GREATER TAREE CITY COUNCIL

MANNING RIVER
ESTUARY PROCESSES STUDY

SEPTEMBER, 1997

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CONSULTING ENGINEERS

GREATER TAREE CITY COUNCIL

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FOREWORD

The Estuary Management Policy is one of a suite of natural resource management policies being implemented by the NSW Government using the principles of total catchment management and ecologically sustainable development. The policy focuses on tidal rivers and coastal lakes which have been adversely affected by catchment development.

The goal of the policy is to achieve integrated, balanced, responsible and ecologically sustainable use of the State's estuaries. A specific objective of the policy is to encourage preparation of long term management plans for each estuary in which all values and uses are considered.

The policy promotes cooperation between various authorities, catchment management committees, landholders and estuary users in the development and implementation of management plans. Whilst the approach is strongly community focused, it is based on implementation by local Councils rather than by private landholders.

The process by which the policy seeks to develop and implement estuary management plans can be summarised in the following stages:

- formation of Estuary Management Committee,
- compilation of existing data,
- Estuary Processes Study,
- Estuary Management Study,
- draft Estuary Management Plan,
- draft Plan review,
- Plan adoption and implementation.

The Manning River Estuary Processes Study constitutes the third stage of the implementation process. It has been prepared for Greater Taree City Council by Webb, McKeown & Associates.

1. INTRODUCTION

The Manning River estuary is located within the Greater Taree City Council area on the Mid North Coast of New South Wales, about 300 km north of Sydney (see Figure 1). The estuary/river system is unique on the NSW coast because it has two natural entrances, both of which are predominantly open. The catchment has an area of 8420 km^2, which makes it the sixth largest on the coast of New South Wales.

The actual study area comprises the tidal waterways of the Manning River, Lansdowne River, Dawson River and associated tidal creeks (see Figure 1). These waterways have a total surface area of around 21 km^2 and a mean tide volume of approximately 70 Mm^3. Also included in the study were the foreshores, adjacent lands and coastal entrance areas at Harrington and Farquhar Inlets. Consideration has also been given to the wider catchment insofar as it affects the issues addressed.

Historically the Manning River has been important as an area of timber getting, shipbuilding, mixed farming, dairying, fishing, oyster growing, tourism and light secondary industry. The waters of the estuary provide a multitude of diverse uses, ranging from recreational pursuits such as swimming and sailing through to commercial fishing, oyster farming and gravel extraction; from fish and water birds breeding grounds to receiving waters for treated sewage.

In recognition of the various uses and pressures facing the estuary, Council, through its Estuary and Coastline Management Committee, and with the assistance of the State Government's Estuary Management Program, proposes to prepare a Management Plan for the estuary. This Estuary Processes Study follows on from an earlier Data Compilation Study (PWD, 1990), and is a review and re-evaluation of existing and new data on the physical, water quality and biological processes of the estuary, and human use impacts on those processes. Baseline conditions for the various processes, and interactions between the processes, have been examined and quantified where possible.

A number of concerns have been raised by the community over recent years with respect to the Manning River Estuary. These concerns will be specifically addressed by the Estuary Management Plan when it is prepared. Information relevant to the future examination of these concerns has therefore been included in this Processes Study. The identified community concerns include:

- the characteristics and behaviour of the Manning River's entrances at Harrington and Old Bar (Farquhar Inlet) including the net sediment transport into the inlets,
- bank erosion and sedimentation and general shallowing of the river and creeks by deposition of sand and gravel,
- water quality input into the river and creeks, and the effects of effluent discharge, stormwater pollution, agricultural discharges and industrial waste,

- sediment and water quality problems from existing and new urban and rural developments,
- effects of wetland drains and canals through low lying land containing acid sulphate soils,
- fish productivity and the impact of harvesting on fish availability,
- protection of wetlands and foreshore aquatic vegetation by physical means and public education,
- provision of boat ramps and recreational facilities, and enhancement of general tourism development,
- development controls for estuary foreshores, and provision of public open space,
- conflicts between waterway users, particularly during peak holiday periods,
- the need to ensure the long term conservation of important values of the estuary including scenic quality, ecosystem productivity, and species diversity, public access and recreational amenity,
- long term effects of sedimentation in the Harrington Lagoon and Back Channel areas.

