PROJECTING A GREENHOUSE RISE IN SEA LEVEL ON SALTMARSH AND MANGROVE HABITATS IN NEW SOUTH WALES

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INTRODUCTION

A half metre to one metre rise in sea level will reshape much of the NSW coastline; among other things, ocean beaches will be eroded and restructured, and estuarine foreshores will be altered. As there are over 100 estuaries in NSW (West *et al.* 1985), the extent of shoreline change could be enormous.

Wetland communities comprised mainly of seagrass, mangrove and saltmarsh species exist in most NSW coastal water bodies. A rise in water level will change the distribution of these communities, and a landward migration can be expected. The extent of migration will be determined by available space, i.e. if floodplains are extensive there could be a net gain in estuarine vegetation; however, in catchments where landward barriers predominate, a net loss would be expected. Barriers could be of two types: natural barriers such as ridges and steep hills, and artificial barriers such as causeways and embankments.

As most of NSW's commercially and recreationally important fish species are dependent at some stage of their life cycle on estuarine habitats, the financial impact to the fishing community of an altered sea level could be large. For this reason, and in order to plan an adequate government response to rising sea level, it is desirable to know the degree of loss or gain of estuarine habitats which might ensue.

A prerequisite for assessing these losses and gains is a set of appropriate maps. Bridgman (1988) initiated sea level rise mapping in NSW at a 1:25,000 scale by projecting various height rises onto a large river system (Hunter River) and a large area of the central NSW coast (Lake Macquarie and Port Stephens). He produced his maps as a qualitative rather than quantitative input to long-term coastal planning.

Bolin *et al.* (1986) initially quoted a 0.2-1.4 m range in sea level rise by the year 2030. Bryant (1990) advises that the expected sea level rise has been more recently revised to 0.25-0.3 ± 0.1 m within the same time frame. In either case, maps with 0.5 m contours would be useful in assessing the extent of sea level rise on estuarine vegetation. However, there is no set of maps which shows this interval for the NSW coast. One metre contours are shown on Land Information Centre (LIC, formerly Central Mapping Authority) 1:2,000 and 1:4,000 orthophoto and topographic maps, but only a limited amount of coastline has been mapped. The table below summarises LIC maps which could be used in projecting sea level rise.

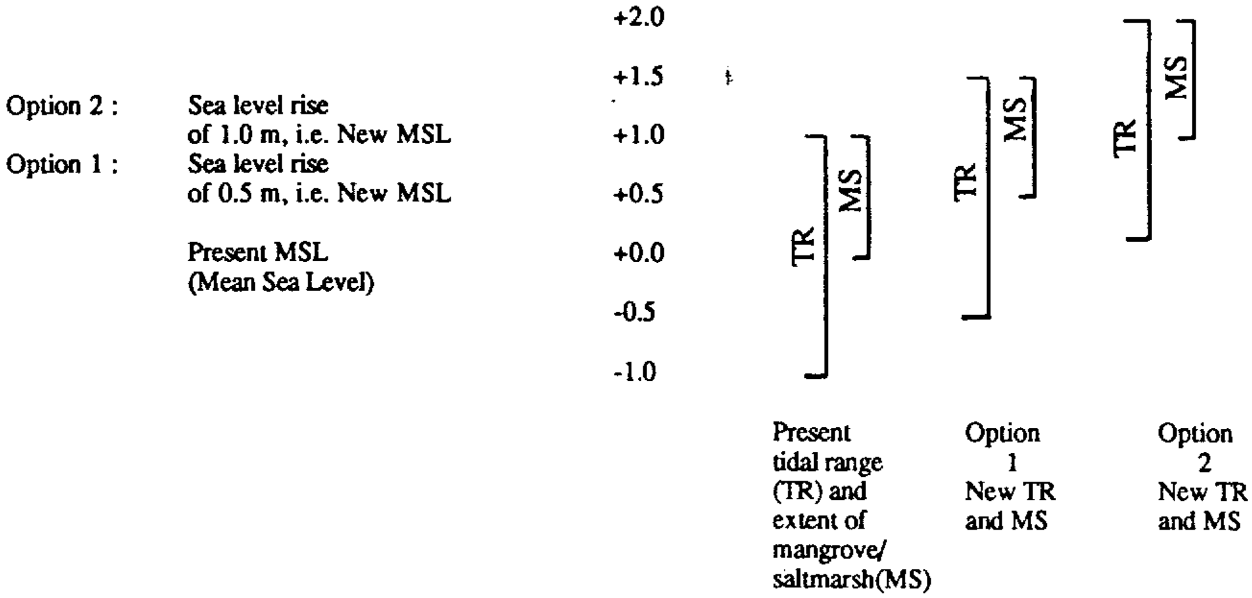
Mapping Scale	Contour Interval	% of NSW Coastline Covered	Precision
1 : 25,000	10 m	100	±5 m
1 : 4,000	2 m	30*	±1 m
1 : 2,000	1 m	20*	±0.5 m

* estimated from LIC's 1989 catalogue of map coverage.

