

BEYOND THE BRUUN RULE:

HISTORICAL VS. MODELLED RESPONSE TO SEA-LEVEL RISE ON WAVE DOMINATED BEACHES



Climate Change – IPCC 2007

IPCC 4AR predictions of the impacts of global warming to 2100

■ **Sea-level to rise by between 0.2 –0.6 m**

■ **with some additional rise likely in response to ice-melt..**

– Range now - 0.8 to 2.0m by 2100 (Pfeffer et al 2008)

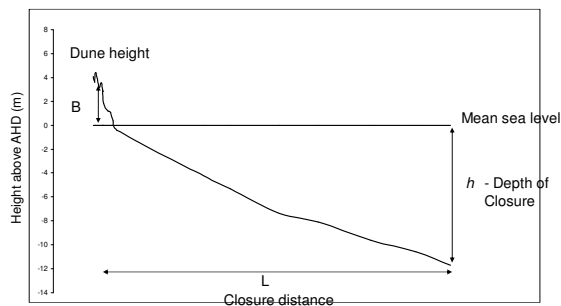
Implications of sea-level rise

- Accelerated erosion of the coastal margin
- Change in the shape of the coast and location of shoreline
- Increase in the incidence of coastal flooding

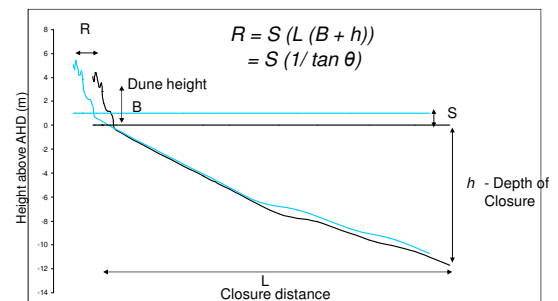
Coastline monitoring

- Few specific tools available
- Dominated by the Bruun Rule

The Bruun Rule



The Bruun Rule

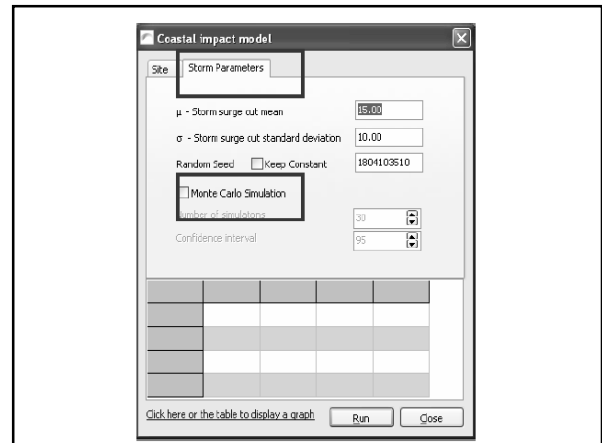
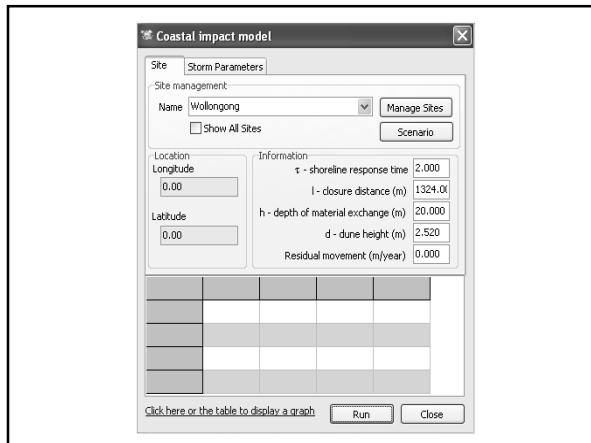


The Bruun Rule

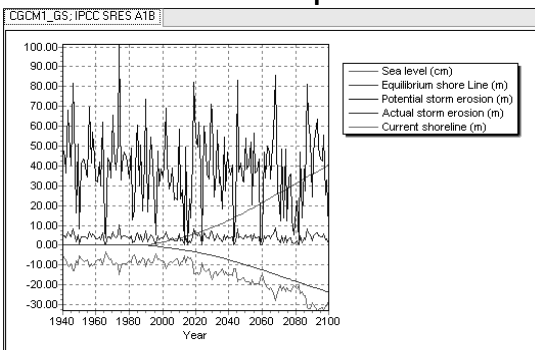
- Due to its simplicity....
- This model has been incorporated into...
 - Beach nourishment projects
 - Establishing set back margins
 - Other commercial products.....e.g.

