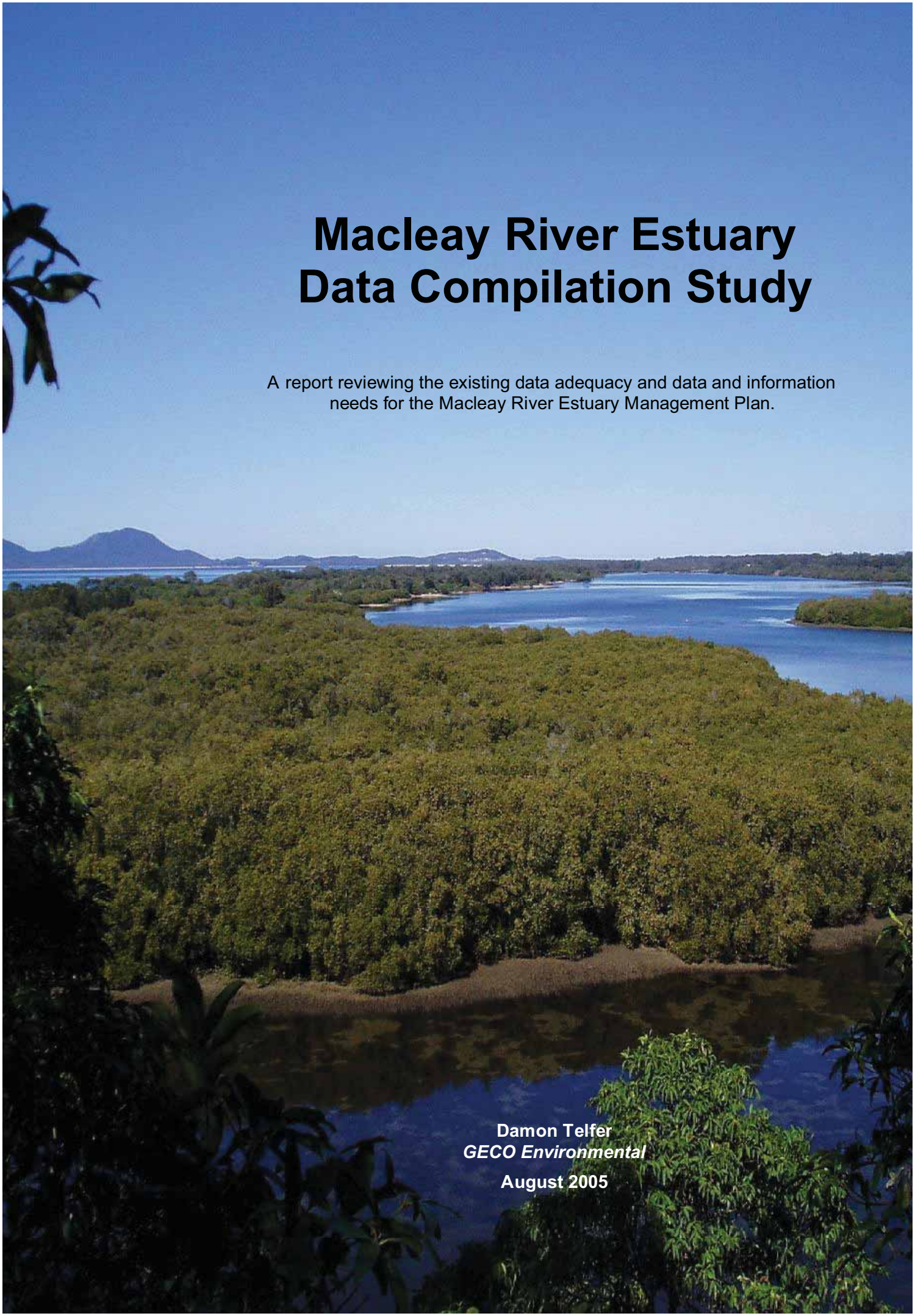
Macleay River Estuary Data Compilation Study

A report reviewing the existing data adequacy and data and information needs for the Macleay River Estuary Management Plan.



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Cover Photo: Macleay Arm, the old entrance of the Macleay Estuary, as viewed from the site of the old Pilot's Station, Grassy Head

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Introduction

In 1992, the NSW State Government introduced an Estuary Management Policy aimed at managing the growing pressures on estuarine systems. Under the policy the Department of Infrastructure, Planning and Natural Resources is responsible for coordinating in cooperation with local Councils the preparation of Estuary Management Plans (EMP). The procedure for developing an EMP is set out in the Estuary Management Manual (NSW Government, 1992). The current revision of the procedure follows an 8 step process;

1. Form an Estuary Management Committee
2. Identify issues and set goals
3. Assemble existing data
4. Carry out an Estuary Process Study
5. Carry out an Estuary Management Study
6. Prepare and review the Estuary Management Plan
7. Adopt and implement the Estuary Management Plan
8. Monitor and review the management process

In accordance with this process, Kempsey Shire Council has formed a local Estuary Management Committee with representatives of all key stakeholder groups. In 2004 the EMC drafted an issues paper which was subsequently adopted as the basis for moving forward towards the preparation of an Estuary Management Plan.

This study, the Macleay River Estuary Data Compilation and Review Study and Report, is Step 3 in the Estuary Management Process.

Aims

The major aims of this study and report are to;

- Identify and collate all available existing data sources of relevance to the management of the Macleay River estuary (including reports, proceedings, journal articles, digital data sets, aerial photographic records, etc) and compile into a web-accessible electronic register.
- Review the data sources to determine their usefulness and adequacy for addressing the issues identified by the EMC.
- Determine gaps in the data and information set that are potentially limiting to the development of the Estuary Management Plan.
- Make recommendations as to what additional datasets or investigations are required to be collected during subsequent stages of the EMP, particularly the Estuary Processes Study (Stage 4)

Scope of this Report

This scope of this report is generally limited to the collation and review of existing data and information sources. This information is presented in Section 2 of the report but is also contained in an electronic database in both MS Excel format, Adobe PDF format, and in a web-based register. The information in this report is a summary of the review and more detail can be found in the electronic register which is cross-referenced throughout the report. The interpretation of these data and information sources should be undertaken in subsequent phases of the EMP process, specifically in the Estuary Management Study and Estuary Management Planning phase.

The major exception to this is in the areas of estuarine geomorphology, estuary flora and fauna, and estuary infrastructure, each of which were identified as important data gaps prior to the commencement of this study. In these cases, this study has sought to collect this data at a resolution that will meet the requirements of future stages of the EMP process. The data collected and preliminary interpretations are provided in Section 3 of this report.

In terms of the collation of digital data and photographic resources, issues of copyright and data custodianship and licencing have in some cases limited the collation to the identification of the resources only. Nevertheless, some datasets have been obtained for the project and others created such as a full set of 2003 orthorectified 1:25,000 colour airphotographs that cover the entire study area and several new datasets related to estuarine geomorphology, vegetation, and infrastructure (available sets detailed in Section 3)

As part of this study it was also requested that the historical context of the Macleay River estuary and its management be investigated. This is presented in Section 1 of the report but is limited to available written records and does not include the extensive oral history which is potentially available from some of the longer term residents of the valley.

Section 4 of the report identifies important gaps in the current data and information set and Section 5 provides recommendations for the Estuary Management Committee for future stages of the Estuary Management Planning Process.

This project has reviewed and collected an enormous amount of information and for ease of use the report is a summary of this information. For further detail consult the Macleay River Estuary Data Compilation Project CD located on the back cover of this report.

PART 1 HISTORICAL CONTEXT - MACLEAY RIVER ESTUARY

The Macleay River estuary extends some 54 km upstream from the ocean to the tidal limit at Belgrave Falls, about 10km upstream of Kempsey (Figure 1.1). The coastal floodplain has an area of approximately 400km^2 below Kempsey. The floodplain includes well defined natural levees up to 7 m above 0 AHD along the river and creeks below Kempsey, grading to large semi-permanent backswamps often <1 m above 0 AHD, and occasionally below sea level (Tulau & Naylor, 1999). These backswamps cover some 240km^2 representing approximately 60% of the floodplain.

Until the flood of 1893, the river reached the sea at Grassy Head, 3 km north of Stuarts Point. In a major flood in that year the river breached the sand barrier just north of South West Rocks. Since that date, the entrance has been at South West Rocks (assisted by extensive breakwalls), although floodwaters may also drain to the ocean through Korogoro Creek, Ryans Cut, Killick Creek and South West Rocks Creek. Floodwaters may also flow either to or from the Hastings catchment, depending on relative flood and tide levels, via Connection Creek (Webb, McKeown & Associates Pty Ltd 1997). The old estuary channel between South West Rocks and Grassy Head is now an extensive backwater known as the Macleay Arm. Other major tributaries of the estuary include Christmas, Borirgalla and Clybucca Creeks and Andersons Inlet in the north and Belmore River and Kinchella Creek in the south.

Figure 1.1 *The Macleay River estuary and coastal subcatchment.*

1.1 Evolution of the Macleay River Estuary

The position of Australia's coastline has varied with global climatic variations over the last 2 million years. Although glaciation did not occur extensively throughout Australia over this time period, periods of glaciation elsewhere produced dramatic effects on sea levels along the coast. During periods of glacial maxima lower sea levels occurred, displacing the coastline seaward onto the continental shelf. Under these conditions rivers cut deep valleys as they flowed to the sea. In interglacial periods, when sea levels are high, the coastal river valleys become drowned forming embayments which then become progressively infilled from both land (catchment erosion) and sea based sources (waves pushing sand into embayments). Research along the eastern coastline has revealed that there have been a succession of these events with the last period of glacial influence beginning to decline around 10- 12,000 years ago (Roy et al., 2001).

Since this period (10-12,000 years ago) sea levels have risen from 120 m below present to one to two metres above present by 7500 – 6500 years ago. Sea levels have since fallen to their present level approximately 3000 years ago and have remained essentially stable since.

In the period between 6,500 and 3,000 years ago the current day Macleay floodplain did not exist. As sea levels reached their maximum the Macleay valley would have been inundated with the deposition of a transgressive sand sheet between the rocky headlands of Crescent Head to South West Rocks (Figure 1.2). This transgressive sand sheet would have formed a barrier that bounded an open marine embayment.

Plate 1 *Birdsfoot delta formation on Kinchella Creek (Source: LIP 2003 1:25000 aerial photography, orthorectified for this study)*

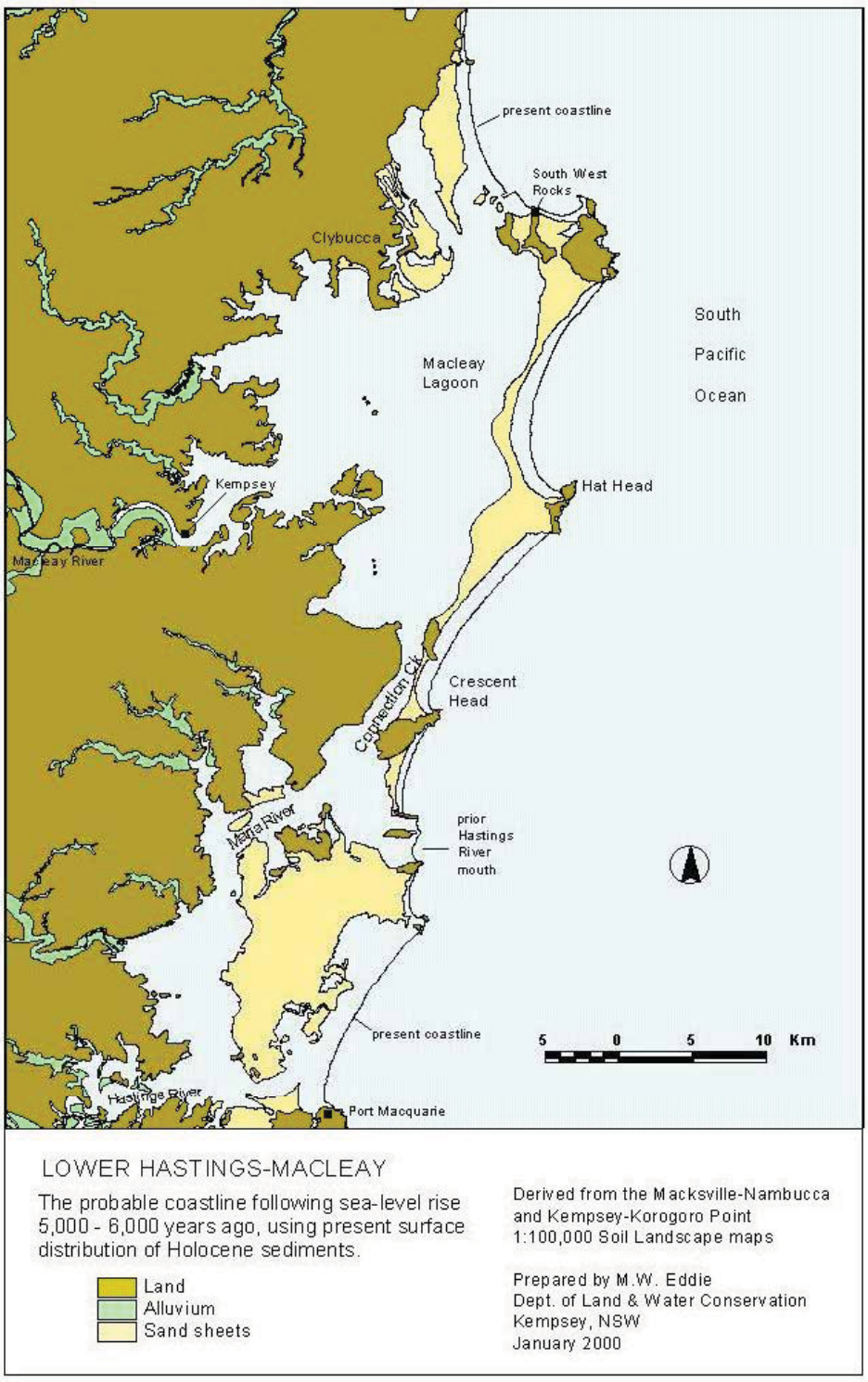

Figure 1.2 *Schematic of the Macleay Estuary in the mid-Holocene (5-6,000 years ago, after Eddie, 2000).*

Under stable sea level conditions and the influence of ongoing coastal processes such as littoral drift (the northward progression of sands up the eastern Australian coastline) and estuarine and tidal processes associated with flood-tide delta formation and back-barrier deposition, the coastal barrier would have built. This emergent barrier produced a low-energy environment in the central mud basin — conducive to the deposition of estuarine muds. On the Macleay River the deposition of these estuarine muds along with continued progradation of fluvial sediments at the landward side (*i.e.* immediately downstream of Kempsey) has essentially filled the lower valley producing a deltaic plain.

The timing of the final stages of infilling is unknown but may coincide with terrace formation upstream of Kempsey (~ 3000 years ago; see Walker 1970).

The gradual infilling of the central basin results in the main river and tributaries growing progressively out as deltas (Plate 1). The present day alluvial levees are remnants of these deltas, while the Belmore and Clybucca swamps represent the last areas of the central mud basin, which are continuing to slowly infill. The birds foot deltas of Kinchella Creek and Belmore River indicate the continued progradation of sediment from the Macleay River into these basins.

In partially filled estuaries, areas of central mud basin are replaced by salt marshes, mud flats and/or mangrove swamps. Such depositional environments are a reflection of the increased dominance of riverine processes in the mature stage of estuary development. During these latter infilling stages connectivity between the river channel and tidal inlet increases resulting in a more efficient delivery of sediment to the ocean (www.ozestuaries.org). This often results in the bypassing of the remaining central mud basin and the formation of an ebb-tide delta. The preservation of such features on the eastern seaboard of Australia however, is often restricted due to the naturally low sediment supply rates, shoreline recession and sediment redistribution by high wave energy (Heap et al., 2004).

Today, the Macleay Lagoon that existed between 3,000 and 6,500 years ago is now mostly infilled and the processes driving the ongoing evolution of the estuary are now dominated by fluvial or river processes along most of its length with the exception of reaches below Pelican Island. In technical terms the Macleay estuary is described as a "mature infilled barrier estuary".

For more information on the geomorphic history of the Macleay River estuary refer to ***Appendix D*** on the accompanying Project CD.

1.2 Pre-European settlement conditions of the Macleay Estuary

Although the entrance to the Macleay River was only located by Europeans in 1817, Aboriginal people had been inhabiting the area for many thousands of years. The huge midden deposits found on the old Macleay Lagoon shoreline near Clybucca are evidence both of the natural bounty of the Macleay and of the importance of the estuary to the original peoples.

Apart from cultural sites such as the Clybucca Historical Site which provide some indication as to what conditions may have been like prior to European settlement, there are relatively few records preserved of the original condition of the Macleay estuary. Of most interest are the observations of the explorer Clement Hodgkinson who travelled through the Macleay Valley in the 1830s and 1840s (Hodgkinson, 1844);

> "*In ascending the Macleay River, from its entrance, the first objects which meet the eye on both banks are extensive mangrove flats, with thickets of myrtle, palm, and swamp oak, which a few miles further on, are superseded by dense alluvial brushes, rising like gigantic green walls on both sides of the river*."

He goes on to explain the term brush;

> "*brush trees in general possess a rich umbrageous foliage of bright shining green. The popular names of the most remarkable brush trees are as follows:- Red Cedar, White Cedar, Mahogany, Tulipwood, Rosewood, Ironwood, Lightwood, Sassafras, Corkwood the Australian Tamarind, Box numerous and elegant varieties of the Myrtle genus, the Australian Palms, and the Brush Fig……..But the peculiar appearance of the brush is principally caused by the countless species of creepers, wild vines and parasitical plants of singular conformation, which interlaced and intertwined in inextricable confusion, bind and weave together the trees almost to their summits, and hang in rich and elegant flowering festoons from the highest branches. ……..When this brush land is cleared, and cultivated, its fertility seems inexhaustable.*"

Now, continuing with the description of the Macleay River;

> "*It is navigable for vessels of fifty or sixty tons, to a distance of thirty four miles from its bar (Grassy Head), the water being of good depth, except at Shark and Pelican islands, where sand flats extend across the river, which can be passed by vessels only at high water. The reaches of the river are long and straight, averaging about a quarter of a mile in width, flanked on both sides by huge walls of the dense brush I have just described. These borders of alluvial brush land on the banks of the river, are generally half a mile, or a mile wide, and are then backed by extensive swamps of many thousand acres in extent, whose verdant sea, of high waving reeds and sedge, stretches away to the base of the distant forest ranges. There are several lagoons in these swamps, and the stagnant water is very generally diffused over their surface.*"

Plate 2 *Is this what Hodgkinson saw beyond the brush? "extensive swamps of many thousand acres in extent, whose verdant sea, of high waving reeds and sedge, stretches away to the distant forest ranges".* Image of Belmore Swamp *(Source: Kempsey Shire Council archives).*

1.3 Chronology of post settlement events and changes on the Macleay Estuary

1817 – 1886

The Brig *Judy Nelson* located the entrance of the Macleay River in 1817 and in the following year John Oxley sailed up the coast of New South Wales stopping briefly at Trial Bay. Oxley searched along the shore from Trial Bay but found only shallow and unnavigable streams and reported that "there is nothing of interest in the valley". It took until 1827 for timber cutters to prove Oxley wrong. Enoch

Rudder became the first land buyer on the Macleay after the area was opened up for free settlement in 1835. In 1836 the ship building industry started in Kempsey and at Stewarts Point (now Stuarts Point).

In 1864 there was a large flood and another larger one in 1875 (rising 14'6" above the Gladstone Wharf). In fact between 1863 and 1875 (13 years) there were 18 floods of which eight were considered serious.[1] However, the advantages of settling on the floodplains for many years outweighed the disadvantages.

The colonial *Drainage Promotion Act* was enacted in 1865 and as early as 1870, the Secretary for Works petitioned for assistance to drain certain lands adjacent to the Macleay River, particularly around Darkwater Creek (now known as Belmore River) and Kinchella Creek[2].

In 1886 a southerly gale opened a second entrance below Stewarts Point[3]. In the same year, a proposal was put forward for a North Coast Rail Line to reduce expenditure on entrances.

1887 – 1906

In 1888 the following notes were made by Captain Howard in his General Description of the Macleay River (which formed an appendix to Sir John Coodes report to the Secretary for Public Works on options for fixing the Macleay River Entrance[4]);

> *"The river at Stewarts Point is 1,400ft wide and from 8-12 feet deep over a clear and sandy bottom.*
>
> *The former ship channel between Shark Island and Fisherman's Island is shoaling up.*
>
> *Dredging is occurring westward of Fisherman's Island.*
>
> *Shark Island was actually a peninsular in 1863 (although not recorded as such by Hodgkinson), but after a Mr Salmon made a small cutting from Spencers Creek through to the main river to allow easy access for his boats to the main river, a great scour developed. In 1888 the scoured channel was 1,800 ft wide and 15-17 ft deep at low water.*
>
> *Nearly 200 people were camped at South West Rocks in January 1888*
>
> *In 1885, South West Creek did not actually meet the sea* (ie. It was an intermittently open/closed system).*In March 1887, a gutter was dug to run-off floodwaters and the resulting channel that was formed spanned 200ft and was 2-3ft deep. It regularly almost silted up.*
>
> *At Seven Oaks bend great changes have taken place; the concave bank is continually washing away, and the opposite point growing out…what is now the ships channel was once dry land."*

In 1890 Sir John Coode recommended to the Secretary for Public Works that fixing the entrance at North Head (Grassy Head) was the most sound option of four investigated for the improvement of the Macleay Entrance. However in 1893 a 1:100 year flood (the last having occurred in 1875) broke

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1 Macleay Valley Flood Mitigation Committee (1953) Report of the Macleay Valley Flood Mitigation Committee (The Jacka Report). Government Printer, Sydney.

2 Macleay Valley Historical Society. Notes from miscellaneous documents found in the society's archives on 6 September 2004; assisted by Ruth Woodward.

3 Anon. (1881). Draining flooded lands, Macleay River. Legislative Assembly of NSW 1880-81, Vol.2, pp 567-602.

4 Coode, J. (1891). Macleay River (Report by Sir John Coode, K.C.M.G., on entrance to.) Legislative Assembly of NSW, 26 May 1891. Includes a General Description of the Macleay River, by Captain Howard, R.N. dated 18 December 1890.

through about 600m north of Coodes #3 entrance option, north of South West Rocks. Consequently, Coodes recommendations were obsolete and in 1896 Public Works commenced work on the new entrance and by 1897 a channel 2000 feet long and 250 feet wide had been cut.

In 1901 the old entrance was closed and the Pilot Station moved from Stewarts Point (now Stuarts Point) to South West Rocks. In 1903 floods washed away 1900ft of stone wall plus a wharf, a 10ft crane, 13 trucks and a quantity of rails. 5-6' of silt was deposited on several other wharves showing that bank erosion was already very active in the lower reaches of the river. In 1906 works on the new entrance were completed and it was reported that the new entrance saved 2 hours sailing time. Fixing of the entrance at this point did not please everybody, as it was believed that it caused salt-water to ingress up Clybucca Creek and damage farmlands in the Rainbow Reach area too. Anecdotally, a lot of erosion occurred soon after at Rainbow Reach as well[5]

Drainage of swamp lands on the floodplain was of increasing interest. The *Drainage Promotion Act 1901*, was enacted to provide for the "better drainage of lands" and the establishment of drainage unions. The NSW Public Works Department also facilitated drainage by making investigations and surveying and designing swamp drainage schemes from the early 1900s under the provisions of the *Water and Drainage Act 1902* (Tulau, 2002). Although frequently justified on flood mitigation grounds, an additional, and often primary motive was the "reclamation" of dry land, often by the drainage of backswamps and the exclusion of tidal waters. The Public Works Department Annual Report of 1906 noted that;

> *"On the ... coastal rivers, there are thousands of acres of swamp lands of the richest character which only need proper drainage to make them very valuable"*,

and concluded that;

> *"the drainage of these lands appears to be one of the surest and most profitable investments on which money can be employed. It will undoubtedly be the means of inducing closer settlement of the coastal districts of the State."*

1907 – 1948

Drainage continued to be a prominent issue through this time period. By 1907 steps had been taken to drain Kinchella, Frogmore and Seven Oaks swamps[6]. Cooroobongatti Swamp Drainage Union was proclaimed on 10th July 1908, followed by Gladstone Drainage Union in 1912, Frogmore in 1913, followed by 7 others up until 1935 (three more drainage unions were also proclaimed in 1953).

Although shipping was still the mainstay of the lower Macleay communities the first road charter service began replacing horse-drawn coaches in 1910 and construction of the Wauchope –Kempsey section of the North Coast Railway began in 1913. The first train arrived in Kempsey in 1917. From 1915 sand spits encroached on either side of the entrance and at times almost met but the cost of regular dredging became increasingly difficult to justify after increasing improvements to roads and motor vehicles following World War One.

Up until the 1920s shipping was the life blood of the communities and people were "happy" to settle on the floodplain despite the inconvenience of flooding. With improved means of inland transport dependence on shipping reduced.

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5 Macleay Argus, September 30, 1961

6 Tulau, M.J. (2002). Agricultural Drainage in Acid Sulfate Soil Backswamps in New South Wales, Australia - Technical, Regulatory and Policy Responses. In: C. Lin, M.D. Melville and L.A. Sullivan (eds.) Acid Sulfate Soils in Australia and China.

In 1921 heavy flooding caused extensive shoaling and washed away many river beacons, while the heavy seas broke through the beach in two places 2 ½ miles and 3 ½ miles north of the entrance. Dredging to facilitate navigation and maintenance of the entrance and river protection works was constantly required. Through the 1930s unemployment relief funds were used for the repairs and dredging essential to maintaining the entrance and channels of the Macleay. Funds were spent on repairs to breakwaters and training walls including Shark Island Training Wall, bank protection at Jerseyville and Shark Island, dredging of Belmore River, and on building groynes to prevent scour to the eastern training wall.[8] Bank erosion was considered a major problem at the time and in 1934 a Departmental Committee on Erosion reported on Macleay River Erosion including extent and severity and probable causes (see *Appendix E* for the major findings of this report and a comparison to today's erosion situation).

Ongoing dredging and channel maintenance continued through the later 1930s and 1940s. Repairs to both breakwaters, bank protection at Jerseyville and Shark Island, and repairs to the Shark Island training wall all occurred in the early 1930s. In 1936 construction of ~2700 lineal feet of rock walling downstream of Jerseyville Wharf were completed[9] (using 18,700 tonnes of rock). Bank protection works near Jerseyville[10] were done in 1939, extensive repairs to the eastern entrance training wall[11] in 1945 and then again in 1948, and *Hermes* and *Neptune* dredged in excess of 600,000 tonnes from the entrance bar and channel[12].

1949 – 1976

Winter floods in 1949 were the highest ever recorded (26' at Kempsey Traffic Bridge) and caused widespread damage to farms and floodplain townships. Six lives and more than 7000 stock were lost, with more than 600 buildings also damaged or destroyed. Extensive shoaling occurred throughout the river and between 1949 and 1950, 49,200 tons of silt were removed by the dredge *Hermes* from reaches around Longreach, Kinchella and Smithtown. 1000ft of the western training wall at the entrance was also washed away and not repaired until 1951.

In 1950 winter floods (25'6" at Kempsey Traffic Bridge) again caused havoc but cleared some of the shoaling which occurred in 1949 around Smithtown. Bank protection works at Jerseyville were damaged.[13]

The effect of the floods was devastating on the local communities and in October, 1950, the then minister for Conservation, Mr Weir, met a large number of local people, organisations, and the local government to discuss the impacts of the two recent floods.

In 1951 The Macleay Valley Flood Mitigation Committee was set up under the chairmanship of C.K. Jacka, Chairman of the NSW Conservation Authority. The committee considered a joint submission by Macleay Valley local councils, reports by government departments, and representations by drainage unions and local landholders and farmers. Options for flood mitigation dams, river improvement works, drainage, hydroelectricity, and improvements to drain management and administration were investigated. The Committee's report of 1953 (known as the The Jacka Report) recommended flood "mitigation" as the only viable option as opposed to flood "control". The report ruled out dams as an effective option due to costs and instead put forward a proposal for a valley-wide scheme which

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7 Public Works Department Annual Report 1922.

8 Coltheart, L. (1997) Between Wind and Water – A history of the ports and coastal waterways of New South Wales. NSW Department of Public Works and Services. ISBN 0 86806 598 6.

9 Public Works Department Annual Report 1936.

10 Public Works Department Annual Report 1939.

11 Public Works Department Annual Report 1948.

12 Public Works Department Annual Report 1941, Public Works Department Annual Report 1947, Public Works Department Annual Report 1948.

13 Coltheart, L. (1997) Between Wind and Water – A history of the ports and coastal waterways of New South Wales. NSW Department of Public Works and Services. ISBN 0 86806 598 6.

involved extensive drain construction and enlargement, headwater construction, levee construction and enlargement, river bank protection, ocean cuts, training walls, and dredging at a total estimated cost of 1,090,000 pounds. The stated aims of the scheme were 1) Protection of all land from an overbank flow of a 17' flood at Kempsey Traffic Bridge; 2) The removal of approximately 90% of water from grazing land within 6-10 days of the flood peak (ie. The time it takes for introduced pastures to die from immersion).

In 1954 Macleay River County Council was delegated the powers and duties to implement the flood mitigation strategies of the Jacka Report. Flood mitigation works were progressively implemented until the mid-1970s. These included constructing 210 floodgates in 47 separate structures servicing approximately 116 km of excavated drains, and 180 km of levees. Three major control works were constructed on the Belmore River and Kinchela Creek. In addition, channel "improvements" and obstacle removal (Berrigan 1993) were undertaken on Kinchela Creek, Belmore River and Clybucca Creek. Korogoro Creek and Ryans Cut were also cleared as outlets for floodwaters (Laurie, Montgomery & Pettit Pty Ltd 1980).

Although the dangers of draining acid sulfate soils, or 'cat clays' had been understood by scientists by the 1960s (Walker 1960, 1961, 1963), this decade appears to have been the most energetic period for the construction of drainage and flood mitigation works generally. Much of this work was supported and/or undertaken by successive local and State governments that facilitated the construction of extensive drainage systems by drainage unions and private landholders.

An approximate timetable for construction of structural works in the lower Macleay over the period 1949 –1976 is outlined in Table 1.1.

Table 1.1 *Approximate construction timetable for structural works in the lower Macleay 1949 - 1976(Webb, McKeown & Associates Pty Ltd, 1997)*

Pre 1949	Eden Street levee raised to 4.1m
1955	Eden Street, Kempsey levee raised to 6.1m AHD (to suit 5.2m flood)
Pre 1958	Killick Creek headworks, training wall and dune stabilisation.
Pre 1960	Austral Eden, Seven Oaks, Belmore headworks, drainage, bank protection and levees
Pre 1960	Kempsey to Frederickton bank protection and levees
Pre 1960	Kinchela to Longreach bank protection
1960 - 1962	Belmore Kinchela area, several drains and gates
1961	Belmore/ Kinchela headworks, drains, drainage improvements
1963 and 1967	Christmas Creek headworks and drains
1964	Belmore to Killick Creek waterway
1965 and 1967	Pola Creek headworks and drain
1966 - 1970	Clybucca – Seven Oaks Headworks and drainage
1966	Kempsey, Frederickton bank protection
1967	Frogmore – Darkwater drains extensions
1968	Korogora Creek headworks, drain and levees
1968	Glenrock/ Tennessee – Willows drain
1968	Kinchela Creek fabridam floodways and barrage
1967 - 1969	Gladstone, Glenrock, Saltwater headworks drains
1969	Y arrahappini headworks and drains
1969	Euroka Creek headworks and drainage
1969	Eden Street, Kempsey levee raised to 7.0m AHD (to suit 6.1m flood)
1969	Maria River headworks and drainage systems
1971	Gladstone bank protection
1973	Ryans cut ocean outlet, headworks and drain
1974	Scotts Drain headworks and drainage improvements
1975	Big Hill ocean outlet, headworks and drain

1976	Belmore River flood control and barrage
1976	Cochrane Street levee raised to 6.1m AHD
1976	Eden Street levee raised to 7.5m AHD
1976	Concrete levee constructed in vicinity of Traffic Bridge to 7.3m AHD

Plate 3 *Blasting of coffee rock along Andersons Inlet to create a new drainage channel which eventually would shortcut Clybucca Creek (Source: Kempsey Shire Council archives)*

By 1958 shipping along the New South Wales Coast was in decline. Although there were 31 proclaimed ports in NSW the only general cargo trade was at the Macleay River, where dairy products were shipped to Sydney (from Nestles) and coal and other supplies brought in.[14] During the 1960s Trial Bay was a petroleum Port.

In 1962 the Macleay Argus published a Flood Mitigation "special" which reviewed the 1953 Jacka Report. It is evident in this report that much of the science on how rivers work was available in 1962 but socio/economic demands drove the agenda. In 1963 the Federal Government commenced contributions to the flood mitigation works, consequently works were funded on a ratio of $2 Federal: $2 State: $1 Local Government.

By 1968 questions were being asked about the potential environmental effects of the flood mitigation scheme. A report published that year by the Department of Geography, University of New England on "Problems of secondary drainage on the Macleay Flood Plain and their possible solution by the Macleay River County Council with extended powers" states on page 48 under "Wildlife"…

> *At present the poorly drained areas on the lower Macleay are a haven for wildlife eg.ducks, black swans, etc. Often Wildlife Protection Societies object to drainage works since they destroy the habitat of wildlife by changing the ecology of the area; should any Wildlife*

[14] Coltheart, L. (1997) Between Wind and Water – A history of the ports and coastal waterways of New South Wales. NSW Department of Public Works and Services. ISBN 0 86806 598 6.

Preservation Societies exist in the Lower Macleay, then suitable steps should be taken to ensure that a small minority does not jeopardise the construction of drainage works on the Macleay.

Prior to 1969, the controlling and funding authority for works was the Public Works Department and any proposed works were not referred to Fisheries. In 1969, following representations by State Fisheries to the PWD, it became necessary for the County Councils to carry out cost/benefit studies and to obtain Fisheries and NPWS approval. In 1970 the CSIRO Division of Wildlife Research in their report "A Survey of Wetlands of Coastal New South Wales - Technical Memorandum NO.5" drew attention to the effects of flood mitigation on wildlife. In 1972 Environmental Impact Assessments became a requirement.

In 1975 a submission by 15 Shire Councils to the Commonwealth seeking $33,163,300 for flood mitigation works, it was detailed that;

4/5th of the cost of the programme has been provided by grants from State and Federal Governments (2/5th each), while the Councils responsible for flood mitigation in the river valleys have raised 1/5th of the cost of the work by means of loans. The loan repayments are now forming a large part of the valleys' rate collections and only the strong flow of benefits from the completed works keeps public opinion in favour of the work.

The 1975 submission also notes on page 17 that;

In the early years environmental awareness was not as well developed either by the public or authorities as it is now. Therefore, this proposed programme of flood mitigation works will be concerned over wildlife and environmental issues which have already led to close examination of some flood mitigation projects. ... The process of resolving conflicting objectives has only just commenced, and much valuable information for the whole community can undoubtedly come from the negotiations which will take place between the flood mitigation and environmental interests if, with State Government and Commonwealth assistance, current projects and those anticipated for the future may be completed to the mutual satisfaction of all concerned bodies.

The Macleay River County Council's asked for $540,000 for up-river works and $1,490,000 for works below Kempsey (figures in 1975 $ amounts). In that same year the Macleay River County Council, Kempsey Municipal Council and the Macleay Shire Council amalgamate and form the Kempsey Shire Council.
In 1976 The Macleay Argus presented "A Seminar on Flood Mitigation". At the seminar Councillor D.E. Hopkins outlined the total expenditure on flood mitigation between 1955-1976:

- Down River Works $7,533,045
- Up River Works $1,101,800
- Local Contribution $1,874,759
- Annual Maintenance $73,830.

A preliminary analysis of early aerial photography (eg. 1942 and 1956 runs) reveals that many sections of the lower freshwater reaches of the river were in poor condition with often poor bank stability and river bank vegetation. Despite the obvious need for remedial attention it is not clear from available reports and documents where the idea of up-river bank realignments came from as such proposals were not contained in the original flood mitigation scheme as proposed by Jacka in 1953. In fact the Water Conservation and Irrigation Commission expressly stated that they did not believe them to be necessary.

Nevertheless, upstream works occurred on a large scale including channel realignments, shingle removal, and extensive clearing of within channel vegetation. Although these works were aimed at "river improvement", in retrospect, such works are now known to more likely exacerbate channel instability with increased sediment loads eventually being shunted into downstream estuarine reaches.

1977 – present

Through the 1970s public awareness of environmental issues was on the increase. In NSW, both the Coastal Protection Act and the Environmental Planning and assessment Act were passed in 1979. With the passage of the EPA Act 1979, environmental impact assessments became mandatory for any proposed development or activity. Middleton *et al.* (1985) noted two main drawbacks to the EIA process;

- A lack of quantitative data concerning estuaries including how they function
- A lack of predictive ecological models to quantify how an estuary will respond to different types of proposals.

These issues are likely to still exist today.

Despite the publication of a number of scientific works (eg. Walker 1963, 1972), it was not until 1987 that the link between acid sulfate soils and a history of water quality problems and fish kills was generally recognised (Tulau, 2002). Research through the later decades of the 20th century showed that although the flood mitigation have mostly achieved their stated aims, the works have also drained wetlands, oxidised the sulfidic estuarine clays and delivered acid leachate to receiving waters. The legacy of over-drainage has been the change in wetland vegetation, extensive acid scalding, soil acidity, land slumping, wind erosion and poor water quality (Henderson *et al,*, 2002). The alterations to estuarine processes that accompany the impacts described above are known to directly effect aspects of estuarine ecology including floral distributions, faunal species richness and commercial fisheries production (Roy et al., 2001).

Through the 1980s and 1990s a number of flood studies and floodplain management studies were completed including;

- Macleay Valley Flood Plain Management Study in 1980 (a broad overview of total catchment topography, hydrology and major floods) completed.
- A study of options for flood protection at Kempsey completed in 1985.
- Macleay River Flood Study completed in 1989 (hydraulic and hydrologic effects from Aldavilla downstream)
- A review of Kinchella Creek and Belmore River floodway capacities completed in 1993.
- A study of proposed Kinchella Creek flood channel to Korogora Creek in 1994
- Lower Macleay Flood Study Completed 1998
- Lower Macleay Flood Plan completed and adopted by Kempsey Shire Council in 1999

Some flood mitigation works continued through this period (Table 1.2) although from the records it would appear that the major period of drain construction works has passed. More recent changes to drainage patterns have accompanied economic changes, mainly in the tea tree and dairy industries, and remediation works (Henderson *et al,*, 2002). In both cases, new works have generally been confined to shallow, wide drains, and the main focus now in agricultural areas is on the redesign of existing works and alternative ways of operating control structures. In the 1990s the Landcare movement facilitated a greater understanding of the water quality impacts of overdrainage (particularly in the Belmore River area). However, more recently the Macleay River Floodplain Project has provided an opportunity for Council, Government and local landholders to work in partnership to implement remedial works aimed at improving environmental condition in floodplain, wetland, and estuary areas.

Table 1.2 *Approximate construction timetable for structural works in the lower Macleay.*

1976 - 1978	Kempsey and Macleay River levees raised for 5.2m flood
1980	Flood restoration and minor improvements
1980	Kinchela Floodway, replacement of fabridam with steel gates

1990	River Street, concrete levee constructed to 11m AHD near Cooks Lane
1997	Cochrane Street and Eden Street levees checked and adjusted, (Eden St = 7.52mAHD, Cochrane St = 6.15mAHD)
1999	Hat Head Control and Village levees reinforced
1999	Kinchela Creek and Belmore River Right Bank levees commenced raising

Over the period 1991 to present the population of Kempsey Shire has expanded by approximately 10.9% (from 25343 to 28114) and numbers continue to rise as the "seachange" phenomena sees more people settling in regional coastal areas. Over the same period, tourism has expanded rapidly and the river entrances and estuaries are now more the focus of recreational pursuits than the important commercial arteries that they once were. A major challenge now in estuary management is how to provide safe boating while also maintaining river and estuary health. (HRC, 2003).

1.4 Summary of events

Up until 1920s shipping was the life blood of Macleay Valley communities. People were "happy" to settle on the floodplain despite inconvenience of flooding because of the easier access to transport and supplies and the highly fertile nature of the soils which greatly assisted agricultural endeavours. In fact, upriver towns such as Kempsey owe their existence to the breakwaters that allowed ships to enter the rivers, and it was shipping on which they entirely depended, until roads and railways linked them.

As Coleheart summarises in her history of ports and coastal waterways of NSW (1997);

> *The breakwaters and training walls built to maintain shipping channels by directing tidal and flood scour also flushed floodwaters out to sea much more efficiently, reducing the inundation of the coastal plain. Flood mitigation and reclamation works in recent decades have enhanced this effect, allowing new subdivision and residential development to extend on the coastal floodplain. Now the breakwaters do not bring ships in they guide floodwaters out, and in what has been a very rapid development they protect seaside towns with many communities depending on these public works as surely as did the upriver ports.*

The floodplain of the Macleay River has been extensively modified, with large networks of floodgated drainage channels owned and operated by local councils, drainage unions and private landholders. Important changes in the patterns of land ownership on the floodplains have resulted from the drainage schemes with some subdivided small holdings comprising lower floodplain land only. These landholders now rely on an effective drainage and flood mitigation system for current agricultural production systems to continue, although in past years the lower floodplain lands were used for drought refuge only.[15]

The historical records show that the Macleay River system is hugely responsive to floodplain and channel modifications, with numerous examples of extreme channel response to relatively minor modifications. Floods such as were experienced in 1949 and 1950 are a salient reminder of the capacity of the river to change. Although not as drastic as extreme floods, over 150 years of agricultural development and more recently coastal development also has changed the river system and its estuary. Such development has undoubted impacted on the current physical condition of the estuary and is also likely to be impacting on estuary based industries such as fisheries and aquaculture. Some of the effects, such as those associated with acid sulphate soils and over drainage, are well documented and researched where as other impacts such as on estuary sedimentation can only be hypothesised without extensive research which to date has not commenced.

[15] Tulua, M. Agricultural Drainage in Acid Sulphate Soil Backswamps in New South Wales, Australia - Technical, Regulatory and Policy Responses.

PART 2 EXISTING DATA - COMPILATION AND REVIEW

A great deal of data and information on the Macleay estuary has been collected over the years. Many of the documents and datasets are held in various Council and State Government Agency libraries, or with other organisations (such as Universities and non-government bodies) making the identification of relevant information and access to that information sometimes difficult, especially by general community members.

With regard to existing information on the Macleay River estuary, this study has two major objectives;

1. To identify all available resources relating to the Macleay Estuary and evaluate their usefulness for the Estuary Management Planning process.
2. To compile the identified resources into an electronic register accessible by anybody through a simple and easy to use searchable web-based database (Figure 2.1).

In order to meet the first objective 140 documents, reports, proceedings, database sets, and journal articles were reviewed (estimated to represent 90% of available written information). The intention of the review was not to provide a definitive summation of the "state of knowledge" of the identified issues but rather to determine what information and data is currently available to assist the estuary management process and which datasets are lacking and therefore require further attention in the subsequent estuary processes study. The following sections summarise the existing dataset and make reference to entries in the Data and Information Register through the use of "Reference" numbers (eg. ***Ref 22***). A full listing of each reviewed document including abstract and statement of use for EMP is provided on the Data Compilation Project CD in Microsoft excel and Adobe PDF format. Additionally, the information is available through the Macleay River Estuary Information and Data Register web site at http://macleay.kempsey.nsw.gov.au/managed by Kempsey Council and the Kempsey Library.

Figure 2.1 *Macleay River Estuary Information and Data Register (http://macleay.kempsey.nsw.gov.au/)*

The sections below describe the available data on the basis of issues. These issues have been identified by the Macleay Estuary Management Committee, a committee of Kempsey Shire Council made up of stakeholders including Government and Industry representatives. This set of identified issues combined with the submission put forward by the authors of this report and accepted by the Council form the boundaries for what was considered in the data review.

At the time of writing this report two other initiatives were being undertaken with the aim of compiling information and data on natural resource management (albeit not focussed on the Macleay River or estuaries specifically);

1. The ***Comprehensive Coastal Assessment*** (CCA) is a whole-of-government initiative and forms part of the NSW Coastal Protection Package. The package is a three year program managed by the Department of Infrastructure, Planning and Natural Resources with projected funding of $8.6 million. The CCA has the objective of providing better data sets and planning tools to improve coastal planning and management decisions along the coast of NSW. It focuses on estuarine waters in the coastal zone from the Queensland border to the Hunter River, and from Lake Illawarra to the Victorian border.

2. The ***NSW Natural Resources Data Directory*** (NRDD) provides a search interface to metadata for natural resources information held within NSW. Metadata ("data about data") describes the content, quality, currency and availability of data. The NRDD can be found at: www.nratlas.nsw.gov.au

Both these sources can be found on the Community Access to Natural Resource Information (CANRI) website: http://www.canri.nsw.gov.au/activities/projects/2003/

2.1 Existing data adequacy

Land Use Planning and Development Control

In NSW the responsibility for land use planning and development control is generally shared between the State and Local Governments, although Local Councils have the major responsibility for determining local landuse. This means that Local Councils have a very significant and practical role in estuary management.

The major Legislative Acts, Policies, and Plans that influence landuse planning and development control in estuarine and coastal floodplain areas of the Macleay include;

- NSW Environmental Planning and Assessment Act 1979, NSW Fisheries Management Act, and the Rivers and Foreshores Improvement Act 1948
- NSW Threatened Species Conservation Act 1995, specifically provisions relating to "Endangered Ecological Communities".
- NSW Estuary Management Policy 1992 and NSW Coastal Policy 1997,
- State Environmental Planning Policies (that stem from the EP&A Act) such as SEPP 14 Coastal Wetlands, SEPP 26 Littoral Rainforests, SEPP 35 Maintenance dredging of tidal waterways, and SEPP 71 Coastal Protection.
- North Coast Regional Environment Plan (NCREP)
- Kempsey LEP 1987
- Various Development Control Plans that deal with development in specific parts of Kempsey Shire or where certain issues are known to occur, for example associated with Acid Sulphate Soils (DCP 27) or on-site sewerage disposal (DCP 32).

Currently, all NSW Councils are being asked to review their LEPs to standardise terminology, format, and content including zonings and development control provisions. The timeline for the review is expected to be 5 years from 2005. The Standard Provisions for LEPs – Working Draft[16] (September 2004, produced by DIPNR NSW) identifies Environment Protection Zones and various discretionary local planning provisions including provisions relating to environmental attributes, flood prone land, foreshore building lines, wetlands and fisheries, and preservation of trees.

Currently, little consideration is given within the planning framework to the possible effects of sea level rise and changes to climatic extremes associated with greenhouse effects (HRC, 2003).

A number of current land claims by local indigenous groups may also affect land use planning and development if successful.

Other sources of information that relate to land use planning and development in the Macleay estuary study area include;

Ref 43 *Independent inquiry into North Coast Rivers - Final Report* (2003) gives thorough analysis of the planning framework with reference to river and estuary management.

Ref 37 *NSW North Coast Sustainable Aquaculture Strategy - Land based aquaculture* (2000). The strategy contains two components - a best management practice component and an integrated approval process component - which are intended to ensure development in an efficient and sustainable manner. The strategy concerns land based aquaculture only.

Ref 55 *Kempsey Shire Urban Stormwater Management Plan 2000-2005* (2000) outlines issues, strategies and actions for urban stormwater management within Kempsey Shire.

Ref 17 *Kempsey Integrated Water Cycle Management Strategy. Part 1 : Concept Study Final Draft* (2003). Issues addressed include surface and groundwater supply, water quality of urban water supplies and resources, and sewerage and stormwater systems for urban and village centres. Includes comprehensive background information, a catchment and water resource audit, and urban area audit, and recommendations for potential actions to address identified issues.

Ref 109 *Draft assessment of crown lands at Fisherman's Reach* (2001). This assessment applies to a part of the Macleay Arm bed and was undertaken to rationalise future allocation of licences for waterfront structures over Crown Land.

Ref 67 *South West Rocks Structure Plan Review* (2003)

Riparian Land Management and Bank Erosion

The problems of accelerated bank erosion and its consequent deleterious effects, such as increased within channel sedimentation and loss of productive lands, have been referred to and recorded in the Macleay estuary system since the earliest remaining written records. Although the highly alluvial river banks are highly productive, history shows that the Macleay is very responsive to disturbance. Classic examples include the rapid retreat of the banks around Rainbow Reach after the new entrance broke through in 1893 and the “great scour” 1800ft wide that developed after Mr Salmon made a cut through from Spencers Creek to the Macleay (Coode, 1891; see Part 1 for more descriptions).

Despite the fact that this issue is more than 120 years old, there is a general lack of quantitative data and background information that would allow a thorough assessment of options for mitigation of bank erosion problems. The main exception to this statement is the analysis of bank erosion that occurred in

[16] For further information go to http://www.dipnr.nsw.gov.au/planningreform.html

1934 (***Ref 1***) which documented areas of severe, moderate and minor erosion in the lower reaches of the Macleay and attempted to explain the causes.

In addition to the 1934 Report on Bank Erosion which is reviewed in detail in Appendix E, other sources of information and/or data identified that relate specifically to the Macleay Estuary include;

Sedimentation

Ref 14 *Macleay River Sand and Gravel Resource Assessment – Draft* (2003) outlines the geomorphic characteristics of the Macleay River between Nulla Nulla Creek and Sherwood bridge crossing. Quantifies the rates of gravel extraction from 1997/98 to 2001/2002 and addresses the geomorphic impacts of gravel extraction.

Mapping

Ref 82 *Mapping of Bass Habitat in the Macleay, Hawkesbury and Shoalhaven Rivers - Interim Report for the Recreational Freshwater Trust Expenditure Committee*(NSW Fisheries, Port Stephens Fisheries Centre) has recently been undertaken along much of the Macleay River (2003/04). The report has not yet been finalised and consequently has not been reviewed for this study. The mapping looked at aspects of channel morphology and recorded eroded banks, cover of vegetation, and snags as either point, line or polygon features. Digital data may also be available on finalisation of the documentation during 2005.

Remediation Works Planning

Ref 105 *Report of the Macleay Valley Flood Mitigation Committee* (1953: known as "The Jacka Report"). The report puts forward a proposal for a valley-wide scheme which involved extensive drain construction and enlargement, headwater construction, levee construction and enlargement, river bank protection, ocean cuts training walls, and dredging at a total estimated cost of 1,090,000 pounds. Contains several maps and appendicies outlining government department opinion of the day.

Ref 106 *Overall Plan of Flood Mitigation for the Lower Valley. Report by the Council's Civil Engineer reviewing the 1953 proposals of the Macleay Valley Flood Mitigation Committee*(1962). This report reviews the recommendations of the Jacka Report and the progress to date and proposes a detailed program of further works to be undertaken including bank protection.

Ref 87 Riverbank Restoration for the Nambucca Estuary - A Decision Making Guide (2000). Concepts relevant to Macleay Estuary riverbank restoration.

Ref 102 *Design report for riverbank remediation – Stuarts Point Caravan Park* (2003).

Geology and Geomorphology

Ref 19 *Soil Landscapes of the Kempsey & Korogoro Point 1:100 000 Sheets Report* (1999). Geomorphic processes are touched upon but soil landscapes are the primary focus of this report. The data is able to be interrogated to produce for example Acid Sulphate Soil hazard maps.

