Scientific basis of the 2009 sea level rise benchmark

Draft Technical Note

Department of **Environment & Climate Change** NSW

Submissions invited

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Closing date for submissions

Submissions must be received by the Department of Environment and Climate Change by **5 pm, Friday 3 April 2009**.

Published by:

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ISBN 978 1 74232 149 3
DECC 2009/126
February 2009

Introduction

The NSW Government has prepared this Technical Note to support the *Draft Sea Level Rise Policy Statement*. The Policy Statement includes sea level rise planning benchmarks that can be used for sea level rise adaptation and also for consideration when land-use planning and development decisions are made for coastal areas.

The Policy Statement's sea level rise planning benchmarks are an increase above 1990 mean sea levels of 40 cm by 2050 and 90 cm by 2100. This Technical Note outlines the derivation of these benchmarks.

The components of these sea level rise planning benchmarks are noted in Table 1, with details of the derivation of these components provided in the following sections. These benchmarks were based on the sea level rise projections developed by Australian and international experts and considered most appropriate for NSW, while acknowledging the uncertainty associated with these projections.

Table 1: Components of the sea level rise planning benchmarks

Component	Year 2050	Year 2100
Sea level rise	30 cm	59 cm
Accelerated ice melt	(included in above value)	20 cm
Regional sea level rise variation	10 cm	14 cm
Rounding*	-	-3 cm
Total	40 cm	90 cm

* Rounding was adopted as the projections have a degree of uncertainty, and adopting values to the nearest centimetre would imply a high degree of accuracy in the projections.

Observations of sea level rise

An analysis of tide gauge records from around the world has found that during the 20th century (1870–2001), global sea level rose by 17 cm at a rate of 1.7±0.3 mm per year, with the rate of sea level rise accelerating during the 20th century[1]. This information is summarised in Figure 1[2], which includes global average tide gauge data between 1870 and 2001 and global average satellite altimeter data from 1993 to 2006.

[1] Church, J.A. & White, N.J. 2006, A 20th Century acceleration in global sea-level rise, *Geophysical Research Letters,* Volume 33, L01602.

[2] UNEP/GRID-Arendal, 'Trends in sea level, 1870–2006', UNEP/GRID-Arendal Maps and Graphics Library, June 2007.

