POTENTIAL EFFECTS OF GREENHOUSE-INDUCED SEA LEVEL RISE ON THE SOUTHERN SHORES OF BOTANY BAY

M.J. Pollard*
Senior Geography Student
Fort Street High School
Petersham NSW 2049

INTRODUCTION

Over the next 40 years or so, the Greenhouse effect will affect many aspects of the environment. Not the least of these changes is an expected rise in sea level. With mean annual temperatures predicted to rise by between 2 and 4°C by the year 2030, sea levels are expected to rise by between 0.2 and 1.4 m, mainly due to thermal expansion of the oceans plus limited melting of mountain glaciers and the polar ice-caps. This paper considers the potential effects of a Greenhouse-induced sea level rise of one metre on the southern shores of Botany Bay.

The Greenhouse effect is an extremely important environmental issue, and also a very real one, to which little attention is being paid by local councils, engineers and the general public. My investigation has therefore included a number of different aspects of Botany Bay, comprising both natural features and the built environment. From this study I aimed at achieving a better understanding of what impact sea level rise may have on this area, and what can be done to minimise the resulting damage.

BACKGROUND TO THE GREENHOUSE EFFECT

Although the term Greenhouse effect is generally used as a convenient, popular expression to describe the accelerated artificial warming of the earth's surface caused by human-induced changes to the composition of gases in the lower atmosphere, the Greenhouse effect is actually a naturally occurring phenomenon in which the atmosphere forms a warm blanket around the earth and some of the energy radiated to the earth by the sun is re-radiated downwards at infra-red wavelengths to keep the planet at an average temperature of about 15°C.

The human-induced Greenhouse effect is caused by the release of various gases from energy production and modern industries and has occurred since the Industrial Revolution. The main offending gas is carbon dioxide, but nitrous oxides, methane and chlorofluorocarbons (CFCs) are also major Greenhouse gases. Modern industries and energy use have been estimated to be responsible for two-thirds to three-quarters of the increase in carbon dioxide in the atmosphere, and deforestation accounts for the remainder.

The Greenhouse effect is no longer simply a theory. In the 1890s Arrhenius concluded that a doubling of atmospheric carbon dioxide would cause a 5°C temperature rise. At the rate we are going, by the year 2030 we can expect average temperatures to have risen about 2°C in the tropics and 4°C at the poles. This is the equivalent, in 30 to 50 years, of normal temperature rises which occurred over time periods of 10 to 20 thousand years in the geological past.

Although the warming of the atmosphere is the primary Greenhouse effect, the secondary effects can be more closely related to our human well being. These include a rise in sea level, increases in global rainfall, a shift in tropical cyclones to the south by 200-400 km in the Southern Hemisphere, increases in cyclone intensity of 30-60%, increases in wave heights and wave action, changes in wind speeds, shifts in the locations of temperate and semi-arid zones, increases in flash floods, increases in droughts, increases in erosion from runoff, higher snowlines, increased risk of extinction of some flora and fauna, and shifts in wildlife distribution and habitat.

A predicted rise in sea level is probably the most important secondary effect in the context of this study. This effect is caused mainly by thermal expansion of the oceans and, contrary to popular belief, only minimally as a result of the melting of the fringes of the polar ice caps. Sea level rises are predicted to be greater than one metre for every 2°C warming of the atmosphere, although there is much dispute over this figure. It is generally accepted that sea levels may rise somewhere between 0.2 and 1.4 m by the year 2030.

METHODS OF INVESTIGATION

During the latter part of spring 1989, I carried out the following investigations:

- photographed high and low tide marks, residential areas, vegetation, bird habitats and other relevant features of this area;
- examined existing topographic and land use maps, and attempted to map the new coastline on contour maps after a one metre rise in sea level and from this to predict any changes to the landscape along the shoreline of the bay;
- visited the Maritime Services Board hydraulic model of Botany Bay and discussed problems of sea level rise and coastal erosion with the hydraulic engineer;

*Editor's Note: One of the particular aims of the Coast and Wetlands Society is to promote a general knowledge of the coastal environment. Saltmarsh and mangrove communities are often studied as part of school science biology and geography courses. They are particularly suitable for such studies, having an unusual biota with often only a few species, strong environmental gradients, and are generally easily accessible. The present paper arose from a senior geography project designed to investigate the potential effects of Greenhouse-induced sea level changes in southern Botany Bay.

