Quinn (1975), O'Shea (1975) and appendix I.

ratio between insurance cost and total cost developed by Joy (1991). Joy's ratio for cyclones suggests that insurance costs should be multiplied by 5 to give total costs. The BTE estimates suggest that the factor of 5 may be excessive for Cyclone Tracy.

Ash Wednesday Bushfire (1983)

Prior to the Ash Wednesday bushfires in February 1983, most of Victoria and South Australia had been in the grip of drought for almost a year (Oliver, Britton & James 1984, p. 6). On 16 February temperatures were high (over 40 degrees for much of Victoria) relative humidity was low (below 10 per cent at Melbourne airport) vegetation was dry and winds were strong (Oliver, Britton & James 1984, pp. 19–21). Although there had been some fires in the weeks leading up to Ash Wednesday, the weather conditions on that day were extremely favourable for the development of bushfires, and once started, the fires would be virtually uncontrollable. In a matter of hours, fires promoted by the adverse weather conditions, caused considerable loss of life and property.

Although much was written about Ash Wednesday, the BTE was unable to locate a single source of data that covered the losses in both South Australia and Victoria. The following analysis is therefore derived from a range of sources. The errors inherent in estimating total costs from a variety of sources were discussed in the previous section and apply equally well to the following estimates.

Direct costs

It is not clear how many houses were destroyed or damaged in the Ash Wednesday bushfires. Healey (1985, p. 4) gave the number of destroyed houses as 207 in South Australia and 1511 in Victoria.

The Country Fire Authority (1983) estimated that 2104 houses, (including 14 holiday houses), were destroyed in Victoria, whereas Oliver, Britton and James (1984, p. 42) put the figure at 1719. None of the sources contains an estimate of the number of houses damaged in Victoria. Healey (1985, p. 4) estimated that 178 houses were damaged in South Australia.

It is possible that the Victorian estimates include damaged as well as destroyed houses. For purposes of analysis, the average of the estimates for destroyed houses was used and the difference between the average and the maximum number was assumed to be the number damaged. For Victoria, this gave 1778 houses destroyed and 326 damaged.

The costs of houses destroyed and damaged in the 1994 New South Wales bushfires formed the basis of the estimates for Ash Wednesday. The cost of a destroyed house in the New South Wales fires was reduced by 25 per cent to take account of the difference between insurance payout figures and economic cost and updated to 1999 prices using the CPI. The resulting estimate of costs, per destroyed and damaged house, was $18 300 and $29 000 respectively. The total cost of damage to houses in South Australia and Victoria was $378 million in 1999 prices.

There were an estimated 7 timber mills, 82 commercial premises and 23 dairies destroyed in the fire (Healy, Jarrett, McKay 1985, p. 4, Oliver, Britton and James 1984, p. 42). In this analysis, the damage costs were estimated at the same rate as the damage to commercial premises during the 1994 New South Wales bushfires, updated to 1999 prices and insurance values adjusted to reflect economic values. The total direct damage to commercial buildings was $31.6 million (table 5.5).

Oliver, Britton and James (1984, p. 42) estimated damage to government assets at $26 million in 1983 prices or $52 million in 1999 prices (table 5.5).

There was no firm estimate of the number of cars destroyed in the bushfire. The best estimate available was that of Healey (1985, p. 4) of between 564 and 768. The upper limit was considered to also include uninsured and unreported damage. The value of the cars was set at $14 500, which is an estimate of the depreciated value, based on a representative new car price of $25 000. Under these assumptions, the total cost of destroyed vehicles in 1999 prices was estimated to be $11.2 million.

Thomson (1985, p. 34) provides the only estimate of infrastructure costs. His estimate was based on NDRA funding and thus represents

TABLE 5.5 ESTIMATED COSTS OF ASH WEDNESDAY BUSHFIRE, 1983

($'000)[a]

Cost category	Estimated cost
Direct costs	
Residential structures and contents	377 870
Commercial & industrial building structures and contents	31 584
Public buildings—structures & contents	52 000
Vehicles	11 165
Infrastructure	15 484
Agriculture	
Crops	173 466
Pastures	2 086
Fences	79 500
Livestock	17 760
Sub-total	760 915
Indirect costs[b]	
Business disruption	
Loss of public services	
Business clean-up	
Household clean-up	
Public buildings clean-up	
Household alternative accommodation	12 801
Agriculture	
Transport networks	
Disaster response & relief (excluding volunteers)	16 205
Volunteer contribution to disaster relief	11 291
Sub-total	40 297
Intangible costs	
Fatalities	96 200
Injuries	69 117
Health effects	
Environmental damage, memorabilia & cultural heritage	
Sub-total	165 317
TOTAL	966 528

a Costs are in 1999 prices.

b Indirect costs are 5.3 per cent of direct costs.

Source BTE estimates based on Bentick 1985, Country Fire Authority (1983), Healey (1985), McFarlane (1984a,b), McKay (1985), Mental Health Research and Evaluation Centre (1985), Mules (1985), Oliver, Britton & James (1984), Thomson (1985).

the incremental cost of restoration. His estimate refers only to South Australian costs. Victorian costs are likely to have been similar, so the estimate in table 5.5 is equal to twice the South Australian estimate updated to 1999 prices.

The only information available on crops and pastures was for South Australia. In 1999 prices, the South Australian costs for lost horticultural crops and pastures were $3.7 million and $1.04 million respectively (Mules 1985, p. 17). In the absence of better information, Victorian damage costs were assumed to be the same as South Australian costs. In addition, large-scale damage occurred in forest plantations of pinus radiata. Bentick (1985, p. 145) estimated the cost of the loss, in terms of the damage to existing crops and reduced future crops, as $83 million in 1983 prices, ($166 million in 1999 prices).

The fires destroyed 266 650 sheep, 18 450 cattle and 8940 kilometres of fencing (Mental Health Research and Evaluation Centre 1985, p. 75). The costs of these losses were estimated using the values suggested in Read Sturgess & Associates (2000) and analysed in chapter 4 (table 5.5).

Indirect costs

Very little information was available on indirect costs. Some limited information was available on alternative accommodation and disaster response.

Alternative accommodation

About 8000 people were made homeless in Victoria (Oliver, Britton and James 1984, p. 42). There was no information for South Australia, but if it is assumed that there were four people per destroyed or damaged house, the number of homeless in South Australia would have been 1540. It is not known how long homeless people required alternative accommodation. However, $1500 was granted to those forced to find alternative accommodation (Mental Health and Evaluation Centre 1985, p. 4). It was not clear whether this payment was per person or per household. In calculating the cost it was assumed to be per household. The cost, in 1999 prices, was $12.8 million.

There would have also been many people who were evacuated as a precautionary measure. The BTE had no information on the number of such persons or for how long they were unable to return to their homes. There may have also been traffic delays due to road closures as a result of the fires. There was no information on this potential source of indirect costs in the documents available to the BTE.

Disaster response

The cost of disaster response was estimated to be $16.2 million (table 5.5). This estimate included NDRA expenditure (Thomson 1985, p. 34), coronial costs (Thomson 1985, p. 34) and Department of Defence costs. Thomson's costs were for South Australia only. Similar amounts were assumed for Victoria.

In South Australia, there were about 2700 volunteer firefighters (McKay 1985, p. 81) and 5000 in Victoria (McFarlane 1984b). According to McFarlane (1984a), volunteer fire fighters spent approximately six days each in fire fighting and mopping up. Based on 1999 average weekly earnings, the cost of volunteer firefighters was $5.6 million. The volunteer effort is much larger than this. Volunteers are active in arranging alternative accommodation, feeding firefighters and many other activities that are needed to support the response effort. Allowing an amount equal to the value of volunteer fire fighters is a reasonable estimate of the work of the other volunteers. The total estimated contribution of volunteers is therefore $11.3 million in 1999 prices (table 5.5).

Intangible costs

As a result of the bushfires, 74 people lost their lives, 133 were admitted to hospital and a further 2543 received minor injuries. Using the values for fatalities and injuries derived in appendix I, a total cost of $165.3 million is arrived at for deaths and injuries.

The overall cost of $967 million is similar to the estimate in the EMA database of $975 million. However, the BTE estimate includes a value for deaths and injuries that are not included in the EMA estimate. In addition, the ratio of indirect to direct costs of 5.3 per cent appears excessively low. This suggests that the total cost is substantially higher than that indicated here or in the EMA database. If flood disasters are any guide, indirect costs could be expected to be more like 30 per cent of direct costs, which would increase indirect costs to around $230 million and the total costs to around $1150 million. However, the information needed to make an estimate of indirect costs that has any pretensions to being accurate is unlikely to exist.

Edgecumbe Earthquake (1987)

On 2 March 1987, an earthquake of magnitude 6.3 on the Richter scale occurred in the Bay of Plenty region of New Zealand. Assessed intensities as measured by the Modified Mercali scale[14] had a maximum value of 10 in parts of Edgecumbe (Butcher, Andrews & Cleland 1998, p. 5).

The BTE analysis is based on the work of Butcher, Andrews and Cleland (1998) who provided a comprehensive study of the effects of the earthquake and its aftermath. The method of categorising costs in Butcher, Andrews and Cleland (1998) differs from that suggested in chapter 4, but the method for estimating the different cost components is generally in accord with the suggested principles.

Direct costs

The direct damage costs are mostly based on insurance costs. The main insurer, the New Zealand Earthquake and War Damage Commission, offered indemnity cover for natural disaster damage. Indemnity insurance covers the depreciated value of the asset and is therefore consistent with the economic principles in chapter 4. By far, industrial buildings and equipment suffered the largest degree of damage (table 5.6).

The Butcher, Andrews and Cleland report (1998, p. 37–38) indicates that the damage covered by insurance overstates the residential damage that could realistically be attributed to the earthquake. Chimneys were replaced by insurance that were more likely damaged by normal wear and tear before the earthquake. The authors could not estimate the extent of overstatement, but said that 'several millions of dollars is entirely credible' (Butcher, Andrews & Cleland 1998, p. 37).

Indirect costs

Paper producers in the affected region suffered significant damage that prevented operations for a considerable period. Because much of the paper is exported, loss of production is a valid indirect cost. The figures in table 5.6 are the total costs of lost value added by the two major paper producers in the region. The figures will overstate the economic cost, as not all of the paper would have been exported.

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14 The Modified Mercali scale comprises 12 increasing levels of intensity. It does not have a mathematical basis, being based instead on an arbitrary ranking of observed effects.

TABLE 5.6 ESTIMATED COSTS OF THE EDGECUMBE EARTHQUAKE, 1987

(NZ$'000)[a]

Cost category	Estimated cost
Direct costs	
Residential structures and contents	25 650
Commercial & industrial building structures and contents	252 500
Public buildings—structures & contents	3 031
Vehicles	
Infrastructure	24 541
Agriculture	
Crops	
Pastures	
Non-house structures and equipment	4 100
Livestock	
Sub-total	309 822
Indirect costs	
Business disruption	42 034
Loss of public services	2 635
Business clean-up	
Household clean-up	
Public buildings clean-up	
Household alternative accommodation	
Agriculture	
Transport networks	
Disaster response & relief (excluding volunteers)	1 667
Volunteer contribution to disaster relief	80
Other indirect costs[b]	1 500
Sub-total [c]	47 916
Intangible costs	
Fatalities	
Injuries	
Health effects	
Environmental damage, memorabilia & cultural heritage	
Sub-total	
TOTAL	357 738

a Costs are in New Zealand 1987 prices.
b Assessor's fees.
c Indirect costs are 15.5 per cent of direct costs.
Source BTE estimates based on Butcher, Andrews & Cleland (1998).