Ref 64 *Soil Landscapes of the Macksville & Nambucca 1:100 000 Sheets Report* (2000).

Ref 45 *River Styles in the Macleay Catchment, North Coast, NSW* (1999). A broad-based catchment wide geomorphic characterisation of the Macleay Valley's major streams and rivers is described.

As referred to elsewhere, a great deal of work has been undertaken for the purposes of "Flood Mitigation" in both the tidal and non-tidal reaches of the Macleay River and Kempsey Shire Council maintains records of many of the works that have occurred in up-river locations and in estuarine reaches. The Council continues to undertake flood mitigation work in the estuary and is likely to have files on these works. These files were not reviewed for this study. Although many of these works are

undertaken to address site specific issues it is probable that the works impact on adjacent reaches due to the complex nature of geomorphic response in river and estuarine systems.

A range of projects also continue under various "Landcare" sponsored programs. Information on current projects is provided in Section 3.8 of this report.

There is very little existing data on riparian vegetation in the estuary area. 170 years of agriculture and farming have left very little of the original vegetation intact (as described by Hodgkinson in the 1830s). It has been estimated that as little as 2 ha of the original floodplain rainforest exists today. Alex Floyd has mapped 2 important areas and described the species present (***Ref 91,92,93***).

Given that riparian land management and bank erosion has been identified as an issue of major importance to the Estuary Management Planning Process, a geomorphic assessment and bank erosion mapping exercise was undertaken as a part of the Data Compilation Study in late 2004 to address some of the data shortfalls. The results of this assessment are summarised in Part 3 of this Report with the full assessment available in Appendix E.

Floodplain Wetlands Management

Floodplain wetland management is another issue with a long and dynamic history. In past years wetlands have been the subject of intensive drainage and land reclamation efforts. The colonial *Drainage Promotion Act* was enacted in 1865 and as early as 1870, the Secretary for Works petitioned for assistance to drain certain lands adjacent to the Macleay River, particularly around Darkwater Creek (now known as Belmore River) and Kinchella Creek[17]. The Flood Mitigation era (1958 – 1976) saw massive changes to wetlands on the Macleay. More recently, it has been recognised that wetlands serve important ecological functions, some of which are complimentary to sustainable floodplain farming operations. Consequently, government and non-government bodies along with individual landholders have sort to redress some of the issues of degradation that have occurred as a result of past land management actions and government sponsored programs.

Under the Environmental Protection and Assessment Act 1979, State Environmental Planning Policy 14 (SEPP 14) was gazetted to preserve and protect coastal wetlands as identified by the Department of Land and Water Conservation (now DIPNR). Under SEPP 14 seven different accepted wetland types have been mapped at a scale of 1:25,000 including mangroves, saltmarshes, melaleuca forests, casuarina forests, sedgelands, brackish and freshwater swamps, and wet meadows.

The consistency of mapping and level of accuracy has been criticised due to the exclusion of a number of groundwater dependent ecosystems such as Wet Heath and Wet Shrubland and low-lying forests such as Swamp Mahogany (*Eucalyptus robusta)*, and Red Mahogany (*Eucalyptus resinifera)* from the mapping. Additionally, in this study area there is a degree of discrepancy between the communities mapped under SEPP 14 and their actual physical extent within the estuary. Discrepancies can be attributed to the scale of photography being at 1:25,000 and environmental changes over the preceding years.

Whilst there are inconsistencies and inaccuracies with the SEPP 14 mapping within the study area it is not considered relevant to identify all discrepancies as under the provisions of the Threatened Species Conservation Act 1995 many types of 'wetland' vegetation are now gazetted as 'Endangered Ecological Communities' thus providing new mechanisms of protection. Coastal Saltmarsh, Freshwater Wetlands, Swamp Sclerophyll on Floodplains, Subtropical Coastal Floodplain Forest, Swamp Oak Floodplain Forest and River-flat Eucalypt Forest on Coastal Floodplains which may have been excluded under SEPP 14 now have provisions designed to increase protection under the new legislation.

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[17] Macleay Valley Historical Society. Notes from miscellaneous documents found in the society's archives on 6 September 2004; assisted by Ruth Woodward.

A great deal of information is available on the coastal wetlands of the Macleay, including survey descriptions, mapping, monitoring projects, remediation projects, and policies. A summary of the available information is outlined below along with review notes for documents considered to be particularly relevant to the estuary planning process[18].

Surveys, mapping and monitoring

Ref 128 *Macleay Wetlands Management Plan and Mapping* (1999). This Mapping produced by the North Coast Environment Council Inc in 1999 defined 21 Vegetation Units representing an area of 40,232 hectares. Problems with distortion associated with transferral into a digital layer in ARCView GIS have reduced the usability of this information as a digital layer without considerable work in corrections. However, it still supplies important information which can be integrated into other update mapping.

Ref 79 *A Survey of Wetlands of Coastal New South Wales* - Technical Memorandum NO.5 CSIRO Division of Wildlife Research (1970). 14 ecological types of wetland were defined and the distribution and extent of each type listed by geographic districts. The report draws attention to the impact of flood mitigation on wildlife and stresses the need to preserve areas for wildlife.

Ref 81 *Wetlands of the Lower Macleay Floodplain, Northern Coastal New South Wales* (1989). A comprehensive survey of 432 wetlands on the lower Macleay floodplain including an inventory of species. Wetlands were mapped and grouped according to their size and the number of plant taxa within.

Ref 77 *Yarrahapinni Wetland Vegetation Monitoring - Final Report to Yarrahapinni Reserve Trust* (2004)

Policies and management plans

Ref 80 *NSW Wetlands Management Policy ACTION PLAN* (1999).

Ref 76 *Yarrahapinni Wetlands Reserve Plan of Management* (2001).

Ref 74 *Environmental impact statement for the proposed restoration of tidal inundation of Yarrahapinni Wetland, Mid-North Coast, NSW*. Prepared for Yarrahapinni Wetlands Reserve Trust. (1997).

Acid Sulphate Soil Management

Acid Sulphate Soil (ASS) remediation projects are currently occurring on the Macleay floodplain at Kinchela, Belmore, Frogmore-Darkwater, Clybucca, Yarrahapinni, Raffertys Drain and Upper Maria River - Connection Creek. Approximately 8 000 ha, or 23% of the floodplain, comprising most of the highest risk ASS, is now under active management for ASS remediation (Henderson et al, 2003).

Acid sulphate soil hot spot reports are currently available on the on DIPNR website at: http://www.dlwc.nsw.gov.au/care/soil/ass/hotspots.html

The following references provide further information on ASS and are presented in general order of perceived relevance to the estuary planning process;

[18] As this issue is also intrinsically linked to issues such as Acid Sulphate Soil management and Floodgate and Drain Management, other documents and references may also be found under these subject headings.

Ref 18 *Agricultural Drainage in Acid Sulphate Soil Backswamps in New South Wales, Australia - Technical, Regulatory and Policy Responses* (2002). Provides a thorough overview of history of drainage and different mechanisms for addressing ASS issues.

Ref 57 *Acid Sulphate Soil Priority Management Areas on the Lower Macleay Floodplain* (1999). A comprehensive overview of the nature and extent of Acid Sulfate Soils in the Lower Macleay Floodplain. See Figure 2.2 for an example of an ASS Priority Management area map from the report.

Ref 99 *Macleay River Catchment Acid Sulphate Soil Remediation Projects Review* (2001). A comprehensive overview of projects underway at the time is provided.

Ref 61 *Collombatti-Clybucca Acid Sulfate Soils Hot Spot – Final Report* (2004).

Ref 60 *Acid Sulphate Soils in the lower Macleay Catchment, Northern NSW, Australia* (2000).

Ref 59 *The Macleay River Floodplain, Land Use and Acid Sulfate Soils* (1996).

Ref 70 *Seasonal and Stratigraphic Controls in Coastal Flood Plain Soils* (1971).

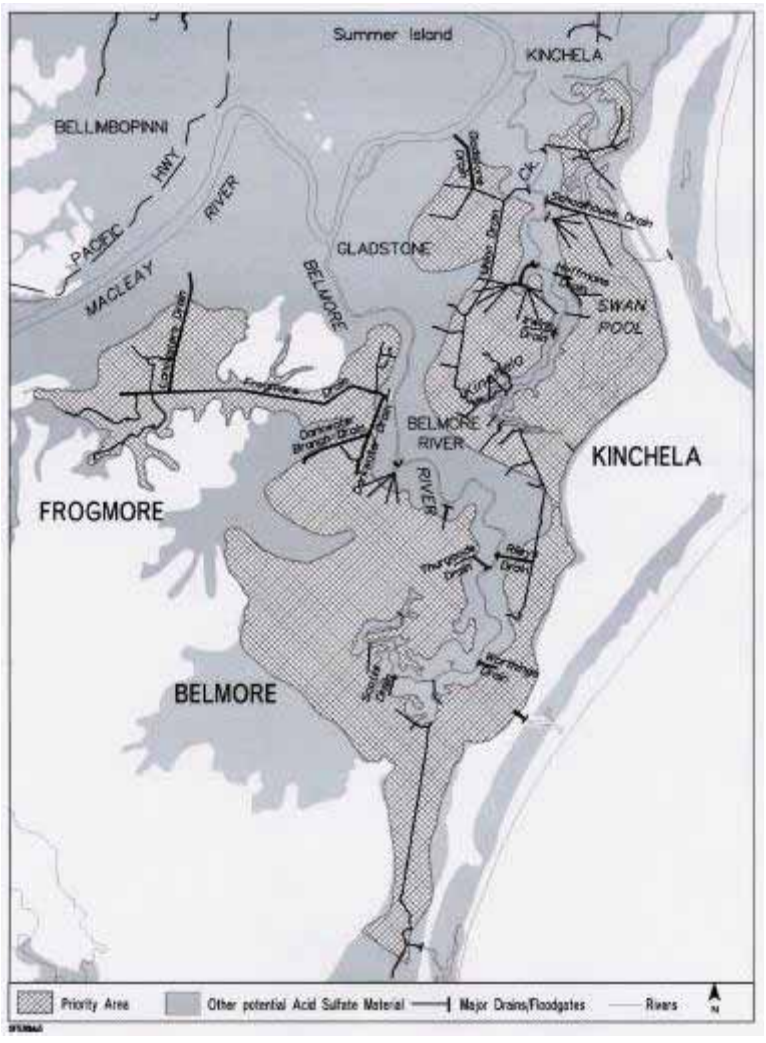

Figure 2.2 *An example from the Macleay ASS Hotspot program: Belmore, Frogmore and Kinchela Acid Sulphate Soil Management Priority Areas (source: Tula and Naylor, 1999).*

Floodgate and Drain Management

Kemsley (2001) notes that since the early 1900s the Macleay floodplain has been extensively modified with 34.4km of constructed levees, 180 structures supporting 382 gates and 138.12km of constructed drains. The issue of management of these structures is intrinsically linked to the previously discussed issues of floodplain wetland management and acid sulphate soil management as well as to water quality. As such many of the reports detailed in these three sections are also relevant to floodgate and drain management. Nevertheless a number of additional projects, reports, and data sources have been reviewed and are documented below.

Kempsey Council in association with community-based organisations such as MASSLAC, industry representatives such as Oyster Growers, individual landholders, and government agencies such as DIPNR and DPI Fisheries have been attempting to address floodgate and drain management issues through the Macleay River Floodplain Project since January 2000. The project develops management plans for major drainage areas and undertakes on-ground rehabilitation projects including drain and floodgate modifications.

A project to map floodplain drains was undertaken by DLWC (now DIPNR) in 2001. The results of this project can be viewed at http://www.dlwc.nsw.gov.au/care/soil/ass/management_and_remediation.html

Additional documents and information sources reviewed include;

Ref 96 *Issues in flood mitigation and land management on the lower Macleay River* (1996). Reviews the status of issues that were current in 1989 as identified in the "Review of land and water impacts on fisheries and agricultural resources in the lower Macleay - Working Party Report". The report assesses the progress in addressing the issues and identifies additional issues related to land and water management in the lower Macleay. The report focuses on technical issues, equity issues, fisheries impacts and implementation problems.

Ref 129 *Review of Land and Water Management Impacts on Fisheries and Agriculture Resources in the Lower Macleay - Working Party Report* (1989). Available published information on the linkages between fish kills, fish decline and the agronomy of soils of the lower Macleay is reviewed with specific reference to the effect of flood mitigation and drainage works.

Ref 99 *Macleay River Catchment Acid Sulphate Soil Remediation Projects Review* (2001). Contains background information on the Macleay River Floodplain Project and Lower Macleay Water Quality Monitoring Project plus useful recommendations related to the barriers to uptake of incentive and planning mechanisms for landholder management of floodgate and drain structures.

Ref 51 *Lower Macleay Floodplain Management Strategy: Aquatic Ecology and Fisheries. Review of existing information* (1996). The lower Macleay floodplain has been changed physically due to extensive flood mitigation works. Earlier studies have indicated that these works have had potential or actual effects on the aquatic ecology of the floodplain, such as fish kills and reduced estuarine production. The aim of this report is to collate and review existing information with respect to aquatic ecology and fisheries, identify data needs, and contribute to a process of evaluating management options.

Ref 28 *Sustainable land management of coastal floodplains in northern NSW - Macleay River Catchment Final Report* (2002). 180 floodgates have been identified within the Macleay Valley. An assessment was made to prioritise the 180 floodgates to determine their suitability for active management and reduce negative effects of their operation. 24 gates were selected as high priority for active management. The report outlines a methodology for developing floodgate management plans, giving two examples of implementation in the lower Macleay (Marriot's floodgates and Clancy's floodgates).

Ref 7 *New South Wales Coastal Rivers Floodplain Management Studies - Macleay Valley Summary Report* (1980). Outlines a summary of the physical extent of flooding, the nature of past flood mitigation works and makes recommendations for future drainage improvements.

Ref 12 *Upper Belmore Floodplain Management Strategy* (2000). Draft document dealing with issues relating to the Upper Belmore floodplain including five major floodplain strategies that deal with floodgate and drain management, local floodgate and drain management groups and acid sulphate soils.

Ref 40 *The ecological effects of structural flood mitigation works on fish habitats and fish communities in the lower Clarence River system of south-eastern Australia* (1994). Investigates the effects of flood mitigation structures on the quality of estuarine and freshwater fish habitats in the lower Clarence River system. Findings are relevant to the Macleay Estuary.

Ref 65 *Fish kill in the Belmore River, Macleay River drainage, NSW, and the possible influence of flood mitigation works* (1980).

Ref 97 *Status Report to Floodplain Management Steering Committee Meeting, 16 February 1996* (1996). Documents the various issues raised at 3 community meetings held in the lower Macleay to discuss floodplain management. The report summarises the various issues and provides possible solutions as a starting point for further discussion at a Floodplain Management Steering Committee Meeting.

Tidal guaging

Ref 16 *DIPNR Macleay River Estuary Tidal Data Collection April - May 2003. Report MHL 1250.* (2004). Describes the results of tidal gauging data collection undertaken at 29 sites in the Macleay estuary between 14 April and 23 May 2003. Tidal limits, tidal range, tidal lag and current velocities for all major estuarine waterways are recorded.

The Terms of Reference for this project specifically requested that elevation mapping of the floodplain surface be undertaken to assist the management of floodgates and drains. To be practical, such modelling would need to have a sub-metre accuracy and preferably map topographic variation to a 0.1 metre resolution. Whilst the technology exists to create such a dataset the process is prohibitively expensive for an area the size of the Macleay floodplain ($100,000 +) and such an exercise is most likely outside the resources available to the estuary management planning process.

Boating Use

NSW Maritime Authority is responsible for coordinating the preparation of Boating Management Plans on a State-wide priority basis. The Macleay River is not currently considered a priority system for the preparation of such a plan until beyond 2006 (Rod McDonagh, NSW Maritime, pers. Comm.. 2005).

NSW Maritime Authority also maintains spatial datasets of relevance to boating and estuary management including the location of boating facilities, moorings, navigation aids, restricted waters, river crossings, and oyster leases. As with other Government Departments these datasets are available under licence. NSW Maritime also records complaints made to their office and these are currently being compiled for the Macleay system (Rod McDonagh, NSW Maritime, pers. Comm.. 2005).

Figure 2.3 *"No Wash Zone" on the Macleay Arm*

Other digital datasets held by Government agencies include;

- Permissive Occupancy sites (jetties, pontoons, etc), Crown access points, Crown lease areas and foreshore parcels held by Department of Lands and available under licence
- Council Reserves held by Kempsey Shire Council.

Documents and information sources reviewed for this study include;

Ref 108 South West Rocks Creek - Review of hydrographic surveys

Ref 122 South West Rocks Creek Hydraulic Investigations of Boat Harbour Proposal

Ref 103 Proposed maintenance dredging - Macleay River. Review of Environmental Factors. (limited info on commercial uses of the estuary).

Ref 62 Macleay River Fishing Port Facilities Management Plan (Gutteridge Haskins & Davey)

The following research and experimentation on the impacts of boat wash on riverbank stability are also of relevance to the Macleay River estuary as boat waves are exacerbating erosion in some parts of the estuary, particularly on the southern end of the Macleay Arm, Clybucca Creek, and lower end of Anderson's Inlet (see Section 3);

Cowell, P.J. (1996). Wave Action and bank erosion behind Seaham Weir in the Williams River. Occasional Paper 1001. Healthy Rivers Commission of NSW. Sydney.

Nanson, G.C., Von Krusenstierna, A., and Bryant, E.A. (1994). Experimental measurements of river-bank erosion caused by boat-generated waves on the Gordon River, Tasmania. In: Regulated Rivers: Research and Management, Vol. 9, pp 1-14.

Willoughby, M.A. (1992). Boat wash on enclosed waterways. In: Forth Ports and Harbours Conference, Sydney, 24-27 August 1992, pp.223-227.

Glamore, W., Hudson, R., Cox, R. (2004). Managing inland and coastal waterways: boat wakes and wave dynamics. In: NSW Coastal Conference 2004, 13th Annual Coastal Conference, 9-12 November 2004, Lake Macquarie, pp.198-203.

Sedimentation

Little to no quantitative information exists on sediment loads for the Macleay River in either the tidal or non-tidal reaches. Furthermore, only rudimentary records exist for the volume of material extracted from the river. For example, the 1934 report on river erosion (***Ref 1***) provides an assessment of tidal dredging volumes for a short period in the early 20th century while the Macleay River Sand and Gravel Resource Assessment (***Ref 14*** Patterson Britton & Partners, 2003) provides an indication of the volume of aggregate material being extracted from the non-tidal reaches (*i.e.* the source zone for the estuary). Unfortunately, the information on sediment loads in both these reports is limited and sometimes poorly substantiated.

Other information on estuarine sedimentation must be gleaned from studies where the primary focus has not been on sediment distribution or quantification of sediment loads. Ashley and Graham (2001) provide some context as to where the fine-grained sediment in the estuary is sourced. Their analysis of heavy metals and isotopic signatures identified a distinct downstream dispersal trend for Antimony (Sb) and Arsenic (As). Importantly, their analysis highlighted the nature of floodplain sedimentation in the estuary with the preferential accumulation of sediment (and associated heavy metals) on the southern side of the Macleay River downstream of Kempsey (*e.g.* in levees and backswamps such as Belmore swamp). At present it is unknown whether such preferential accumulation is a natural phenomena or as the result of various flood mitigation measures which seek to control flooding in the valley. The Ashley and Graham study also highlights important potential implications of Arsenic and Antimony contamination in Macleay floodplain land and estuarine based productive systems.

There has been no systematic compilation of historical channel changes of the Lower Macleay River, despite the extensive post-European modification. Indeed there is no synthesis of the changes to channel dimensions or planform of the Lower Macleay River. Isolated comparisons of hydrographic surveys from the 1950s show variable results with both increases and decreases in waterway area. Very few hydrographic surveys have demonstrated cross-sectional or longitudinal changes in bed elevation.
In 2003, the Department of Commerce undertook an extensive bathymetric survey of the Macleay River estuary area which has potential for use for future monitoring of changes in sedimentation patterns, shoaling and bed level changes.

The Department of Infrastructure Planning and Natural Resources has information on past and current dredging operations in the estuary area and negotiates conditions of licence for such operations including those undertaken under SEPP 35 (Maintenance Dredging in Tidal Waterways).

Other documents that have relevance to the issue of sedimentation in the Macleay estuary include;

General
Ref 4 *Depositional and soil history along the lower Macleay River, New South Wales* (1970)

Ref 100 *Transport, retention and transformation of material in Australian estuaries.* (1998)

Specific to South West Rocks Creek or Back Creek
Ref 63 *South West Rocks Fishing Port Siltation Investigation* (1990)

Ref 108 *South West Rocks Creek - Review of hydrographic surveys* (1986)

Ref 122 *South West Rocks Creek Hydraulic Investigations of Boat Harbour Proposal* (1980)

Dredging

Ref 42 *Independent advice on dredging of river entrances and lower estuaries.* (prepared for the Healthy Rivers Commission, 2002)

Ref 103 *Proposed maintenance dredging - Macleay River. Review of Environmental Factors* (1994)

Floodplain heavy metal distribution and loadings

Ref 13 *Heavy Metal Loadings of streams in the Macleay River catchment* (2001).

Ref 98 *Soil, water and pasture enrichment of antimony and arsenic within a coastal floodplain system* (2005)

The paucity of information on sedimentation has significant ramifications for future stages of the estuarine planning process as sedimentation processes are intrinsically linked to other important issues of estuarine management (eg. bank and channel stability and recreational and boating use). Some preliminary investigations into this issue have been undertaken for this study with the results presented in Section 3.4.

Tourism Management

Whilst it is generally acknowledged that tourism is increasing in coastal areas of New South Wales there is very little specific information on trends for the Macleay estuary area. Tourism NSW has some limited statistics and report that domestic tourist visitor nights on the mid-north coast increased 8% between 2001/02 and 2002/03 to 13.9 million domestic visitor nights (Tourism Research Australia, 2004). NSW Tourism statistics include the purpose of visit but few of the categories are directly relevant to estuary management.

In terms of facilities and infrastructure for tourism and recreation, several government agencies maintain databases on structures such as private and public jetties and wharf's (Department of Lands, now DIPNR, including the location of permissive occupancy structures), Crown Reserves including road reserves and accesses (DIPNR), and Council Reserves and access points (Kempsey Council). These databases are often linked to Geographic Information Systems (GIS) although, depending on the data, restrictions on use may apply. As a part of this project all identifiable access points and access infrastructure (such as moorings, jetties, road accesses, tracks, etc) were logged by hand-held GPS and incorporated into an ArcVIEW based GIS system (see Section 3.7 below).

In terms of managing facilities for tourism and recreational use, a Plan of Management for the Mattys Flat area near South West Rocks has recently been identified as a priority by Council. However at the time of writing this study the Plan was in its preliminary consultation phases and the terms of reference had not yet been developed.

NSW Department of Primary Industries Fisheries recently attempted a project to combine information of interest to recreational anglers into a "one stop shop" under the banner of the Angler's Oracle. A map interface was intended to give access to primary datasets such asstocking locations, species & numbers, river/estuary access points (including boat ramps, public lands etc), regulations by locality, likely species to be found by locality, and declared special management areas (trout waters, fishing havens etc). Although this project was not completed due to funding shortfalls the data has been incorporated into the Natural Resource Atlas available through the CANRI website (Antonia Creese, DPI Fisheries pers.comm.. 2005).

Habitat Protection

The Macleay River estuary area represents a diverse array of habitat types including extensive backswamp and wetland areas, a mosaic of terrestrial and estuarine vegetation communities, and various aquatic and marine habitat environments. These habitats are not only important to local and migratory fish, bird, and mammal populations but to the primary productivity of estuaries and floodplains and to commercial enterprises such as oyster cultivation and fisheries.

In terms of land-based habitats, significant areas of littoral rainforest and coastal wetland have been mapped under SEPP 26 and SEPP 14 respectively. However, as mentioned elsewhere the consistency and accuracy of this mapping has been criticised due to the degree of discrepancy between the communities mapped and their actual physical extent within the estuary. More recently 8 *Endangered Ecological Communities* have been identified (under the TSC Act 1995) which improves the mechanisms of protection for these communities although the distribution and extent of most of the identified communities are not well documented in the Macleay.[19]

The NSW National Parks and Wildlife Service has undertaken Key Habitats and Corridors Mapping across northern NSW including the Macleay Estuary area (see Figure 3.7). The identified Regional Corridor under this NPWS Project is the Fishermans Bend Nature Reserve Regional Corridor which links from Hat Head NP and Arakoon SRA through Yarrahappini Wetlands, Tamban State Forest to Fishermans Bend NR and Mt Yarrahappini and Yarriabini National Park and then westwards to Ngambaa NR.

In terms of the riparian corridor, prior to commencing this study there was little quantitative information on the condition of the Macleay Estuary riparian corridor although it was known to be highly degraded along the main arm of the estuary and Belmore River, Kinchella Creek, and Christmas Creek (data collected on riparian condition for this study is presented in Section 3.5). Vegetation within 1km of the Coastal Zone (which includes all tidal waters) is specifically protected under provisions of the Native Vegetation Conservation Act 2000 although compliance with and enforcement of the new regulations is inconsistent at best.

The following documents and data sources provide further specific information on land-based habitat attributes in the Macleay estuary area;

Ref 84 *Saltwater Creek Catchment - Flora and Fauna Study, South West Rocks* (2003).

Ref 85 *Vegetation Survey of Saltwater Creek, Arakoon State Recreation Area, NSW* (1995).

Ref 91 *Rainforests of the Lower Macleay River Flats* (1984).

Ref 92 *Rainforest Islands on the Lower Reaches of the Northern Rivers of NSW* (1978).

Ref 93 *Report on Forests of Shark Island* (1977).

Ref 40 *The ecological effects of structural flood mitigation works on fish habitats and fish communities in the lower Clarence River system of south-eastern Australia* (1994). Investigates the effects of flood mitigation structures on the quality of estuarine and freshwater fish habitats in the lower Clarence River system.

Information on the extent and location of estuarine vegetation including mangrove, saltmarsh and seagrass (Zostera spp.) communities was collected as part of the NSW Estuary Inventory project completed by NSW Fisheries in 1984 (West et al, 1985). This dataset is also available in digital format

[19] Refer to Section 3.5 for a list of *Endangered Ecological Communities* gazetted under the *NSW Threatened Species Conservation Act 1995*

as a GIS layer. Currently, this dataset is being updated using 2003 aerial photography and ground-truthed using differential GPS and is expected to be completed for the Macleay River estuary in 2005 (West, pers. Comm., 2004). The *Fisheries Management Act 1994* protects all marine and freshwater aquatic fish and invertebrates, and marine and estuarine vegetation (Coastal Saltmarsh is also a gazetted Endangered Ecological Community).

Other data sources relating to estuarine and aquatic habitats that have been identified and reviewed include;

Ref 83 *Estuarine Fisheries Resources of Two South-east Australian Rivers* (1993). Describes changes in area (km2) for Seagrass, Mangrove and Saltmarsh from 1947, 1962, 1981, and 1986 for the Tweed, Clarence and Macleay Rivers.

Ref 73 *Water Habitats of the Nambucca, Macleay and Hastings Catchments - North Coast Water Habitats Study Report #3*. Report prepared for the Mid North Coast Water Management Committee (2001). Overviews Water Habitat types and their water requirements and sensitivity to water management activities and threats to these habitats types . Summarises Threatened Species and Protected Areas under variety of recognised listings and differing legislative mechanisms (needs updating for more recent listings).

Ref 78 *The Importance of groundwater to seagrass habitats at Stuarts Point* (2000). Highlights the need to consider groundwater (quantity and quality) implications on lands above aquifers on aquatic habitats within adjacent rivers.

Ref 82 *Mapping of Bass Habitat in the Macleay, Hawkesbury and Shoalhaven Rivers - Interim Report for the Recreational Freshwater Trust Expenditure Committee* (Draft 2004).

Ref 74 *Environmental impact statement for the proposed restoration of tidal inundation of Yarrahapinni Wetland, Mid-North Coast, NSW* (1997). Prepared for Yarrahapinni Wetlands Reserve Trust. Identifies flora and fauna habitat issues which are now somewhat out-of- date. Includes Flora, Fauna and "'Threatened Species likely to occur" lists.

A list of *Threatened Species of the Lower North Coast of New South Wales* is also available (***Ref 86***).

Fish and Shellfish Management

The *Fisheries Management Act 1994* (FM Act) was established to "conserve, develop and share the fishery resources of the State for the benefit of present and future generations". The FM Act protects all marine and freshwater aquatic fish and invertebrates, and marine and estuarine vegetation. The Department of Primary Industries Fisheries (previously NSW Fisheries) is the primary agency responsible for the management of the state's fisheries resources. As such they are responsible for conserving and managing fisheries resources, protecting fish habitats, promoting viable commercial fishing and aquaculture industries and undertaking research to assist these activities.

DPI Fisheries is the custodian of several datasets relevant to Fisheries and estuary management (many available under licence in GIS format). They include the location of existing Aquaculture Leases (both former and current), Estuarine Inventory information (seagrass, mangrove, and saltmarsh areas), and Bass Habitat Mapping (expected to be available late 2005). In addition, commercial fisheries catch statistics from licensed fishers are available on request for the period 1940 to 2002, with detailed information on reported catch and catch methods available post July 1997. The number of Commercial Licences operating in the Macleay River is also available. In terms of research projects, a summary of projects being undertaken by Fisheries is provided in (last updated 22 April 2005): http://www.fisheries.nsw.gov.au/__data/assets/pdf_file/5230/Project-Summaries.pdf#PDF

In terms of recreational fishing, DPI Fisheries released an interim report on a survey of recreational fishing in NSW in December 2002. The report states that NSW has an estimated 998,500 recreational fishers of which 74, 440 are estimated to live on the mid-north coast NSW (representing approximately 29.9% of the Mid-North Coast population). Recreational fishing in saltwater (offshore, coast, and estuaries) accounts for 74% of all fishing trips in NSW with 47% occurring in estuaries. The average direct expenditure on recreational fishing per person per year is $550. A quick extrapolation of the number of fishers data and average expenditure shows that recreational fishing is worth an estimated $40.92 million per year to the mid-north coast regional economy. Unfortunately, no figures specific to the Macleay catchment are currently available. While the catch of individual fishers is not large (about 2 fish per event), the recreational sector as a whole has the potential to impact aquatic resources. The recreational catch of several common estuarine species is larger than the commercial catch. However, for most species, the commercial catch is substantially greater than the recreational catch.

The Macleay River estuary has had numerous fishkills reported over recent years including 11 events between December 2000 and March 2001 (Kemsley, 2001). Investigations have shown that the extensive draining of swamps and wetland areas that occurred during the flood mitigation era have impacted aquatic life through loss of habitat and reduced water quality (with deoxygenated water, acid water, and aluminium toxicity being the major impacts, see references below for further information). In recent years, there have been increased efforts by some landholders to manage water tables to reduce these negative effects but to a large extent the issues still remain.

NSW Food Authority (previously SAFE FOODS) has conducted a survey of water bacteriology (faecal coliforms) and toxic phytoplankton for all NSW Aquaculture Shellfish Harvest Areas in the state including the Macleay River (NSW Food Authority, 2004).

The following documents provide further information on fish and shellfish management in the Macleay Estuary area;

Ref 126 *Review of Land and Water Management Impacts on Fisheries and Agriculture Resources in the Lower Macleay - Working Party Report* (1989). Available published information on the linkages between fish kills, fish decline and the agronomy of soils of the lower Macleay is reviewed with specific reference to the effect of flood mitigation and drainage works.

Ref 83 *Estuarine Fisheries Resources of Two South-east Australian Rivers* (1993). Describes changes in area (km2) for Seagrass, Mangrove and Saltmarsh from 1947, 1962, 1981, and 1986 for the Tweed, Clarence and Macleay Rivers.

Ref 73 *Water Habitats of the Nambucca, Macleay and Hastings Catchments - North Coast Water Habitats Study Report #3.* Report prepared for the Mid North Coast Water Management Committee. (NPWS 2001)

Ref 40 *The ecological effects of structural flood mitigation works on fish habitats and fish communities in the lower Clarence River system of south-eastern Australia* (1994).

Ref 88 *NSW Fisheries 'Policies and Guidelines' - Aquatic Habitat Management and Fish Conservation* 1998/1999

Ref 21 *Scientific reports on the recovery of the Richmond and Macleay Rivers following fish kills in February and March 2001* (2002). Monitoring of the recovery of fish, crustaceans and water quality was undertaken over a 12 month period, the results of which are presented in a series of discrete reports compiled into this document.

Ref 37 *NSW North Coast Sustainable Aquaculture Strategy - Land based aquaculture* (2000). The strategy contains two components - a best management practice component and an integrated approval process component - which are intended to ensure development in an efficient and sustainable manner. The strategy concerns land based aquaculture only.

Ref 89 *Indigenous Fisheries Strategy and Implementation Plan* (2002).

Water Quality

The most comprehensive assessment of water quality monitoring programs in the Macleay River Catchment is provided by Sue Botting in her 2000 analysis of programs that operated over the period from 1987 to 2000 (***Ref 20***). Botting assessed the adequacy of the dataset against four main criteria;

- To identify any potential water quality problems
- To be used as a baseline for future monitoring
- To identify areas of poor water quality from an aquatic ecosystem and human health perspective
- To diagnose likely causes of poor water quality, and;
- To identify areas of good stream health.

Botting's report made a number of useful recommendations relating to data management, modifications to existing monitoring programs and priorities for new programs, public involvement in monitoring, and the identification of areas of poor water quality. Many of these recommendations are still valid today and this report would be worth revisiting in future stages of the EMP process.

Unfortunately, community-based collection of water quality data is now almost non-existent since the Waterwatch program has been locally inactive for a number of years.

Kempsey Council currently has three main water quality programs that are relevant to the Macleay Estuary;

1. The Macleay River Water Quality Monitoring Project was initiated in 1997 with an initial focus on the Belmore River. The project uses telemetric water quality stations to collect data on water depth, dissolved oxygen, temperature, pH (acidity), and electrical conductivity (salinity) on a continuous basis at 15 minute intervals. Sixteen stations are currently in operation with all transmitting water level data, 9 sites also measuring the five water quality parameters, and 4 sites also recording rainfall data. The gauges are also able to take physical samples for later laboratory analysis for Aluminium, Iron, sulphides or other toxic elements. The data is transferred to the Manly Hydraulics Laboratory and is accessible over the internet at: http://www.mhl.nsw.gov.au/www/kempwqindex.htmlx

   The data is also linked to councils flood warning system and integrated with 17 rain gauges and 14 river height gauges in the Macleay catchment to provide a very comprehensive coverage of the catchment. A review of the Macleay Water Quality Monitoring Project is available at: http://www.mhl.nsw.gov.au/www/MacleayWaterQualityMonitoringProject.pdf

2. The Council's Beachwatch Program commenced in early October 2003 and is aimed at monitoring faecal coliform levels at beaches during the Summer period. 10 locations are monitored including Killick Creek, Killick Beach, Trial Bay, Horseshoe Bay, Back Creek, Hat Head, Stuarts Point, Grassy Head, Korogoro Creek, Saltwater Creek. Results are available on the Council website.

3. The Macleay River Floodplain Project seeks to establish a consensus approach to improving overall environmental condition and water quality of the Macleay River Floodplain. The project actively works with landholders to seek solutions to problems associated with drainage and ASS impacts.

As mentioned previously, the NSW Food Authority conducted a survey of water bacteriology (faecal coliforms) and toxic phytoplankton in the lower Macleay River between January 2003 and December 2003 (NSW Food Authority, 2004).

Other reports and data sources on estuarine water quality in the Macleay study area include:

Tidal gauging data

Ref 16 *DIPNR Macleay River Estuary Tidal Data Collection April - May 2003. Report MHL 1250.* (2004). 59 water quality profiles were collected (excluding coliform and nutrient levels) between 14 and 16 April 2003 as part of a tidal gauging survey.

Effects of flood mitigation

Ref 15 *Macleay River Floodplain Post January and March 2001 Flood Event Water Quality Monitoring Report* (2001). Reports the results of pH and DO testing conducted post the January and March 2001 floods at 10 floodplain waterbody sites in the lower Macleay and attempts to link pH and DO levels to recorded fish kills over the period.

Ref 26 *Water Quality in the Macleay River - Northern Rivers Study No. 8* (1987). Presents the results of water quality sampling in the Macleay River undertaken between June 1984 and June 1986. 36 sites were sampled including 25 estuarine sites. Includes sewerage treatment plant and industrial site sampling. Sampling dates were selected to represent pre-determined flow regimes as opposed to fixed interval sampling. Extensive professional analyses including nutrients. Draws conclusions as to potential sources of poor water quality including an assessment of the effects of flood mitigation.

Ref 29 *DLWC Water quality monitoring at Yarrahapinni Wetland. Report MHL986* (2001).

Ref 31 *Water quality monitoring program - Belmore River Landcare Group Progress Report* 1990-1992

Guidelines and Policies

Ref 27 *Water quality and river flow interim environmental objectives* (1999). This document sets out broad goals and guidelines for achieving improved river health outcomes in the Macleay River catchment. Interim water quality objectives with key indicators and numerical criteria are provided.

Ref 48 *Guidelines for managing risks in recreational waters - Draft* (May 2004).

Ref 55 *Kempsey Shire Urban Stormwater Management Plan 2000-2005* (2000).

Heavy metal contamination

Ref 98 *Soil, water and pasture enrichment of antimony and arsenic within a coastal floodplain system* (2005; in press). This study builds a previous work by Ashley and Graham (2001; ***Ref 13***), and sets out to determine the spatial and vertical distribution of Arsenic (As) and Antimony (Sb) contamination across the Macleay Coastal floodplain and to investigate possible uptake of these contaminants into selected pasture species. Includes water quality analyses.

Ref 13 Heavy Metal Loadings of streams in the Macleay River catchment (2001).

Nutrients

Ref 30 Monitoring of Macleay River in the vicinity of Christmas Creek. Report MHL853 (1997).

River Health

A number of documents which broadly address "river health" issues have been reviewed and are summarised below;

Ref 43 *Independent inquiry into North Coast Rivers - Final Report* (2003). This report is the culmination of the Healthy Rivers Commission independent and public inquiry into the health of NSW North Coast rivers. The report is based on extensive public, agency, and stakeholder submissions (175 in total) to the Commission's Draft Issues Statement released in 2002. The purpose of the report is to recommend to the NSW Government long-term river health goals and management strategies to achieve these goals. 10 recommendations are provided covering issues such as agriculture and river health, aquaculture, fishing, regional planning, local planning, estuary management and navigation, and river health goals.

Ref 35 *Stressed Rivers Assessment - Macleay River* (1999). The stressed rivers approach incorporates the assessment and classification of environmental and hydrological stress and conservation value of rivers. Environmental stress is based on river health factors such as bank and bed erosion, riparian vegetation, land use, fish barriers, water quality, macroinvertebrates, algal blooms, fish kills, point source discharge, levee banks and acid runoff. The overall stress rating is based on combining the environmental and hydrological stress rating. High conservation values have been identified by Fisheries and NPWS.

Ref 36 *State of the Rivers and Estuaries Report - Mid North Coast Catchments* (1995). A report on waterway health and management for water users and resource managers. The main objectives of the report are to: provide information about the status and condition of the Mid North Coast waterways; indicate the accessibility of the information; prevent duplication of effort and improve communication between those concerned with the management of estuarine and riverine resources; present information on benchmarks and trends for assessment of the cumulative effects of management policies and programs; identify unresolved or emerging issues; identify substantial gaps in the information; and; to provide a basis of current data collection and monitoring programs.

Climate Change and Sea Level Rise

In 2002 The Healthy Rivers Commission recommended that PlanningNSW assess the social, economic and ecosystem risks that may result from a rise in sea level and change in storm events for coastal lakes and other coastal lakes (HRC, 2002). At the time, this recommendation was based on CSIRO's 2001 predictions on climate change which have since been further reinforced by CSIRO's most recent report, "*Climate Change in New South Wales – Part 2 Projected changes in climate extremes*". Hennesy et al. (2004) in this report estimate that if there are no explicit policies to limit greenhouse gas emissions;

> *"By the year 2100, global average temperature may rise 1.4 to 5.8^{o}C and global-average sea level may rise 9 to 88 cm, relative to 1990."*

The Terms of Reference requested that projected inundation levels for climate change scenarios be mapped and the implications for current planning and development controls of Council be determined. This simply was not possible for this study. However, given the nature of the potential changes it would seem prudent to commence investigation in areas that may be subject to inundation effects under different sea level change scenarios.

It is not known whether Kempsey Council or any State-based planning Authority has adopted any standard to address predicted rises in sea level or increase in extreme storm events.

Information availability and Integration of Projects

Whilst there has been a substantial amount of scientific work done on the Macleay River estuary, access to this information has been limited by the lack of a centralised depository or database. In some cases this has led to duplication of projects, poor project integration, in worst cases poor management decisions.

The problems of duplication and poor integration of policies, planning activities and programs in natural resource management have been referred to in numerous reports over the last 15 years. More recently, the Healthy Rivers Commission Independent Inquiry into the North Coast Rivers comprehensively overviews the issues associated with poor integration of natural resource management planning and makes specific reference to estuary management planning (***Ref 43***: pp.74-78).

As mention in the introduction to this section, the Comprehensive Coastal Assessment program and NSW Natural Resources Data Directory are currently being undertaken with the aim of compiling information and data on natural resource management. Both these programs have the potential to reduce project duplication and improving integration.

Other documents that attempt to summarise or make recommendations in this regard are

Ref 51 *Lower Macleay Floodplain Management Strategy: Aquatic Ecology and Fisheries. Review of existing information* (1996).

Ref 36 *State of the Rivers and Estuaries Report - Mid North Coast Catchments* (1995)

Ref 58 *Environmental Management Issues of the Coastal Floodplains of New South Wales* (1996). An overview of issues related to the environmental management of coastal floodplains in NSW produced through a review and collation of technical reports, strategic plans, workshop proceedings and consultations with stakeholders. Identifies 35 major issues under four broad categories: water, land, riparian zones, and, land use planning and management.

Ref 126 *Review of Land and Water Management Impacts on Fisheries and Agriculture Resources in the Lower Macleay - Working Party Report* (1989) are two early reports that make recommendations in this regard.

For this project, a centralised registry of information that relates to the Macleay Estuary and its floodplain has been established in the form of a internet accessible and searchable electronic database. The electronic data register currently contains 124 entries including references and abstracts of reports, journal articles, digital datasets, aerial photograph resources, proceedings, management plans and scientific studies dating back to 1891.

2.2 Additional data collated and reviewed

The initial focus of the data collation and review process was to focus on the issues identified by the EMC. These datasets have been presented in Section 2.1 above. In the process of collating this information several other existing datasets were reviewed which although relevant to Estuary Management Planning were not identified in the EMC issues. These additional datasets are summarised below with more details provided in Appendix A on the Project CD.

Flood Investigations relating to the Kempsey Pacific Highway Upgrade

Ref 94 *Interim Flood Assessment Report - Comparison of Route Options* (2003)

Ref 95 *Supplementary Flood Investigations - Eastern Route Options* (2004)

Social Attitudes

Ref 47 *TCM Community Study - Macleay Catchment* (1996). The purpose of the TCM Community Study was to provide actionable and appropriate data which could be used in the development of a detailed marketing strategy aimed at promoting a good understanding of TCM within the community and encouraging participation. Areas of investigation included awareness of local environmental issues, awareness of environmental programs, perceptions of the state of the environment, attitudinal segmentation, and perceptions of TCM objectives. The findings included that 32% of people were unable to identify any environmental issues in their area, spontaneous awareness of environmental programs was low, community identified issues are similar to TCM committee identified issues, and waterways and water quality are regarded as being in poor condition. The majority of those surveyed support the aims of TCM so it is concluded that there are no concept barrier to adoption.

Digital Data Resources

Ref 34 *North Coast Assessment - Available Digital Data Sets* (2004). Provides a table of current natural resource management related GIS (geographical information systems) digital data sets held mostly by NSW Government Agencies with some datasets from Commonwealth Agencies and Local Government. The list was compiled for the North Coast Assessment Process and contains Keyword identifier, data layer name, capture scale, data currency, custodian, GIS format, storage medium, attributes, comments and any restrictions on use.

Aerial photography resources.

Ref 32 *United Photo and Graphic.* www.unitedphoto.com.auAllows searching of historic and archival aerial photography by 1:100 000 map sheet. Includes flight paths for aerial photography from early 1940s over the Macleay Estuary area.

Ref 33 *Air Photo library index abstract* (2003). Provides an index by area of available aerial photography resources. Resources can be obtained through Land and Property Information (02) 6332 8123.

Marine, beach and dune systems

Ref 68 *Stuarts Point Coastline Hazard Advice* (2000). Evaluates the coastal dune system in the vicinity of Stuarts Point with respect to the following coastline hazards: short-term beach erosion; slope instability/reduced bearing capacity; long-term recession; oceanic inundation; and, climatic change. The evaluation was requested by the Urban Water Branch so that any proposed effluent infrastructure could be placed outside the influence of coastal hazards. The report briefly describes the various hazards, the methods used to assess them and the results of the assessment. It concludes that the area is not subject to long-term recession but that the other hazards are present. As a result it defines zone widths of 40, 60 and 75 metres as the landward limits of hazards for the immediate, 50 year and 100 year planning horizons, respectively. Includes graphical results of analyses and several aerial photograph mosaics including diagrams of 100 year coastline hazard line.

Groundwater

Ref 49 *Groundwater characteristics of the Kempsey District, NSW* (1961).

Ref 50 *The NSW Groundwater Quality Protection Policy* (1998).

Ref 115 *Groundwater for Stuarts Point Water Supply* (1983).

Ref 124 and ***125*** also deal with groundwater issues within the study area but have limited application to estuary management.

2.3 Data sources identified but not reviewed

Whilst it is believed that the vast majority of the available written information and data has been identified during this study, not all information was able to be collated and reviewed. A major source of information was identified during early research for the project at the Department of Commerce (previously the Public Works Department) premises in Sydney. A summary of the items available in the old PWD archives is provided in Table 2.1 as many of the records are of significant historical interest if not of contemporary management application.

Table 2.1 *Summary of plans related to the Macleay River estuary held at the Department of Commerce head office (old Public Works Department)*

Plan No	Plan Sub Heading	Survey Date	Comments
53062	Hydrographic monitoring survey	05 Mar 1997	Bathymetry available as A3
52067	Hydrographic monitoring survey at entrance	13 Aug 1996	Bathymetry available as A3
52062	Post flood survey at entrance	28 May 1996	Bathymetry available as A3
51236	Lower floodplain sections and locality plan	01 Apr 1994	
13498	Shark Island reduced levels	01 May 1983	
50235	Proposed dredging – old course – Stuarts Point	01 Jan 1982	Completed by Kempsey Shire Council
12093	Entrance leads soundings	01 May 1979	
11350	Index plan – soundings on Orthophoto maps	30 Sep 1972	Hydrographic survey related to AHD, mostly up to Rainbow reach with some U/S cross-sections
15551	Shark Island diversion	01 July 1963	
6821	Rainbow Reach soundings and levels bank protection	01 Nov 1962	Includes many cross-sections
6214	Flood mitigation – bench marks and levels	01 Sep 1961	Survey goes up to Greenhills and down to Point Plomer
15545	Shark Island diversion	01 Jun 1961	Shows intended diversion cut
6603	Soundings – cross sections entrance to Kempsey	01 Mar 1959	
6601	Tidal gradient	01 Sep 1958	
6602	Soundings cross sections and BM schedule	01 May 1958	To Kempsey
6600	Entrance soundings	01 May 1958	
6150	Compilation plan showing bridges, ferries and wharves	03 Jan 1956	Shows heads of navigation and limits of tidal influence
5889	Cross sections	01 Oct 1952	Cross sections from Greenhills down
5888	Shark Island soundings	20 Oct 1951	
5907	Soundings – entrance to Aldavilla	01 Oct 1951	Basic soundings all up the river

Plan No	Plan Sub Heading	Survey Date	Comments
			with basic Planform and building locations, etc
4565	Compilation plan	01 Jan 1940	
4136	Rainbow Reach cross sections bank protection	01 Jan 1936	
4149	Tidal gradient	01 Jan 1936	
4089 & 4195	Jerseyville to Lady Beatrice wreck bank protection	01 Nov 1935	Bank protection design, cross sections, bank bore logs
4014	Entrance soundings – Shark Island	01 Mar 1935	
3998	Spencers Creek to Jerseyville erosion plan	01 Jan 1935	Shows location of erosion, levee banks, 1893 flood, hydrogarhics, tide levels, vegetation descriptions (basic), flood levels at Jerseyville, wharves and other infrastructure
4084	Lower propsed flkood relief openings	01 Jan 1935	
15899	Entrance to Goat Island	01 Apr 1929	Shows an “ocean break” near Stuarts Point presumably after the 1929 flood.
15898	Entrance soundings	01 Apr 1929	Shows new entrance conditions and soundings
1953	Ocean break near Stewarts Point	01 Sep 1923	Shows the old river mouth still open plus numerous ICOLLs along the Arm
1258	Entrance – proposed breakwall	01 Jan 1920	
493	Soundings – new Spencer Creek entrance	01 Nov 1914	Shows works at mouth plus bathymetry plus descriptions of vegetation, etc.
15899	Entrance soundings	01 Nov 1895	Shows new cuts and proposed works
15887	Entrance soundings	01 Nov 1895	Showing new entrance
15892	Entrance soundings	01 Feb 1889	Shows old entrance and is very descriptive of shoaling and vegetation, etc.
15894 & 15893	Soundings – entrance to Belgrave Falls	01 Jun 1888	Painted in colour and very descriptive
15896	Entrance to Shark Island soundings	01 Sep 1887	
15888	Entrance and Trial Bay soundings	01 Jan 1866	Shows trace of coastline in 1866 and soundings at Grassy Head bar
15891	Entrance soundings	11 Nov 1861	Shows old entrance and some vegetation descriptions

PART 3 ADDITIONAL DATA COLLECTED FOR THIS STUDY

Prior to the commencement of this data compilation study, it was determined that three important sets of baseline data were crucial to future stages of the estuary management process. The three areas were;

- Estuarine Geomorphology (incorporating estuary classification, bank erosion, riparian land management, and estuary sedimentation)
- Estuarine Flora and Fauna (incorporating estuarine and riparian vegetation, fauna and habitat), and
- Estuarine Infrastructure and Works

The following sections of the report present preliminary information on the three identified baseline data gaps determined prior to the commencement of the study.

3.1 *Estuary Geomorphology and Classification*

The Macleay estuary is a mature barrier-dominated system in a high-energy ocean wave setting. It is a filled (delta) system dominated by fluvial processes. It can be broken into three broad process zones that reflect differing degrees of fluvial and tidal interactions (Figure 3.1). The fluvial process zone is the spatially most extensive and extends from Belgrave Falls to Kinchela and can be broken into three reaches with different morphological attributes. Collectively, these three fluvial reaches represent a transition from the non-tidal gravel bed reaches of the middle Macleay catchment to the entirely estuarine-dominated reaches of the Lower Macleay River. A short transitional zone exists from Kinchela to Jerseyville Bridge and on Clybucca Creek. These segments of the estuary reflect a transition from entirely fluvial processes to both fluvial and tidal processes. In contrast, the remaining Lower Macleay River is dominated by tidal processes and the presence of marine-derived sediment. Table 3.1 summarises the morphological and tidal attributes of the Macleay Estuary (source: http://www.ozestuaries.com.au).