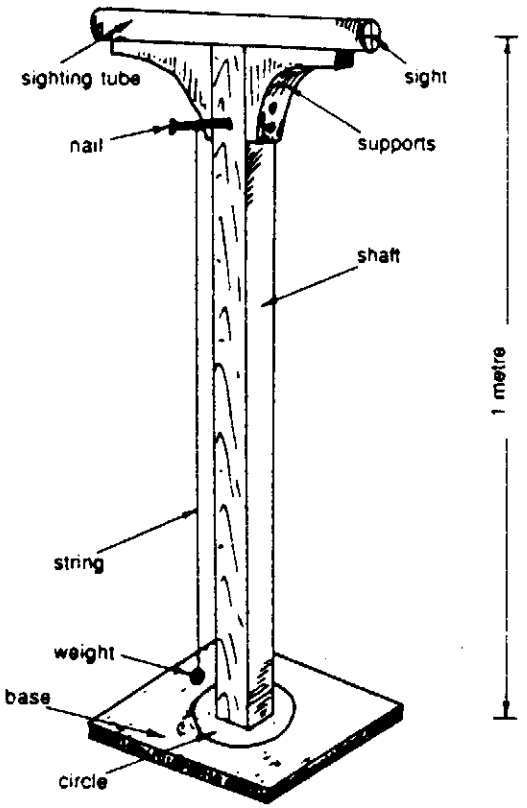

Figure 1 Primitive theodolite used in fieldwork, to estimate the potential effects of a 1 m rise in sea level.

- examined differences in vegetation below and above mean high water mark at different levels using transect methods;
- designed a questionnaire to investigate whether people living on the waterfront accept the fact that Greenhouse-induced sea level rise may have an impact on their local area;
- conducted interviews with relevant experts involved with different aspects of this study (see acknowledgements);
- investigated written material already in circulation, such as newspaper clippings, reports and books; and
- discussed all of the above in a preliminary report, illustrated where appropriate with maps, graphs and tables.

For the fieldwork on the natural environment a primitive theodolite was constructed from simple materials (figs 1, 2). This theodolite is exactly one metre high and has a sighting tube with cross wires along the top. When this theodolite is placed on the high water mark and the terrain viewed shorewards through the tube, it is possible to ascertain approximately where a one metre sea level rise would come to on the land surface. An assistant can then mark this point using a coloured wooden stake. A number of such marks can then be joined to give the horizontal line showing the approximate position of a one metre sea level rise.

Figure 2 The author using the surveying instrument in the field, Towra Point.

RESULTS

A. The Natural Environment

Topography

The southern shore of Botany Bay has an extremely flat topography. This is partly the reason I chose this particular area in which to carry out my case study regarding the effects of sea level rise. The flatness of the area is illustrated in Figure 3, which was photographed at low tide from approximately mean tide mark (halfway between high and low tide) on Quibray Beach. The high tide mark, where drift material has been deposited, can be seen. Because of the flat topography, the tide covers an extremely large land area although it only fluctuates over a small vertical range.

Figure 3 The beach at Quibray Bay. This photograph taken at mean (half) tide shows the large area of land covered by the tide in an area of very flat topography.

Flora

Estuarine environments, such as Botany Bay, usually have distinct vegetation patterns around the water's edge. Distinct boundaries between vegetation types with respect to their tolerance to tidal inundation are apparent. The vegetation in these environments usually progresses from seagrasses, through mangroves and saltmarsh, to terrestrial vegetation above the highest water mark. These terrestrial vegetation areas in southern Botany Bay are often characterised by *Casuarina glauca*. There are distinct boundaries between the mangroves, the saltmarsh and the terrestrial *Casuarina* belt.

Seagrasses are submerged plants which are able to complete their life cycles underwater. The two main types in Botany Bay are *Posidonia* and *Zostera*, the *Posidonia* (often known as strapweed) having broad leaves up to one metre long and 10-15 mm, wide and the *Zostera* (often known as eelgrass) having thin leaves 1.3 m long and approximately 25 mm wide.

Mangroves are trees or shrubs that grow from spring tide low water mark to slightly above mean sea level, and so are adapted to saline environments and periodical inundation. The main mangrove species in Botany Bay is *Avicennia marina* (grey mangrove) but the smaller *Aegiceras corniculatum* (river mangrove) also occurs in isolated pockets in the area. The roots of the *Avicennia* trees have cylindrical protrusions called pneumatophores rising several centimetres above the surface of the sediment which act as air exchangers. The *Aegiceras* trees have no pneumatophores.

Saltmarsh is located landward of the mangrove stands, and consists of several plant species - the rush (*Juncus*), the saltwort (*Sarcocornia*) and the salt couch (*Sporobolus*) being the main types. The saltmarshes at Towra Point comprise the largest area of this habitat type in the Sydney region.

The effect of sea level rise on the vegetation would depend greatly on how fast it occurred. If the water were to rise slowly over a very long period, this would allow mangroves in the intertidal areas time to colonise landwards up the

slope with the rising sea level, since they only live within the tidal boundaries indicated above. This would reduce the area of saltmarsh behind them since the saltmarsh in many areas would not be able to move back due to the built environments (e.g. Captain Cook Drive) which surround them on their landward sides.

On the other hand, if the Greenhouse effect were to cause a rapid water level rise over a short period of time, the mangrove communities would be swamped. The soil would not be aerated properly, and dieback would occur in the mangrove belt. If, instead of being able to encroach upon the saltmarsh, the mangroves were killed, the whole system would be jeopardised. This would seriously affect the nutrient flow of the system, since the mangroves are such an important part of the environment. The estuarine flora and fauna have evolved over a very long period of time, much longer than it would take for the Greenhouse effect to occur, and therefore may be unable to adapt in the time available.