The local milk processor suffered substantial damage and was unable to process milk for many months after the earthquake. Indirect costs were mostly due to increased transport costs for the diversion of milk to alternative processing facilities. The additional transport costs due to the earthquake were estimated to be NZ$3 million. The report included an estimate of NZ$14 million for lost trading surplus. As there was no significant loss in quantity processed, the loss of trading surplus could have been expected to be roughly the same as the additional processing costs. The report gave no indication of additional costs other than those due to increased transport. For this reason, the figures in table 5.6 include only the NZ$3 million, or NZ$11 million less than the costs estimated in the report. This is the main difference between the costs shown in table 5.6 and those in Butcher, Andrews and Cleland (1998).

The ratio of indirect to direct costs of 15.5 per cent appears low. One factor leading to the low ratio is the absence of any estimates of clean-up costs in the report.

CONCLUSION

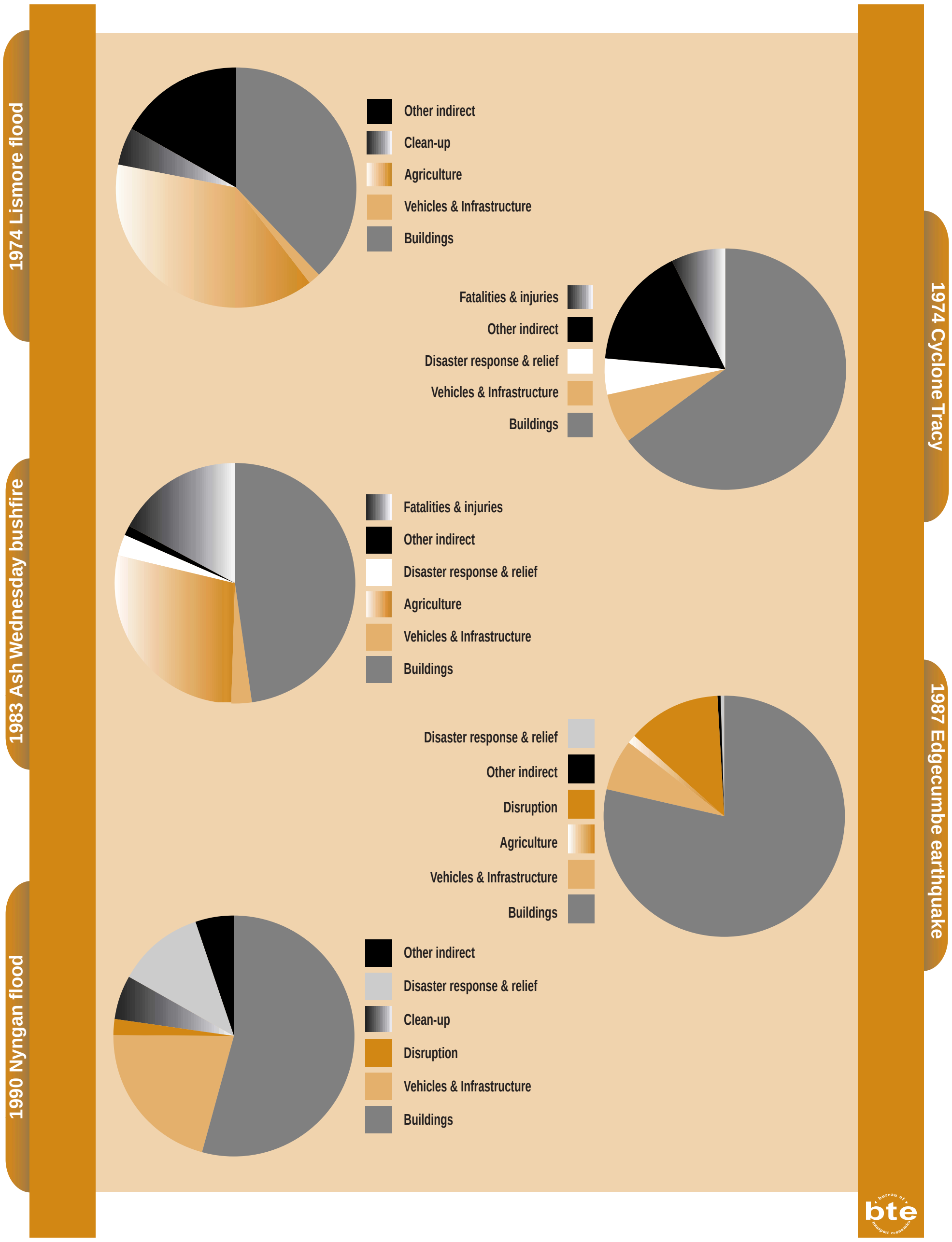
Despite the range of disaster types included in the sample, direct damage to buildings (residential, commercial and industrial combined) is the largest component of the total costs. Consistent with the findings in chapter 3, costs of deaths and injuries were most significant for the Ash Wednesday bushfire and also significant for Cyclone Tracy. Where clean-up costs are documented, they are significant. This suggests that a proper accounting of clean-up costs would also be significant for other disasters (figure 5.1).

Although the disasters discussed in this chapter are small in number, the sample illustrates there is wide variation in the approach to estimating disaster costs. There is always some arbitrariness in the way things are categorised, so it is not surprising that the method of categorising costs exhibits the greatest variation. Reports of floods show the most consistency, almost certainly as a result of flood research attracting the largest amount of interest over a lengthy period.

Indirect costs in the sample are only partially analysed for disasters other than floods. The incomplete analysis of indirect costs leads to an understatement of the total costs of the disasters. However, the inclusion of intangible costs, if they could be estimated with any reliability, would significantly increase the costs even further.

The analysis also illustrates the need to be careful about defining the boundaries of any estimation project carefully. Too narrow a set

FIGURE 5.1 SUMMARY OF DISTRIBUTION OF DISASTER COSTS FOR SELECTED DISASTERS



Source Based on tables 5.1, 5.2, 5.3, 5.5 & 5.6.

of boundaries can result in important costs being ignored. It may not always be possible to encompass all of the costs, but the report should make clear where the boundaries have been set and explain the implications of them for the final results.

The analysis also illustrates that the factors for converting insurance costs to total costs should be used with caution. For example, the factor of 5 for cyclones almost certainly overstates the total direct and indirect costs for Cyclone Tracy, but the factor of three for bushfires appears reasonable for the Ash Wednesday bushfire. Similarly, the use of a single factor to calculate indirect costs from direct costs is likely to be fraught with errors.

Most importantly, the analysis serves to illustrate that there is a need to ensure that future analysis of disaster costs would be best done using a common agreed framework and estimation methods. The suggestions in this report could serve as a starting point.

HOW DO THE RESULTS COMPARE WITH OTHER ESTIMATES?

A comparison of the estimates derived in chapter 3 using the EMA database with other published research on the costs of natural disasters in Australia gives a useful context and perspective on the results and conclusions contained in this report. The results are compared with work done by Joy in 1991 and analysis based on the NHRC PerilAus database.

Joy (1991, pp. 4–7) examined the costs of natural disasters on a state-by-state and national basis using insurance data as a basis for total cost estimates covering the period 1970 to 1989. Congruent with the findings in chapter 3, Joy's paper found:

- New South Wales, Victoria, Queensland and Western Australia experience more incidents than other States;
- storms followed by cyclones, floods and then bushfires are the most common incidents;
- floods, droughts, cyclones and storms were the big events in terms of cost;
- floods accounted for nearly one-third of total cost;
- New South Wales and Queensland sustained the greatest costs; and
- an average annual cost of natural disasters of approximately $1250 million in 1989 prices ($1624 million in 1999 prices) or $75 per head per year. The average cost per head was considerably higher in the Northern Territory and Queensland

but lower in most other states except New South Wales, which was about average.

This report found a somewhat lower estimate of the average annual cost of natural disasters for the 1967 to 1999 period ($1.14 billion in 1999 prices, including the cost of deaths and injuries). This can be largely explained by the fact that droughts—a major cost—were included in Joy's analysis but excluded from this report.

The NHRC PerilAus database was discussed in the introductory chapter of this report. However, it is important to reiterate that the database uses a damage index based on buildings damaged or destroyed—it does not include other substantial components of damage, such as building contents, cars, machinery, aircraft or crops. With this difference in mind, it is still valuable to examine how the results found using PerilAus compare with the analysis in chapter 3. In line with the results of chapter 3, preliminary findings from PerilAus (NHRCb 1999, pp. 3–4) concerning damage to buildings by natural hazards were that:

- the number of events per year for which a damage index was calculated showed a progressive increase, reflecting among other things, the improved record of recent events;
- the total damage index is greatest for tropical cyclones, with floods and bushfires in second place, followed by gusts, hailstorms and earthquakes; and
- New South Wales and Queensland represented 56 per cent of the total damage index.

The ranking of the hazard types differ somewhat; however, this predominantly reflects the different classification systems used. If gusts, hail and tornados were summed as one category of 'severe storm' (like in the EMA database) storms would then be among the top three damaging disaster types together with cyclones and floods.

Given the differences between the various pieces of research, the results of the BTE analysis appears to be reasonably compatible with other work on the costs of natural disasters. The different information sources all appear to lead to similar conclusions.

6

CONCLUSIONS

Natural disasters impact on Australia in many different ways. When a natural disaster strikes, lives are thrown into chaos, houses, businesses and community infrastructure get damaged or destroyed, people's livelihoods are temporarily (and sometimes permanently) disrupted and, most significantly, people get hurt and sometimes killed. Beyond these physical effects are the mental and psychological stress suffered by those involved, often for a long time after the disaster has faded from most people's memories. These impacts can all be devastating to individuals and the community as a whole.

For these reasons, governments and communities take action to reduce the impact of disasters. The action is usually in the form of expenditure on preparation, prevention, response and mitigation. In order to understand and prepare for, respond to, and mitigate these risks better, it is important to improve our knowledge of the impacts and costs of disasters. To do this, the quality of the data and methods on which decisions are based need to be examined and improved.

This report has focused on one aspect of the impact of natural disasters—the estimation of the economic costs of natural disasters at a national level. Existing data has been used to produce an improved understanding of the historical costs of natural disasters. Methodological issues and estimation techniques were then examined with a view to improving the future costing of disaster events.

The study has taken a national perspective in estimating the costs of natural disasters, as it is the appropriate approach to achieve the objectives set out in chapter 1. A local perspective might be relevant in the estimation of the benefits of a mitigation proposal that is designed primarily to achieve local benefits (that is, avoidance of damage). However, the sum of locally estimated disaster losses would be greater than the losses estimated from a national perspective, because the national perspective takes account of the transfers between economic agents affected by the disasters.

DISASTER COSTS IN THE PAST

In examining historical costs (1967–99) the BTE found:

- Natural disasters (with a total cost per event over $10 million) cost the Australian community $37.8 billion (including the costs of deaths and injuries) in 1999 prices over the period 1967 to 1999.
- The average annual cost of these disasters between 1967 and 1999 was $1.14 billion (including the costs of deaths and injuries). This translates to approximately $85 per year per person.
- Estimated average costs were $1.3 million for a fatality, $317 000 for a serious injury and $10 600 for a minor injury. The estimated total cost of deaths and injuries during the period 1967 to 1999 was $1.4 billion at an average cost of $41 million per year.
- The average annual cost is strongly influenced by three extreme events—Cyclone Tracy (1974), Newcastle earthquake (1989) and the Sydney hailstorm (1999). If the costs of these three events are removed from the calculations, the average annual cost declines to $860 million. This may be a better estimate of the costs of disasters that can be expected in a year in which extreme events do not occur.
- The annual cost of disasters is highly variable. The annual cost in years in which extreme events do not occur can be as high as $2.7 billion in 1999 prices. In years in which extreme events occur, the total cost can be much higher. As a result, it is not possible to assess whether the annual cost is increasing or decreasing over time.
- There is no evidence in the data that the total cost of smaller and more frequent events (less than the $10 million threshold) exceed the total cost of large rarer events.
- There have been 265 natural disasters costing more than $10 million each during the period 1967 to 1999.
- The total cost of most disasters is between $10 million to $50 million. More costly events are much less common. Despite the large number of events in the $10 million to $50 million range, the sum of total costs of these events remains small (around 10 per cent of total cost) in comparison to the costs of

the infrequent extreme events. (Again, it is worth bearing in mind that many smaller disasters go unrecorded).