In contrast to Bridgman (1988), the objective of this study was to assess the utility of 1:25,000 maps for projecting increase in water area and loss/gain of the mangrove-saltmarsh community in small coastal water bodies. Depending on the outcome, it was anticipated that specialist mapping exercises using appropriately scaled maps might be needed in order to make accurate sea level and vegetation projections.

METHODS

There is nothing conceptually difficult about extrapolating a family of contour heights but it can become confusing if multiple sea level options are presented. The schematic below identifies the present and altered positions of mean sea level, maximum tidal range and the range over which mangrove and saltmarsh occur in NSW.



Spot heights (figs. 1, 2) were located on 1:25,000 maps (LIC 1973, 1974, 1975) and used to interpolate 0.5, 1.0, 1.5 and 2.0 m contours for two small NSW estuaries (identified below). For the purpose of this study a critical and tenuous assumption had to be made: the land-sea boundary shown on the map was assumed to be mean sea level; it was derived from aerial photography taken at an unknown time in the tidal cycle. The interpolated +0.5 m and +1.0 m contours were assumed to be the new (and alternative) mean sea levels; the area between them and the land-sea boundary was assumed to be the new water surface area. This area was calculated using CAD software on an IBM-compatible P.C.

For the purpose of estimating changes in area of mangrove and saltmarsh, additional assumptions had to be made, i.e. about the levels at which the dominant plants in these communities grow. Few (if any) topographic studies have established the upper and lower height datum for mangroves and saltmarsh in NSW (P. Adam, pers. comm.). On the basis of field observations, I assumed that mangroves grow no lower than mean tide (0 m) and saltmarsh no higher than +1.0 m. The area of land lying between these contours was calculated and assumed to be the potentially colonisable area for the mangrove and saltmarsh communities.

The two small south coast estuaries chosen for study were: Minnamurra River and Crooked River. Minnamurra River (fig. 1) is 130 km south of Sydney, is permanently open to the ocean, has a total water surface area of approximately 60 ha (West *et al.* 1985), and in 1982 was estimated to contain approximately 48 and 20 ha of mangrove and saltmarsh, respectively (West *et al.* 1985). Roy (1982) classified Minnamurra River as a barrier estuary at a mature stage of infilling.

Crooked River (fig. 2)is located 20 km further south, has a total water surface area of 22 ha, is open to the sea (West *et al.* 1985), but was not classified by Roy (1982). West *et al.* (1985) did not show mangrove or saltmarsh but a review of West's 1982/83 field notes (pers. comm.) indicated the presence of about 10 small, widely scattered mangrove trees that could not have been mapped at the scale used. Fringing saltmarsh is present (P. Clarke, pers. comm.) and there are many more seedlings of mangroves present today than there were in 1982/83 (P. Adam, pers. comm., McNeill, pers. comm.).

"Contour" mapping of small estuaries such as the Minnamurra and Crooked Rivers (and of large estuaries) with 1:25,000 maps has some obvious disadvantages, the foremost being precision of plotting. The areas calculated are indicative of change; they are not quantitatively rigorous. As well, the contour approach assumes no attenuation of tide within an estuary. This is a very important point because in some NSW estuaries (e.g. Lake Macquarie) tidal range is only a fraction of what it is in the open ocean. Hence the lateral extent of sea level rise will vary considerably between estuaries (for a fuller discussion, see Williams 1983).

Furthermore, this type of contouring does not discriminate mangroves from saltmarsh. Generally mangroves grow downslope of saltmarsh (however, these two communities are extremely complex; see Mitchell & Adam 1989, p. 42 for exceptions).