SimCLIM

- Tool to simulate shoreline behaviour in response to SLR.
- Based on the Bruun Rule
- Two important drawbacks recognised;
 1. Natural systems have some time lag
 2. Shoreline retreat is irregular and spasmodic



SimClim Output



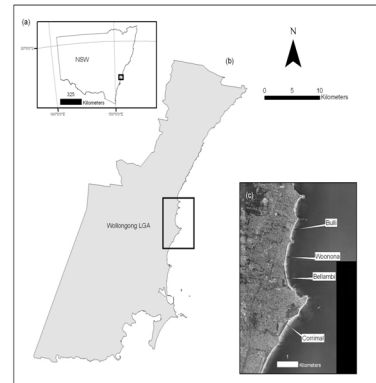
However.....

- There is considerable debate in the literature about the validity of modelling coastal behaviour
- Cooper and Pilkey (2004a & b) argue that the Bruun Rule should be abandoned.

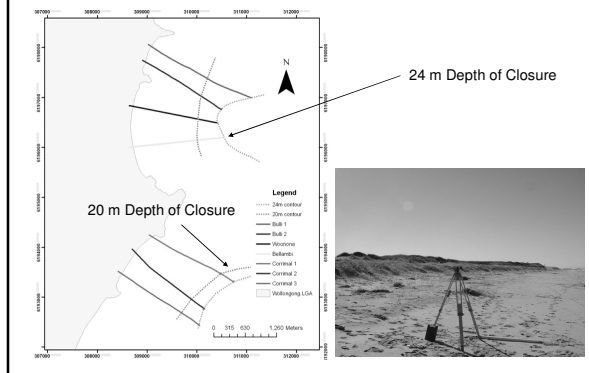
Study Objectives

- To evaluate the ability of 2 models to predict or simulate the response of local beaches to SLR
- To address the gaps in our present knowledge of historical shoreline response to SLR.

Study area



Beach and Offshore Surveys



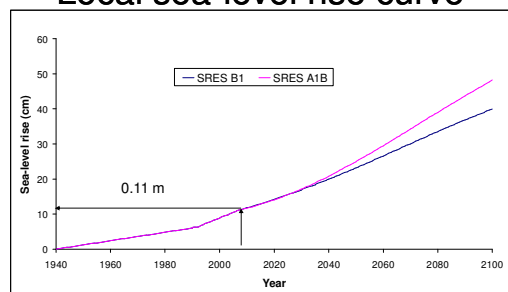
Historical Shoreline Analysis

- Identification of modern shoreline;
 1. Incipient foredune crest
 2. Vegetation line
- The modern shoreline indicators were then
 1. located on aerial photographs from 1938, 1951, 1972
 2. Digitised on 2001 and 2006 ortho-rectified aerial photographs

Photogrammetric Analysis



Local sea-level rise curve



From 1940 to 2007 observed (Church et al. 2006; BOM, 2007)

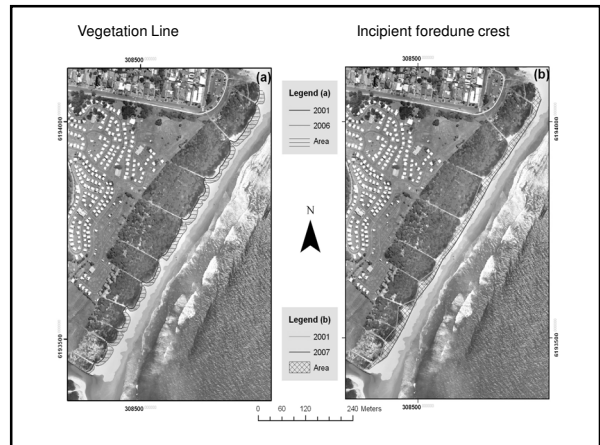
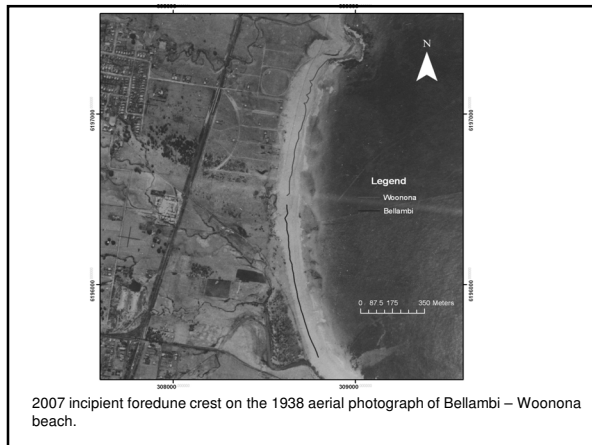
From 2008 onwards IPCC (2001) TAR projections

