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Climate change and the coastal zone: the science and the impacts

There is an urgent need to nationally coordinate and increase research on the impacts of sea level rise to improve our capacity to devise and apply appropriate, robust and cost-efficient adaptation strategies.[1]

Introduction

2.1 Chapter 2 focuses on the Committee's terms of reference to investigate the impact of climate change on coastal areas, with particular emphasis on developments in climate change science.

2.2 The Australian Government recently adopted a National Climate Change Science Framework to set directions for climate change science over the next decade, following a review of the Australian Climate Change Science Program. The framework identifies 'coasts and oceans' as one of five key challenges in climate change science.

2.3 Federal, state and local government clearly play a crucial governance role in implementing climate change policy. Industry, academic and community sectors are also involved in important work on climate change risk analysis and adaptation, and, along with the general public, have a key role to play in promoting community resilience to climate change.

2.4 At a federal level, the Australian Government's climate change policy has been formulated on the basis of three 'pillars': 'action to reduce

1 Antarctic Climate and Ecosystems Cooperative Research Centre, *Submission 46*, p. 5.

greenhouse gas emissions, action to adapt to climate change that we cannot avoid, and action to help shape a global solution'.[2]

2.5 The Council of Australian Governments (COAG), the peak intergovernmental forum in Australia, brings together federal, state and local governments and has initiated significant policy reforms with regard to climate change issues that require cooperative action, such as the National Climate Change Adaptation Framework.

2.6 The recently formed Australian Council of Local Governments (ACLG) similarly provides a forum for the Australian Government and local government, including the Australian Local Government Association, to consider policies and initiatives in areas of mutual interest. One of the priorities of ACLG is climate change and local government.

2.7 The coastal zone, of all regions and sectors in Australia, would appear to be worst hit by projected climate change impacts—firstly, because of its population and economic significance; and, secondly, because it is forecast to be not just affected by more severe droughts, heatwaves, floods and bushfires (which will impact on the whole of Australia) but also uniquely affected by sea level rise, tropical cyclones of increasing intensity, ocean acidification and higher ocean temperatures.

Recent developments in climate change science

Intergovernmental Panel on Climate Change: Fourth Assessment Report

2.8 The Intergovernmental Panel on Climate Change (IPCC) is the authoritative international scientific advisory body on human-induced climate change science. The IPCC produces regular reports dealing with the science of climate change, most recently the Fourth Assessment Report (AR4) released in 2007.[3] This report summarised the state of climate change science up to 2005-06, with strong scientific consensus on the following core aspects of climate change science:

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2 Department of Climate Change, *Australian Climate Change Science: A National Framework*, May 2009, p. 1, DCC website accessed on 24 July 2009 <http://www.climatechange.gov.au/science/publications/pubs/cc-science-framework.pdf>

3 IPCC, *Climate Change 2007: The Physical Science Basis*, Contribution of Working Group I to the Fourth Assessment Report of the IPCC, Cambridge University Press, Cambridge, 2007. (The comprehensive information in the IPCC reports is based on peer-reviewed, published scientific evidence from relevant experts from all regions.)

- Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level ...
- At continental, regional and ocean basin scales, numerous long-term changes in climate have been observed. These include changes in Arctic temperatures and ice, widespread changes in precipitation amounts, ocean salinity, wind patterns and aspects of extreme weather including droughts, heavy precipitation, heatwaves and the intensity of tropical cyclones ...
- Palaeoclimate information supports the interpretation that the warmth of the last half century is unusual in at least the previous 1,300 years. The last time polar regions were significantly warmer than at present for an extended period (about 125,000 years ago), reductions in polar ice volume led to 4 to 6 m of sea-level rise ...
- Most of the observed increase in global average temperatures since the mid 20th century is *very likely*[4] due to the observed increase in anthropogenic greenhouse gas concentrations. … Discernible human influences now extend to other aspects of climate, including ocean warming, continental-average temperatures, temperature extremes and wind patterns ...
- Continued greenhouse gas emissions at or above current rates would cause further warming and induce many changes in the global climate system during the 21st century that would very likely be larger than those observed during the 20th century.[5]

2.9 Greenhouse gases listed under the Kyoto Protocol include carbon dioxide (CO_2), methane, nitrous oxide, sulphur hexafluoride, hydroflurocarbons and perflurocarbons. The 'greenhouse effect' involves the sun's light energy travelling through the Earth's atmosphere to reach the planet's surface, where some of it is converted to heat energy and radiated back towards space. Some of that heat energy is absorbed by greenhouse gases in the lower atmosphere and re-emitted in all directions. Thus, some of this re-emitted heat is radiated back towards the ground. This keeps temperatures higher than they would otherwise be. Human activities, such as burning fossil fuels, release large quantities of greenhouse gases into the atmosphere, particularly CO_2, which trap more heat and further raise the Earth's surface temperature.

4 'Very likely' is defined by the IPCC to mean >90% probability of the occurrence or outcome.

5 IPCC, 'Summary for policymakers', *Climate Change 2007: The Physical Science Basis*, pp. 5-13.

Research findings since the IPCC Fourth Assessment Report

2.10 The Committee received submissions from internationally recognised climate change scientists, including Professor Will Steffen, Executive Director of the Climate Change Institute at the Australian National University (ANU), and Dr John Church, Principal Research Scientist with the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and Leader of the Sea Level Rise Program with the Antarctic Climate and Ecosystems Cooperative Research Centre (ACE CRC). These experts support the IPCC's conclusions. However, as Professor Steffen and Dr Church noted in their evidence, climate change science is a rapidly evolving field of study and much important research has been published since the IPCC AR4 was released in 2007:[6]

> The science surrounding the sea-level rise issue is in a state of rapid change, and, in fact, has progressed significantly since the publication of the IPCC AR4.[7]

2.11 Figure 2.1 provides a summary of recent developments in climate change science since the IPCC AR4. As this summary indicates, more rapid climate change is occurring—anthropogenic emissions of CO_2 and sea levels have been rising at or near the upper limit of the envelope of the IPCC projections—and more costly and dangerous impacts are associated with this faster change. Figures 2.2-2.5 set out recent data on anthropogenic CO_2 emissions, surface air temperature, sea level change and Arctic sea-ice extent.

2.12 While much more needs to be understood about these aspects of climate science, the Committee notes that they have significant consequences for climate change policy and management of the coastal zone.

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6 The IPCC's Fifth Assessment Report will be finalised in 2014.

7 Professor Steffen, *Submission 45*, p. 1. See also Dr Church, CSIRO, *Transcript of Evidence*, 28 January 2009, p. 5.

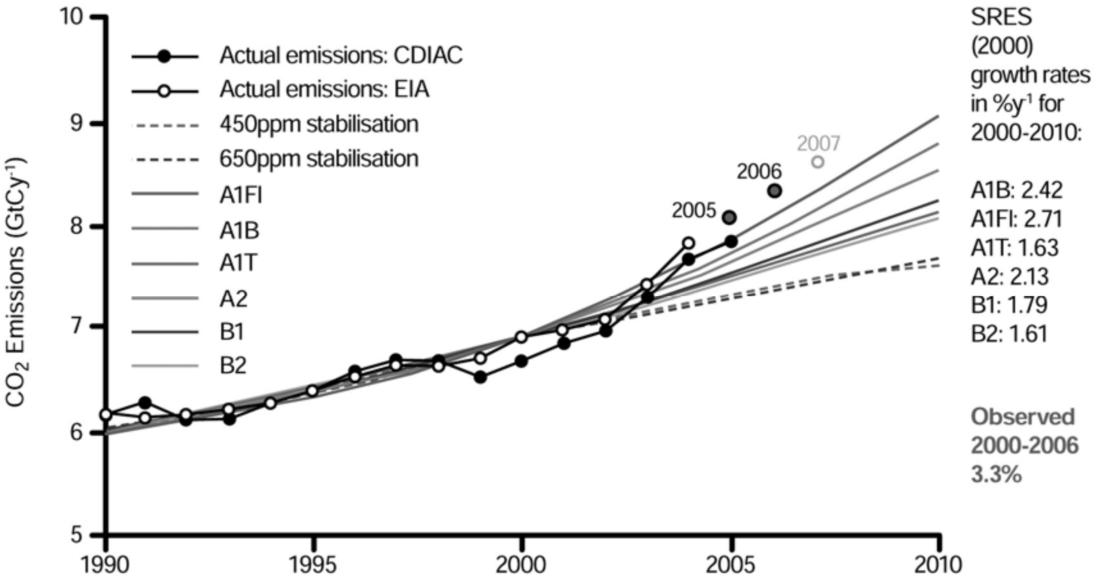
Figure 2.1 Summary of recent developments in climate change science post-IPCC AR4

[C]limate science is a rapidly moving field as researchers respond to the challenges laid out by the IPCC and the needs of governments and other groups for even better knowledge about climate change. Over the past three to four years, many new developments have occurred and many significant new insights have been gained. The most important of these are:

