Climate Change

CSIRO

and Australia's coastal communities

Introduction

Australia is a vast island continent with offshore islands, stretching from the tropics to the temperate zone, and its coastal environment is important to the culture and lifestyle of Australians. It is used for settlement, industry, agriculture and mariculture and valued as a recreation resource.

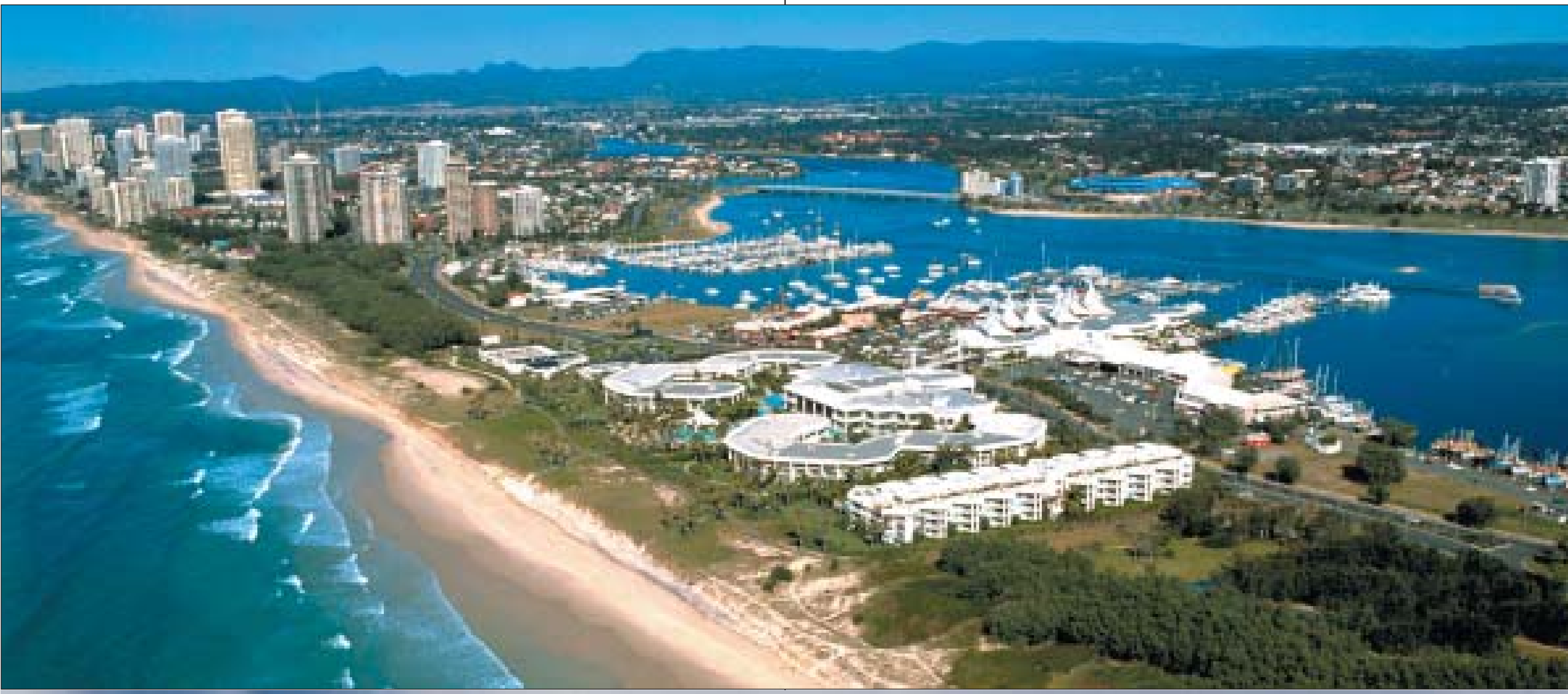
More than 80% of Australia's population resides within 50 km of the coast, concentrated in towns and cities along the coastal fringes of the east, south-east and south-west. Between 1991 and 1996, one-quarter of Australia's total increase in population was concentrated within three kilometres of the coastline – predominantly within the "sun-belt" locations on the New South Wales and Queensland coast and in the south-west of Western Australia. This population growth means that the community's exposure to extreme events — notably tropical cyclones, storm surges and flooding of rivers in deltas and other outflow regions — is growing rapidly.