- There is some evidence that the number of disasters per year is increasing, although the better reporting of more recent events and increasing population densities in hazardous areas are likely to explain at least some of this trend.
- New South Wales and Queensland accounted for 66 per cent of total disaster costs and 53 per cent of the total number of disasters over the period 1967 to 1999. The Northern Territory ranked third in terms of total disaster costs (13 per cent), followed by Victoria (9 per cent), Western Australia (6 per cent), South Australia (4 per cent), Tasmania (2 per cent) and the Australian Capital Territory (0.02 per cent). No events were recorded for Norfolk Island or the Indian Ocean Territories.
- Floods were the most costly of all disaster types, contributing $10.4 billion or 29 per cent of the total cost. Storms (26 per cent of total cost) and cyclones (24 per cent) caused similar levels of damage. Together, the combined cost of floods, storms and cyclones was almost 80 per cent of total disaster cost. They also accounted for 89 per cent of the total number of disasters. The costs of bushfires were a relatively small proportion of total disaster costs. However, bushfires are the most hazardous type of disaster in terms of deaths and injuries.

- The two most costly hazard types for each State and Territory are:
  - New South Wales (floods, storms);
  - Queensland (floods, tropical cyclones);
  - Victoria (floods, bushfires);
  - Western Australia (tropical cyclones, storms);
  - South Australia (floods, storms);
  - Tasmania (bushfires, floods);
  - Northern Territory (tropical cyclones, floods); and
  - Australian Capital Territory (bushfires, storms).

In terms of the implications for expenditure on mitigation, these results provide some, albeit tentative, evidence to support the focus on flood mitigation and higher spending in New South Wales and Queensland.

However, these findings must be tempered by the limitations of the data used to derive them. While the EMA database was found to be the most comprehensive available, it remains limited by:

- the relatively short time period covered and the large variability in annual costs, which limits the reliability of trend analysis;

- the use of simple ratios between insurance and total cost;
- the influence of the media in defining newsworthy events; and
- the better reporting and recording of more recent events.

As a consequence of these limitations, the results must be interpreted as indicative or approximate only and any conclusions drawn must be regarded as tentative. Without more accurate and reliable data, definitive conclusions are not possible. In the absence of better information, the estimates provide some guide for policy and decision-making, establish a reference point for further work on data quality and a means of testing the findings of this report.

It is also important to remember that the influence of a single large event could change the picture presented here quite dramatically. The estimates and information contained in this report give a snapshot at a point in time. The analysis is static and it would only take one event like Cyclone Tracy or the Newcastle earthquake to substantially alter much of the story presented here.

There is little to be gained from further examination of past events. The analysis in chapter 5 illustrates that there are gaps in the estimation of the costs of past events, but the data required to improve the estimations are unlikely to exist. Instead, it is more profitable to focus on both improving the analysis of future events and the methods of predicting the likely impact of such events. This is especially true for extreme events.

FUTURE COST ESTIMATION

Looking to the future, the framework of costs and examination of estimation techniques in this report attempts to include all disaster impacts, but in practice, economic costs (in terms of monetary values) can only typically be placed on some of these. Existing research tends to cover direct damage costs reasonably well. Some research has included selected indirect costs (such as clean-up costs) but very few have incorporated intangible costs, as the methods to do so are lacking. There is no simple relationship between the indirect and direct costs of a disaster. Previous disaster reports indicate that, as a broad estimate, indirect costs are usually in the range of 25 to 40 per cent of direct costs. This report does include simplified estimates of death and physical injury costs. Existing research is also dominated by floods, as this literature is more highly developed than for other disaster types.

The purpose of the framework and analysis of estimation methods is intended to provide a first step in the development of a more consistent approach to measuring the costs of natural disasters in Australia. The framework attempts to cover the major elements of disaster costs. However, each disaster has unique characteristics. Consequently, a general framework of the type presented here will inevitably omit some categories of costs that become evident during the analysis of specific disasters. The framework should therefore be considered as a guide, and not a total prescription of the costs that should be estimated. The analyst will need to decide, on the basis of the nature of the event being investigated and the availability of data, which categories to include.

NEXT STEPS IN DISASTER COST RESEARCH

The lack of reliable, consistent data on the costs of natural disasters means that while this report is based on the best available data, the conclusions drawn are somewhat limited by the accuracy of the data. To obtain more accurate cost estimates there would need to be a system for the consistent collection of disaster costs in the wake of a disaster occurring. In the meantime, some of the findings, such as the issue of the cost of smaller versus larger disasters, could be explored in more detail by using a larger sample and better data.

There are also many factors influencing the future direction of data collection and analysis of natural disasters. For economic cost purposes, the continuity of data sets is a big issue. The currently short time series of data available means that it is very difficult to come to grips with any trends that may be occurring. Any change in basic data parameters, such as insurance costs, has considerable implications for the future ability to analyse trends. For example, planned changes to insurance coverage, to include flash floods within the severe storm category and tsunami under the earthquake category, are likely to distort any future data analysis based on insurance payouts. A strategy for handling these types of issues is essential if trends in natural disaster costs are to be reliably examined in the future.

An equally important issue is the question of definitions. For example, what is included in clean-up costs? Do flood clean-up costs just include the removal of mud and stains? Do they also include the disassembly and cleaning of appliances? What is included in individual disaster types is not always clear. For example, do cyclone damage costs include costs of associated floods or are they restricted to wind damage? Can the distinct sources of damage be separated? These are some of the issues that became apparent during the preparation of the report. They are not major research items, but clarification is important to ensure future disaster cost estimates are consistent.

Related to the lack of data is also a lack of a consistent approach to estimating costs. Existing data and reports examining disaster costs have used differing methods and approaches; they have had different areas of focus and as a result the estimates produced in the different disaster reports are not strictly comparable. The cost framework suggested in this report and the discussion of estimation methods are a first step in attempting to reach a more consistent approach to estimating disaster costs across Australia. The next step would be to test these methods in a variety of future disasters so that they can be refined to achieve greater agreement and consistency in costing Australian disasters.

The cost estimating framework also illustrates that there are important gaps in the ability to estimate disaster costs. The major gap is in how to bring intangible costs into the estimation procedure. For example, it is known that psychological impacts of disasters can be substantial. If disaster victims lose their homes or become separated from family members, the psychological effects can be devastating. Yet, effective estimation methods have still to be fully developed. The exploratory approach suggested by Parker, Green and Thompson (1987, p. 107) is one approach that could warrant further research.

Even if reliable methods of estimating the costs of psychological impacts are unavailable, they should not be ignored in reports of disaster costs. More importantly, assessments of mitigation proposals would benefit from the inclusion of potential health savings of the proposal. Development of multi-criteria analysis techniques to augment conventional benefit-cost analysis would be a valuable contribution to disaster mitigation evaluation methods.

The development of better methods for estimating disaster costs ultimately has the purpose of facilitating better prediction of future costs and means of reducing these costs. The ability to better predict and reduce disaster costs would be valuable in vulnerability studies such as those undertaken by AGSO in the Cities Project (Granger et al. 1999, Middleman and Granger 2000). Australia has had little experience with extreme events, yet it is inevitable that more of them will occur. A better understanding of the potential damage costs would assist in planning disaster response and mitigation measures. Dore and Etkin (2000) put the issue very well in their comment:

> ... extreme climate events are natural disasters, which cause damage to capital and infrastructure. A sensible adaptation policy requires

> preparing to make the capital stock and infrastructure resilient to such extreme events. But resilience will require investment and new regulations such as new or improved building codes. The level of the necessary investment can only be determined if the social costs of disasters are known. However, estimating the social costs of disasters requires a consistent methodology.

The Cities Project (Granger et al.1999, Middleman and Granger 2000) together with improved cost estimation methods could provide a means of estimating the possible costs of extreme events to vulnerable communities. An outcome of this type of research could have an impact on land use and the reduction of community vulnerability.

Much of the report is based on the analysis of past events. Society has changed rapidly over the past decade. Technology has changed many of our production methods and has changed the way we live, and will continue to do so. The results of the report will need to be considered in the context of these changes. For example, what effect does increasing technology in the home have on the prediction of potential disaster costs? Does the greater integration of the economy affect some of the assumptions in the report, such as those regarding business disruption costs? These are important issues for future research.

Appendix I

ESTIMATING THE COST OF DEATHS AND INJURIES IN AUSTRALIAN DISASTERS

INTRODUCTION

To some people the idea of placing a dollar value on the lives lost and injuries sustained in a natural disaster may seem unnecessary and inappropriate. In contrast to other fields of research, such as the costing of transport accidents, values for death and injury are not usually used in estimating the cost of natural disasters in Australia. In fact, David I. Smith (pers. comm. 1999) argues that it is current international practice to estimate the number of fatalities and not cost them in dollar terms. However, an accurate estimate of the cost of natural disasters is a necessary input to policy-makers' decisions about hazard prevention and mitigation expenditure. The more inclusive these cost estimates are of intangible factors like death and injury, the better the opportunities for more informed decision-making. Inclusion of these costs allows a more thorough evaluation of the cost-effectiveness of funding which aims to reduce or mitigate the impacts of natural disasters.

In a financial environment where the demand on government budget funds is always considerable, accurate estimates of disaster costs are important as a basis for decisions about expenditure to reduce the impact of disasters on Australian communities. It may also be the case that excluding values for death and injury equates to assigning zero values. Therefore, the inclusion of these costs, even if they are lower bound estimates, represents an improvement in more accurately identifying the full costs of natural disasters borne by Australian society. Studies on the cost of transport accidents have found that the values placed on life and injury tend to be a substantial component of total costs (BTE 2000, p. 19). Little is known about the significance (in dollar terms) of these costs in natural disasters. For these reasons, this report examines the issue and includes cost estimates, where possible, for fatalities and injuries in natural disasters. These estimates are contained in chapter 3.

The methodology used to include these costs in natural disaster cost estimates is discussed below.

METHODOLOGY

The BTE has developed considerable expertise in estimating the cost of transport accidents, including the costs of deaths and injuries. Many of the techniques developed for the analyses of road crashes can be used for the analysis of disaster costs. The estimation of values for deaths and injuries in this report draws heavily on a recent BTE report on the cost of road crashes (BTE 2000).

There are generally two approaches available for estimating the value of human life: 'human capital' and 'willingness to pay'. Before describing each approach, it is useful to clarify what is meant by 'value of life' and whose life is being valued.

The value of life

Most people would consider that their own lives and those of loved ones are priceless. There are many examples where large amounts of money have been spent to save a single life (for example, a person stranded at sea). There are also many examples in everyday life where the implicit values placed on life are much lower. The amount of funding allocated to activities which save lives or prevent injuries, such as hospitals and emergency services, reflects implicit decisions made about the price society is willing to pay to save lives.

The values placed on life depend on one critical distinction—whose life is being valued? When people are asked to value life, they naturally come up with a value that reflects their own lives and the lives of individuals close to them. When a 'value of life' is being developed for use in public policy decision-making, it is not any particular person's life that is valued, but that of an unknown or 'statistical' individual. A statistical life is based on the probability of death in a given population.

It is the value of a statistical life that is important in making decisions about disaster mitigation expenditure, as the individual lives saved are not known in advance. The use of a statistical life also avoids the problem of subjective judgements associated with assessing the worth of particular individuals. As a result, the funds allocated to saving statistical lives are typically much less than what may be spent saving identified lives.

The methodological discussion below is largely drawn from BTE (2000, pp. 19–23). For more detailed information on these methods refer to BTCE (1992), BTCE (1996) or BTE (1998).

The human capital approach

The human capital approach characterises people, and therefore life, as a labour source and input to the production process. This approach argues that the value to society of preventing a death or injury is the saving in potential output or productive capacity. It is an ex post accounting approach that uses the discounted present value of a victim's potential future earnings as a proxy for the cost of premature death or permanent injury. The human capital approach can also be used to value non-paid work in the form of service to family and community. A non-economic loss can also be incorporated to represent pain and suffering and lost quality of life.