- The climate system appears to be changing faster than earlier thought likely. Key manifestations of this include the rate of accumulation of carbon dioxide in the atmosphere, trends in global ocean temperature and sea level, and loss of Arctic sea ice.
- Uncertainties still surround some important aspects of climate science, especially the rates and magnitudes of the major processes that drive serious impacts for human societies and the natural world. However, the majority of these uncertainties operate in one direction—towards more rapid and severe climate change and thus towards more costly and dangerous impacts.
- The risk of continuing rapid climate change is focusing attention on the need to adapt, and the possible limits to adaptation. Critical issues in the Australian context include the implications of possible sea-level rise at the upper end of the IPCC projections of about 0.8 m by 2100; the threat of recurring severe droughts and the drying trends in major parts of the country; the likely increase in extreme climatic events like heatwaves, floods and bushfires; and the impacts of an increasingly acidic ocean and higher ocean temperatures on marine resources and iconic ecosystems such as the Great Barrier Reef.
- Climate change is not proceeding only as smooth curves in mean values of parameters such as temperature and precipitation. Climatic features such as extreme events, abrupt changes, and the nonlinear behaviour of climate system processes will increasingly drive impacts on people and ecosystems. Despite these complexities, effective societal adaptation strategies can be developed by enhancing resilience or, where appropriate, building the capacity to cope with new climate conditions. The need for effective reduction in greenhouse gas emissions is also urgent, to avoid the risk of crossing dangerous thresholds in the climate system.
- Long-term feedbacks in the climate system may be starting to develop now; the most important of these include dynamical processes in the large polar ice sheets, and the behaviour of natural carbon sinks and potential new natural sources of carbon, such as the carbon stored in the permafrost of the northern high latitudes. Once thresholds in ice sheet and carbon cycle dynamics are crossed, such processes cannot be stopped or reversed by human intervention, and will lead to more severe and ultimately irreversible climate change from the perspective of human timeframes

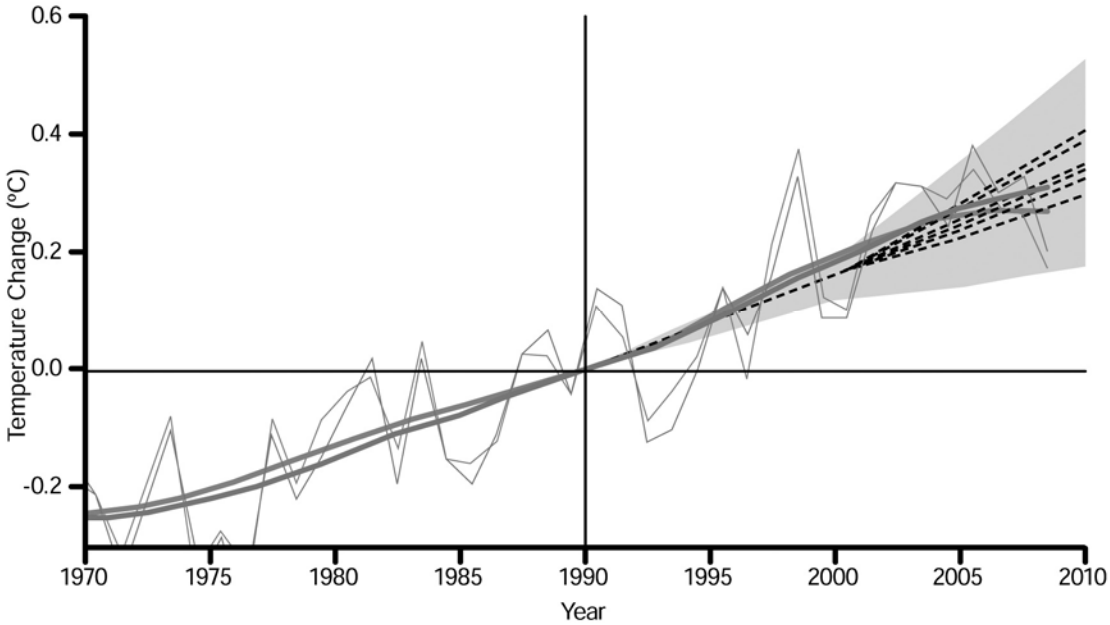
Source *W Steffen, Climate Change 2009: Faster Change and More Serious Risks, Department of Climate Change, Commonwealth of Australia, 2009, p. 1*

Figure 2.2 Observations of anthropogenic CO_2 emissions from 1990 to 2007



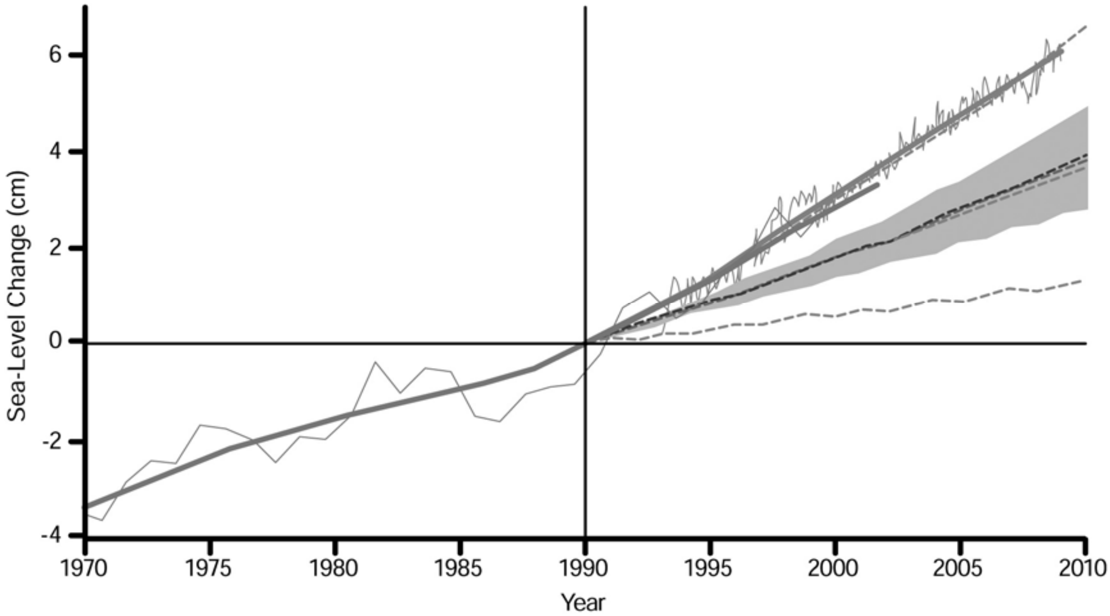
Source W Steffen, *Climate Change 2009: Faster Change and More Serious Risks*, Department of Climate Change, Commonwealth of Australia, 2009, p. 4 (Note: see IPCC Special Report on Emissions Scenarios (SRES) for description of six scenarios: A1B, A1F1, A1T, A2, B1, B2; Carbon Dioxide Information Analysis Center (CDIAC); Energy Information Administration (EIA))

Figure 2.3 Global average surface air temperature (smoothed over 11 years)



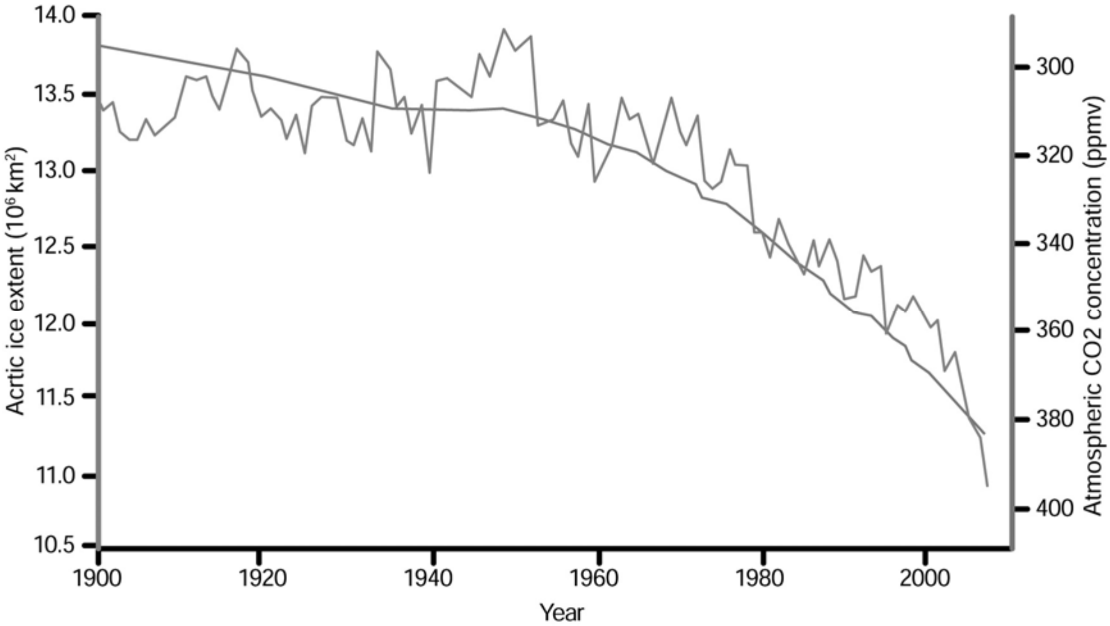
Source W Steffen, *Climate Change 2009: Faster Change and More Serious Risks*, p. 5 (The broken lines are projections from the IPCC, with shading indicating uncertainties around the projections; other data from the Hadley Center and Goddard Institute for Space Studies (GISS))