Over the past 200 years, human activities have significantly altered the world's atmosphere. Increases in greenhouse gas concentrations have led to a warming of the Earth's surface and, because greenhouse gas concentrations are continuing to increase, this warming will continue. Other changes in climate, such as rainfall and storm intensity, and sea-level rise are likely to be associated with this warming.

Sea-level rise will have impacts on soft sediment shorelines and intertidal ecosystems, which will be especially vulnerable to change with additional impacts from extreme events. The interaction of severe weather events, such as tropical cyclones, with the coastal ocean has the potential to generate severe waves and storm surge, which in turn can have significant impacts on the coast. Low-lying coastal terrain may become inundated, beaches eroded, coastal infrastructure damaged or destroyed, and people injured or killed. Warmer ocean waters and sediment transport following heavy rainfall will affect fisheries and coastal ecosystems.

This brochure describes projected changes in the climate that may affect the Australian coastline and also discusses some of the impacts that may affect the prosperity of these communities. Adaptation strategies are highlighted, where possible, and future scientific challenges are proposed.

The information here draws on research undertaken by CSIRO and collaborators. For more information, see the chapter on Australia and New Zealand in the Third Assessment Report on impacts, adaptation and vulnerability published by the Intergovernmental Panel on Climate Change (IPCC, 2001).



Greenhouse gases and global warming

Since the time of the Industrial Revolution, greenhouse gas and sulphate aerosols concentrations in the atmosphere have increased as a result of human activities such as agriculture, deforestation and the use of fossil fuels. Future global emissions will depend on population growth, energy sources and regional and global economic growth. The Intergovernmental Panel on Climate Change (IPCC) has used this information to produce emission scenarios that are used to determine future greenhouse gas concentrations. These future greenhouse gas concentrations are input to computer models of the global climate to provide estimates of future climate. From these model estimates, the IPCC projects a globally averaged warming of 1.4 to 5.8ºC by 2100, relative to 1990. Over the past century the Earth has warmed 0.6 ±0.2ºC.

Sea-level rise

Associated with global warming will be a rise in sea level. The IPCC estimates a rise in sea level of between 0.09 and 0.88 m by 2100 relative to 1990, or 0.8 to 8.0 mm per year. The largest source of sea-level rise is due to the expansion of the oceans as they warm. Contributions can also be expected from the melting of glaciers and ice sheets. Other factors such as the storage of water in dams or increased snowfall over Antarctica will slightly offset some sea-level rise. In addition, coastal subsidence or uplift can influence local sea level. Lastly, on seasonal, inter-annual, and decadal time-scales, sea level responds to changes in atmospheric and ocean dynamics, with the most striking example occurring during El Niño events, when the sea level rises in the eastern Pacific and falls in the western Pacific. Regional variations from the global average can be expected due to regional differences in weather patterns and ocean currents.

As sea level rises, material on sandy shorelines is eroded from the upper beach and deposited on the near-shore ocean bottom. Consequently the ocean moves landwards or, in other words, the shoreline recedes. It is generally accepted that the coastline will retreat horizontally 50 to 100 times the vertical sea-level rise. Hence, the predicted global sea-level rise would cause a coastal recession of sandy beaches of 4.5 to 88 metres by 2100.

The rate of sea-level rise relative to the land is important for impacts. Australia's oldest sea level records are from Port Arthur, Fremantle and Sydney. They show that relative sea level has risen 0.86±0.12 mm per year at Fremantle for the period 1915–1998, and 1.38±0.18 mm per year at Sydney between 1897 and 1998. At Port Arthur, sea level is estimated to have risen 1.2±0.2 mm per year since 1890. Over the past 50 years, global-average sea level has risen 1 to 2 mm per year.

Projected changes in weather extremes

El Niño-Southern Oscillation (ENSO)

The strongest natural fluctuation of climate from year to year is the El Niño-Southern Oscillation (ENSO). In El Niño years, eastern Australia tends to be drier and hotter than normal and in La Niña years, eastern Australia tends to be wetter and cooler. Changes associated with ENSO often have a profound impact on society because of associated droughts, floods, heat waves and other changes that can affect agriculture, fisheries, energy demand and fire risk. ENSO affects the region of formation of tropical cyclones in the South Pacific and their tracks. During La Niña years, tropical cyclone activity is located closer to the coast of north-eastern Australia than during El Niño years. ENSO also affects the frequency of severe weather such as hailstorms and east coast lows. Such variations are expected to continue under enhanced greenhouse conditions, though possibly with greater hydrological extremes in Australia as a result of more intense rainfall in La Niña years and more intense drought during El Niño years. ENSO has been observed to vary over the past century with an increase in the frequency of El Niño conditions over the past decade.