2. CATCHMENT CHARACTERISTICS

The Manning River Data Compilation Study (PWD, 1990) included a review of catchment characteristics. Following on from that report, this study examines those aspects for which new or additional information has become available, plus any characteristics of particular importance in developing a fuller understanding of estuarine processes.

2.1 Topography

The Manning Valley drains from the Mount Royal Range and the Great Dividing Range in the west, the Barrington Tops in the southwest, and the Bulga and Comboyne Plateaux in the north (see Figure 2). To the east of Wingham, the river forms a coastal plain with an estuary delta that eventually discharges into the South Pacific Ocean (Tasman Sea) through both Harrington and Farquhar Inlets.

Topographically, the Manning Valley can be divided into three major units according to structure and elevation. These land units include:

- the coastal plain and estuary,
- the ridges and valleys,
- the dissected uplands and plateaux.

2.1.1 Coastal Plain and Estuary

The Manning River Valley includes a small section of coast between Crowdy Head/Harrington and Old Bar. Along the coast there is a narrow strip of sand dunes which forms a barrier between the ocean and coastal plain. At the back of the dune system there are swamps and marshes separated by low lying sand plains which drain back into the Manning River. Where drainage works have taken place these low lying areas have generally been converted to pasture land for dairying (Birrell, 1987).

Further west, towards the middle and upper estuary areas near Taree and Wingham, the Manning River is flanked by extensive riverine floodplains. The floodplains consists of alluvial deposits which form a delta through which the river has cut large meanders. The banks of these channels tend to have slightly elevated levees which fall gently away from the river into low lying, poorly drained swamps and marsh land.

2.1.2 Ridges and Valleys

West of Wingham and the floodplain area the land rises moderately to form the second major land unit consisting principally of ridges and valleys. Terrain varies according to the erosion characteristics of the soil parent materials with the result that the landscape has a rolling appearance in some areas while elsewhere it tends to be hilly and heavily dissected (Dyson, 1985).

2.1.3 Dissected Uplands and Plateaux

The boundaries of the Manning Valley in the north and west are delineated by extensive areas of dissected uplands and plateaux. A number of isolated topographic features exceed an elevation of 1500 metres, but generally the area is within the 500 metre to 1100 metre range. The edges of the plateau formations usually have very steep escarpments. The plateau streams flow in broad valleys with gentle gradients, but when they reach the escarpment they plunge over waterfalls into the rugged foothills below.

2.2 Geology

2.2.1 Catchment Geology

The Manning River catchment is part of the New England Geosyncline, a Paleozoic (250 to 600 million year old) sedimentary basin, which lies between Port Stephens and Queensland. Catchment geology is characterised by a range of sediments and metamorphic rocks overlain by further sediments. Extensive faulting and folding of the Paleozoic sediments has produced the complex drainage patterns and steep landforms evident in the catchment. More recent Tertiary (5 to 65 million year old) basalt overlies granite on the western perimeter of the catchment in the Barrington-Gloucester Tops area.

Mapping sourced from the NSW Department of Mineral Resources has been included in the Data Compilation Study at Figure 4.2 (PWD, 1990).