The willingness to pay approach

The willingness to pay approach estimates the value of life in terms of the amounts that individuals are prepared to pay to reduce risks to their lives (or amounts accepted as compensation for bearing increased risk). The approach uses people's preferences (either stated or revealed) to ascertain the value they place on reducing risk to life and reflects the value of intangible elements such as quality of life and joy of living.

BTE (1998) provides a detailed and comprehensive review of the theory and practice of willingness to pay methods.

A comparison of approaches to valuing life

The human capital and willingness to pay approaches are different in concept and, in terms of the 'value of life' issue, produce different results. Willingness to pay methods typically measure the intangible losses associated with death and injury, whereas the human capital approach typically measures direct and indirect losses. However, the approaches are not mutually exclusive. Willingness to pay methods can include direct, indirect and intangible elements in some contexts. As a result, it is important to recognise that in some cases adding the results of the human capital and willingness to pay approaches would be reasonable, but in others this may involve double counting. Both approaches are imperfect in estimating the economic value of life. Table I.1 provides a summarised version of the arguments for and against the use of the two approaches.

As the willingness to pay approach includes elements that the human capital approach has difficulty in costing, the former will generally give higher values than the latter. This is particularly the case for fatalities. Willingness to pay estimates across the world have varied markedly in value (from $1.8 million to $4.2 million in 1998 Australian dollar equivalents). The wide variation in willingness to pay estimates of the value of statistical lives is, in part, due to the fact that the value depends on circumstances and individual preferences in avoiding or accepting physical risk. For example, different attitudes towards risk mean that how a person dies affects the values derived. People's perceptions and attitudes toward risk can vary widely over different types of natural hazards. Some individuals may be willing to pay more to avoid drowning in a flood than burning in a bushfire. As a result, the willingness to pay method will produce different values of life for different disaster types. This can be viewed either as a complicating and inconsistent factor, or as a strength of the approach in more precisely recognising people's preferences for particular disaster mitigation activities.

The variation in willingness to pay values is also partly due to country differences. Willingness to pay is country-specific and inter-country comparisons of willingness to pay values are difficult to make as social, cultural and income factors confuse the picture.

Methodology used

In previous research estimating the cost of transport accidents, the BTE has used the human capital approach to value life. This is also the preferred approach here for a number of reasons. The availability, reliability and consistency of data and information are the chief reasons for using the human capital approach. The data and information necessary to conduct a willingness to pay evaluation are extremely resource intensive and, as such, exceed the resource limits of this project. Human capital values are also more easily compared with other values, as willingness to pay studies have not been conducted in Australian transport or disaster research fields.

The 'value of life' estimates generated in BTE (2000) applied the human capital approach, using lost income and lost value of unpaid labour (in the workplace, household and community). However, in recognition that life is more than labour, a non-economic loss was also incorporated to represent pain and suffering and lost quality of life.

TABLE I.1 COMPARISON OF APPROACHES TO VALUING HUMAN LIFE

Advantages	Disadvantages
Human Capital	
• Data reliable and readily available. • Consistent and transparent results. • Simple to use.	• Values some lives higher than others due to labour market imperfections, such as wage discrimination. If simplistically applied, the very young and old are undervalued. • Overestimates costs in an economy with less than full employment. • Does not reflect a key reason for investment in safety: aversion to death / injury rather than income protection. • Ignores the loss of 'joy of life', while values for pain, suffering and grief are often arbitrary. • Actuarial uncertainties regarding life expectancy and earnings. • Selection of the appropriate discount rate is controversial.
Willingness to Pay	
• Comprehensive. • Incorporates subjective welfare costs. • Reflects individual preferences.	• People have difficulty understanding and valuing small risks (generally less than 1 in 10 000). • Individual perceptions of risk may differ. • Willingness to pay does not necessarily imply ability to pay. • Differences exist between people's expenditure patterns / actions and their real preferences. • Aggregating individuals' willingness to pay may not produce the social willingness to pay, as individuals may ignore external social costs. • Difficulty in applying concept of a statistical life rather than a particular life. • Methodological difficulties (eg. inaccurate responses) and strategic behaviour in surveys. • Equity is not taken into account, as results are income-related. • Discrepancy in results using willingness to pay and willingness to accept approaches. • Value will change with incomes and variations in safety.

Source BTE (2000), p. 22.

COST FRAMEWORK

The composition and estimates of costs derived in BTE (2000) are used in this report as a base for exploring the costs of deaths and injuries associated with natural disasters (table I.2). In deciding which costs to include in estimating the value of fatalities and injuries in Australian disasters, two key criteria were used: transferability / applicability to natural disasters and significance in terms of overall cost.

BTE (2000) derives total cost estimates of $1.5 million per fatality, $325 000 per serious injury and $11 611 per minor injury in 1996 dollars. These estimates include human costs, vehicle costs and other general costs associated with road accidents. BTE (2000) does not provide ‘value of life’ estimates per se. The estimates contained in the report represent the present value of lifetime economic costs to society of a road crash. The cost the death imposes on society is not the same as the value of life. The value of life estimate is the sum of productivity losses and the lost quality of life (estimated as approximately $1.4 million in BTE 2000).

For the purposes of this report, it is the human cost categories that are relevant in estimating a monetary value for deaths and injuries caused by natural disasters. BTE (2000) found that total human costs (in 1996 dollars) as a result of road crashes were almost $1.4 million per fatality, $221 000 per serious injury and $2100 per minor injury. Human costs comprise lost labour productivity, lost quality of life, medical costs, long-term care costs, coronial costs, premature funeral costs, legal costs, correctional service costs and workplace disruption and staff replacement costs. The estimation of these costs in the road crash report and their applicability to disasters is discussed below.

Value of labour

Estimates of the value of labour comprise:

- productivity losses in the workplace due to premature death, temporary injury and permanent disability; and
- losses in household production due to premature death, temporary injury and permanent disability.

When a person is killed, injured or permanently disabled as a result of a natural disaster, their potential labour output over what could reasonably have been expected to be the remainder of their life is lost. This loss occurs at three levels—the workplace, the household and the community. The value of these losses is typically a significant proportion of the total cost of fatalities and injuries.

TABLE I.2 HUMAN COSTS OF ROAD CRASHES PER PERSON INJURED IN 1996

(1996 prices)

	Loss / cost per fatality	Loss / cost per serious injury	Loss / cost per minor injury
Value of labour lost (workplace)	540 000	27 241	0
Value of labour lost (household / community)	500 000	24 755	0
Lost quality of life	319 030	34 228	0
Medical costs			
Ambulance	254	254	138
Hospital in-patient	1 373	5 493	28
Other medical costs	1 018	8 246	40
Long-term care	0	90 476	0
Coronial costs	558	0	0
Premature funeral costs	1 700	0	0
Legal costs—criminal	1 548	448	55
Legal costs—insurance	12 000	21 147	1 264
Correctional service costs	8 511	0	0
Workplace disruption and staff replacement	8 077	8 301	538
Total human cost	1 394 069	220 589	2 063

Source Based on estimates contained in BTE (2000).

The value of labour lost in the workplace depends on how much working life a person could have reasonably expected to have remaining at the time of death or injury and the worth of their labour to the workplace. Estimating a value for the labour lost in terms of contribution to the home (for example, child minding) and the community (including voluntary assistance to schools, sporting and community groups) is essential. Although unpaid, this work is critical to the quality of life for individuals, families and the wider community.

Estimates of labour lost in BTE (2000) are based on ABS age-and gender-specific life expectancy tables, employment rate data, average wage and salary data, gross wages and salaries data and time use survey data. These were applied to road crash fatalities and injuries in 1996. The values of labour lost in the workplace and in the household / community per fatality and serious injury are shown in table I.2. Values for labour lost due to minor injuries were not estimated in BTE (2000), as they were considered too small. The values of labour lost contained in BTE (2000) are thought to be reasonably representative of the general population and therefore transferable to disaster victims.

Quality of life

Loss of quality of life includes both the pain and suffering of the injured and their inability to return to their way of life before the injury. These losses cannot easily be given a dollar value. Severe injury may lead to a permanent disability, which is likely to produce a permanent loss of quality of life. In addition to physical pain, the uncertainty about recovery affects an injured person. The loss of ability to play sport, drive a car or perform everyday tasks, for example, represent significant losses to individuals, families and communities. Loss of quality of life also includes loss of future quality of life, such as having to abandon career or family plans.

Death or very severe permanent injury is the most extreme consequence of natural disasters. Death is difficult to fit logically into the scale of quality of life losses, because, although the loss should increase as injuries become more severe, once dead there is no ongoing suffering. BTE (2000) treats the quality of life effects of death as equivalent to the most extreme injury, because the losses suffered by the victim are similar.

Traditionally, the human capital method does not attempt to estimate non-economic losses. Suffering does not necessarily have any effect on an individual's ability to work or to consume. However, the inclusion of non-economic loss estimates to reflect the full range of costs born by society is a valuable refinement. There are a number of methods available for measuring loss of quality of life. These range from willingness to pay techniques through to the use of proxies such as court awards and other compensation payments.

BTE (2000) used non-economic compensation data from the Victorian Transport Accident Commission (TAC) scheme as a proxy for loss of quality of life. NSW and Queensland data was also used. The lost quality of life estimates derived in BTE (2000) are contained in table I.2. Estimates of lost quality of life based on payments to road crash victims through these schemes may not be particularly applicable or representative for disaster victims, as these schemes apply specifically to road crash victims. More general compensation paid to a wider range of victims would be better. Road crash compensation schemes also appear to undervalue the quality of life lost due to serious injury.

BTE (1999a) estimated lost quality of life for victims of aviation accidents using a time-series of non-economic court awards, which list different levels of impairment. The major issues in using court awards are their variability and inconsistency. BTE (1999a) used awards data from 1973–1996 to derive mean awards of $8450 per minor injury, $127 000 per serious injury and $214 000 per fatality.

Natural disasters are likely to be similar to road crashes, having larger proportions of serious and minor injuries than deaths; whereas aviation accidents tend to be dominated by fatalities. However, because road crash compensation schemes typically undervalue serious injuries, the aviation estimates are believed to be more appropriate to placing a value on the lost quality of life resulting from deaths and injuries in natural disasters. These values are thought to be more representative of quality of life losses for disaster victims, as they represent a wider range of injuries across all causes of injuries rather than specifically for road crashes. The BTE therefore includes the lost quality of life estimates from BTE (1999a) in table I.4 to estimate values for deaths and injuries caused by natural disasters. They are lower bound estimates and do not include the pain and suffering of friends and relatives.

Medical costs

The medical costs of disasters comprise charges arising from the use of ambulance, hospital in-patient, outpatient and casualty / emergency services, general practitioners, specialists and allied health services such as radiography and physiotherapy.

Ambulance

BTE (2000) ambulance cost estimates are based on national averages per emergency call-out and adjusted for some specific road crash factors. These estimates are believed to be reasonably representative for natural disasters and are therefore included in the estimation of medical costs arising from natural disasters in table I.4.

Hospital in-patient

Hospital in-patient costs were estimated using data from the Australian Institute of Health and Welfare (AIHW) and the Australian Transport Safety Bureau (ATSB) in BTE (2000). AIHW data contain average costs for each injury type [Diagnosis Related Group (DRG)] and injury cause [External Cause Code (E-code)]. BTE (2000) used these data to estimate a total cost of hospital care for road crash in–patients in 1996.

TABLE I.3 AIHW HOSPITAL IN-PATIENT COSTS ASSOCIATED WITH NATURAL DISASTERS

E-Code	Average Cost	No. of separations	Total cost
E-908	$2 176	17	$36 996
E-909	$4 505	20	$90 103
	$3 341	37	$127 099

Source BTE analysis of AIHW data.