Fauna

Fish. The water rise could have an initial positive effect on the fish communities in this area. It may open up new areas of habitat, reducing competition for nursery space. It may also expose the fish to more invertebrates found in the littoral area, upon which they could feed. Towra Point is very important as a nursery ground and feeding habitats for juvenile mullet, blackfish and bream (fig. 4).

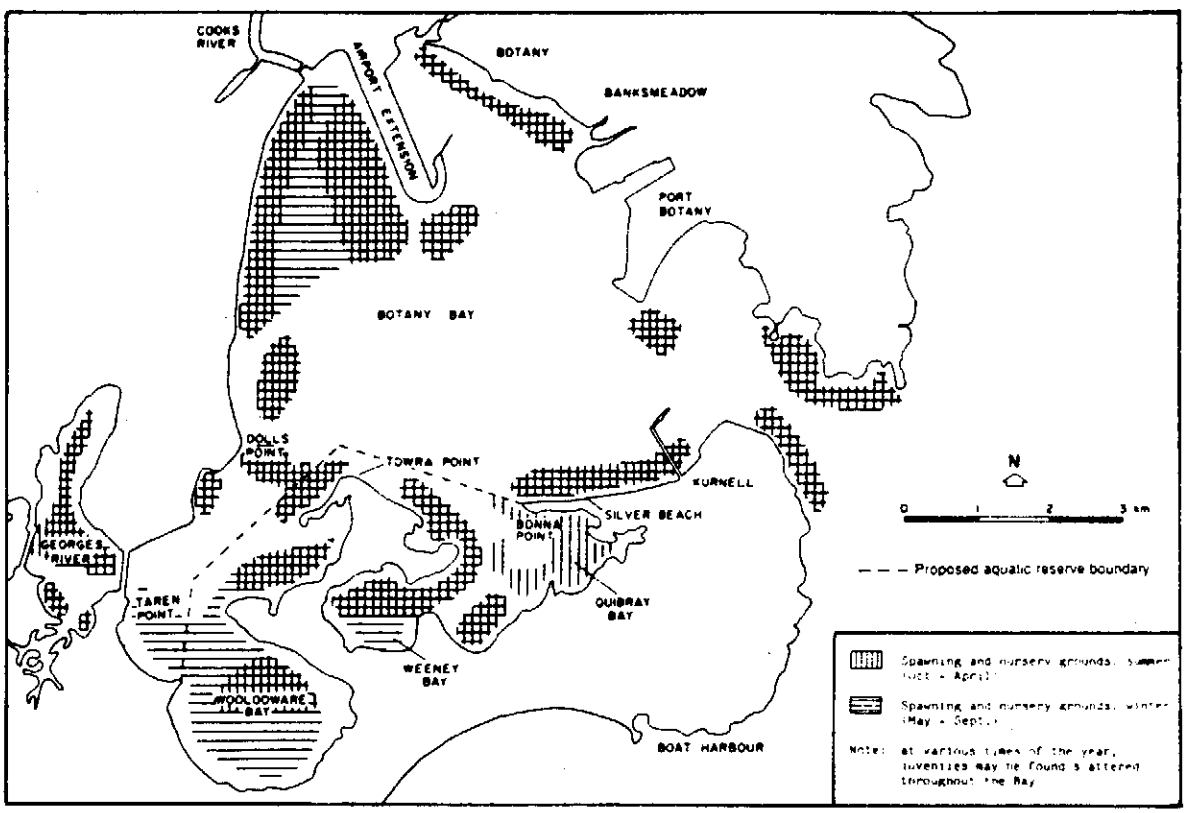

Figure 4 Location of a fish nursery and spawning grounds in Botany Bay (from SPCC, 'Coastal resource atlas for oil spills in Botany Bay', 1985).

Wading Birds. Towra Point supports, on either a temporary or permanent basis, a wide variety of native and migratory birds. Of particular importance are migratory waders whose migratory patterns bring them southwards from parts of the Northern Hemisphere, such as Japan and Siberia. Australia and Japan signed an agreement in 1974 for the "protection of migratory birds, birds in danger of extinction, and their environment". Obviously, any rise in sea level will reduce the amount of habitat remaining for the birds in Botany Bay, having detrimental effects on the breeding, growth and survival of native birds and the migratory cycle of the migratory waders.

Other Fauna. Many invertebrates characteristic of marine, estuarine and terrestrial habitats inhabit the Towra Point area. The Australian Littoral Society survey of 1977 recorded that no native mammals were found to inhabit the region, although it is thought that there may be a native rat and a species of bat in the Towra Point Nature Reserve. Most of the mammals are introduced, for example domestic cats and dogs, brown and black rats, rabbits and foxes. Amphibians tend not to inhabit this saline area but several snakes (such as the red-bellied black snake), eastern long-necked tortoises and skinks were recorded.

Recreational and Scientific Uses

Recreational activities are being restricted in the Towra Point Nature Reserve because of their impact on the environment. Activities such as fishing, water skiing, swimming, pleasure boating, horse riding, trail biking and

picnicking take place outside the nature reserve, and walking and bird watching can take place inside the reserve under permit. On the whole, though, recreational use is not a primary concern when considering sea level rise.