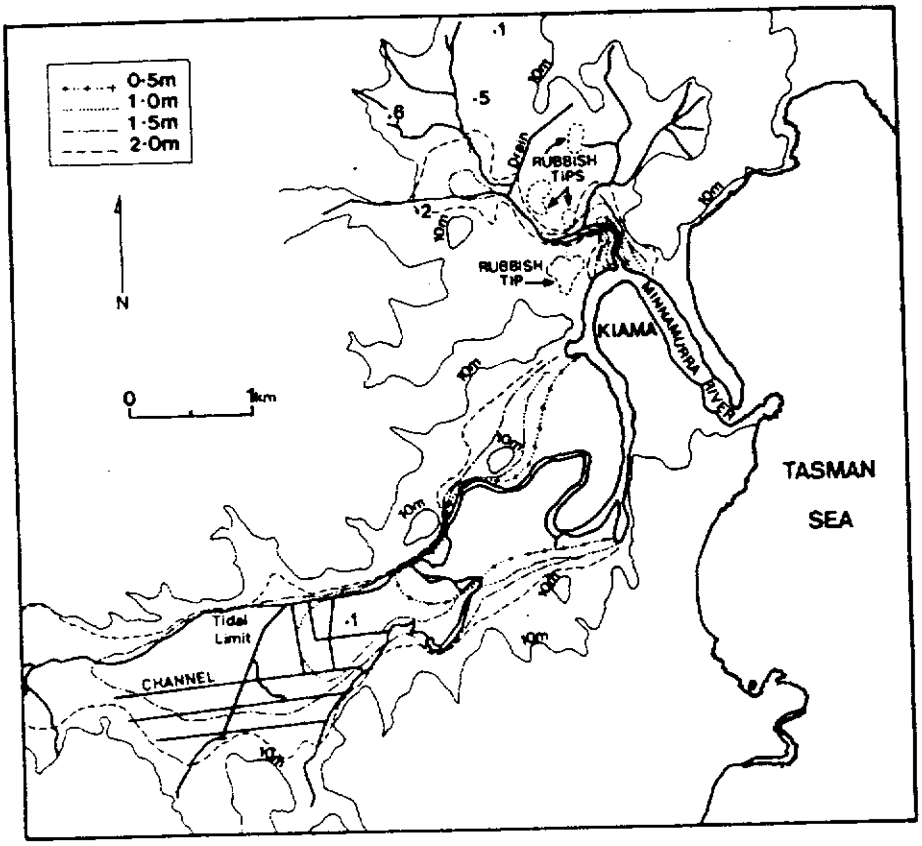


Figure 1 Minnamurra River. This map was traced from LIC 1:25,000 maps Albion Park and Kiama. The edge of the river shows assumed mean tide level. The 10 m contour is traced from the original map as are the five (e.g. ".6") spot heights. 0.5, 1.0, 1.5 and 2.0 m contours are interpolated from the spot heights.

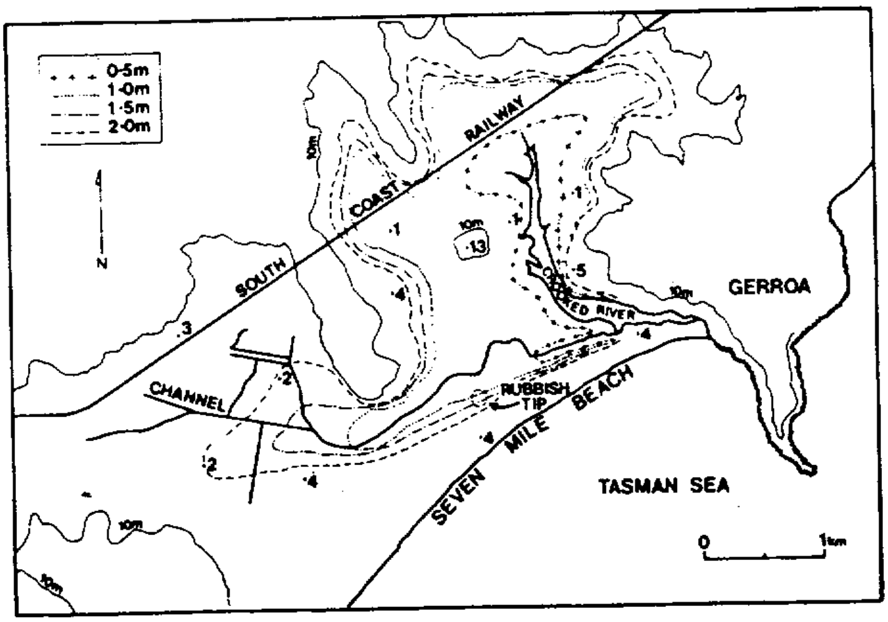


Figure 2 Crooked River. This map was traced from LIC 1:25,000 map Gerroa. The details are as for Fig. 1 and twelve spot heights are indicated.

RESULTS

I estimated that the changes in water area and mangrove/saltmarsh vegetation in these two rivers would be as follows:

	Water Area	**Minnamurra River** (ha)	**Crooked River** (ha)
a	1970[1] (LIC 1973, 1974, 1975; as determined in this study)	73	27
b	1982 (West *et al.* 1985)	60	22
c	0.5 m sea level rise	235	181
d	1 m sea level rise	317	438[2]
	Difference: a -> c	~3.2x	~ 6.7x
	Difference: a -> d	~4.3x	~16.2x
	Combined Mangrove and Saltmarsh Area		
e	1970 (LIC 1973, 1974, 1975; potentially colonisable as determined in this study)	245	410
f	1982 (actual, as determined by West *et al.* 1985)	68	0.1 (assumed)
g	0.5 m sea level rise (potentially colonisable)	243	411
h.	1 m sea level rise (potentially colonisable)	433	234
	Difference: e -> g	nil	nil
	Difference: e -> h	~1.8x	~0.6x

[1] Date of aerial photography used to produce LIC maps.