Table 3.1 *Morphological and tidal attributes of the Macleay Estuary (www.ozestuaries.org)*

Barrier backbarrier (km^2)	3.67	Tidal sand banks (km^2)	1.22
Central basin (km^2)	0.91	Rocky reef (km^2)	0
Fluvial bayhead delta (km^2)	0	Coral (km^2)	0
Flood/ebb delta (km^2)	1.13	Channel (km^2)	10.21
Intertidal flats (km^2)	1.74	Bedrock (km^2)	0
Mangrove (km^2)	5.94	Floodplain (km^2)	4.76
Saltmarsh/saltflat (km^2)	4.22	Bedrock perimeter (km)	3
Water area (km^2)	19.91	Entrance width (km)	0.18
Perimeter (km)	157.73	Entrance length (km)	0
Maximum length (km)	49.65		
Maximum width (km)	0.56		
Mean wave height (m)	1.55	Mean wave period (sec)	7.11
Max wave height (m)	6.9	Max wave period (sec)	13.5
Tidal range (m)	1.2 – 1.8	Tidal period (sec)	Semi-diurnal

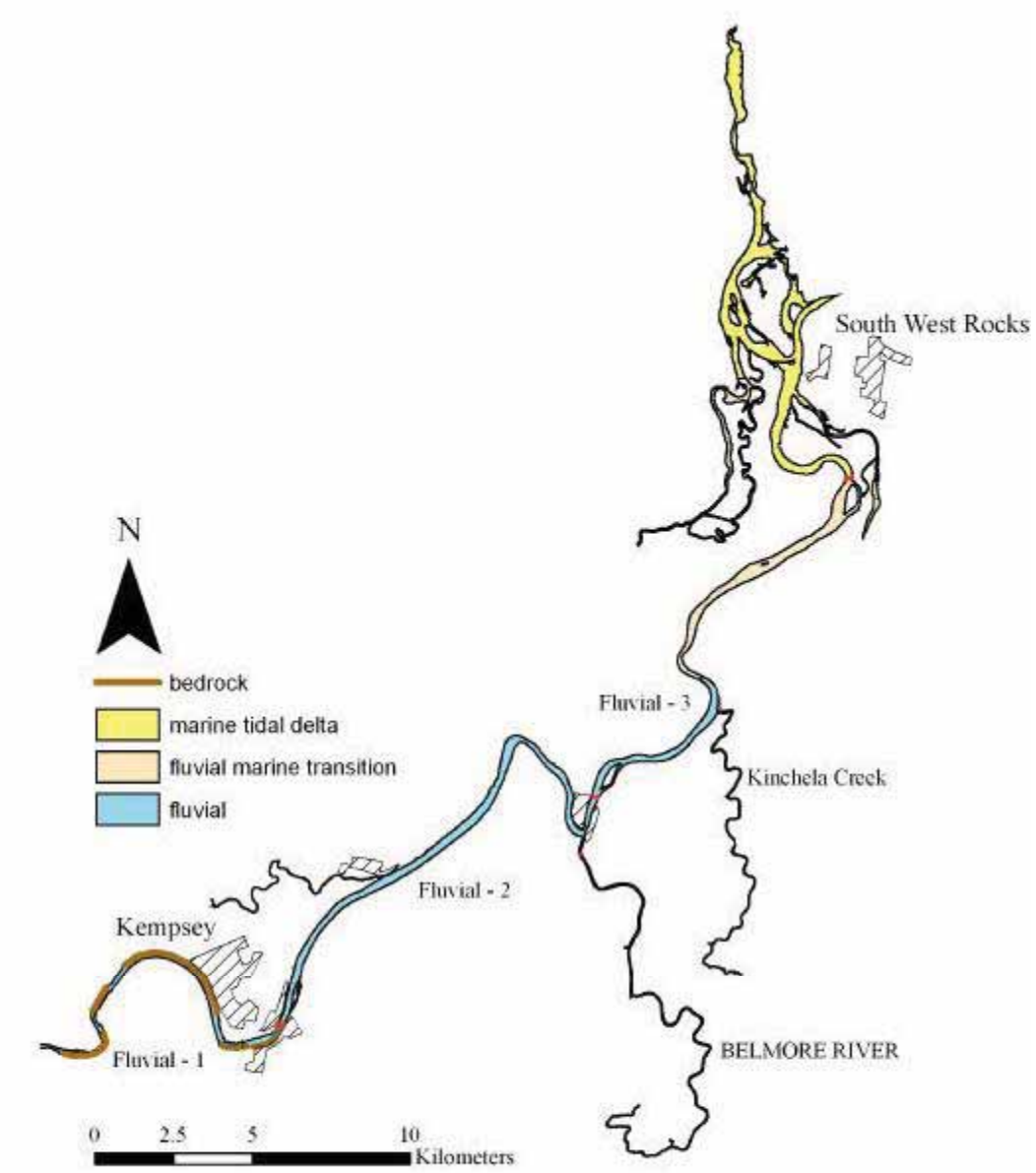

Figure 3.1 *Distribution of process zones in the Macleay Estuary*

3.2 *Bank Erosion and Riparian Land Management*

Ninety per cent of the entire surveyed estuary is stable with 27 % of this being stabilised by rockwork. There are 25 km of eroding riverbanks with minor erosion being the most common erosion category. While there has been an increase in the incidence of minor bank erosion in the last 70 years there has been a marked reduction in moderate and severe bank erosion since 1934 (26 % and 68 % reduction respectively; *Table 3.2*). The most active areas in the estuary are Kinchela Bench and Fattorini Island (fluvial reach 3). Kinchela Bench has eroded by up to 35 m since 1942 with the greatest rate of change occurring between 1942 - 1956 (reflecting the large floods of 1946, 1949 and 1950). Fattorini Island has also been reduced in length by 70 – 50 m since 1942. These locations are continuing to erode at high rates from wind and/or boat waves (relative contribution unknown).

Table 3.2 *Comparison of bank erosion data from 1934 to 2004*

BANK EROSION	*Minimum (km)*	*Moderate (km)*	*Severe (km)*	TOTAL
1934	1.6	5.4	9.5	16.5
2004	18	4	3	25
% change	+ 1025	- 26	- 68	+ 52

Table 3.3 shows the severity of bank erosion in the Macleay estuary by process zone. The Fluvial Process Zone has the most extensive occurrence of minor and moderate erosion and the only incidence of severe erosion, with 10 km of eroding riverbanks. Seventy eight per cent of the stable banks are naturally stable with the remaining 22 % stabilised with rockwork. The Transitional Process Zone has 7.5 km of minor and moderate bank erosion with 43 % of the stable banks being rocked. The Marine Flood-tide Delta process zone has the least erosion with 94 % of the surveyed area being stable (of which 77 % is naturally stable).

Table 3.3 *Severity of bank erosion in the Macleay estuary process zones*[20]

	Total length (km)	*Total surv. (km)*	*Stable (km)*	*Min. (km)*	*Mod. (km)*	*Severe (km)*	*% Stable*	*% Min.*	*% Mod.*	*% Severe*	*% stable= rocked*
ENTIRE ESTUARY	357	270	245	18	4	3	90	7	2	1	27
Fluvial	187	134	120.1	8	2.8	3	90	6	2	2	22
Transitional	80.5	69	61.2	6.3	1.2	-	89	9	2	-	43
Marine delta	95.9	70	66.1	3.8	-	-	94	6	-	-	23

The dominant causes of bank erosion in the Macleay estuary are:

- Fluvial processes
- Wind and/or boat waves
- In-channel sedimentation
- Stock disturbance/reduced riparian vegetation
- Presence of rockwork on adjacent banks

The relative role of these controls varies considerably between process zones and is partly determined by local factors (deep or shallow water profiles). Furthermore, the history of catchment disturbance in the Macleay valley, including the 1.24 million tonnes of sediment that have been dredged from the estuary between 1929 and 1963, continues to have important impacts on estuarine processes.

A summary of the physical condition of the process zones of the Macleay estuary is provided in Table 3.4.

More detail can be found in ***Appendix E - The Geomorphology of the Macleay River Estuary*** (available on the ***Macleay Estuary Data Compilation Project CD***).

[20] "Transitional" equals the fluvial-marine transitional zone. Percentages are calculated as proportion of area surveyed.

Table 3.4 *Summary of the physical condition of the process zones of the Macleay Estuary*

PROCESS ZONE	PRIMARY CHARACTERISTICS	NATURE OF IMPACTS	CONDITION	RECOVERY POTENTIAL
FLUVIAL	• Three reaches dominated by fluvial processes. • Reach 1 – Gravel bed reach, confined with bedrock outer margins. Localised mass failure of entire alluvial channel margin, controlled by fluvial processes. • Reach 2 – Gravel-sand bed reach. First major depositional reach in the process zone. Onset of wind and /or boat wave erosion. Extensive rockwork. • Reach 3 – Sand bed reach with extensive rockwork, in-channel sedimentation. Slab-and-block failure of inset features (*e.g.* Kinchela Bench, Fattorini Island).	• Greatest extent of erosion and only occurrence of severe erosion. • 22 % of stable banks are rocked. • Reach 1 – aggregate extraction, widespread stock impacts. • Reach 2 – dredging of main channel, levee construction, channel expansion. Belmore River and Kinchela Creek modified severely by drainage works. Loss of continuous native riparian zone. • Reach 3 – dredging of main channel, levee construction. Loss of continuous native riparian zone.	Poor-moderate	• ***Reach 1 – Moderate***. This reach has bedrock outer channel margins which are well vegetated and naturally stable. • ***Reach 2 – Poor***. This reach is greatly modified with large lengths of channel margin that are rocked and/or lacking riparian vegetation. Given the its landscape position, this reach will always be a major depositional zone. • ***Reach 3 – Poor***. This reach will also receive ongoing terrestrially-derived sediment
TRANSITION	• Dominated by fluvial and marine processes with the presence of marine-derived shoals reworked by tidal processes. • Formation of intertidal flats.	• High percentage of rockwork on the Macleay River with active minor and moderate erosion on remaining alluvial margins. • 43 % of stable banks are rocked. • Loss or alteration of levees. • Tributary modification. • Widespread stock impact. • Erosion dominated by wind and/or boat waves.	Poor	• **Macleay River – *Poor***. The high proportion of rock and the diminished riparian zone results in a greatly modified channel margin. Sediment supply from the fluvial process zone along with marine-derived sediment will also result in continued erosion of alluvial channel margins (*e.g.* Pelican Island).
MARINE	• Dominated by marine processes with the presence of marine-derived shoals reworked by tidal processes. Formation of sand and intertidal flats.	• Lowest percentage of erosion and highest percentage of naturally stable banks. • Localised stock impacts. • Wind and/or boat wave disturbance.	Moderate-good	• **Macleay Arm – *High.*** The large extent of native vegetation and naturally stable banks will increase the potential to improve the physical condition

3.3 *Sites of Accelerated Change*

This section reviews the nature and extent of planform changes (derived from ortho-rectified historical photographs) for the two most actively eroding sections identified in Section 3.2 above (Kinchela Bench and Fattorini Island). These rectified images provide a data source in which to quantify rates of bank erosion within a ± 4 m error between individual photos. It draws upon the 1942, 1956, 1974, 1982, 1997 and 2003 aerial photographs. The 1942 photograph provides an indication of channel dimensions in a period of below-average flood activity prior to the large floods in 1946, 1949 and 1950. The 1956 and 1974 photographs represent a period of above-average flood activity while the 1982 – 2003 photographs represent another period of below-average flood activity.

Kinchela Bench

Kinchela Bench — as identified in Section 5 — is the most actively eroding section of the Lower Macleay River with the unusual occurrence of bench erosion on the inside of the bend. An analysis of the ortho-photographs indicates that the low bench at Kinchela Bend has eroded by up to 37 m since 1942. The greatest rate of bank erosion between individual time periods occurred between 1942 and 1956 at the apex of the bench — directly opposite Kinchela village (Figure 18). This rate of erosion has slowed at the apex since 1974 but increased at the upstream limb (immediately downstream of the Kinchela Creek confluence – Figure 18). It is most likely that the concave bank at Kinchela was rocked following the recommendations of the 1934 report. As such, the outer bank at Kinchela became resistant to erosion, halting rates of concave bank erosion and promoting the erosion of the inner bend. Net gains of fluvial sediment (*i.e.* bed aggradation) in this section of Fluvial Reach 3 will ultimately result in an adjustment of channel dimensions with the preferential erosion of the inner bend (the only deformable channel margin).

While large floods appear instrumental in shifting sediment into this reach and eroding the bench margin, it is clear that wind and/or boat waves also actively erode this site. A bank exposure experiment over a 72–hour period (with a prevailing southerly wind) clearly demonstrated the importance of wind and/or boat waves in eroding Kinchela Bench at mid-high tide (Figure 19a-b). This experiment further indicated the notching of a sand unit immediately overlying the basal estuarine clays resulted in active (~ 1 m) block failure (Figure19c-d). The basal estuarine clay unit eroded marginally (< 5 cm) over the 72–hour period but the notching of the overlying sand units produced the rapid rate of bank collapse. The Kinchela Bench therefore, is most susceptible to waves of any kind (southerly and northerly generated wind waves and boat waves) at mid-high tide.

Fattorini Island

Fattorini Island has also undergone major changes since 1942 with an overall reduction in island size, but with the greatest changes occurring at the head and tail of the island (70 and 35 m respectively; Figure 20). As with Kinchela Bench, rates of erosion at Fattorini Island varied spatially with the greatest rate of erosion between an given time interval occurring in the period from 1942 – 1956. This period of enhanced flood activity occurred when there was little to no riparian vegetation, increasing the susceptibility of the riverbanks to ongoing erosion, resulting in the loss of 6000 m^2 (~1.5 acres) of land at the head of the island (Figure 20). In contrast, the tail of the island has experienced the greatest rates of erosion since 1982. The erosion of Fattorini Island has been further compounded by the prevalence of rock on the outer bend making Fattorini Island more likely to erode. It is most likely that Fattorini Island will continue

to erode from fluvial processes and from wind and/or boat waves at both low and high tide given the rocked outer margin, the evidence of bed aggradation upstream of Fattorini Island (Figure 17) and the current 'deep water' bank profile.

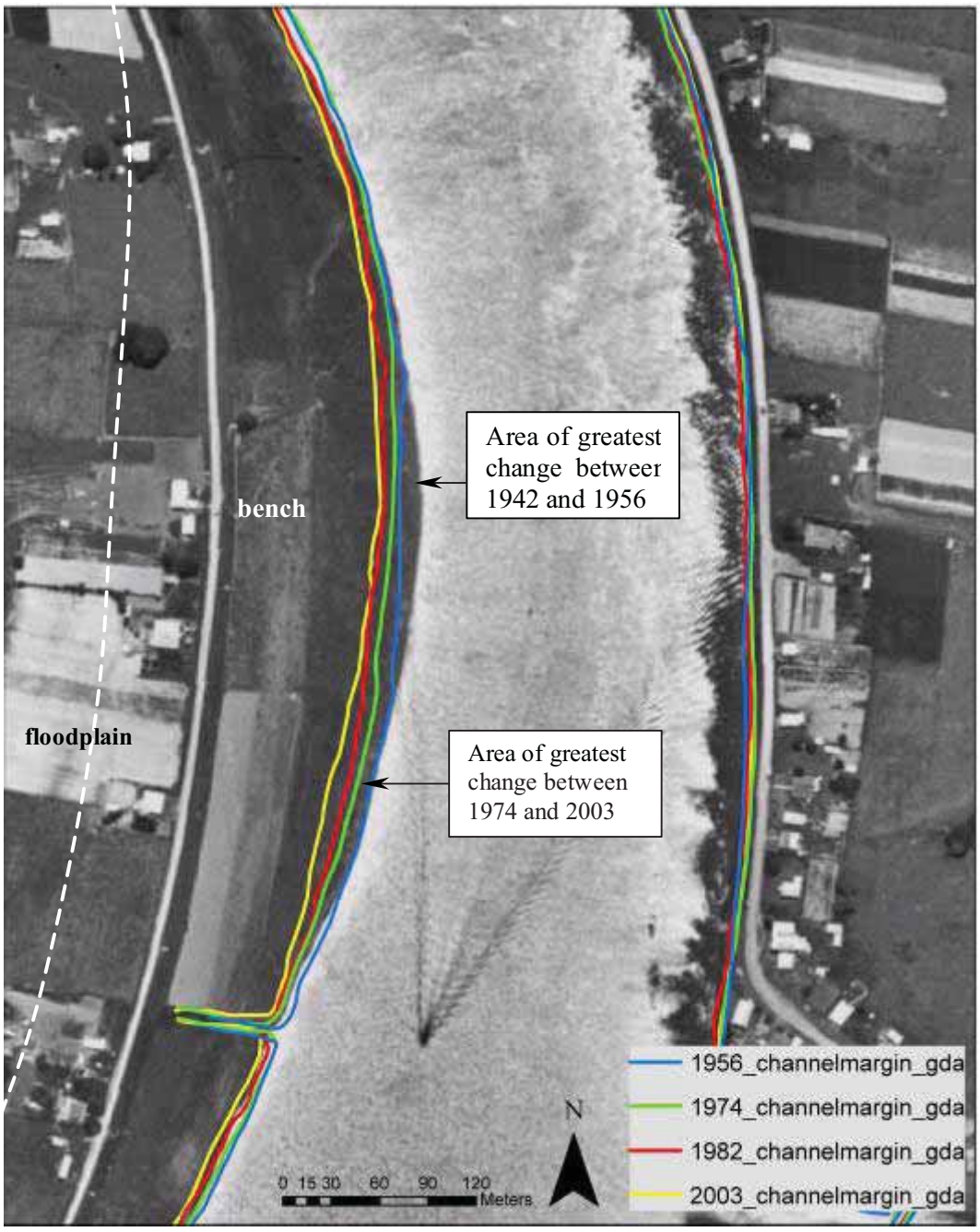

Figure 3.2 *Ortho-photograph of Kinchela Bench in 1942 with channel margin locations for 1956 – 2003 (derived from ortho-photographs). Flow is from bottom to top.*

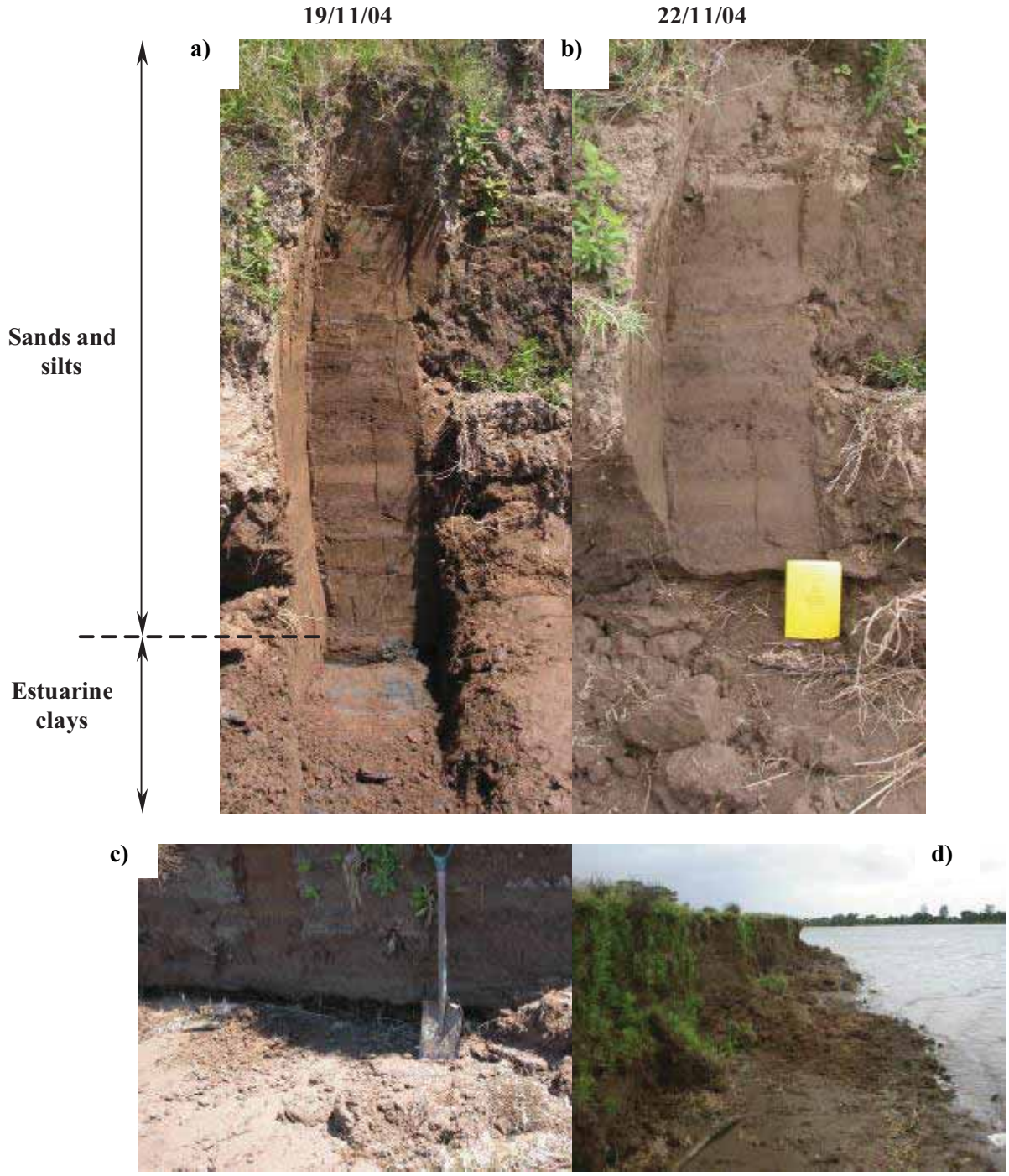

Figure 3.3 *Bank exposure experiment at Kinchela Bench. a) Clean vertical exposure on 19/11/04; b) Notch development in 72 hours from a southerly wind; c) – d) Erosion of sandy alluvium overlying the basal clays results in undercutting with subsequent block failure.*

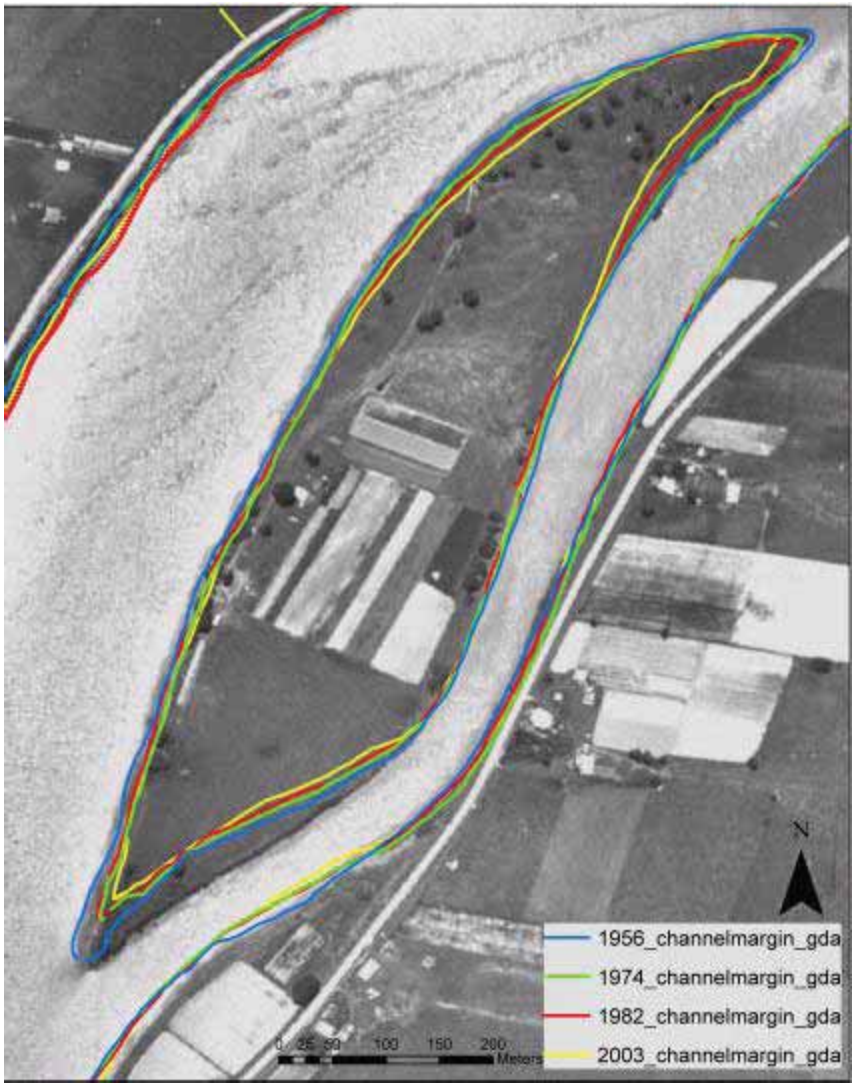

Figure 3.4 *1942 ortho-photograph of Fattorini Island with channel margin locations for 1956 – 2003 (derived from ortho-photographs). Flow is from bottom to top.*

3.4 *Estuary Sedimentation*

As discussed in Section 2.1 (Sedimentation), virtually no quantitative information exists on sediment loads for the Macleay River in either the tidal or non-tidal reaches. Of the two existing studies Laronne and Gurion (1994; cited in Patterson Britton & Patners, 2003) estimate the annual bedload sediment transport rate to be approximately 17,000 m^3 in the reach between Toorooka and Belgrave Falls (upstream of the estuary) while Patterson Britton & Partners (2003) estimate the rate at approximately 20,000 m^3. In either case, the estimated annual transport rate is extremely poorly quantified and should be considered unreliable. The net result is that there is little data that allows the quantification of sediment entering the estuary.

In order to provide a preliminary estimate of the sediment distribution in the estuary, bathymetric data collected by the Department of Commerce has been used to derive a longitudinal profile of the Macleay River trunk stream from Belgrave Falls to the entrance (based on cross-sections spaced at 1 km intervals; see Figure 3.5)

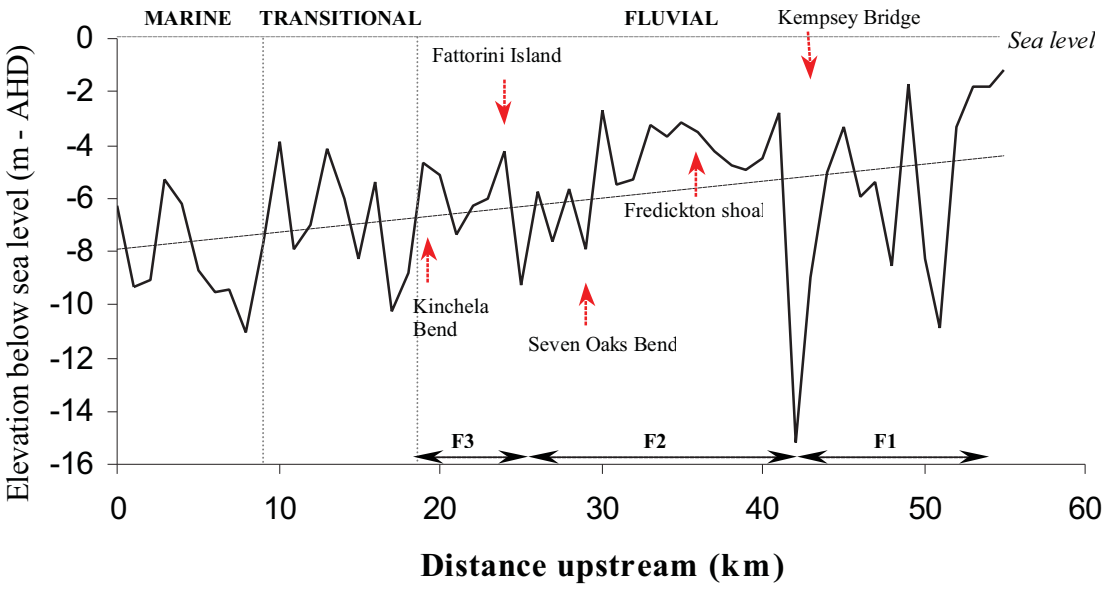

Figure 3.5 ***Longitudinal profile of the thalweg of the Macleay River trunk stream from Belgrave Falls to the mouth - with linear regression (slope = 0.0006). Topography derived from bathometric data (source: Dept of Commerce).***

Even at this coarse resolution the longitudinal profile still highlights the nature of in-channel sediment storage along the Macleay trunk stream. A linear regression indicates areas of positive and negative residuals (*i.e.* areas of the channel bed above or below the line of best fit). These correspond to areas of net sediment storage and scour respectively with each of the three process zones having distinct sediment storage patterns. The three reaches within the Fluvial process zone are characterised by alternating locations of sediment accumulation and scour. Fluvial reach 1 (F1) is characterised by deep pools (10 – 12 m) while Fluvial reach 2 (F2) is predominantly characterised by sediment accumulation (Kempsey Bridge to Seven Oaks Bend – Figure 3.5). Sediment is preferentially scoured from the lower half of Fluvial reach 2 and deposited in Fluvial reach 3 (around Kinchela Bend). The transitional process zone is also characterised by zones of sediment accumulation (*e.g.* Pelican Island – Figure 3.5) whereas the marine flood-tide process zone is predominantly characterised by net scour. This is presumed to be a function of tidal scour of the marine sands and the increased flushing efficiency provided by the training walls.

Figure 3.5 provides a 'snap shot' of current sediment storage patterns along the Lower Macleay River. It does not however, provide an indication of how these longitudinal patterns have changed through time. The sand and silt eroded from the banks and floodplains of the Middle and Upper Macleay River throughout the 20th century have been transported into the estuarine reaches and then re-distributed by later floods and tidal processes. Ultimately, it is these temporal and spatial patterns of sediment redistribution that determine current estuarine dynamics.

3.5 *Riparian and Estuarine Vegetation*

The aims of the flora survey of the Macleay Estuary undertaken for the data compilation project were to;

- Describe the range of riparian *Vegetation Communities* existing along the entire estuary,
- Segregate the riparian zone into reaches and describe the vegetation within each reach (from hereon referred to as *Vegetation Areas*);
- Classify the broad range of riparian vegetation types along the estuary into 3 *Vegetation Zones* (to assist in determining species suitable for restoration/ revegetation);
- Determine the presence and where possible the extent of significant vegetation species and/or communities - riparian, floodplain and estuarine.
- Document the degree of disturbance and degree of weed infestation in the riparian zone (using 3 categories of weed status based on environmental threat)

The survey area included the main trunk of the Macleay River from Belgrave Falls (upstream of Kempsey) to the entrance at South West Rocks and including Belmore River, Kinchella Creek, Andersons Inlet, Macleay Arm, Clybucca Creek, Spencers Creek and South-west Rocks Creek.

The full report text, maps and tables are available as ***Appendix D*** on the ***Macleay Estuary Data Compilation Project CD***.

Vegetation Communities

Sixteen (16) *Vegetation Communities* have been recorded throughout the survey area. Table 3.5 summarises the relative extent of the main communities described. Full descriptions of each community are contained within ***Appendix D Flora and Fauna Assessment of the Macleay Estuary***.

Table 3.5 *Major vegetation communities occurring along the Macleay River estuary*

Vegetation Type	Length of Riparian Zone	% of total length of riparian Zone surveyed
[33] (2502) Mangrove Forest and Woodland	81.3 km	23.4%
(6502) Maritime Rush and Sand Couch	7.2 km	2.07%
[25] (0503) Headland Brushbox	5.5 km	1.58%
[211] River Oak	4.7 km	1.36%
[23] Myrtle – degraded	4.7 km	1.36%
(6102) Samphire – Sand Couch	4.1 km	1.19%
[41] (3506) Sand-hill Black-butt	4.1 km	1.17%
[24] (0502) - Tuckeroo	3.9 km	1.11%
[107] Banksia	3.6 km	1.03%
[32] (4005) Swamp Oak	1.2 km	0.34%
[62] Grey Gum – Grey Ironbark	0.7 km	0.21%
[53] Brush Box	0.7 km	0.19%
[216] Improved Pasture and Cropland	207.3 km	59.74%
[221] Introduced Scrub	4.9 km	1.39%
[220] Cleared and Partially Cleared	3.3 km	0.95%
[219] Settlements and Roads	2.1 km	0.60%
Breakwall	12.5 km	3.60%
TOTAL	**347.1 km**	

Vegetation Areas

The purpose of defining *Vegetation Areas* was to facilitate a thorough description of the current state of riparian vegetation along the entire length of the estuary survey area, a process which to date has not been attempted. 150 different *Vegetation Areas* were identified over the 347 kilometers of riparian zone investigated. Each of these areas has been described according to Vegetation Community, Native Vegetation Status, Weeds Status, Disturbance Level, Vulnerability Class, Flora and fauna Significance and Habitat Value.

The information compiled on vegetation status, weed status and significant species is in a format which makes it readily usable for determining management strategies, revegetation priorities, and "action plans".

The descriptions of vegetation areas are highly detailed and encompass some 37 pages of text and tables and is included in ***Appendix D***. In addition the information has been compiled into a database and is searchable and viewable using any Geographic Information System (GIS)[21].

Vegetation Zones

Three general *Vegetation Zones* have been identified. Factors affecting the distribution of vegetation along the estuary include the degree of maritime influence such as salt laden winds and saline waters and levels of tidal fluctuation. The spatial extent and location of the vegetation zones correlate reasonably with the Geomorphic Process Zones described in the previous section. The three zones identified are (see Figure 3.6 Vegetation Zones);

Zone A Marine is where maritime influences are predominant and extends from the Jerseyville Bridge to the mouth of the Macleay River (corresponds to Cohen's, 2005 Marine Flood-tide Process Zone).

Zone B Transition is a transition zone with both freshwater and saline influences affecting vegetation composition. It extends from the Belmore River Confluence to some 5 km upstream of the Jerseyville Bridge (corresponding closely to Cohen's, 2005 Fluvial Reach 3 and Fluvial – Marine Transition Zone).

Zone C Freshwater is where *Freshwater* is the dominant influence on vegetation composition. It extends from some 5 km upstream of the Jerseyville Bridge to Belgrave Falls. (corresponding closely to Cohen's 2005 Fluvial Reach 1 and 2).

The typical identifying species for each of these zones are listed in ***Appendix F – Species Suitable for Estuarine Revegetation***. The species lists provide a guide to the species most suitable for inclusion in riparian revegetation projects.

[21] The current format is an ArcVIEW shapefile which is included on the *Data Compilation Project CD#3 – GIS Layers and associated metadata*.

Figure 3.6 *Macleay River estuary vegetation zones.*

Significant Flora occurring in the Macleay Estuary Area

Table 3.6 shows the number of significant flora species known and potentially occurring in the Macleay estuary study area.

Table 3.6 *Significant flora species summary*

Number of Significant Flora Species *Known* to occur in the Study Area		
Status	**TSCAct**	**EPBCAct**
Endangered	4	3
Vulnerable	5	3
Approaching Geographical Limit	7	

Number of Significant Flora Species *Potentially* occurring within the Study Area		
Endangered	1	0
Vulnerable	3	3

Eight 'Endangered Ecological Communities' occur within the Macleay estuary study area and are currently listed in Part 3 of Schedule 1 of the TSC Act 1995. Table 3.7 provides habitat descriptions for these communities. Several of the identified endangered ecological communities have been previously listed under State Environmental Planning Policies including SEPP 26 and SEPP 14. The significance of listing under Part 3 Schedule 1 of the TSC Act for many of these communities is that where there have been recognised inadequacies in the SEPP 26 and SEPP 14 mapping, significant ecological communities (such as Freshwater Wetlands on Coastal Floodplains and Littoral Rainforest and Lowland Rainforests on the NSW North Coast) are protected. Table ?? provides a preliminary list of "Endangered Ecological Communities" identified within the scope of this project.

Table 3.7 *"Endangered Ecological Communities" occurring in the Macleay estuary study area.*

ENDANGERED ECOLOGICAL COMMUNITY *(listed under the Threatened Species Conservation Act)*	**HABITAT DESCRIPTION**
Littoral Rainforest in the NSW North-coast, Sydney Basin and South-east Corner bioregions	Littoral rainforest is generally a closed forest, the structure and composition of which is strongly influenced by proximity to the ocean.
Lowland Rainforest on Floodplain in the NSW North Coast bio-region	Occurs on floodplains and now covers less than 1000 hectares in NSW. In an undisturbed state it is a closed canopy forest characterised by high species richness and structural complexity.
Coastal Saltmarsh in the NSW North-coast, Sydney Basin and South-east Corner bioregions	Intertidal zones on the shores of estuaries and lagoons including when areas are intermittently closed along the NSW coast.
Freshwater Wetlands on Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions	Periodic or semi-permanent inundation by freshwater, although there may be minor saline influence in some wetlands. Typically occur on silts, muds or humic loams in depressions, flats, drainage lines, backswamps, lagoons and lakes associated with coastal floodplains. Generally occurs below 20m elevation.
Swamp Sclerophyll Forest on Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions	Ecological community associated with humic clay loams and sandy loams, on waterlogged or periodically inundated alluvial flats and drainage lines associated with coastal floodplains. Generally occurs below 20m elevation (although sometimes up to 50m).
Subtropical Coastal Floodplain Forest on the NSW North Coast bioregion	Ecological community associated with clay-loams and sandy loams, on periodically inundated alluvial flats, drainage lines and river terraces associated with coastal floodplains. Generally occurs below 50m elevation, but may occur on localised river flats up to 250m. This community has a tall tree layer of Eucalypts.

ENDANGERED ECOLOGICAL COMMUNITY *(listed under the Threatened Species Conservation Act)*	HABITAT DESCRIPTION
Swamp Oak Floodplain Forest of the NSW North Coast, Sydney Basin and South East Corner bioregions.	Grey-black clay-loams and sandy loams, where the groundwater is saline or sub-saline, on waterlogged or periodically inundated flats, drainage lines, lake margins and estuarine fringes associated with coastal floodplains. Generally occurs below 20m (rarely above 10m) elevation.
River-Flat Eucalypt Forest on Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions.	Associated with silts, clay-loams and sandy loams, on periodically inundated alluvial flats, drainage lines and river terraces associated with coastal floodplains. Generally occurs below 50m elevation, but may occur of river flats up to 250m.

Limited mapping of four of the identified endangered ecological communities has occurred under this project but the mapping is not exhaustive and should be considered preliminary. Table 3.8 summarises the results. More concise mapping of the "Endangered Ecological Communities" is identified as an important next step in future stages of the Estuary Management Planning process.

Table 3.8 *Preliminary list of "Endangered Ecological Communities" mapped in the Macleay estuary study area.*

Endangered Ecological Community	Identified areas *(polygons on rainforest Theme in ArcView)*	Area within (ha)
Littoral Rainforest in the NSW North-coast, Sydney Basin and South-east Corner bioregions	*24a*	32.064
	24b	0.226
	24c	0.667
	24d	0.485
	10a	1.082
	10b	0.320
	10c .228	*0.228*
	25	6.607
	26	20.914
	Total	**62.566 ha**

Lowland Rainforest on Floodplain in the NSW North Coast bio-region	*1*	*1.918 ha*
	2	*1.657 ha*
	3	*0.858 ha*
	4	*1.617 ha*
	Total	**6.05 ha**

Endangered Ecological Community	Identified areas *(polygons on rainforest Theme in ArcView)*	Length of bank (km)
Coastal Saltmarsh in the NSW North-coast, Sydney Basin and South-east Corner bioregions	*(6102) Samphire – Sand Couch*	*4.124 km**
	(6502) Maritime Rush and Sand Couch	*7.198 km**
	Total	**11.322 km***

Swamp Oak Floodplain Forest of the NSW North North Coast, Sydney Basin and South-east Corner Bioregion	77 and 100	**1.18 km#**

* *This figure only represents Saltmarsh areas that interface with the rivers / creeks and is not the total area of Saltmarsh*

\# *This figure only represents areas of Swamp Oak Forest immediately adjacent to the rivers and creek banks and is not the total area of such forest*

Riparian Vegetation Disturbance

Disturbance of riparian vegetation was assessed with reaches grouped into the following categories;

INTACT	Vegetation showing negligible signs of disturbance, relatively continuous cover with natural regeneration occurring.
LOW	Low levels of disturbance from regimes including grazing, burning flood damage etc. Reduced levels of canopy continuity and regeneration occurring. May have some low levels of weed infestation.
MODERATE	Moderate levels of disturbance from a range of regimes including clearing and grazing. Minimal natural regeneration occurring and / or moderate levels of weed invasion
HIGH	High degree of removal of vegetation structure or degradation of native cover. Weed invasion can be extensive or minimal depending on management practices.

The survey of riparian vegetation revealed the following

- 66.9% or 232 km of river bank has a HIGH degree of disturbance;
- 13.8% or 48 km is considered to be INTACT;
- 10.1% or 35 km having a LOW degree of disturbance;
- 9.1 % or 31.6km of the vegetation varying in disturbance from LOW - MODERATE disturbance levels.

The main mechanisms of disturbance of riparian vegetation along the Macleay estuary are:

- clearing
- ongoing disturbance associated with grazing and some agricultural practices
- disturbance associated with infrastructure including roads in close proximity to the river, and bank protection works particularly rock revetment
- weed invasion including into otherwise intact remnant vegetation
- periodic flooding

Weed Occurrence

Weed Species have been grouped into 3 categories depending on their invasiveness, capacity to dominate natural vegetation communities and degree of difficulty to control (refer **Appendix D**).

The most serious environmental weeds (Category 1) include madiera vine (*Anredera cordiflora*), balloon vine (*Cardiospermum grandiflorum*), cats claw creeper (*Macfadyena unguis-cati*), spike rush (*Juncus acutus*), small-leaved privet (*Ligustrum sinense*), water hyacinth (*Eichhornia crassipes*), and bitou bush (*Chrysanthemoides monilifera subsp. Rotunda*).

The abundance of each of the three weed categories has been listed for each of the identified Vegetation Areas, a summary of which is provided in Table 3.9.

Table 3.9 *Summary of weed categories and abundance levels for the Macleay River estuary.*

Weed Category	**Length of bank with this category of weeds as the highest category listed**	**Abundance level**
1 *Most Serious Environmental Weeds –highly invasive and difficult to control*	2.133 km	Rare
	63.17 km	Rare – Occasional
	24.767 km	Occasional
	21.222 km	Occasional – Common
	41.007 km	Common
	129.851 km	Common – Heavy
	0.333 km	Heavy
TOTAL	**282.483 km**	
% of Total Riparian length	**81.4%**	
2 *Troublesome Environmental Weeds – highly invasive and moderate degree of difficulty in control*	Nil	Rare
	3.206	Rare – Occasional
	10.186	Occasional
	Nil	Occasional – Common
	10.583	Common
	Nil	Common – Heavy
	Nil	Heavy
TOTAL	**24.055 km**	
% of Total Riparian length	**6.9%**	
3 *Problematic Environmental Weeds - invasive and moderate degree of difficulty in control*	NIL	Rare
		Rare – Occasional
		Occasional
		Occasional – Common
		Common
		Common – Heavy
		Heavy
TOTAL	**NIL**	
0 *No significant weeds species (i.e. Category 1, 2 or 3 as described)*	**40.539 km**	N/A
% of Total Riparian length	**11.7%**	

From Table 3.9 it can be seen that 282.4 km or 81.4% of the mapped riparian zone contains *Category 1 Weeds* which are the most serious environmental weeds on the North Coast, capable of displacing native communities. For approximately half of this length, 130.1 km, these *Category 1 Weeds* are ranked as Common – Heavy. In addition, 24 km or 6.9% of the mapped riparian zone contains *Category 2 Weeds*, as the worst environmental weeds recorded. Category 2 weeds are highly invasive but control is considered to be easier than for Category 1 weeds. 40.5 km or 11.7% of the mapped riparian zone does not contain any significant environmental weeds.

Estuarine Vegetation

NSW Fisheries Mapping of Mangrove, Saltmarsh, and Sea Grass species (Zostera spp.) was undertaken in 1985 (West et al., 1985) and is currently being updated by DPI Fisheries and is anticipated to be available during 2005 (Greg West, DPIF, pers.comm.).

The dataset currently being collated by DPI Fisheries is expected to be more comprehensive and relevant to present day estuary management and therefore the 1985 data is not presented here.

3.6 *Fauna and Habitat*

Information on the fauna and habitat of the Macleay River estuary and floodplain have been collated from existing information and documents, records from the NSW NPWS Database, and from local knowledge.

The aims of the fauna and habitat description for the Macleay River estuary undertaken for this study were to;

- Collate existing records and knowledge of significant fauna occurring within the Macleay River estuary study area including their conservation status.
- Determine from existing data and research the location of key habitats and regional wildlife corridors occurring in the study area and describe the current condition of those habitats and corridors.
- Identify and describe current and potential threats to the long-term sustainability of major habitat types with specific focus on riparian areas.

The following sections are a summary of the data collected. The full report text, maps and tables are available as ***Appendix D*** on the ***Macleay Estuary Data Compilation Project CD***.

Significant Fauna occurring in the Macleay Estuary Area

7 Endangered and 39 Vulnerable Fauna species listed under the Threatened Species Conservation Act (TSCAct) have been identified as occurring within the Macleay estuary. 7 of these species are also listed on the Commonwealth Government's Environment Protection and Biodiversity Conservation Act (EPBCAct).

In addition, 21 other threatened fauna species listed under the TSCAct are considered to potentially occur in the Macleay Estuary. 3 of these species are also listed on the EPBCAct.

82 Migratory species (71 birds, 6 mammals, 3 reptiles, and 2 sharks) are also listed under the EPBCAct as occurring or potentially occurring in the Macleay estuary.

Refer to ***Appendix D***, Table 14 and Table 15 for further details.

Habitat Corridors

A considerable proportion of the Macleay estuary is recognised as Key Habitat or within a Regional Corridor under the NSW NPWS 'Key Habitats and Corridors' mapping of NE NSW (Figure 3.7). The identified Regional Corridor under this NPWS Project has been identified as the Fishermans Bend Nature Reserve Regional Corridor which links from Hat Head NP and Arakoon SRA through Yarrahappini Wetlands, Tamban State Forest to Fishermans Bend NR and Mt Yarrahappini and Yarriabini National Park and then westwards to Ngambaa NR. This corridor has a good deal of continuity of native vegetation cover and where gaps occur they are not large distances.

The Macleay River 'riparian corridor' is highly degraded due to the extent of clearing and the paucity of remnant pockets along the riparian margin or in pockets across the floodplain. Weed infestations are extensive. Nevertheless the riparian margin does act as a conduit for a variety of mobile species.

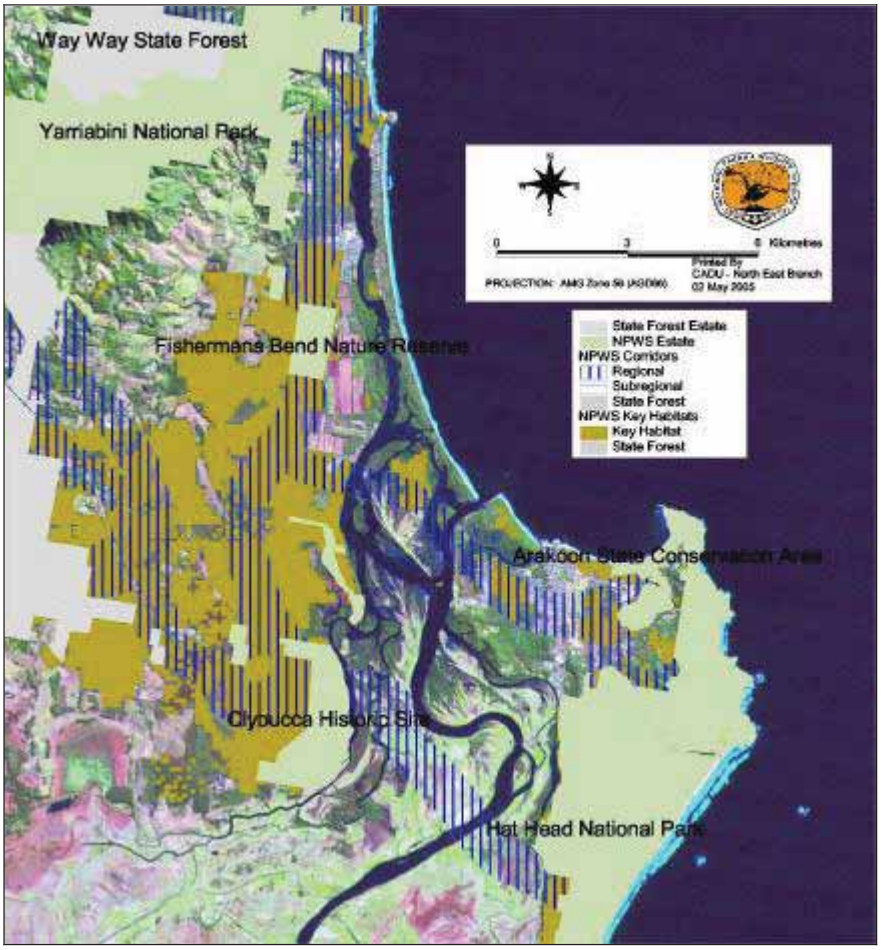

Figure 3.7 *Macleay River estuary Key Habitats and Corridors (source: Department Environment and Conservation).*

Threats and Habitat Vulnerability

The identification of threats, both current and potential, to the long-term sustainability of the identified flora and fauna habitat has been included for each mapped vegetation area. The relative vulnerability of

each site to these threats has been identified and grouped into 3 classes - High, Medium, Low. A summary of the results of the survey reveal that;

- 33.5 km or 9.6% of the riparian zone mapped has been classed as having a HIGH vulnerability to identified threats.
- 184.6 km or 53% of the riparian zone mapped has been classed as having a MEDIUM vulnerability to identified threats.
- 129 km or 37.18% of the riparian zone mapped has been classed as having a LOW vulnerability to identified threats.

The dataset of information compiled on Vegetation Status, Weed Status and Significant Species is comprehensive and too large to be presented in this report. However, the data has been compiled in a format suitable for use in a Geographical Information System (GIS). The relevant files are contained on the ***Macleay Estuary Data Compilation Project CD***. See ***Appendix D*** for further information.

3.7 *Estuary Infrastructure and Protection Works*

As part of this project, a wide variety of estuary infrastructure including floodgates, stormwater outlets, access infrastructure (including wharves, jetties, moorings, road accesses, camping areas, and access tracks) and bank protection works were logged by handheld GPS (accuracy <20m). These datasets have been compiled into discrete Digital datasets for use in any Geographical Information System. A summary of the datasets available is provided in Section 3.9.

In general, the datasets related floodplain works are less comprehensive than those on access infrastructure and bank protection works as much work has been done on mapping drains and associated infrastructure (the results of DIPNR's floodplain drain mapping project can be viewed at http://www.dlwc.nsw.gov.au/care/soil/ass/management_and_remediation.html). Access infrastructure and bank protection works mapping was more comprehensive as it was determined through the data review that the existing database for such infrastructure was poor.

Estuary Access Infrastructure

Estuary access infrastructure was recorded during boat-based field survey with 8 main types of access infrastructure logged by hand-held GPS. 184 access points were logged a summary of which is provided in Table 3.10. The tenure of each access point was estimated although in many cases it was not clear and so this part of the dataset should not be relied upon. Many access points may have appeared to be private accesses but may in fact have been located on foreshore reserve or crown lands. Similarly, ownership of boat ramps, wharfs and jetties was generally not able to be ascertained in some cases.