The area is unique in that it contains one of the last remaining large stands of mangrove and saltmarsh in the Sydney region, so a lot of scientific research is carried out there. Flat wetland areas will be extremely good indicators of sea level rise, so the area may become increasingly important to scientific interests in the future.

Fieldwork Findings

Fieldwork in the area involved the use of the primitive theodolite (figs 1, 2) to take measurements in order to find and plot on a contour map the new coastline after a hypothetical one metre sea level rise. The only feasible area was along Towra Point Road, since most of the other areas were inaccessible at high tide.

The theodolite was placed on the high water mark, on a day of a very high tide, close to Indian Spring High Tide Mark, and the view through it marked to landward. In this way the areas of land over one metre above this level could be determined. An assistant placed markers along this new line, and then the distance of the high water mark from the fringes of the mangroves was measured, and also that from the high water mark to the markers indicating the one metre higher level. Since the mangrove fringes are distinctly shown on the topographic map, the new coastline could be plotted easily.

As it turned out, this exercise was much easier than I had anticipated. When looking through the theodolite, I realised that the **entire area** would be inundated, except, perhaps, for the road (fig. 5).

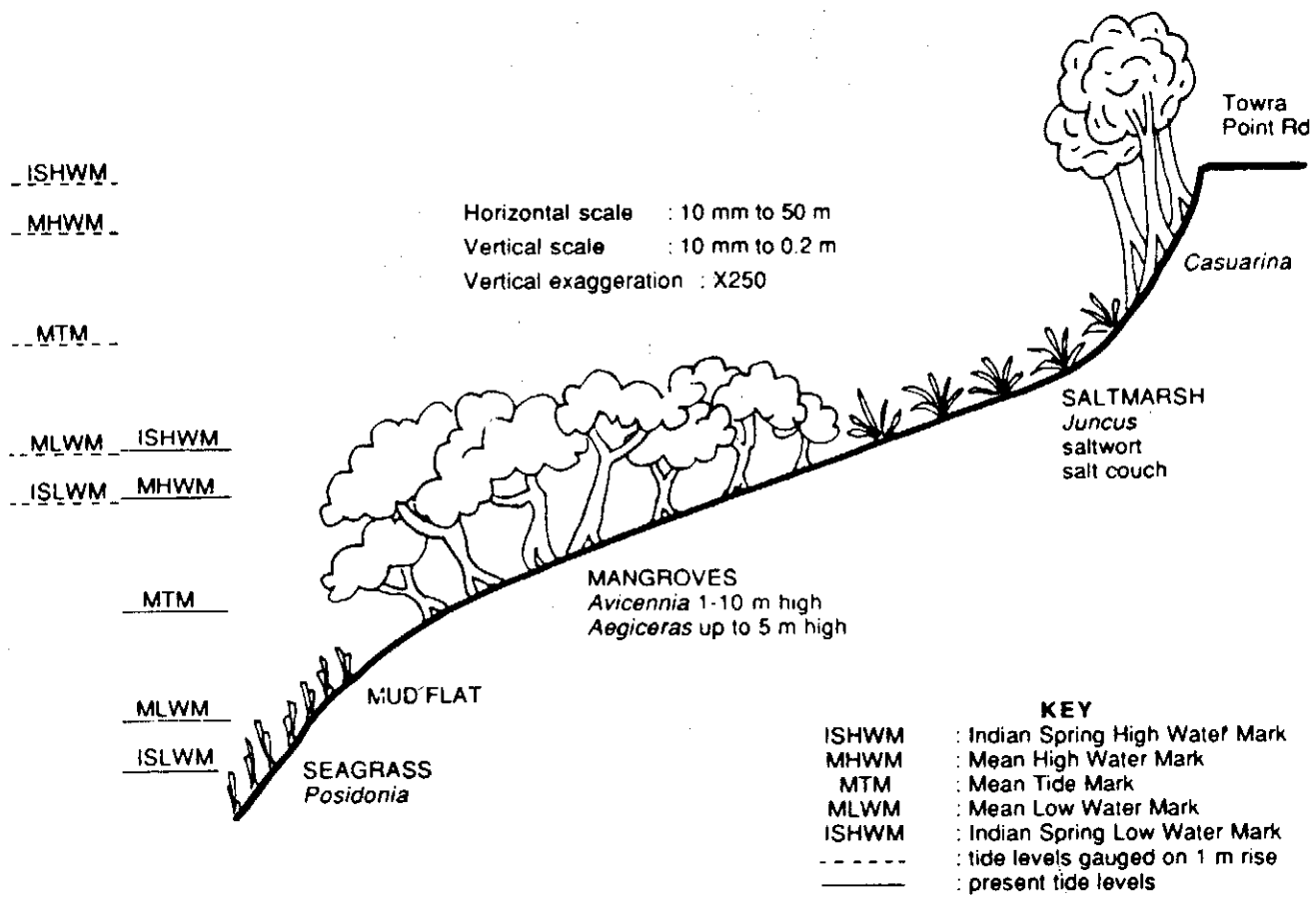

Figure 5 A section across the wetland adjacent to the Towra Point road, indicating present tidal levels and those based on a predicted rise in sea level of 1 m.