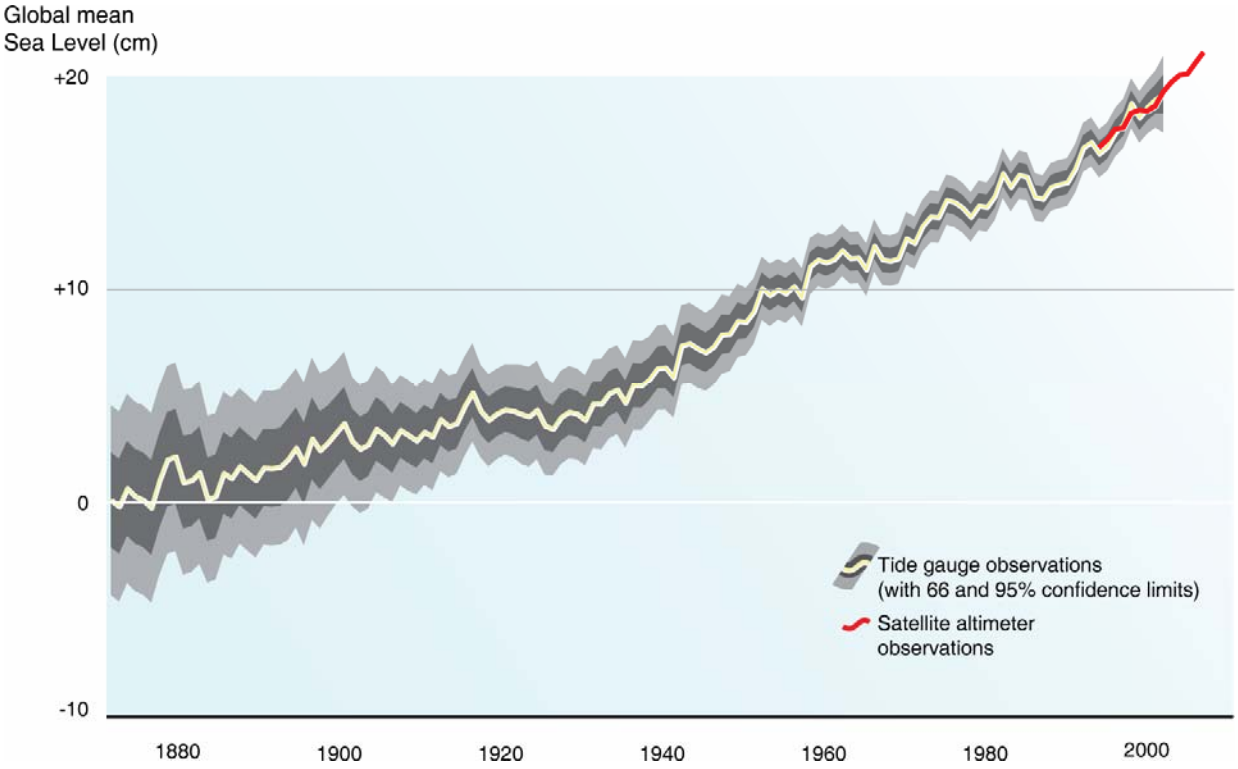

Figure 1: Annual averages of the global mean sea level (cm).

Recent data (1993–2007) shows the current global average annual sea level rise to be 3.4 mm per year[3].

Sea level rise associated with global warming

Increasing global temperature has a direct impact on sea level. As atmospheric temperature increases so too does water temperature through heat transfer. As water warms, it expands; therefore any increase in global temperature will result in sea level rise. In addition, increases can be expected from the melting of glaciers and ice caps (but not sea ice), although these may be slightly offset by changes to land-based water storage and snowfall over Antarctica. Ice sheets can also break up and slide into the ocean. This process is referred to as 'dynamic melting of ice sheets'. The process involves surface meltwater flowing down crevasses in the ice sheet. This meltwater pools between the ice and the underlying rock forming a slip surface along which the ice can move en masse.

Global sea level rise and dynamic melting of ice sheets

The sea level rise and dynamic melting of ice sheet data for 2100 was obtained from a 2007 report prepared by the Intergovernmental Panel on Climate Change (IPCC)[4]. The predictions

[3] Beckley, B.D., Lemoinse, F.G., Lutchke, S.B. Ray, R.D. & Zelensky, N.P., 2007. A reassessment of global and regional mean sea level trends from TOPEX and Jason-1 altimetry based on revised reference frame and orbits, *Geophysical Research Letters*, Volume 34, L14608.

[4] IPCC, 2007, *Climate Change 2007: The Physical Science Basis*, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Geneva

for 2050 were obtained from an earlier 2001 IPCC report[5], as the more recent report did not specifically include projections for 2050. The sea level rise projections between the two IPCC reports are considered to be similar, particularly for the upper-bound projections[6].

The 2001 IPCC report's projected increases are relative to 1990 global mean sea levels, whereas the 2007 IPCC report's increases are relative to average sea levels between 1980 and 1999, approximately equal to 1990 values. The IPCC 2007 report provides projections for the decade 2090–2099 – it has been assumed that these projections are applicable to 2100.

The IPCC reports base their projections of sea level rise on various future greenhouse gas emissions scenarios.

The reports provide a range of sea level rise projections for each emissions scenario, with the upper limit of the projections (which uses the A1FI emissions scenario) being adopted for the purpose of the NSW Government Sea Level Rise Policy Statement. That emissions scenario is considered to be the most appropriate because the rate of global greenhouse gas emissions have already exceeded those projected from that scenario[7,8].The range of sea level rise projections from the IPCC reports is presented in Figure 2[9] together with projections incorporating ice sheet dynamic melt processes.