The data has not been compared to existing datasets on Council and Crown Reserves (which may for example show correlations between existing road accesses and road reserves) or against Department of Lands "permissive occupancy" datasets (which licence structures such as jetties and moorings). Such comparisons would be possible in future stages of the estuary planning process such as in the estuary management study.

It should be noted that no attempt has been made to document the quality of the facilities for example the state of repair, access to parking facilities, presence of toilets, tables, fish cleaning facilities, etc.

Table 3.10 *Inventory of recorded access infrastructure – Macleay River estuary*

Infrastructure or Access Type	**Public Facility**	**Presumed Private**	**Unknown Ownership**	**Total**
Beach track	1	-	-	1
Boat ramp or slip	11 (one decommissioned)	12	3	26
Camping area	1 (Stuarts Point)	-	1 (Whisky Island)	2
Ferry	-	2	-	2
Jetty	3	40	1	44
Minor access track or foot track	2	56	3	61
Moorings/pontoons/wharfs	3	31	1	35
Road access	11	1	1	13
TOTAL	32	142	10	184

This information is available in GIS format, see Section 3.9 for details.

Existing bank protection works

In total 72.63 km of bank protection works were identified in the 270 km of estuary bank length surveyed. The types of protection works used in each branch of the estuary system is summarised in Table 3.11. The location of all bank protection works identified including short descriptions of the type of works and preliminary comments on effectiveness are available in GIS format on the Project CD.

Table 3.11 *Types of bank protection works by estuarine system – Macleay River estuary*

Estuary System	Rock (km)	Concrete (km)[22]	Logs or timber (km)	Tyres (km)	Reveg & Fencing (km)	% of bank length not surveyed	% of bank length treated with works
Andersons Inlet	6.1	-	-	-	-	-	28.8 %
Belmore River	0.5	-	-	-	-	14.6 %	1.3 %

[22] Includes where rock and concrete are used in conjunction

Estuary System	Rock (km)	Concrete (km)[22]	Logs or timber (km)	Tyres (km)	Reveg & Fencing (km)	% of bank length not surveyed	% of bank length treated with works
Clybucca Creek	6.9	-	0.1	-	0.1	-	27.4 %
Christmas Creek	-	-	-	-	-	100 %	-
Kinchella Creek	0.4	0.02	-	0.03	-	37 %	1.5 %
Macleay Arm	0.96	-	-	0.02	-	17.7 %	1.8 %
Macleay River	55.0	0.25	0.06	0.04	1.4	0.3 %	44.5 %
Spencers Creek	0.75	-	-	-	-	94.8 %	5.2 %
TOTAL FOR ESTUARY	**70.61**	**0. 27**	**0.16**	**0.09**	**1.5**	**20.2 %**	**26.9 %**

3.8 *Active Riparian Restoration Projects*

In addition to the projects being implemented by Council and landholders under the Macleay River Floodplain Project (operating since 2000) and projects being implemented under the Acid Sulphate Soils Hotspot Remediation Program, 24 riparian and wetland management projects have been identified within the Macleay estuary area. Funding is from a range of sources including Kempsey Council, the Northern Rivers Catchment Management Authority, Natural Heritage Trust, Envirofund, Macleay Voluntary Streamcare Grants Scheme, corporate initiatives from Nestles, plus considerable landholder contributions. A list of active projects is provided in ***Appendix D*** with each of the projects also compiled into a GIS layer (see following section).

3.9 *New GIS data layers produced*

A vast quantity of data has been collected for this study and recorded into GIS layers. Many of the layers contain comprehensive detail which is most suitable for display through a GIS system where relationships between spatial data are more easily represented and interpreted.

The following datasets have been produced as a result of this study and are included on the Project CD.[23] Metadata ("data about data") is also included for each GIS coverage.

Estuarine Infrastructure

- Bank Protection Works
- Macleay Estuary infrastructure

[23] All GIS data is in ArcView format (shapefiles) and in AGD66 Zone 56 projection.

- Macleay Estuary access points
- Active remediation project locations 2005

Geomorphology and Bank Erosion Layers

- Geomorphic process zones
- Bank erosion
- Location of bedrock outcrops

Flora and Habitat Layers

- Floodplain rainforest pockets
- Juncus acutus (preliminary survey locations)
- V egetation mapping Macleay Estuary 2005

Orthorectified photographic base images

- Full set of 2003 1:25,000 images in .ecw format covering the Macleay Coastal subcatchment as defined by DIPNR (AGD66 Zone 56 Projection) – not available on the project CD due to copyright restrictions.
- Orthorectified historic aerial photography covering the area of estuary between Kinchella and Fattorini Island including 1942 (limited), 1956, 1974, 1982, and 1997 years. Delineation of the channel position has also been completed - not available on the Project CD due to copyright restrictions.

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PART 4 GAP ANALYSIS – ESTUARY PLANNING DATA NEEDS

4.1 *Riparian Land Management, Bank erosion and Sedimentation issues*

The data compilation and mapping stage has identified a number of important key gaps in the existing database for the Lower Macleay River. These gaps relate to critical questions regarding riparian land management, bank erosion and sedimentation (as per the project brief). As these issues are inter-dependent they will be collectively outlined below.

The causes and preferred treatment options for a range of typical bank erosion scenarios cannot be answered at present as this study has only qualitatively assessed the primary causes of erosion in the Lower Macleay River, which are:

- Fluvial processes
- Wind and/or boat waves
- In-channel sedimentation
- Stock disturbance/reduced riparian vegetation
- Presence of rockwork on adjacent banks

It is important to note however, that very few alluvial channel margins (especially in Fluvial Reach 2 and 3 and the transitional process zone) have riparian vegetation with any structural or floristic integrity, greatly reducing bank strength in most locations. Furthermore, these primary causes have been shown to vary between process zones indicating that there is no one major cause of erosion for the entire Lower Macleay River.

The Lower Macleay River has undergone major direct modification throughout the 20th century. In addition, the middle to upper Macleay River has also been vastly transformed since European settlement, resulting in a greatly modified sediment supply regime. Both these factors partly determine where sedimentation and bank erosion currently occurs. To date however, there has been very little compilation of this information in which to make an informed assessment of the primary causes of erosion and sedimentation in the Lower Macleay River. It is this historical context that will provide an important insight into current channel processes. Hence, it is suggested that the following gaps be addressed in the process study.

1. Systematic collation of planform changes for the Lower Macleay River. This should focus on all styles of lateral adjustment (*i.e.* channel expansion, changes to meander wavelength, sinuosity within each of the three process zones) and should include the georeferencing of historical parish maps and/or portion plans. This will provide the context to current channel processes.

2. Systematic collation of historical hydrographic surveys demonstrating where bed elevations have changed. Many hydrographic surveys are presently held in the Department Of Commerce head office in Sydney.

3. Examination of changes to bankfull cross-sectional capacity at areas of accelerated change and representative sections of process zones. This should use photogrammetrically derived topographic data and should be compared with permanent bench-marked cross-sections (see following recommendations).

4. Systematic collation of the nature and timing of tidal dredging in the Lower Macleay River (*i.e.* how much, where and when?). This component should also aim to determine what proportion was entirely removed from the system.

4.2 *Flora and Fauna, Wetland and Habitat Protection Issues*

With regard to flora and fauna, wetlands, and habitat protection issues the following data gaps have been identified;

1. There is a lack of definitive mapping for vegetation recently listed as 'Endangered Ecological Communities'. The specific vegetation communities included within the 'Endangered Ecological Communities' needs to be clarified and mapped accordingly.

   For example, Subtropical Coastal Floodplain Forest on the NSW North Coast bioregion potentially occurs along the Clybucca Creek in a number of places beyond the immediate riparian fringe. This needs further investigation and mapping.

   Saltmarsh communities will be mapped as part of the DPI Fisheries Mapping due to be completed in late 2005 (contact for this project is Greg West of DPI Fisheries).

2. There is a lack of a strategic long-term plan to guide riparian, coastal and rainforest regeneration / restoration activities.

3. It is presently not known what impact the weed species of submerged aquatic vegetation *Elodea sp*. and *Egeria sp*. have on aquatic habitat in the lower Macleay?

   How do these species react to drought, normal flow, flood and increased nutrient from discharges? To what degree do these species displace native submerged vegetation?

4. There is a lack of specific local documentation on habitat corridors and a clear strategic plan for conserving or establishing local corridors.

   There is a need to preserve and consolidate a diverse mosaic of vegetation types for the conservation of flora and dependent fauna species. Many species utilize a variety of vegetation communities habitat types for different parts of their lifecycles e.g. Blossom bats, Fruit doves, migratory waders.

   Another important factor is 'altitudinal migration' for fruit and nectar dependent species – species of rainforest plants flower and fruit earlier at lower elevations than higher due to warmer conditions that prevail at low elevations or near the coast.

5. There is currently no coordinated control program for *Juncus acutus* (Spike Rush) in the Rainbow Reach locality. Spike Rush is a serious environmental weed and is encroaching on estuarine Rushlands and Samphire – Sand-Couch Vegetation which is listed as an 'Endangered Ecological Community' under the Threatened Species Conservation Act 1995.

6. There is a lack of data on the invasion of Saltmarsh communities by Mangroves in the locality. The potential subsequent changes to adjoining wetland and swamp forest communities and the implications of this in terms of habitat changes are not currently known. The mangrove invasion limits the use of Saltmarshes by birds that would normally make use of this habitat and has been a factor in the decline of these bird species.

4.3 *Water Quality Issues*

The installation of the telemetric stations in the lower Macleay River and tributaries has vastly improved the regularity and quality of data collection. However, some water quality issues remain unresolved and may need to be further addressed in subsequent phases of the EMP process. These include;

1. The enrichment of the majority of the Macleay floodplain with arsenic (As) and antimony (Sb), and the reportedly elevated levels of these heavy metals in surface waters and pastures is a significant cause of concern for both land and water based industries in the study area. Further research into these contaminants and the consequent effects is required.

2. The extensive growth of aquatic weeds in the vicinity of Kempsey and Frederickton is potentially indicative of elevated nutrient levels in the water column (see Point 3 in Section 4.2).

3. Although a tidal gauging survey has been completed by Manly Hydraulics Laboratory, it would be useful to know the tidal flushing times for different parts of the estuary. This information can assist with determining where water quality issues are likely to arise.

4.4 *Climate Change and Sea Level Rise*

Although the Project Brief has identified the need to begin to consider the likely effects of climate change on sea level rise, the CSIRO report (Hennessy et al., 2004) shows that other effects of climate change such as changes to rainfall patterns, temperature and storminess are as likely to initiate broad-scale changes as sea level rise. Obviously such drastic changes as are predicted will affect hydrology, drainage, wetlands, water quality and property. These issues also need to be considered when considering climate change issues and potential strategies for dealing within them, although the scale of the issue probably more easily sits within State and Commonwealth Government jurisdictions.

4.5 *Other important estuarine data gaps not identified in the study brief*

The following other important data gaps of information relevant to estuary management planning have been identified as either not currently existing or not able to be obtained under the resources allocated to this study;

1. The integration of Aboriginal Heritage Issues into the estuary planning process was not highlighted in the brief. However, there are many important aboriginal cultural sites within the study area and several areas of land with significant values (eg. Shark Island's littoral rainforests and Clybucca Historical site)

2. Very little work has been done on determining the attitudes and perceptions of local residents and visitors to the Macleay Estuary. Whilst a great deal of effort is spent incorporating the views of local "stakeholders" such as industry, government, and conservation interests, the views of other estuary users are also very important. A survey of local users and visitor attitudes may be an appropriate action to assist in determining the issues and concerns of "general" estuary users. Such issues may concern the provision of boating facilities, areas of interest for recreation including skiing and wake boarding, and issues of environmental concern.

3. Accurate tourism statistics and trends of specific relevance to the Macleay Estuary are virtually non-existent. This information is pertinent to Estuary Management Planning.

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PART 5 RECOMMENDATIONS TO THE MACLEAY RIVER ESTUARY MANAGEMENT COMMITTEE

5.1 *Riparian Land Management, Bank erosion and Sedimentation issues*

In order to more confidently determine the causes of current bank erosion it is suggested that a number of process-based investigations be undertaken. These include:

1. Detailed topographic analysis from current bathometric data (*i.e* cross section every channel widths distance) on trunk stream with an equivalent analysis on tributaries (*i.e* Clybucca Creek, Belmore River and Kinchela Creek). This will provide a more thorough assessment of current sediment storage patterns.

2. Construct a sediment budget for the Lower Macleay River from the bathometric data, floodplain topographic data and the ortho-photographs. This should aim to assess sediment storage in each of the identified process zones while also incorporating current research undertaken by Ashley and Graham from UNE.

3. Determine the relative contribution of wind and boat waves for deep and shallow water profiles. A controlled experiment (*sensu* Nanson et al., 1994) in targeted areas that measures wave height, wave direction, wind speed and wind direction, bank erosion, sediment production and turbidity will quantitatively determine the relative contribution of wind and boat waves for the Lower Macleay River.

4. Establish permanent bench-marked cross-sections from floodplain to floodplain in areas of accelerated change and in representative sections of each process zone. These should be located using differential GPS and marked adequately for long-term monitoring.

A process study that investigates both the historical and current bank erosion processes will ultimately provide Kempsey Shire Council and DIPNR a more valuable database in which to make and develop management policies relevant to bank erosion and sedimentation.

5.2 *Fauna, Flora and Habitat issues*

The following actions are recommended for future stages of the EMP process to address deficiencies in the existing fauna, flora and habitat management dataset ;

1. Prepare definitive mapping for vegetation which encompasses recently listed as 'Endangered Ecological Communities' and ensure that all future mapping be able to be incorporated into a GIS database with accuracy for use in development and planning scenarios.

2. Develop a strategic approach to prioritising restoration and revegetation works based on the weed status and degree of disturbance defined in this Project. A 'Conservation and Restoration Plan' should be developed as a framework with specific goals and actions to guide activities to ensure long term aims are achieved. Such a Plan would be a useful document to aid in sourcing funding for the works over extended periods as opposed to short-term options currently available.

   The 'degree of disturbance' data collected in this Project can be used to determine the selection of sites which have reasonable native canopy condition (e.g Intact, Low, Low-Moderate, Moderate) as high priorities for weed control and regeneration activities.

3. Undertake investigation into:
    - The impact of weed species of submerged aquatic vegetation –*Elodea sp*. and *Egeria sp*. - on aquatic habitat.
    - The reaction of these weed species and native species of submerged aquatic vegetation to drought, normal flow, flood and increased nutrient from discharges.
    - The degree to which these species displace native submerged vegetation.

4. It is recommended that a two pronged approach to 'habitat corridor conservation' be adopted:

    a) The NPWS 'Key Habitats & Corridors' regional corridor be identified as a priority for habitat protection and rehabilitation activities. Lands within and adjoining the mapped areas should be targeted to maximize habitat opportunity. This corridor contains a diverse mosaic of vegetation types for the conservation of flora and dependent fauna species.

    This should be considered as a high priority and integrated into landuse planning and development control processes and recognized as a priority to attract funding assistance for rehabilitation and extension works.

    b) Floodplain and Riparian forest remnants should be targeted as part of a long-term 'Macleay Riparian Corridor Restoration Program'. Actions such as:
        - undertaking priority weed control to promote natural regeneration and sustainability of the remnants;
        - development of a seed bank and propagation program to maintain genetic integrity and expand diversity of species for fauna foraging and extension of habitat area.
        - establishment of revegetation areas in priority locations and extension of works and areas over realistic period of time, should be initiated as soon as possible as this is a long term strategic project.

    The 'Landcare' movement and Community Support Officers could play a vital role in this priority as ~90% of floodplain and riparian rainforest (subtropical) of the Macleay is within private land. However, a definitive 'Conservation and Restoration Plan' as a framework with specific goals and actions should be established early-on to guide activities to ensure long term aims are achieved.

    This 'Conservation and Restoration Plan' would need to integrate resources from the community, DEC, DIPNR and the local aboriginal community.

    Rehabilitation projects should also integrate Australian Bass habitat features identified in the NSW Fisheries documentation.

5. Develop a strategic works plan for the control of Spike Rush *Juncus acutus*, an introduced rush which has been identified in the Rainbow Reach locality, downstream of Jerseyville.

    In terms of community structure and function this species is considered as the most serious threat to 'coastal saltmarsh' communities. The approximate current distribution of *Juncus acutus* was recorded during field assessment however a more detailed appraisal of the extent of the infestation (which at this point in time seems to be localised), should be made.

    Other weed species of threat are Groundsel Bush *Baccharis halimifolia*, Pampas Grass *Cortaderia selloana* and in some localities Pennywort *Hydrocotyle bonariensis*. Groundsel Bush is a listed Noxious Weed and as such does undergo control activities through Kempsey Council and its liaison with landholders.

    Work should not only focus on mapping the current extent of Spike Rush *Juncus acutus* but also in establishing control works. Control works should be aimed at:

- limiting the spread of the species beyond current by identifying isolated populations and targeting them;
- reducing the extent of main population areas.

This is seen as an urgent priority which should be addressed now and not wait until the preparation of the overall Estuary Management Plan.

This study could be undertaken by a Research Student associated with the New England or Newcastle Universities where some work has already been done in association with this species and impacts on the Hunter wetlands.

Alternatively, and possibly preferably, by a Consultant who can manage the determination of extent of infestation in a relatively short time frame and then instigate control works in association with Kemspey Shire Council, DIPNR, NSW Fisheries and landowners.

6. In recent decades there has been widespread invasion of Saltmarsh in south-east Australia by mangroves and the factors causing this are unclear The factors driving mangrove invasion are still unclear. Sea level rises as a result of global warming are considered likely to pose an increasing threat to the survival of many areas of Coastal Saltmarsh.

   Mangrove colonization of Saltmarsh has been noted for some areas have been recorded as part of this Data Compilation Study.

   It is recommended that a series of survey transects and monitoring points be established from river through Saltmarsh to Swamp Forest at a variety of locations to track the progression or change within the vegetation communities over time and identify areas where Saltmarsh communities etc are vulnerable due to rises in sea level and the implications on adjoining vegetation communities. This study could be undertaken by a Research Student.

   Progression and change can be rapid and it is therefore seen as a high priority which should be commenced now to further our understanding for incorporation into the Estuary Management Plan.

5.3 *Boating Management*

The Macleay Estuary area is not currently considered a priority for a NSW Maritime Authority Boating Management Plan. However, in several sections of the Macleay Estuary there is obvious damage from wave wash associated with boating. These areas include;

- Damage to mangrove communities in the lower reaches of the Macleay Arm. This is an important issue as once the protective mangrove fringe is lost then erosion generally accelerates into adjacent Saltmarsh areas (which are listed as a endangered ecological community" under the Threatened Species Conservation Act 1995)
- Damage to riverbanks on Clybucca Creek, often adjacent to oyster leases where because of the narrow channel boats are forced close to the outside bend causing significant wash if speeds are not reduced.

In lieu of the preparation of a Boating Management Plan, it is recommended that future stages of the EMP Process consider in association with the EMC and NSW Maritime Authority appropriate zones for safe and responsible use of the estuary by recreational boaters, in particular wake boarders and Personal Watercraft users.

5.4 *Aboriginal Cultural Information*

Cultural links for local aboriginal people are strong within the Macleay Estuary area with sites such as the Clybucca Historical Site showing the long association of aboriginal people and the estuary. It is recommended that a mechanism for consultation and involvement of local indigenous groups in the EMP process be developed to ensure aboriginal heritage and land management issues are incorporated within the EMP process.

5.5 *Attitudinal Survey*

It is recommended that an attitudinal survey be taken to determine the views, values, and needs of local residents and estuary users. To be most useful the survey should span both "low season" and peak season" periods.

5.6 *Water Quality*

It is recommended that;

1. The tidal flushing times for the lower Macleay River and its major estuarine tributaries be determined which areas of the estuary may be susceptible to water water degradation in the event of sustained pollution loadings (nutrient, E.coli, etc).

2. The EMC support ongoing research into the distribution of heavy metals (specifically Arsenic and Antimony) across the lower Macleay River floodplain and in surface waters and pastures, and to determine possible impacts on land and water-based industries in the area.

5.7 *Estuary Planning Processes*

Although only limited public consultation was undertaken during this phase of the EMP process, a common issue raised by many of those spoken with was the length of time that the planning process takes. Although it was generally acknowledged that having the right information was necessary for making proper planning decisions, having too lengthy a period of planning was perceived to be as frustrating has not doing anything at all.

Although this Report recommends only actions which the authors have perceived to be critical to address important data gaps, it is probable that some actions have timeframes associated that are beyond a "reasonable" planning timeframe. For example, developing a sediment budget for the Macleay Estuary is a very important step in determining the underlying issues and processes driving bank erosion in the estuary, however such an action may take 2 – 3 years to complete. For this reason it is suggested that the EMC consider carefully the recommendations made in this Report with the view to determining which of the actions are likely to have significant timeframes attached and which may be acted upon in the short-term. The committee will then be able to proceed with an interim plan on the basis of the available information and that which is able to be obtained within a reasonable time period through the Estuary Process Study, while the critical information that requires a longer term effort is collected. New information from longer term studies can be incorporated at the earliest opportunity as revisions to the Estuary Management Plan are made.

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REFERENCES

Anon. (1881). Draining flooded lands, Macleay River. Legislative Assembly of NSW 1880-81, Vol.2, pp 567-602.

Ashley, P. and Graham, B. (2001). Heavy Metal loadings of streams in the Macleay River catchment. Report to Mid North Coast Catchment Management Board, NSW Department of Mineral Resources and Armidale Dumaresq Council.

Cohen, T.J. (2003) Late Holocene floodplain processes and post-European channel dynamics in a partly confined valley of New South Wales, Australia. School of Geosciences, University of Wollongong unpublished PhD thesis.

Cohen, T.J. (2005) The geomorphology of the Macleay River Estuary. Prepared for Kempsey Shire Council as a component of the Macleay Estuary Data Compilation Study 2005.

Coltheart, L. (1997) Between Wind and Water – A history of the ports and coastal waterways of New South Wales. NSW Department of Public Works and Services. ISBN 0 86806 598 6.

Coode, J. (1891). Macleay River (Report by Sir John Coode, K.C.M.G., on entrance to.) Legislative Assembly of NSW, 26 May 1891. Includes: A General Description of the Macleay River, by Captain Howard, R.N. dated 18 December 1890.

Cowell, P.J. (1996). Wave Action and bank erosion behind Seaham Weir in the Williams River. Occasional Paper 1001. Healthy Rivers Commission of NSW. Sydney.

Dalrymple, R.W., Zaitlin, B.A., and Boyd, R. (1992). Estuarine facies models: conceptual basis and stratigraphic implications. Journal of Sedimentary Petrology, 62, 1130 – 1146.

Department of Lands (1934). Report by Departmental Committee on Erosion – Macleay River Erosion.

DIPNR (2004), Standard Provisions for Local Environmental Plans – Working Draft.

DPI Fisheries (2002). Survey of Recreational Fishing in New South Wales Interim Report by NSW Fisheries, December 2002. http://www.fisheries.nsw.gov.au/recreational/general/survey_of_recreational_fishing_in_new_south_wales

Dunstan, D (1976). Environment and Fisheries of the Macleay Valley. Proceedings of A Seminar on Flood Mitigation organised by the Macleay Argus, 6 December 1976. Desmond J Dunstan, Biologist, State Fisheries NSW.

Erskine, W.D. and Warner, R.F., 1988. Geomorphic effects of alternating flood-and drought-dominated regimes on NSW coastal rivers. In: R.F. Warner (Editor), Fluvial Geomorphology of Australia. Academic Press, Sydney, 223-266.

Erskine, W.D. and Warner, R.F., 1998. Further assessment of flood- and drought-dominated regimes in south-eastern Australia. Australian Geographer, 29(2): 257-261.

Glamore, W., Hudson, R., Cox, R. (2004). Managing inland and coastal waterways: boat wakes and wave dynamics. In: NSW Coastal Conference 2004, 13th Annual Coastal Conference, 9-12 November 2004, Lake Macquarie, pp.198-203.

Hails, J.R. (1964). The geomorphological history of the Macleay deltaic plain. Australian Journal of Science, 27 (1): 214-215.

Healthy Rivers Commission (2003). North Coast Rivers, Independent Inquiry into the North Coast Rivers Final Report.

Heap, A.D., Bryce, S and Ryan, D.A. (2004). Facies evolution of Holocene estuaries and deltas: a large-sample statistical study from Australia. Sedimentary Geology, 168, 1 – 17.

Henderson, S., Kemsley, R., Smith, B., Hayes, M., Devine, B., Tulau, M. and Atkinson, G. (2002) Broadacre acid sulfate soils remediation and management trials, Macleay River, New South Wales, Australia. Poster paper. Proceedings, 5th International Acid Sulfate Soils Conference, August 25th - 30th 2002, Tweeds Heads, p. 141.

Hennessy, K. McInnes, D. Abbs, R. Jones, J. Bathols, R. Suppiah, J. Ricketts, T. Rafter, D. Collins* and D. Jones* (2004) Climate Change in New South Wales – Part 2 Projected changes in climate extremes. Climate Impact Group, CSIRO Atmospheric Research.

Hodgkinson, C. (1844). Australia from Port Macquarie to Moreton Bay; with descriptions of the natives, their manners and customs; the geology, natural productions, fertility and resources of that region. T. and W. Boone, London.

Kemsley, R. (2001). Macleay River Floodplain Post January and March 2001 Flood Event Water Quality Monitoring Report. Kempsey Shire Council.

Laurie, Montgomerie & Pettit Pty. Ltd. (1980) New South Wales Coastal Rivers Floodplain Management Studies Summary Report Macleay Valley, 1 – 30.

Macleay Valley Flood Mitigation Committee (1953) Report of the Macleay Valley Flood Mitigation Committee (The Jacka Report). Government Printer, Sydney.

Macleay Valley Historical Society. Notes from miscellaneous documents found in the society's archives on 6 September 2004; assisted by Ruth Woodward.

Manly Hydraulics Laboratory. (undated) Development and operation of the Macleay River Flood Mitigation Scheme.www.mhl.nsw.gov.au/www/DevelopFloodMitsystem.pdf

Nanson, G.C., Von Krusenstierna, A., and Bryant, E.A. (1994). Experimental measurements of river-bank erosion caused by boat-generated waves on the Gordon River, Tasmania. In: Regulated Rivers: Research and Management, Vol. 9, pp 1-14.

Nanson, G.C., Von Krusenstierna., and Bryant, E.A. (1994). Experimental measurements of riverbank erosion caused by boat-generated waves on the Gordon River, Tasmania. Regulated Rivers: Research & Management, 9, 1 – 14.

NSW Food Authority (2004). NSW Aquaculture Shellfish Harvest Area Water Bacteriology and Phytoplankton Survey Data January 2003 – December 2003 Volume 1 Bellinger River – Merimbula Lake.

NSW Government (1992). Estuary Management Manual. NSW Government. October 1992.

Patterson Britton & Partners Pty Ltd (2003). Draft Macleay River Sand and Gravel Resource Assessment. Report to the Department of Land and Water Conservation.

Roy, P.S. (1994). Holocene estuary evolution-stratigraphic studies from southeastern Australia. In Dalrymple, R.W., Boyd, R., and B.A. Zaitlin (Eds) Incised valley systems: Origins and sedimentary sequences. Society for Sedimentary Petrology, Special Publication 51, 241 – 264.

Roy, P.S., Cowell, P.J., Fierland, M.A., and Thom, B.G. (1994). Wave-dominated coasts. In Carter, R.W.G. and Woodroffe, C.D. (Eds), Coastal Evolution: Late Quaternary shoreline morphodynamics. Cambridge University Press, Cambridge, 121 – 186.

Roy, P.S., Thom, B.G. and Wright, L.D. (1980). Holocene sequences on an embayed high-energy coast: an evolutionary model. Sedimentary Geology, 26, 1 – 19.

Sloss, C.R., Jones, B.G., Murray-Wallace, C.V., and McClennen, C.E. (in press). Holocene sea level fluctuations and the sedimentary evolution of a barrier estuary: Lake Illawarra, New South Wales, Australia. Journal of Coastal Research.

Tourism Research Australia (2004). North Coast NSW Region Tourism Profile for the year ended June 2003. Report prepared for Tourism NSW. Tourism NSW, Sydney.

Tulau, M.J. (2002). Agricultural drainage in acid sulfate soil backswamps in New South Wales, Australia - technical, regulatory and policy responses. In: C. Lin, M.D. Melville and L.A. Sullivan (eds.) Acid Sulfate Soils in Australia and China. pp. 158-176. Science Press, Beijing, China.

Tulau, M.J. and Naylor, S.D. (1999). Acid Sulphate Soil Management Priority Areas in the Lower Macleay Floodplain. Report. Department of Land and Water Conservation, Sydney.

Umitsu, M., Buman, M., Kumiko, K and Woodroffe, C.W. (2001). Holocene palaeoecology and formation of the Shoalhaven River deltaic-estuarine plains, southeast Australia. The Holocene, 11, (4), 407 – 418.

Walker, P.H. (1963) A reconnaissance of soils in the Kempsey District, N.S.W. CSIRO Soils and Land Use Series, 44.

Walker, P.H. (1970) Depositional and soil history along the Lower Macleay River, New South Wales. Journal of the Geological Society of Australia, 16 (2): 683-696.

Walker, P.H. (1972). Seasonal and Stratigraphic Controls in Coastal Floodplain Soils*Aust. J. Soil Res*. 10: 127-42.

Webb, McKeown & Associates Pty Ltd. (1997). Lower Macleay Floodplain Management Study. Kempsey Shire Council.

West, R.J., Thorogood, C., Walford, T. and Williams, R. (1985). An estuarine inventory for New South Wales, Australia. Fisheries Bulletin 2, Department of Agriculture, Sydney.

Willoughby, M.A. (1992). Boat wash on enclosed waterways. In: Forth Ports and Harbours Conference, Sydney, 24-27 August 1992, pp.223-227.

APPENDICIES

A Table of information contained in the***Macleay River Estuary Electronic Information Register*** (Excel and PDF Format available on Project CD, also available on the web at macleay.kempsey.nsw.gov.au)

B ***Species suitable for revegetation by Estuary Zone*** (Hardcopy at the back of this Report plus on Project CD)

C ***GIS Datasets*** created through the project + metadata summaries (available on the Project CD)

D ***Flora and Fauna Assessment*** (Separate hardcopy report by ID Landscape management Pty Ltd plus digital copy in PDF format available on Project CD)

E ***The Geomorphology of the Macleay River Estuary*** including Bank Erosion and Sedimentation Assessments (Separate hardcopy report by IRM Consulting plus digital copy in PDF format available on Project CD)

Appendix A

Macleay River Estuary Information and Data Register

Please view at *macleay.kempsey.nsw.gov.au* or refer to the Project CD for *Microsoft Excel* and *Adobe PDF* versions.

Appendix B

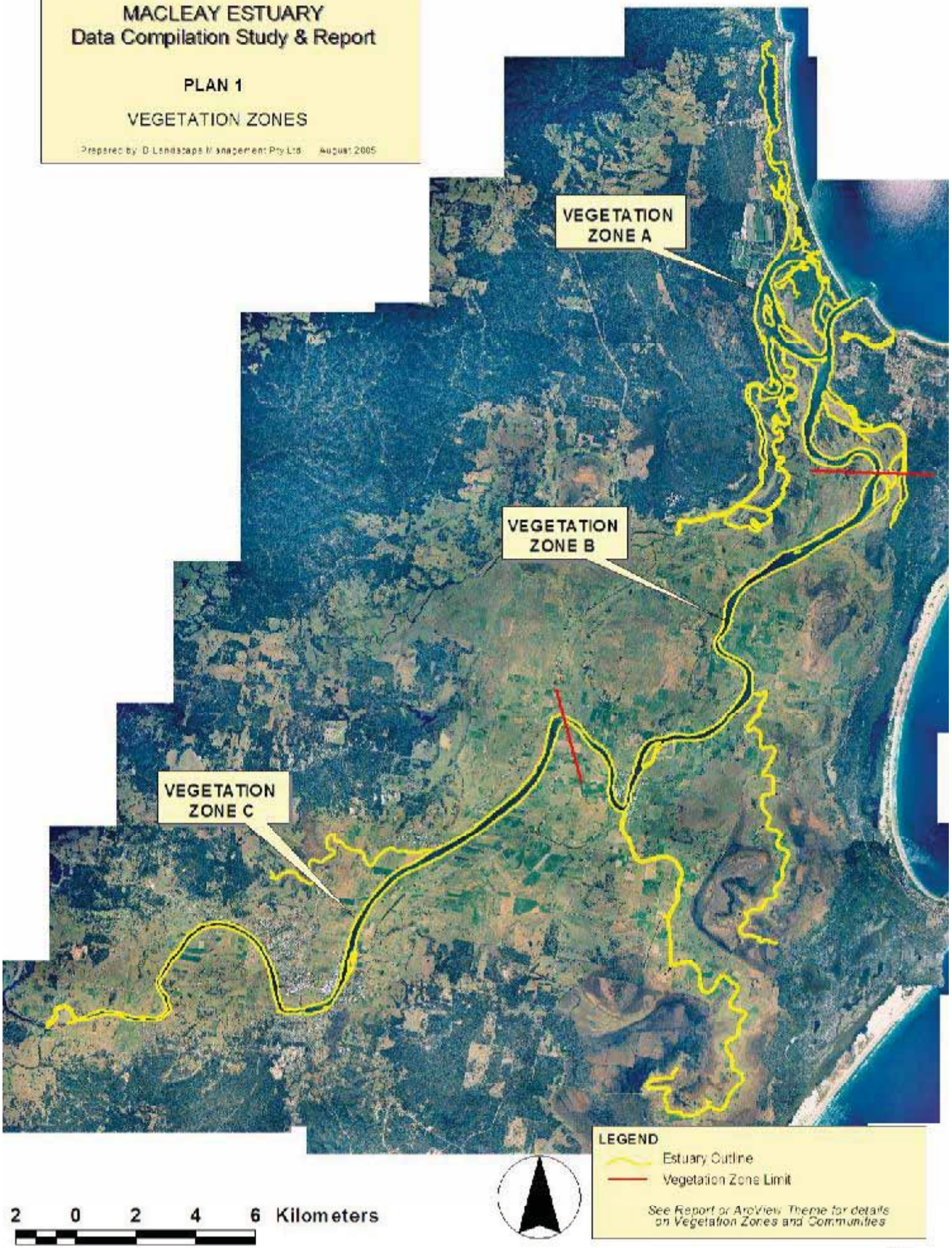
Macleay River Estuary Species Suitable for Revegetation

MACLEAY ESTUARY
Data Compilation Study & Report

PLAN 1

VEGETATION ZONES

Prepared by: D Landscape Management Pty Ltd August 2005



Plant species suitable for revegetation ZONE A SALINE ~ MARINE

Mid to high tide mark	High tide to upper bank	Upper bank - bank top
TREES & SHRUBS	***TREES & SHRUBS***	***TREES & SHRUBS***
Aegiceras corniculatum	Acacia sophorae	*Species listed for Mid bank plus:*
Avicenna marina	Banksia integrifolia	Acmena smithi
Casuarina glauca	Callistemon salignus	Alphitonia excelsa
	Cupaniopsis anacardioides	Aphananthe philippinensis
	Elaeocarpos obovatus	Commersonia fraseri
	Glochidion ferdinandi	Ficus superba
	Guoia semiglauca	Ficus rubiginosa
	Melaleuca bracteata	Jagera pseudorhus
	Melaleuca quinquenervia	Podocarpos elatus
	Melia azedarach	
	Myoporum acuminatum	
	Pittosporum undulatum	
	Rhagodia candolleana	
	Syzygium australe	
	Syzygium leuhmanni	
TUSSOCKS & RUSHES	***TUSSOCKS & RUSHES***	***TUSSOCKS & RUSHES***
Crinum pedunculatum	Crinum pedunculatum	Dianella caerula
Juncus usitatus	Dianella caerula	Lomandra longifolia
Phragmites australis	Lomandra longifolia	
	Tetragonia implexicoma	

Plant species suitable for revegetation ZONE B BRACKISH ~ SALINE

Mid to high tide mark	High tide to upper bank	Upper bank - bank top
TREES & SHRUBS	***TREES & SHRUBS***	***TREES & SHRUBS***
Aegiceras corniculatum	Acmena smithii	*Species listed for Mid bank plus:*
Avicenna marina	Backhousia myrtifolia	Acacia irrorata
Callistemon viminalis	Callistemon salignus	Acacia longifolia
Casuarina glauca	Casuarina cunninghamiana	Acacia melanoxylon
	Cupaniopsis anacardioides	Alphitonia excelsa
	Elaeocarpos obovatus	Aphananthe philippinensis
	Ficus coronata	Commersonia fraseri
	Glochidion ferdinandi	Jagera pseudorhus
	Guoia semiglauca	Ficus rubiginosa
	Melaleuca bracteata	Ficus superba
	Melia azedarach	Ficus rubiginosa
	Myoporum acuminatum	Ficus superba
	Pittosporum undulatum	
	Syzygium australe	
TUSSOCKS & RUSHES	***TUSSOCKS & RUSHES***	***TUSSOCKS & RUSHES***
Bolboschoenus sp.	Crinum pedunculatum	Dianella caerula
Crinum pedunculatum	Dianella caerula	Lomandra longifolia
Juncus usitatus	Lomandra hystrix	
Phragmites australis	Lomandra longifolia	
Typha sp.	Tetragonia implexicoma	

Plant species suitable for revegetation ZONE C FRESH ~ BRACKISH

Mid to high tide mark	High tide to upper bank	Upper bank - bank top
TREES & SHRUBS	***TREES & SHRUBS***	***TREES & SHRUBS***
Backhousia myrtifolia	Acmena smithii	*Species listed for Mid bank plus:*
Callistemon viminalis	Alphitonia excelsa	Ficus superba
Casuarina cunninghamiana	Aphananthe philipinensis	Ficus rubiginosa
Lept. brachyandrum	Backhousia myrtifolia	Acacia melanoxylon
Tristaniopsis laurina	Callistemon salignus	Commersonia fraseri
	Casuarina cunninghamiana	
	Elaeocarpus obovatus	
	Glochidion ferdinandi	
	Guioa semiglauca	
	Leptospermum brachyandrum	
	Melaleuca bracteata	
	Melia azedarach	
	Tristaniopsis laurina	
TUSSOCKS & RUSHES	***TUSSOCKS & RUSHES***	***TUSSOCKS & RUSHES***
Juncus usitatus	Dianella caerula	Dianella caerula
Lomandra hystrix	Lomandra hystrix	Lomandra hystrix
Potamophila parviflora	Lomandra longifolia	Lomandra longifolia

Appendix C

Macleay River Estuary GIS Datasets

Please refer to the Project CD for all datasets and associated descriptions (metadata). All GIS data is in Arcview Shapefile format in AGD66 Zone 56.

Appendix D

Macleay River Estuary Flora and Fauna Assessment

Macleay Estuary *Data Compilation Study*

FLORA and FAUNA HABITAT STUDY

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02 65 565 099

for
Kempsey Shire Council
September, 2005

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ACKNOWLEDGEMENTS

John Schmidt, DIPNR Coasts and Estuaries Manager made a significant contribution of time and energy to the field survey work undertaken. The Dept. of Environment and Conservation and NSW Fisheries staff also assisted with information on Threatened Species and available mapping. In addition, Ron Kemsley - Kempsey Shire Council and Natasha English - Macleay Landcare Officer provided a range of valuable information.

1 EXECUTIVE SUMMARY

16 Vegetation Communities have been recorded throughout the survey as occurring along the riparian zones of the Macleay River from Belgrave Falls upstream of Kempsey to the entrance into the Ocean at South West Rocks. The Belmore River, Kinchella Creek, Andersons Inlet, Macleay Arm, Clybucca Creek, Spencers Creek and South-west Rocks Creek have also been included in the survey.

150 different Vegetation Areas have been identified over the 347 kilometres of riparian zone investigated. Each of these areas has been described according to Vegetation Community, Native Vegetation Status, Weeds Status, Disturbance Level, Vulnerability Class, Flora and fauna Significance and Habitat Value.

The Riparian Zone is comprised of :

- 59.7% Improved Pasture and cropland;
- 23.4% Mangrove Forest and Woodland;
- 3.6% artificial breakwalls;
- 3.3% Saltmarsh vegetation dominated by Maritime Rush, Samphire and Samphire;
- 1.6% Littoral Rainforest (incorporates Tuckeroo and Headland Brush Box types);
- 1.4% Introduced Scrub;
- 1.4% typical River Oak vegetation;
- 1.2% Sand-hill Black-butt vegetation;
- 1.1% degraded Dry Rainforest – Myrtle Scrub;
- 1.1% Banksia Woodland along the coastal zone;
- 1.5% settlements, roads and semi-maintained lands partially cleared;
- 0.3% Swamp Oak vegetation;
- 0.2% Dry Sclerophyll Forest (Grey Gum - Grey Ironbark);
- 0.2% Wet Sclerophyll (Brush Box), and
- 0.05% Littoral Rainforest (Headland Brush Box).

The **degree of disturbance** of riparian vegetation has been documented as:

- 66.9% or 232 km having a HIGH degree of disturbance;
- 13.8% or 48 km considered to be INTACT;
- 10.1% or 35 km having a LOW degree of disturbance;
- 9.1 % or 31.6km of the vegetation varying in disturbance from LOW - MODERATE disturbance levels.

Weed Species have been grouped into 3 categories depending on their invasiveness, capacity to dominate natural vegetation communities and degree of difficulty to control. The abundance of these species has been listed for each of the identified Vegetation Areas.

282.4 km or 81.4% of the mapped riparian zone contains Category 1 Weeds which are the most serious environmental weeds on the North Coast, capable of displacing native communities. For approximately half of this length, 130.1 km, these Category 1 Weeds are ranked as Common – Heavy.

24 km or 6.9% of the mapped riparian zone contains Category 2 Weeds, as the worst environmental weeds recorded. Category 2 weeds are highly invasive but control is considered to be easier than for Category 1 weeds.

40.5 km or 11.7% of the mapped riparian zone does not contain any significant environmental weeds.

Three Vegetation Zones have been identified which correlate reasonably with the Geomorphic Process Zones described by Tim Cohen.

Zone A is where *Maritime* influences are predominant and extends from the Jerseyville Bridge to the mouth of the Macleay River (corresponds to Cohens Marine Flood-tide Process Zone).

Zone B is a *Transition Zone* with both freshwater and saline influences affecting vegetation composition. It extends from the Belmore River Confluence to some 5 km upstream of the Jerseyville Bridge (corresponding closely to Cohens Fluvial Reach 3 and Fluvial – Marine Transition Zone).

Zone C is where *Freshwater* is the dominant influence on vegetation composition. It extends from some 5 km upstream of the Jerseyville Bridge to Belgrave Falls. (corresponding closely to Cohens Fluvial Reach 1 and 2).

The typical identifying species for each of these zones are listed and provide a guide to the species suitable for inclusion in riparian revegetation projects.

Significant Flora and Fauna has been researched and documented.

FLORA
Eight 'Endangered Ecological Communities', 4 Endangered and 5 Vulnerable Flora species listed under the Threatened Species Conservation Act (TSCAct) have been identified as occurring within the Macleay estuary. Six of these species are also listed on the Commonwealth Government's Environment Protection and Biodiversity Conservation Act (EPBCAct). A further 7 flora species are known to be at or near their southern geographical limits in the area.

In addition, 4 other threatened flora species listed under the TSCAct are considered to potentially occur in the Macleay Estuary. Three of these species are also listed on the EPBCAct.

FAUNA
Seven Endangered and 39 Vulnerable Fauna species listed under the Threatened Species Conservation Act (TSCAct) have been identified as occurring within the Macleay estuary. Seven of these species are also listed on the Commonwealth Government's Environment Protection and Biodiversity Conservation Act (EPBCAct).

In addition, 21 other threatened fauna species listed under the TSCAct are considered to potentially occur in the Macleay Estuary. 3 of these species are also listed on the EPBCAct.

Eighty-two Migratory species (71 birds, 6 mammals, 3 reptiles, and 2 sharks) are also listed under the EPBCAct as occurring or potentially occurring in the Macleay estuary.

Habitat Corridors
A considerable proportion of the Macleay estuary is recognised as Key Habitat or within a Regional Corridor under the NSW NPWS 'Key Habitats and Corridors' mapping of NE NSW. The Regional Corridor identified under this NPWS Project is the Fishermans Bend Nature Reserve Regional Corridor which links from Hat Head NP and Arakoon SRA through Yarrahappini Wetlands, Tamban State Forest to Fishermans Bend NR and Mt Yarrahappini and Yarriabini National Park and then

westwards to Ngambaa NR. This corridor has a good deal of continuity of native vegetation cover and where gaps occur they are not large distances.

The Macleay River 'riparian corridor' is highly degraded due to the extent of clearing and the paucity of remnant pockets along the riparian margin or in pockets across the floodplain. Weed infestations are extensive. Nevertheless the riparian margin does act as a conduit for a variety of mobile species.

Threats and Habitat Vulnerability

The identification of threats, both current and potential, to the long-term sustainability of the identified flora and fauna habitat has been included for each mapped vegetation area. The relative vulnerability of each site to these threats has been identified and grouped into 3 classes - High, Medium, Low.

33.5 km or 9.6% of the riparian zone mapped has been classed as having a HIGH vulnerability to identified threats.

184.6 km or 53% of the riparian zone mapped has been classed as having a MEDIUM vulnerability to identified threats.

129 km or 37.18% of the riparian zone mapped has been classed as having a LOW vulnerability to identified threats.

The information compiled on Vegetation Status, Weed Status and Significant Species is in a format which makes it readily usable for determining management strategies revegetation priorities and 'action plans'. These proposed strategies, priorities and plans would provide a sound basis for on-going management and the preparation of funding submissions for implementing on-ground works.

State Environmental Planning Policy #26 – Littoral Rainforest listings

Three State Environmental Planning Policy 26 – Littoral Rainforests are listed for the Macleay Estuary. They are Sites #100, 101 and 101B at Shark Island, the breakwall Island and Clybucca Historic Site. This vegetation has been mapped under the current project and has been found to cover 62.6 hectares in 9 fragments. The main Shark Island remnant is 32 hectares.

Twenty-six smaller fragments of littoral / lowland rainforest have also been identified and mapped in this project. These fragments have a combined total of 39.2 hectares in 24 small remnants of varying degrees of degradation. These fragments are however considered important as part of a habitat conservation program as they offer a diversity of species and genetic material for restoration programs. With appropriate management these fragments will hopefully be sustainable and provide an important element of diversity within the identified habitat corridors.

The listing of 'Littoral Rainforest' as an 'Endangered Ecological Community' means that where there are recognised inadequacies in the SEPP 26 mapping the significant vegetation is protected under the Threatened Species Conservation Act.

State Environmental Planning Policy #14 – Wetlands listings

Seven different accepted wetland types - Mangroves, Saltmarshes, Melaleuca Forests, Casuarina Forests, Sedgelands, Brackish and Freshwater Swamps, Wet Meadows - were mapped at a scale of 1:25,000 under SEPP #14.

The consistency of mapping and level of accuracy has been criticised due to the exclusion of a number of groundwater dependent ecosystems such as Wet Heath and Wet Shrubland and low-lying forests such as Swamp Mahogany *Eucalyptus robusta*, Red Mahogany *Eucalyptus resinifera* from the mapping.

On this study site there is a degree of discrepancy between the communities mapped under SEPP#14 and their actual physical extent within the estuary. Discrepancies can be attributed to the scale of photography being at 1:25,000 and environmental changes over the preceding years.

Whilst there are inconsistencies and inaccuracies with the SEPP #14 mapping within the study area it is not considered relevant to identify all discrepancies as the new 'Endangered Ecological Communities' gazetted under the TSCAct address the ecological significance of 'wetland' vegetation. Coastal Slatmarsh, Freshwater Wetlands, Swamp Sclerophyll on Floodplains, Subtropical Coastal Floodplain Forest, Swamp Oak Floodplain Forest and River-flat Eucalypt Forest on Coastal Floodplains which may have been excluded under SEPP 14 have now been protected under the new legislation.

NSW Fisheries Mapping of Mangrove, Saltmarsh, Sea Grass sp. (Zostera sp.) is currently being updated and is anticipated to be available during 2005.

Macleay Wetlands Management Plan and Mapping

This Mapping produced by the North Coast Environment Council Inc in 1999 defined 21 Vegetation Units representing an area of 40,232 hectares. Problems with distortion associated with transferral into a digital layer in ArcView have reduced the usability of this information as digital layer without considerable work in corrections. However, it still supplies important information which can be integrated into other update mapping.

Active Riparian Restoration Projects

Tenty-four riparian and wetland / floodgate management projects have been listed as active within the Macleay estuary. Funding is from a range of sources including Kempsey Council, the Catchment Management Authority, Natural Heritage Trust, Envirofund, Voluntary Streamacre Grants Scheme, corporate initiatives from Nestles, plus considerable landholder contributions.

2 SUMMARY OF IDENTIFIED GAPS IN THE DATA BASE

1. Lack of definitive mapping for vegetation recently listed as 'Endangered Ecological Communities'. The specific vegetation communities included within the 'Endangered Ecological Communities' needs to be clarified and mapped accordingly.

   For example, Subtropical Coastal Floodplain Forest on the NSW North Coast bioregion potentially occurs along the Clybucca Creek in a number of places beyond the immediate riparian fringe. This needs further investigation and mapping.
   Saltmarsh communities will be mapped as part of the NSW Fisheries Mapping.

2. Lack of a strategic long-term plan guide to riparian, coastal and rainforest regeneration / restoration activities.

3. What impact do the weed species of submerged aquatic vegetation – *Elodea sp*. and *Egeria sp*. have on aquatic habitat?

   How do these species react to drought, normal flow, flood and increased nutrient from discharges?
   To what degree do these species displace native submerged vegetation.

4 Lack of specific local documentation on habitat corridors and a clear strategic plan for conserving or establishing local corridors.

   There is a need to preserve and consolidate a diverse mosaic of vegetation types for the conservation of flora and dependent fauna species. Many species utilize a variety of vegetation communities habitat types for different parts of their lifecycles e.g. Blossom bats, Fruit doves, migratory waders.

   Another important factor is 'altitudinal migration' for fruit and nectar dependent species – species of rainforest plants flower and fruit earlier at lower elevations than higher due to warmer conditions that prevail at low elevations or near the coast.

5 Lack of control program for the Serious Environmental Weed Spike Rush *Juncus acutus* in the Rainbow Reach locality . Spike Rush is encroaching on estuarine Rushlands and Samphire – Sand-Couch Vegetation listed as an 'Endangered Ecological Communities'.

6 Lack of data on the invasion of Saltmarsh communities by Mangroves in the locality and the potential subsequent changes to adjoining wetland and swamp forest communities and understanding of the implications of this in terms of habitat changes. The mangrove invasion limits the use of saltmarshes by birds that would normally make use of this habitat and has been a factor in their decline

7 The integration of Aboriginal Heritage Issues into the estuary planning process has not been highlighted.

3 SUMMARY OF RECOMMENDATIONS

1 Prepare definitive mapping for vegetation which encompasses recently listed as 'Endangered Ecological Communities' and ensure that all future mapping be able to be incorporated into the ArcView database with accuracy for use in development and planning scenarios.