2.2.2 Coastal Plain Fluvial Deposits

The coastal plain/river delta exhibits extensive deposits of much more recent Quaternary (10 000 to 1.8 million years old) alluvium including clay, silt, sand and gravel (see Figure 3). The geology of the delta has been examined and classified into four distinct fluvial depositional units (Jenks, 1982):

- *Scotts Creek Formation:* the oldest fluvial deposits which influenced development of the delta. This unit forms the low hills on Mitchells and Oxley Islands and consists of gravels mixed with silty sands.
- *Kolodong Formation:* which includes gravels and boulders in the lower and thicker portion and silts in the upper portion. This formation occurs mainly between Wingham and Mondrook Point (Kolodong) and in meander bends of the lower valley. Gravel outcrops of this formation also occur in delta channels near Wingham and Taree and in a reach of the South Passage,

- *Melvan Formation:* which is also evident in the meander bends of the lower valley and in the central delta areas. These sediments mainly consist of deep friable fine sands and silts, often reddish brown in colour, and some gravels and cobbles. Erosion of these banks constitutes much of the current river bed sediments.
- *Unaltered Holocene Alluvia:* which is the most recent and extensive fluvial unit. This unit particularly occurs in levees along river channels and consists of very fine sands and silts overlaying gravels.

2.2.3 Coastal Plain Bedrock, Estuarine and Marine Deposits

In addition to the fluvial deposits, bedrock outcrops are evident in the coastal plain at Abbotts Falls, Mondrook Point and Tinonee. Remnant estuarine and marine deposits also remain from previous inter-glacial periods (Jenks, 1982). The remnant estuarine deposits are mainly present away from the more recent alluvial deposits, around the lower valley margins, along the Dawson River and particularly in the Lansdowne River lowlands. They consist of silt and clay lagoon deposits and silty sand delta sediments grey-green in colour with shell fossils.

Marine deposits form a barrier dune system which runs in a flat arc from south of Old Bar to Crowdy Head north of Harrington. The barrier consists of a series of ridges which together form a dune system. On Mitchells Island this system extends up to 400 m inland. Both river entrances, which cut the coastal barrier, are generally heavily shoaled by beach and near shore sands which have been brought into the estuary by tides.

2.3 Soils

2.3.1 Catchment Soils

As a result of the dominance of sedimentary parent material, soils in the Manning Valley are mainly podzols. These soils are derived in-situ, light coloured and highly leached. They vary from brown to yellow and red depending on the parent material.

2.3.2 Coastal Plain Soils

Most of the coastal depositional plain consists of easily erodible and relatively loosely aggregated fine grained loams and areas of gravel. The resulting soils tend to vary according to the source of the parent materials (see Figure 3). As an example Floyd (1990) cites alluvial flats near the town of Wingham as having been enriched by basalts of the Comboyne and Bulga Plateaux and Barrington - Gloucester Tops. Conversely, alluvial soils which occur on terraces beside the Lansdowne River have not had access to such enrichment. These soils have a lower fertility being essentially a relatively dry sandy alluvium.

Closer to the coast where dunes and beach ridges occur, sandy podzols and peaty podzols are evident on sandy parent material which allows unrestricted drainage over much of the area. Where peaty podzols occur, thin humic pans may exist at relatively shallow depths. These podzol soils tend to be generally of low fertility and may be very acid.

2.3.3 Acid Sulphate Soils

Acid sulphate soils are the result of the deposition of organic rich sediments in coastal embayments during and after the last ice age some 10 000 years ago. Bacteria in the presence of sea water then reduce the available plant sulphates to form iron sulphide or iron pyrite. When these soils are drained due to either natural or artificial lowering of the water table, pyrite is oxidised to sulphuric acid and an acid leachate is formed. This leachate then takes iron and aluminium from the soil, and when washed into estuaries, can among other problems result in the death of fish and crustaceans.

Department of Land and Water Conservation acid sulphate soil maps indicate that large areas of the Manning River estuary have an acid leachate potential (see Figure 4). The main areas of acid sulphate soils in the Manning Valley are in the Great Swamp and the Ghinni Ghinni Creek areas adjoining the Lansdowne River. Significant drainage has been undertaken in these areas, including construction of the 6 km long Pipe Clay Canal. These works have lowered the water table and created acid leachates which are an issue of significance for the estuary.

2.4 Climate

The Manning Valley has a warm temperate to subtropical climate. The climate is influenced by topography, latitude, local differences in altitude, proximity to the ocean, and temperature and precipitation patterns determined by the Tasman Sea.