Effects on Other Estuarine Areas

In estuarine areas where there are fewer landward boundaries (such as rocky cliffs or built environments) to limit shoreward progression of vegetation zones, a rising sea level may be beneficial. Small river mouths will widen, seagrasses, mangroves and saltmarshes may have more opportunity to flourish, and these systems may become more extensive. On the other hand, when other factors related to the Greenhouse effect are taken into account, these may detract from any benefits caused by the sea level rise. An example would be increased rainfall introducing turbid waters into the system. Nobody knows what the balance will be, and at present no one seems to have the time, resources or dedication to do much research into a model which will be able to conclusively say in what ways seagrasses, mangroves and saltmarshes will be affected.

B. The Built Environment

Oyster Leases

The southern shores of Botany Bay are a major source of the Sydney rock oyster. More than 23 hectares of oyster leases are located in Woolooware Bay, Quibray Bay and around the Towra Point area (fig. 6). The Botany Bay estuary is closed to further leasing as it is considered to be fully utilised. Stick and rack cultivation are the predominant methods, with trays being used for fattening. Only around 15% of the oysters leave the Sydney region as the area is ideally placed for this major market.

In the course of my studies of the Botany Bay area, I interviewed an oyster farmer at an oyster depot located on the southern shores of Woolooware Bay. However, when the interview progressed to the possible effects of sea level rise on the industry, the oyster farmer displayed little knowledge of this possibility. After I had explained to him the Greenhouse effect and the predicted sea level rises, he told me that he wasn't sure he believed the theories of the scientists and that if it were ever to happen, it would be a problem for his great grandchildren, not him. When asked hypothetically to predict the effects on his industry if sea level rise were to occur, he responded that it was not a problem worth considering at this stage, and that if the Government didn't find a solution to the Greenhouse effect itself, then it would have to financially help the oyster industry adapt to any changes.

This indicates that sea level rise may generally have been ignored by the oyster farmers regarding their methods and plans for the future. In effect, the oyster leases would have to move back with the rising waters, but would be unable to do so because of houses and roads blocking their paths, and because of associated financial reasons.

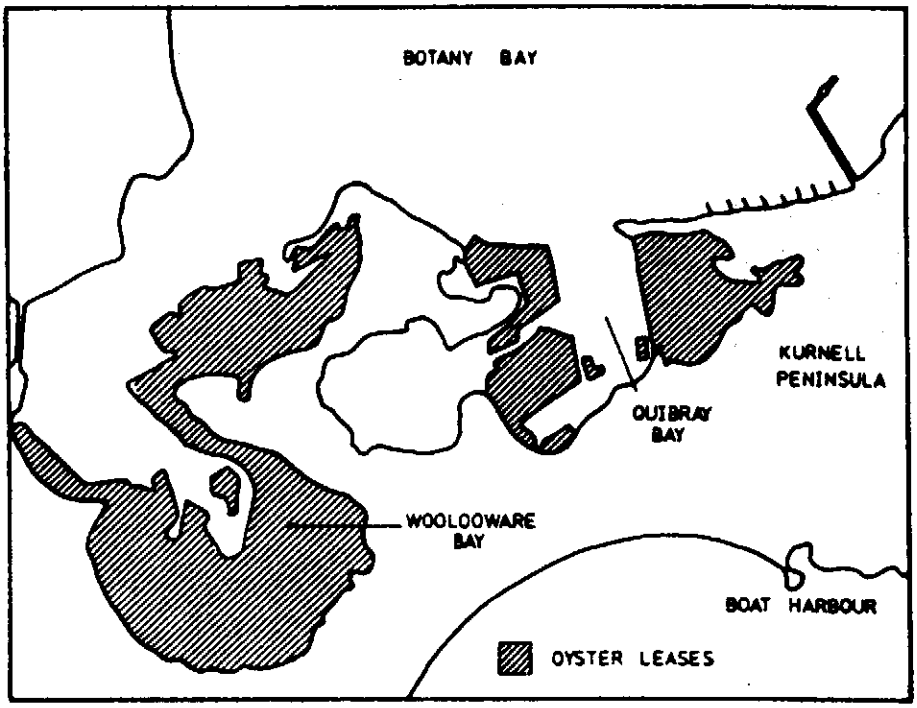

Figure 6 Location of oyster leases in Botany Bay (from SPCC, 'Coastal resource atlas for oil spills in Botany Bay', 1985).

Results of Questionnaire Survey

A questionnaire was designed for the residents of Kurnell Village (Appendix 1) to determine the extent of their knowledge regarding the impacts of sea level rise on their local area, and to see whether they were willing to begin taking preventative measures. The sample size was 20 questionnaires, and the streets surveyed were those waterfront streets which would be most affected.