Figure 2.4 Sea level change from 1970 to 2008



Source W Steffen, *Climate Change 2009: Faster Change and More Serious Risks*, p. 5 (Note: the envelope of IPCC projections is shown for comparison (broken lines with shading showing the uncertainty levels. Solid lines are data from satellite altimetry and tide gauges; broken lines are model projections)

Figure 2.5 Arctic sea ice extent and CO_2



Source W Steffen, *Climate Change 2009: Faster Change and More Serious Risks*, p. 6 (Note: time series of annual Arctic sea ice extent and atmospheric concentrations of CO_2 for the period 1900-2007; the CO_2 scale is inverted)

Kyoto Protocol and future international climate change negotiations

2.13 Australia is a party to the United Nations Framework Convention on Climate Change (UNFCCC), which came into force on 21 March 1994. The UNFCCC sets out the broad framework for international cooperation to address climate change, including differentiated responsibilities for developed and developing countries. The objective of the UNFCCC is to stabilise 'greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system'.[8] A negotiating body, known as the Conference of the Parties, has been established as the highest decision-making authority of the UNFCCC and meets annually.

2.14 The Kyoto Protocol, an international agreement setting legally binding greenhouse gas emissions reduction targets for developed countries, was adopted at the third meeting of the UNFCCC Conference of Parties on 11 December 1997 and entered into force on 16 February 2005.

2.15 Australia signed the Kyoto Protocol on 24 April 1998 but it was not ratified until December 2007, following the change of government at the November 2007 election.

2.16 The Kyoto Protocol serves to give effect to the UNFCCC's objective of reducing human-induced greenhouse gases in an effort to address climate change. Under the protocol, Australia is committed to reducing its average annual greenhouse gas emissions to 108 per cent of 1990 emissions, over the 2008-2012 commitment period.[9]

2.17 Negotiations on a successor to the Kyoto Protocol are due to be completed in December 2009 at the 15th Conference of Parties to the UNFCCC in Copenhagen, Denmark.

2.18 The White Paper on *Australia's Low Pollution Future* sets a target to reduce greenhouse gas emissions by 60 per cent on 2000 levels by 2050.[10] In May 2009, the Australian Government committed to 'reduce Australia's carbon pollution by 25 per cent below 2000 levels by 2020 if the world agrees to an ambitious global deal to stabilise levels of CO_2 equivalent at 450 parts per million'. Further, the government announced:

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8 Article 2, United Nations Framework Convention on Climate Change, 1992.

9 See Annex B, Kyoto Protocol to the UNFCCC, 1998.

10 *Carbon Pollution Reduction Scheme: Australia's Low Pollution Future*, White Paper, Volume 1, Commonwealth of Australia, 2008, p. xix.

- an unconditional commitment to reduce carbon pollution by 5 per cent by 2020; and
- a commitment to reduce carbon pollution by 15 per cent by 2020 if there is an agreement where major developing economies commit to substantially restrain emissions and advanced economies take on commitments comparable to Australia's.[11]

Reducing Australia's greenhouse gas emissions and helping shape a global solution

2.19 Scientific evidence indicates that climate change is already occurring and will continue to occur for some time even if greenhouse gas emissions were reduced immediately. Past greenhouse gas emissions will lead to ongoing climate change and sea level rise over the 21st century, regardless of current and future mitigation action. As the Department of Climate Change noted, '[s]ome degree of impact is unavoidable because of the elevated levels of greenhouse gases already in the atmosphere'.[12]

2.20 While a key focus of this inquiry is therefore to investigate what adaptation measures need to be implemented to ensure that the unavoidable impacts of climate change are addressed, the Committee supports the call for urgent action to reduce Australia's greenhouse gas emissions, while preserving growth in incomes and employment across the economy, to minimise more severe future impacts.

2.21 Many of those who gave evidence to the inquiry emphasised the need for urgent action in this regard:

> It is very important that Australia take an active part in efforts to mitigate climate change. Australia, with particularly high emissions per capita, must reduce greenhouse emissions and join, indeed lead, international initiatives to stabilise greenhouse gas concentrations.[13]

> Addressing climate change has to be the Australian government's highest priority in order to mitigate unavoidable impacts such as rising sea levels, wild and unpredictable weather events, increasing drought and high temperatures.[14]

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11 Media release by the Treasurer and the Minister for Climate Change and Water, 'A new target for reducing Australia's carbon pollution', 4 May 2009.

12 Department of Climate Change, *Submission 85*, p. 3.

13 Professor Woodroffe, *Submission 24*, p. 7.

14 Ms Brooke, Climate Action Newcastle, *Transcript of Evidence*, 26 March 2009, p. 68.

> reducing greenhouse gas emissions should be core business. We need to act on this. We can act now. Everything we do to reduce greenhouse gas emissions will ultimately assist with reducing the impacts of climate change on the coast.[15]

2.22 Two recent major reports on climate change have argued that the benefits of acting early to reduce greenhouse gas emissions far outweigh the long-term economic costs of allowing climate change to take its course. Lord Nicholas Stern, in the *Economics of Climate Change: the Stern Review* (2006), the most comprehensive review conducted to date on the economics of climate change, commented that:

> The scientific evidence is now overwhelming: climate change is a serious global threat, and it demands an urgent global response. This Review has assessed a wide range of evidence on the impacts of climate change and on the economic costs, and has used a number of different techniques to assess costs and risks. From all of these perspectives, the evidence gathered by the Review leads to a simple conclusion: the benefits of strong and early action far outweigh the economic costs of not acting.[16]

2.23 Professor Ross Garnaut, in the *Garnaut Climate Change Review* (2008), similarly noted that '[t]he weight of scientific evidence tells us that Australians are facing risks of damaging climate change. The risk can be substantially reduced by strong, effective and early action by all major economies'.[17]

2.24 According to the White Paper on *Australia's Low Pollution Future*, the Australian Government is seeking to manage the transformation to a low-carbon economy:

> through the implementation of the Carbon Pollution Reduction Scheme,[18] an expanded national Renewable Energy Target, investment in renewable energy technologies and in the

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15 Mr Clarke, Great Ocean Road Coast Committee, *Transcript of Evidence*, 20 May 2009, pp. 71-72.

16 N Stern, *The Economics of Climate Change*: *the Stern Review,* 2006, p. vi, UK Treasury website accessed on 20 July 2009 <http://www.hm-treasury.gov.uk/stern_review_report.htm>

17 R Garnaut, *The Garnaut Climate Change Review: Final Report*, Cambridge University Press, Cambridge, 2008, p. xvii.

18 The Carbon Pollution Reduction Scheme (CPRS) is a cap-and-trade emissions trading scheme designed as Australia's contribution to limiting the global emissions of greenhouse gases so as to contain global warming and climate change. The Australian Government released Green and White Papers on the scheme in July and December 2008 respectively. Exposure drafts of the bills to introduce the CPRS were released in March 2009 and the bills were introduced into Parliament on 14 May 2009.

> demonstration of carbon capture and storage and action on energy efficiency ...
>
> Together, these elements comprise the four arms of the Government's climate change emissions reduction strategy, and will ensure that Australia has the incentives to reduce its emissions, can develop the technologies to help reduce greenhouse gas emissions both here and abroad, and can contribute to helping the international community to reach a global solution.[19]

2.25 As inquiry participants noted, while adaptation strategies can be developed to enhance the resilience of coastal communities to climate change impacts, the need for effective reduction in greenhouse gas emissions is also urgent, to avoid the risk of crossing dangerous thresholds or 'tipping points' in the climate system. As Dr Church stated:

> There is an important issue of thresholds. We are likely to cross a threshold leading to an ongoing disintegration of the Greenland icesheet—and remember that the Greenland icesheet contains the equivalent of seven metres of sea level rise. We could cross that threshold late this century. At a 550 ppm CO_2 equivalent level there is approximately a 50 per cent risk of crossing that threshold. That is not to say that the Greenland icesheet will disappear as soon as we cross that threshold, but unless we substantially reduce levels below that value there will be an ongoing disintegration of the icesheet ...
>
> and if we cross that threshold there will be major impacts over many centuries or perhaps even millennia. To avoid the impacts that would result from that requires ... significant, urgent and sustained mitigation.[20]

2.26 Similarly, Professor Steffen noted that:

> Mitigation, as vigorously and rapidly as we can, is the best insurance against the worst of the projected coastal impacts. Obviously this is a global task, but as a country with a very high percentage of population and infrastructure in the coastal zone, it should be a high priority for Australia that the international community achieves an effective mitigation strategy at Copenhagen.[21]

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19 *Carbon Pollution Reduction Scheme: Australia's Low Pollution Future*, White Paper, Volume 1, pp. 1-8.