Study Findings

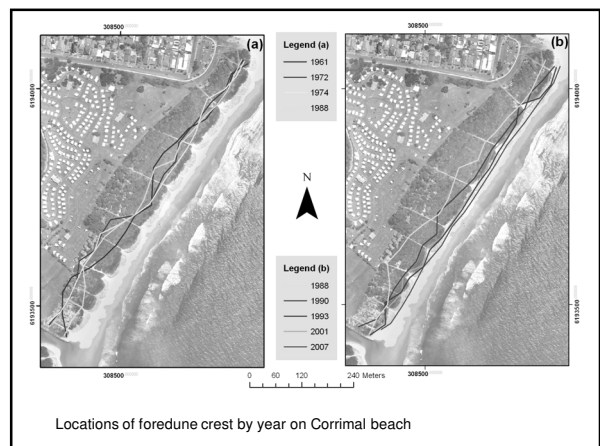
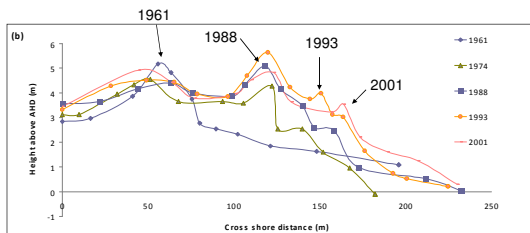
- Model output
- Change in shoreline position between 1938 to 2007 and 2001 to 2007
- Photogrammetric data

Modelled Shoreline retreat

	Bruun Rule	SimCLIM
■ 1940 to 2007	6.5 – 9.5 m	
■ 2007 to 2050	8.0 – 13 m	15 – 23 m
■ 2007 to 2100	18.0 – 28 m	26 – 36 m



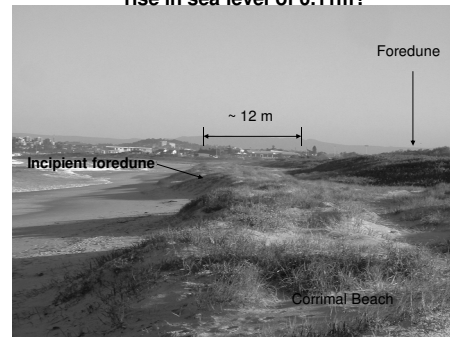
Photogrammetric Profile – Block 1 profile 3



Significant Findings

- Over the past 60 or so years, the shoreline was found to have been accreting, with the seaward migration of the foredune.
- Since the late 1980's, an incipient foredune has developed on each of the study beaches.
- This contradicts what both models predicted (or simulated) – shoreline retreat!

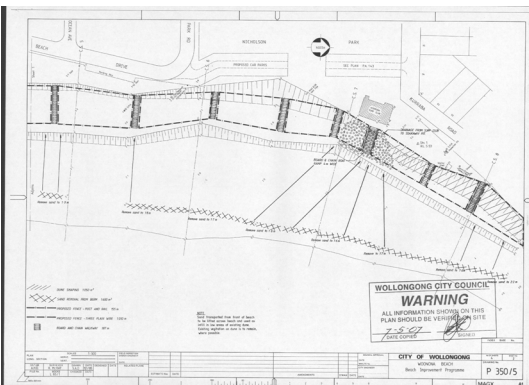
So how were these beaches able to accrete despite a rise in sea level of 0.11m?



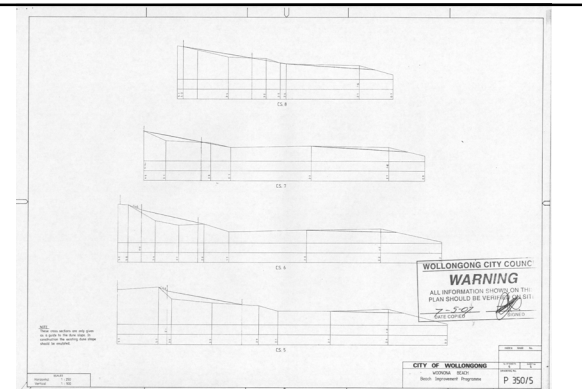
Sand drift from 1986 storm event along Woonona beach.