2 Develop a strategic approach to prioritising restoration and revegetation works based on the weed status and degree of disturbance defined in this Project. A 'Conservation and Restoration Plan' should be developed as a framework with specific goals and actions to guide activities to ensure long term aims are achieved. Such a Plan would be a useful document to aid in sourcing funding for the works over extended periods as opposed to short-term options currently available.

The 'degree of disturbance' data collected in this Project can be used to determine the selection of sites which have reasonable native canopy condition (e.g Intact, Low, Low-Moderate, Moderate) as high priorities for weed control and regeneration activities.

3 Undertake investigation into:
- The impact of weed species of submerged aquatic vegetation – *Elodea sp*. and *Egeria sp*. - on aquatic habitat.
- The reaction of these weed species and native species of submerged aquatic vegetation to drought, normal flow, flood and increased nutrient from discharges.
- The degree to which these species displace native submerged vegetation.

4 It is recommended that a two pronged approach to 'habitat corridor conservation' be adopted:

a) The NPWS 'Key Habitats & Corridors' regional corridor be identified as a priority for habitat protection and rehabilitation activities. Lands within and adjoining the mapped areas should be targeted to maximize habitat opportunity. This corridor contains a diverse mosaic of vegetation types for the conservation of flora and dependent fauna species.

This should be considered as a high priority and integrated into landuse planning and development control processes and recognized as a priority to attract funding assistance for rehabilitation and extension works.

b) Floodplain and Riparian forest remnants should be targeted as part of a long-term 'Macleay Riparian Corridor Restoration Program'. Actions such as:
- undertaking priority weed control to promote natural regeneration and sustainability of the remnants;
- development of a seed bank and propagation program to maintain genetic integrity and expand diversity of species for fauna foraging and extension of habitat area.
- establishment of revegetation areas in priority locations and extension of works and areas over realistic period of time, should be initiated as soon as possible as this is a long term strategic project.

The 'Landcare' movement and Community Support Officers could play a vital role in this priority as ~90% of floodplain and riparian rainforest

(subtropical) of the Macleay is within private land. However, a definitive 'Conservation and Restoration Plan' as a framework with specific goals and actions should be established early-on to guide activities to ensure long term aims are achieved.

This 'Conservation and Restoration Plan' would need to integrate resources from the community, NSW NPWS, DIPNR and the local aboriginal community.

Rehabilitation projects should also integrate Australian Bass habitat features identified in the NSW Fisheries documentation.

5 Develop a strategic works plan for the control of Spike Rush *Juncus acutus*, an introduced rush which has been identified in the Rainbow Reach locality, downstream of Jerseyville.

In terms of community structure and function this species is considered as the most serious threat to 'coastal saltmarsh' communities. In the current study we have identified where its occurrence is noted during field assessment however a more detailed appraisal of the extent of the infestation, which at this point in time seems localised, should be made.

Other weed species of threat are Groundsel Bush *Baccharis halimifolia*, Pampas Grass *Cortaderia selloana* and in some localities Pennywort *Hydrocotyle bonariensis*. Groundsel Bush is a listed Noxious Weed and as such does undergo control activities through Kempsey Council and its liaison with landholders.

Work should not only focus on mapping the current extent of Spike Rush *Juncus acutus* but also in establishing control works. Control works should be aimed at:

- limiting the spread of the species beyond current by identifying isolated populations and targeting them;
- reducing the extent of main population areas.

This is seen as an urgent priority which should be addressed now and not wait until the preparation of the overall Estuary Management Plan.

This study could be undertaken by a Research Student associated with the New England or Newcastle Universities where some work has already been done in association with this species and impacts on the Hunter wetlands.

Alternatively, and possibly preferably, by a Consultant who can manage the determination of extent of infestation in a relatively short time frame and then instigate control works in association with Kemspey Shire Council, DIPNR, NSW Fisheries and landowners.

6 In recent decades there has been widespread invasion of Saltmarsh in south-east Australia by mangroves and the factors causing this are unclear The factors driving mangrove invasion are still unclear. Sea level rises as a result of global warming are considered likely to pose an increasing threat to the survival of many areas of Coastal Saltmarsh.

Mangrove colonization of Saltmarsh has been noted for some areas have been recorded as part of this Data Compilation Study.

It is recommended that a series of survey transects and monitoring points be established from river through Saltmarsh to Swamp Forest at a variety of locations to track the progression or change within the vegetation communities over time and identify areas where Saltmarsh communities etc are vulnerable due to rises in sea level and the implications on adjoining vegetation communities. This study could be undertaken by a Research Student.

Progression and change can be rapid and it is therefore seen as a high priority which should be commenced now to further our understanding for incorporation into the Estuary Management Plan.

7 Aboriginal Heritage Issues need to be addressed within the estuary and incorporation of the NSW Indigenous Fisheries Strategy and Implementation Plan should be undertaken.

Integration of Vegetation Restoration works with Aboriginal communities is necessary so that there is a cohesive approach to restoration programs (e.g Shark Island has the Landcare network which has a history of funding weed control activities and now Department of Infrastructure, Planning and Natural Resources has funded a Management Agreement with the local Aboriginal Community.

4 VEGETATION DESCRIPTION

4.1 Methodology

Field investigations were undertaken in order to verify the mapping of the vegetation communities, degree of disturbance of canopy, understorey, groundcover and the weed status from Belgrave falls in the west to the top of the Macleay Arm and the new entrance of the Macleay River.

16 different 'Vegetation Communities' were identified over the 347 kilometres of riparian zone investigated. These are listed below and summarised in Table 1 below. Descriptions of each 'Vegetation Community' are on the following pages.

3 different 'Vegetation Zones' have been identified (see 4.2 for details).

150 different 'Vegetation Areas' have been described according to Vegetation Community, Native Vegetation Status, Weeds Status, Disturbance Level, Vulnerability Class, Flora and fauna Significance and Habitat Value.
See Appendix 1 for full details.

Vegetation has been described in terms of forest types (Forestry Commission NSW 1989); the codes are indicated in square brackets [ ]. Supplementary vegetation associations in coastal areas are from National Parks and Wildlife Service classifications and these codes are quoted in round brackets ( ).

Table 1 – Vegetation Type – length of Riparian Zone Summary

Vegetation Type	Length of Riparian Zone	% of total length of riparian Zone surveyed
[33] (2502) Mangrove Forest and Woodland	81.285 km	23.4%
(6502) Maritime Rush and Sand Couch	7.198 km	2.07%
[25] (0503) Headland Brushbox	5.489 km	1.58%
[211] River Oak	4.725 km	1.36%
[23] Myrtle – degraded	4.726 km	1.36%
(6102) Samphire – Sand Couch	4.124 km	1.19%
[41] (3506) Sand-hill Black-butt	4.074 km	1.17%
[24] (0502) - Tuckeroo	3.851 km	1.11%
[107] Banksia	3.587 km	1.03%
[32] (4005) Swamp Oak	1.180 km	0.34%
[62] Grey Gum – Grey Ironbark	0.738 km	0.21%
[53] Brush Box	0.660 km	0.19%
[216] Improved Pasture and Cropland	207.331 km	59.74%
Breakwall	12.507 km	3.60%
[221] Introduced Scrub	4.854 km	1.39%
[220] Cleared and Partially Cleared	3.293 km	0.95%
[219] Settlements and Roads	2.074 km	0.60%
TOTAL	**347.077 km**	

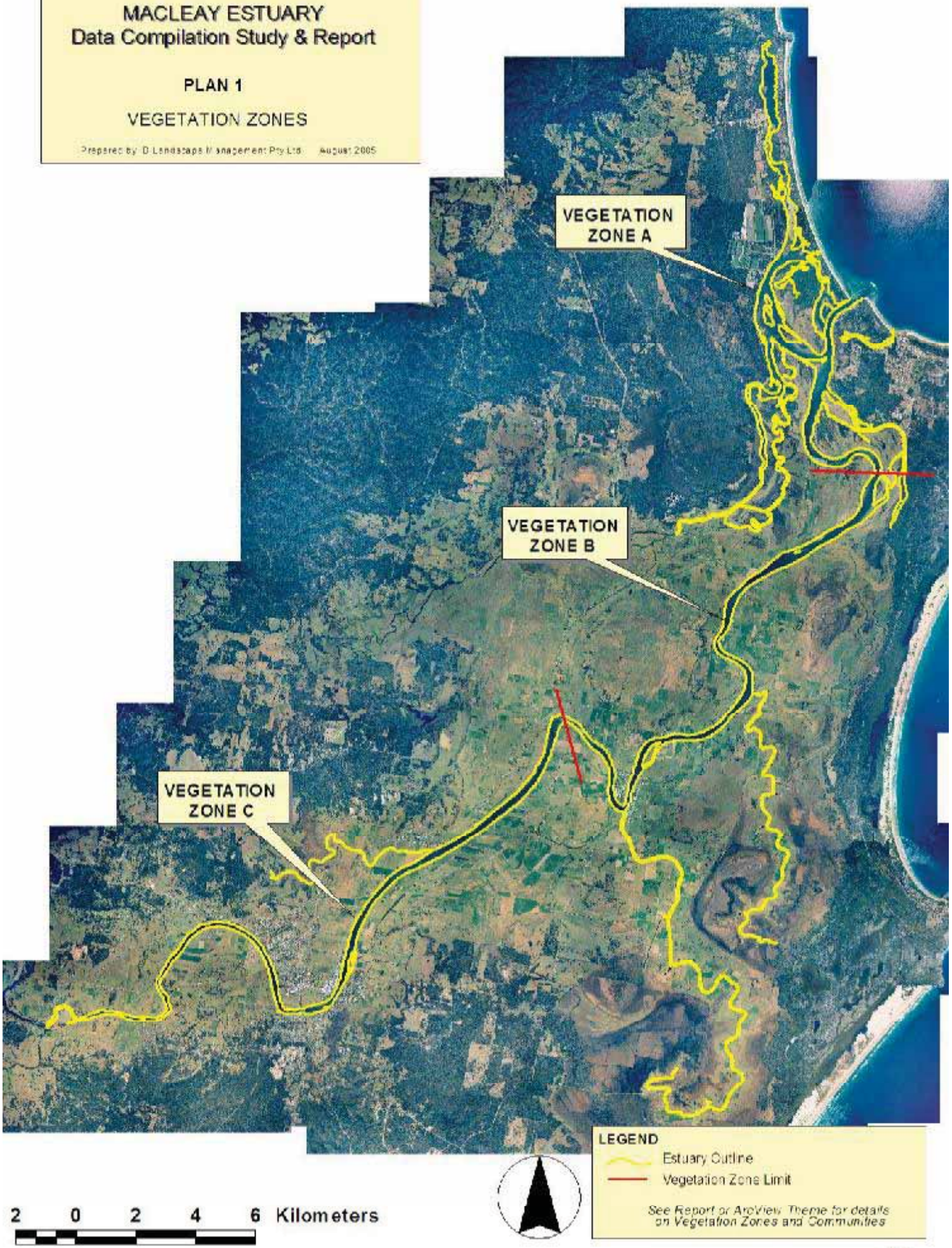
* [24] Tuckeroo and [25] Headland Brushbox have been grouped into Littoral Rainforest in the Executive summary

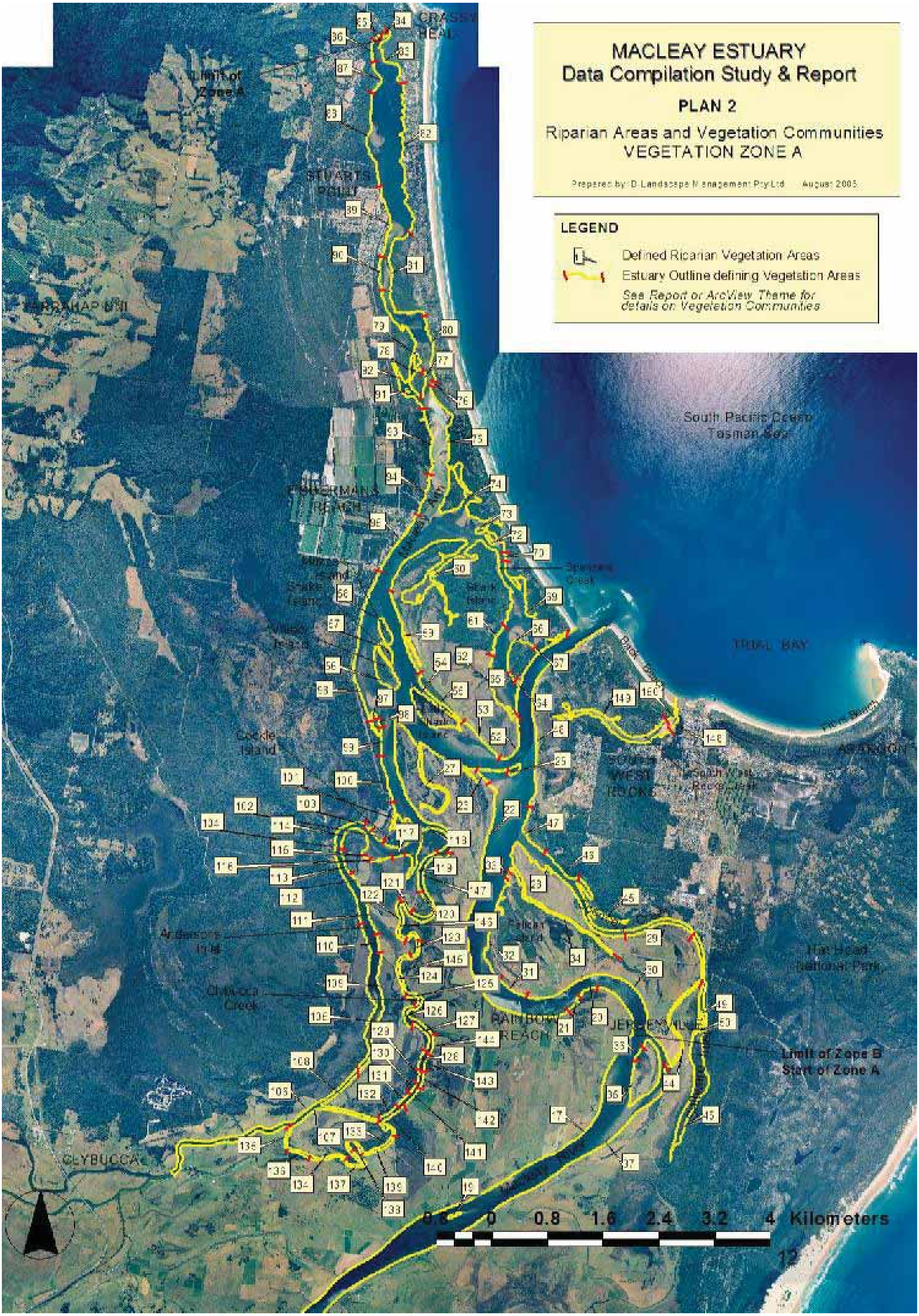
MACLEAY ESTUARY
Data Compilation Study & Report

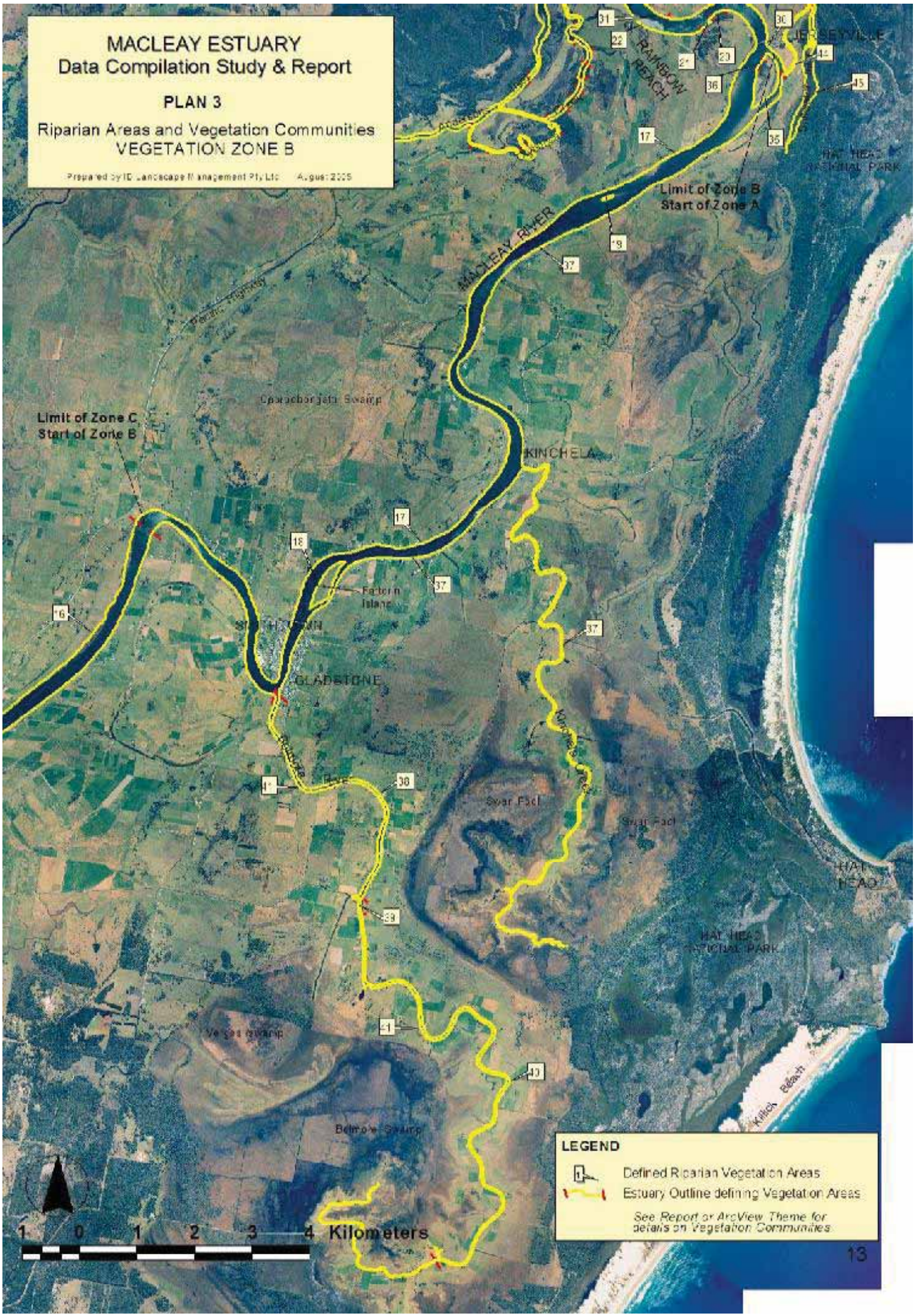
PLAN 1

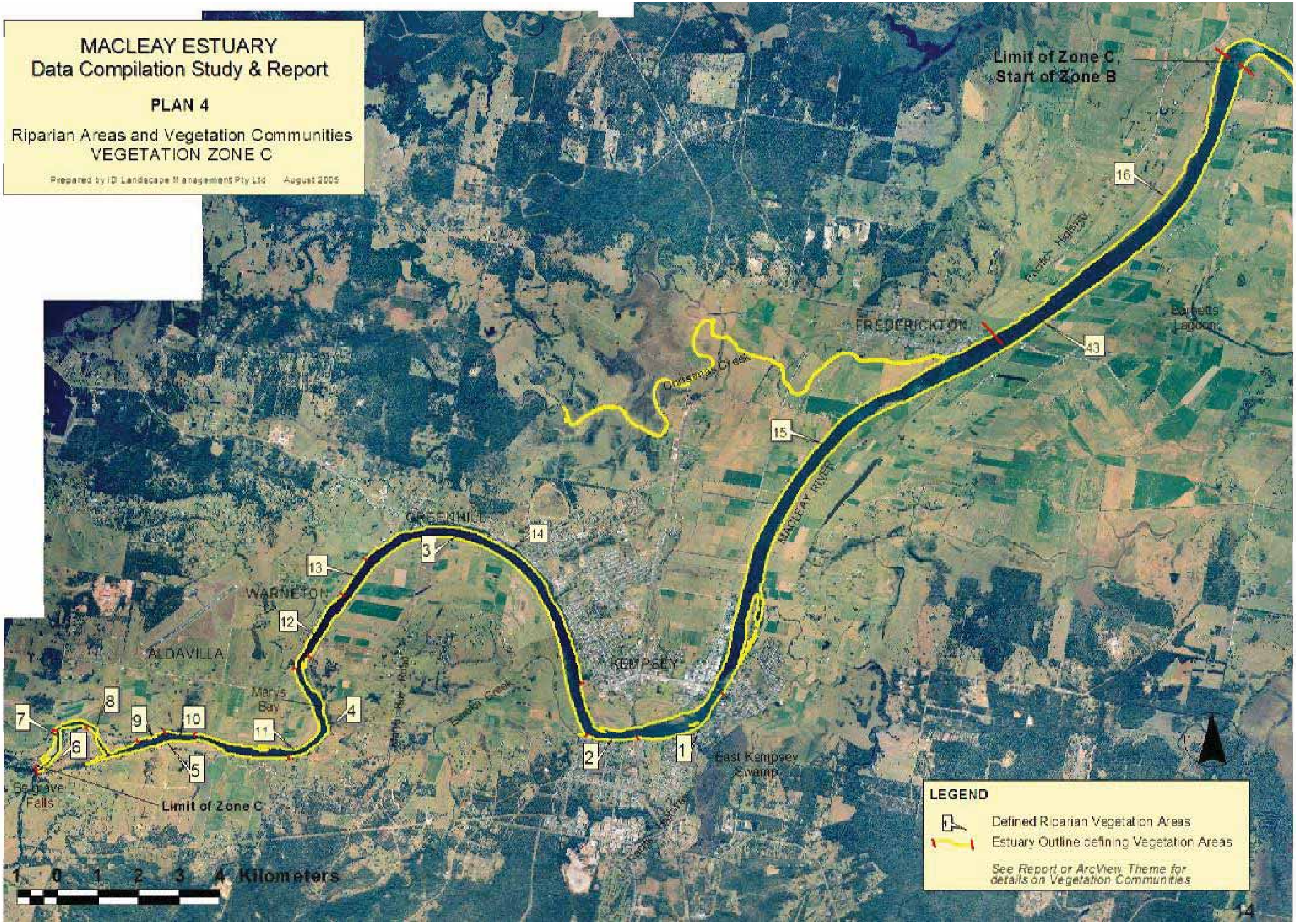
VEGETATION ZONES

Prepared by: D Landscape Management Pty Ltd August 2005




MACLEAY ESTUARY
Data Compilation Study & Report
PLAN 2
Riparian Areas and Vegetation Communities
VEGETATION ZONE A
Prepared by: D Landscape Management Pty Ltd August 2005
LEGEND
Defined Riparian Vegetation Areas
Estuary Outline defining Vegetation Areas
See Report or ArcView Theme for details on Vegetation Communities
Limit of Zone A
STUARTS POINT
South Pacific Ocean
Tasman Sea
TRIAL BAY
Cockle Island
SOUTH WEST ROCKS
Anderson Inlet
Hat Head National Park
RAINBOW REACH
JERSEYVILLE
Limit of Zone B
Start of Zone A
CLYBUCCA
0.8 0 0.8 1.6 2.4 3.2 4 Kilometers


MACLEAY ESTUARY
Data Compilation Study & Report
PLAN 3
Riparian Areas and Vegetation Communities
VEGETATION ZONE B
Prepared by ID Landscape Management Pty Ltd August 2005
Limit of Zone B
Start of Zone A
Limit of Zone C
Start of Zone B
MACLEAY RIVER
RAINBOW REACH
KINCHELA
GLADSTONE
Eastern Island
Pacific Highway
HAT HEAD NATIONAL PARK
HAT HEAD
Killick Beach
Belmore Swamp
LEGEND
Defined Riparian Vegetation Areas
Estuary Outline defining Vegetation Areas
See Report or ArcView Theme for details on Vegetation Communities
1 0 1 2 3 4 Kilometers


MACLEAY ESTUARY
Data Compilation Study & Report
PLAN 4
Riparian Areas and Vegetation Communities
VEGETATION ZONE C
Prepared by ID Landscape Management Pty Ltd August 2005
Limit of Zone C,
Start of Zone B
FREDERICKTON
Barretts Lagoon
Christmas Creek
MACLEAY RIVER
GREENHILL
WARNETON
ALDAVILLA
KEMPSEY
Marys Bay
East Kempsey Swamp
Belgrave Falls
Limit of Zone C
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
43
1 0 1 2 3 4 Kilometers
LEGEND
Defined Riparian Vegetation Areas
Estuary Outline defining Vegetation Areas
See Report or ArcView Theme for details on Vegetation Communities
14

GRASSLAND / HIGHLY DISTURBED

[216] Improved Pasture and Crop Land.

Typical example of riparian zone within [216] Improved Pasture and Cropland

[219] Settlements, roads etc
[220] Cleared / Partially Cleared – this type covers land that was forested and which is now maintained in an open condition by grazing and periodic burning
[221] Introduced scrub – Introduced woody weeds dominate the site. E.g. Bitou Bush dominated coastal scrubland

CHENOPOD SHRUBLAND (Saltmarsh)

(6102) Samphire – Sand Couch *Sarcocornia quinqueflora – Sporobolus virginicus*
Forms a shrubland (often termed Saltmarsh) on estuarine mudflats inland of Mangroves, inundated by high spring tides. Maritime Rush *Juncus krausii* is common and forms an inland intergrade.
Synonymous with NSW Fisheries *Saltmarsh* category.

Samphire- Sand Couch along Clybucca Creek

RUSHLAND

(6502) Maritime Rush *Juncus kraussii* and Sand Couch *Sporobolus virginicus* Forms a common association on estuarine mudflats just above the high tide level. Occasional emergents of Swamp Oak *Casuarina glauca*. Grades into Chenopod Shrubland downslope and *Casuarina glauca* swamp sclerophyll forest above tidal influence.
Synonymous with NSW Fisheries *Saltmarsh* category.

MANGROVE FOREST AND WOODLAND

[33] (2502) Mangrove Forest and Woodland – fringing tidal estuaries. Grey mangrove *Avicennia marina* as the dominant tree with River Mangrove *Aegiceras corniculatum* common as a shrub. Milky Mangrove *Exocecaria agallocha* occurs less frequently. Located on mudflats in intertidal zone of estuaries as a narrow stripalong deepwater shore lines, creeks and constructed drains or as broader forests on shallow water mudflats. Grades sharply into chenopod shrubland (Saltmarsh) or Rushland above high tide level.
Synonymous with NSW Fisheries *Saltmarsh* category.

DRY RAINFOREST

[23] Myrtle Scrub – a type dominated by the family Myrtaceae excluding water gum, coachwood and Lilly Pilly. Includes grey Myrtle Backhousea myrtifolia, Silky Myrtle Decaspermum paniculatum, Brush Cherry Syzygium oleosum, Blackwood Acacia melanoxylon and Brushbox.

LITTORAL RAINFOREST

24] (0502) Tuckeroo *Cupaniopsis anacardioides* - a type of Littoral Rainforest dominated by Tuckeroo with associated Plum Pine *Podocarpos elatus* Red-fruited Olive Plum *Cassine australe*, Black Plum *Diospryos australis*, Yellow Tulip *Drypetes australasica*, Rusty Fig *Ficus rubiginosa* Lilly Pilly *Acmena smithi*, Elk Horn Fern *Platycerium bifurcatum*, and Birds Nest Fern *Asplenium australasicum* .

[25] (0503) Headland Brush Box (*Lophostemon confertus*) Littoral rainforest on exposed coastal headlands. Dominated by Brush Box with associated Tuckeroo *Cupaniopsis anacardioides*, Scentless Rosewood *Synoum glandulosum*, Black Apple *Planchonella australis* and Grey Myrtle *Backhousea myrtifolia*.

SWAMP SCLEROPHYLL FOREST

[31] Paperbark *Melaleuca quinquenervia* has been extensively cleared on the Macleay Floodplain for agricultural purposes. This community is often dominated by *Melaleuca quinquenervia* but may be associated with other paperbarks including *Melaleuca alternifolia* and *Melaleuca linarifolia* or Swamp Oak *Casuarina glauca*, Willow Bottlebrush *Callistemon salignus*, Swamp Mahogany *Eucalyptus robusta* and Forest Red Gum *Eucalyptus tereticornis.*

[32] (4005) Swamp Oak *Casuarina glauca*. Usually consists of almost pure stands of Swamp oak with Broad leaved Paperbark *Melaleuca quinquenervia* and Swamp Mahogany *Eucalyptus robusta* as occasional associates.

FLOODPLAIN RIPARIAN FOREST – WOODLAND

This type is a mixed community often difficult to define due to past disturbance such as clearing, grazing, burning and bank erosion.

Elements of Swamp Sclerophyll Forest tend to dominate where levee banks are lower and Littoral Rainforest on higher banks. Fragments of the following communities are generally evident within this community:

[31] Paperbark *Melaleuca quinquenervia* has been extensively cleared on the Macleay Floodplain for agricultural purposes. This community is often dominated by *Melaleuca quinquenervia* but may be associated with other paperbarks including *Melaleuca alternifolia* and *Melaleuca linarifolia* or Swamp Oak *Casuarina glauca*, Willow Bottlebrush *Callistemon salignus*, Swamp Mahogany *Eucalyptus robusta* and Forest Red Gum *Eucalyptus tereticornis.*

[32] (4005) Swamp Oak *Casuarina glauca*. Usually consists of almost pure stands of Swamp oak with Broad leaved Paperbark *Melaleuca quinquenervia* and Swamp Mahogany *Eucalyptus tereticornis* as occasional associates.

[24] (0502) Tuckeroo *Cupaniopsis anacardioides* Littoral Rainforest - a type dominated by Tuckeroo with associated Plum Pine *Podocarpos elatus* Red-fruited Olive Plum *Cassine australe*, Black Plum *Diospryos australis*, Yellow Tulip *Drypetes australasica*, Rusty Fig *Ficus rubiginosa* Lilly Pilly *Acmena smithi*, Elk Horn Fern *Platycerium bifurcatum*, and Birds Nest Fern *Asplenium australasicum* .

Sub-tropical Coastal Floodplain Forest of the NSW North Coast bioregion has been recently listed under the Threatened Species Act as an Endangered Ecological Community. This classification and the species composition listed under the Act indicate that this would also be an appropriate classification for what we have described here as Floodplain Riparian Forest – Woodland.

DRY SCLEROPHYL FOREST

[62] Grey Gum-Grey Ironbark – White Mahogany (*Eucalyptus propinqua – E.paniculata – E. carnea*).

[41](3506) Sand Blackbutt – Bloodwood (*Eucalyptus pilularis – Corymbia intermedia*)

[107] Banksia *Banksia integrifolia* Open stands on deep sands usually only a short distance in from the ocean. Scattered Eucalypts may be found.

[211] River Oak *Casuarina cunninghamiana.*

WET SCLEROPHYLL FOREST

[53] Brush Box *Lophostemon confertus*

4.2 Zonation of Vegetation within the Estuary

Zonation of Vegetation types is apparent throughout the estuary dependent on the degree of maritime influence such as salt laden winds and saline waters and levels of tidal fluctuation. The degree of clearing has somewhat masked clear definition of these boundaries or transition zones.

3 vegetation zones have been identified which correlate reasonably with the Geomorphic Process Zones described by Tim Cohen. These are described in Table 2 below.

Table 2 – Vegetation Zones within the Estuary

Geomorphic Process Zone	Vegetation Zones	*Identified Vegetation Communities within*
Fluvial Reach 1 Belgrave Falls to Kempsey Bridge **Fluvial Reach 2** Kemspey Bridge to Belmore River Confluence	**Zone C** *Freshwater the predominant influence on vegetation*	[221] River Oak [62] Grey Gum Ironbark [216] Improved Pasture and Crop Land [23] Myrtle [211] Introduced Scrub
Fluvial Reach 3 Belmore River Confluence to Kinchela **Fluvial - Marine Transition Zone** Kinchella to Jerseyville Bridge	**Zone B** *Transition Zone with both freshwater and saline influences affecting vegetation composition*	[216] Improved Pasture and Crop Land [33] (2502) Mangrove Forest and Woodland [211] River Oak
Marine Flood-tide Process Zone Jerseyville Bridge to the mouth of the Macleay	**ZONE A** *Maritime influences predominant*	(6502) Maritime Rush and Sand Couch [216] Improved Pasture and Crop Land [33] (2502) Mangrove Forest and Woodland (6102) Samphire – Sand Couch [24] (0502) Tuckeroo [53] Brush Box Forest [220] Cleared / Partially Cleared [32] (4005) Swamp Oak [107] Banksia [25] (0503) Headland Brush Box [41] (3506) Sand Blackbutt – Bloodwood [219] Settlements Roads etc [221] Introduced Scrub - Bitou

The typical identifying species for each of these zones are listed below. Table 3 on the following page provides a guide to the species suitable for inclusion in riparian revegetation projects.

Table 3: Species suitable for riparian revegetation projects for each Vegetation Zone

Vegetation Zone	Mid to high tide mark *Toe of bank*	High tide to upper bank *Mid Bank*	Top of bank *Upper bank*
A	**TREES & SHRUBS**	**TREES & SHRUBS**	**TREES & SHRUBS**
	Aegiceras corniculatum	*Acacia sophorae*	Species listed for Mid bank plus:
	Avicenna marina	*Banksia integrifolia*	*Acmena smithi*
	Casuarina glauca	*Callistemon salignus*	*Alphitonia excelsa*
		Cupaniopsis anacardioides	*Aphananthe philippinensis*
		Elaeocarpos obovatus	*Commersonia fraseri*
		Glochidion ferdinandi	*Ficus superba*
		Guoia semiglauca	*Ficus rubiginosa*
		Melaleuca bracteata	*Jagera pseudorhus*
		Melaleuca quinquenervia	*Podocarpos elatus*
		Melia azedarach	
		Myoporum acuminatum	
		Pittosporum undulatum	
		Rhagodia candolleana	
		Syzygium australe	
		Syzygium leuhmanni	
	TUSSOCKS & RUSHES	**TUSSOCKS & RUSHES**	**TUSSOCKS & RUSHES**
	Crinum pedunculatum	*Crinum pedunculatum*	*Dianella caerula*
	Juncus usitatus	*Dianella caerula*	*Lomandra longifolia*
	Phragmites australis	*Lomandra longifolia*	
		Tetragonia implexicoma	

B	**TREES & SHRUBS**	**TREES & SHRUBS**	**TREES & SHRUBS**
TRANSITION ZONE	*Aegiceras corniculatum*	*Acmena smithii*	Species listed for Mid bank plus:
	Avicenna marina	*Backhousia myrtifolia*	*Acacia irrorata*
	Callistemon viminalis	*Callistemon salignus*	*Acacia longifolia*
	Casuarina glauca	*Casuarina cunninghamiana*	*Acacia melanoxylon*
		Cupaniopsis anacardioides	*Alphitonia excelsa*
		Elaeocarpos obovatus	*Aphananthe philippinensis*
		Ficus coronata	*Commersonia fraseri*
		Glochidion ferdinandi	*Jagera pseudorhus*
		Guoia semiglauca	*Ficus rubiginosa*
		Melaleuca bracteata	*Ficus superba*
		Melia azedarach	*Ficus rubiginosa*
		Myoporum acuminatum	*Ficus superba*
		Pittosporum undulatum	
		Syzygium australe	
	TUSSOCKS & RUSHES	**TUSSOCKS & RUSHES**	**TUSSOCKS & RUSHES**
	Bolboschoenus sp.	*Crinum pedunculatum*	*Dianella caerula*
	Crinum pedunculatum	*Dianella caerula*	*Lomandra longifolia*
	Juncus usitatus	*Lomandra hystrix*	
	Phragmites australis	*Lomandra longifolia*	
	Typha sp.	*Tetragonia implexicoma*	

C	**TREES & SHRUBS**	**TREES & SHRUBS**	**TREES & SHRUBS**
	Backhousia myrtifolia	*Acmena smithii*	Species listed for Mid bank plus:
	Callistemon viminalis	*Alphitonia excelsa*	*Ficus superba*
	Casuarina cunninghamiana	*Aphananthe philipinensis*	*Ficus rubiginosa*
	Lept. brachyandrum	*Backhousia myrtifolia*	*Acacia melanoxylon*
	Tristaniopsis laurina	*Callistemon salignus*	*Commersonia fraseri*
		Cas. cunninghamiana	
	TUSSOCKS & RUSHES	*Elaeocarpos obovatus*	
	Juncus usitatus	*Glochidion ferdinandi*	**TUSSOCKS & RUSHES**
	Lomandra hystrix	*Guoia semiglauca*	*Dianella caerula*
	Potamophila parviflora	*Lept. brachyandrum*	*Lomandra hystrix*
		Melaleuca bracteata	*Lomandra longifolia*
		Melia azedarach	
		Tristaniopsis laurina	
		TUSSOCKS & RUSHES	
		Dianella caerula	
		Lomandra hystrix	
		Lomandra longifolia	

5 REVIEW OF EXISTING MAPPING

5.1 Existing State Environmental Planning Policy #26 – Littoral Rainforest

Three State Environmental Planning Policy 26 – Littoral Rainforests are listed for the Macleay Estuary. These 3 rainforest remnants are synonymous with Forest Type *[24] (0502)* Tuckeroo *Cupaniopsis anacardioides.* See Plan 4.

1 **Shark Island – SEPP26 Site # 100**
Floyd (1977) describes the significant features of the rainforest in the following terms:
- Widespread occurrence of Riberry *Syzygium leuhmanni* which is the southernmost occurrence of this species.
- Three-veined Laurel *Cryptocarya triplinervis*, Green Tree *Acronychia imperforata*, Bumpy Ash *Flindersia schottiana*, Malletwood *Rhodamnia argentea* and Smooth Clerodendron *Clerodendron floribundum* approach their southern limits in this remnant.
- 58 species of trees and 23 species of vines occur within the site.
- 7 of the 8 species of figs recorded in NSW occur on this site.

2 **Unnamed Island bounded by Spencers Creek and the NEW Entrance Breakwall - SEPP 26 Site # 101**

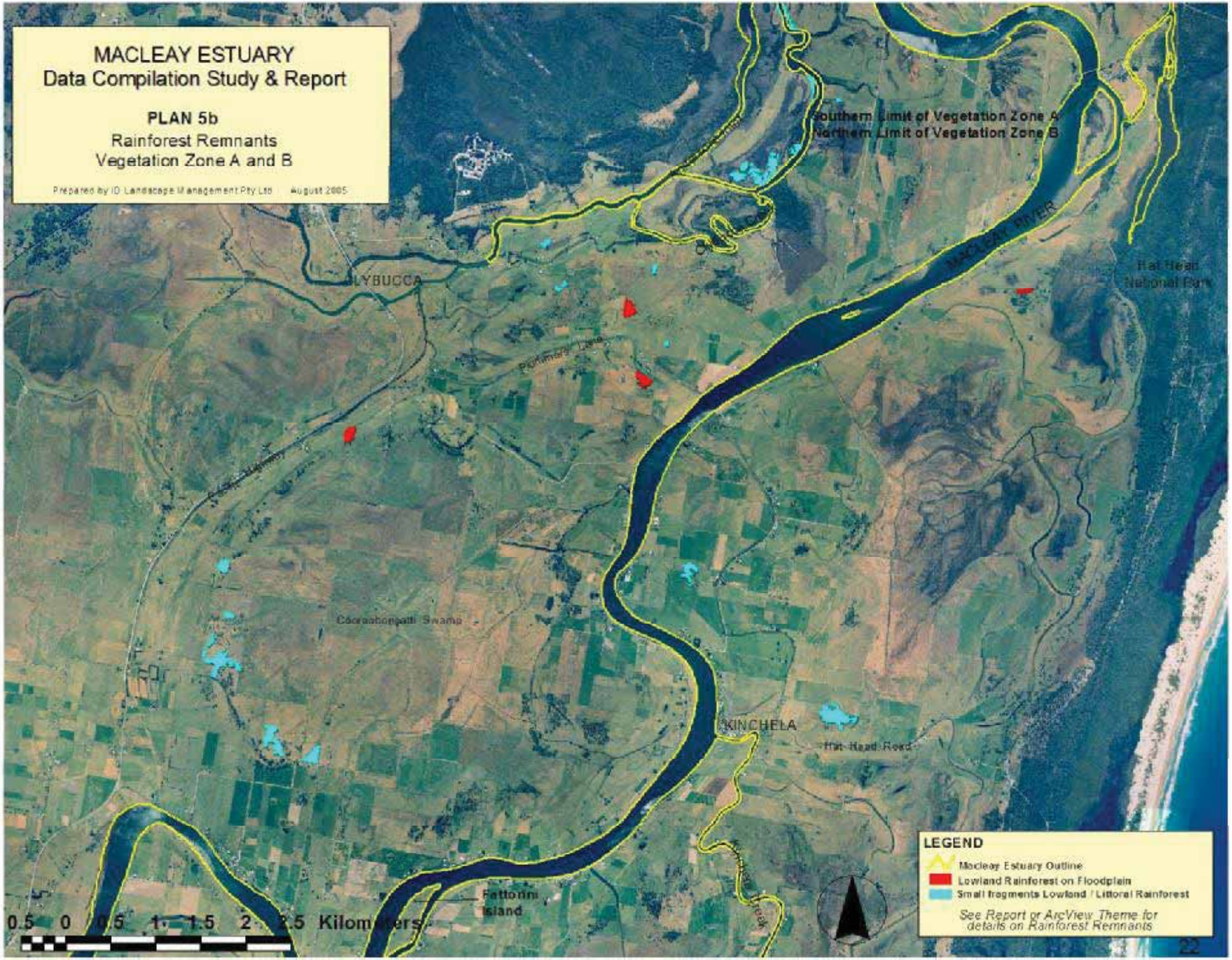
3 **Clybucca Historic Site (NSW NPWS Heritage Site) between Macleay Arm and Yarrahapinni Wetlands – SEPP 26 Site #101B**

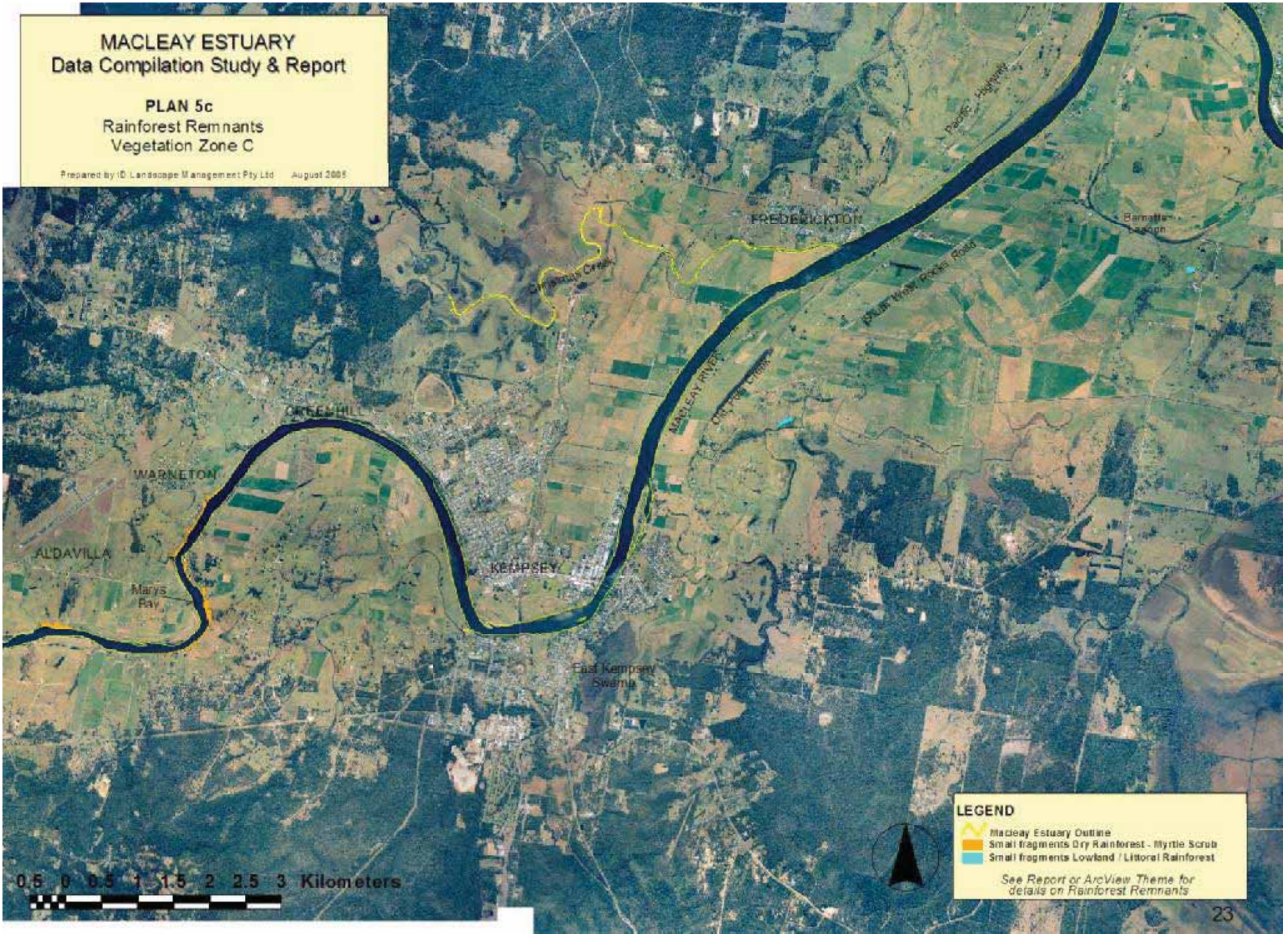
When the SEPP 26 boundaries are overlain on the Ortho-rectified Aerial Photography for the Macleay Estuary there is a discrepancy which needs to be taken into consideration when determining management strategies. Within this Project 'littoral rainforest' vegetation has been identified and mapped on a separate ArcView Theme along with Lowland Floodplain Rainforest and Myrtle Scrub (some small degraded fragments in the upper estuary riparian zone).

26 smaller fragments of littoral / lowland rainforest have also been identified and mapped in this project. See Plan 4. With appropriate management these fragments will hopefully be sustainable and provide an important element of diversity within the identified habitat corridors. These fragments are also important from the perspective of providing *diversity* for seed collection and propagation materials for revegetation programs.

The SEPP 26 Policy applies to mapped areas of littoral rainforest which should be considered as 'core' areas and to a 'buffer area' surrounding the remnants to a distance of 100 metres. The original SEPP 26 mapping was not exhaustive and some areas along the NSW coastline were not included. The listing of 'Littoral Rainforest' as an 'endangered ecological community' means that where there are recognised inadequacies in the SEPP 26 mapping the significant vegetation is protected under the Threatened Species Conservation Act.


MACLEAY ESTUARY
Data Compilation Study & Report
PLAN 5a
Rainforest Remnants
Vegetation Zones A and B
Prepared by ID Landscape Management Pty Ltd August 2005
Includes SEPP 26 Littoral Rainforest 100
Includes SEPP 26 Littoral Rainforest 101
Includes SEPP 26 Littoral Rainforest 101b
Shark Island
Pelican Island
RAINBOW REACH
SOUTH WEST ROCKS
Southern Limit of Vegetation Zone A
Northern Limit of Vegetation Zone B
LEGEND
Macleay Estuary Outline
Littoral Rainforest
Lowland Rainforest on Floodplain
Small fragments Lowland / Littoral Rainforest
See Report or ArcView Theme for details on Rainforest Remnants
0.4 0 0.4 0.8 1.2 1.6 2 Kilometers


MACLEAY ESTUARY
Data Compilation Study & Report
PLAN 5b
Rainforest Remnants
Vegetation Zone A and B
Prepared by ID Landscape Management Pty Ltd August 2005
Southern Limit of Vegetation Zone A
Northern Limit of Vegetation Zone B
LYBUCCA
MACLEAY RIVER
Hat Head National Park
Cooraboongalli Swamp
KINCHELA
Hat Head Road
Fattorini Island
0.5 0 0.5 1 1.5 2 2.5 Kilometers
LEGEND
Macleay Estuary Outline
Lowland Rainforest on Floodplain
Small fragments Lowland / Littoral Rainforest
See Report or ArcView Theme for details on Rainforest Remnants


MACLEAY ESTUARY
Data Compilation Study & Report
PLAN 5c
Rainforest Remnants
Vegetation Zone C
Prepared by ID Landscape Management Pty Ltd August 2005
FREDERICKTON
Pacific Highway
Barnatts Lagoon
Christmas Creek
Old Pacific Highway
MACLEAY RIVER
Old Pac Creek
CREES HILL
WARNETON
ALDAVILLA
Marys Bay
KEMPSEY
East Kempsey Swamp
0.5 0 0.5 1 1.5 2 2.5 3 Kilometers
LEGEND
Macleay Estuary Outline
Small fragments Dry Rainforest - Myrtle Scrub
Small fragments Lowland / Littoral Rainforest
See Report or ArcView Theme for details on Rainforest Remnants

Shark Island Littoral Rainforest

5.1.1 Threatened Species Conservation Act - New Legislation on Littoral Rainforests as 'Endangered Ecological Communities'

In June 2004 'Littoral Rainforest in the NSW North-coast, Sydney Basin and South-east Corner Bioregions' was listed as an 'endangered ecological community', under the Threatened Species Conservation Act.

The definition of this community from NSW NPWS Scientific Committee determinations is:

'Closed Forest strongly influenced by proximity to the ocean. Most stands occur within 2 kilometres of the sea but may occur further inland where there is strong maritime influence.

Littoral rainforest occurs on both sand dunes and soils derived from underlying rocks. Headland stands are severely wind-pruned thickets whilst in more sheltered sites in hind-dune situations the stands are generally taller behind the wind-sheared edge.'

Littoral Rainforest under this Legislation includes the *Cupaniopsis anacardioides – Acmena spp*. Alliance and the *Lophostemon confertus* Sub-alliance of Floyd(1990) which are synonymous with Forest Types *[24] (0502)* Tuckeroo *Cupaniopsis anacardioides* and [25] Headland Brush Box *Lophostemon confertus* which have been mapped in this study.

5.2 Existing State Environmental Planning Policy #14 – Wetlands listings

Under this Policy seven different accepted wetland types - Mangroves, Saltmarshes, Melaleuca Forests, Casuarina Forests, Sedgelands, Brackish and Freshwater Swamps, Wet Meadows - were mapped at a scale of 1:25,000. Appendix 2 defines the Wetland Components defined, and excluded in the Survey.

The consistency of mapping and level of accuracy has been criticised due to the exclusion of a number of groundwater dependent ecosystems such as Wet Heath and Wet Shrubland and low-lying forests such as Swamp Mahogany *Eucalyptus robusta*, Red Mahogany *Eucalyptus resinifera* from the mapping.

On this study site there is a degree of discrepancy between the communities mapped under SEPP 14 and their actual physical extent within the estuary. This was mainly noted with Saltmarsh / Rushland communities which may potentially have changed in extent since SEPP 14 was gazetted.

Discrepancies can also be attributed to the scale of photography being at 1:25,000.

Some of the designated wetlands along the north coast have taken a more liberal approach to the inclusion of a broader range of wetland landform patterns, for example Wetland #484 in Limeburners Creek Nature Reserve #'s 543 and 545 in Crowdy Bay National Park and # 686 in Myall Lakes National Park have included and protected extensive areas of beach ridge – swale (open depression) – swamp (closed depression) and dune – swale – swamp toposequences supporting mosaics of forest, shrubland, heathland and sedgeland.

