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HISTORICAL DISTRIBUTION OF ESTUARINE WETLANDS AT KURNELL PENINSULA, BOTANY BAY

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ABSTRACT

Estuarine wetlands are important habitats for fish and birds and information concerning changes to their distribution is required to aid management decisions. Analysis of a series of aerial photographs taken between 1956 and 1996 showed a substantial increase in area of mangrove (39.5 ha, 33%) and woodland (67.6 ha, 60%) in an estuarine wetland on the eastern side of Quibray Bay, Kurnell. Simultaneously, saltmarsh vegetation decreased by a substantial amount (62.4 ha, 79%). These changes in vegetation coverage appear to be related to landuse on the Kurnell Peninsula, particularly an increase in industrialisation and urbanisation over the last 50 years.

Keywords: estuarine vegetation, GIS, Kurnell Peninsula, mangrove, saltmarsh, wetlands.

INTRODUCTION

Wetland ecosystems cover approximately 6% of the world's land area (Saenger *et al.* 1983) and include estuaries and inland flooded plains. Although their full range of ecological functions is not always known, wetlands can be valuable habitats for birds and fish, and help maintain water quality.

In Australia, various estimates have been made of the extent of wetland coverage, ranging from 0.3% (Anon. 1990) to 3% (Cocks 1992). Galloway (1982) estimated that mangrove forests covered 11,500 km^2. Approximately 8% of this area is protected as conservation reserves (Robertson & Alongi 1995), which compares well to other nations with extensive mangrove habitats. This level of protection can be attributed to the remoteness from urban centres of our major mangrove resources and the lack of population and development pressure on these areas (Saenger *et al.* 1983, McComb & Lake 1990).

Wetlands along the coast of NSW have been extensively modified since European settlement. For example, on the basis of calculations by Goodrick (1970), there was a net loss of 40% of coastal wetland (from 1072 km^2 to 663 km^2) between settlement (1788) and 1969. The most recent documentation of estuarine wetlands in NSW was

based on aerial photographs taken in the late 1970s and early 1980s (West *et al.* 1985).

Nonetheless, there are still several wetlands in NSW that are recognised as being of international significance, e.g., Towra Point and Kooragang Island, which are listed in the Ramsar convention. However, these two sites represent only a small proportion of the overall area of coastal wetlands in NSW. There are many smaller wetlands that may be important, though are unrecognised and as such are poorly managed.

The reasons for the decline in coastal wetlands are sometimes obvious and otherwise obscure. The object of this study was to conduct an historical assessment of large-scale vegetation changes in an estuarine wetland in relation to evolving landuse. A study site was chosen at Kurnell Peninsula and a suite of GIS techniques used to analyse change.

STUDY SITE

The Kurnell Peninsula, located on the southern shore of Botany Bay 16 kilometres to the south of Sydney (Figure 1), is steeped in Australian history. Since Captain James Cook's landing in 1770, it became a site of agricultural and industrial activity, a place of increasing urban development, and has an extensive and internationally significant wetland at Towra Point. The study area is located east of the Towra Point Nature Reserve, and within the sanctuary zone of the Towra Point Aquatic Reserve. No activities affecting fisheries resources are allowed in the sanctuary zone. The limits of this zone extend to the mean high water level, thus including some of the mangrove vegetation but not the saltmarsh ecosystem.

Over the past 200 years, there have been substantial environmental changes to the Kurnell region as a result of European settlement. In his comprehensive review of the ecology Botany Bay, McGuinness (1988) identified some of these activities. Table 1 summarises the events between 1788 and 1990 that may have impacted on the wetland studied in this report. Note that the majority of disturbances in the

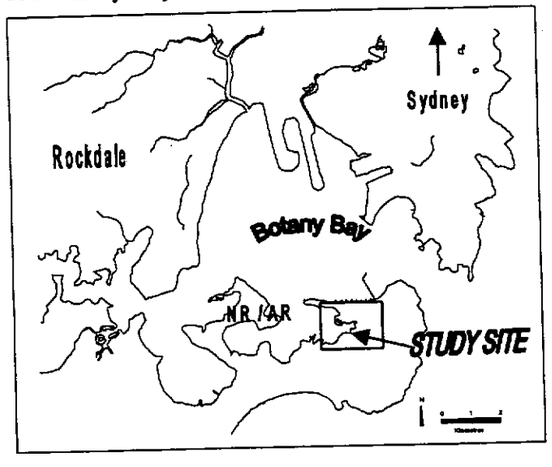

Figure 1: Location map of the study area, adjacent to Quibray Bay and Towra Point. NR/AR = Towra Point Nature Reserve/Aquatic Reserve.