Most of the people interviewed were convinced of the validity of the Greenhouse effect predictions; however, the majority thought that the water level would not rise as high as one metre. The "white collar" workers interviewed were more convinced of the theory, and generally more determined that something should be done immediately to counteract the effects of sea level rise on the area. The group who were less convinced or concerned were the housewives. Half of this group did not expect the Greenhouse effect to happen in their lifetimes or didn't think any money should be spent until further evidence became apparent. The older age group (50+ years) also seemed less concerned. There was a wide range of responses from the younger and middle-aged groups, some of whom seemed educated regarding the issue, and others who were a little more ignorant in this respect.

Most of the people accepted that the risks of flood damage and rising damp would increase in the future, but a quarter of them replied that their property values would not depreciate, and half were unsure whether or not they would. Just under 50% said that they would consider moving away from the waterside before evidence becomes more apparent and

before people become more aware of the problems; however, a resident with a "for sale" sign outside the front of her house said that the potential threat of sea level rise had not been a factor taken into consideration regarding the decision to sell.

The majority of interviewees wanted preventative measures to be initiated immediately and to a great extent, but only 55% said that they would be willing to pay extra taxes towards these measures or feasibility studies in the area. Some people, however, said that existing money should be re-allocated towards this cause. Obviously the people right on the waterfront (i.e. within 50 metres of present high water mark) generally seemed more willing to pay the extra taxes.

Coastal Erosion

Many of the interviewees drew my attention to the fact that the erosion of Bonna Point (fig. 7) had occurred over the previous few months, and could be evidence of increased wave action due to the Greenhouse effect. The beach groynes on Silver Beach were designed to stop the beach sand being washed along the beach and off the end of Bonna Point, but wave action on these areas had apparently increased dramatically over the past few years.

Whilst visiting the Maritime Services Board's scale model of Botany Bay, I brought the obvious erosion at Bonna Point to the attention of Mr Bruce Hudson, the hydraulic engineer. He informed me that the increase in wave action and resulting erosion had not been caused by the Greenhouse effect. It was actually due to the dredging of the Bay to allow the entrance of container ships to Port Botany. This dredging changed the shape of the floor of the Bay , and thus changed the direction of wave action. The Kurnell area received a large increase in wave intensity as a result. However, generally increased wave action in the future, due to the Greenhouse effect, would have similar results.

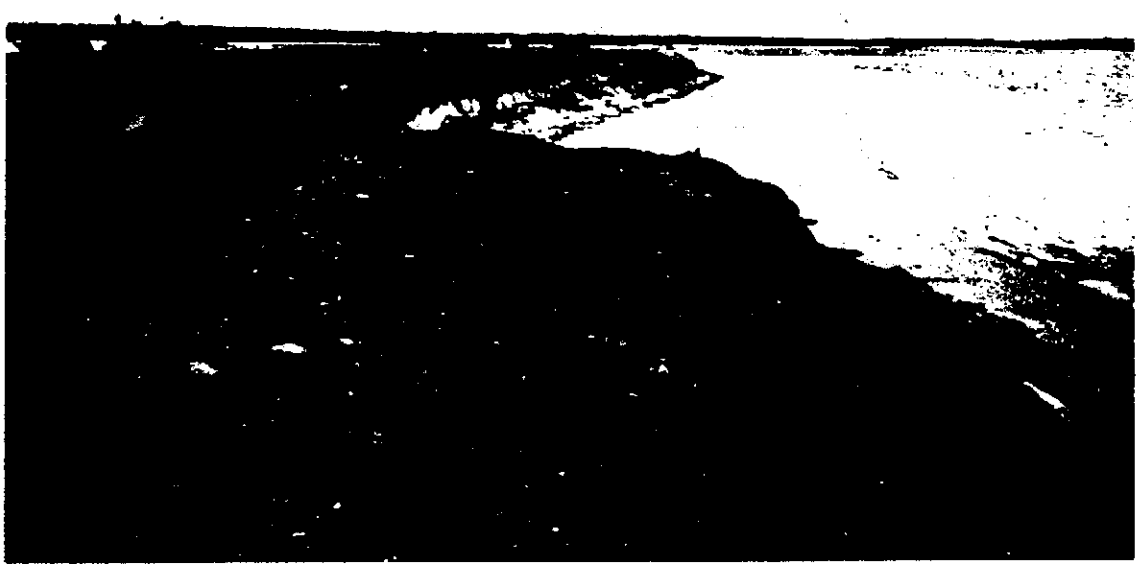

Figure 7 Effects of erosion at Bonna Point. The road has been washed away due to wave action.

Inundation of Kurnell Village

Figure 8 indicates the levels of tidal inundation on the Kurnell Village region, for both a 0.6 m and 1 m rise in sea levels. It was provided by Ms Wendy Barron, the Senior Policy Advisor to the New South Wales Minister for the Environment. It shows that a 1 m rise would submerge almost all of the peninsula, while a 0.6 m rise would inundate Horning Street and parts of Tasman, Torres, Bridges and Balboa Streets. This observation was reinforced on the MSB scale model of Kurnell. At the time, the model contained an accidental excess of water, and simulated a water rise of approximately 0.6 m.

Residential Properties at Risk

Properties such as those in Figure 9 are in an extremely high risk category with regard to any sea level rise. Even now some attempts have been made (e.g. using tyres) to prevent further erosion which would allow water to enter the properties, but a 1.m rise would cause total inundation. The tide was a height of approximately 1.9 m when these photographs were taken.