Whilst there are inconsistencies and inaccuracies with the SEPP 14 mapping within the study area it is not considered relevant to identify all discrepancies as new Legislation gazetted under the TSCA addresses the ecological significance of 'wetland' vegetation and associated fauna habitat which may have been excluded under SEPP 14.

5.3 NSW Fisheries Mapping

An Interim Report mapping aquatic habitat elements:

- Mangrove;
- Saltmarsh,
- Zostera and
- Other

was prepared by NSW Fisheries for 3 rivers including the Macleay.

Ortho-rectified aerial photographs were processed and digital images were examined and overlain with data collected in the field. This work is currently being extended and updated reports and digital layers are expected to be available in 2005.

Gaps in the Information base are:

- What impact do the weed species of submerged aquatic vegetation – Elodea sp. and Egeria sp. have on aquatic habitat?
- How do they react to drought, normal flow, flood and increased nutrient from discharges?
- To what degree do these species displace native submerged vegetation.

NSW Fisheries is undertaking on-going research into these issues.

Recommendation

Undertake investigation into:

- The impact of weed species of submerged aquatic vegetation – Elodea sp. and Egeria sp. - on aquatic habitat.
- The reaction of these weed species and native species of submerged aquatic vegetation to drought, normal flow, flood and increased nutrient from discharges.
- The degree to which these species displace native submerged vegetation.

Another issue which needs to be addressed is the relationship between sea grass areas and freshwater outflow from aquifers.

5.4 Macleay Wetlands Management Plan and Mapping

This Mapping was produced by the North Coast Environment Council Inc in 1999. In this Plan vegetation was mapped initially from 1:25,000 colour aerial photography taken in 1997, using a stereoscope to aid in mapping.

The minimum size of map units used was about 1.5 hectares. The minimum unit size for vegetation maps obtained from the NPWS was about 0.5 hectares.

The Plan indicates that boundaries of the vegetation units mapped and the extent of wetland should not be considered exact for the following reasons:

- Distortion is an inherent feature of air photos from which the vegetation was mapped;
- It is often difficult to define the boundaries between plant formations such as gradational change from sedgeland to grassland which is influenced by seasonal climatic conditions
- It is evident from air photographs that some vegetation formations are intermingled such as saltmarsh and mangrove in estuarine environments
- Some distortion of boundaries would have occurred when maps were scanned into the computer and incorporated into MapInfo.

Twenty-one Vegetation Units were identified in this mapping representing an area of 40,232 hectares.

When reviewing this layer of vegetation mapping as a theme / layer over the Ortho-rectified imagery available for the current project considerable distortion of shape in polygons was detected and some inconsistencies were noted with mapped vegetation communities.

Recommendation

That the overall vegetation mapping be upgraded so as to maximise the capacity and usefulness of the ArcView database for management and development planning scenarios.

Belmore River – 5-leaf Morning Glory (a Category 2 Weed) smothering native trees.

Belmore River – native vegetation cover in pockets of ‘improved pasture land’.

6 CONDITION OF THE VEGETATION AND WEED STATUS

6.1 Methodology

The status of native vegetation cover was recorded for each Area described. The status the Canopy, Understorey and Groundcover was described according to the following definitions and an overall description of the 'Degree of Disturbance' for native vegetation was also attributed for each area.

Table 4: Definitions for Native Vegetation Status

INTACT	*Vegetation showing negligible signs of disturbance, relatively continuous cover with natural regeneration occurring.*
LOW level of DISTURBANCE	*Low levels of disturbance from regimes including grazing, burning flood damage etc. Reduced levels of canopy continuity and regeneration occurring. May have some low levels of weed infestation.*
MODERATE level of DISTURBANCE	*Moderate levels of disturbance from a range of regimes including clearing and grazing. Minimal natural regeneration occurring and / or moderate levels of weed invasion*
HIGH level of DISTURBANCE	*High degree of removal of vegetation structure or degradation of native cover. Weed invasion can be extensive or minimal depending on management practices.*
nil	*No stratum naturally occurring. E.g Saltmarsh communities do not have canopy or understorey*

This information will be useful in determining management strategies and revegetation opportunities.

Recommendation
A strategic approach to prioritising restoration and revegetation works should be developed based on the weed status and degree of disturbance defined in this Project. A **'Conservation and Restoration Plan'** should be developed as a framework with specific goals and actions to guide activities to ensure long term aims are achieved.

The following Table summarises the results of the Native Vegetation Status - 'Degree of Disturbance' classifications.

Table 5: Native Vegetation Status Summary Table

Native Vegetation Status – Degree of Disturbance	Length of Riparian Zone (km)	% of total length of Riparian Zone (347.077 km)
Moderate – High	3.793 km	1.09%
Low – High	5.857 km	1.69%
Moderate	9.043 km	2.61%
Low – Moderate	12.936 km	3.73%
Low	35.075 km	10.11%
Intact	48.095 km	13.86%
High	232.278 km	66.92%

Recommendation
Further Outcomes from this 'degree of disturbance' data would include the selection of sites which have reasonable native canopy condition (e.g Intact, Low, Low-Moderate, Moderate) as high priorities for weed control and regeneration activities

6.2 WEED CATEGORY

Locally recorded environmental weeds have been ranked to aid in collation of information and determination of management priorities. The ranking defines 3 categories reflecting:

- Potential for significant ecological impacts;
- Potential for invasion and encroachment into native plant communities, and
- Degree of difficulty to control.

The ranking system has been adapted from Williams and Gerrand 1998 'Coastline Survey of Asparagaceae and other Environmental Weeds in the Manning Valley' with reference to the North-coast Environmental Weeds Task Force listings for the Worst Weeds on the North Coast collated in 2000.

Area 14 (north of Kempsey) – Heavy Weed infestations

Table 6 : Significant Environmental Weed Categories

Category 1 *Most Serious Environmental Weeds –highly invasive and difficult to control*
Anredera cordifolia Madeira Vine
Cardiospermum grandiflorum Balloon Vine
Chrysanthemoides monilifera subsp. rotundata Bitou Bush
Cinnamonum camphora Camphor Laurel
**Eichhornia crassipes* Water Hyacinth
Juncus acutus Spike Rush
Ligustrum lucidum Broad-leaf Privet
Ligustrum sinense Small-leaf Privet
Macfadyena unguis-cati Cats Claw Creeper
Protasparagus aethiopicus Asparagus Fern
Protasparagus plumosus Climbing Asparagus
Category 2 *Troublesome Environmental Weeds – highly invasive and moderate degree of difficulty in control*
Acacia salignus Golden Wattle
Araujia hortorum Moth Plant
**Baccharis halimifolia* Groundsel Bush
Delairea odorata Cape Ivy
Erythrina X sykesii Coral tree
Ipomea indica Blue Morning Glory
Ipomoea cairica 5-leaf Morning Glory
Lantana camara Pink Lantana
Lantana camara Red Lantana
Lonicera japonica Honeysuckle
Morus sp. Mulberry tree
Passiflora subpeltata White Passion Flower
Ricinus communis Castor Oil Plant
Senna sp. Cassia
Solanum seaforthianum Brazilian Nightshade
Category 3 *Problematic Environmental Weeds - invasive and moderate degree of difficulty in control*
**Ageratina adenophora* Crofton Weed
Albizzia sp Albizzia
Bambusa sp. Bamboo
Banana
Bryophyllum delagoense Mother-of-millions
Cestrum parqui Green Cestrum
Cyperus involucratus Umbrella Sedge
Gleditsea sp. Gleditsea
Jacaranda mimosifolia Jacaranda
Nephrolepis cordifolia Fishbone Fern
Ochna serrulata Ochna
Opuntia sp. Prickly Pear
Populus sp. Poplar
Rubus fruticosus Blackberry
Salix sp. Willow
Schefflera actinophylla Umbrella Tree
Solanum mauritianum Wild tobacco

**also listed as Noxious Weeds*

6.3 WEED STATUS

Definition
Weed status information has only been listed for species recognised as Category 1, 2 or 3 Significant Environmental Weeds (as listed in previous Table).

The following Table defines the abundance codes used.

Table 7: Weed Abundance Codes

Code	Abundance Code	DEFINITION
Not applicable	**N/A**	No category 1, 2 or 3 weed species noted during field survey.
Rare	**R**	Single or very few isolated plants, or single isolated small clump
Rare – Occasional	**R – O**	
Occasional	**O**	Infrequent , but dispersed plants and small clumps
Occasional - Common	**O - C**	
Common	**C**	Plants and small clumps readily located, sometimes uniformly distributed other times clustered. Occasional large clumps
Common – Heavy	**C - H**	
Heavy	**H**	Continuous infestations or extensive large clumps or combinations of numerous propagules and established plants

Abundance codes have been assigned to individual weed species within the identified Vegetation Area Descriptions. An overall Abundance Score for Weeds in general has been assigned to each AREA defined and listed (See the ATTRIBUTES Table in ArcView and Appendix 1). This overall weed abundance score has been determined by considering all the significant weeds present, their Category (i.e. Category 1, 2, or 3) and their relative abundances.

Recommendation

This system should be utilised to aid in determining Management Priorities as sites will be able to be selected on the basis of level of weed infestation and status of native vegetation cover.

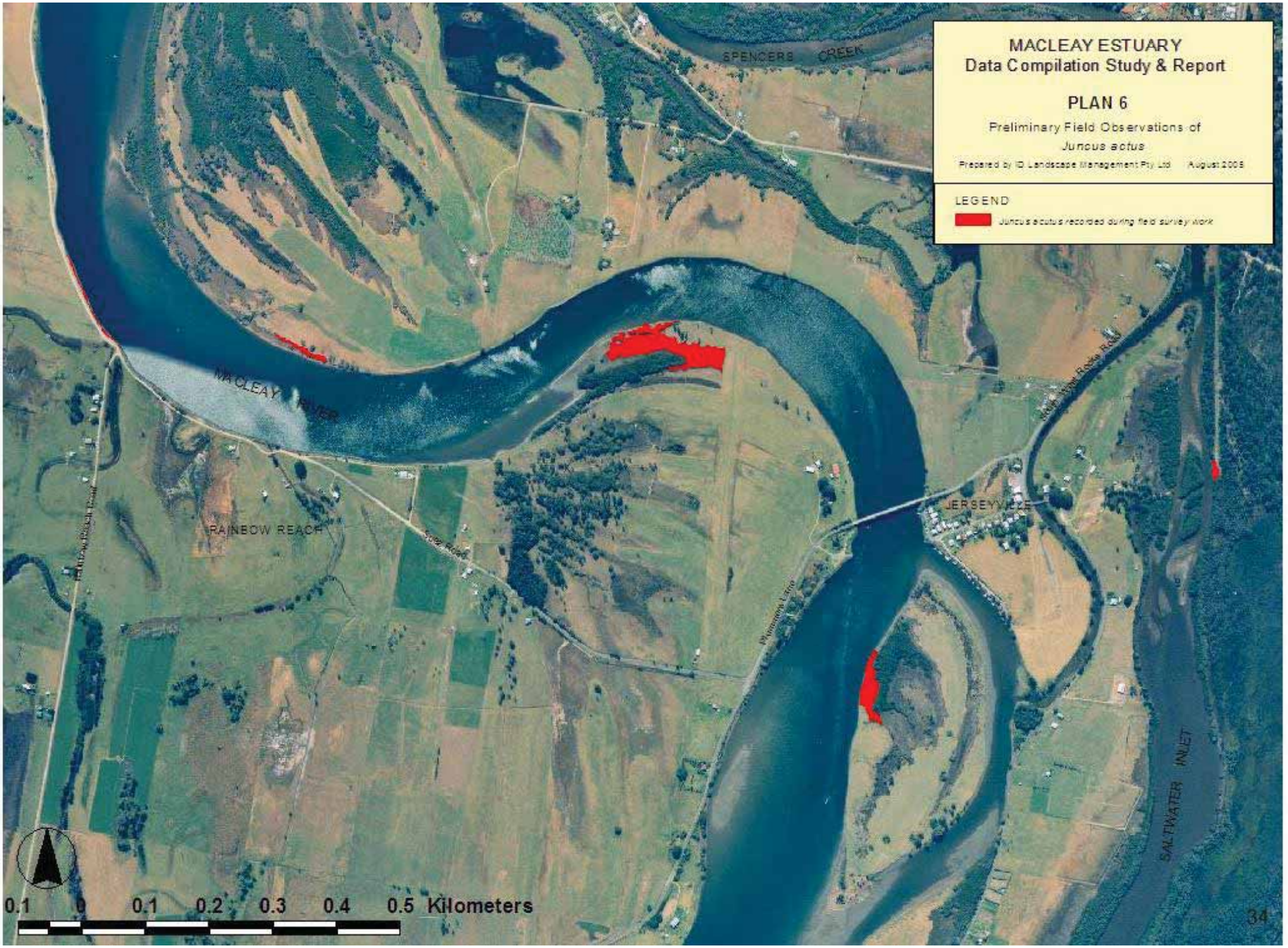

MACLEAY ESTUARY
Data Compilation Study & Report
PLAN 6
Preliminary Field Observations of
Juncus acutus
Prepared by ID Landscape Management Pty Ltd August 2008
LEGEND
Juncus acutus recorded during field survey work
SPENCERS CREEK
MACLEAY RIVER
RAINBOW REACH
JERSEYVILLE
SALTWATER INLET
0.1 0 0.1 0.2 0.3 0.4 0.5 Kilometers

Table 8: Summary of Riparian Weed Categories and Abundance Levels for the Estuary

Weed Category	Length of bank with this category of weeds (km) as the highest category listed	Abundance level
1 *Most Serious Environmental Weeds –highly invasive and difficult to control*	2.133 km	Rare
	63.17 km	Rare – Occasional
	24.767 km	Occasional
	21.222 km	Occasional – Common
	41.007 km	Common
	129.851 km	Common – Heavy
	0.333 km	Heavy
TOTAL	**282.483 km**	
% of Total Riparian length	**81.4%**	
2 *Troublesome Environmental Weeds – highly invasive and moderate degree of difficulty in control*	Nil	Rare
	3.206	Rare – Occasional
	10.186	Occasional
	Nil	Occasional – Common
	10.583	Common
	Nil	Common – Heavy
	Nil	Heavy
TOTAL	**24.055 km**	
% of Total Riparian length	**6.9%**	
3 *Problematic Environmental Weeds -* *invasive and moderate degree of difficulty in control*	NIL	Rare
		Rare – Occasional
		Occasional
		Occasional – Common
		Common
		Common – Heavy
		Heavy
TOTAL	**NIL**	
0 *No significant weeds species (i.e. Category 1, 2 or 3 as described)*	**40.539 km**	N/A
% of Total Riparian length	**11.7%**	

Gaps in the Data base

Spike Rush *Juncus acutus*, an introduced rush, has been identified in the Rainbow Reach locality, downstream of Jerseyville. See Plan 5 for preliminary mapping results.

In terms of community structure and function this species is considered as the most serious threat to 'coastal saltmarsh' communities. In the current study we have identified where its occurrence is noted during field assessment however a more detailed appraisal of the extent of the infestation, which at this point in time seems localised, should be made.

Recommendations

A clear indication of the extent of this species needs to be defined and a control program put in place.

Work should not only focus on mapping the current extent of Spike Rush *Juncus acutus* but also in establishing control works. Control works should be aimed at:

- limiting the spread of the species beyond current by identifying isolated populations and targeting them and
- reducing the extent of the main population areas.

This is seen as an *urgent priority* which should be addressed now and not wait until the preparation of the overall Estuary Management Plan.

This study could be undertaken by a Research Student associated with the New England or Newcastle Universities where some work has already been done in association with this species and impacts on the Hunter wetlands.

Alternatively, and possibly preferably, by a Consultant who can manage the determination of extent of infestation in a relatively short time frame and then instigate control works in association with Kemspey Shire Council, DIPNR, NSW Fisheries and landowners.

Spike Rush – *Juncus acutus* on Rainbow Reach.

7a SIGNIFICANT FLORA

7a.1 Significant Flora Species *Known* and *Potentially* occurring in the Macleay Estuary

Appendix 4 lists species listed as endangered or vulnerable under the State Governments Threatened Species Conservation Act (TSCAct) and the Commonwealths Environment Protection and Biodiversity Conservation Act (EPBCAct) and regionally significant species (e.g. those at or near their geographical limits in the locality).

Table 9: Significant Flora Species Summary

Number of Significant Flora Species *Known* to occur in the Study Area		
Status	**TSCAct**	**EPBCAct**
Endangered	4	3
Vulnerable	5	3

Approaching Geographical Limit	7

Number of Significant Flora Species *Potentially* occurring within the Study Area		
Endangered	1	0
Vulnerable	3	3

These lists have been derived from a compilation of information from existing documents, the NSW NPWS Database and local knowledge.

The following Tables show the threatened flora species known and considered to have potential to occur in the Macleay Estuary and the vegetation communities in which they occur or are considered likely to occur:

Table 10: Significant Flora Species (Known) listed under Vegetation Communities

Vegetation Community (as mapped)	**Areas noted in mapping** (See Appendix 1 or Arview Theme for details)	**Significant Flora species KNOWN to occur in Macleay estuary area**
Littoral Rainforest		**Endangered (3 species)** Marsdenia *Marsdenia longiloba* (TSCA & EPBCA) Scented Acronychia *Acronychia littoralis* (TSCA & EPBCA) White-flowered Wax Plant *Cynanchum elegans* (TSCA & EPBCA) **Vulnerable (2 species)** Asperula *Asperula asthenes* (TSCA / EPBCA) **Southern Geographical Limit (6 species)** Riberry *Syzygium leuhmanni* Three-veined Laurel *Cryptocarya triplinervis* Green Tree *Acronychia imperforata* Bumpy Ash *Flindersia schottiana* Malletwood *Rhodamnia argentea* Smooth Clerodendron *Clerodendron floribundum*
Lowland Rainforest		**Endangered (3 species)** Marsdenia *Marsdenia longiloba* (TSCA & EPBCA) Scented Acronychia *Acronychia littoralis* (TSCA & EPBCA) White-flowered Wax Plant *Cynanchum elegans* (TSCA & EPBCA) **Vulnerable (1 species)** Asperula *Asperula asthenes* (TSCA & EPBCA) Raspwort *Haloragis exaltata subsp. velutina* (TSCA & EPBCA) **Southern Geographical Limit (4 species)** Green Tree *Acronychia imperforata* Bumpy Ash *Flindersia schottiana* Malletwood *Rhodamnia argentea* Smooth Clerodendron *Clerodendron floribundum*

Vegetation Community (as mapped)	**Areas noted in mapping** (See Appendix 1 or Arview Theme for details)	**Significant Flora species KNOWN to occur in Macleay estuary area**
Mangroves		**Protected under NSW Fisheries Legislation (3 species)** River Mangrove *Aegiceras corniculatum* Grey Mangrove *Avicenna marina* Milky Mangrove *Exocecaria agallocha* **Southern Geographical Limit – approaching (1 species)** Milky Mangrove *Exocecaria agallocha*
Swamplands	Not within the immediate riparian zones mapped within this study	**Vulnerable (1 species)** *Maundia triglochinoides* (TSCA)
Heath	Not within the immediate riparian zones mapped within this study	**Endangered (1 species)** *Thesium australe* Austral Toadflax (TSCA & EPBCA)
Riparian Vegetation		**Southern Geographical Limit (1 species)** Paperbark *Melaleuca bracteata*

Table 11: Significant Flora Species (Potential) listed under Vegetation Communities

Vegetation Community (as mapped)	**Areas noted in mapping** (See Appendix 1 or Arview Theme for details)	**Significant Flora species POTENTIALLY occurring in Macleay estuary area**
Coastal Scrubland / Dunes /		**Endangered (1 species)** *Chamaesyce psammogeton* (TSCA)
Heath	Not within the immediate riparian zones mapped within this study	**Vulnerable (2 species)** *Melaleuca groveana* (TSCA) Leafless Tongue-Orchid *Cryptostylis hunteriana* (TSCA & EPBCA)
Wetlands		**Vulnerable (1 species)** Frog-bit *Hydrocharis dubia* (TSCA & EPBCA)
Subtropical / Littoral Rainforest		**Vulnerable (2 species)** Milky Silkpod *Parsonia dorrigoensis* (TSCA & EPBCA) Rusty Plum *Amophorspermum whitei* (TSCA)

Gap: Identification of all listed 'endangered ecological communities' within the Macleay estuary and floodplain.

For example, Subtropical Coastal Floodplain Forest on the NSW North Coast bioregion potentially occurs along the Clybucca Creek in a number of places beyond the immediate riparian fringe. This needs further investigation and mapping.

Saltmarsh areas are included within the scope of the NSW Fisheries mapping which is currently under review.

Recommendation:
Establish a mapping program which builds on the current information and which targets clear identification of all listed 'endangered ecological communities' under the TSCA within the Macleay estuary and floodplain.

7a.2 Threatened Species Conservation Act - New Legislation on Wetland Communities as 'Endangered Ecological Communities'

Eight 'endangered ecological communities' relative to the Macleay estuary are currently listed in Part 3 of Schedule 1 of the TSCA. They are listed in the Table below and have been discussed in the preceding sections on SEPP #26 Littoral Rainforest and SEPP #14 and Wetland communities.

Table 12: 'Endangered Ecological Communities' relative to the Macleay Estuary

ENDANGERED ECOLOGICAL COMMUNITY *listed under the Threatened Species Conservation Act*	**HABITAT DESCRIPTION**
Littoral Rainforest in the NSW North-coast, Sydney Basin and South-east Corner bioregions	Closed canopy forest on sand dunes and on soils derived from underlying rocks. Stands on headlands exposed to strong wind action may take the form of dense wind-pruned thickets.
Lowland Rainforest on Floodplain in the NSW North Coast bio-region	Closed canopy forest on floodplains characterised by high species richness and structural complexity. Rainforest sub-alliances described by Floyd (1990) are included.
Coastal Saltmarsh in the NSW North-coast, Sydney Basin and South-east Corner bioregions	Intertidal zones on the shores of estuaries and lagoons including when areas are intermittently closed along the NSW coast.
Freshwater Wetlands on Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions	Periodic or semi-permanent inundation by freshwater, although there may be minor saline influence in some wetlands. Typically occur on silts, muds or humic loams in depressions, flats, drainage lines, backswamps, lagoons and lakes associated with coastal floodplains. Generally occurs below 20m elevation.
Swamp Sclerophyll Forest on Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions	Ecological community associated with humic clay loams and sandy loams, on waterlogged or periodically inundated alluvial flats and drainage lines associated with coastal floodplains. Generally occurs below 20m elevation (although sometimes up to 50m).
Subtropical Coastal Floodplain Forest on the NSW North Coast bioregion	Ecological community associated with clay-loams and sandy loams, on periodically inundated alluvial flats, drainage lines and river terraces associated with coastal floodplains. Generally occurs below 50m elevation, but may occur on localised river flats up to 250m. This community has a tall tree layer of Eucalypts.
Swamp Oak Floodplain Forest of the NSW North Coast, Sydney Basin and South East Corner bioregions.	Grey-black clay-loams and sandy loams, where the groundwater is saline or sub-saline, on waterlogged or periodically inundated flats, drainage lines, lake margins and estuarine fringes associated with coastal floodplains. Generally occurs below 20m (rarely above 10m) elevation.
River-Flat Eucalypt Forest on Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions.	Associated with silts, clay-loams and sandy loams, on periodically inundated alluvial flats, drainage lines and river terraces associated with coastal floodplains. Generally occurs below 50m elevation, but may occur of river flats up to 250m.

The following Table lists specific areas, identified within the scope of this Project, which are considered to contain 'endangered ecological communities'. This Table is limited by the scope of this study but provides important base data.

Table 13: Preliminary list of 'Endangered Ecological Communities' identified in the Macleay

Endangered Ecological Community	**Identified areas** *(polygons on rainforest Theme in ArcView)*	**Area within (ha)**
Littoral Rainforest in the NSW North-coast, Sydney Basin and South-east Corner bioregions	*24a*	32.064
	24b	0.226
	24c	0.667
	24d	0.485
	10a	1.082
	10b	0.320
	10c 0.228	*0.228*
	25	6.607
	26	20.914
	Total	**62.566 ha**
Coastal Saltmarsh in the NSW North-coast, Sydney Basin and South-east Corner bioregions		*Length of bank km NB This is deceptive as it only represents what Saltmarsh interfaces with the rivers / creeks it is not the area of Saltmarsh*
	(6102) Samphire – Sand Couch	*4.124 km*
	(6502) Maritime Rush and Sand Couch	*7.198 km*
	Total	**11.322 km**
Lowland Rainforest on Floodplain in the NSW North Coast bio-region	***Identified areas*** *(polygons on rainforest Theme in ArcView)*	*Area within ha*
	1	*1.918 ha*
	2	*1.657 ha*
	3	*0.858 ha*
	4	*1.617 ha*
	Total	**6.05 ha**
Swamp Oak Floodplain Forest of the NSW North North Coast, Sydney Basin and South-east Corner Bioregion		*Length of bank km NB This is deceptive as it only represents what Saltmarsh interfaces with the rivers / creeks it is not the area of Saltmarsh*
	77 and 100	**1.18 km**

7b SIGNIFICANT FAUNA

7b.1 Threatened Fauna Species *Known* and *Potentially* occurring in the Macleay Estuary

Appendix 4 lists species listed as threatened under the State Governments Threatened Species Conservation Act (TSCAct), the Commonwealths Environment Protection and Biodiversity Conservation Act (EPBCAct) which includes species listed under the Japan / Australia Migratory Birds Agreement (JAMBA) and China / Australia Migratory Birds Agreement (CAMBA) and regionally significant species (e.g. those at or near their geographical limits in the locality).

Table 14: Significant Fauna Species Summary

Number of Threatened Fauna Species *Known* to occur in the Study Area		
Status	**TSCAct**	**EPBCAct**
Endangered	7	5
Vulnerable	39	2

Number of Threatened Fauna Species *Potentially* occurring within the Study Area		
Status	**TSCAct**	**EPBCAct**
Endangered	8	2
Vulnerable	13	1

Number of Migratory Species *Potentially* occurring within the Study Area			
	EPBCAct	**JAMBA**	**CAMBA**
Birds	71	45	41
Mammals	6	-	-
Reptiles	3	-	-
Sharks	2	-	-

These lists have been derived from a compilation of information from existing documents, the NSW NPWS Database and local knowledge.

The following Tables show the threatened fauna species KNOWN to occur in the Macleay Estuary and the vegetation communities in which they occur or are considered likely to occur :

Table 15: Significant Fauna Species (Known) listed under Vegetation Communities

Vegetation Community (as mapped)	**Areas noted in mapping** (See Appendix 1 or ArcView Theme for details)	**Significant Fauna species KNOWN to occur in Macleay estuary area**
Littoral Rainforest		**Vulnerable** Queensland Blossom Bat *Syconycteris australis* (TSCA) Osprey *Pandion haliaetus* (TSCA) Barred Cuckoo-shrike *Coracina lineata* (TSCA) Marbled Frogmouth *Podargus ocellatus* (TSCA) Wompoo Fruit Dove *Ptilinopus magnificus* (TSCA) Rose-crowned Fruit Dove *Ptilinopus regina* (TSCA) Powerful Owl *Ninox strenua* (TSCA) Sooty Owl *Tyto tenebrisco* (TSCA) Hoary Wattled Bat *Chalinolobus nigrogriseus* (TSCA) Little Bentwing-bat *Miniopterus australis* (TSCA) Eastern Freetail-bat *Mormopterus norfolkensis* (TSCA) Grey-headed Flying-fox *Pteropus poliocephalus* (TSCA & EPBCA) Yellow-bellied Sheathtail-bat *Saccolaimus flaviventris* (TSCA) Greater Broad-nosed Bat *Scoteanax rueppellii* (TSCA) Stephens' Banded Snake *Hoplocephalus stephensi* (TSCA)
Floodplain Riparian Forest Woodland		**Endangered** Swift Parrot *Lathamus discolour* (TSCA & EPBCA) **Vulnerable** Queensland Blossom Bat *Syconycteris australis* (TSCA) Square-tailed Kite *Lophoictinia isura* (TSCA) Osprey *Pandion haliaetus* (TSCA) Glossy Black-Cockatoo Calyptorhynchus lathami (TSCA) Barred Cuckoo-shrike *Coracina lineata* (TSCA) Marbled Frogmouth *Podargus ocellatus* (TSCA) Barred Cuckoo-shrike *Coracina lineata* (TSCA) Wompoo Fruit Dove *Ptilinopus magnificus* (TSCA) Rose-crowned Fruit Dove *Ptilinopus regina* (TSCA) Powerful Owl *Ninox strenua* (TSCA) Sooty Owl *Tyto tenebrisco* (TSCA) Hoary Wattled Bat *Chalinolobus nigrogriseus* (TSCA) Little Bentwing-bat *Miniopterus australis* (TSCA) Eastern Freetail-bat *Mormopterus norfolkensis* (TSCA) Grey-headed Flying-fox *Pteropus poliocephalus* (TSCA & EPBCA) Yellow-bellied Sheathtail-bat *Saccolaimus flaviventris* (TSCA) Greater Broad-nosed Bat *Scoteanax rueppellii* (TSCA) Stephens' Banded Snake *Hoplocephalus stephensi* (TSCA)
Lowland Rainforest		**Vulnerable** Queensland Blossom Bat *Syconycteris australis* (TSCA) Osprey *Pandion haliaetus* (TSCA) Marbled Frogmouth *Podargus ocellatus* (TSCA) Barred Cuckoo-shrike *Coracina lineata* (TSCA) Wompoo Fruit Dove *Ptilinopus magnificus* (TSCA) Rose-crowned Fruit Dove *Ptilinopus regina* (TSCA) Powerful Owl *Ninox strenua* (TSCA) Sooty Owl *Tyto tenebrisco* (TSCA) Hoary Wattled Bat *Chalinolobus nigrogriseus* (TSCA) Little Bentwing-bat *Miniopterus australis* (TSCA) Eastern Freetail-bat *Mormopterus norfolkensis* (TSCA) Grey-headed Flying-fox *Pteropus poliocephalus* (TSCA & EPBCA) Yellow-bellied Sheathtail-bat *Saccolaimus flaviventris* (TSCA) Greater Broad-nosed Bat *Scoteanax rueppellii* (TSCA) Stephens' Banded Snake *Hoplocephalus stephensi* (TSCA)

Vegetation Community (as mapped)	**Areas noted in mapping** (See Appendix 1 or ArcView Theme for details)	**Significant Fauna species KNOWN to occur in Macleay estuary area**
Dry Rainforest - Myrtle Scrub		**Vulnerable** Wompoo Fruit Dove *Ptilinopus magnificus* (TSCA) Rose-crowned Fruit Dove *Ptilinopus regina* (TSCA) Little Bentwing-bat *Miniopterus australis* (TSCA) Eastern Freetail-bat *Mormopterus norfolkensis* (TSCA) Grey-headed Flying-fox *Pteropus poliocephalus* (TSCA & EPBCA) Yellow-bellied Sheathtail-bat *Saccolaimus flaviventris* (TSCA) Greater Broad-nosed Bat *Scoteanax rueppellii* (TSCA)
Saltmarsh / wetlands / mudflats		**Endangered** Jabiru *Ephippiorhynchus asiaticus* (TSCA & EPBCA) Painted Snipe *Rostratula benghalensis* (TSCA) **Vulnerable** Magpie Goose *Anseranus semipalmate* (TSCA) Sooty Oystercathcer *Haematopus fuliginosus* (TSCA) Pied Oystercathcer *Haematopus longirostris* (TSCA) Comb-crested Jacana *Irediparra gallinacea* (TSCA)
Mangroves		**Vulnerable** Sooty Oystercatcher *Haematopus fuliginosus* (TSCA) Pied Oystercatcher *Haematopus longirostris* (TSCA) Black Bittern *Ixobrychus flavicollis* (TSCA) Osprey *Pandion haliaetus* (TSCA) Grey-headed Flying-fox *Pteropus poliocephalus* (TSCA & EPBCA) Yellow-bellied Sheathtail-bat *Saccolaimus flaviventris* (TSCA)
Open Forest / Sandhill Blackbutt		**Endangered** Swift Parrot *Lathamus discolour* (TSCA & EPBCA) Regent Honeyeater *Xanthomyza phrygia* (TSCA & EPBCA) **Vulnerable** Barred Cuckoo-shrike *Coracina lineata* (TSCA) Square-tailed Kite *Lophoictinia isura* (TSCA) Glossy Black-Cockatoo Calyptorhynchus lathami (TSCA) Squirrel Glider *Petaurus norfolcensis* (TSCA) Brush-tailed Phascogale *Phascogale tapoatafa* (TSCA) Koala *Phascolarctos cinereus* (TSCA) Eastern Chestnut Mouse *Pseudomys gracilicaudatus* (TSCA) Grey-headed Flying-fox *Pteropus poliocephalus* (TSCA & EPBCA) Yellow-bellied Sheathtail-bat *Saccolaimus flaviventris* (TSCA) Greater Broad-nosed Bat *Scoteanax rueppellii* (TSCA) Stephens' Banded Snake *Hoplocephalus stephensi* (TSCA)

7c HABITAT CORRIDORS

There is a need to preserve and consolidate a diverse mosaic of vegetation types for the conservation of flora and dependent fauna species. Many species utilize a variety of vegetation communities habitat types for different parts of their lifecycles e.g. Blossom bats, Fruit doves, migratory waders.

Another important factor is 'altitudinal migration' for fruit and nectar dependent species – species of rainforest plants flower and fruit earlier at lower elevations than higher due to warmer conditions that prevail at low elevations or near the coast.

Hat Head National Park, Arakoon SRA, Fishermans Bend Nature Reserve and Yarriabini National Park and lands with remnant vegetation in between form a coastal corridor.

These areas are recognized within the NSW NPWS 'Key Habitats and Corridors' mapping in NE NSW as Key Habitat Areas and Regional Corridors. The identified Regional Corridor under this NPWS Project has been identified as the Fishermans Bend Nature Reserve Regional Corridor which links from Hat Head NP and Arakoon SRA through Yarrahappini Wetlands, Tamban State Forest to Fishermans Bend NR and Mt Yarrahappini and Yarriabini National Park and then westwards to Ngambaa NR. This corridor has a good deal of continuity of native vegetation cover and where gaps occur they are not large distances.

See Plan 6 on the following page.

The Macleay River 'riparian corridor' is highly degraded due to the extent of clearing and the paucity of remnant pockets along the riparian margin or in pockets across the floodplain. Weed infestations are extensive. Nevertheless the riparian margin does act as a conduit for a variety of mobile species.

Recommendations

It is recommended that a two pronged approach be adopted:

- **The NPWS 'Key Habitats & Corridors' regional corridor, as identified above, be a priority for habitat protection and rehabilitation activities.** Lands within and adjoining the mapped areas should be targeted to maximize habitat opportunity. This corridor contains a diverse mosaic of vegetation types for the conservation of flora and dependent fauna species.
This should be considered as a high priority and integrated into landuse planning and development control processes and recognized as a priority to attract funding assistance for rehabilitation and extension works.

- **Floodplain and Riparian forest remnants should be targeted as part of a long-term 'Macleay Riparian Corridor Restoration Program'**. Actions such as:
  - undertaking **priority weed control** to promote natural regeneration and sustainability of the remnants;
  - **development of a seed bank and propagation program** to maintain genetic integrity and expand diversity of species for fauna foraging and extension of habitat area.

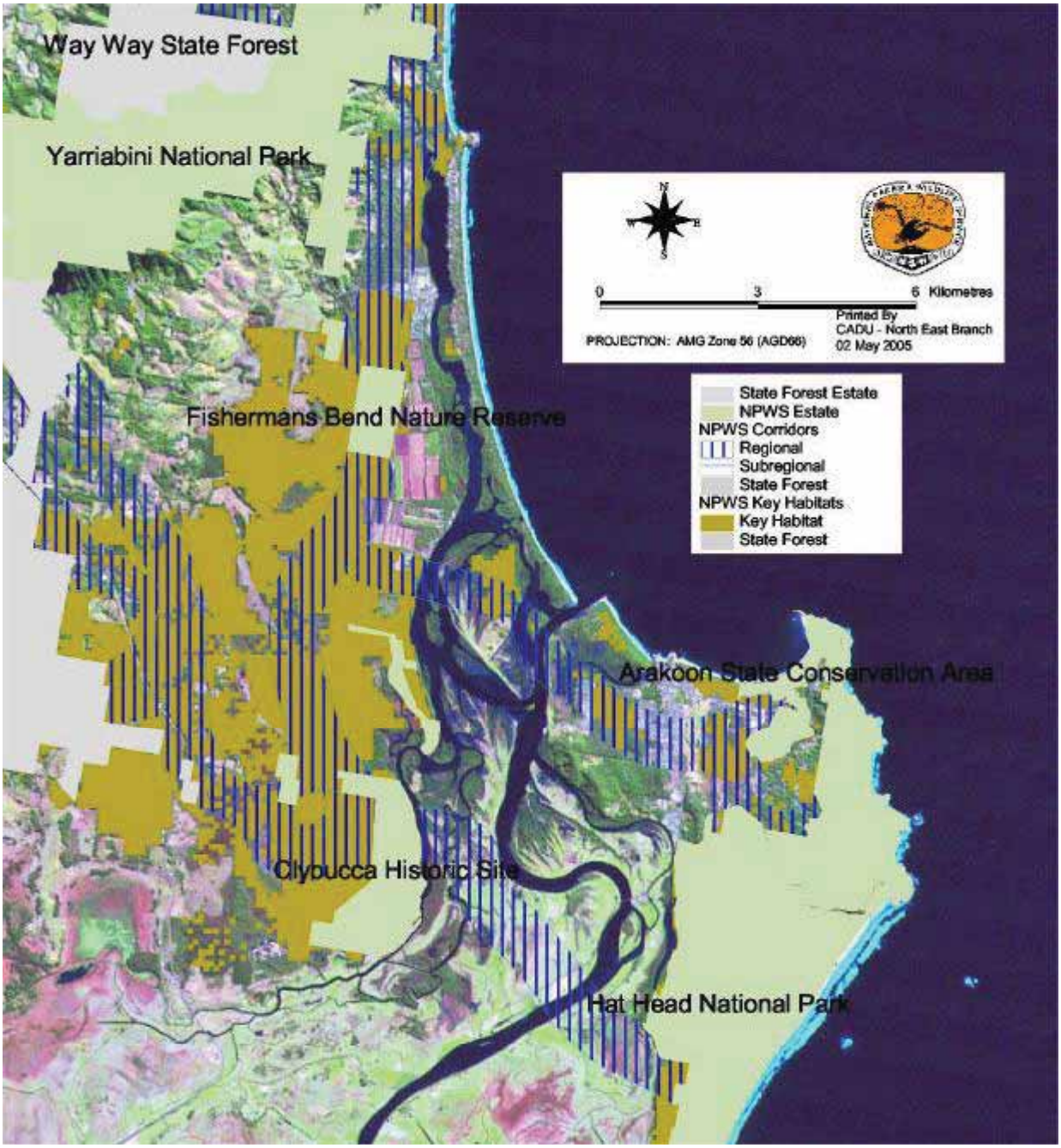
  - **establishment of revegetation areas in priority locations** and extension of works and areas over realistic period of time should be initiated as soon as possible as this is a long term strategic project. The 'Landcare' movement and Community Support Officers could play a vital role in this priority as ~90% of floodplain and riparian rainforest (subtropical) of the Macleay is within private land. However, a

definitive 'Conservation and Restoration Plan' as a framework with specific goals and actions should be established early-on to guide activities to ensure long term aims are achieved.

This 'Conservation and Restoration Plan' would need to integrate resources from the community, NSW NPWS, DIPNR and the local aboriginal community.

Rehabilitation projects should also integrate Australian Bass habitat features identified in the NSW Fisheries documentation.

Plan 7 : Key Habitats and Corridors



Provided by Department of Environment and Conservation

8 Identification of Threats – Vulnerability Classes

The identification of threats, both current and potential, to the long-term sustainability of the identified flora and fauna habitat, is included for each mapped vegetation area.

The relative vulnerability of each site to these threats has been identified and grouped into 3 classes - High / Medium / Low.

Table 16: Definitions of Vulnerability Classes

Vulnerability Class	Definition
HIGH	High Conservation Value habitats of Low disturbance levels under threat from increasing or changing disturbance regimes E.g. Encroaching urban development, weed infestations, increasing bank erosion.
MEDIUM	Existing Agricultural / horticultural practices Existing Urban situations Native vegetation with no change in disturbance regimes anticipated.
LOW	Highly Disturbed lands with no change in the disturbance regime anticipated.

Table 17: Summary of Vulnerability Classes and length of riparian zone

Vulnerability Class	Length of Riparian Zone within each class	% of total length of riparian zone mapped
HIGH	**33.484 km**	**9.65%**
MEDIUM	**184.588 km**	**53.19%**
LOW	**129.004 km**	**37.18%**

6 Active Vegetation Management / Revegetation Projects in the riparian zone of the Macleay Estuary

Table 18: Active Riparian Zone Conservation Projects in the Macleay Estuary

Upstream from Kempsey

Project	Locality or Waypoints where available	Works Description	Funding Source *Contact Person*
(#16)	E - 0481766 N - 6563197	Demonstration of 3 types of management	Older works ? NHT NLP landholder
Bass Kempsey - Voluntary Streamcare Grants Scheme *(#12/17)*	Riverbank opposite Mary Bay – Warneton Aldavilla	Bank battering, fencing, revegetation and weed control.	Bass Kempsey / Catchment Management Authority *Macleay Landcare Network Inc. Community Support Officer 02 65622076*
Voluntary Streamcare Grants Scheme *(#1)*	E - 0478799 N - 6560500	Revegetation and riverbank fencing, floodplain scour stabilisation	Catchment Management Authority *Macleay Landcare*
Voluntary Streamcare Grants Scheme *(#3)*	E - 0475549 N - 6560300	Riverbank fencing 700m, revegetation 900 plants	Catchment Management Authority *Macleay Landcare*
Voluntary Streamcare Grants Scheme *(#6)*	E - 0480999 N - 6563550	Shade trees and 1 off-stream watering point	Catchment Management Authority *Macleay Landcare*
Voluntary Streamcare Grants Scheme *(#7)*	E - 0480700 N - 6563600	Weed control and revegetation on riverbank 145 plants	Catchment Management Authority *Macleay Landcare*
Voluntary Streamcare Grants Scheme	E - 0479200 N - 6561500		Catchment Management Authority *Macleay Landcare*

Comparison of bank treatment in older Works upstream of Kempsey – showing fenced and revegetated (left), fenced with weed growth, no fencing.
(ArcView Site #16)

Bass Kempsey – Bank battering, revegetation works adjacent Mary Bay *(ArcView Project # 12 / 17)*

Downstream from Kempsey to Jerseyville

Project *(Arc View Project #)*	**Locality or Waypoints where available**	**Works Description**	**Year Undertaken Funding Source** ***Contact Person***
Polo Creek Bank Restoration – Kempsey Council *(#18)*	Polo Creek Bank	Active Floodgate management and vegetation rehabilitation	Kempsey Council 2005 Landholders and NSW Fisheries *Tim Morris , Ron Kemsley Kempsey Council*
Voluntary Streamcare Grants Scheme *(#14)*	E - 0497499 N - 6570100	Rock embayments to quell wave wash and revegetation using 220 plants	Catchment Management Authority *Macleay Landcare*
Private Landowner - Steve Green *(#19)*	Fattorini Island	Trialling different methods of wave barriers to protect banks from wave wash.	On-going Steve Green (landholder) *John Schmidt DIPNR*
Voluntary Streamcare Grants Scheme *(#9)*	E - 0500500 N - 6570300	Fencing of wetland and revegetation	Catchment Management Authority *Macleay Landcare*
Macleay Landcare Network *(#20)*	E - 0502800 N - 65 78700 South West Rocks Rd near Jerseyville Bridge	Slashing, spot-spraying weeds and planting 1600 lowland rainforest species Work Area - 2400m^2	2005 Envirofund $6,000 *Macleay Landcare Network Inc. Community Support Officer 02 65622076*
Voluntary Streamcare Grants Scheme *(#10)*	E - 0500500 N - 6576000	Rock wave barriers to quell wave wash and to allow establishment of mangroves to help control erosion – 110m	Catchment Management Authority *Macleay Landcare*
South West Rocks Rotary Club *(#23)*	E - 0503500 N - 6577800 Rotary Park and Road Reserve - Jerseyville	Weed Control, mulching and planting 10,000 trees	2005 Envirofund $3000 Nestles $40,000 over 3 years *Macleay Landcare Network Inc. Community Support Officer 02 65622076*
Voluntary Streamcare Grants Scheme *(#8)*	E – 0503350 N - 6576150	700m of fencing along river bank	Catchment Management Authority *Macleay Landcare*

Voluntary Streamcare Grants Scheme Project on the Macleay River. Rock wave barriers, planting and fencing. (E – 0497278, N – 6569866) (ArcView Project # 10 and 14)

Voluntary Streamcare Grants Scheme Project. Brush groyne erosion control works along the bank of Clybucca Creek. (E – 0500000 N – 6578100)

Rainbow Reach - Macleay Arm – Clybucca Creek

Project	Locality or Waypoints where available	Works Description	Year Undertaken Funding Source *Contact Person*
Voluntary Streamcare Grants Scheme *(#5)*	E – 0501350 N – 6579499 Pelican Island	1.7km of Wetland fencing	Catchment Management Authority *Macleay Landcare Network Inc. Community Support Officer 02 65622076*
Voluntary Streamcare Grants Scheme *(#4)*	E – 0500000 N – 6578100 Clybucca Creek	Brush groyne erosion control works along bank, wetland fencing	Catchment Management Authority *Macleay Landcare Network Inc. Community Support Officer 02 65622076*
Voluntary Streamcare Grants Scheme *(#15)*	E – 0500094 N – 6580209 Clybucca Creek	210m riverbank fencing and revegetation using 300 plants	Catchment Management Authority *Macleay Landcare Network Inc. Community Support Officer 02 65622076*
Voluntary Streamcare Grants Scheme *(#2)*	E – 0499450 N – 6581700 Andersons Inlet	Weed control, removal of Lantana	Catchment Management Authority *Macleay Landcare Network Inc. Community Support Officer 02 65622076*
(#21)	Pelican Island Boyters Lane	Tidal floodgate management and associated proposals fro Playing Fields and Wetland Management	Kempsey Council *Ron Kemsley Kempsey Council*
(#22)	Pelican Island	Fencing to exclude stock from wetland areas	Greening Australia and NSW Fisheries
Shark Island – Macleay Coastline Littoral Rainforest Regeneration Project *(#24)*	Shark Island	260 hrs of weed control undertaken between Feb 2002 and Feb 2004	Coastcare 2000-2001 South-west Rocks Dune Care and Kempsey Council *Macleay Landcare Network Inc. Community Support Officer 02 65622076*
Voluntary Streamcare Grants Scheme *(#11)*	E – 0500349 N – 6581200 Clybucca Creek	Bank protection using rock rubble and riverbank fencing	Catchment Management Authority *Macleay Landcare Network Inc. Community Support Officer 02 65622076*
Voluntary Streamcare Grants Scheme *(#13)*	E – 0503000 N - 6579850 Pelican Island	Riverbank Fencing	Catchment Management Authority *Macleay Landcare Network Inc. Community Support Officer 02 65622076*

Bibliography

Auld B.A, Medd R.W (2002) 'Weeds, an illustrated botanical guide to the weeds of Australia' Inkata Press.

Bale C.L (1992) 'Eucalypts and Angophoras of the North Coast New South Wales' Department of Botany University of New England Armidale.

Briggs J.D, Leigh J, H, CSIRO Australia, Australian Nature Conservation Agency (1995) 'Rare or Threatened Australian Plants'

Buchanan R. A (1989) 'Bush Regeneration, Recovering Australian Landscapes'

Churchill S (1998) 'Australian Bats' New Holland Publishers.

Cronin L (1991) 'Key Guide to Australian Mammals'. Reed Books Australia.

Day N, Ken S (1996) 'Field Guide to the Birds of Australia' Fifth Edition

Dwyer L (1995) 'Vegetation Survey of Saltwater Creek, Arakoon State Recreation Area, NSW'

Floyd A, NSW National Parks and Wildlife Service (1984) 'Rainforests of the Lower Macleay River Flats'

Floyd A, NSW National Parks and Wildlife Service (1978) 'Rainforest Islands on the Lower Reaches of the Northern Rivers of NSW'

Floyd A, NSW National Parks and Wildlife Service (1977) 'Report on Forests of Shark Island'

Forestry Commission of New South Wales (1989) 'Research Note No. 17, Forest Types in New South Wales'

Goodrick G, N (1970) 'A Survey of Wetlands of Coastal New South Wales – Technical Memorandrum No.5 CSIRO Division of Wildlife Research

Graham J, Duggin J, Ecosystem Management, University of New England (2004) 'Yarrahapinni Wetland Vegetation Monitoring – Final Report to Yarrahapinni Reserve Trust'

Harden G.J (1990) 'Flora of New South Wales' Volumes 1 – 4. Royal Botanic Gardens Sydney

Johnstone S for Bellinger Valley Landcare / Coastcare 'Bellinger River – estuary Revegetation Guide'

Kendall and Kendal Pty Ltd (2003) 'Saltwater Creek Catchment – Flora and Fauna Study, South West Rocks prepared for Kempsey Shire Council Coastal and Estuary Management Committee'

Land and Water Conservation (1998/99) 'NSW Wetlands Management Policy Action Plan'

Land and Water Conservation (1999) 'Soil Landscapes of the Kempsey 1:100 000 Sheet'

Laegdsgaard Dr P , NSW Dept. of Land and Water Conservation (2002) The Importance of groundwater to seagrass habitats at Stuarts Point'

Lord E.E, Willis J.H (1984) 'Shrubs and Trees for Australian Gardens'

Nambucca Valley Landcare Inc. / Coastcare (2000) 'Riverbank Restoration for the Nambucca Estuary – A decision Making Guide'

New South Wales Fisheries (2002) 'Indigenous Fisheries Strategy and Implementation Plan'

New South Wales Fisheries (1998/1999) 'NSW Fisheries "Policies and Guidelines" – Aquatic Habitat Management and Fish Conservation 1998/1999'

New South Wales Government (1992) 'Estuary Management Manual'

North Coast Environment Council (1999) 'Macleay Wetlands Management Plan'

Nicholson N, Nicholson H (1985) 'Australian Rainforest Plants' Series 1 – 6. Terania Rainforest Nursery

NSW National Parks and Wildlife Service, Lunney D, Curtin A.L, Ayers D, Cogger H.G, Dickman C. R, Maitz W, Law B, Fisher D (2000) 'The Threatened and non-threatened native vertebrate fauna of New South Wales: Status and ecological attributes

NSW National Parks and Wildlife Service (2005) 'Clybucca Historic Site – Draft Plan of Management'

NSW National Parks and Wildlife Service Northern Directorate (2001) ' Water Habitats of the Nambucca, Macleay and Hastings Catchements – North Coast Water Habitats Study Report #3' Prepared by the Mid North Coast Water Management Committee.

Pressey R, L (1989) 'Wetlands of the Lower Macleay Floodplain, Northern Coastal New South Wales – Proceedings of the Linnean Society NSW 111(3) 1989

Robinson M. (2000) 'A Field Guide to Frogs of Australia' An Australian Museum/Reed New Holland Publication.