Table 1: Historical events between 1788 and 1950 that may have affected the Kurnell wetlands (all from McGuinness [1988] unless otherwise stated).

Year	Event
1800	Extensive timber harvesting began, and nearly all the large trees were felled in the following 40 years (Walker 1968 and Neve 1969).
1810	Soap manufacturing near Botany Bay; mangroves used for production of alkaline ash (Mitchell & Adam 1989b).
1820	John Connell establishes his agricultural estate "Quibray", covering 450 ha of the Peninsula and 70 ha of saltmarsh, hence agriculture began to expand rapidly (Walker 1968 and Neve 1969).
1885	Mobile sand dunes created from land clearing were moving towards Quibray Bay at nine metres a year, spilling into the Bay in 1923.
1900	Systematic cultivation of oysters began; 40,000 stone slabs at Towra Point; 400,000 at Pelican Point. The timber used in harvesting came from the mangroves.
1900-1920	Several severe bushfires swept the Kurnell Peninsula.
1940	Sand extraction on Kurnell Peninsula began on a regular basis.
1953	A permanent road was built along the length of Kurnell Peninsula; saltmarsh was reclaimed for a major stretch of the roadway (Pearton 1983).
1955	Kurnell Refinery was constructed; dredging and wharfage works initiated.
1964	Dredging projects commissioned to provide for access to refinery jetty and For the airport runway. Wave regime disturbed (Walker 1968).
1980	Extensive areas of mangrove dieback in Quibray Bay. Thought to be a result of the 1979 *World Encouragement* oil spill.

early years originated from agricultural activities, while industrial change was evident from the 1950s onwards.

In the 1800s, early pioneers harvested timber and subsequently cleared the land of other native vegetation for agricultural purposes (Neve 1969). As it is known that soap was produced on the northern side of Botany Bay (Mitchell & Adam, 1989a), it is possible that mangroves from Towra Point and Quibray Bay were burnt to yield the alkaline ash for use in soap manufacturing.

By 1842, nearly all large trees had been cut for lumber (Walker 1968).

Mobile sand dunes were created by the clearing of land, and these spilled into the surrounding waterways, including Quibray Bay, possibly creating new substrate for mangroves to colonise. The township of Kurnell quickly grew from a fishing village, linked to the rest of Sydney only by boat, into an area of great economic importance. With the development of the Australian Oil Refinery (a subsidiary of Caltex Petroleum Corporation), a road needed to be constructed to link Kurnell to Cronulla. The road was completed in 1953, and whilst the refinery was under construction, urban development expanded rapidly. Two years later the oil refinery was completed.

Between 1955 and the mid-1960s, other industrial activities were established in and around Kurnell. Aside from the permanent facilities to extract sand from the region, other industries (e.g., Abbott Laboratories) were also developed. These industrial facilities had an impact on the environment when additional amounts of vegetation were cleared and when drains were constructed to remove excess water from the newly developed sites.

A wharf was constructed for the oil tankers. Oil spills were occasionally washed onto the shores of the wetlands, and in several cases have been related to instances of mangrove dieback. For example, after a major oil spill of 95 tonnes in September 1979, mangrove dieback was extensive on the south-western side of Quibray Bay by mid-1980 (NSW National Parks & Wildlife Service 1989).

MATERIALS & METHODS

To determine the history and impact of development on the selected wetland, a series of aerial photographs were examined. Changes in the spatial distribution of mangrove, saltmarsh and woodland vegetation within the study area from 1956 to 1996 were evaluated using the photographs, an orthophotomap and a geographical information system (GIS).

One aerial photograph from each of the years 1956, 1966, 1970, 1982 and 1996 (details in **Appendix 1**) was scanned to create electronic images using a flat-bed scanner operating with a resolution of 300 dots per inch (dpi). Taking into account the difference in scale of the photographs, the resolution (pixel size) varied greatly. In order to compare images, a standard resolution was chosen of 1 pixel equal to $4m^2$.