20 Dr Church, CSIRO, *Transcript of Evidence*, 28 January 2009, p. 2, p. 11.

21 Professor Steffen, *Submission 45*, p. 3.

2.27 The Committee agrees that the earlier Australia acts to reduce emissions, the lower the cost of action will be. Conversely, the longer we delay, the more damage we risk to the Australian economy, society and environment. A report on the Great Barrier Reef, an Australian and international icon, released just before the Committee completed its report reinforces this message:

> the overall outlook for the Great Barrier Reef is poor and catastrophic damage to the ecosystem may not be averted. Ultimately, if changes in the world's climate become too severe, no management actions will be able to climate-proof the Great Barrier Reef ecosystem.[22]

2.28 The Committee therefore shares the concerns raised by leading climate change scientists and others who gave evidence to the inquiry about more rapid climate change and the particular threat this poses to the Australian coastal zone.

Recommendation 2

2.29 **The Committee notes the importance of mitigation measures in addressing climate change impacts and accordingly recommends that the Australian Government continue to take urgent action to ensure that Australia can best contribute to a reduction in global greenhouse gas emissions.**

Climate change science and the coastal zone

2.30 The IPCC Fourth Assessment report, released in 2007, included sections on 'Coastal systems and low-lying areas'[23] and on 'Australia and New Zealand'.[24] The major findings of the coastal section were that:

- Coasts are experiencing the adverse consequences of hazards related to climate and sea level (very high confidence) ...

22 *Great Barrier Reef Outlook Report 2009: In Brief,* Great Barrier Reef Marine Park Authority, Commonwealth of Australia, 2009, p. ii.

23 RJ Nicholls et al, 'Coastal systems and low-lying areas', *Climate Change 2007: Impacts, Adaptation and Vulnerability*, Contribution of Working Group II to the Fourth Assessment Report of the IPCC, Cambridge University Press, Cambridge, 2007, pp. 315-356.

24 K Hennessy et al, 'Australia and New Zealand', *Climate Change 2007: Impacts, Adaptation and Vulnerability*, pp. 507-540.

> - Coasts will be exposed to increasing risks, including coastal erosion, over coming decades due to climate change and sea-level rise (very high confidence) ...
> - The impact of climate change on coasts is exacerbated by increasing human-induced pressures (very high confidence) ...
> - Adaptation costs for vulnerable coasts are much less than the costs of inaction (high confidence) ...
> - The unavoidability of sea-level rise, even in the longer-term, frequently conflicts with present-day human development patterns and trends (high confidence).[25]

2.31 As inquiry participants noted, climate change impacts on the Australian coastal zone include 'rising sea level, more intense storms, larger wave and storm surges, altered precipitation/runoff and ocean acidification'.[26]

2.32 Dr Hunter explained 'the rule of thumb' for the effects of sea level rise on erosion:

> if you get one metre of sea level rise—which is pretty well the upper limit of what we expect this century—that will give us a shoreline recession of between 50 and 100 metres. In other words, the shoreline on average will move back 50 to 100 metres. So if we take a middle of the range projection of half a metre for this century then we are talking about a recession of the shoreline, on average, of between 25 and 50 metres back.[27]

2.33 This approximates the so-called 'Bruun rule'— '[a]n oft cited rule of thumb is the "Bruun rule" which states that each 1cm of rise in sea level results in about 1m of coastal recession'. However, as ACE CRC further clarified:

> The actual amount of coastal recession because of sea level rise is variable ... depending on the wind and wave environment in a region, the longshore currents, the nearshore topography and the nature of the sediments on the coast. Hence, each cm of sea level rise will likely result in considerably more than 1m of coastal recession in some places and less that 1m in others.[28]

2.34 Figure 2.6 sets out the potential impacts of climate change on the coastal zone by state and territory, and associated costs. This summary provides

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25 Nicholls et al, 'Coastal systems and low-lying areas', *Climate Change 2007: Impacts, Adaptation and Vulnerability*, p. 317.

26 Australian Bureau of Meteorology, *Submission 15*, p. 1.

27 Dr Hunter, ACE CRC, *Transcript of Evidence*, 28 January 2009, p. 4.

28 ACE CRC, *Submission 46*, p. 2.

an indication of the potentially severe impacts of climate change on all coastal regions around Australia.

2.35 The discussion below focuses on two major areas of concern with regard to climate change and the coastal zone: rising sea levels, melting ice and increasing frequency of extreme sea level events; and ocean acidification, higher ocean temperatures and changing ocean currents. The Committee's attention was drawn to a number of significant publications by ACE CRC on recent developments in climate change science relating to these areas.[29]

Figure 2.6 Climate change and the coastal zone: potential impacts and costs, by state and territory

Department of Climate Change fact sheet

NSW

Coastal flooding, erosion and other hazards currently cost New South Wales around $200 million a year.

It is plausible that uncontrolled climate change could see global sea level rise of 1 metre or more by 2100 and more intense storms threatening coastal housing and infrastructure.

More than 200,000 buildings along the State's coast are vulnerable. For example a sea-level rise of just 20 centimetres together with a 1-in-50 year storm surge could push the coastline at Narrabeen back by 110 metres and cause local damage of around $230 million.

If sea-levels rose by 0.9 metres, 4700 residential building lots along the Lake Macquarie waterway foreshore would be inundated. A 1-in-100 year flood, compounded by such sea-level rise, would inundate an additional 3700 lots along Lake Macquarie waterways.

NT

... Nearly 900 coastal buildings, together with harbour and port facilities, are vulnerable to sea-level rise and associated changes.

QLD

... Queensland's highly developed and populated coastal communities, such as the Gold Coast and the Sunshine Coast, will be particularly affected by the predicted increase of sea level rise and floods.

With almost 250,000 vulnerable coastal buildings, Queensland is at the highest risk from all Australian states from projected sea level rise, coastal flooding and erosion.

29 See J Church et al, 'Briefing: a post-IPCC AR4 update on sea level rise', ACE CRC, 2008; 'Position analysis: climate change, sea-level rise and extreme events—impacts and adaptation issues', ACE CRC, 2008; Position analysis: polar ice sheets and climate change—global impacts', ACE CRC, 2009; Position analysis: changes to Antarctic sea ice—impacts', ACE CRC, 2009; and Position analysis: CO_2 emissions and climate change—ocean impacts and adaptation issues, ACE CRC, 2008. ACE CRC website accessed on 28 July 2009 <http://www.acecrc.org.au/drawpage.cgi?pid=publications&aid=797037>

A doubling of carbon dioxide concentrations could increase the flood level associated with a 1-in-100 year flood in Cairns by 0.4 metres.

SA

... More than 60,000 buildings along the State's coast are likely to be at risk from sea-level rise, coastal flooding and erosion.

A subsiding coastline across Lefevre Peninsula and Barker Inlet will exacerbate the impacts of rising sea levels.

TAS

Over 20 per cent of the Tasmanian coastline will be at risk from sea level rise and more severe storm surges associated with climate change.

Within the next 50-100 years, 21 per cent of Tasmania's coast is at risk of erosion and recession from sea-level rise affecting 17,000 coastal buildings.

VIC

... More than 80,000 coastal buildings and infrastructure are at risk from the projected sea level rise, coastal flooding and erosion.

Sea level rise, more frequent and severe storm surges will damage the coastal environment and coastal infrastructure in the Western Port region.

Eighteen per cent of the Western Port Region is likely to be affected by inundation or overland flow paths. It is estimated that 18,000 properties, valued at almost $2 billion, are vulnerable to flood events.

The area of land subject to inundation by storm surge is likely to increase by 4-15 per cent by 2030 and 16-63 per cent by 2070. It could affect more than 2000 individuals, more than 1000 dwellings and approximately $780 million in improved property value.

A 1-in-100 year storm surge is likely to happen every 1 to 4 years by 2070.

WA

... Coastal housing and infrastructure will be at risk as sea levels rise and storms become more intense.

In coastal areas, more than 94,000 coastal buildings are at risk from projected sea level rise, coastal flooding and erosion.

Between Fremantle and Mandurah, an estimated 28,000 buildings and 641 kilometres of road are at risk from erosion due to rising sea levels.