The BTE has obtained data for external cause codes (E-codes) associated with natural disasters for 1997–98. E-code 908 refers to storm and flood events and E-code 909 refers to earthquakes and other earth surface movement-related events. The BTE used the number of hospital separations in each of these E-code categories and the average costs of injuries (DRGs) associated with these E-codes to estimate a total cost of hospital care for disaster related in-patients in 1997–98 of approximately $127 000 (table I.3). However, AIHW data did not include hospital separations caused by bushfires. Other difficulties with the data mean that this is likely to represent a considerable underestimate.

Data are not available to allow a breakdown of costs by injury type for natural disasters. In BTE (2000), data from the ATSB allowed the BTE to supplement the AIHW data and derive hospital in-patient costs by injury type for road crashes in 1996. These averages are presented in table I.2. The average of both fatal and serious injury hospital costs in the road crash report is just under $3500 and the average cost for natural disaster related external cause codes in 1997/98 is also just under $3500 (table I.3). The BTE therefore believes that the average hospital in-patient costs in the road crash report are reasonably representative and can be used to estimate the hospital in-patient cost associated with natural disasters.

Other medical costs

In BTE (2000), other medical costs (such as outpatient and casualty/emergency services, general practitioners, specialists and allied health services) associated with road crashes were estimated using data from the AIHW that estimated the total medical cost arising from road crashes and the utilisation of medical services in 1993–94. These figures were inflated to 1996 values and time spent in hospital was used to derive estimates of other medical costs by injury type (table I.2). In the absence of better or specific disaster-related information, these estimates were used in the estimation of medical costs for natural disasters.

Long-term care

Some people injured in disasters will require long-term treatment and ongoing care. The length of this care, and therefore its cost, will depend on the type and severity of the injury or disability. These rehabilitation and long-term care costs associated with ongoing medical problems are not always a purely medical cost.

BTE (2000) estimated costs associated with long-term care using ABS survey data on disabled persons and the national average level of government support for the disabled ($25 822 per disabled person supported in 1996). The net present value of this cost was then derived to estimate long-term care costs per serious injury (table I.2). Road crash victims represent about one-third of the disabled population, making the use of this national average cost of government support for the disabled a reasonable estimate. The extent to which these figures can be reasonably transferred for use in estimating disaster costs is not clear. Disaster victims requiring long-term care as a result of disablement are not likely to be many in number. However, in the absence of better information, the BTE assumes the average long-term care cost derived in BTE (2000) to be a reasonable estimate for disaster victims falling into this category.

Coronial costs

Every fatality for which the cause is violent, suspicious or unknown requires a coroner's report. Deaths from natural disasters typically fall into this category. Reports are compiled by the police and the medical profession and forwarded to the coroner. In many instances, the procedure is purely an administrative matter, with the coroner examining the submission of reports. However, in some cases, there may be a coroner's inquest with a full hearing. BTE (2000) estimated the cost of coronial investigations into road deaths as $558 per fatality (table I.2). This estimate is believed to be representative of coronial costs for most causes of death and therefore can be used to estimate disaster-related costs in most cases. However, for large natural disasters involving many deaths, the costs are likely to be much greater. For example, the inquest into the Thredbo landslide of July 1997 took two years to complete and involved substantial legal and administrative resources.

Premature funeral costs

A death caused by natural disaster places an unexpected financial burden on the estate or family of the victim, as a funeral must be funded. People do not tend to save for funerals—generally not thinking of them at all until old age. However, a funeral is not a small expense and savings may be used or the money may even be borrowed. Either method of payment incurs a financial loss. Premature funeral costs represent the difference between costs at the time of death and costs at the end of the actuarially expected lifetime with appropriate discounting.

In BTE (2000), these costs were estimated using a weighted average of funeral costs for Australia as a whole, life expectancy data and a 4 per cent discount rate to calculate the difference between the cost of a funeral in 1996 and one at the end of the statistically expected lifespan of each victim. The estimated costs in table I.2 are believed to be representative of premature funeral costs associated with natural disasters, since the cause of death has no bearing on this cost component.

Legal costs

BTE (2000) estimated legal costs resulting from road crashes, including legal assistance with insurance claims and criminal prosecution costs. These are presented in table I.2. The applicability of these estimates in estimating the human costs of natural disasters is somewhat questionable. Legal assistance with household and business insurance claims resulting from natural disasters may be a significant cost. However, the estimates contained in BTE (2000) are based on specific motor vehicle insurance schemes. While the appropriateness of the road crash report estimates are unclear, the BTE believes that in the absence of specific disaster-related data, the use of these estimates is better than ignoring legal costs.

The BTE did not identify any comparable criminal prosecution costs resulting from natural disasters, and as a result did not include the BTE (2000) estimates in the estimation of human costs arising from natural disasters.

Correctional services costs

BTE (2000) estimated the correctional services costs associated with road crashes using the average daily cost of maintaining prisoners. With no comparable criminal prosecution costs resulting from natural disasters, the BTE also excluded correctional service costs from the estimates contained in this report.

Workplace disruption and staff replacement

The workplaces of disaster victims suffer additional losses related to the loss of a staff member. Productivity will decline for a time and other staff may have to work overtime or temporary staff employed to fill the gap. When a fatality has occurred, or in the case of some serious injuries, the workplace will face recruitment and training costs.

The National Highway Traffic Safety Administration (NHTSA) [part of the US Department of Transportation] estimated the extent of these costs for fatalities (3 months wages), severe injuries (4 months wages) and minor injuries (2 days wages). BTE (2000) used these figures (table I.2) to derive estimates of these costs for Australian road crash victims in 1996. In the absence of better information, these estimates are thought to be reasonably representative for use in estimating workplace disruption costs in relation to natural disasters.

TOTAL HUMAN COSTS

BTE (2000) found that total human costs amounted to $8385 million for road crashes in 1996—lost labour (37.19 per cent), long-term care (23.73 per cent), workplace disruption (3.73 per cent), legal (9.7 per cent), correctional services (0.2 per cent), coroner (0.01 per cent), funeral (0.04 per cent), ambulance (0.48 per cent), quality of life (21.1 per cent), medical (3.83 per cent) and other (0.73 per cent). By injury type, BTE (2000) found total human costs were around $1.4 million per fatality, $221 000 per serious injury and $2100 per minor injury in 1996 dollars.

Table I.4 presents the estimates of costs associated with fatalities and injuries in natural disasters that are used to construct a more complete picture of the total cost of disasters in Australia (chapter 3).

In applying BTE (2000) estimates to examine the human costs of natural disasters, some adjustments to these figures were made (reflecting their applicability to natural disasters). Of the cost

TABLE I.4 HUMAN COST ESTIMATES APPLIED TO NATURAL DISASTERS

(dollars)

	Loss / cost per fatality	Loss / cost per serious injury	Loss / cost per minor injury
Value of labour lost (workplace)	540 000	27 241	0
Value of labour lost (household / community)	500 000	24 755	0
Lost quality of life	214 000	127 000	8 450
Medical costs			
Ambulance	254	254	138
Hospital in-patient	1 373	5 493	28
Other medical costs	1 018	8 246	40
Long-term care	0	90 476	0
Coronial costs	558	0	0
Premature funeral costs	1 700	0	0
Legal costs—insurance	12 000	21 147	1 264
Workplace disruption and staff replacement	8 077	8 301	538
Total human cost (1996 prices)	1 278 980	312 913	10 458
Total human cost (1998 prices)	1 300 000	317 000	10 600

Source BTE analysis of BTE (2000).

categories discussed above, only three adjustments were made. The lost quality of life estimates from the aviation accidents report were used instead of the road crash estimates and both the legal costs associated with criminal cases and correctional service costs were excluded from the estimates. These adjustments mean that the cost per fatality ($1.3 million) is reduced compared to the road crash report estimate, while cost per serious injury ($317 000) and minor injury ($10 600) both increase.

Appendix II

NUMBER AND COSTS OF NEW ZEALAND DISASTERS

The data used to analyse the impact of natural disasters in New Zealand are substantially less reliable and less extensive than the data used in the Australian analyses. The data are derived from two sources—the New Zealand Earthquake Commission (EQC)[15] and the Insurance Council of New Zealand. The Earthquake Commission provided data covering the period 1962 to 1998 and included all earthquakes of any significance since the commencement of the Commission's fund. No indication was given about how an event was determined to be significant. The costs were derived from the claims made to the EQC.

The data provided by the Insurance Council of New Zealand contained insurance industry payouts for disasters, both natural and non-natural, over a 30-year period from 1968 to 1998. As for the Australian analysis, non-natural events were excluded. Descriptions of event type were not provided for several events that had occurred. In the absence of better information, the BTE assumed that these were natural disasters and included them in the number and total cost analysis. However, as their descriptions were absent, they were excluded from the cost breakdown of the various disaster types. The descriptions used by the Insurance Council of New Zealand to explain the type of disaster and the impact of the disaster differed from that used by EMA. In order to achieve consistency, disasters such as windstorms, snowstorms, tornados and hailstorms were all classified as severe storms.

Furthermore, the limited information available on New Zealand disasters and the varying cost range meant that it was not practical

15 The Earthquake Commission's primary role is to provide residential natural disaster insurance to property owners. The Commission insures against earthquake, natural landslip, volcanic eruption, hydrothermal activity, tsunami; in the case of residential land, a storm or flood; or fire caused by any of these (Earthquake Commission 1999).

to establish a threshold, such as the one used in the Australian data, because this would have significantly reduced the size of the already small data set. As a result, any comparisons with Australian data should be undertaken cautiously.

Data limitations

Several problems were faced in analysing the New Zealand data due to a number of inconsistencies and limitations. It was impossible to determine whether the data provided by the EQC represented total insurance cost, total residential insurance cost or the insurance cost for residents who held insurance policies with the Commission. For the purposes of this analysis, the BTE assumes that the data refer to the residential insurance payout associated with EQC policies.

The data provided by the Insurance Council of New Zealand did not include the figures provided by the EQC. Hence, there was no reference made to earthquakes in the Insurance Council of New Zealand's database (except for the Edgecumbe earthquake in 1987). As a result, the cost of earthquake damage to commercial and industrial premises (except for Edgecumbe earthquake) is not likely to be captured in this analysis. The implications of this are best illustrated with an example. The New Zealand Insurance Council's database contains an insurance industry payout of NZ$341 million for the Edgecumbe earthquake, while the EQC data lists a residential cost of NZ$20 million. The gap between these two figures includes the cost of earthquake damage to commercial and industrial premises. A major report on the costs of the Edgecumbe earthquake was carried out and this is examined in chapter 5. On the whole, however, the total cost information presented for New Zealand represents the best information available to the BTE, but is not a complete picture of total costs because of the significant gaps and limitations as indicated.

Another problem with the data was the large gap in the number of events recorded in the Insurance Council's database between 1968 and 1975. Considering the frequency of events that occurred after this period, it is highly unlikely that no disasters occurred during this time. For example, flooding in New Zealand is a significant problem with an impact almost every year. However, the first record of a flood in the database is 1976. Some possible reasons why the data lacks records for this period are the lack of media attention, the availability of residential flood insurance or flooding occurring in non-residential areas.

Finally, the data provided by the Insurance Council of New Zealand has been inflation-adjusted, but no indication has been given as to which price index or time period was used. The data provided by the EQC were not inflation adjusted. As a result, the BTE had difficulties in inflating EQC data in a conventional manner in order to be able to combine the two data sources. The EQC costs were therefore inflated using the approximate relativities of the Insurance Council data. This allowed the BTE to combine the two data sources to produce the analysis that follows. However, considering the uncertainty surrounding the New Zealand data contained in this report, the results should be viewed with a great deal of caution.