While aerial photographs are a valuable resource with which to assess vegetation and landuse change, they are distorted due to the effects of the camera lens and the moving aeroplane from which they are taken. To establish a common scale and orientation, the images were spatially corrected to a set of x and y ground control point coordinates obtained from the orthophotomap (Appendix 1). Orthorectification was not considered necessary due to the low relief within the study site.

Spatial correction required a minimum of six ground control points per photograph, though the ideal situation of using the same points from permanent, identifiable structures was not possible due to ongoing changes within the study site. The effectiveness of the rectification transformation was checked by calculating the root mean square error (RMS). If a high RMS value was present (greater than $\pm$ 2m, Smith 1986), new ground control points were identified and the procedure repeated.

Spatial correction was carried out within the software package DIMPLE. This software resampled each image using a quadratic polynomial transformation and nearest neighbour interpolation. Distinction of the vegetation boundaries required refinement to establish clarity. The images were enhanced using the graphics software package Image-In. Edges of the boundaries were sharpened, and the images were saved as Tagged Image Format (TIF) binary files in a raster format. Subsequently, the images of the study area were registered to Arcview GIS Version 3.0, so that area measurements could be obtained.

Inspection of the photographs, in addition to providing an understanding of basic coastal vegetation communities, suggested that three

main vegetation classes were present: mangrove, saltmarsh and woodland. A fourth class (residual vegetation) was used to define heath, coastal grasses, and some exotic species such as bitou bush and lantana on the sand dunes and around industrial sites. Changes in area of the latter zone were not assessed.

Three other classes were set up to deal with the residential area, the industrial area and the roadways. Two more classes dealt with sand and water. In total, nine classes were used to map the vegetation and landuse types in the five aerial photographs. Two additional classes were created in the maps from 1966 onwards to cover the impacts of development. One class was made for the two drains which run into the wetland via a culvert under Captain Cook Drive, and the other class identified areas which were wholly or partially cleared in the process of further developing the Kurnell Peninsula (bare earth).

The boundaries of each class were distinguished using differences in contrast, tone and texture, and then digitised. Each layer was digitised using a polygon theme and corrected for errors. The areas of each vegetation type within the study area were calculated within Arcview and compared by overlaying the successive years onto one another. A table of change in area of mangrove, saltmarsh and woodland was produced.

The process of manually digitising enables particular areas to be highlighted, calculated and analysed, but errors can occur. The nature of manually digitising areas is in itself problematic, as the production of adjacent polygons can result is line overruns, gaps between polygons (sliver polygons), unsnapped nodes and duplicated lines. These are potential intraoperator errors in a GIS analysis, which need to be corrected. Therefore, the vegetation boundaries of the mangroves, saltmarsh and woodland were digitised three times in each photograph to determine the intraoperator error.

The 1996 aerial photograph, and a printout of its electronic image were taken into the field to check the validity of the present day vegetation and boundary classifications, and to create a firm basis on which to evaluate the earlier photographs. The distribution of existing wetland vegetation (1997) was assumed to be the same as at the time of the latest aerial photograph (1996), as it is unlikely major vegetation shifts occurred in that interval.

Inspection tracks were set out to identify the range of vegetation communities within the study area. Two mangrove species (*Avicennia marina* and *Aegiceras corniculatum*) and six saltmarsh species (*Juncus kraussii, Sporobolus viginicus, Sarcocornia quinqueflora, Suaeda australis, Triglochin striata* and *Baumea juncea*) were found. No attempts were made to discriminate between *Casuarina* and *Eucalyptus* species, and both were considered as the "woodland" community. The boundaries shown in the photograph and the image were compared to those found in the field, and the image altered where necessary. The same mapping procedure was used to evaluate the earlier photographs, though obviously no ground truthing was carried out.

RESULTS

Analysis of the mangrove/saltmarsh wetland to the eastern side of Quibray Bay, by use of aerial photographs and

Arcview GIS, produced of a time series of vegetation and landuse maps. The development of a time series of maps enables changes in wetland coverage to be correlated with the potential impact of human activities. Five vegetation maps were constructed: 1956, 1966, 1970, 1982, 1996 (Evans 1997), but only the 1956 and 1996 maps are reproduced in this report, and are shown at a scale of approximately 1: 20,000.

Nine different classes were identified in the 1956 map (Figure 2A), and eleven classified in the 1996 map (Figure 2B) due to the inclusion of the two "urban development" classes. Of primary interest is the change in area of mangrove, saltmarsh and woodland over successive decades; these results are presented in Table 2. Figure 3 is a graphical representation of these changes.