The 2007 IPCC projections do not include the effects of ice sheet dynamic melt processes. The 2007 IPCC report advises that if ice sheet flow were to grow linearly with global average temperature, then the upper bound of the sea level rise projections could be raised by a further 10–20 cm. The 2007 IPCC report also acknowledged that 'larger values can not be excluded'.

The inset in Figure 2 shows that the observed global average sea level from tide gauges and satellites is tracking along the upper bound of the IPCC projections, since projections started in 1990. This has raised concerns among the scientific community that the sea level projections made by the IPCC may have been underestimated[10,11].

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[5] IPCC, 2001, *Climate Change 2001: The Scientific Basis*, Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Geneva

[6] Church, J.A., White, N.J., Hunter, J.R. & Lambeck, K., 2008, *Briefing: a post IPCC AR4 update on sea-level rise*, Antarctic Climate and Ecosystems Cooperative Research Centre, Hobart.

[7] Raupach, M.R., Marland, G., Ciais, P., Le Quéré, C., Canadel, J.G., Klepper, G., & Field, C.B., 2007. Global and regional drivers of accelerating CO2 emissions. *Proceedings National Academy of Sciences*, 104: 10288–10293.

[8] Sheehan, P., Jones, R., Jolley, A., Preston, B., Clark, M., Durack, P., Islam, S., Sun, F., & Whetton, P., 2007, *Climate Change and the New World Economy: Implications for the Nature and Timing of Policy Responses*. CSES Working Paper No. 12, Centre for Strategic Economic Studies, Melbourne.

[9] UNEP/GRID-Arendal, 'Projected sea-level rise for the 21st century', UNEP/GRID-Arendal Maps and Graphics Library, June 2007, <http://maps.grida.no/go/graphic/projected-sea-level-rise-for-the-21st-century>

[10] Rahmstorf, S., Cazenave, A., Church, J.A., Hansen, J.E., Keeling, R.F., Parker, D.E. & Somerville, R.C.J., 2007, Recent climate observations compared to projections. *Science,* 316:709.

[11] Church, J.A., White, N.J., Hunter, J.R. & Lambeck, K., 2008, *Briefing: a post IPCC AR4 update on sea-level rise*, Antarctic Climate and Ecosystems Cooperative Research Centre, Hobart.