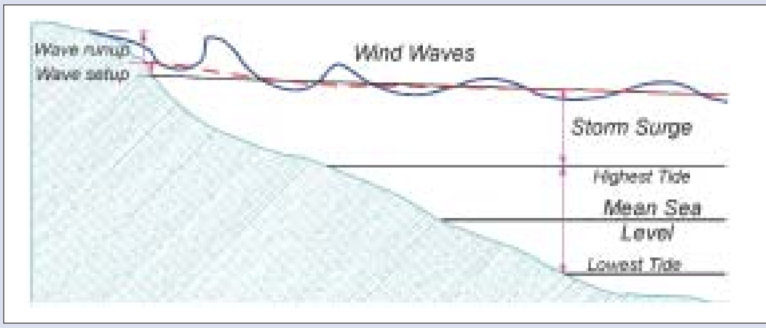
Tropical cyclones

Tropical cyclones bring severe winds and rainfall and can have devastating impacts on society. Since 1967, 46 tropical cyclones each causing more than A$10 million damage, have impacted communities of northern Australia. The Bureau of Transport and Regional Economics estimates the total cost of cyclones to have been A$8.8 billion since 1967. The most devastating tropical cyclone to affect Australia in the last 30 years was tropical Cyclone Tracy. Tracy devastated Darwin in December 1974,

Damage caused by tropical Cyclone Tracy in Darwin – December 1974. Image courtesy of the Bureau of Meteorology

Storm surges

A storm surge is a region of elevated sea level at the coast caused by the combined effect of falling atmospheric pressure and intense winds of severe weather events such as tropical cyclones. The rise in sea level is about 10 mm per hectopascal fall in pressure (the so-called inverse barometer effect) although the larger contribution is due to wind that, in effect, pushes the water against the coast. Factors influencing the storm surge include the wind strength, its direction relative to the coast and how the storm moves in relation to the coast. For example, a tropical cyclone-induced storm surge would be most intense over the region of strongest onshore winds as the cyclone moves onshore. The shape of the sea floor and the proximity to bays, headlands and islands also affects the storm surge height. Wide and gently sloping continental shelves amplify the storm surge, and bays and channels can funnel and increase the storm surge height. Storm systems such as tropical cyclones and mid-latitude storms and their associated cold fronts are the main cause of storm surges. The most severe storm surges in Australia reach several metres in height, and occur as a result of tropical cyclones. Storm surges can interact with other ocean processes such as tides and waves to further increase the coastal sea levels and flooding. A storm surge will have maximum impact if it coincides with high tide. Breaking waves at the coast can also produce an increase in coastal sea levels known as wave setup.



Contributions to coastal sea level from tide, storm surge and wave processes.

resulting in 65 deaths, A$4 billion in total damages and an insured loss of A$837 million. Therefore, accurate estimates of future changes in their frequency, intensity and location would be of great value.

Climate variability has a significant impact on the frequency of these events and there is some evidence of long-term variations in the characteristics of tropical cyclones in the Australasian region. A decrease in tropical cyclone numbers occurred in the Australian region between 1969 and 1996 but in the same period there has been an increase in the frequency of intense tropical cyclones with central pressures of less than 970 hPa. No significant global trends have been detected in the frequency of tropical cyclones to date. Projections are difficult since tropical cyclones are not well resolved by global or regional climate models. Present indications are:

- Maximum wind speeds may increase by 5–10% and precipitation rates may increase by 20–30%. More intense tropical cyclones would have serious implications for storm surge heights, wind damage, flooding and landslides on the steep escarpments of eastern Australia.
- Regions of origin are likely to remain unchanged.
- Preferred paths and poleward extent may alter, but changes remain uncertain. If they were to travel further poleward they would be more likely to impact on coastal regions in south-west Western Australia, southern Queensland and northern NSW.
- Future changes in frequency will be affected by changes in ENSO.