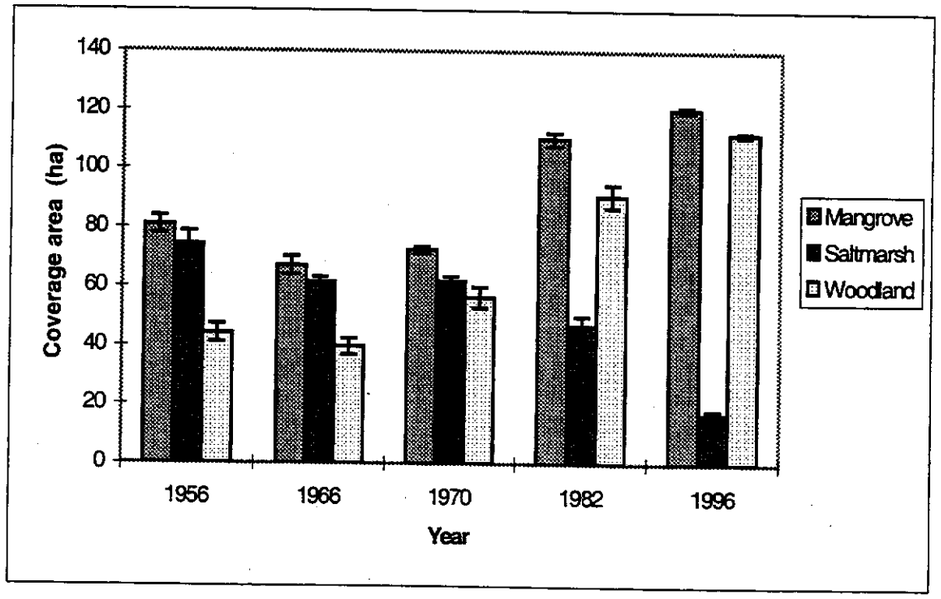

Figure 3: Changes in the distribution of wetland vegetation over the past 40 years within the study area on the Kurnell Peninsula. Mean and standard error of three separate estimates of area are shown.