Sainty G.R, Jacobs S.W (1981) 'Waterplants of New South Wales' Water Resources Commission NSW

SWC Consultancy – a division of Shortland Wetlands Centre Ltd (1997) ' Environmental Impact Statement for the Proposed Restoration of tidal inundation of Yarrahapinni Wetland, Mid-north Coast, NSW

Thraetened Species Unit, NSW National Parks and Wildlife Service (2000) 'Threatened Species of the Lower North Coast of New South Wales'

West G, Laird R, Williams RJ (2004) 'Mapping of Bass Habitat in the Macleay, Hawkesbury and Shoalhaven Rivers – Interim Report for the Recreational Freshwater Trust Expenditure Committee (NSW Fisheries, Port Stephens Fisheries Centre)'

West G (1993) 'Estuarine Fisheries Resources of Two South-east Australian Rivers'

Williams G (1993) 'Hidden Rainforests, Subtropical Rainforests and their invertebrate Biodiversity' Published in Association with the Australian Museum.

Williams J.B, Harden G.J, McDonald W.J.E (1884) 'Trees and shrubs in Rainforests of New South Wales & southern Queensland'. Botany Department, University of New England.

Williams J.B, Harden G.J (1988) 'Rainforest Climbing Plants'. University of New England Printery

Yarrahapinni Wetlands Reserve Trust (2000) 'A Proposal to build a boardwalk at the Yarrahapinni Wetland – Environmental Impact Statement'

Yarrahapinni Wetlands Reserve Trust (2000) 'Yarrahapinni Wetlands Reserve Plan of Management 2001'

Appendix E

Macleay River Estuary Geomorphology

(includes 2005 Bank Erosion and Estuary Sedimentation investigations)

The geomorphology of the Macleay River estuary

September - 2005

Prepared by: Dr Tim Cohen
Prepared for: Kempsey Shire Council

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1.0 EXECUTIVE SUMMARY

The Macleay estuary is a mature barrier-dominated system in a high-energy ocean wave setting. It is a filled (delta) system dominated by fluvial processes. It can be broken into three broad process zones that reflect differing degrees of fluvial and tidal interactions. The fluvial process zone is the spatially most extensive and extends from Belgrave Falls to Kinchela and can be broken into three reaches with different morphological attributes. Collectively, these three fluvial reaches represent a transition from the non-tidal gravel bed reaches of the middle Macleay catchment to the entirely estuarine-dominated reaches of the Lower Macleay River. A short transitional zone exists from Kinchela to Jerseyville Bridge and on Clybucca Creek. These segments of the estuary reflect a transition from entirely fluvial processes to both fluvial and tidal processes. In contrast, the remaining Lower Macleay River is dominated by tidal processes and the presence of marine-derived sediment.

Ninety per cent of the entire surveyed estuary is stable with 27 % of this being stabilised by rockwork. There are 25 km of eroding riverbanks with minor erosion being the most common erosion category. While there has been an increase in the incidence of minor bank erosion in the last 70 years there has been a marked reduction in moderate and severe bank erosion since (26 % and 68 % reduction respectively). The most active areas in the estuary are Kinchela Bench and Fattorini Island (fluvial reach 3). Kinchela Bench has eroded by up to 35 m since 1942 with the greatest rate of change occurring between 1942 – 1956 (reflecting the large floods of 1946, 1949 and 1950). Fattorini Island has also been reduced in length by 70– 50 m since 1942. These locations are continuing to erode at high rates from wind and/or boat waves (relative contribution unknown).

The fluvial process zone has the most extensive occurrence of minor and moderate erosion and the only incidence of severe erosion, with 10 km of eroding riverbanks. Seventy eight per cent of the stable banks are naturally stable with the remaining 22 % stabilised with rockwork. The transitional process zone has 7.5 km of minor and moderate bank erosion with 43 % of the stable banks being rocked. The marine flood-tide process zone has the least erosion with 94 % of the surveyed area being stable (of which 43 % is naturally stable).

The dominant causes of bank erosion in the Macleay estuary are:

- Fluvial processes
- Wind and/or boat waves
- In-channel sedimentation
- Stock disturbance/reduced riparian vegetation
- Presence of rockwork on adjacent banks

The relative role of these controls varies considerably between process zones and is partly determined by local factors (deep or shallow water profiles). Furthermore, the history of catchment disturbance in the Macleay valley— including the 1.24 million tonnes of sediment that have been dredged from the estuary between 1929 and 1963— continues to have important impacts on estuarine processes.

2.0 INTRODUCTION

2.1 Aims

To investigate the nature and extent of bank erosion and sedimentation at two spatial scales (*i.e*. process zone and site specific scales).

The Process-Zone Analysis will:

- Review existing information made available by Kempsey Council and DIPNR (including the 1934 report by Departmental Committee on Macleay River Erosion and the 2003 Patterson Britton Report).

- Develop draft mapping from rectified orthophotos

- Differentiate areas of the estuary with similar characteristics (bank forms, sediment type, broad physical processes and tidal regimes) with a particular view to identify the occurrence and extent of four main depositional environments (*i.e*. coastal barrier sands, tidal delta sands, central mud basin and fluvial delta sands).

- For each process zone identify and map the major physical attributes associated (e.g. location of shoals, intertidal mud and sand flats)

- Provide a basis in which to assess the relative contribution of fluvial and tidal processes, while also providing a temporal context to the evolutionary pathway of the Macleay Estuary

The site-specific analysis will:

- Map and identify estuary related physical condition attributes focusing on the extent of bank erosion, areas of accelerated change, bank protection works and riparian vegetation.

- Provide basic statistical information that quantifies the relative extent of bank erosion classes, bank protection and riparian vegetation for each process zone.

The description of the Macleay floodplain and estuary at these two scales will encompass:

1. The spatial extent of each process zone
2. The extent of the bank erosion (mapped to a minimum resolution of 20 m)
3. The identification of the type and severity of bank erosion in each process zone
4. The extent and type of bank protection works — summarised within, but presented in full in Telfer (2005).
5. The identification of areas of accelerated change

6. The assessment of condition of each process zone
7. The identification of gaps in the data base relevant to riparian land management, bank erosion and sedimentation issues

3.0 WAVE-DOMINATED COASTLINES IN SOUTH-EASTERN AUSTRALIA

The coastline of south-eastern Australia is dominated by a high-energy ocean wave climate with a prevailing southerly swell pattern. The topography of the coastline is characterized by prominent headlands alternating with bay-beaches, barrier beaches and numerous micro-tidal estuaries partially filled with late Quaternary sediments (Roy et al., 1980, 1994; Roy, 1994; Sloss, et al., in press). Estuaries have been previously classified based on their biochemical properties, their physiographic attributes and their geomorphic/sedimentological characteristics (*e.g* Roy et al., 1980; Dalrymple et al., 1992). The latter of these classification schemes provides the most useful framework for assessing geomorphic processes, providing a sense of the depositional environments and an insight into the evolutionary pathway of any given estuary. Furthermore, the classification of estuaries based on their geomorphology and sedimentology incorporates an assessment of the spatial distribution of sedimentary units produced by fluvial, wave and tidal dominated sedimentary processes (Figure 1).

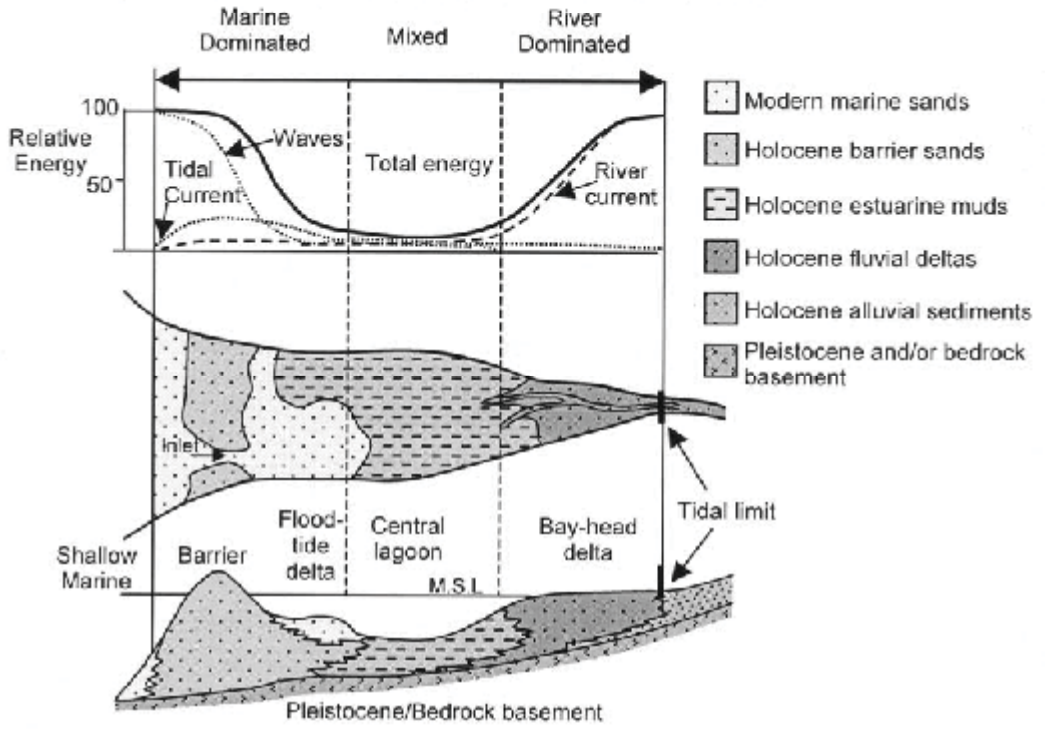

Figure 1 Distribution model of energy and morphological tripartite facies distribution (after Dalrymple et al., 1992).

Roy et al., (1980) identified three primary types of estuaries in New South Wales based on the geomorphic attributes and entrance conditions of any given estuary. These include:

1. Wave-dominated barrier estuaries dominated by supra-tidal coastal barriers intersected by narrow entrance channels that connect low-energy back-barrier lagoons to the open ocean with attenuated tidal regimes.

2. Open ocean embayments with deep and relatively wide entrances with full tidal exchange.

3. Drowned river estuaries formed in steep and narrow incised valleys with large subaqueous tidal sand bodies and full tidal exchange.

The formation of such estuaries is a function of inherited topography, the extent of late Quaternary fill and catchment characteristics (*i.e.* sediment supply and river discharge). The evolutionary characteristics for the Macleay River (a wave-dominated estuary) are briefly discussed in the following section.

3.1 Estuary evolution for the Macleay River: a wave-dominated barrier estuary

Post-glacial marine transgression following the last glacial maximum (LGM) resulted in the deposition of much of the coastal alluvium in south-eastern Australia. While there are morphological examples of previous sea-level highstands in many parts of the eastern seaboard — including the Macleay — much of the alluvial morphology of the New South Wales coastline has formed as a function of rapid sea level rise since the LGM (20,000 years before present). Sea levels rose from 120 m below present in the LGM to one to two metres above present by 7500 – 6500 ^{14}C years. Sea levels have fallen since then to the present level ~ 3000 years ago and have remained essentially stable since. Very little chronological work has been undertaken on the Macleay estuary and the work by Walker (1963, 1970) really remains the only chrono-stratigraphic assessment. The closest analogue for which there is substantial data is the Clarence River to the north and the Shoalhaven River in the Illawarra (*e.g.* Umitsu, et al., 2001). Both represent mature infilled estuaries whose pattern and timing of infilling is likely to be similar to the Macleay River estuary.

While not dated the elevated terraces (Corangula and Madron) upstream of Kempsey described by Walker (1970) more than likely relate to lower sea levels prior to 7500–6500 years ago. As sea levels reached their maximum at this time the pre-Holocene Macleay valley would have been inundated with the deposition of a transgressive sand sheet between the rocky headlands of Crescent Head to South West Rocks (Figure 2). This transgressive sand sheet would have become the proto-barrier that bounded an open marine embayment— further bounded to the north by an inner Pleistocene barrier at Stuarts Point. Walker (1970) identified that this period also coincided with the formation of the Mungay terrace upstream of Kempsey. The presence of the transgressive sand sheet near the current coastline would have resulted in the deposition of river-dominated sediments on the Kempsey side (fluvial bay-head delta formation), deposition of terrigenous derived mud-dominated units in the central lagoon and additional marine influenced sediments associated with the barrier and tidal inlet processes (*sensu* Sloss et al., in press).

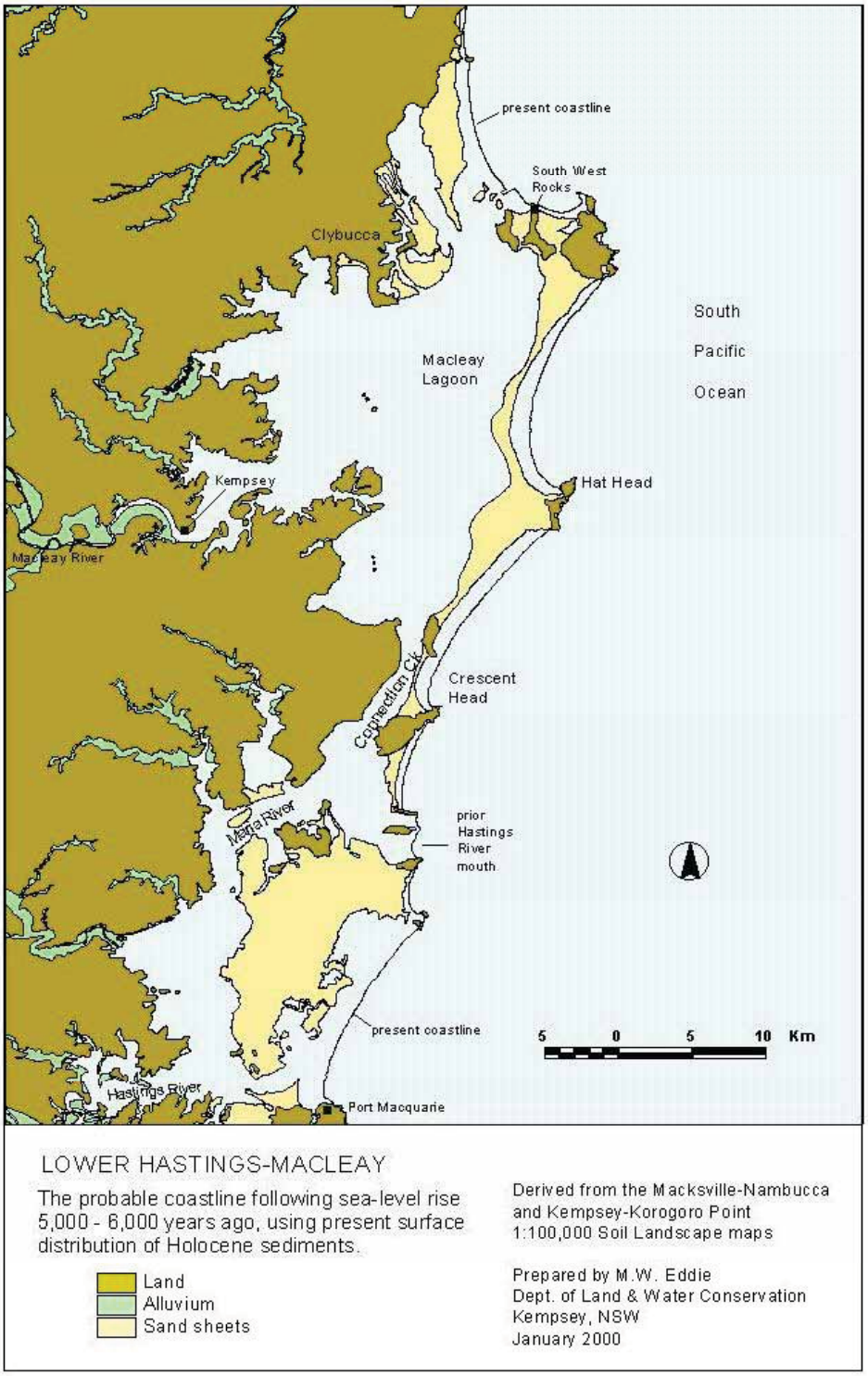

Figure 2 Schematic of the Macleay Estuary in the mid-Holocene (after Eddie, 2000).

The formation of the proto-barrier further promotes barrier development with flood-tide delta and back-barrier deposition (Figure 2). This emergent barrier produces a low-energy environment in the central mud basin— conducive to the deposition of estuarine muds. On the Macleay River the deposition of these estuarine muds along with continued progradation of fluvial sediments at the landward side (*i.e.* immediately downstream of Kempsey) has essentially filled the lower valley producing a deltaic

plain. The timing of the final stages of infilling is unknown but may coincide with terrace formation upstream of Kempsey ~ 3000 years ago. The Belmore and Clybucca swamps represent the last areas of the central mud basin, which are continuing to slowly infill. The birds foot deltas of Kinchella Creek and Belmore River indicate the continued progradation of sediment from the Macleay River into these basins.

In partially filled estuaries the central mud basin facies are replaced by salt marshes, mud flats and/or mangrove swamps. Such depositional environments are a reflection of the increased dominance of riverine processes in the mature stage of estuary development. During these latter infilling stages connectivity between the river channel and tidal inlet increases resulting in a more efficient delivery of sediment to the ocean (www.ozestuaries.org.). This often results in the bypassing of the remaining central mud basin and the formation of an ebb-tide delta. The preservation of such features on the eastern seaboard of Australia however, is often restricted due to the naturally low sediment supply rates, shoreline recession and sediment redistribution by high wave energy (Heap et al., 2004). Indeed, Heap et al., (2004) further suggest that the final infilling stages of wave-dominated deltas in Australia— characterised by an increased sedment delivery to the ocean and greater tidal penetration — may never actually result in the development of the "classic" delta morphology.

4.0 GEOMORPHIC PROCESS ZONES OF THE MACLEAY ESTUARY

At the broadest scale the contemporary Macleay estuary can be classified as a wave-dominated filled (delta) system— equivalent to the mature barrier-dominated estuary of Roy et al., (1980). The system is river dominated by infilled mud basins (*e.g.* Belmore and Clybucca Swamps) and extensive floodplains and levees that are inundated by approximately the mean annual flood (LM&P, 1980). The mature state of the estuary is also reflected in the relative abundance of intertidal flats, mangroves and saltmarsh (Table 1).

Table 1 Morphological and tidal attributes of the Macleay Estuary(www.ozestuaries.org).

Barrier backbarrier (km^2)	3.67	Tidal sand banks (km^2)	1.22
Central basin (km^2)	0.91	Rocky reef (km^2)	0
Fluvial bayhead delta (km^2)	0	Coral (km^2)	0
Flood/ebb delta (km^2)	1.13	Channel (km^2)	10.21
Intertidal flats (km^2)	1.74	Bedrock (km^2)	0
Mangrove (km^2)	5.94	Floodplain (km^2)	4.76
Saltmarsh/saltflat (km^2)	4.22	Bedrock perimeter (km)	3
Water area (km^2)	19.91	Entrance width (km)	0.18
Perimeter (km)	157.73	Entrance length (km)	0
Maximum length (km)	49.65		
Maximum width (km)	0.56		
Mean wave height (m)	1.55	Mean wave period (sec)	7.11
Max wave height (m)	6.9	Max wave period (sec)	13.5
Tidal range (m)	1.2 – 1.8	Tidal period (sec)	Semi-diurnal

The current morphology of the estuary can be broken into three broad process zones (Figure 3) that reflect differing degrees of fluvial and tidal interactions. These are:

- Fluvial process zone
- Fluvial-marine transitional zone
- Marine flood-tide process zone

4.1 Geomorphic attributes of the fluvial process zone

The fluvial process zone is the most extensive process zone within the estuary (reflecting the mature infilled character) and extends from the tidal limit at Belgrave Falls to Kinchela (including Belmore and Kinchela Creek and the upper Clybucca, Figure 3). While subject to varying degrees of tidal processes the overall morphology of this section of the estuary is dominated by fluvial processes and fluvial sediment and can be divided into three reaches each of which exhibit a similar morphology (reflecting the dominant fluvial process).

Belgrave Falls to Kempsey Bridge – Fluvial Reach 1

The upper most fluvial reach occurs from the tidal limit at Belgrave Falls to Kempsey and is characterised by bedrock outcropping on the concave banks with additional outcrops also occurring in the bed of the channel itself (Figure 3). This reach is characterised by a riffle-pool sequence with coarse bed material (cobble-gravels). Despite the coarse nature of the bedload, deep pools — up to 14 m depth — occur in this most upstream fluvial reach (*e.g.* at Kempsey Bridge, at Kempsey railway Bridge and at Mary's Bay).

The Macleay River in this most upstream reach is set within Late Pleistocene and early Holocene terraces (*e.g.* Alda Villa, Huntingdon and Long Flat Soil Groups — Eddie, 2000) with a distinctly stepped channel margin. The older clay-rich terraces form an important lateral control on the channel location forming a resistant channel boundary. This lateral constraint provided by both the bedrock and the older terraces produce the highest degree of valley confinement throughout the Macleay estuary resulting in the formation of large vegetated chute-channels. This confinement along with slightly steeper gradients and the variable hydrological regime produce the stepped channel margin seen within this reach. This form of channel margin is a characteristic of south-eastern Australian rivers which experience extremely variable hydrological conditions (*sensu* Erskine and Warner, 1988, 1998) and which have undergone various degrees of post-European channel expansion (*sensu* Cohen, 2003). These features set within the floodplain or terrace can be either erosional or depositional and are prone, when unvegetated, to fluvial erosion (most likely a function of the 2001 flood — Figure 4).

Kempsey Bridge to Belmore River confluence – Fluvial Reach 2

Fluvial Reach 2 extends from Kempsey Bridge to Belmore River confluence and represents a major shift in depositional processes. Downstream of Kempsey valley width increases dramatically, producing the wide deltaic plain of the Lower Macleay River (Figure 3). This increase in valley width results in a progressive reduction in bank and levee height in a downstream direction with bank heights decreasing from 6– 5 m upstream of Kempsey to 5 – 4 m at Kempsey and 4 – 3 m at Belmore confluence.

Fluvial Reach 2 — between Kempsey and Seven Oaks — is characterised by alternate shoal, bar and bench development inset within an enlarged channel. Therefore, unlike the upstream reach, Fluvial Reach 2 represents the first major depositional zone within the estuary. The consistently shallower water depths seen in this reach further highlight this.

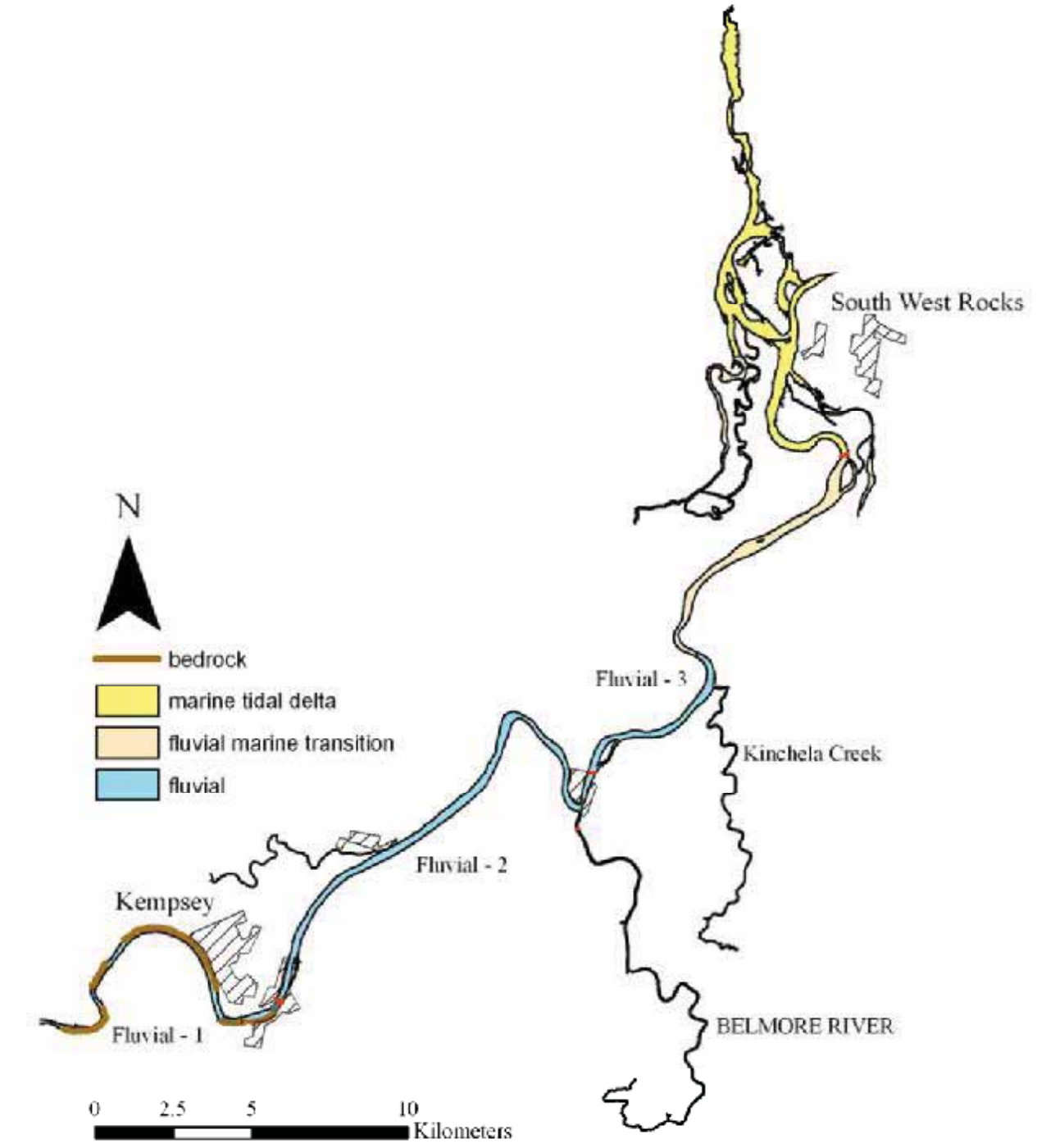

Figure 3 Distribution of process zones in the Macleay Estuary

Figure 4 Failure scars (dormant shallow slip) on the toe of the stepped channel margin in Fluvial Reach 1. This stepped bank form is a result of valley confinement and steep gradients producing erosional and depositional units set within the current floodplain.

Belmore River confluence to Kinchela – Fluvial Reach 3

Fluvial Reach 3 represents the most downstream reach dominated by fluvial processes and extends from Belmore confluence to Kinchela (including Belmore River and Kinchela Creek — Figure 3). Levee and bank heights on the Macleay River continue to decrease from 3 m to 2.5 m and the reach is characterised by the greatest extent of active erosion in the estuary. The major depositional units within the reach (*i.e* Fattorini Island and Kinchela Bench) are actively eroding and the rate and extent of erosion is determined by both fluvial processes and wind and/or boat waves (expanded upon in Section 6). In contrast to the trunk stream, Belmore River and Kinchela Creek exhibit less in-channel sediment storage with sediment accumulation occurring through levee development. These low gradient tributaries — while predominantly stable — are extensively modified by drainage works. Thus, current channel processes most likely reflect the history of drainage operations while long-term depositional processes of the Macleay River (*i.e*. infilling of the Belmore and Kinchela swamps) have determined their overall morphology.

4.2 Geomorphic attributes of the fluvial-marine transitional zone

This process zone which extends from Kinchela to Jerseyville Bridge on the Macleay River and includes most of Clybucca Creek reflects a transition from entirely fluvial processes to both fluvial and tidal processes (Figure 3). This is apparent by the appearance of shoals that are deposited by fluvial processes but which are actively

modified by diurnal tidal processes. Thus, shoals within this transitional zone contain fluvially and marine-derived sediment. This transition zone also denotes a further reduction in bank height from 2.5 m to 1.5 m with the formation of intertidal flats and the dominance of estuarine sediments in bank profiles.

The lower sections of this process zone (*i.e.* immediately upstream of Jerseyville Bridge and the lower end of Clybucca Creek) exhibit extensive shoal development. The deposition on the trunk stream is also accompanied by active erosion of Pelican Island (expanded upon in Section 6). Clybucca Creek — like Belmore River and Kinchela Creek — has also been extensively modified by drainage works in Clybucca Swamp and floodgates in Yarrahapinni Wetland. This has resulted in the formation of two active channels (one of which has been artificially created) with greatly modified depositional processes. Despite, the modifications most of Clybucca Creek has extensive areas of intertidal flat, salt marsh and mangrove development.

4.3 Geomorphic attributes of the marine flood-tide process zone

The Marine flood-tide zone is dominated by marine-derived sediment sourced from the inner continental shelf and from the coastal barrier systems. It extends from Jerseyville Bridge to the mouth of the Macleay River (including the abandoned Macleay arm— Figure 3). Extensive intertidal and supra-tidal flats occur within this process zone with extremely low bank heights (< 1.5 m) with little to no levee development. Thus, this process zone contains abundant marine sand and fine-grained (terrestrially sourced) estuarine sediment. Back swamp areas tend to firstly accumulate the fine-grained estuarine sediment. As such, many of the intertidal and supra-tidal flats are dominated by organic rich estuarine sediment. Individual floods influence the gross location of the sand shoals but tidal processes dominate the continued formation of the abundant sand flats, sand banks, mangroves and salt marshes (Table 1). The shoals within this process zone migrate upstream on the incoming tide and are partly reworked on the outgoing tide. This is particularly prevalent in areas such as the abandoned Macleay arm, which is progressively being infilled by marine-sourced sand.

5.0 AN ASSESSMENT OF BANK EROSION IN THE MACLEAY ESTUARY

Bank erosion was determined over a five day boat trip where lengths of bank erosion > 20 m were mapped with a GPS. Bank erosion severity, failure mechanism, along with inferred dominant processes were recorded for each location. In addition, bank erosion status (*i.e*. active or dormant) and the extent to which failed bank material was stored on the channel margin was also recorded. Absolute locations of bank erosion and the aerial extent of erosion are estimated to be accurate within ± 20 m. The entire study area represents 357 km of riverbank, 24% of which were inaccessible by boat. These unsurveyed areas only represent minor tributaries such as Fredrickton Creek, Spencers Creek and Upper Kinchela Creek.

The spatial extent of bank erosion is presented for the entire estuary as well as for individual process zones (presented as a percentage of area surveyed and as an absolute value). Table 2 presents a summary of the results and highlights that 90 % (245 km) of the area surveyed is stable with 10 % (25 km) experiencing erosion of some sort. Banks

Table 2 Severity of bank erosion in the Macleay estuary process zones

	Total length (km)	*Total surv. (km)*	*Stable (km)*	*Min. (km)*	*Mod. (km)*	*Severe (km)*	*% Stable*	*% Min.*	*% Mod.*	*% Severe*	*% stable= rocked*
ENTIRE ESTUARY	357	270	245	18	4	3	90	7	2	1	27
Fluvial	187	134	120.1	8	2.8	3	90	6	2	2	22
Transitional	80.5	69	61.2	6.3	1.2	-	89	9	2	-	43
Marine delta	95.9	70	66.1	3.8	-	-	94	6	-	-	23

Transitional (fluvial-marine transitional zone). Percentages are calculated as proportion of area surveyed.

that are mapped as stable however, may be naturally stable or stabilised by rock revetment. To determine the extent of naturally stable banks the bank erosion layer and the rockworks layer (see Telfer, 2005) were joined and analysed collectively. Twenty seven per cent of the 245 km that have been mapped as stable have been stabilised with rock or other type of bank revetment material (*e.g.* concrete, rubble, tyres). This suggests that approximately 75% (178 km) of the stable banks in the Macleay estuary are naturally stable.

5.1 *Bank erosion in the fluvial process zone*

The fluvial process zone has the most severe bank erosion in the Macleay estuary (Table 2). Figure 5 presents the spatial distribution of bank erosion in the fluvial process zone and highlights that the areas of greatest erosion occur in Fluvial Reach 3 (around Kinchela Bend). Ninety percent (120 km) of the fluvial process zone is stable with 22 % of this being stabilised with rock or any other type of bank revetment material. The bank erosion type and severity differs for each of the three fluvial reaches, reflecting the varying dominant processes and will be described below.

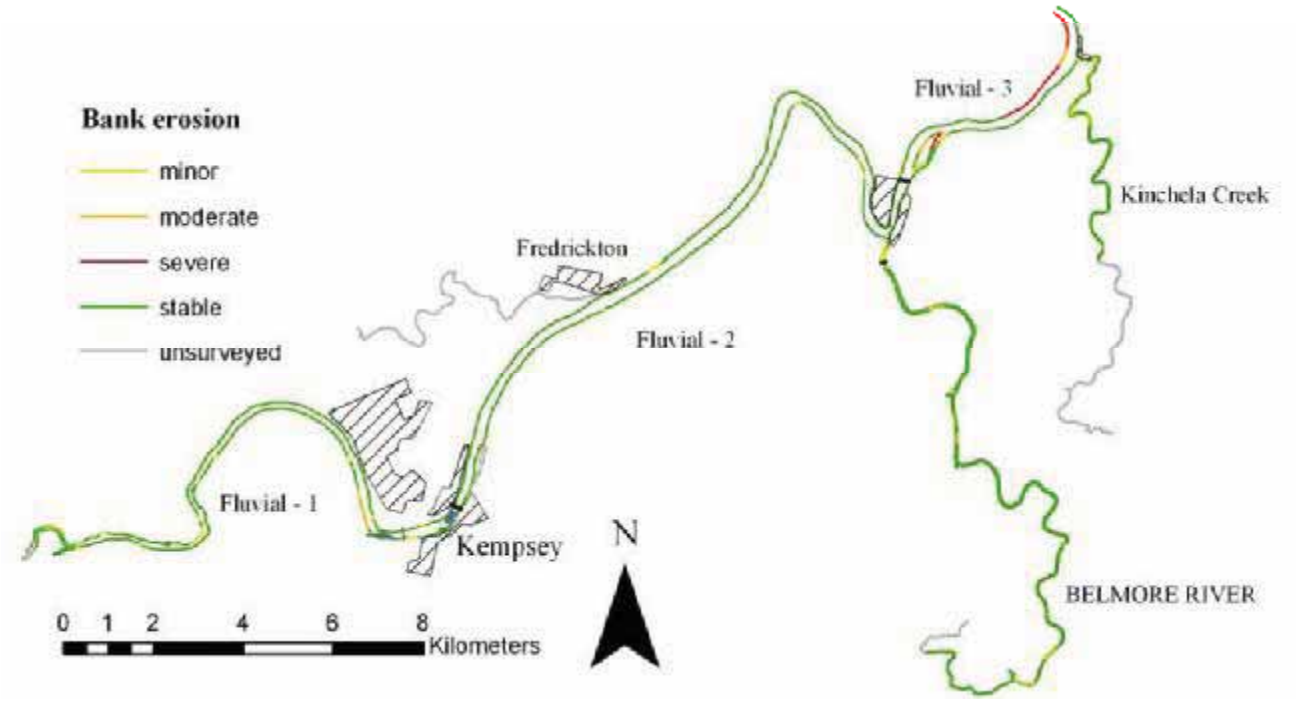

Figure 5 Spatial distribution of bank erosion severity in the Fluvial Process Zone

Fluvial Reach 1

Bank erosion in Fluvial Reach 1 is dominated entirely by fluvial processes with most of the isolated occurrences being dormant. This reflects the four years since the last major flood (March 2001) which most likely caused most of the mapped erosion. Shallow slide of the bank or bench toe is the dominant failure mechanism for most of the smaller (< 100 m) cases of bank erosion within the reach. In contrast, mass failure is the dominant failure mechanism for the larger occurrences (> 100 m) of bank erosion seen in the reach (*i.e.* immediately downstream of Belgrave Falls on the left-bank and upstream of Kempsey Railway Bridge on the right-bank— Figure 5). The rotational slumps and slab-and-block type failure occur across the whole bank, rather than the shallow slides of the toe, indicating that critical bank height for the given bank strength has been exceeded (Figure 6).

In most instances of bank erosion bank strength has been markedly reduced due to the lack of structurally diverse riparian vegetation. Furthermore, continual stock access on the composite banks (*i.e.* gravel underlying silty or sandy loam) has rendered many of the alluvial banks more susceptible to both mass failure and shallow slides.

Figure 6 Mass failure (rotational slump) of banks downstream of Belgrave Falls. Bank strength of the Alda Villa and Huntingdon terrace material has been markedly reduced by the replacement of structurally diverse native vegetation with pasture species. Piping and gullying of the slumped zone, along with continued stock access, makes the banks susceptible to ongoing erosion.

Fluvial Reach 2

This depositional reach within the fluvial process zone is predominantly stable with extensive rockwork between Kempsey and Seven Oaks (Figure 5). Isolated toe scour (< 20 m) occurs on the depositional margin and there are small sections (< 100 m) of

fluvial erosion of inset features. Fluvial Reach 2 also exhibits the onset of wind and/or boat wave erosion. This is compounded, like the upstream reach, by stock access to the riparian zone making the small remaining alluvial banks susceptible to bank erosion (Figure 7).

Figure 7 a) Notching of bank toe by wind and/or boat waves in Fluvial Reach 2 **b)** The impacts of stock on macrophyte growth and toe erosion with varying land use of the channel margin. Property on left has fenced off stock from the channel margin.

Fluvial Reach 3

Fluvial Reach 3 is the most actively eroding section throughout the fluvial process zone with the presence of 3 km of severely eroding bank at Kinchela bend and another 0.5 km of severe bank erosion at Fattorini Island (Figure 5). Both sections represent areas of active mass failure with slab-and-block type failure being the dominant process. Both sites represent sandy alluvium susceptible to flood-driven erosion ***and*** ongoing wind and/or boat wave erosion, albeit with differing tidal controls.

Fattorini Island has a steep sub-water surface profile resulting in deep water adjacent to the bank toe at both high and low tide (Figure 8). This morphology represents an ideal situation for ongoing erosion as a function of wind and/or boat waves. In contrast, Kinchela Bend has more subdued sub-water surface topography resulting in beach development at low tide. Thus, Kinchela bend only actively erodes at mid-high tide (Figure 9). The primary determinant in these two types of bank profiles is substrate type and local hydraulics (influenced by planform location). The right-hand channel of Fattorini Island represents an area of flow constriction combined with sandy and silty alluvium. Kinchela Bend however, is on the inside of a bend with sandy and silty alluvium overlying more erosion-resistant estuarine basal clay. Section 7 reviews the

nature of historical channel changes at Kinchela Bend and addresses current rates and causes of current bank erosion.

Belmore River is predominantly stable with isolated locations of minor active bank erosion and one location (~ 330 m) of moderate and active bank erosion. The impacts of stock access are common throughout Belmore River resulting in the increased susceptibility of the channel margin to tidal fretting by wind and/or boat waves (Figure 10). Shallow slides and block failure are the two most common forms of bank failure on Belmore River. In addition, there are many examples of dormant bank erosion— fluvial in origin — with evidence of failure scars on the channel margin. The pattern of bank erosion on Kinchela Creek is similar, with isolated locations of minor active bank erosion (Figure 5). Lower Kinchela Creek exhibits the greatest extent of bank erosion with evidence of stock impacts increasing the susceptibility of the banks to fretting by wind and/or boat waves at mid tide. This mid-tide notching of the bank toe by wind and/or boat waves appears to be the dominant erosion process.

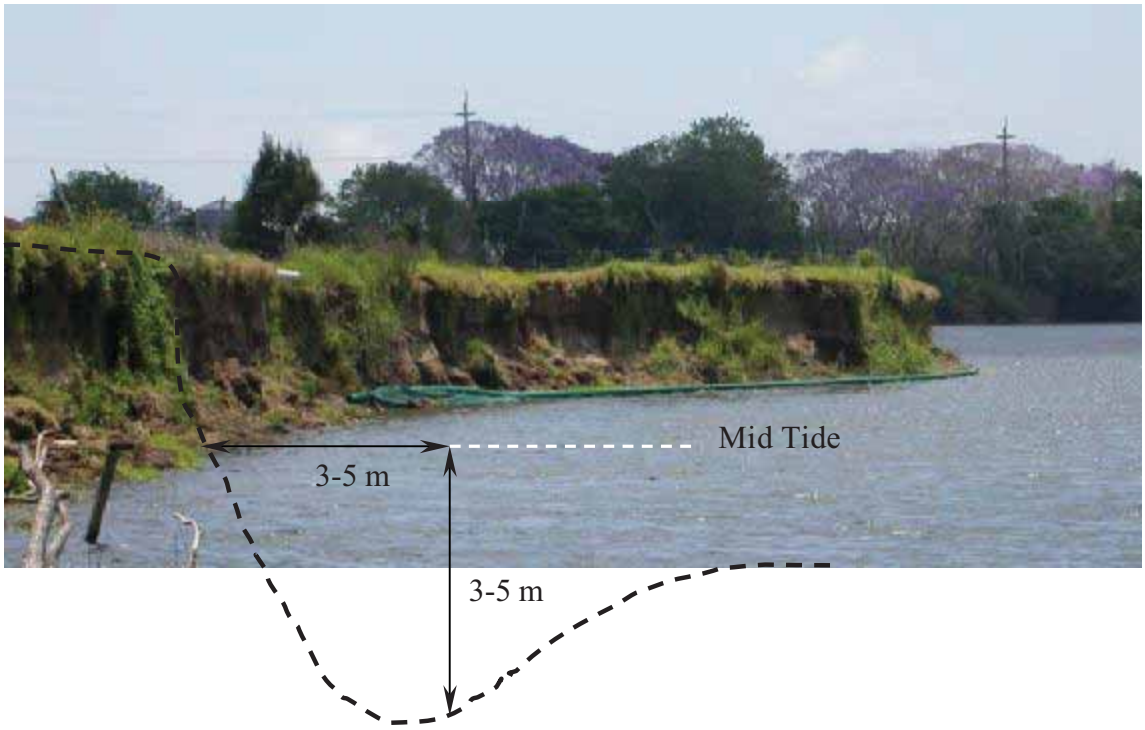

Figure 8 Bank erosion of a 'deep water' profile at Fattorini Island. A steep sub-water surface profile results in active erosion at low and high tide

Figure 9 a) Bank erosion on the inside of Kinchela Bend at high tide**b)** The local hydraulics and basal estuarine clay has resulted in the development of a more subdued sub-water topography with ongoing erosion occurring at mid-high tide only

Figure 10 Stock impacts on Belmore River resulting in reduced bank strength and increased susceptibility to wind and/or boat waves leading to slab-type block failure

5.2 Bank erosion in the fluvial-marine transitional zone

The fluvial-marine transitional process zone represents the second most unstable process zone throughout the estuary with 6.3 km of minor bank erosion and 1.2 km of moderate bank erosion (9% and 2% of the process zone respectively) with no severe bank erosion (Table 2). Eighty-nine percent of the 69 km assessed in the fluvial-marine transitional zone are stable, of which 43 % (30 km) are rocked (Table 2). This suggests that only half of the stable banks within this process zone are naturally stable. Indeed, the majority of the trunk stream within the transitional zone has been rocked with the unrocked areas around Pelican Island undergoing the most active minor and moderate erosion (Figure 11).

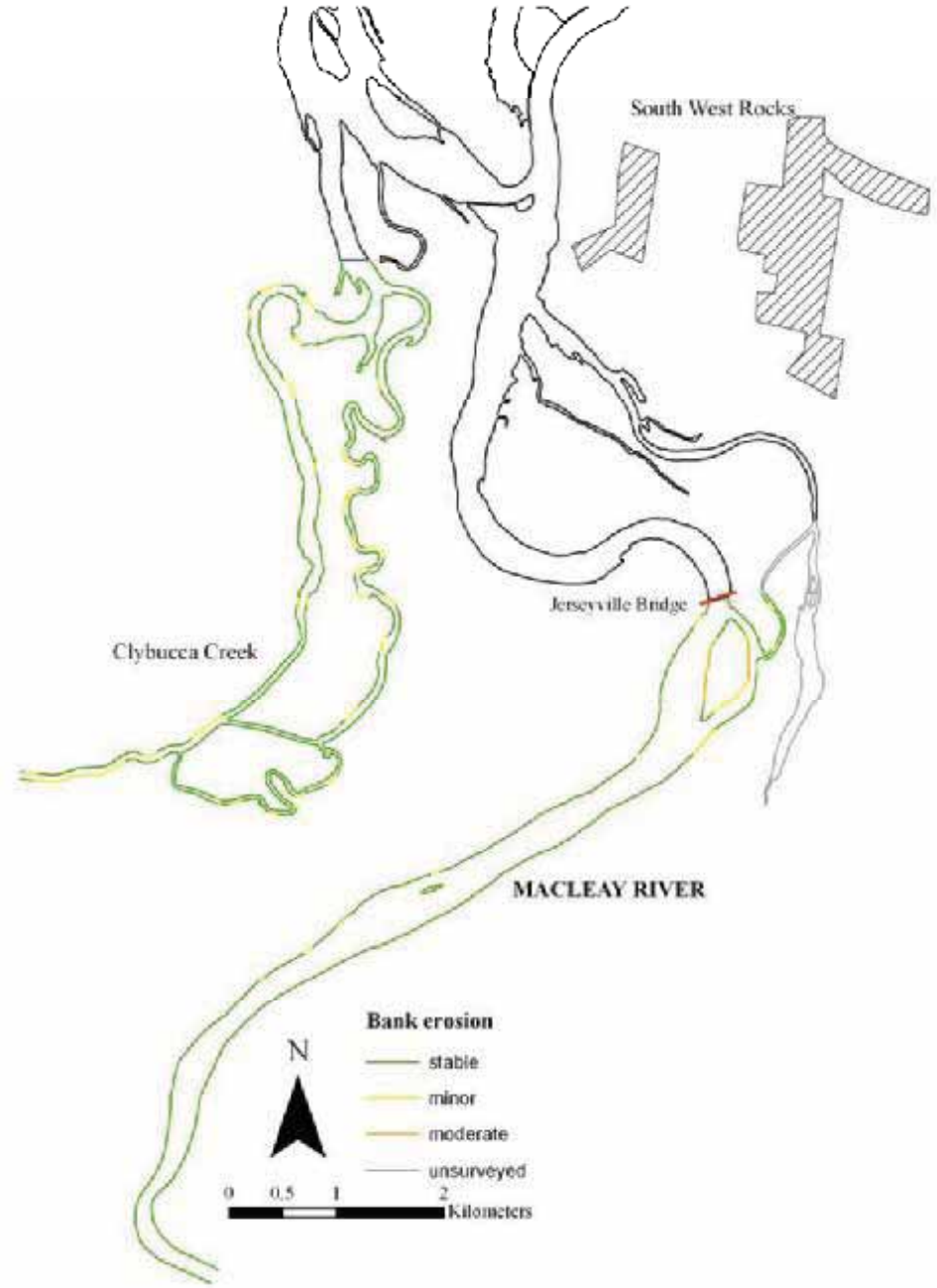

Figure 11 Spatial distribution of bank erosion in the fluvial-marine transitional zone. Note the erosion of Pelican Island.

Like Fattorini Island, the active erosion of Pelican Island is an example of a'deep water' profile. The sedimentology of this island is composed of estuarine basal clays underlying stratified sands and silts. This results in a stepped profile with the estuarine clays forming a more erosion resistant ledge adjacent to deep water. The left-bank of the island is exposed to both northerly and southerly wind-generated waves***and*** boat wake resulting in a 570 m length of moderate erosion occurring at both high and low tides (Figure 12). The basal estuarine clays are actively bioturbated by crabs at low tide resulting in the pre-conditioning of the bank profile to ongoing erosion while the loose overlying sandy alluvium erodes at high tide.

Figure 12 Bank erosion of a 'deep-water' profile at Pelican Island – low tide. Note the crab pellets of the basal clays resulting in the basal clay ledge being pre-conditioned to wind/boat wave erosion.

Clybucca Creek exhibits numerous examples of active minor erosion but no evidence of moderate or serious erosion. Clybucca Creek, like other areas in the transition zone, has low banks with many rocked channel margins. The history of drainage works in Clybucca Creek resulted in the formation of a new straight channel and the maintenance of the old sinuous channel. Almost the entire length of Upper Clybucca Creek (*i.e.* downstream of the barrage) has been rocked. Many areas however, have only been rocked for two thirds of the bank height resulting in the upper bank being susceptible to wind and/or boat wave erosion at mid-high tide. Slab-type block failures along with shallow slide are the dominant failure mechanisms— determined primarily by wind and/or boat wave erosion. This is also particularly apparent in areas where rockworks are discontinuous. Clybucca Creek also exhibits a riparian zone heavily impacted by stock increasing the susceptibility of banks to mid-high tide erosion. The planform location (*i.e.* outside of bend) of the active erosion in Lower Clybucca Creek suggests that erosion seen throughout this tributary may be indeed initiated in floods (*i.e.* fluvial in origin) but maintained by wind and/or boat waves.

5.3 *Bank erosion in the marine flood-tide process zone*

The marine-flood tide process zone is the most stable of the three process zones with 94 % of the 70 km assessed being stable and 6 % (3.8 km) experiencing minor bank erosion (Table 2). Of the stable banks 23 % (16 km) are rocked highlighting that the majority of stable banks in the marine-flood tide process zone are naturally stable. The trunk stream within this process zone is predominantly stable with most of the channel margins being rocked. Minor bank erosion in this process zone occurs around Anderson's Inlet, the old arm of the Macleay River and around Fishermans Beach (Figure 13). The first is dominated by slab-type block failure of the supra-tidal flat with active erosion occurring from wind and/or boat waves (Figure 14a). Most locations experiencing this type of minor erosion are 'shallow water' profiles, and as such erode at mid-high tide. The second type of bank erosion is the undercutting of mangrove and salt marsh by boat waves in the old arm between Fishermans Reach and Stuart's Point (Figure 14b). In these areas buoy location — a function of shoal location — is resulting in boat waves impinging on the alluvial channel margin.