Dune Rehabilitation Works

- Existing dunes were reshaped to conform to an arbitrary engineering specification:
 1. dune height ~ 4.5m above AHD
 2. seaward dune face slope maximum of 1:4.
 3. All surfaces of the dunes were planted : landward face – small trees and shrubs and the seaward face with Spinifex sp.



Engineering drawings of Dune modification work at Woonona beach



Engineering drawings of the profiles for Woonona beach.

The significance....

Following the completion of the Dune Works:

- Seaward migration of the fore dune
- Development of an incipient foredune
- Subsequently dunes have evolved towards a pre-disturbance state...
- Increased dune resilience to the impact of storms (rapid recovery)

Corrimal Beach



Post – Storm Dune scarp – 3/8/07



Dune recovery - 22/10/07

New Research Question

- What is the origin of the sand that has enabled seaward migration of foredune and the development of an incipient foredune?

Lesson Learnt - Good

1. The value of site specific coastal process studies.

- The local beaches are accreting with rising sea levels.
- Identification of a potential sea-level adaptation strategy
 - Dune reconstruction and re-vegetation works

Lessons learnt – Good contd...

2. Highlights the benefits of engaging students from local universities to undertake localised coastal process studies.
3. Caution should be exercised in the application of models to predict shoreline behaviour in response to SLR.

Questions

References

- Baker, C. 2006. The Better Management of Wollongong's Beaches. Honours Thesis. University of Wollongong (unpublished).
- Boak, E.H. and Turner, I. L. 2005. Shoreline Definition and Detection: A Review. *Journal of Coastal Research*, 21(4), 688-703.
- Basher, P. A. 1977. Wave Energy Influence on Offshore Sediment Distribution - Port Kembla, N.S.W. 3rd Australian Conference on Coastal and Ocean Engineering, Melbourne.
- Bruun, P. 1984. Coast erosion and the development of beach profiles. Technical Memorandum, vol. 44. Beach Erosion Board. Corps of Engineers. SPO.
- Bruun, P. 1982. Sea-level rise as a cause of shore erosion. *Journal of the Waterways and Harbors Division*, 88, 117-130.
- Bryant, E.A. 1983. Coastal erosion and accretion, Stanwell Park beach, NSW, 1950-1980. *The Australian Geographer*, 15, 382-90.
- Bryant, E.A. 1988. Storminess and high tide beach change, Stanwell Park, Australia, 1943-1978. *Marine Geology*, 79, 171-87.
- Bureau of Meteorology (BOM). 2007. Monthly Data Report July 2007. National Tide Centre. Accessed online August 2007. http://www.bom.gov.au/tide/IC020101/IC020101_200712.pdf
- Clarke, D. J. and Etkin, L. G. 1988. Low-frequency changes of sediment volume on the beachface at Warilla Beach, New South Wales, 1975-1985. *Marine Geology*, 78, 189-211.
- CLIMsystems (2007). User Guide for SimCLM Version 2. R. Warrick. Hamilton.
- Church, J., Hunter, J., McInnes, K. L. and White, N. J. 2006. Sea-level rise around the Australian coastline and the changing frequency of extreme sea-level events. *Australian Meteorological Magazine*, 56(4), 253-260.
- Cooper, J. A. G. and Pilkey, O. H. 2004a. Alternatives to Mathematical Modeling of Beaches. *Journal of Coastal Research* 20(3), 641-644.
- Cooper, J. A. G. and Pilkey, O. H. 2004b. Sea-level rise and shoreline retreat: time to abandon the Bruun Rule. *Global and Planetary Change*, 43, 157-171.
- Cooper, J. A. G. and Pilkey, O. H. 2007. "Rejoinder to: Cowell, P.J. and Thom, B.G. 2006. Reply to: Pilkey, O.H. and Cooper, A.G. 2006. Discussion of: Cowell et al., 2006. Management of Uncertainty in Predicting Climate-Change Impacts on Beaches." *Journal of Coastal Research* 23(1), 225-45. *Journal of Coastal Research*, 22(6), 1577-1579. *Journal of Coastal Research*, 22(6), 1580-85. *Journal of Coastal Research* 23(1), 277-80.
- Cowell, P. J., Roy, P.S. and Jones, R.A. 1992. Shoreface Transition Model: Computer Simulation of Coastal Sand-Body Response to Sea-level rise. *Mathematics and Computers in Simulation*, 33, 603-8.
- Cowell, P. J. and Thom, B. G. 2006. Reply to: Pilkey, O.H. and Cooper, A.G. 2006. Discussion of: Cowell et al., 2006. Management of Uncertainty in Predicting Climate-Change Impacts on Beaches. *Journal of Coastal Research*, 22(2), 232-245. *Journal of Coastal Research*, 22(6), 1577-1579. *Journal of Coastal Research*, 22(6), 1580-85.
- Cowell, P. J., Thom, B. G., Jones, R. A., Everts, C. H. and Simanovic, D. 2006. Management of uncertainty in predicting climate-change impacts on beaches. *Journal of Coastal Research* 22(1), 232(14).
- Davidson-Arnslett, R. G. D. 2005. Conceptual Model of the Effects of Sea-level rise on Sandy Coasts. *Journal of Coastal Research*, 21(6), 1166-1172.
- Etkin, L.G. and Clarke, D. J. 1982. Seasonal and biennial fluctuation in subaerial beach sediment volume on Warilla beach, New South Wales. *Marine Geology*, 48, 89-103.
- Foreman 1. 2007. Personal communication. Meeting at Wollongong City Council offices, 30th April 2007.
- Galgano, F. A., Douglas, B. C. and Leatherman, S. P. 1998. Trends and Variability of Shoreline Position. *Journal of Coastal Research*, 14(2), 282-91.
- Hanslow, D. 2007. "Beach Erosion Trend Measurement: A Comparison of Trend Indicators". *Journal of Coastal Research*, 90(S), Proceedings of the 9th International Coastal Symposium, Gold Coast, Australia.
- Hazlewood, M.G. 2007. Climate Change and Coastal Communities: an assessment of the impact of sea-level rise on four Wollongong beaches. Honours Thesis. University of Wollongong (unpublished).
- Hennecke, W. G., Greve, C. A., Cowell, P. J. and Thom, B. G. 2004. GIS-Based Coastal Behavior Modeling and Simulation of Potential Land and Property Loss: Implications of Sea-Level Rise at Collaroy/Narrabeen Beach, Sydney (Australia). *Coastal Management*, 32(4), 449-470.
- 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. S. Solomon, M. Qin, M. Manning et al., (eds.) Cambridge, Cambridge University Press. 386 pp. Accessed online May 2007. http://www.ipcc.ch/publications_and_products.htm