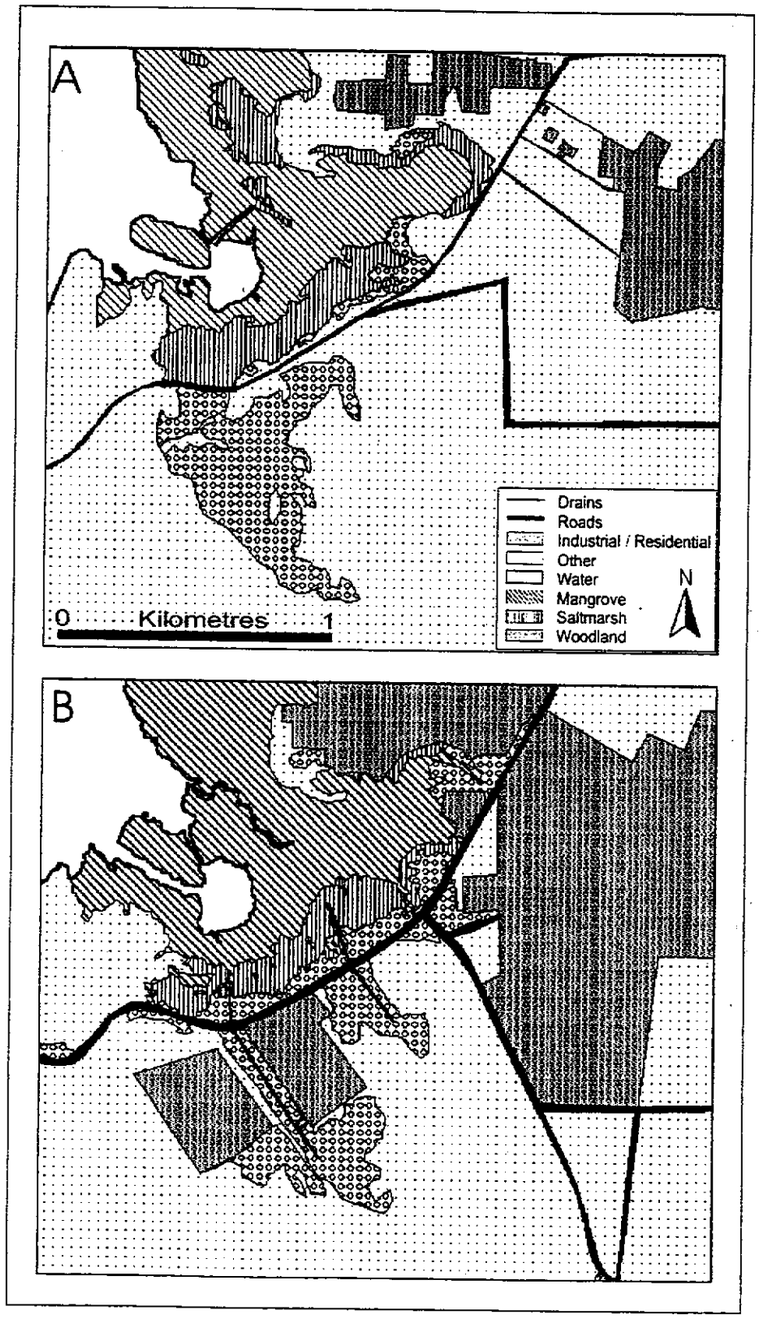

Figure 2: GIS generated vegetation and landuse maps of the study area, Kurnell **A** – 1956 coverage map; **B** – 1996 coverage map.

Table 2: Areas of wetland and woodland vegetation in the study area, and the degree to which each has changed over the past 40 years.

Year	Vegetation Type	Coverage (ha)	Change (ha)	Cumulative Change (%)	Standard Error (ha)
1956	Mangrove	80.8	-	-	0.51
	Saltmarsh	79.3	-	-	0.75
	Woodland	44.3	-	-	0.56
1966	Mangrove	67.1	-13.7	-17.0	0.50
	Saltmarsh	61.6	-17.7	-22.3	0.27
	Woodland	39.8	-4.5	-10.2	0.45
1970	Mangrove	72.5	5.4	7.5	0.19
	Saltmarsh	62.0	0.4	0.7	0.26
	Woodland	56.6	16.8	29.7	0.60
1982	Mangrove	110.1	37.6	34.2	0.37
	Saltmarsh	47.0	-15.0	-24.2	0.55
	Woodland	90.8	34.2	37.7	0.66
1996	Mangrove	120.3	10.2	8.5	0.12
	Saltmarsh	16.9	-30.1	-64.0	0.22
	Woodland	111.9	21.1	18.9	0.09
NET CHANGE (1956 – 1996)	**Mangrove**		**39.5**	**32.8**	
	Saltmarsh		**-62.4**	**-78.7**	
	Woodland		**67.6**	**60.4**	

The area of mangrove in the Kurnell study site experienced an overall increase, from 80.8 ha in 1956 to 120.3 ha in 1996, an increase of 39.5 ha (~33%) in 40 years (Table 2, Figure 3). Initially there was a loss between 1956 and 1966, possibly related to the construction of the oil refinery; but since that time there has been an increasing trend. The major part of the expansion occurred between 1970 and 1982, when mangroves colonised the area of sand that spilled out into the southern shores of Quibray Bay.

Another sizeable increase within these 12 years occurred when the saltmarsh once present in the northeastern sector of the study area (Figure 2) was invaded by *A. marina*. Mangrove expansion levelled off after 1982.

Saltmarsh vegetation decreased substantially from 1956, where losses in area amounted to 62.4 ha (~79%) in 40 years (Table 2, Figure 3). In 1956 (Table 2) the total amount of saltmarsh was 79.3 hectares, though this area decreased to a mere 16.9 hectares by 1996. From 1956 to 1970 the loss was relatively small, but 45 ha were lost between 1970 and 1996 (Figure 3), i.e., at the same time the major mangrove expansion was seen.

In addition to the loss of the large meadow of saltmarsh in the northeastern sector (between 1970 and 1982), losses to the fringing saltmarsh have also been quite large. These losses occurred in conjunction with

urban expansion to the east side of the study site, and reclamation for the electricity sub-station and horse riding facilities. Other, and smaller losses, occurred with the expansion of woodland west of Captain Cook Drive.

The area of woodland increased by 67.6 ha from 1956 to 1996. The major change in area occurred between 1966 and 1996.