Source *'Climate change—potential impacts and costs: fact sheet', DCC website accessed on 27 July 2009 <http://www.climatechange.gov.au/impacts/costs.html>*

Rising sea levels, melting ice and increasing frequency of extreme sea level events

2.36 Global atmospheric temperature rise has resulted in sea level rise through warming of the oceans (thermal expansion) and melting of ice on land (non-polar glaciers and icecaps).[30] There are also increasing concerns about the potential instability of the Greenland and West Antarctic ice sheets leading to more rapid sea level rise. Climate change will further see an increase in storm frequency and intensity, which will exacerbate the impacts of sea level rise (eg through storm surge). Impacts of sea level rise as a result of both changes in mean sea level and increases in the frequency and intensity of extreme events include inundation of coastal areas, coastal erosion, saltwater intrusion into aquifers and loss of coastal biodiversity.

Past and present rates of sea level rise

2.37 To provide some context to modern day sea level rise, it is useful to look at the historical record. As Dr Church noted in his evidence, 'sea level has varied dramatically in the past—over 100 metres':

> At the last interglacial—the last time temperatures were similar to today's—sea level was four to six metres higher than today's sea level, at temperatures we would expect by the end of this century under a continued global warming. The rates of rise at this time were large: 1½ metres per century—with considerable error bars, but that is the estimate.[31]

2.38 Over the last 2,000 years, however, when many of our coastal cities became established, sea level has been relatively steady—'sea level rise was less than 0.2 mm/year on average'. However, the rate of sea level rise increased from the 19th to the 20th century, 'when it reached an average rate of about 1.7 mm/year'. Recent estimates suggest that 'the average rate of sea level rise from 1961 to 2003 was 1.8 mm/year and increased to 3.1 mm/year from 1993 to 2003'.[32]

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30 See Church et al, '[o]bservations since 1961 show that widespread decreases in glaciers and ice caps (excluding the Greenland and Antarctic Ice Sheets) have contributed significantly to sea-level rise. These areas are estimated to contain only enough water to raise global average sea level by less than about 40 cm,' 'Briefing: a post-IPCC AR4 update on sea level rise', p. 5.

31 Dr Church, CSIRO, *Transcript of Evidence*, 28 January 2009, p. 2.

32 Church et al, 'Briefing: a post-IPCC AR4 update on sea level rise', p. 5.

Projected rates of sea level rise: IPCC and beyond

2.39 The IPCC's Third Assessment Report in 2001 estimated that global rises in sea level of between 0.09m and 0.88m are possible by 2100.[33] However, the IPCC's Fourth Assessment Report (AR4) in 2007 estimated that global rises in sea level of between 0.18m and 0.59m are possible by 2100.[34] The Committee notes that these AR4 sea level rise projections have been the cause of some confusion:

> When you first looked at the IPCC fourth assessment report, it appeared that they had downgraded the projections because the upper limit was only about 0.59 ... In fact, the confusion that arose has to do with the large ice sheets ... All the big ice sheets, in Greenland and west Antarctica, were taken out of the model projections.[35]

2.40 The Committee understands that the Third Assessment Report estimated the potential contributions from the dynamics of polar ice sheets and included this in the projections to 2100, while AR4 excluded estimates of the contributions from polar ice sheet dynamics from its projections on the basis that these figures could not yet be modelled quantitatively with confidence. However, as both Professor Steffen and Dr Church explained, the sea level projections for the Third Assessment Report and AR4 are not significantly different when qualifying statements in the AR4 are considered[36] and estimates from the contributions from polar ice sheet dynamics are therefore included:

> in the fine print you can find an estimate of the contributions of these large ice sheets ... That brings the upper limit to about 0.8 metres.[37]

> You can look at either the third assessment report or the fourth assessment report, and, when you consider the icesheet

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33 '[W]e project a sea level rise of 0.09 to 0.88 m for 1990 to 2100, with a central value of 0.48 m', IPCC, *Climate Change 2001: The Scientific Basis*, p. 642.

34 IPCC, *Climate Change 2007: The Physical Science Basis*, p. 13.

35 Professor Steffen, *Transcript of Evidence*, 23 October 2008, p. 1.

36 The IPCC noted that higher sea level rises could not be ruled out: '[m]odels used to date do not include ... the full effects of changes in ice sheet flow, because a basis in published literature is lacking ... Larger values cannot be excluded, but understanding of these effects is too limited to assess their likelihood or provide a best estimate or an upper bound for sea level rise', IPCC, *Climate Change 2007: The Physical Science Basis*, p. 14.

37 Professor Steffen, *Transcript of Evidence*, 23 October 2008, p. 2.

> contributions from Greenland and Antarctica, the limits of these two projections are actually fairly similar.[38]

2.41 The Committee notes that IPCC projections therefore indicate that global average sea level might be up to about 0.8m higher at the end of the 21st century than at the end of the 20th century.

2.42 However, as discussed earlier, climate change science has moved on since IPCC AR4. In his evidence to the inquiry, Professor Steffen noted the progress in climate change science on sea level rise and that sea level rise was currently tracking at or near the upper limits of IPCC projections:

> The science surrounding the sea-level rise issue ... has progressed significantly since the publication of the IPCC AR4 last year. The most important features of recent scientific advances are:
>
> - The observed rate of sea-level rise (ca. 20 cm over the past century or so, but with an acceleration since the 1990s) is tracking at or near the upper limits of the envelope of IPCC projections ...
> - More recent studies of the rate of sea-level rise in the past (e.g., when the Earth shifted from a glacial state (ice age) to an interglacial state (such as now) suggest that rates of ca. 1 m/century are not unusual and that a rate of 4 m/century is possible.
> - The biggest uncertainty in the projected rates of sea-level rise is associated with the behaviour of the large polar ice sheets (Greenland, West and East Antarctica) ...
> - The other critical factor associated with sea-level rise is the coincidence of storm surges that accentuate the impacts of sea-level rise itself.[39]

2.43 It is useful to look more closely at the recent research on polar ice sheets and their potential contribution to sea level rise.

Uncertainty about contribution of polar ice sheets to sea level rise

2.44 As discussed, there is increasing concern about the potential instability of both the Greenland and the West Antarctic ice sheets leading to a more rapid rate of sea level rise than the current model projections. A change in the mass of freshwater locked up as ice in Antarctica and Greenland has

38 Dr Church, CSIRO, *Transcript of Evidence*, 28 January 2009, p. 2.

39 Professor Steffen, *Submission 45*, pp. 1-2. See also Dr Church, '[t]he current rate of rise, as observed both from satellite altimeters and in situ tide gauges, is tracking along the upper limit of those projections ... that upper limit leads to a sea level rise in the order of 80 to 90 centimetres, by 2100, relative to 1990', *Transcript of Evidence*, 28 January 2009, p. 2.

the greatest potential to affect global sea level. As Professor Steffen explained, we need to differentiate here between surface melting—'which is an ongoing but very slow process' that 'would not lead to a large increase in the rate of sea-level rise on its own'[40]—and dynamic changes in the ice sheets and shelf ice.

2.45 Dynamic changes in the icesheet mean that:

> the outlet glaciers, the glaciers that drain the big interior of the icesheet, seem to be accelerating and seem to be calving off blocks of ice which then slide from the bedrock into the sea. Once you take grounded ice and move it into the sea you get a sea-level rise from that effect, and that has only been estimated very crudely in the IPCC estimates. We believe that we are beginning to understand some of the processes that lie behind the acceleration. Some of them in fact are linked to the surface melting, in that you get surface streams of water as the ice melts on the surface and some of those run down through crevasses that run all the way to the base of the glacier and lubricate it as it is attached to the bedrock. That makes it easier for the ice, particularly when it is near the sea coast and probably on a downward slope, to break off, slide and go into the sea.[41]

2.46 In terms of the impact on sea level rise of this phenomenon, as Professor Steffen noted, 'you get a very different range. You get a lower range of about half a metre, which was our median range a year or so ago, you get an upper range of about 1.4 metres and you get a median of around 0.9 metres, somewhere close to a metre'.[42]

2.47 Shelf ice, which is in the seawater already and so does not itself contribute to sea level rise, is what 'buffers a lot of Antarctica':

> We are seeing now that some of these ice shelves are breaking up and disintegrating, particularly around the Antarctic Peninsula, which is warming more than the bulk of the continent. That gives you a sort of 'cork in the bottle' effect. As this shelf ice breaks up and it moves away from the coast, the outlet glaciers then accelerate—it is like pulling the cork out of a bottle—and so you get faster drainage ... the concern is that if we see this phenomenon more generally around the big icesheets on Antarctica west and

40 Professor Steffen, *Transcript of Evidence*, 23 October 2009, p. 2.

41 Professor Steffen, *Transcript of Evidence*, 23 October 2009, p. 2.

42 Professor Steffen, *Transcript of Evidence*, 23 October 2009, p. 2.

> east, particularly west, you could see accelerated sea-level rise there'. [43]

2.48 In terms of the impact on sea level of this phenomenon, as Professor Steffen noted, 'if all of the Greenland icesheet were to be lost that is equivalent to approximately seven metres of sea-level rise. West Antarctica is equivalent to about six metres of sea-level rise. So that is a total of about 13 metres that is locked up in those two icesheets'.[44]

2.49 The Committee notes that there are uncertainties about sea level rise projections associated with these ice sheet processes, but these uncertainties do not mean that these projections can be disregarded. As Dr Church noted, '[i]t is important to recognise that these uncertainties associated with the icesheets are essentially one-sided—that is, they could lead to a substantially greater amount of sea level rise, or at a higher rate than in the current projections, but not at a significantly lower rate'.[45]

2.50 It is also important to emphasise at this point that current scientific estimates 'do not support contentions of many metres of sea-level rise during this century, although such values might apply over several centuries'.[46]

What sea level rise figures should Australia be working from?