References contid

- McLean, R. and Shen, J.-S. 2006. From foreshore to foreshore: foreshore development over the last 30 years at Moruya Beach, New South Wales, Australia. *Journal of Coastal Research*, 22(1), 28-37.
- Moon, L.L. 2003. Shoreline Mapping Techniques. *Journal of Coastal Research*, 18(1), 111-124.
- Patterson, Britton, and Partners. 1993. Collaroy/Narrabeen Beach nourishment investigation (Draft Report). Sydney: Warringah Council.
- Pilkey, O.H. and Cooper, J.A.G. 2006. Discussion of: Cowell et al., 2006. Management of Uncertainty in Predicting Climate-Change Impacts on Beaches. *Journal of Coastal Research*, 22(1), 225-54. *Journal of Coastal Research*, 22(6), 1577-79.
- Ransinghe, R., McLoughlin, R., Short, A.D. and Symonds, G. 2004. The Southern Oscillation Index, wave climate and beach rotation. *Marine Geology*, 204, 275-87.
- Roy, P. S. 1984. New South Wales Estuaries - their origin and evolution. In: *Developments in Coastal Geomorphology in Australia*. Thom, B.G. (ed.) New York, Academic Press, pp9-121.
- Roy, P. S., Williams, R.J., Jones, A. R., Yessini, I., Gibbs, P. J., Coates, B., West, R. J., Scanes, P. R., Hudson, J. P., and Nichol, S. 2001. Structure and Function of South-east Australian Estuaries. *Estuaries, Coastal and Shelf Science* 53(3), 351-384.
- Ruggiero, P., Kaminsky, G. M. and Gelfenbaum, G. 2003. Linking Proxy-Based and Datum-Based Shorelines on a High-Energy Coastline: Implications for Shoreline Change Analysis. *Journal of Coastal Research*, 19(36), 57-62.
- Thom, B. G. 1983. "Transgressive and regressive stratigraphies of coastal sand barriers in southeast Australia." *Marine Geology* 68, 137-158.
- Thom, B.G. and Hall, W. 1991. Behaviour of beach profiles during accretion and erosion dominated periods. *Earth Surface Processes and Landforms*, 16, 113-27.
- Wain, K. J. E., Bets, M., Church, J., Pittcock, A. B., McInnes, K. L., Jackett, D. R. and McDougall, T. J. 2004. Using sea-level rise projections for urban planning in Australia. *Journal of Coastal Research*, 20(2), 586-598.