Severe beach erosion at Palm Beach, Queensland. Image courtesy of the Environmental Protection Agency, Queensland

Mid-latitude storms

Mid-latitude storms also may increase in intensity, and their frequency and location may change as a result of changes in the westerlies and ENSO. Recent decades have seen a reduction in the numbers of mid-latitude storms to the south of Australia, but the intensity of these storms has on average increased. Climate models also indicate a future decrease in the number of storm centres over southern Australia but an increase in their intensity. These changes are likely to affect the coasts in the south-east of the continent that are vulnerable to shifts in wave direction and energy. They will also impact the return periods for mid-latitude storm surges, landslides, high winds, coastal erosion and other phenomena.

Heavy rain in south-east Queensland, 9 March 2001. Photograph: James Chambers

Rainfall

Australian regional rainfall could increase or decrease in future. Annual average rainfall changes tend towards decreases in the south-west (–20% to +5% in 2030 and –60% to +10% in 2070), and in parts of the south-east and Queensland (–10% to +5% by 2030 and –35% to +10% by 2070). Decreases are most pronounced in winter and spring. Some eastern coastal areas may become wetter in summer (–5% to +10% by 2030 and –10% to +35% by 2070).

Most models simulate an increase in extreme daily rainfall leading to more frequent heavy rainfall events. This can occur even where average rainfall decreases slightly. Reductions in extreme rainfall occur where average rainfall declines significantly. Increases in extreme daily rainfall are likely to be associated with increased flooding and an increased risk of landslides in some areas.

Severe storms

Severe local storms may be associated with hail, flash flooding and wind damage. The Bureau of Transport and Regional Economics estimates that between 1967 and 1999, 112 storms, each causing damage of more than A$10 million, occurred in Australia. The total cost of damage from severe local storms over this period was A$9.4 billion. The data show a statistically significant increase in the damage due to these storms over time, but this is due largely to increased population in the storm-prone coastal areas of Queensland and New South Wales.

Future changes in the frequency and severity of these events are uncertain, but projected climate change could result in an increased number of severe storms. This is because a warmer, moister atmosphere is more conducive to the development of severe thunderstorms.

Temperature

CSIRO projects an annual average warming of 0.4 to 2°C over most of Australia by 2030 (relative to 1990), with slightly less warming in coastal areas and Tasmania, and slightly more warming in north-western Australia. By 2070, the warming may be 1 to 6°C over most of Australia. Greatest warming occurs in spring and least in winter. In the north-west, most warming may occur in summer. Changes in extreme temperatures, assuming no change in variability, are given in Table 1.

	Present	*2030*	*2070*
Hobart	1	1–2	1–4
Sydney	2	2–4	3–11
Brisbane	3	3–6	4–35
Canberra	4	6–10	7–30
Melbourne	8	9–12	10–20
Adelaide	10	11–16	13–28
Perth	15	16–22	18–39

Table 1: The average number of summer days over 35°C at capital cities (excluding Darwin) for present conditions, 2030 and 2070

Severe hail and thunderstorm in Brisbane, 16 December 1998. Photograph: James Chambers

Coastal impacts

Communities and infrastructure

Coastal communities and urban infrastructure will be affected by changes in sea level and extreme weather. Torrential rainfall over cities and surrounding catchments can produce severe runoff and flooding. Damage to buildings is caused by both the depth of floodwaters and by the force of the water flow. Both contribute to structural fatigue. Gales and strong winds directly damage buildings and also generate waves and storm surges that can contribute to coastal flooding. More frequent high-intensity rain in some areas will also increase the risks of landslides and erosion, particularly in the urbanised catchments on Australia's east coast.

The Bureau of Transport and Regional Economics estimates that for the past three decades, the total cost of floods has ranged between $2.5 billion and $4 billion per decade. It has been estimated that more than 80% of the buildings at risk from flooding are located within Queensland and New South Wales. In Queensland, the Gold Coast City Council area has the greatest number of buildings at risk from a 100-year return period flood. Increases in population in risk-prone areas, combined with increases in storm intensities and rising sea levels, mean that the cost of flood damage to the built environment will increase.