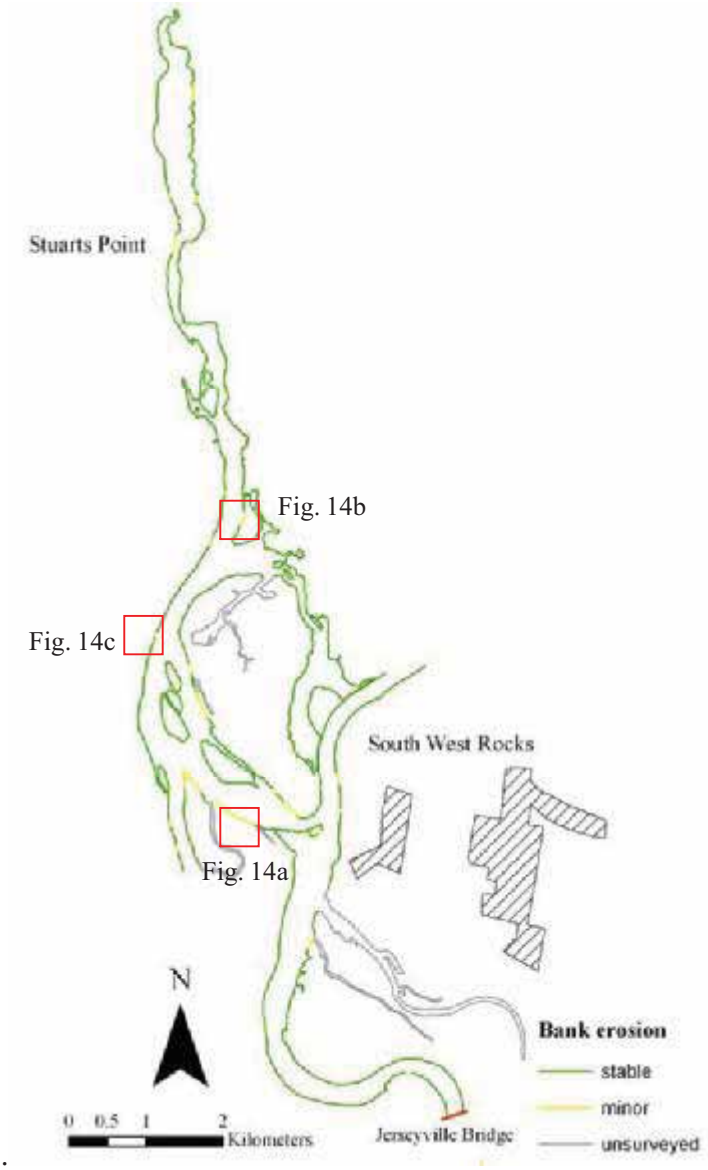

Figure 13 Spatial distribution of bank erosion in the marine flood-tide process zone

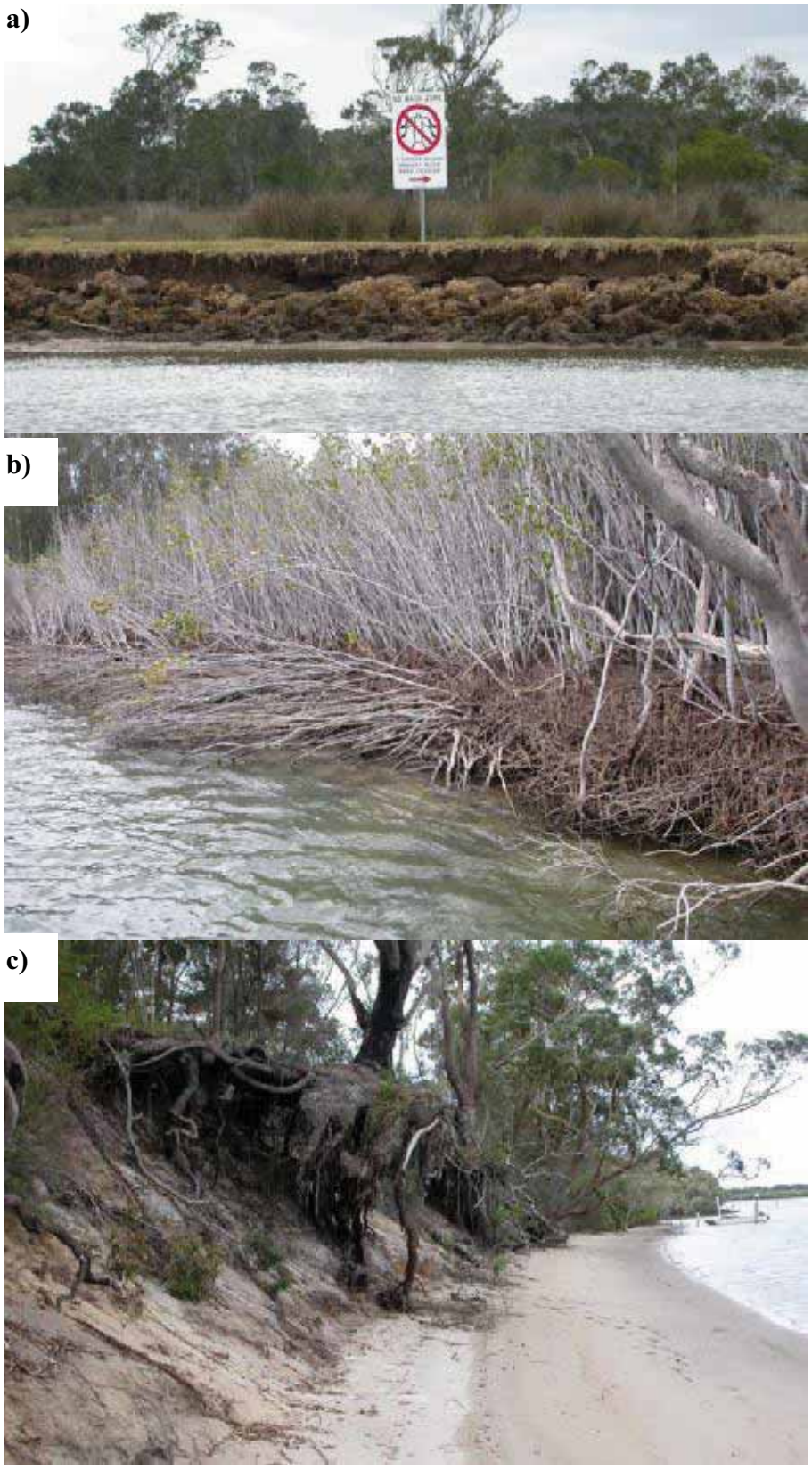

Figure 14 Bank erosion in the marine flood-tide process zone **a)** Slab-type block failure; **b)** Scour and undercutting of mangroves; **c)** Scour and undercutting of dune vegetation at Fisherman's Beach.

The final type of erosion in the marine flood-tide process zone is that of the vegetated sand dunes where wind and/or boat waves are causing shallow slides and active undercutting of the remnant vegetation (Figure 14c). This is compounded in some locations — such as Fisherman's Beach — by the impacts of access tracks which have reduced the vegetation density on dune margins.

6.0 A REVIEW OF HISTORICAL CHANNEL CHANGES AND CURRENT SEDIMENTATION ON THE LOWER MACLEAY RIVER

This section reviews a number of documents that relate to historical channel changes and to issues of sedimentation in the Macleay Estuary. It then assesses historical trends of bank erosion to those previously described in Section 5 and investigates a number of sites that are currently the most active within the estuary.

6.1 Departmental Committee on Erosion – Macleay River Erosion, 1934

In 1934 a report by the Department of Lands was commissioned into erosion of the Macleay River (Departmental Committee on Erosion– Macleay River Erosion, 1934). This report presented a synopsis of a number of investigations identifying the various opinions as to the major causes of the erosion seen through out the estuary. Based on these assessments it then provided an overall summary of the active erosion. The twelve major findings of the 1934 report include:

1. 700 acres had been lost by 1934 (but over the previous 40 years) (p.6).
2. Areas most severely impacted totalled ~ 6 miles.
3. Represents a loss of £20 per acre (total loss of £14,000).
4. Erosion of riverbanks changed inundation patterns.
5. Subsequent floods may result in a new waterway being cut in the vicinity of Jerseyville into Tidal or Cox's Creek.
6. The principal causes of erosion are:
    - Floods
    - Wind-wave action
    - Tidal currents

    With minor contributions by:-
    - River traffic
    - Shoaling of the straighter reaches of the river
    - Removal of natural protective cover and cultivation of banks
    - Cattle grazing
7. Dredging has not caused the erosion but may have intensified erosion in some locations.
8. Remedial measures are called for if erosion is to be prevented
9. Cost is estimated to be £20,250 per annum with total costs of £225,000
10. Remedial measures in most cases are beyond the financial means of frontage landholders
11. The serious erosion seen on the Macleay is evident on other coastal streams
12. Due to regional scale of problem expenditure of public funds to determine effective means of protection is justified

These twelve major findings vary to other sources of information presented within the report and are therefore discussed in greater detail.

In 1934 it was estimated by Mr. Greg Brooks (Supervising Engineer, Department of Public Works) that 10.25 miles of riverbank (~ 16.5 km) were eroding in the Lower Macleay River. Of this, 9.5 km were rated as serious erosion (severe), 5.4 km of not so serious erosion (moderate) and 1.6 km of slightly eroded sections (minor). The 1934 report adopted and accepted the opinions of Mr. Greg Brooks with regards to the four primary causes of this erosion. Figure 15 highlights the approximate location of this erosion from maps presented within the 1934 report. This figure demonstrates that most of the areas of active erosion in 1934 are now predominantly stable— as a function of extensive rockwork (excluding Pelican Island, which is still actively eroding). A comparison of the 1934 figures with data presented in Section 5 demonstrates that there has been an increase in the spatial extent of bank erosion seen throughout the Lower Macleay River since 1934 (Table 3).

Table 3 Comparison of bank erosion data from 1934 to 2004

BANK EROSION	*Minor (km)*	*Moderate (km)*	*Severe (km)*	TOTAL
1934	1.6	5.4	9.5	16.5
2004	18	4	3	25
% change	+ 1025	- 26	- 68	+ 52

Caution must be exercised in this style of comparison, as the increase is primarily a function of the large increases in minor bank erosion. This in turn may simply reflect differing methodologies and definitions of 'minor' bank erosion and a reduced extent of the spatial survey. Importantly, these comparisons highlight that there has been a 26 % and 68 % reduction of moderate and severe bank erosion respectively since 1934.

In addition to the four major causes of bank erosion, Mr. Greg Brooks (Departmental Committee on Erosion – Macleay River Erosion, 1934, p.4) also identified large overhanging trees, destruction of protective cover by cattle, cultivation of the banks below flood levels, crabs and the formation of shoals in the straight reaches of the river as additional causes of bank erosion. Dredging however, was not stated as a contributing factor due to the fact that it had not occurred within 45 ft of the bank. This opinion differed to those presented by landholders who in 1934 attributed the erosion to:

1. Floods
2. Dredging, too near high banks
3. Wind-wave action set up by prevailing winds
4. Tidal currents
5. Wash from river traffic
6. Diversion of channels consequent on accretions of flood debris
7. Removal of timber and the like cover from frontage lands
8. Cultivation of banks too close to river edge
9. Presence of hull of "Lady Beatrice" in river
10. Crabs

Dredging of the river channel was identified as the second most important mechanism for initiating erosion on the Lower Macleay River. At the time of the 1934 report

dredging was occurring to preserve navigation to a depth of 9 feet. This tended to occur at the crossings. Indeed, the specifications for dredging in the early 20th century indicate a technique similar to the removal of riffles in non-tidal reaches with an overall shortening of the thalweg (Figure 16). This form of localised channel shortening— in addition to the complete removal of shoals — certainly would have promoted localised gradient adjustments and/or re-orientation of the thalweg (see comments by Whalen, H *in* Departmental Committee on Erosion – Macleay River Erosion, 1934, Appendix A). Furthermore, the 1934 report identified that 440,650 tonnes of sediment were dredged between 1929 and 1934. It does not however, specify how much of this sediment was exported from the system totally or simply relocated to the channel margin as'spoil'. A further 812,000 tonnes were dredged over a twenty year period from 1943 – 1963 (Public Works Department Macleay River dredging file– R1029/7).

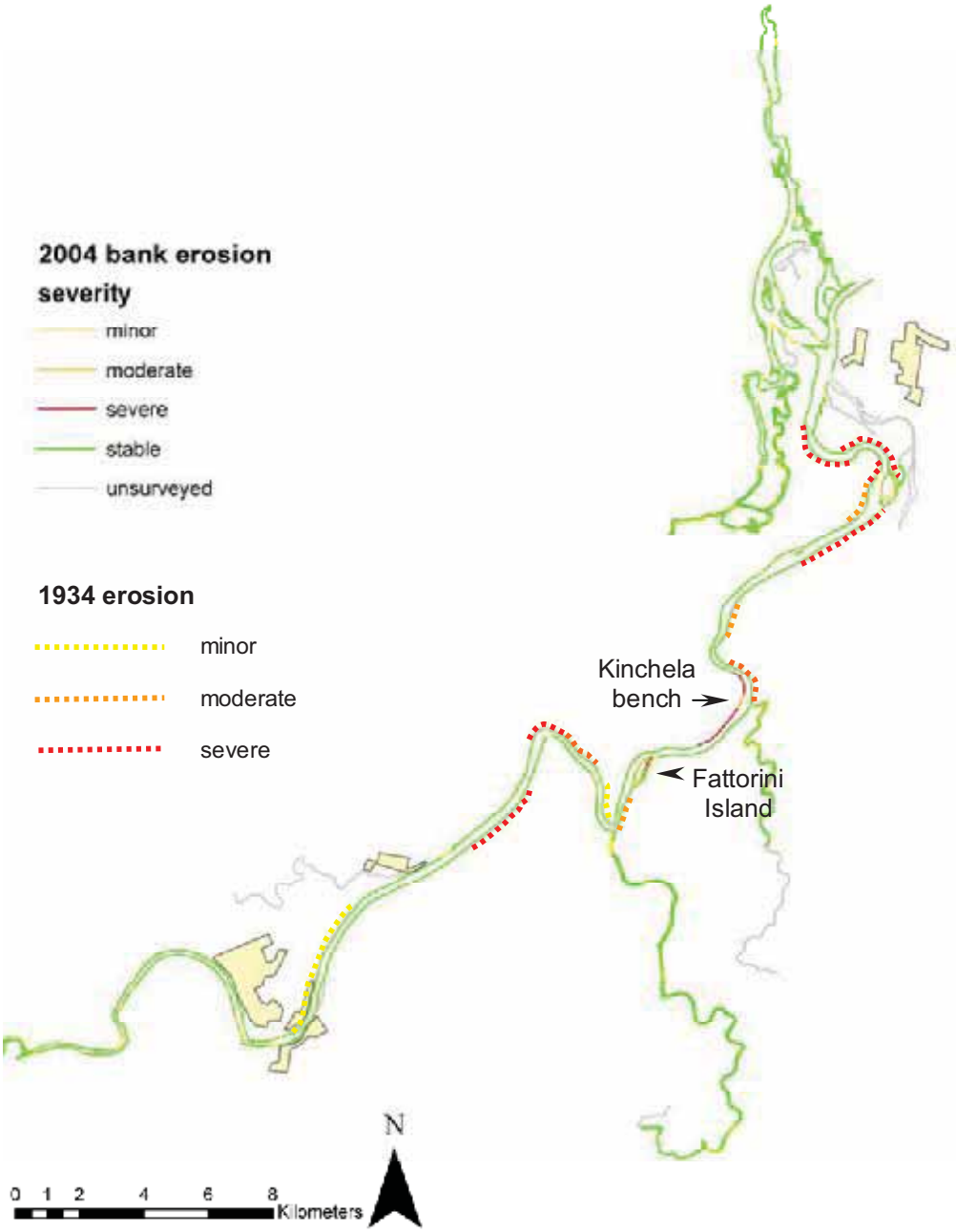

Figure 15 Current distribution of bank erosion with approximate locations of 1934 bank erosion.

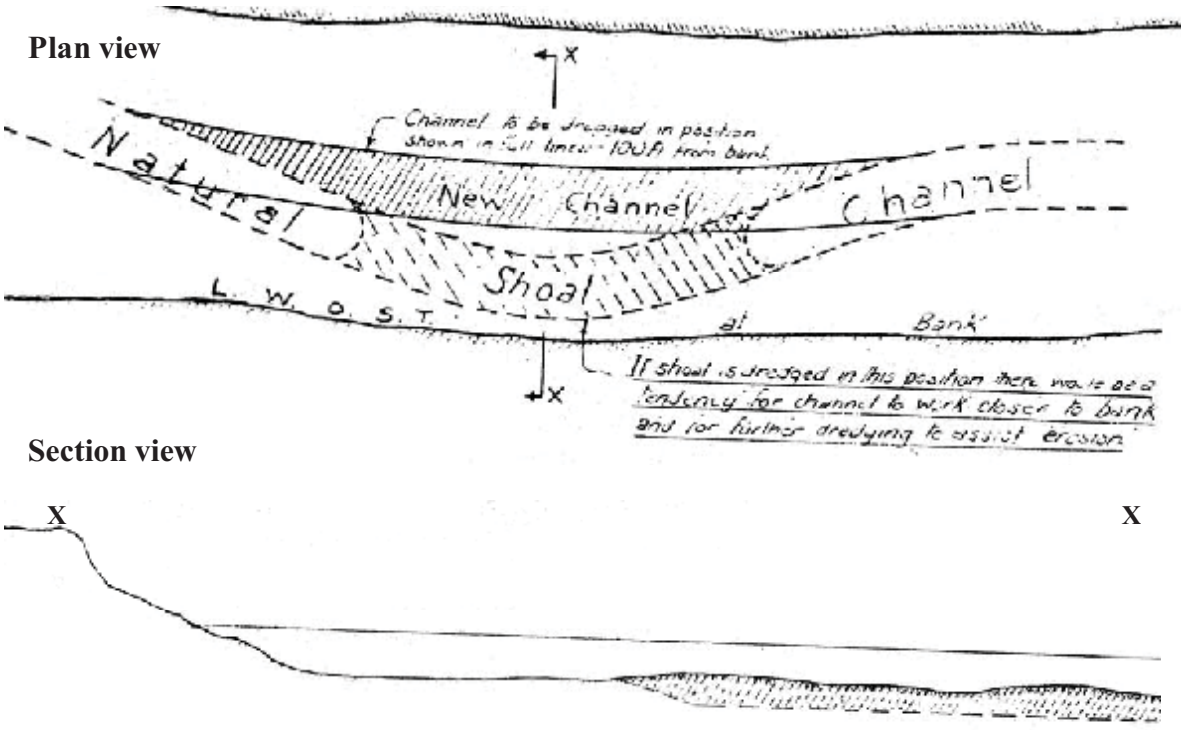

Figure 16 Specifications for the tidal dredging of shoals for the Lower Macleay River (sourced from Departmental Committee on Erosion– Macleay River Erosion, 1934).

It is safe to assume that the direct physical impacts of dredging in the early 20th century and the potential indirect impacts on sediment supply would have had profound implications for bank stability. Following the 1934 report instructions were given that no dredging should be carried out within 100 feet of riverbanks and that the ends of navigable channels at river crossings be"eased off'. It is unlikely however, that these modified dredging operations prevented further bank instability.

It is clear from the 1934 report that the Macleay River had already undergone a series of large channel changes in the early 19th century. These included an unquantified extent of bank erosion in the fluvial process zone following the 1864 flood and the formation of a new entrance south of Grassy Head in 1893 — essentially straightening the mouth of the estuary (Departmental Committee on Erosion – Macleay River Erosion, 1934, Appendix A). These channel changes, along with the onset of dredging, resulted in large areas of the channel margin becoming unstable by the early 20th century. The cause of these early changes was most likely related to changes to the overall boundary conditions of the Lower Macleay River (*i.e.* reduction in bank strength and floodplain roughness), but triggered by large flood events and maintained by wind wave action.

6.2 Sedimentation patterns of the Lower Macleay River

Little to no quantitative information exists on sediment loads for the Macleay River in either the tidal or non-tidal reaches. Furthermore, only rudimentary records exist for the volume of material extracted from the river. While the 1934 report provides an assessment of tidal dredging volumes for a short period in the early 20th century

Patterson Britton & Partners (2003) provide an indication of the volume of aggregate material being extracted from the non-tidal reaches (*i.e* the source zone for the estuary).

Current extraction licenses for the non-tidal reaches between Toorooka and Belgrave Falls amounts to 86,000 m^3/yr but with only 123,610 m^3 actually extracted between 1997/98 and 2001/02 (in contrast to the 311,000 m^3 that was permitted to be extracted). This equates to 24,722 m^3/yr since 1997, which is approximately 7,000 m^3 over the estimated annual transport rate of Laronne and Gurion (1994 – cited in Patterson Britton & Partners, 2003) or 4700 m^3 over the annual rate estimated by Patterson Britton & Partners (2003). In either case, the estimated annual transport rate is extremely poorly quantified and should be considered unreliable. The net result is that there is little data that allows the quantification of sediment entering the estuary.

Ashley and Graham (2001) provide some context as to where the fine-grained sediment in the estuary is sourced. Their analysis of heavy metals and isotopic signatures identified a distinct downstream dispersal trend for Antimony (Sb) and Arsenic (As). Antimony values remain 3 – 90 times background from Bakers Creek in the upper catchment right down to the Pacific. In contrast, As values remain at 1.5 times background (primarily derived from Hillgrove mineral field). Importantly, their analyses highlighted the nature of floodplain sedimentation in the estuary with the preferential accumulation of sediment (and associated heavy metals) on the southern side of the Macleay River, downstream of Kempsey (*e.g.* in levees and backswamps such as Belmore swamp). Backswamps on the northern side of the river (*e.g.* Doughboy Swamp) appear to have been little affected by contaminated sediment from the Macleay River (Ashley and Graham, 2001). Their floodplain cores on the southern side showed a 15 times background Sb enrichment and 4 times background for As. Furthermore, they demonstrated that levees on the southern side had accumulated a greater volume of sediment (and associated heavy metals) than the backswamps.

Their preliminary findings indicate some important sedimentation patterns for the Lower Macleay River that ultimately reflect flooding patterns. The preferential accumulation of heavy metals on the southern floodplains and swamps suggest that either the drainage works in Clybucca Swamp are more effective in draining floodwaters than on the southern side, thus reducing rates of sedimentation. Or alternatively, the flood mitigation scheme diverts significant quantities of floodwaters to the southern floodplains and backswamps that previously were distributed over Clybucca swamp via Seven Oaks. Floodplain and estuary sediments exceed ISQG guidelines for Sb however their analyses did not detect metal uptake into edible tissue above food quality guidelines. As such, their investigation is continuing on the behaviour of Sb and As in floodplain and estuary sediments and the potential for uptake into plants and grazing animals. The study by Ashley and Graham demonstrates the importance of understanding sediment storage in both the tidal and non-tidal reaches. It is clear that there have been large-scale channel changes along with significant changes to the nature of floodplain sedimentation on the Lower Macleay River. The following section briefly assesses areas of accelerated channel change while relating these changes to in-channel sediment storage.

6.3 In-channel sediment storage on the Lower Macleay River

There has been no systematic compilation of historical channel changes of the Lower Macleay River, despite the extensive post-European modification. Indeed there is no synthesis of the changes to channel dimensions or planform of the Lower Macleay River. Isolated comparisons of hydrographic surveys from the 1950s show variable results with both increases and decreases in waterway area. Very few hydrographic surveys have demonstrated cross-sectional or longitudinal changes in bed elevation. Figure 17 presents a longitudinal profile of the Macleay River trunk stream from Belgrave Falls to the mouth (based on bathometrically derived cross-sections spaced at 1 km intervals).

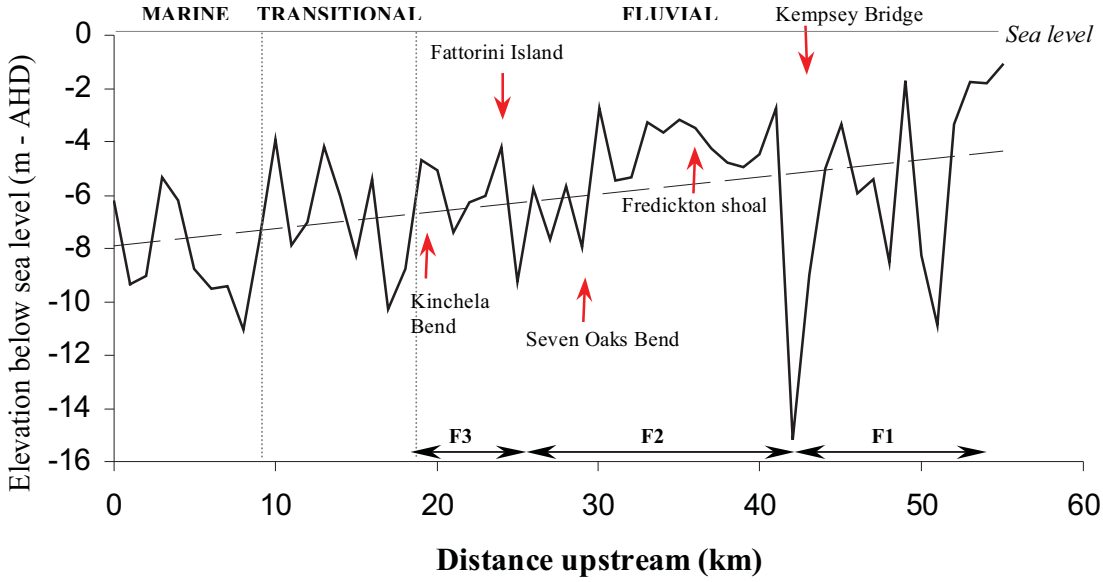

Figure 17 2003 Longitudinal profile of the thalweg of the Macleay River trunk stream from Belgrave Falls to the mouth — with linear regression (slope = 0.0006). Topography derived from bathometric data (source: DIPNR).

Even at this coarse resolution the longitudinal profile still highlights the nature of in-channel sediment storage along the Macleay trunk stream. A linear regression indicates areas of positive and negative residuals (*i.e.* areas of the channel bed above or below the line of best fit). These correspond to areas of net sediment storage and scour respectively with each of the three process zones having distinct sediment storage patterns. The three reaches within the Fluvial process zone are characterised by alternating locations of sediment accumulation and scour. Fluvial reach 1 (F1) is characterised by deep pools (10 – 12 m) while Fluvial reach 2 (F2) is predominantly characterised by sediment accumulation (Kempsey Bridge to Seven Oaks Bend – Figure 17). Sediment is preferentially scoured from the lower half of Fluvial reach 2 and deposited in Fluvial reach 3 (around Kinchela Bend). The transitional process zone is also characterised by zones of sediment accumulation (*e.g.* Pelican Island – Figure 17) whereas the marine flood-tide process zone is predominantly characterised by net scour. This is presumed to be a function of tidal scour of the marine sands and the increased flushing efficiency provided by the training walls.

Figure 17 provides a 'snap shot' of sediment storage patterns along the Lower Macleay River in 2003. It does not however, provide an indication of how these longitudinal patterns have changed through time. The sand and silt eroded from the banks and floodplains of the Middle and Upper Macleay River throughout the 20th century have been transported into the estuarine reaches and then re-distributed by later floods and tidal processes. Ultimately, it is these temporal and spatial patterns of sediment redistribution that determine current estuarine dynamics.

6.4 Sites of accelerated channel change on the Macleay River

This section reviews the nature and extent of planform changes (derived from ortho-rectified historical photographs) for the two most actively eroding sections identified in Section 5 (Kinchela Bench and Fattorini Island). These rectified images provide a data source in which to quantify rates of bank erosion within a ± 4 m error between individual photos. It draws upon the 1942, 1956, 1974, 1982, 1997 and 2003 aerial photographs. The 1942 photograph provides an indication of channel dimensions in a period of below-average flood activity prior to the large floods in 1946, 1949 and 1950. The 1956 and 1974 photographs represent a period of above-average flood activity while the 1982 – 2003 photographs represent another period of below-average flood activity.

6.4.1 *Kinchela Bench*

Kinchela Bench — as identified in Section 5 — is the most actively eroding section of the Lower Macleay River with the unusual occurrence of bench erosion on the inside of the bend. An analysis of the ortho-photographs indicates that the low bench at Kinchela Bend has eroded by up to 37 m since 1942. The greatest rate of bank erosion between individual time periods occurred between 1942 and 1956 at the apex of the bench — directly opposite Kinchela village (Figure 18). This rate of erosion has slowed at the apex since 1974 but increased at the upstream limb (immediately downstream of the Kinchela Creek confluence – Figure 18). It is most likely that the concave bank at Kinchela was rocked following the recommendations of the 1934 report. As such, the outer bank at Kinchela became resistant to erosion, halting rates of concave bank erosion and promoting the erosion of the inner bend. Net gains of fluvial sediment (*i.e.* bed aggradation) in this section of Fluvial Reach 3 will ultimately result in an adjustment of channel dimensions with the preferential erosion of the inner bend (the only deformable channel margin).

While large floods appear instrumental in shifting sediment into this reach and eroding the bench margin, it is clear that wind and/or boat waves also actively erode this site. A bank exposure experiment over a 72–hour period (with a prevailing southerly wind) clearly demonstrated the importance of wind and/or boat waves in eroding Kinchela Bench at mid-high tide (Figure 19a-b). This experiment further indicated the notching of a sand unit immediately overlying the basal estuarine clays resulted in active (~ 1 m) block failure (Figure19c-d). The basal estuarine clay unit eroded marginally (< 5 cm) over the 72–hour period but the notching of the overlying sand units produced the rapid rate of bank collapse. The Kinchela Bench therefore, is most susceptible to waves of any kind (southerly and northerly generated wind waves and boat waves) at mid-high tide.

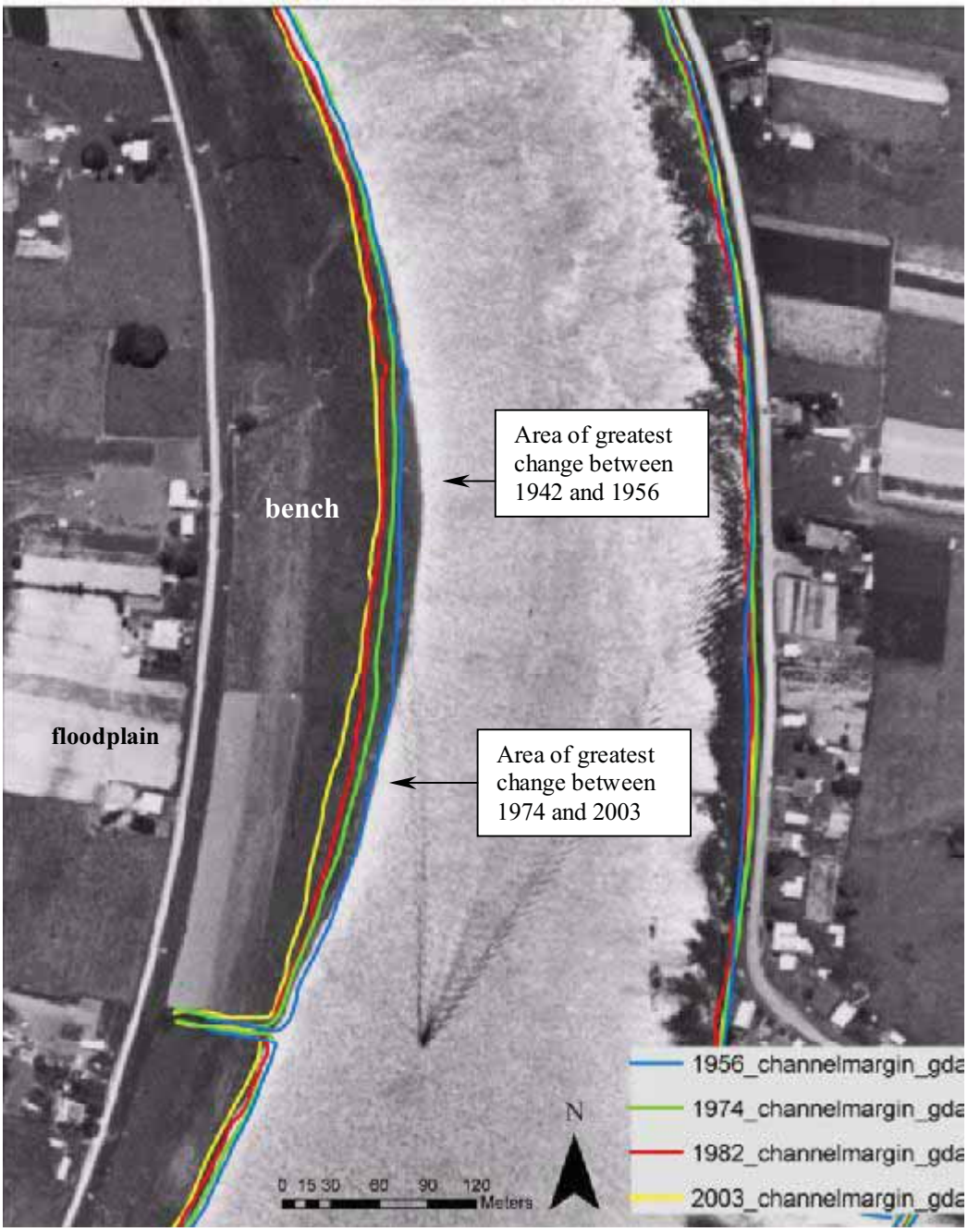

Figure 18 Ortho-photograph of Kinchela Bench in 1942 with channel margin locations for 1956 – 2003 (derived from ortho-photographs). Flow is from bottom to top.

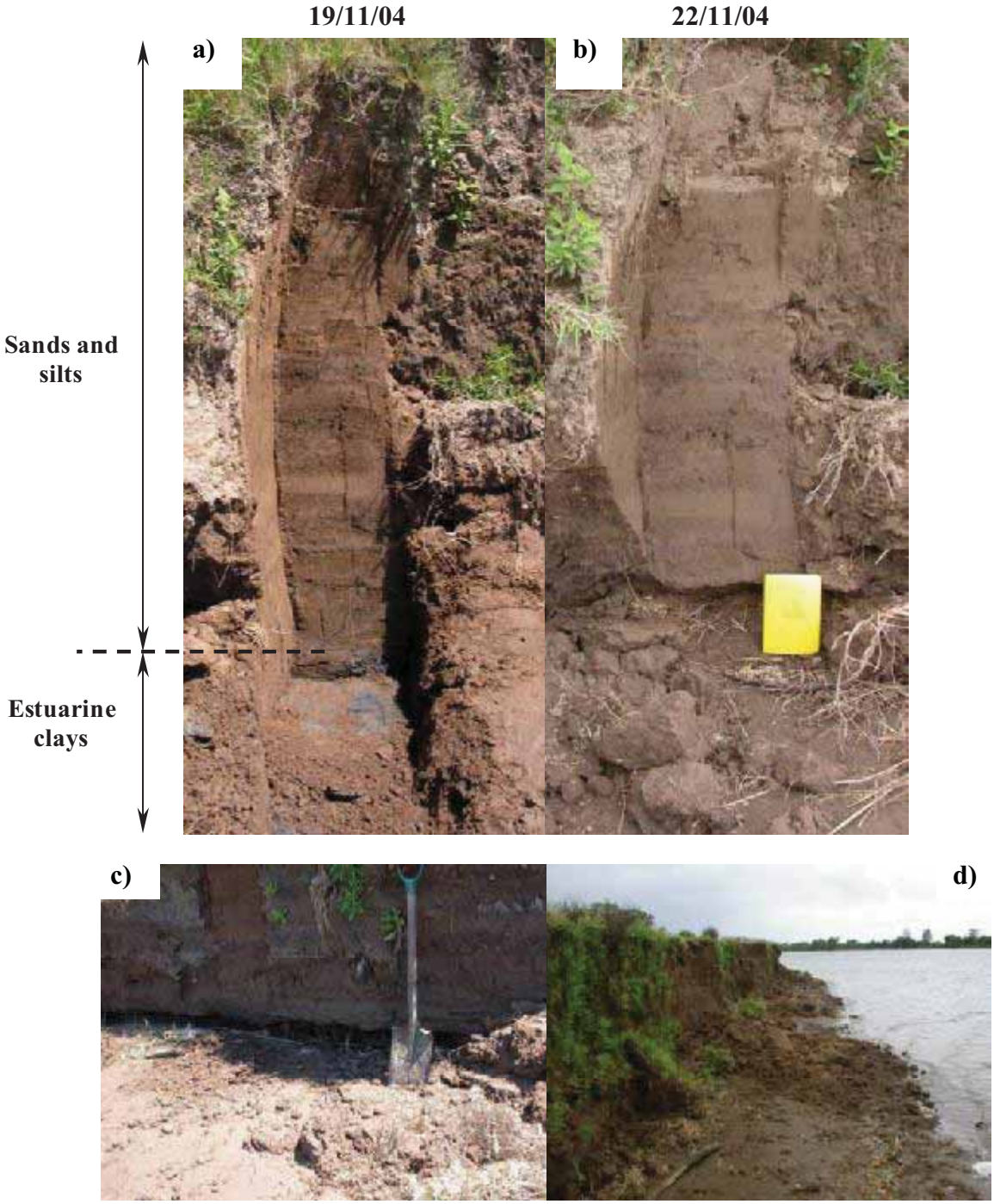

Figure 19 Bank exposure experiment at Kinchela Bench. **a)** Clean vertical exposure on 19/11/04; **b)** Notch development in 72 hours from a southerly wind; **c) – d)** Erosion of sandy alluvium overlying the basal clays results in undercutting with subsequent block failure.

6.4.2 *Fattorini Island*

Fattorini Island has also undergone major changes since 1942 with an overall reduction in island size, but with the greatest changes occurring at the head and tail of the island (70 and 35 m respectively; Figure 20). As with Kinchela Bench, rates of erosion at Fattorini Island varied spatially with the greatest rate of erosion between an given time interval occurring in the period from 1942 – 1956. This period of enhanced flood activity occurred when there was little to no riparian vegetation, increasing the susceptibility of the riverbanks to ongoing erosion, resulting in the loss of 6000 m^2 (~1.5 acres) of land at the head of the island (Figure 20). In contrast, the tail of the island has experienced the greatest rates of erosion since 1982. The erosion of Fattorini Island has been further compounded by the prevalence of rock on the outer bend making Fattorini Island more likely to erode. It is most likely that Fattorini Island will continue to erode from fluvial processes and from wind and/or boat waves at both low and high tide given the rocked outer margin, the evidence of bed aggradation upstream of Fattorini Island (Figure 17) and the current 'deep water' bank profile.

7.0 A SUMMARY OF CONDITION FOR THE MACLEAY PROCESS ZONES

Table 4 presents a summary of the physical condition of each of the process zones, based on extent and types of erosion, the extent of 'naturally' stable banks and the spatial distribution of riparian vegetation. It provides a snap shot of the current physical condition and presents an indication of the future impacts and the likelihood of physical improvement. In general, the marine flood-tide process zone is in the best physical condition with the highest percentage of naturally stable banks and the least amount of erosion. In contrast, the fluvial process zone is in poor-moderate condition and has the greatest extent of erosion, extensive rockworks, major levee alteration and major tributary modification. The transitional process zone is also in poor condition with the greatest percentage of rocked stable banks, major levee alteration, little to no native riparian vegetation on the trunk stream and major tributary modification.

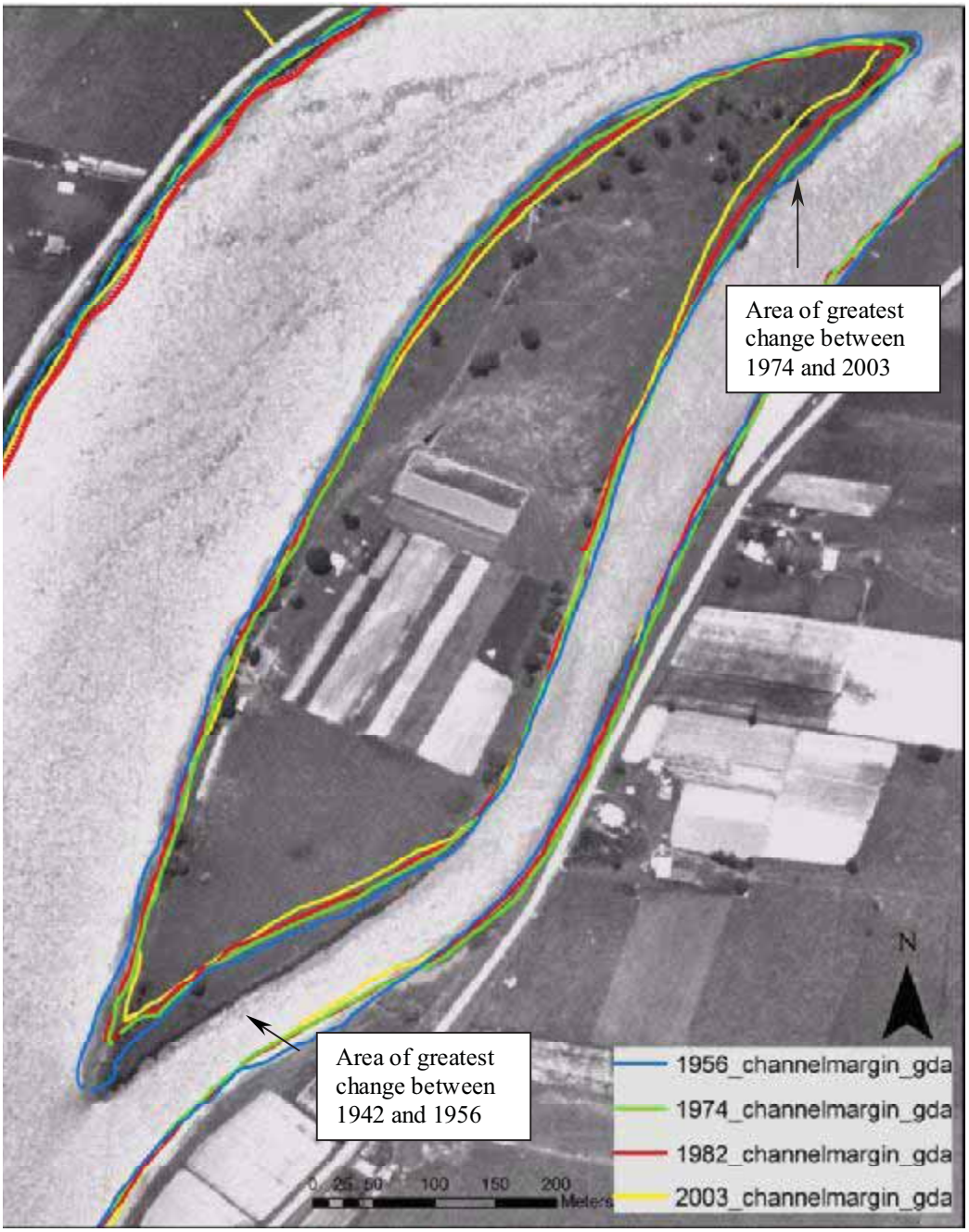

Figure 20 1942 ortho-photograph of Fattorini Island with channel margin locations for 1956–2003 (derived from ortho-photographs). Flow is from bottom to top.

Table 4 Summary of the physical condition of the process zones of the Macleay Estuary

PROCESS ZONE	PRIMARY CHARACTERISTICS	NATURE OF IMPACTS	CONDITION	RECOVERY POTENTIAL
FLUVIAL	• Three reaches dominated by fluvial processes. • Reach 1 – Gravel bed reach, confined with bedrock outer margins. Localised mass failure of entire alluvial channel margin, controlled by fluvial processes. • Reach 2 – Gravel-sand bed reach. First major depositional reach in the process zone. Onset of wind and /or boat wave erosion. Extensive rockwork. • Reach 3 – Sand bed reach with extensive rockwork, in-channel sedimentation. Slab-and-block failure of inset features (*e.g.* Kinchela Bench, Fattorini Island).	• Greatest extent of erosion and only occurrence of severe erosion. • 22 % of stable banks are rocked. • Reach 1 – aggregate extraction, widespread stock impacts. • Reach 2 – dredging of main channel, levee construction, channel expansion. Belmore River and Kinchela Creek modified severely by drainage works. Loss of continuous native riparian zone. • Reach 3 – dredging of main channel, levee construction. Loss of continuous native riparian zone.	Poor-moderate	• ***Reach 1 – Moderate***. This reach has bedrock outer channel margins which are well vegetated and naturally stable. • ***Reach 2 – Poor***. This reach is greatly modified with large lengths of channel margin that are rocked and/or lacking riparian vegetation. Given the its landscape position, this reach will always be a major depositional zone. • ***Reach 3 – Poor***. This reach will also receive ongoing terrestrially-derived sediment
TRANSITION	• Dominated by fluvial and marine processes with the presence of marine-derived shoals reworked by tidal processes. • Formation of intertidal flats.	• High percentage of rockwork on the Macleay River with active minor and moderate erosion on remaining alluvial margins. • 43 % of stable banks are rocked. • Loss or alteration of levees. • Tributary modification. • Widespread stock impact. • Erosion dominated by wind and/or boat waves.	Poor	• **Macleay River – *Poor***. The high proportion of rock and the diminished riparian zone results in a greatly modified channel margin. Sediment supply from the fluvial process zone along with marine-derived sediment will also result in continued erosion of alluvial channel margins (*e.g.* Pelican Island).
MARINE	• Dominated by marine processes with the presence of marine-derived shoals reworked by tidal processes. Formation of sand and intertidal flats.	• Lowest percentage of erosion and highest percentage of naturally stable banks. • Localised stock impacts. • Wind and/or boat wave disturbance.	Moderate-good	• **Macleay Arm – *High.*** The large extent of native vegetation and naturally stable banks will increase the potential to improve the physical condition

8.0 GAPS IN THE DATABASE RELEVANT TO RIPARIAN LAND MANAGEMENT, BANK EROSION AND SEDIMENTATION ISSUES

The data compilation and mapping stage has identified a number of important key gaps in the existing database for the Lower Macleay River. These gaps relate to critical questions regarding riparian land management, bank erosion and sedimentation. As these issues are inter-dependent they will be collectively outlined below.

The causes and preferred treatment options for a range of typical bank erosion scenarios cannot be answered at present as this study has only qualitatively assessed the primary causes of erosion in the Lower Macleay River, which are:

- Fluvial processes
- Wind and/or boat waves
- In-channel sedimentation
- Stock disturbance/reduced riparian vegetation
- Presence of rockwork on adjacent banks

It is important to note however, that very few alluvial channel margins (especially in Fluvial Reach 2 and 3 and the transitional process zone) have riparian vegetation with any structural or floristic integrity, greatly reducing bank strength in most locations. Furthermore, these primary causes have been shown to vary between process zones indicating that there is no one major cause of erosion for the entire Lower Macleay River.

The Lower Macleay River, as shown in Section 6.0, has undergone major direct modification throughout the 20th century. In addition, the middle to upper Macleay River has also been vastly transformed since European settlement, resulting in a greatly modified sediment supply regime. Both these factors partly determine where sedimentation and bank erosion currently occurs. To date however, there has been very little compilation of this information in which to make an informed assessment of the primary causes of erosion and sedimentation in the Lower Macleay River. It is this historical context that will provide an important insight into current channel processes. Hence, it is suggested that the following gaps be addressed in the context component of the process study.

1. Systematic collation of planform changes for the Lower Macleay River. This should focus on all styles of lateral adjustment (*i.e.* channel expansion, changes to meander wavelength, sinuosity within each of the three process zones) and should include the georeferencing of historical parish maps and/or portion plans. This will provide the context to current channel processes.

2. Systematic collation of historical hydrographic surveys demonstrating where bed elevations have changed.

3. Examination of changes to bankfull cross-sectional capacity at areas of accelerated change and representative sections of process zones. This should use photogrammetrically derived topographic data and should be compared with permanent bench-marked cross-sections (see following recommendations).

4. Systematic collation of the nature and timing of tidal dredging in the Lower Macleay River (*i.e*. how much, where and when?). This component should also aim to determine what proportion was entirely removed from the system.

In order to more confidently determine the causes of current bank erosion it is suggested that a number of process-based investigations be undertaken. These include:

1. Detailed topographic analysis from current bathometric data (*i.e* cross section every channel widths distance) on trunk stream with an equivalent analysis on tributaries (*i.e* Clybucca Creek, Belmore River and Kinchela Creek). This will provide a more thorough assessment of current sediment storage patterns.

2. Construct a sediment budget for the Lower Macleay River from the bathometric data, floodplain topographic data and the ortho-photographs. This should aim to assess sediment storage in each of the identified process zones while also incorporating current research undertaken by Ashley and Graham from UNE.

3. Determine the relative contribution of wind and boat waves for deep and shallow water profiles. A controlled experiment (*sensu* Nanson et al., 1994) in targeted areas that measures wave height, wave direction, wind speed and wind direction, bank erosion, sediment production and turbidity will quantitatively determine the relative contribution of wind and boat waves for the Lower Macleay River.

4. Establish permanent bench-marked cross-sections from floodplain to floodplain in areas of accelerated change and in representative sections of each process zone. These should be located using differential GPS and marked adequately for long-term monitoring.

A process study that investigates both the historical and current bank erosion processes will ultimately provide Kempsey Shire Council and DIPNR a more valuable database in which to make and develop management policies relevant to bank erosion and sedimentation.

9.0 REFERENCES:

Ashley, P. and Graham, B. (2001). Heavy Metal loadings of streams in the Macleay River catchment. Report to Mid North Coast Catchment Management Board, NSW Department of Mineral Resources and Armidale Dumaresq Council.

Cohen, T.J. (2003) Late Holocene floodplain processes and post-European channel dynamics in a partly confined valley of New South Wales, Australia. School of Geosciences, University of Wollongong unpublished PhD thesis.

Dalrymple, R.W., Zaitlin, B.A., and Boyd, R. (1992). Estuarine facies models: conceptual basis and stratigraphic implications. Journal of Sedimentary Petrology, 62, 1130 – 1146.

Department of Lands (1934). Report by Departmental Committee on Erosion – Macleay River Erosion.

Erskine, W.D. and Warner, R.F., 1988. Geomorphic effects of alternating flood-and drought-dominated regimes on NSW coastal rivers. In: R.F. Warner (Editor), Fluvial Geomorphology of Australia. Academic Press, Sydney, 223-266.

Erskine, W.D. and Warner, R.F., 1998. Further assessment of flood- and drought-dominated regimes in south-eastern Australia. Australian Geographer, 29(2): 257-261.

Hails, J.R. (1964). The geomorphological history of the Macleay deltaic plain. Australian Journal of Science, 27 (1): 214-215.

Heap, A.D., Bryce, S and Ryan, D.A. (2004). Facies evolution of Holocene estuaries and deltas: a large-sample statistical study from Australia. Sedimentary Geology, 168, 1 – 17.

Laurie, Montgomerie & Pettit Pty. Ltd. (1980) New South Wales Coastal Rivers Floodplain Management Studies Summary Report Macleay Valley, 1 – 30.

Nanson, G.C., Von Krusenstierna., and Bryant, E.A. (1994). Experimental measurements of riverbank erosion caused by boat-generated waves on the Gordon River, Tasmania. Regulated Rivers: Research & Management, 9, 1 – 14.

Patterson Britton & Partners Pty Ltd (2003). Draft Macleay River Sand and Gravel Resource Assessment. Report to the Department of Land and Water Conservation.

Roy, P.S. (1994). Holocene estuary evolution-stratigraphic studies from southeastern Australia. In Dalrymple, R.W., Boyd, R., and B.A. Zaitlin (Eds) Incised valley systems: Origins and sedimentary sequences. Society for Sedimentary Petrology, Special Publication 51, 241 – 264.

Roy, P.S., Thom, B.G. and Wright, L.D. (1980). Holocene sequences on an embayed high-energy coast: an evolutionary model. Sedimentary Geology, 26, 1 – 19.

Roy, P.S., Cowell, P.J., Fierland, M.A., and Thom, B.G. (1994). Wave-dominated coasts. In Carter, R.W.G. and Woodroffe, C.D. (Eds), Coastal Evolution: Late Quaternary shoreline morphodynamics. Cambridge University Press, Cambridge, 121 – 186.

Sloss, C.R., Jones, B.G., Murray-Wallace, C.V., and McClennen, C.E. (in press). Holocene sea level fluctuations and the sedimentary evolution of a barrier estuary: Lake Illawarra, New South Wales, Australia. Journal of Coastal Research.

Telfer, D. (2005) Macleay River estuary data compilation and mapping study. Report prepared for Kempsey Shire Council.

Umitsu, M., Buman, M., Kumiko, K and Woodroffe, C.W. (2001). Holocene palaeoecology and formation of the Shoalhaven River deltaic-estuarine plains, southeast Australia. The Holocene, 11, (4), 407 – 418.

Walker, P.H. (1963) A reconnaissance of soils in the Kempsey District, N.S.W. CSIRO Soils and Land Use Series, 44.

Walker, P.H. (1970) Depositional and soil history along the Lower Macleay River, New South Wales. Journal of the Geological Society of Australia, 16 (2): 683-696.