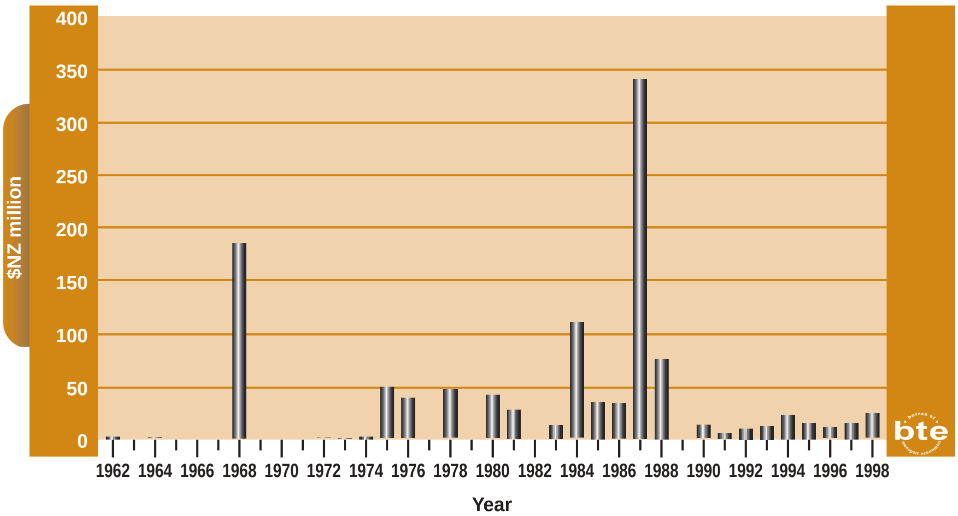
COSTS OF NATURAL DISASTERS IN NEW ZEALAND

The total cost of natural disasters in New Zealand from 1962 to 1998 was estimated to be approximately NZ$1.2 billion. However, the severe limitations of the data mean that this is likely to be a significant underestimate.

Several large events dominate New Zealand disasters between 1962 and 1998 (figure II.1). These include the Wahine storms (1968) and the Edgecumbe earthquake (1987). In more recent times, the cost of disasters has been relatively small, with no recorded disasters over NZ$25 million since 1989. It is not possible to comment on any trends, due to the incompleteness of the data provided.

The average annual cost of disasters in New Zealand during the period from 1962 to 1998 was NZ$31 million. Estimation of the

FIGURE II.1 TOTAL COST OF DISASTERS IN NEW ZEALAND, 1962–1998



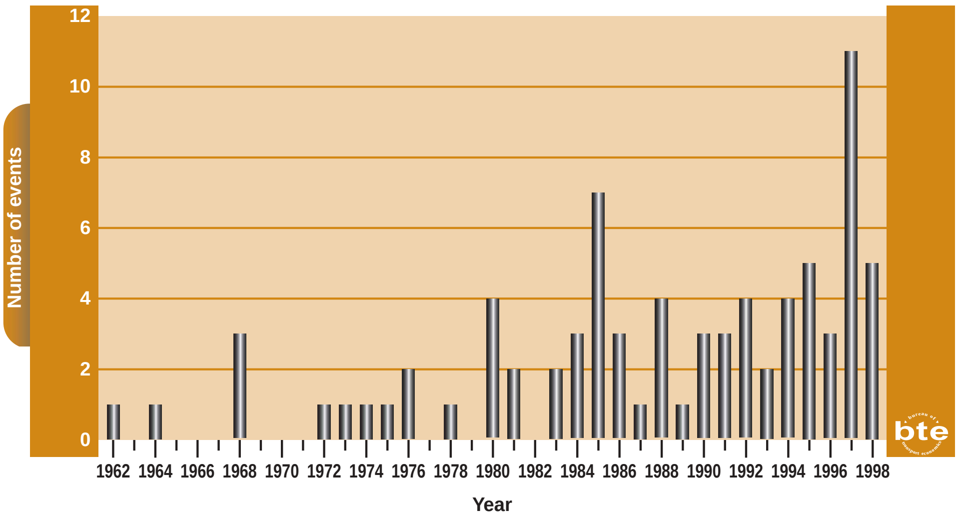
Source BTE analysis of Insurance Council of New Zealand and Earthquake Commission's database.

average annual cost of disasters over a shorter period (since 1980, when records are likely to be better) results in a higher average annual cost of NZ$43 million.

THE NUMBER OF NATURAL DISASTERS IN NEW ZEALAND

There were 79 natural disasters recorded in the combined New Zealand data between 1962 and 1998 (figure II.2). As in the case of Australia, the frequency of natural disasters in New Zealand appears to have been increasing, and the upward trend in the

FIGURE II.2 NUMBER OF NATURAL DISASTERS IN NEW ZEALAND, 1962–1998



Source BTE analysis of Insurance Council of New Zealand and Earthquake Commission's database.

number of disasters is statistically significant. Better recording of events may also be partly responsible for this upward trend.

The number of disasters varies considerably from year to year. During 1997, New Zealand suffered its highest annual number of disasters with a total of 11. Interestingly, the total cost of natural disasters in 1997 was less than NZ$25 million, indicating there were a large number of events with relatively small costs.

ANALYSIS BY DISASTER TYPE

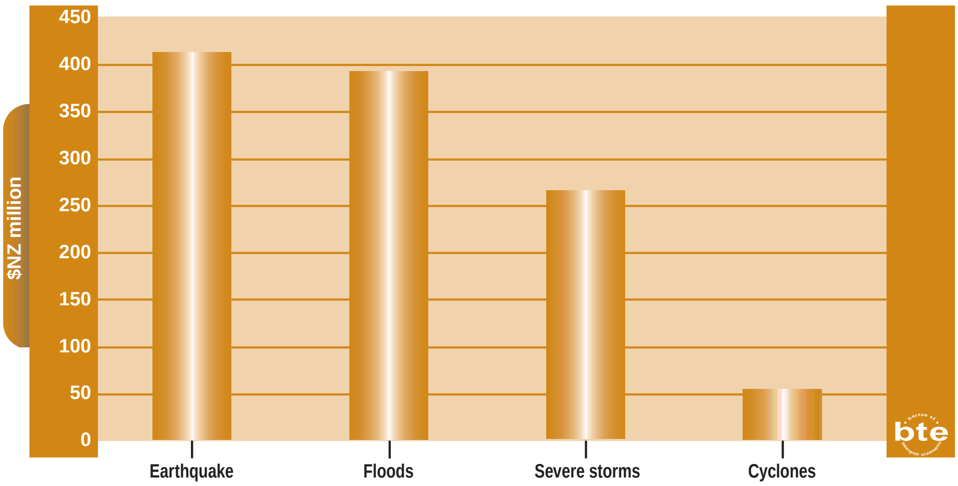
The limited New Zealand data available showed that over the period 1962 to 1998, earthquakes were the most costly natural disaster, followed by floods and severe storms (figure II.3). Cyclones at a cost of NZ$55 million were the least costly category. Costs were highly influenced by the Edgecumbe earthquake in 1987 and a severe storm in 1968. These two events account for NZ$497 million (43 per cent) of the total cost of disasters included in the New Zealand data. These events would still be likely to dominate if the data set were more comprehensive.

By comparison, floods were the most common type of disaster with 34 events (or 43 per cent of the total number of events) in the period from 1962 to 1998. This is substantially greater than earthquakes, which recorded 21 events or 27 per cent of the total.

Due to the limitations of the New Zealand data provided, with the exception of floods, it was not possible to put together a collection of charts that illustrate the change over time in the total cost of individual disaster types.

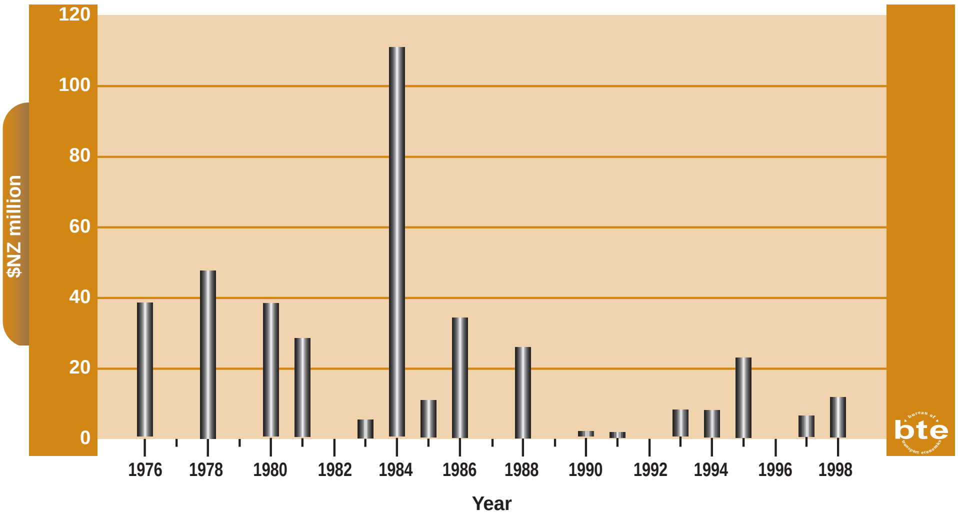
Figure II.4 shows that the 1970s and 1980s were characterised by more damaging and costly floods than the 1990s. Between 1976 and 1998, the total available cost of floods in New Zealand was NZ$393 million. On average, floods have cost the New Zealand community NZ$18 million per year since 1976. However, the analysis is only indicative due to the previously discussed limitations of the New Zealand data.

FIGURE II.3 COSTS OF DISASTERS BY TYPE IN NEW ZEALAND, 1962–1998



Source BTE analysis of Insurance Council of New Zealand and Earthquake Commission's database.

FIGURE II.4 ANNUAL COST OF FLOODS IN NEW ZEALAND, 1976–1998



Source BTE analysis of Insurance Council of New Zealand and Earthquake Commission's database.

Appendix III

DEPRECIATED VALUE OF AN ASSET

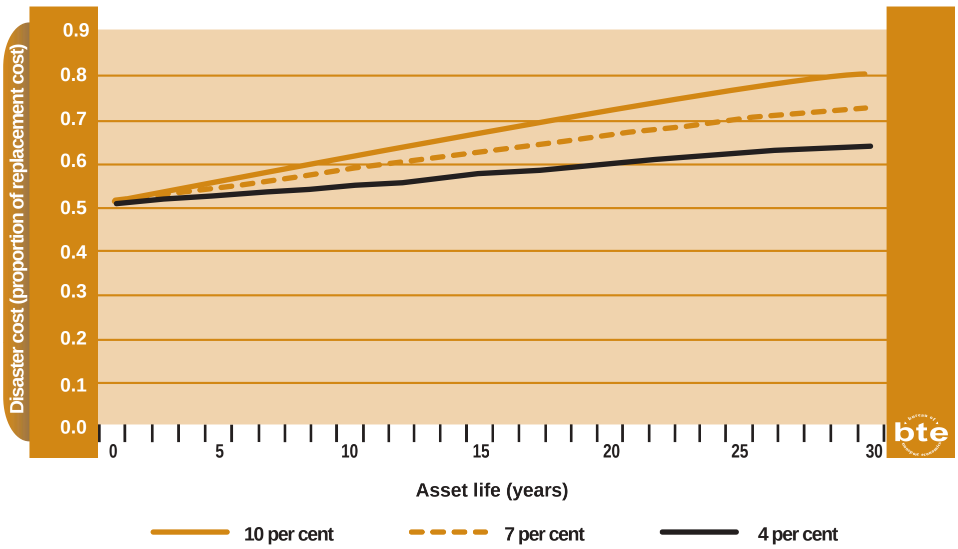
A common assumption is that a durable asset destroyed in a natural disaster is half way through its life, and that its value will correspondingly be 50 per cent of its replacement value. This appendix examines that assumption.

At the end of its economic life it can be expected that a durable asset will be replaced with an equivalent asset. If the asset has a new market value of $K and a life of *m* years, then at the time of replacement, the present value of the investment outlays can be shown to be given by equation III.1

$$P_1 = K \frac{(1+r)^m}{(1+r)^m - 1} \qquad \text{Equation III.1}$$

where r = discount rate

FIGURE III.1 ASSET LOSS AS A PROPORTION OF NEW MARKET VALUE



Source BTE analysis.