[2] Assumes expansion of water and mangrove/saltmarsh areas beyond the South Coast railway line.

Based on the assumption that the land-sea boundary shown in the LIC maps is mean sea level, a 0.5 m rise in sea level would increase water area about 3 fold and 7 fold in the Minnamurra and Crooked Rivers, respectively. The present water surface area of the Crooked River is about one third that of the Minnamurra but would approach that of the latter if sea level were to rise by 0.5 m and exceed it if sea level were to rise by 1 m.

Based on the assumption that mangrove and saltmarsh communities grow between the heights of mean sea level and +1.0 m, 245 and 410 ha of these two communities could potentially have existed in Minnamurra and Crooked Rivers, respectively, at the time of LIC aerial photography (1970). However, West *et al.* (1985) measured only 68 ha of mangrove/saltmarsh in the Minnamurra and showed no measurable amount for the Crooked River. There is no obvious explanation for this.

With a rise in sea level of 0.5 m, 243 and 411 ha of mangrove and saltmarsh could be created at Minnamurra and Crooked Rivers, respectively. This is a negligible change compared to what potentially could exist there. A more significant change could occur if sea level rose 1 m: mangrove and saltmarsh would increase to 438 ha (nearly 2x) in the Minnamurra but would decrease by almost half to 234 ha in Crooked River.

DISCUSSION

It has been suggested that the first priority in managing adverse impacts of the Greenhouse effect is to initiate programs ameliorating the basic cause, i.e. to reduce the injection of Greenhouse gases into the atmosphere. This would include the sponsoring of research into alternative power sources and reducing human reliance on ruminant (particularly cattle) food sources.

The next line of attack would be to mitigate secondary effects, and one of the most important of these is inundation. A basic requirement in assessing the extent of inundation is a set of coastal maps at an appropriate scale with at least +0.5, +1.0, and +1.5 and +2.0 m contours; the production of this map set would take a number of years and be quite expensive.

In the meantime, existing maps will have to be used in coastal planning. Due to the limited precision of 1:25,000 maps, projection of small-scale water level changes is difficult. Accurate projections can only be determined by intensive topographic surveys. One or two pilot studies would be useful in identifying the resources needed.

A new generation of large scale maps with 0.5 m contours originating at the land-sea interface will still have the disadvantage of implying uniform inundation in estuaries, whereas the degree of tidal penetration in any one estuary is determined by the nature of the entrance. Offsetting this will be storm surge, which increases water level within estuaries during bad weather. Furthermore, even though the plotting of 0.5 m contours may suggest that mangrove and saltmarsh may colonise new areas, there is no guarantee that they will. For example, at Crooked River there would seem to have been ample substrate to carry more than the 10 mangrove trees counted by West *et al.* (1985) in 1982/83.

A number of other factors will determine the spread and final extent of vegetation around estuarine waterbodies. For example, a sand mining proposal for an area to the south of Crooked River is now before the NSW Government; bund walls constructed around the mined area may act as artificial barriers to wetland relocation.

Bell and Edwards (1980) estimated the water surface area of the Minnamurra and Crooked Rivers as 200 and 50 ha, respectively, estimates very much at odds with the estimates of 60 and 22 ha produced by West *et al.* (1985). These differences imply that the amount of estuarine surface water in NSW is not known accurately. As this pilot study suggests, with a rise in sea level, substantial increases in water and wetland areas are likely, and an assessment of potential changes in all of the State's estuaries should be initiated. Such an assessment will almost certainly add to the controversy surrounding "State Environmental Planning Policy 14 - Coastal Wetlands". Some of the wetlands now defined in the policy may cease to exist; all will be altered in some way or another. The production and dissemination of Greenhouse sea level maps will be controversial, e.g. with respect to real estate valuations or the continued viability of rubbish tips; however, such maps are essential in planning for future sea level rise.

There are of course other changes forecast to come about as part of the Greenhouse effect, such as alterations in rainfall and frequency of storms, or changes in the growth rates of plants. The impacts of these changes on mangrove/saltmarsh habitats as well as seagrass meadows would need to be estimated separately. Little is known about how more than 100 NSW saltmarsh species (Adam *et al.* 1988) and 5 NSW mangrove species will respond to these changes. Further studies are needed on each to determine tolerances and colonisation rates.

ACKNOWLEDGMENTS

Paul Adam, Peter Clarke, Sally McNeill, Eamonn Clifford, Dave Pollard and Ron West provided useful comments on the draft. Kathy Cann produced the maps and Fiona Hooke persevered with the typing.

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