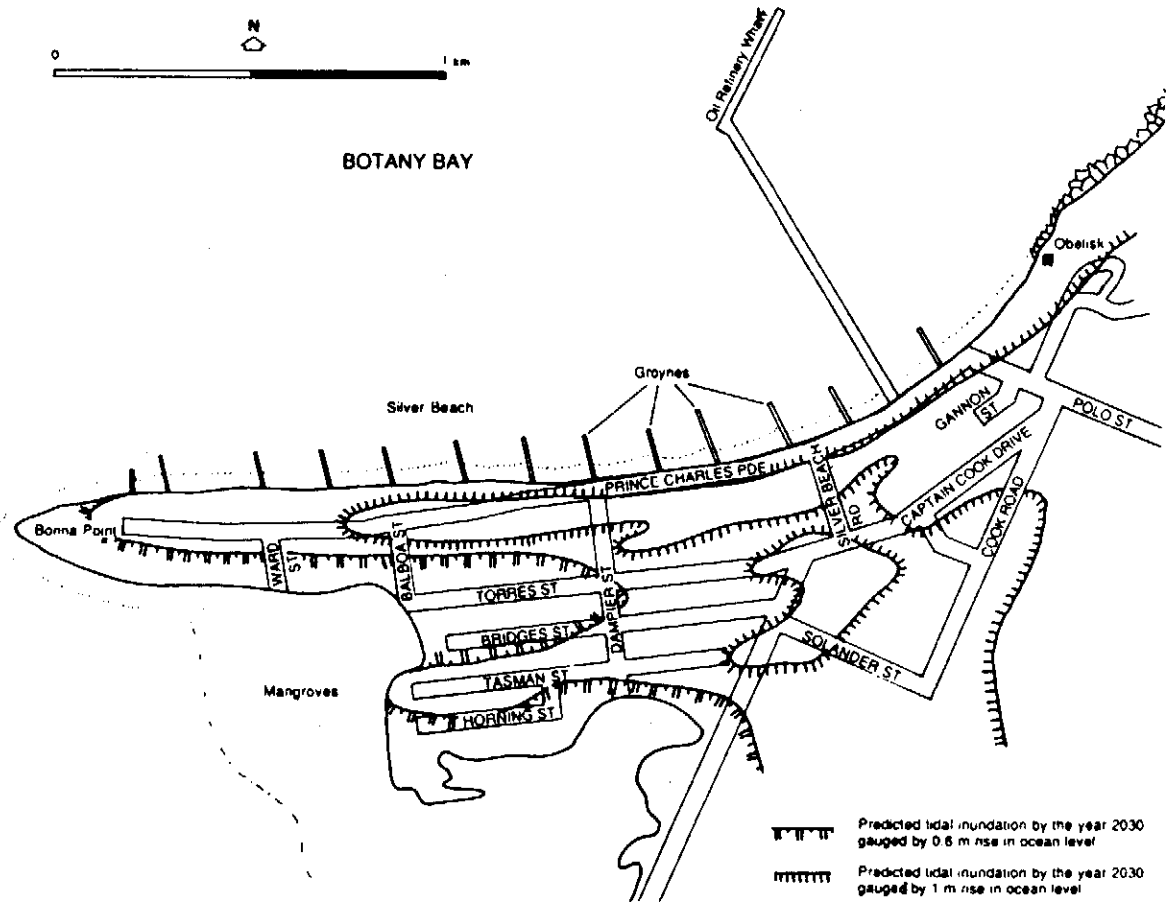

Figure 8 Tidal inundation of Kurnell Village based on two scenarios: a 0.6 m rise in sea level, and a 1.0 m rise.

Figures 9a, b Properties in the Kurnell area in the high risk category.

Inundation of Captain Cook Drive

I discovered that for parts of Captain Cook Drive, the surface of the road was a mere 0.3 m higher than the approximate 1.9 m high tide level. In this regard an officer of the Sutherland Shire Council's Planning Services Department said that there were two options:

i) Building levee walls to keep the waters away from the road. Sea walls are also a viable solution with respect to protecting properties and other coastal developments from sea level rise.

ii) Raising the road level to accommodate the new high tide levels. There would most likely have to be periodic closures of the road as a result of extreme conditions.

When asked about long term re-routing of the road as an alternative, this officer replied that this was not a viable alternative since it depended on the adjacent zoning of the land. It would also mean re-location of retail outlets, service stations, power poles and other land use activities located along the road. The costs associated with this would preclude this alternative.

Sewage Outfalls and Stormwater Drainage

Problems may occur in the future as water levels cover the outfalls. One solution is a tide flap system on the drainage outlets, a valve-like system which lets water out but not in. If this is found to be inadequate, then a pump system involving pumping stations forcing the water out into the Bay could be designed. The State Government has already been carrying out work at Kurnell in relation to this problem.