Equation III.1 is based on the assumption that the asset will continue to be replaced by a new one at intervals of m years in perpetuity.

The effect of the disaster is to bring forward the future investment stream by $m/2$ years. Therefore, the present value of the capital outlays with no disaster (P_2) is given by equation III.2.

$$P_2 = P_1 \frac{1}{(1+r)^{m/2}} \qquad \text{Equation III.2}$$

The loss resulting from the disaster is then given by $P_1 – P_2$.

Generally, the value of the loss is more than 50 per cent of the replacement value of the asset. The value increases with the discount rate and the life of the asset (figure III.1).

Appendix IV

ECONOMIC EFFECTS OF A DISASTER ON BUSINESS ACTIVITY

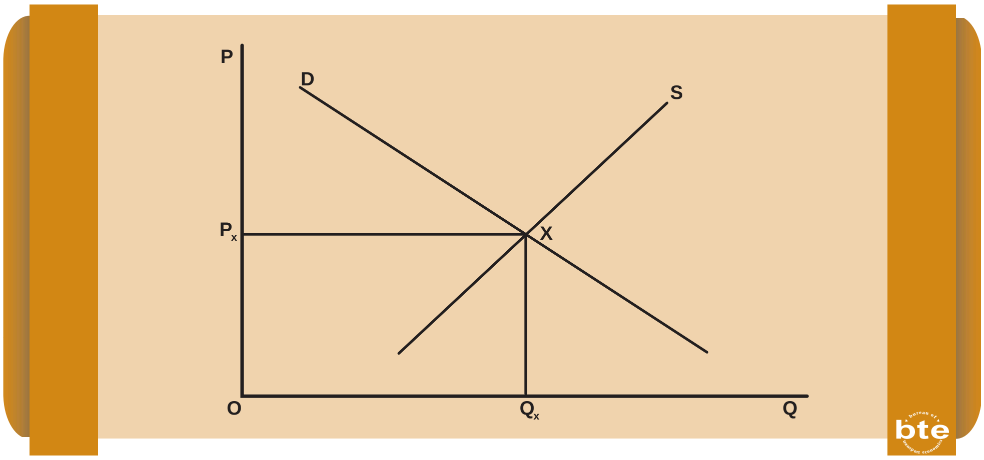
The basic economics relevant to business disruption following a disaster are examined in this appendix. The analysis is simplified, but should serve to illustrate the main points. The effects are discussed in welfare terms using the concepts of consumer and producer surplus.

CONCEPTS OF CONSUMER AND PRODUCER SURPLUS

When an individual purchases a good, the value to the person must at least be equal to the price paid. It is generally true for individuals that the more they have of a particular good, the less value an additional unit of the same good will be to them. A consequence of this is that the higher the price, the fewer goods people will be willing to buy. The relationship between the price people are willing to pay for a good and the number of goods purchased is negative. In figure IV.1, the curve D illustrates the relationship and is usually referred to as a demand curve. The difference between the price paid and the value of the good to the purchaser is called the consumer surplus, as it represents the difference between the price actually paid and the price the consumer was willing to pay for the good. In figure IV.1 the area above the line P_xX and below the demand curve D represents the consumer surplus.

A symmetrical relationship holds for producers. If producers can sell an additional unit of output for more than the cost of producing the additional unit of output, they would be willing to produce it. Generally, as output increases, the cost of producing additional units also increases. Consequently, as output increases, producers will require higher prices to produce additional output. In figure IV.1 this is represented by the upward sloping curve S (the supply curve). The difference between the cost of producing the additional output and the price received is referred to as the producer surplus. In

FIGURE IV.1 BASIC DEMAND AND SUPPLY CURVES



Source BTE analysis.

figure IV.1, the area below the line P_xX and above the supply curve S represents producer surplus.

The intersection of the demand and supply curves is the point of market equilibrium. In figure IV.1, market equilibrium is achieved at a price P_x and quantity Q_x. At this point, consumers are just willing to pay the price producers would require to produce additional output. At higher levels of output, consumers are unwilling to pay the cost to producers of producing additional output.

ECONOMIC EFFECT ON DISASTER-AFFECTED BUSINESSES

Following a disaster, in addition to the direct damage suffered by those in the disaster area, many enterprises, both public and private, will be unable to trade while repairs are undertaken and premises are cleaned. Such disruption may be short term. For some products, such as some agricultural products, the loss may result in an inability to participate in the market for a much longer period.

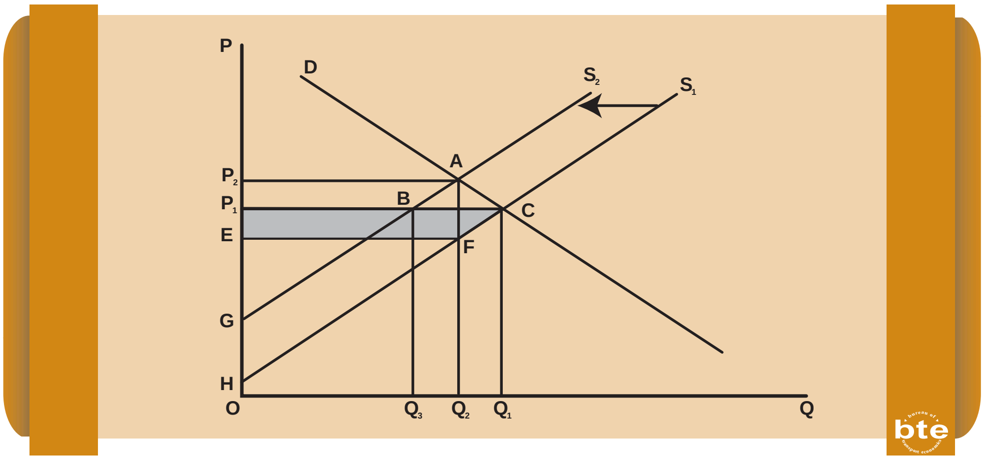
The effect of the inability to participate in the market is to reduce the supply available to the market. In figure IV.2, this is represented by a move to the left of the supply curve from S_1 to S_2. At the old price of P_1, there is a condition of excess demand. Consumers are willing to purchase quantity Q_1 and the remaining producers are now only willing to supply Q_3. Producers are able to increase the price of the good to satisfy the excess demand. The higher prices deter consumers who value the good at less than the new price. The higher price also provides an incentive for producers to increase supply. The combination of reducing demand along the demand curve D and increasing supply along the supply curve S_2 results in a new equilibrium at a new price P_2 (higher than P_1) and a new output Q_2 (less than Q_1).

A consequence of the increased price is that the producer surplus has now been reduced. The area P_1CFE in figure IV.2 represents the reduction. The area P_1CH represents the producer surplus before the disaster and the area P_2AG represents the producer surplus after the disaster. The area P_2AG is equal to the area EFH. Subtracting the area EFH from the area P_1CH (the original producer surplus) leaves the area P_1CFE as representing the loss in producer surplus. The loss in producer surplus is borne by those businesses affected by the disaster.

ECONOMIC EFFECT ON OTHER BUSINESSES

The loss of supply from disaster-affected businesses will result in an increase in demand for the output from other businesses. The increase in demand may be felt in industries other than the disaster-affected industries. For example, it is usual for the necessary rebuilding activity following a disaster to stimulate the construction industry.

FIGURE IV.2 ECONOMIC EFFECT ON DISASTER-AFFECTED BUSINESSES

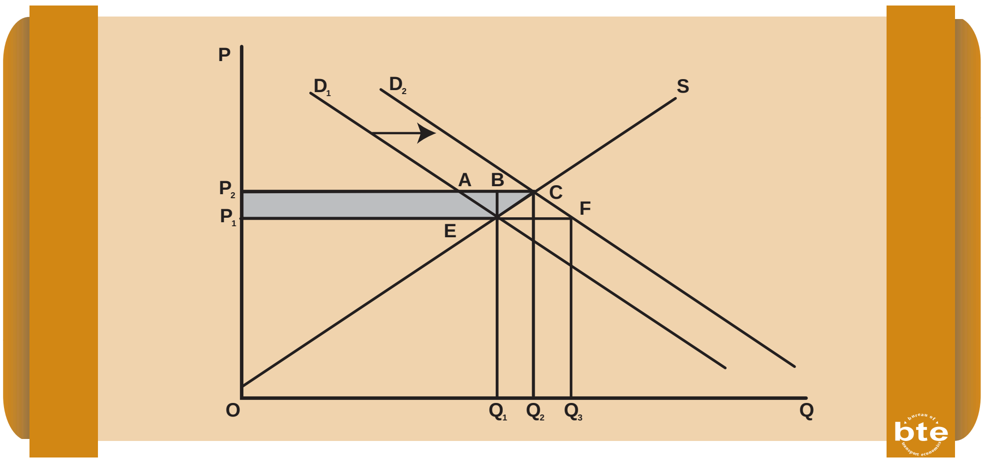


Source BTE analysis.

The increase in demand results in more quantity of the good or service being demanded at each price level. This is illustrated in figure IV.3 by the shift of the demand curve from D_1 to D_2. Initially, there will be excess demand at the price P_1. The excess demand is equal to the difference between Q_3 and Q_1. The response by producers faced with excess demand is to increase prices. Demand will reduce as prices increase until a new equilibrium is reached at price P_2 and quantity Q_2. The area P_2CEP_1 represents an increase in producer surplus. The gain in producer surplus by businesses unaffected by the disaster will largely offset the loss of surplus experienced by the disaster-affected businesses. The gain by one sector may not exactly offset the loss by the other, but the net effect will be much smaller than the loss experienced by the businesses damaged in the disaster.

If as a result of the disaster, supply must be sought from overseas rather than domestically, then the transfer in surplus is to foreign producers and the loss in producer surplus by the disaster-affected businesses is a loss to the economy. Alternatively, if production is for the export market, inability to supply the market will result in an economic loss also equal to the loss in producer surplus.

FIGURE IV. 3 ECONOMIC EFFECT ON OTHER BUSINESSES



Source BTE analysis.

CONCLUSION

The major economic impact of business disruption is a transfer of producer surplus from disaster-affected producers to producers unaffected by the disaster. Transfers of surplus do not represent an economic loss, although they do represent distributional effects of a disaster. There may be a net change in economic welfare, but it is likely to be small relative to the other impacts of the disaster. If the lost supply must be replaced by imports or if the lost production is for export, then there is no offsetting gain in producer surplus by other domestic producers. The loss in producer surplus by the disaster-affected businesses is a loss to the economy.

The analysis is simplified and partial. In practice, the effects will be more complex. Generally, consumers are very likely to substitute alternative goods for the one that has become more expensive. The examination of substitution possibilities involves more complex models than discussed here. However, the simple partial equilibrium model serves to illustrate the main points.

Appendix V

NDRA GUIDELINES

In 1998, the Commonwealth Minister for Finance and Administration issued a determination that sets out the terms and conditions applicable to payments of financial assistance to the States and Territories for the purposes of natural disaster relief.

The Commonwealth meets half of all State and Territory outlays incurred in providing personal hardship and distress relief where State or Territory disaster expenditure exceeds the small disaster threshold of $200 000. Commonwealth assistance for other eligible relief measures is on a dollar-for-dollar basis for State or Territory outlays above a base amount based on a certain percentage of State or Territory revenue. For State or Territory expenditure over the second threshold, the Commonwealth reimbursement is 75 cents for every dollar for eligible measures when the outlays exceed 1.75 times the threshold.

The payments are for eligible measures that are broadly defined in the determination issued by the Minister for Finance and Administration. State and Territory governments are responsible for specifying the measures that apply in their jurisdictions, and to whom they are offered consistent with the Minister's terms and conditions. The following is based on the guidelines issued by the Queensland Department of Emergency Services (1999).