2.51 Against this background, the Committee was therefore concerned to establish what sea level rise figures Australian scientists were working from, and what figures Australia should be depending on, particularly given the uncertainties in the projected rates of sea level rise associated with the behaviour of the large polar ice sheets and that allowances for this are not currently included in the IPCC projections. As Professor Steffen commented, '[t]he real question we have in the scientific community is the rate at which we could, through these dynamical processes, lose the icesheets. There is a lot of debate on that; there is really no consensus'.[47]

2.52 Dr Church argued that we should 'stick to the IPCC projections' that global average sea level might be up to about 0.8m higher at the end of the 21st century than at the end of the 20th century:

43 Professor Steffen, *Transcript of Evidence*, 23 October 2009, p. 2.

44 Professor Steffen, *Transcript of Evidence*, 23 October 2009, p. 2.

45 Dr Church, CSIRO, *Transcript of Evidence*, 28 January 2009, p. 2.

46 J Church et al, 'Briefing: a post-IPCC AR4 update on sea level rise', ACE CRC, 2008, p. 4.

47 Professor Steffen, *Transcript of Evidence*, 23 October 2009, p. 2.

> they are the most robust estimates that we have—but we should note that there are other statistical predictions which include estimates above the IPCC estimates. There are a number of uncertainties. These relate particularly to the sliding of the icesheets, the dynamic response of them, which we inadequately understand ...
>
> we should stick to that IPCC limit because there is a sound basis for making those projections. There have been larger projections than that made in reputable journals by reputable scientists ... we could well exceed the IPCC projections, but there is a sound basis on which those projections have been made.[48]

2.53 Similarly Professor Steffen stated:

> looking at some of the most recent papers that have come out in the last month or two, there seems to be a consensus emerging around a most likely rate this century of somewhere between half a metre and a metre. This particular estimate, which I think is pretty good, is 0.8 of a metre. My best guess, if you asked me, would be somewhere around 0.8 or 0.9 of a metre by 2100.
>
> So, basically, my advice to coastal communities and so on is to say that I think we will be lucky to get away with 0.5 of a metre, as we thought a year or two ago. I think it is unlikely that it will go over a metre ...
>
> I think you are seeing a reasonable consensus with our best knowledge at the moment of somewhere around 0.8 to 0.9 metres by 2100.[49]

2.54 In his evidence, Professor Steffen also referred to a report he was then drafting which sought to update climate change science since the IPCC AR4. This report was recently published. Professor Steffen concluded that:

> the maximum possible increase in sea-level rise by 2100 is around 2 m, but only under the most extreme levels of forcing ... A more plausible estimate of total sea-level rise by 2100 is around 0.8 m. This value lies at the upper end of the IPCC projections ...
>
> *In summary, there is a considerable body of evidence now that points toward a sea-level rise of 0.5 to 1.0 m by 2100 compared to 1990 values.* The main lines of argument include: (i) recent observations have confirmed the conclusion that sea level has been rising near the

48 Dr Church, CSIRO, *Transcript of Evidence*, 28 January 2009, p. 3, 5.

49 Professor Steffen, *Transcript of Evidence*, 23 October 2009, pp. 2-3, p. 4.

> upper bound of the IPCC projections since 1990 ... (iii) recent observations show increasing net mass loss from the Greenland ice sheet ... and the West Antarctic Ice Sheet ... (iv) physically based estimates of sea-level rise due to dynamical loss of ice from the polar ice sheets suggest that a 0.8 m rise is plausible ... Sea-level rise larger than the 0.5-1.0 m range—perhaps towards 1.5 m ... — cannot be ruled out. There is still considerable uncertainty surrounding estimates of future sea-level rise.[50]

2.55 Dr Church also commented that:

> These estimates will be updated. They are projections which are dependent, at least to some extent, on decisions that our society makes and scientific uncertainties. One of the great things about the IPCC is they try to define what those uncertainties are and what the limits are. Those numbers will evolve with time. We would expect them to stay within the IPCC range but they may well not—particularly if we learn more about the icesheets. All the information that we have learnt about the icesheets over the last five years—both glaciologists, who are the specialists in the field, and people like me, who are specialists in sea level and have a working familiarity with the glaciology—is that there is greater reason for concern today than when we wrote, for example, the third assessment report, which was published in 2001.[51]

2.56 The Committee notes the continuing uncertainty surrounding estimates of future sea level rise as a result of uncertainty about the contribution of polar ice sheets but acknowledges that the scientific consensus on sea level rise, based on current knowledge and underpinned by the IPCC projections, could be in the range of 0.5m and 1m by 2100, compared to 1990 values.

2.57 However, the Committee emphasises that other factors also need to be taken into account here—in particular, extreme sea level events and regional variances to sea level rise. As Dr Church observed:

> Like all other aspects of managing our economy and our environment, to combine these different issues, particularly the extreme events such as the storm surges and the cyclones, with the sea level rise is a risk management issue and needs to be put in a risk management framework ...

50 W Steffen, *Climate Change 2009: Faster Change and More Serious Risks*, Department of Climate Change, Commonwealth of Australia, 2009, p. 11 (emphasis added).

51 Dr Church, CSIRO, *Transcript of Evidence*, 28 January 2009, p. 13.

> sea level rise will not stop in 2100. This is a time-evolving issue, and that requires us to change our thinking rather than specify a single number ... It is the different lifetimes of different infrastructure and the different risks associated with different infrastructure that I think we need to be a little more sophisticated about.[52]

2.58 The Committee notes that the rate of projected rise in sea level is critical for estimating the severity of potential impacts, and that several state governments have recently established sea level rise planning benchmarks to serve as guidance in this area. This matter is further discussed in Chapter 4, in the section on planning issues relating to climate change and the coastal zone.

2.59 Noting Dr Church's point, the Committee also emphasises that, while current estimates of sea level rise are generally projected out to 2100, sea level will continue to rise thereafter. It is therefore important to maintain a longer-term outlook in terms of policy development in this area.

Extreme sea level events

2.60 Climate change is projected to have an impact on the frequency and intensity of extreme weather events such as storms, bushfires, drought and heatwaves. The focus on this inquiry is on the impacts of coastal storms and tropical cyclones, with flooding and storm surges creating extreme sea level events resulting in coastal inundation and erosion. Sea level rise will exacerbate the existing problems of erosion or inundation of coastal land caused by high tides, storm surges and cyclones. As ACE CRC noted in their submission to the inquiry:

> Sea level rise will affect our coasts progressively over coming decades more than is generally inferred from the rise in mean sea level because of significant and accelerating changes in the frequency of extremes of sea level ...
>
> Mean sea level ... is not usually the source of greatest concern for effects of the sea on coastal environments, communities and infrastructure. It is the 'extreme sea levels' that cause greatest concern, especially the high extremes associated with large tides, storm surges, severe waves and low pressure systems.[53]

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52 Dr Church, CSIRO, *Transcript of Evidence*, 28 January 2009, p. 7, p. 13.

53 ACE CRC, *Submission 46*, p. 1, p. 2.

2.61 The gradual rise of sea level will continue to be 'almost imperceptible' and it will therefore be the occurrence of occasional extreme events that will cause the 'greatest concern'.[54] Elevated sea levels will lead to an increase in the potential impact of extreme sea level events caused by storm surges and heavy rainfall. In addition, the intensity of wind and waves[55] in some regions may increase with climate change, further increasing the frequency and intensity of extreme sea level events. Extreme sea level events result in increased flooding (inundation) and increased erosion of 'soft' (sandy and muddy) coastlines.

Warning signs on coastal dune at Busselton, WA, as inspected by Committee members

2.62 Dr Hunter, from the ACE CRC, therefore made the important point that, while sea level is going to rise by what some might think is a modest amount, that small amount is going to cause a disproportionately large increase in the frequency of flooding events from the sea associated with high tides and storm surges:

54 Professor Woodroffe, *Submission 24*, p. 5.

55 Changing ocean waves have the potential to add to extreme sea level events through large wave events or changes in wave direction—see MA Hemer et al, *Variability and Trends in the Australian Wave Climate and Consequent Coastal Vulnerability*, Final Report for Department of Climate Change Surface Ocean Wave Variability Project, CSIRO, 2008.