A study of flood damage along the Hawkesbury-Nepean corridor of New South Wales has shown that, by about 2070, average annual direct damage could increase from the current value of A$6.10 million to A$23.2 million for the worst-case scenario. At present, the 1-in-100 year flood would cause failure of about 70 weatherboard dwellings and for the 2070 worst case scenario this rises to 1200 dwellings. These estimates do not account for indirect losses including alternative accommodation in the residential sector or loss of trading profit in the commercial sector. They do not include intangible losses such as illness and death.

Rising sea level, stronger tropical cyclones and increased intensity of associated storm surges are likely with climate change. By 2050, sea level may rise 0.1 to 0.4 metres and tropical cyclone intensity around Cairns in northern Queensland could increase by up to 20%. This would increase the flood level associated with a 1-in-100 year flood in Cairns from the present height of 2.3 to 2.6 metres to 2.7 to 3.0 metres. This equates to flooding occurring over an area about twice that historically affected. Timely, planned adaptation strategies could reduce the associated damage. Options include building or re-engineering defence structures, relocation of buildings, and urban planning and management.

Flooding in Maryborough, Queensland, January 1974. Photograph courtesy of Ted Smith

The rate and nature of degradation of infrastructure is directly related to climatic factors such as winds and relative humidity. Increases in the rate of degradation as a result of climate change may promote additional failures when a severe event occurs. If the intensity increases, or geographical spread of severe events changes, this effect may be compounded.

Population growth and increased demand for water and energy are already placing pressure on existing resources. These pressures are likely to be exacerbated by climate change. For instance, changes in the timing and amounts of peak seasonal energy loads are likely as warmer conditions mean less energy demand for winter heating and more energy demand for summer cooling. A study of changes in electricity demand for various climate change scenarios found that for Sydney and Melbourne there was little increase in average demand. In contrast, Brisbane and Adelaide showed marked increases in demand with climate change due to a larger summer effect compared with winter.

Increases in stream flow are possible in northern Australia if summer rainfall increases, however, decreases in stream flow seem likely for southern Australia due to reductions in rainfall and increased evaporation. Low volume flows are the most sensitive to these changes. Adaptation through increased water use efficiency and demand management strategies is possible in some cases. In south-western Australia, a further reduction in rainfall would seriously affect water supplies for both agriculture and urban communities. More frequent high-intensity rain in some other areas may have some benefits, contributing to groundwater supplies and filling dams. Integrated catchment management, changes to water pricing systems, and water efficiency initiatives are some options for adapting to these changes.

Natural systems (Coral reefs, coastal vegetation, wetlands)

Many natural systems will have difficulty adapting to climate change. The wetlands of Australia are already under threat from dams, irrigation, coastal urban development, and pollution of waterways. Climate change and sea level rise would add to the vulnerability. If sea levels rise significantly, the vast freshwater floodplains of northern Australia will be subject to significant saltwater inundation.

Mangroves occur on low-energy, sedimentary shorelines and are the nursery areas for many commercially important fish, prawns and mudcrabs. They are highly vulnerable but could be adaptable to climate change, migrating shorewards in response to gradual sea-level rise. However, in many locations this adaptation will now be inhibited by human infrastructure such as causeways, flood protection levees and urban and tourist developments, leading to a reduction in the area of wetland or mangrove. Adaptation options include considering wetland and mangrove migration when planning future developments.

Sediment transport and deposition following heavy rainfall can smother extensive areas of estuarine

Hinchinbrook Island. The island is densely covered by wet tropical rainforest and eucalypt forest and is the home of a tremendous variety of tropical birds and other wildlife. Extensive mangrove forests spread along the channel between the Island and the mainland coast. These calm waters are the nursery grounds for many fish species and are also known as valuable refuges for dugongs, dolphins and turtles. © Copyright CSIRO Land and Water.

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habitat, killing the trees, and resulting in loss of breeding habitat essential to many coastal fish species, dugong and turtles. Such an extreme event occurred in Queensland's Hervey Bay in 1992. Any increase in extreme rainfall events and sedimentation would be likely to have major impacts on river, lake, estuarine and coastal waters and lead to reduced ecosystem health and reduced recreational and tourist use. There may be impacts on commercially important fisheries such as prawns and barramundi but the economic impacts are unclear.