ELIGIBLE NATURAL DISASTER EVENTS

Eligible natural disasters under NDRA include any one of or combination of cyclone, flood, storm, bushfire and earthquake or a landslide, which is the direct result of cyclone, flood, storm, bushfire or earthquake.

Drought is not an eligible NDRA event.

Non-natural disasters are not eligible for NDRA funding.

Small natural disasters are ineligible for Commonwealth NDRA funding. The Commonwealth defines a small disaster as one where State or Territory expenditure (on all assistance measures) does not exceed $200 000.

COUNTER DISASTER OPERATIONS

Eligible expenditure categories

The following categories of State or Territory counter disaster expenditure are eligible for reimbursement under NDRA:

(a) The net cost of emergency food / essential supply drops to stranded individuals or communities.

(b) Transport costs for manpower, equipment and materials.

> Includes aircraft / vessel / vehicle transport, charter and hire costs.

(c) Non-capital expenses.

> Includes vehicle and helicopter operating costs, food, fuels and other expendable or consumable items necessary for immediate usage. Also includes vehicle or equipment repairs and additional servicing required as a direct consequence of relief operations.

(d) Overtime, travel expenses / allowances, temporary employment costs.

> Excludes normal (pre-disaster) administrative commitments (salaries etc.) which would otherwise have been incurred.

(e) The activation, coordination and administration of NDRA relief measures.

> Excludes pre-disaster salary and other committed costs, which would otherwise have been incurred.

(f) Emergent expenditure to ensure the safety of life, health and property.

> Includes the construction of structures / earthworks and movement / hire use of; buildings, machinery, equipment, specialist skills and personal possessions (for example, temporary levee banks / sandbagging to divert floodwaters, evacuations and shelters, emergent public health matters etc.).

RESTORATION OF PUBLIC ASSETS

Eligible public authority

An eligible public authority means a public undertaking that provides community, social or economic services outside the normal market mechanism, either free of charge or at a nominal charge well below the costs of production.

Eligible works

Funds are normally provided to restore damage by flood submergence, wind or wave action but may be restricted in a particular disaster to any of a number of conditions. The term 'public assets' may be taken as any structure or facility that is the property of an eligible Public Authority where that Authority is also responsible for the asset's maintenance.

Assets include such items as roads and bridges, buildings, plant, equipment and stores, but not natural banks and beds of streams, undeveloped public land, beaches, natural trees and shrubs, also otherwise eligible public assets damaged by saturation / landslides.

The term 'restoration of damage' may be taken to apply to any expenditure (not covered by insurance) incurred by the Authority on the following:

(a) Emergent works necessary during the course of a disaster to protect public assets or to restore essential services. This could include earthmoving rock placing, sand-bagging, installation of tarpaulins, and removal of an asset or stores to prevent damage.

(b) Immediate post-disaster repairs to an eligible asset to enable it to operate / be operated at a reasonable level of efficiency—would include clean-up costs, removal of silt, debris etc. and emergent repairs.

(c) Reconstruction or replacement of the asset to its previous standard only.

Salaries, wages and other costs that would have been incurred, irrespective of the disaster, are not eligible for assistance.

Damage as a result of 'flood submergence' is regarded as that caused by:

(a) inundation by flood waters rising from natural streams and watercourses; or

(b) concentration of surface runoff in drainage systems including overtopping thereof. Drainage systems are defined as natural streams and watercourses and man-made drains lined and unlined, but not not road pavements, road formations and table drains, catch drains, kerb and channel and associated stormwater systems. Eligible damage under this category is confined to assets constructed within or over the drainage system.

Damage consequential to inundation as defined in (a) and (b) above, due to pavement failure under traffic is eligible.

By way of example under (b) above:

(a) Lengthways scouring of a road would be ineligible for assistance as the damage is not within or over an eligible drainage system.

(b) Cross-road washouts within or over eligible drainage systems would be eligible for assistance (i.e. Damage at creek and gully crossings, inverts, etc.)

(c) Any damage within, or caused by overtopping of road drainage systems, would be ineligible.

PERSONAL HARDSHIP AND DISTRESS

Subject to eligibility, the scheme provides grants towards the replacement or repair of essential household contents, as well as assistance towards the repair of dwellings to a habitable and secure condition.

Eligibility

Broadly, the scheme is aimed at assisting those in the community who, because of their financial situation, are unable to provide for their own recovery from the effects of a natural disaster. Eligibility under the Disaster Relief Assistance Scheme is determined by reference to income and assets tests.

Essential Household Contents Grant

The Essential Household Contents Grant provides assistance with respect to the loss of, or damage to food, essential clothing and household effects. The amount of the grant is not to exceed the value of the loss. The loss or damage attracts assistance up to the following limits:

- Individual applicant $1200
- Applicant couple / Families $3700

Repairs to dwellings

The repair to dwellings, including caravans, is eligible for owner-occupiers to the extent necessary to return the dwelling to a habitable and secure condition. In circumstances where the repair costs of a caravan exceed its pre-disaster value, assistance towards the purchase of a replacement caravan is limited to the lesser of the pre-disaster value or assistance limit.

The upper limit of Repairs to Dwelling assistance is:

- Individual applicant $7600 (less the amount paid as Essential Household Contents grant).
- Applicant couple / Families $10 200 (less the amount paid as Essential Household Contents grant).

Where the cost of essential repairs for eligible applicants exceeds these amounts and all avenues of alternative assistance have been exhausted, consideration will be given to additional assistance on a case-by-case basis.

CONCESSIONAL LOANS

Concessional loans are available to assist:

- needy home-owners to rebuild or replace their residences following a natural disaster;
- primary producers to recover following natural disasters of substantial magnitude;
- small businesses to re-establish operations on a viable basis following the effects of instantaneous natural disasters (cyclones or severe flooding etc.); and
- churches, sporting associations and other voluntary non-profit organisations to re-establish facilities following natural disaster damage.

Concessional loans to needy people

The applicant must personally own and occupy the dwelling. The applicant's net realisable assets (excluding the value of the residence and the land on which it is situated) and income must be insufficient to repair or rebuild the residence without undue hardship.

The applicant must be unable to obtain the finance necessary to repair or rebuild or obtain a substitute residence from normal sources of housing finance and must be able to provide first mortgage security. Assistance would not generally be available where adequate insurance could be effected at reasonable rates.

The amount of the loan is the net cost of repairs, rebuilding or substitute purchase up to a maximum of $100 000. The amount of the loan is reduced when the applicant's income and net realisable assets exceed specified thresholds.

Concessional loans to primary producers

Loans are provided for carry-on requirements including replanting, restoration and re-establishment of affected areas, sustenance, essential property operations and payments of rent, rates and / or replacement of farm buildings or re-stocking. Loans are not intended to compensate for losses suffered.

Eligibility

Primary producers must have their property declared as disaster stricken to be eligible for a concessional loan. Declaration can be for a geographically defined area if a significant number of properties are affected or an individual property can be declared as disaster stricken. In the latter case, an Individual Disaster Stricken Property certificate is issued.

In addition to being declared disaster stricken, applicants must:

- be in working occupation of their properties;
- have used up all their liquid assets and all normal credit sources up to normal credit limits;
- be considered viable with the assistance provided; and
- have taken reasonable precautions to minimise or prevent the disaster.

The loans have the following limits.

- carry-on—up to $100 000.
- restocking—up to $100 000 (cumulative total of $150 000).

Concessional loans to small businesses

Short-term loans may be made available in those cases where significant damage has occurred to buildings, plant and equipment and stock. Assistance would not generally be available where adequate insurance could be effected at reasonable rates.

Eligibility

Loans may be made to business enterprises suffering physical loss as a direct result of the natural disaster event upon the following conditions.

- Applicants must be sole owners, partnerships or private companies, but not public companies alone or in association with other companies.
- Applicants must have sustained substantial damage to buildings, plant, equipment and stock (where the cost of essential repair or replacement is the applicant's responsibility) and have had their financial liquidity severely affected.
- Applicants must be unable to effect repairs or replacement and be unable to return to viable operations from their own resources without this assistance and must be able to demonstrate that normal financial sources or alternative sources of finance have been exhausted.
- Applicants must be able to demonstrate that with the assistance of this loan there are reasonable prospects of re-establishing business on a viable basis.
- The extent of loan assistance is based on careful assessment of the applicant's financial position, including any insurance recoveries.

The maximum loan for any applicant's enterprise is $100 000. Each borrower also has an aggregate loan ceiling of $150 000 for all categories of assistance for all disasters.

Concessional loans to churches, sporting associations and other voluntary non-profit organisations

Eligibility

Those eligible to apply are churches or other associations that have sustained substantial damage as a direct result of a natural disaster. Assistance is limited to the cost of restoration of the organisation's assets to pre-damage standard.

Projects eligible for assistance include restoration of damage to clubrooms, grandstands, playing fields, shower blocks, sporting equipment and other facilities. Assistance towards loss of revenue and replacement of damaged liquor and food stocks is not available. Assistance would not generally be available where adequate insurance is available at reasonable rates.

The financial position of the organisation is taken into account and the applicant body must be unable to effect necessary repairs or replacement from its own resources and have exhausted alternative sources of assistance. Each applicant is judged on its merits as to need of the applicant and the ability of the applicant to repay the loan.

Assistance

Assistance is by way of a combination of loan and grant up to maximum amounts of $100 000 loan and $5000 grant for any one applicant. The first $30 000 (or part thereof) of assistance provided will be by way of loan and grant in the ratio of 5:1. An aggregate loan ceiling of $150 000 for all categories of assistance for all disasters also applies to each borrower. The amount of the loan is not to exceed the net cost of restoring disaster-damaged assets to pre-disaster standard.

FREIGHT SUBSIDIES

Assistance schemes are tailored to address specific deficiencies that have occurred as a direct consequence of an eligible natural disaster event.

Eligible movements

Dependent on circumstances, concessions could apply for the movement of:

- foodstuffs;
- building / fencing materials;
- stock;
- fodder;
- water;
- machinery / equipment; and
- fuels.

A rate of concession will be determined for each assistance scheme activated. A subsidy ceiling of $5000 will apply to each recipient per natural disaster event.

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ABBREVIATIONS

A$	Australian Dollars
ABARE	Australian Bureau of Agriculture and Resource Economics
ABS	Australian Bureau of Statistics
ACT	Australian Capital Territory
AGPS	Australian Government Publishing Service
AGSO	Australian Geological Survey Organisation
AIHW	Australian Institute of Health and Welfare
ANU	Australian National University
ATSB	Australian Transport Safety Bureau
AWE	Average Weekly Earnings
BoM	Bureau of Meteorology
BTCE	Bureau of Transport and Communications Economics
BTE	Bureau of Transport Economics
CFA	Country Fire Authority
CPI	Consumer price Index
CRES	Centre for Resource and Environmental Studies
DOFA	Department of Finance and Administration
DRG	Diagnosis Related Group.
EMA	Emergency Management Australia
EQC	Earthquake Commission
FEMA	Federal Emergency Management Agency
GAM	Goals Achievement Matrix
GDP	Gross Domestic Product
ICA	Insurance Council of Australia

IDNDR	International Decade for Natural Disaster Reduction
MFESB	Metropolitan Fire and Emergency Services Board
NDRA	Natural Disaster Relief Arrangements
NEMC	National Emergency Management Committee
NHRC	Natural Hazards Research Centre
NHTSA	The National Highway Traffic Safety Administration
NRMA	National Roads and Motorists' Association.
NSW	New South Wales
NT	Northern Territory
NZ$	New Zealand Dollars
PBS	Planning Balance Sheet
QLD	Queensland
RAM	Rapid Appraisal Method
RIAM	Road Infrastructure Assessment Model
SA	South Australia
SES	State Emergency Services
SMEC	Snowy Mountains Engineering Corporation
SOI	Southern Oscillation Index
TAC	Transport Accident Commission (Victoria)
TAS	Tasmania
TEC	Total Estimated Cost
USA	United States of America
VIC	Victoria
WA	Western Australia