> The rule of thumb is that on average in Australia—and we get these numbers from looking at the present tidal observations and also at the projections of climate change—if you get a sea level rise of only 20 centimetres, which was pretty well what we got last century, that will increase the frequency of extreme events by a factor of about 10 ... The events will happen 10 times more often, and this compounds ... If you get a 50-centimetre increase, or half a metre, which is about the middle of the projections for this coming century, then you get a factor of about 300 on average for Australia.[56]

2.63 What this means is that, 'if you have a flooding event which only happens every year at the moment, by the end of the century it will be happening ... every day'.[57] As Professor Steffen also observed:

> You may think that a sea-level rise of 20 centimetres or half a metre is not a whole lot, but when you couple it with a wall of water created by a storm coming in at you, it leads to a much bigger area of inundation. That is particularly true where you have urban areas with fairly large low-lying tracts. The classic one for us is Cairns in North Queensland. If you look at the mapping done with a storm surge of, say, half a metre of sea-level rise, you get a very large increase in the area that is actually flooded from the same event that you had earlier.[58]

2.64 Similarly, the Australian Bureau of Meteorology noted that an 'analysis of the increase in frequency of extreme events for a rise of ten centimetres in sea levels at 28 locations around Australia shows that Darwin, Brisbane, Sydney and Melbourne will experience four to six times as many as currently observed'.[59]

2.65 Cyclones clearly pose a major threat in this regard, particularly given the possible increase in the intensity and changing geographical distribution of cyclones due to climate change. Inquiry participants noted that there was a need for more research on tropical cyclones:

> The other thing we need to understand better is tropical cyclones. Certainly for Northern Australia we know that they create a

56 Dr Hunter, ACE CRC, *Transcript of Evidence*, 28 January 2009, pp. 3-4.

57 Dr Hunter, ACE CRC, *Transcript of Evidence*, 28 January 2009, p. 4.

58 Professor Steffen, *Transcript of Evidence*, 23 October 2008, p. 7.

59 Australian Bureau of Meteorology, *Submission 15*, p. 3.

problem with storm surges, and that is going to change in the future.[60]

Regional variances in sea level rise

2.66 The Committee was concerned about the difficulties of moving from global sea level rise projections to regional and local projections. The amount by which sea level rises may vary regionally because of atmospheric and oceanographic conditions, and interactions with ocean and land topography. As Professor Woodroffe stated:

> it is clear that there will be regional variations which are not captured with any great precision in global climate models. The patterns and the consequences of sea-level variations will differ around the Australian coast because of a range of complex factors, such as oceanographic processes, complex tidal variations and the subtle topographic configurations of different coastal landscapes.[61]

2.67 As discussed in Chapter 3, the National Coastal Vulnerability Assessment, or 'first pass' assessment, being coordinated by the Department of Climate Change will provide more information on this area, as will more detailed second and third pass assessments, which bring together the regional information critical for local adaptation strategies.

2.68 Dr Sloss, from the Australasian Quaternary Association (AQA), also emphasised the importance of geological history in understanding future impacts of sea level rise on a regional basis:

> At this time we are in a period where we are potentially going to be having a more rapid sea level rise than we have experienced in the geological past, but we can use that geological past as a framework to help us to accurately model the way these environments will impact in the future ...
>
> By looking at the sedimentary records and how those environments have been affected by different rates of change ... we can say, 'This particular environment has responded in this way to a rapid sea level rise and over here it has been subsiding.' We can then look at the difference in variability on a regional scale right across Australia and, in fact, compare it to international records as well.[62]

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60 Dr Hunter, ACE CRC, *Transcript of Evidence*, 28 January 2009, p. 7.

61 Professor Woodroffe, *Submission 24*, p. 5.

62 Dr Sloss, AQA, *Transcript of Evidence*, 28 April 2009, p. 23, p. 24.

2.69 The AQA observed that a deficiency in our current knowledge base is the integration of past geological history into projections and modelling:

> there is nothing putting it together, and I think they would aid, in terms of a model, putting together what the coastal environment was like 6,000 or 7,000 years ago, when we had a sea level similar to what is expected for the 21st century.[63]

Ocean acidification, higher ocean temperatures and changing ocean currents

2.70 The increased concentration of CO_2 from anthropogenic emissions has increased ocean acidity. These emissions first enter the atmosphere but a proportion of them are then absorbed into the ocean as part of the natural carbon cycle. The term 'ocean acidification' refers to the fact that the CO_2 forms a weak acid (carbonic acid) in water, making the ocean more acidic. This causes a change in ocean carbonate chemistry,[64] with consequences for marine organisms that form shells, such as corals, oysters, sea urchins, mussels, crustaceans and some forms of plankton.

2.71 Higher ocean temperatures are caused by the oceans absorbing more heat: '[o]bservations since 1961 show that the oceans have warmed as the result of absorbing more than 80% of the heat added to the climate system largely because of the enhanced greenhouse effect'.[65] Ocean currents may be influenced by climate change and cause local changes in climate systems, including rainfall patterns.

2.72 Ocean warming, ocean acidification and changing ocean currents increase the stresses on marine species, changing their distribution and putting many marine ecosystems at risk. The Reef and Rainforest Research Centre commented that:

> Ocean acidification is probably the major climate change related risk that we do not currently know enough about to manage effectively. It is recommended that urgent investment be made

63 Dr Sloss, AQA, *Transcript of Evidence*, 28 April 2009, p. 25.

64 See Steffen, '[b]ecause the concentration of carbonate ions is related to the acidity of seawater, marine organisms that use dissolved carbonate ions to build solid calcium carbonate shells ... are sensitive to the pH of the ocean. Higher acidity (lower pH) reduces the saturation state of aragonite (a form of calcium carbonate) and makes it more difficult for these organisms to form shells ... The effects of the increased acidity in the ocean can already be observed in some biological systems', *Climate Change 2009: Faster Change and More Serious Risks*, p. 22.

65 Church et al, 'Briefing: a post-IPCC AR4 update on sea level rise', p. 5.

into research that can generate viable options for managing this risk.[66]

National climate change science policy and programs relevant to the coastal zone

2.73 The Department of Climate Change is charged with leading the development and coordination of Australia's climate change policies. Other federal agencies with a key role in climate change science include CSIRO[67] and the Australian Bureau of Meteorology.[68] Australia's universities further contribute to climate change research.[69] In terms of climate change science relating specifically to the coastal zone, ACE CRC also plays a key role.[70] Major national research infrastructure is provided through initiatives managed by the Department of Innovation, Industry, Science and Research.

Department of Climate Change

2.74 The Australian Climate Change Science Program is administered by the Department of Climate Change and conducted in partnership with leading science agencies, notably CSIRO and the Bureau of Meteorology. The program addresses six key themes:

66 Reef and Rainforest Research Centre, *Submission 30*, p. 13. See also Professor Woodroffe, '[r]esearch on this topic is in its infancy, and more needs to be undertaken', *Submission 24*, p. 5.

67 CSIRO Marine and Atmospheric Research (CMAR) aims to advance Australian climate, marine, and earth systems science. CMAR's research is delivered largely through research themes in CSIRO's Wealth from Oceans Flagship and, with the Bureau of Meteorology, through the Centre for Australian Weather and Climate Research. CSIRO is also involved in sea level research through the ACE CRC.

68 The Bureau of Meteorology seeks to observe and understand Australian weather and climate and provide meteorological, hydrological and oceanographic services in support of Australia's national needs and international obligations. The House of Representatives Standing Committee on Industry, Science and Innovation is currently inquiring into long-term meteorological forecasting in Australia, including potential applications for emergency response to natural disasters—Parliament of Australia website accessed 4 August 2009 <http://www.aph.gov.au/house/committee/isi/weather/tor.htm>

69 For example, a consortium of four major universities undertaking significant climate research have recently integrated their research and education programs under the Universities Climate Consortium. The consortium works in collaboration with CSIRO, the Bureau of Meteorology and other universities—ANU website accessed on 22 July 2009 <http://www.anu.edu.au/climatechange/current-events/aucc>

70 ACE CRC is funded under the Australian Government's Cooperative Research Centres Program. One of the centre's science programs is dedicated to research on sea level rise and its implications for the Australian coastal zone.

- understanding the key drivers of climate change in Australia
- improved climate modelling system
- climate change, climate variability and extreme events
- regional climate change projections
- international research collaboration
- communications[71]

2.75 The National Climate Change Science Framework (May 2009) sets directions for climate change science over the next decade, following a review of the Australian Climate Change Science Program. The framework identifies five challenges in climate change science, including climate change influences on coasts and oceans.[72] The Committee is pleased to note the inclusion of the coastal zone as a priority area for attention.