Coral reefs around the world are becoming stressed by a number of factors: bleaching due to warmer oceans, occasional reductions in salinity due to extreme river outflows, increased cloudiness of water, chemical pollutants, local fishing practices and damage from tropical cyclones. Projected global warming will contribute additional stress. Coral bleaching events as severe as that in 1998 may become common by 2020. Increases in cyclone intensity would cause more reef damage. The effect of higher carbon dioxide levels results in more acidic ocean waters and may lead to reduced coral growth rates. Natural adaptation will probably be too slow to avert a decline in the quality of the world's reefs.

Uncertainties and challenges

Uncertainties about future human behaviour and shortcomings in climate modelling limit our climate change projections to ranges of change for some variables, and qualified statements on possible changes for others. Greenhouse gas emissions are subject to uncertainties concerning population growth, technological change and social and political behaviour. Climate model responses are most uncertain in how they represent feedback effects, particularly those dealing with changes to cloud regimes and ocean-atmosphere interactions. The coarse spatial resolution of climate models also remains a limitation on their ability to simulate the details of regional climate change, especially extreme events. There is the potential for increased understanding of extreme events, especially tropical cyclones, by employing high-resolution models of the atmosphere.

Improved impact assessments will depend on a better understanding of how current climate variability influences human activities and affects coastal processes and ecosystems. It requires coping ranges to be identified for the current climate, and critical thresholds to be agreed upon that will move activities, processes and ecosystems outside their coping range. Risk analysis may then be carried out to identify the likelihood that a given threshold may be exceeded. This opens a window for adaptation where options for risk treatment may be evaluated by researchers in consultation with stakeholder groups. For example, if an urban region is vulnerable to sea-level rise exceeding a particular threshold, then the risk of exceeding that threshold may be calculated from knowledge of climate change and sea-level rise. If warranted, adaptation measures may be initiated to minimise the cost and side effects of sea-level rise to that community.

Studies are required on adaptation and mitigation options, to ascertain their public acceptability, costs, benefits, side effects and limits. These studies need to take into account human behaviour and socio-economic impacts. If these issues are to be addressed by decision-makers, there needs to be strong interaction with regional stakeholders to ensure that socio-economic considerations, ecosystem impacts, adaptation options and regional climate change knowledge are integrated to provide the best adaptation solution for each region.

Summary

Climate change will have social, economic and ecological impacts. There will be both winners and losers. Coastal ecosystems such as coral reefs, mangroves and other wetlands are vulnerable to climate change. Agriculture, fisheries, forests and water resources are also likely to be sensitive to climate change, as are cities and towns, the energy sector and industry, although the net effects are much harder to predict.

Adaptation can potentially offset some adverse climate change impacts, but this will come at a cost. Some systems will adapt automatically to some degree as changes occur, but a better understanding of impacts can contribute to the development of adaptation strategies designed to minimise adverse impacts and optimise benefits. In human systems, the key features of climate change for vulnerability and adaptation are related to coping with variability and extremes, not simply changed average conditions. Societies and economies have been adapting to climate for centuries. Most communities and sectors are able to adapt to changes in average conditions, particularly if the changes are gradual. However, losses from climatic variations and extremes are substantial and, in some sectors, increasing.

Many of these climate sensitivities have already been observed as part of current, natural climate variations, and so confidence is high that a range of impacts will occur. The key regional concern identified in this brochure, regarding vulnerability to climate change impacts, is increased coastal and tropical exposure to climate hazards. This vulnerability is exacerbated by the current bias toward population and economic growth in coastal areas, especially those of the tropics and sub-tropics. Planned adaptation should commence now to avoid adding to the vulnerability.

Further information

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The greenhouse effect www.dar.csiro.au/information/greenhouse.html

Global sea-level rise www.marine.csiro.au/LeafletsFolder/45slevel/45.html

CSIRO Climate Change Research Program www.dar.csiro.au/agsp/index.html

CSIRO climate change projections for Australia (8 page brochure) www.dar.csiro.au/publications/projections2001.pdf

CSIRO climate change impacts for Australia (8 page brochure) www.marine.csiro.au/iawg/impacts2001.pdf

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The impact assessments summarised here are based on results from computer models that involve simplifications of real physical processes that are not fully understood. Accordingly, no responsibility will be accepted by CSIRO for the accuracy of the assessments inferred from this brochure or for any person’s interpretations, deductions, conclusions or actions in reliance on this information

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