2.4.1 Rainfall

Rainfall varies throughout the valley according to distance from the Tasman Sea and proximity to the more elevated uplands. The highest rainfall occurs around the headwaters of Dingo and Cedar Party Creeks in the Bulga and Comboyne Plateaux. The annual rainfall in this area is around 1650 mm, while the annual rainfall at Taree is 1230 mm, and for the valley generally is 1100 mm. A Bureau of Meteorology annual rainfall distribution map was included in the Data Compilation Study at Figure 4.3 (PWD, 1990).

Rainfall can be attributed to a number of different weather systems (Dyson, 1985) including:

- tropical or subtropical lows over the south Coral Sea (in summer),
- low pressure systems and cold fronts from the west and south west,
- localised thunderstorms,

- upper atmosphere low pressure cells which bring widespread rains of long duration.

The valley is subject to a dominant summer rainfall pattern with most rainfall resulting from the passage of tropical or subtropical east coast lows over the south Coral Sea (AWACS, 1989). The wettest period of the year extends from late summer to early winter, while from late winter to early spring there is a dry season which corresponds with the north coast fire season. Dry westerly winds which occur from August to September complement the dry seasonal conditions by further reducing soil moisture.

The highest rainfall occurs along the plateau escarpments in the north and north-west of the valley because they lie across the rain bearing winds from the east and south-east (Birrell, 1987). In the west, rainfall is reduced to some extent by the rain shadow effect of the escarpment. Flooding occurs periodically in the Manning Valley, particularly in the area between Wingham and the coast.

2.4.2 Temperature

Winter temperatures are mild over most of the area except for the more elevated back country. In the uplands minimum winter temperatures fall below 5 °C, on a regular basis and may sometimes fall below 0 °C. Coastal areas are generally free of frost while other lowland areas occasionally experience light frosts.

The hottest months include January and February when temperatures may rise in excess of 28 °C. Periods of extremely high temperatures may sometimes occur, but these are usually tempered by cooling sea breezes. Periodically the Manning Valley experiences short periods of extreme drought but such conditions occur infrequently, about one year in twelve (Birrell, 1987).

2.4.3 Prevailing Winds

The prevailing winds during the summer are from the north-east and during winter are from the west and south-west. Westerly winds tend to be cold and dry although when on occasions they occur in the warmer months they can be hot and dry and may support intense bushfires. Wind roses for Taree and Harrington are given in the Data Compilation Study at Figure 4.4 (PWD, 1990).

2.4.4 Evaporation

Monthly average annual evaporation from a standard Class A pan with bird guard at Taree are available from the Bureau of Meteorology, and are as follows:

Month:	J	F	M	A	M	J	J	A	S	O	N	D
Evaporation (mm):	171	141	128	96	65	54	62	84	112	143	154	173

These evaporation rates are generally considered applicable for exposed locations away from significant water bodies. Local meteorological effects (mainly humidity) near coastal inlets can cause reductions of 5 to 10 percent. These evaporation rates also do not include an allowance for heat loss due to water exchange with the ocean and other localised effects such as sheltering, radiation from the bed and water depth.

2.4.5 Greenhouse Effects

Based on the latest research by the United Nations Intergovernmental Panel on Climate Change (IPCC, 1996), evidence is emerging on the likelihood of climate change and sea level rise as a result of increasing "greenhouse" gasses. In this regard, the following points can be made:

- greenhouse gas concentrations continue to increase,
- the balance of evidence suggests human interference has resulted in climate change over the past century,
- global sea level has risen about 0.1 m to 0.25 m in the past century,
- many uncertainties limit the accuracy to which future climate change and sea level rises can be projected and predicted.

The IPCC best estimate projected sea level rise for the year 2050 is 0.2 m, with a range of between 0.07 m and 0.39 m.