Future Planning for the Greenhouse Effect

In South Australia, the Salisbury City Council became one of the first local governments in Australia to introduce Greenhouse sea level rise into its local plan by specifying that future coastal developments at St Kilda must have a minimum floor level 3.5 m above the present high tide mark. The Sutherland Shire Council, responsible for Kurnell, has no future development requirements along these lines. The officer from the Planning Services Department said that it is on the Council's list for "future investigation" and that the Council was "awaiting direction from central authority".

On the other hand, a major private development company has plans for a tourist resort in the Kurnell region, including golf links and boating facilities. This company has supposedly taken sea level rise and increased storm surges into account in its planning by specifying a minimum fill level 0.3 m higher than the present highest tides. In my opinion, this is an underestimation and should be revised.

CONCLUSION

The flat topography of the region and the presence of the built environment restricting shoreward movement of the aquatic vegetation have combined to place this area at a high risk regarding possible future rises in sea level as a result of the Greenhouse effect. A one metre sea level rise would, in fact, inundate most of Towra Point, destroying the natural habitat of mangroves and saltmarsh, and the fauna that inhabits the area. This would be a great loss, since this is one of the last large stands of mangrove and saltmarsh habitat remaining on the New South Wales coastline.

The built environment on the Kurnell Peninsula is in a particularly susceptible area to sea level rise since the terrain is extremely flat and residential properties are located right on the edge of the water. The Sutherland Shire Council, as yet, does not appear to have given consideration to preparing the area for this eventuality (Appendix 1). Preventing the inevitable damage by acting now is always a better solution than repairing the damage after it has been done.

ACKNOWLEDGEMENTS

I would like to thank the following for providing information: Ms Wendy Barron, Senior Policy Advisor to Mr Tim Moore, NSW Minister for the Environment (*general Greenhouse effect outline and map showing potential inundation around Kurnell Village*); Mr Tony Roach, Technical Officer, Fisheries Research Institute, Cronulla (*effects of sea level rise on vegetation, fauna and other uses of Towra Point*); Mr John Travis, National Parks and Wildlife Service, Kurnell (*vegetation and migratory waders of the Towra Point region*); Mr Bruce Hudson, Hydraulic Engineer at the Maritime Services Board's Botany Bay Model (*erosion at Bonna Point and potential inundation around Kurnell Village, and potential effects and solutions regarding sea level rise on the built environment*); Mr Rob Williams (A taped talk on: *impacts of sea level rise on estuarine environments*).

My thanks are also due to those who co-operated with the interviews and questionnaire survey, and particularly to Tony Roach and Mark James of the Fisheries Research Institute for assistance with the fieldwork, and to my father, Dave Pollard, for his support and encouragement.

BIBLIOGRAPHY

Henderson-Sellers, A. & Blong, R. (1989). *The Greenhouse Effect: Living in a Warmer Australia.* NSW University Press, Kensington.

Pearman, G.I. (ed.) (1988). *Greenhouse: Planning for Climate Change.* CSIRO, Melbourne.

Leadbitter, D. & Pollard, D.A. (1986). *Proposed Towra Point Aquatic Reserve.* Fisheries Research Institute, Department of Agriculture, N.S.W.

APPENDIX 1

QUESTIONNAIRE

EFFECTS OF SEA LEVEL RISE ON THE SOUTHERN SHORES OF BOTANY BAY

QUESTION 1

Street
Age group
Occupation
Distance from the water's edge

QUESTION 2

How convinced are you concerning the truth of the Greenhouse effect theory? (Tick one of the below):

a) It will definitely happen;
b) it will probably happen;
c) if it happens, it won't be during our lifetime;
d) it is unlikely to happen;
e) it will not/ cannot happen.

QUESTION 3

Many scientists have predicted a sea level rise associated with the Greenhouse effect of between 20 and 140 cm by the year 2030. Do you accept that the sea level will rise? Yes/ No

By how much?

a) 140 cm or over;
b) around one metre;
c) around 50 cm;
d) 20 cm or below;
e) not at all.

QUESTION 4

Do you expect to experience any of the following in the next few decades? (For each, put the appropriate letter next to each point, i.e.,A, B, C, D or E).

A: Very much so;
B: a reasonable amount;
C: a little;
D: not at all;
E: don't know.

(i) Water level will cause the whole property to be inundated;
(ii) it will greatly increase the risk of flood damage;
(iii) increased saline (salty) water will cause plants to wither and die;
(iv) it will cause more rising damp in the houses;
(v) it will cause structural damage to the foundations due to increased undermining wave action;
(vi) by how much do you think your property value will be depreciated as a result of the Greenhouse effect?

QUESTION 5

Have you recently experienced any changes with relation to sea levels, wave action or any of the above points?

QUESTION 6

Would you consider moving away from the waterside before evidence of the above points begins to occur and before people become more aware of the problems? Yes/ No

QUESTION 7

When do you think preventative measures should begin to be initiated?

a) Immediately, a lot;
b) immediately, a little;
c) not until more evidence is apparent;
d) no taxpayers' money should be wasted.

QUESTION 8

Would you be willing to pay extra taxes towards preventative measures and feasibility studies in your area?

QUESTION 9

Do you have any comments regarding the issue?

THANKYOU FOR YOUR CO-OPERATION IN THIS SURVEY