DISCUSSION

Over the last 200 years there have been substantial changes to the environment of the Botany Bay region (Table 1). Land clearing and increased runoff have promoted erosion, which we believe has led to increased sedimentation, providing new habitats for colonisation by mangroves. Simultaneously, woodland area has increased and saltmarsh has been destroyed.

The results presented in this report are consistent with similar studies conducted on the southern side of Botany Bay, where a pattern of saltmarsh decrease and mangrove increase has prevailed. Between 1942 and 1986 Mitchell & Adam (1989a) noted a 38% decline in area of saltmarsh at Towra Point which was almost matched by the increase in mangroves. Fenech (1994) calculated a saltmarsh loss of 73% at Quibray Bay between 1956 and 1994, but a mangrove increase of four percent. However, she attributed the small change in mangrove area to the poor quality of the 1956 aerial photograph; it was not possible to clearly distinguish between mangrove and woodland.

From a historical perspective, there is reason to believe that degradation of the saltmarsh environment occurred even before the first aerial photograph used in this report (1956). The construction of Captain Cook Drive began in 1953 and large amounts of the marsh were reclaimed (Pearton 1983) for this road development.

The saltmarsh community is an environment particularly susceptible to the impacts of human action, due to its location at the fringe of the terrestrial environment and of tenures being in private ownership. If the rate of loss identified in this study is maintained, the rest of the saltmarsh around the southern shores of Botany Bay will almost certainly be lost in the next 40 years. Furthermore, if the loss rate is similar elsewhere around the south-eastern Australian coastline, than the future of the saltmarsh appears bleak.

Woodland is the third vegetation community for which areal calculations were made, and the changes over time are significant. Woodland followed the trend shown by mangrove with a slight early loss, though there was a rapid recuperation and an overall increase in area of 67.6 ha (~60%) resulted (Table 2, Figure 2). The greatest expansion occurred between 1970 and 1982 when the woodland increased by 34 ha.

The development of industry near the southeastern shores of Quibray Bay (e.g., Abbott Laboratories) destroyed a large stand of woodland during the early 1960s, which possibly accounts for the earlier loss recorded. This community has since returned and expanded onto fringing land adjacent to the industrial estate as well as encroaching on the saltmarsh from the landward direction. In conjunction with the industrial expansion, two drains were constructed between 1956 and 1966 (Figure 2B) and flow under Captain Cook Drive into the wetland; woodland has colonised the banks of these drains.

In summary, the history of landuse change at Kurnell began with the harvest of timber and the clearing of land for agriculture, but over the past

50 years these activities were followed by the development of industry and an increase in urbanisation. The more recent changes can be readily tracked with aerial photos.

Mangrove and woodland have increased in area, albeit at slightly different rates. The increase in the former has leveled off, whereas the latter would seem to still be increasing. Saltmarsh has continually declined since 1956; its long-term fate is uncertain. The estuarine wetland and woodland environments are linked, although in ways not yet fully understood. To enable the saltmarsh to have a sustainable future, further alterations to the landuse patterns of the southeastern portion of the Kurnell peninsula should be done with the knowledge that even small changes can have a detrimental impact on adjacent vegetative communities.

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APPENDIX 1

Details of the aerial photographs and orthophotomap used in this analysis.

2/1/1956 **Port Hacking** Run 30: 235-5153; 235-5154. 6400' ASL 115.00mm Crown Copy NSW Lands Photo.

29/8/1965 **Cumberland 1965 Series** Run 26: 1405-5146. 8350' ASL 114.44mm Crown Copy NSW Lands Photo.

22/3/1966 **Port Hacking** Run 1c: 1440-5159. 15500' ASL 114.44mm Crown Copy NSW Lands Photo.

6/7/1970 **Cumberland 1970 Series** Run 24: 1906-5204. 7500' ASL 152.37mm Crown Copy NSW Lands Photo.

28/7/1982 **Wollongong 1:16,000 Colour** (M1320) Run 2: 2999-132. 2483m ASL 151.45mm Crown Copy NSW Lands Photo.

31/5/1996 **Kurnell 1:20,000 Colour** (M2031) Run M203103: 161-167. 3060m ASL 152.76mm Land Information Centre.

19/9/1983 **Kurnell Orthophotomap** (U1830-4) 1 : 4000. Central Mapping Authority of New South Wales.