On a regional basis the CSIRO Climate Change Group predicted increased air and water temperatures, and greater frequency and intensity of severe storms for the NSW coastline (CSIRO, 1995). According to these predictions, east coast lows, which are the main causes of storms and floods on the mid north coast, would be more intense, leading to increased occurrence of gale force winds and flooding. However, in a more recent paper by the same group (CSIRO, 1996) the effects of sulphate emissions have now also been considered. The inclusion of these emissions in climate models has resulted in a possible reduction in storminess and rainfall.

2.5 Land Usage and Zoning

Land use and zoning in the Manning Valley reflects the topography, soils and climate of the area. Most development is concentrated around the upper estuary (Taree-Wingham) area, as a result of historical development patterns associated originally with shipping access and then with rail and road access. From this centre, rural development covers the lower valley floodplain and extends up the river along tributary valley floors including some foothills and plateau tops.

2.5.1 Catchment Zoning

The Manning catchment (see Figure 2) covers six local government areas. The following table lists the relevant local governments and divides the respective catchment areas into each of four major zoning categories (Urban and Farmlets, Rural, Environmental Protection, and Forestry).

Table 1: Zoning Areas within the Manning River Catchment

COUNCIL	Greater Taree	Gloucester	Hastings	Walcha	Nundle	Scone	Total
AREA (km^2)	3100	2500	100	1500	400	800	8400
Urban and Farmlets	150	50					200
Rural	2050	1500		550	100	500	4700
Environmental Protection	200	100	100	500	100	100	1100
Forestry	700	850		450	200	200	2400

2.5.2 Catchment Land Usage

Approximately 30% of the catchment has been cleared of native forest and is used for pasture. The coastal plain/estuary area is used mainly for dairy production, and the upper valley and low hills are mainly used for beef production. The remaining 70% of the catchment is moist open forest with pockets of rainforest as well as significant areas of dry open forest.

Of the estimated 45 000 residents of the catchment, approximately 23 000 or 50% live in the Taree-Wingham urban area. A further 15% (7000) live in smaller towns and villages such as Gloucester, Harrington and Coopernook, although there are only around 2500 in the lower valley/estuary area. In total these urban areas cover less than 1% of the catchment.

Of the remaining population most (13 000 or nearly 30%) live on small farms, mainly in the lower valley/estuary area, which occupy around 5% of the catchment. Only 4% of residents live on farms over 150 hectares although these occupy 55% of the catchment. The remaining 40% of land area comprises state forests and national parks.

2.5.3 Estuary Foreshore Zoning

Zoning for the estuary is set out in LEP 1995 City of Greater Taree (see Figure 5). The LEP shows most of the estuary has been zoned for Rural Valley Agriculture 1(b1), although significant areas around the entrances have been zoned for Environmental Protection. Some parts of the bank to the high water mark have been zoned for Rural General or Rural Farmlets, and Coocumbac Island near Taree has been zoned as a Nature Reserve. The Cundletown, Taree and Wingham foreshore areas are zoned for a mixture of urban uses including industrial, residential and open space.

The development objectives, identified by the LEP in relation to estuary management issues are (for the main Rural zonings):

- efficient and sustainable use of the area for agriculture (including oyster farming),
- the protection of soil stability,
- control of drainage on land affected by acid sulphate soils,
- conservation of environmental values and visual amenity.

The relevant development objectives identified for environmental protection (Habitat) zones are:

- protection of features which are environmentally sensitive or of particular environmental interest,
- regulation to avoid destroying or damaging habitat ecosystems (particularly wetlands, significant vegetation or wildlife).

3. HYDRODYNAMICS

The Data Compilation Study (PWD, 1990) included a search for relevant physiographic data which was collated and reviewed in terms of fluvial, marine and human impact characteristics. The estuary's response to these inputs was also discussed in brief.

As part of the current Estuary Processes Study, hydrodynamic information in the Data Compilation Study was again reviewed, and the assessment updated based on information which has become available since the Data Compilation Study was completed.

3.1 Fluvial Hydrodynamics

3.1.1 Fluvial Flows

Since completion of the Data Compilation Study, a Flood Study of the Manning River has been undertaken (PWD, 1991). This study uses numerical hydraulic modelling and a combination of rainfall records and hydrologic assessments to relate recorded catchment flows with model results. Flood flows and heights have been determined for 0.5%, 1%, 2% and 5% Annual Exceedance Probability (AEP) events.