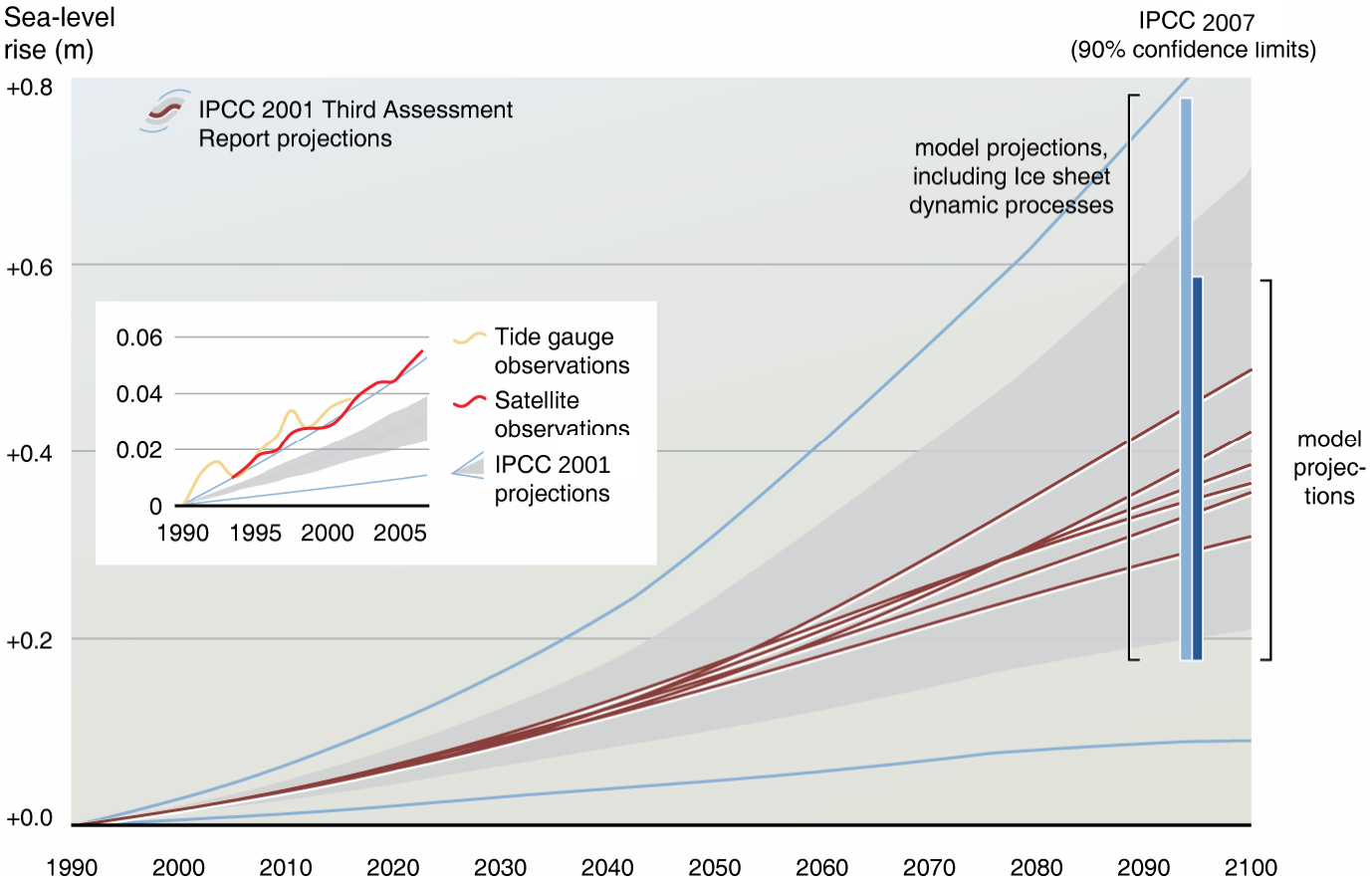

Figure 2: Projected global sea level rise for the 21st century

Regional variation in sea level rise

Increases in sea level will not occur uniformly across the globe with some regions experiencing higher levels of sea level rise and others lower. Such differences can be the result of variations in broad-scale atmospheric and oceanographic circulation patterns.

A recent study by the CSIRO and the Department of Environment and Climate Change[12] projected a NSW regional variation above global levels of up to 8 cm by 2030 and 12 cm by 2070. Linear interpolation and extrapolation of these upper limit projections was adopted. A value of 10 cm was adopted for 2050 and 14 cm for 2100.

Summary of justification for using upper bounds of sea level rise projections

The upper bounds of projections for sea level rise, ice sheet dynamic melt processes and regional variation have been adopted on the basis that:

- current trends in global emissions of carbon dioxide have accelerated sharply since about 2000, consistent with the high-end scenarios. The Garnaut Climate Change

[12] McInnes, K.L., Abbs, D.J., O'Farrell, S.P., Macadam, I., O'Grady, J. & Ranasinghe, R., 2007, Projected changes in climatological forcing for coastal erosion in NSW. A project undertaken for the Department of Environment and Climate Change NSW, CSIRO Marine and Atmospheric Research, Victoria.

Review[13] suggests under a business-as-usual scenario, global emissions will exceed the highest IPCC scenarios

- recent research indicates that the climate system, in particular sea level, may be responding more quickly to climate change than the current generation of models predict[14]. In particular, the IPCC were unable to exclude larger values and there is emerging evidence suggesting the IPCC's 2007 report may have underestimated the future rate of sea level rise[4].

[13] Commonwealth of Australia, 2008, *The Garnaut Climate Change Review: Final Report,* A report prepared by Ross Garnaut, Commonwealth of Australia, Canberra.

[14] Rahmstorf, S., Cazenave, A., Church, J.A., Hansen, J.E., Keeling, R.F., Parker, D.E. & Somerville, R.C.J., 2007, Recent climate observations compared to projections, *Science,* 316:709.