Conclusion

2.76 As the Australian Climate Change Science Framework states:

> Australian science provides the foundation for climate change policy development and international leadership in several areas of climate change science, particularly in the southern hemisphere. An Australian capability is important because science generated in the northern hemisphere, where most research is done, will not provide all the information needed for Australian decision making.[73]

2.77 Climate change science is entering a new phase of complexity as decision makers and the general community demand greater insight into projected impacts and action required for adaptation. Climate change science on the Australian coastal zone, in particular, must deliver information to inform important decisions over the next decade. This will require:

- continued investment in research across a number of key areas
- national coordination of research

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71 DCC website accessed on 22 July 2009 <http://www.climatechange.gov.au/science/accsp/index.html>

72 DCC, *Australian Climate Change Science: A National Framework*, May 2009, p. 1 <http://www.climatechange.gov.au/science/publications/pubs/cc-science-framework.pdf>

73 DCC, *Australian Climate Change Science: A National Framework*, p. 1 <http://www.climatechange.gov.au/science/publications/pubs/cc-science-framework.pdf>

- improved communication of research outcomes

Continued investment in research

2.78 The Committee concludes that there needs to be continuing investment in research on:

- sea level rise projections and the dynamics of polar ice sheets, particularly in the Antarctic
- extreme sea level events
- regional variations in sea level rise
- ocean acidification, higher ocean temperatures and changing ocean currents

2.79 Climate science needs to continue to provide information on the factors that influence the magnitude and rate of sea level rise, including the dynamics of the large polar ice sheets under prolonged global warming. Australian science has a critical role to play in the study of the Antarctic ice sheets, given our location and that northern hemisphere countries are increasingly focused on the future of Arctic ice cover and the Greenland ice sheet. The Committee agrees that improving our monitoring, understanding and modelling of ice sheet responses to global warming is urgent.

2.80 Research agencies will also need to continue to provide quality information about likely changes in sea level as a result of extreme events, to ensure effective management of the coastal zone that acknowledges the risks and minimises the consequences of climate change. The Committee notes that of particular concern here is research progress on the effects of climate change on the intensity of tropical cyclones and how they will track along our coasts.

2.81 Further research into sea surface temperature changes and changes in ocean currents is also necessary, as is continued research on ocean acidification, particularly in terms of monitoring its impacts on coral reefs in our tropics.

2.82 The Committee also notes Dr Church's point that:

> The climate issue—sea level rise ... et cetera—is a global issue. No one nation can address the research side of this problem on its own. The World Climate Research Programme provides 90 per

> cent of the physical information that is required. So support for participation in international programs is absolutely critical.[74]

2.83 The Committee acknowledges the outstanding research being undertaken by CSIRO and the ACE CRC in these areas, particularly on sea level rise projections and extreme sea level events.

Recommendation 3

2.84 **The Committee recommends that the Australian Government increase its investment in coastal based climate change research on:**

- **sea level rise projections and the dynamics of polar ice sheets, particularly in the Antarctic**
- **extreme sea level events, including as a result of storm surge and tropical cyclones**
- **regional variations in sea level rise**
- **ocean acidification, particularly impacts on Australia's coral reefs, higher ocean temperatures and changing ocean currents**

National coordination of research

2.85 At a broader policy level, the Committee notes that the National Climate Change Science Framework emphasises the need for 'national direction and coordination of climate change research efforts'.[75]

2.86 Several inquiry participants called for improved coordination of climate change science on the coastal zone and a consistent mechanism for data sharing among researchers, government agencies and communities across Australia:

> the Federal Government [should] work with the relevant research and academic providers as well as State and Local Government practitioners on a process and framework that allows for the consistent integration and application of climate change science

74 Dr Church, CSIRO, *Transcript of Evidence*, 28 January 2009, p. 15.

75 DCC, *Australian Climate Change Science: A National Framework*, p. 17 <http://www.climatechange.gov.au/science/publications/pubs/cc-science-framework.pdf> See also *Powering Ideas: An Innovation Agenda for the 21st Century*, Commonwealth of Australia, 2009; and Review of National Innovation report, *Venturous Australia: Building Strength in Innovation*, Cutler and Company Pty Ltd, 2008.

and research in policy and strategies for all spheres of Government.[76]

2.87 Similarly, ACE CRC observed that there is an 'urgent need to nationally coordinate ... research on the impacts of sea level rise to improve our capacity to devise and apply appropriate, robust and cost-efficient adaptation strategies'.[77] Dr Hunter, from the ACE CRC, also noted the need to 'coordinate better the existing sea level monitoring around Australia'.[78]

2.88 The National Climate Change Science Framework, which identifies coasts and oceans as key challenge in climate change science, proposes that a National Climate Change Science strategy be established to provide national direction and coordination of climate change research efforts. The strategy would have the following features:

- A high level coordination group comprising major funding bodies, key research organisations and senior scientists and chaired by the Chief Scientist. The coordination group will develop and oversee execution of an implementation plan for this Framework.
- The implementation plan will draw on the resources of all relevant organisations. Where necessary, the high level coordination group will facilitate formation of cross-institutional teams to advance key elements of climate change science.
- The Chief Scientist will report annually to the Minister for Climate Change and Water and the Minister for Innovation Industry Science and Research on progress in implementing this Framework.
- The Department of Climate Change will establish a mechanism to liaise with States and Territories and other stakeholders on climate change science, with a particular emphasis on ensuring the national program delivers useful information about likely future climate change.[79]

2.89 While it is early days for implementation of the framework, the Committee supports such a model for coordinating Australian climate change science and believes an agreed framework and strategy should be

76 Sydney Coastal Councils Group, *Submission 77*, p. 9.

77 ACE CRC, *Submission 46*, p. 5.

78 Dr Hunter, ACE CRC, *Transcript of Evidence*, 28 January 2009, p. 14. See also Dr Church, 'we ... require more coordinated studies, particularly on the issues of inundation and erosion', ACE CRC, *Transcript of Evidence*, 28 January 2009, p. 34.

79 DCC, *Australian Climate Change Science: A National Framework*, p. 17 <http://www.climatechange.gov.au/science/publications/pubs/cc-science-framework.pdf>

implemented as soon as possible. The Committee emphasises that the coastal zone component of this framework and strategy should be clearly identified. The proposed high level coordination group, which will develop and oversee execution of the implementation plan for the framework, should also include representation from key coastal stakeholders.

Recommendation 4

2.90 **The Committee recommends that the coastal zone component of the National Climate Change Science Framework and proposed National Climate Change Science strategy be clearly identified by the proposed high level coordination group and involve key coastal stakeholders.**

Improved communication of research outcomes

2.91 Several inquiry participants emphasised the need for improved communication of climate change research on the coastal zone and improved access to data:

> the Federal Government [should] take responsibility for the development of a central information source that allows for timely access to regionally and locally relevant climate change projections and scientific research.[80]

> what is critically needed is a national approach to coastal marine climate change research, monitoring and data management. This includes national data [and] monitoring and reporting systems ... The Commonwealth Government should facilitate a strategic approach to identify and address the national and regional gaps in research knowledge and develop monitoring and data management systems so as to improve and sustain coastal zone management in the face of climate change. Currently, there are limited mechanisms to assist or encourage information sharing.[81]

> A nationally consistent approach to the collection, storage and accessible retrieval of data will serve to provide Local Government with consistent base line data to undertake risk assessment and project the impact of storm surge, coastal inundation and sea level rise on coastal communities. Once obtained, this data can be scaled

80 Sydney Coastal Councils Group, *Submission 77*, p. 9.

81 NT Government, *Submission 106*, p. 4.

> down to address climate change issues at the regional and local level.[82]

2.92 ACE CRC further commented that:

> Research on the specific and local effects of sea level rise and changes in ocean properties is in its infancy and being done in a relatively fragmented way around Australia. Understanding of the consequences of these effects by policy makers, decision makers, regulators, investors and the broader community lags significantly behind the knowledge in the research community, meaning that proposed adaptation responses are often poorly informed, inadequate or even dangerous.[83]

2.93 The Committee believes that a national coastal zone database, which includes information on developments in climate change science—as well as information on climate change impacts and adaptation strategies—will improve information access, consistency and information sharing, and build public awareness of developments in this area. It will enable coastal stakeholders to share nationally consistent data on climate change risks and impacts.

2.94 The Committee notes that work on the 'first pass' National Coastal Vulnerability Assessment was still underway at the time of this report being printed and that work on adaptation strategies relating to the coastal zone by the National Climate Change Adaptation Facility was also still in train. However, as is further discussed below, there is an urgent need to better communicate the outcomes of these and other research initiatives and coordinate this information on a central database.

2.95 Currently, information on the outcomes of coastal climate change research initiatives is scattered across several websites. For example, details of ACE CRC research outcomes on extreme sea level events are currently available on the ACE CRC website and its 'sea level rise' website. CSIRO also maintains a 'sea level rise' website. Similarly, research outcomes of several coastal climate change projects commissioned by the federal Department of Climate Change are variously available on the department's website or the OzCoasts website, which is maintained by Geoscience Australia. It would be helpful for all of this information to instead be available from one national coastal zone database. Whenever possible, scientific data should be presented in a nationally consistent manner.

2.96 The Committee makes a recommendation about this in Chapters 3 and 6.

82 Local Government Association of Tasmania, *Submission 86*, p. 9.

83 ACE CRC, *Submission 46*, p. 5.