The interaction between catchment runoff and ocean storm tides in the river estuary was also examined by the above studies. Tidal gauging in 1981 was used to calibrate the models for tidal flows, elevated ocean levels were estimated for the same range of AEP as for fluvial flows (AWACS, 1989), and combined fluvial and ocean storm tide flood estimates were then made.

Flows along open channels such as the Manning River are determined by the slope of the water along the channels and the conveyance of the channels. Conveyance is a hydrodynamics term which describes the combined effects of channel width, depth and roughness on flows. The available data show that by far the greatest influence on flows in the Manning River is the lack of conveyance or the restriction to flow caused by the entrance shoals (Section 4.3). As a result, scour of the entrances during floods has a significant effect on flow patterns throughout the estuary.

The studies also show that flood flow volumes, directions and peaks are affected by:

- storm surge levels and wave setup at the entrances,
- ponding and draining into side basins which can result in flow reversal,
- relative timing and distribution of the rainfall and hence the various peak flood levels,
- quicker response times for the Lansdowne and Dawson Rivers when compared with the main river.

3.1.2 Runoff Flow Patterns

Assuming a similar rainfall distribution, because of the quicker response time of the Dawson and Lansdowne Rivers, excess rainfall in these catchments reaches the estuary before the main river. Flood flows in the Dawson are shorter and peakier than flows from the Lansdowne with the result that maximum flows in both systems are of a similar magnitude.

However, because flood rains are usually associated with tropical and sub-tropical depressions over the Pacific Ocean in summer, the rainfall distribution is highest in the Comboyne area and moves in a south-westerly direction. This storm/rainfall pattern helps establish elevated ocean levels at an early stage and a flow pattern which sees the Lansdowne River flood first followed by the Dawson River.

Under these conditions flows from the Lansdowne River would initially flow both upstream to Scotts Creek and then to Farquhar Inlet, or downstream to Harrington Inlet. The relative direction and strength of the flows would depend on the ocean storm level, and timing and size of the Dawson River and Manning River flows.

3.1.3 Fluvial Analysis

The following fluvial analysis is based on twenty five years of daily flow records for Killawarra 5 km upstream of the tidal limit at Abbotts Falls, Australian standard rainfall predictions (AR&R, 1987) and results from the Manning River Flood Study (PWD, 1991) and the Manning Valley Floodplain Management Study (LMP, 1980).

The table below gives the peak flood flows at various locations for estimated 1%, 5% and 50% AEP floods. Also included are estimates of the average and median flows based on daily records. The median and 1% and 50% AEP flows are also shown on Figure 6.

Table 2: Estimated Fluvial Flows

Location	Mean (m^3/s)	Median (m^3/s)	Peak 50% AEP (m^3/s)	Peak 5% AEP (m^3/s)	Peak 1% AEP (m^3/s)
Manning R (Abbotts Falls)	60	18	2100	8400	12800
Manning R (Taree)	63	19	1800	7800	12300
Dawson R (Upper)	1	<1	65	350	400
Lansdowne R (Upper)	2	<1	70	450	600
Lansdowne R (Lower)	3	1	75	550	950
Scotts Creek	2	<1	90	1400	2300
Manning R (South Channel)	13	3	330	2350	3300
Manning R (Harrington)	55	17	1200	4200	5700
Manning R (Farquhar)	15	4	400	3600	5500

The table shows that the mean and the median flows vary by over three times. This is because the median flow (the 50 percentile exceedance flow) does not include a significant flood flow component, whereas the mean flow includes flood flows. The fact that the two values differ so greatly is an indicator that flood flows are much greater than normal (non flood) flows.

As can be seen from the table, even small floods with a 50% AEP have a peak flow over 100 times the median flow. They also have a total volume of around 350 Mm^3 in 7 days which is over 30 times the median volume. The flows during major floods are over 500 times greater than median flows, and every year a flood with a peak flow of at least 100 times the median flow could be expected.

In contrast flood periods, analysis of flow records during the drought period in April 1980 show that flows at Abbotts Falls can drop to below 1 m^3/sec. Such large variations between drought and flood flows (over 10 000 times) are typical of NSW rivers.

The table also shows that peak flows down South Channel and through Farquhar Inlet during minor floods are much smaller proportionally than for major floods. This indicates that flood scour at Farquhar Inlet is an important part of the fluvial/flood process. Indeed, during major events such as the 1% AEP flood, peak flows at the entrances are approximately equal.

Note, peak flows are smaller at Taree than at Abbotts Falls because of the effects of floodplain storage in the reach downstream of Wingham. Further, although the Lansdowne River has a much larger catchment than the Dawson River (215 km^2 versus 100 km^2) peak flows in the two rivers are of a similar magnitude for minor floods. This effect is related to the shape of the catchments and the relative times it takes for the flows to concentrate.

3.2 Tidal Hydrodynamics

3.2.1 Ocean Levels and Wave Setup

Ocean water levels have an important impact on marine inputs to the Manning River estuary. Ocean levels are determined by the normal astronomic tide plus elevated levels caused by wave setup, storm tide effect, etc. Astronomic tides were examined as part of the Data Compilation Study (PWD, 1990). As is the case for all the NSW coast, there are two astronomic tides each day, with a mean tidal range of around 1.0 m and a mean spring range of around 1.4 m. The maximum range is less than 2.0 m.

Analysis of wave rider data from offshore Crowdy Head (SKP, 1982) showed that the daily significant wave height usually exceeds 1.0 m, is around 2.5 m for at least 10% of days, and around 4.0 m for more than 1% of days. A study of elevated ocean levels at Harrington and Farquhar Inlets (AWACS, 1989) found that the inshore wave climates at both inlets was determined by the offshore wave conditions plus refraction, shallow water effects and wave breaking.

Based on the assumptions made (including equal entrance depths), the AWACS study found that the inshore wave climates would be very similar and that elevated ocean levels would be marginally higher at Harrington. The estimated peak water levels at both entrances for selected recurrence intervals were:

	5%	2%	1%
Farquhar Inlet	1.8	1.9	2.0
Harrington Inlet	1.9	2.0	2.1

In addition to astronomic tides, wave setup and storm tide effects, ocean water levels at the Manning entrances are also affected by a number of other factors, such as (continental) shelf waves, which are related to ocean currents and vary around mean sea level. These changes are generally not considered significant in terms of ongoing estuarine processes, although they can be important in determining the impact of specific storms or flood events.

More widespread changes in the world's ocean levels are also predicted to occur as a result of increased greenhouse gas emissions (Section 2.4). The likely long term impacts of these increases on weather conditions and ocean water levels is discussed later as a human impact (Section 3.5).

3.2.2 Estuary Tide Levels

Incomplete records dating back to last century indicate that Farquhar Inlet has been closed at least nine times in the last 100 years and that the entrance at Harrington has always remained open (PWD, 1990). The following table sets out the recorded mean spring tidal ranges at different locations along the estuary for a number of different years during which both entrances were open (PWD, 1990 and MHL, 1985).

Table 3: Recorded Mean Spring Tidal Ranges

Location	Mean Spring Range (m)					
	1957	1988	1989	1990	1991	1992
Ocean	1.30	1.33	1.39	1.38	1.35	1.38
Harrington Inlet	1.14	0.98	0.95	0.97	1.10	1.01
Farquhar Inlet	0.89	0.49		0.48	0.65	0.65
Taree	0.71	0.52	0.57	0.64	0.81	0.72
Wingham	0.79		0.50	0.34	0.47	0.41

A principle feature of the table is the large drop in tidal range over the short distance between the ocean and inside the entrances. Another feature is the relative consistency of ranges inside Harrington Inlet and the variation in ranges inside Farquhar Inlet and at Taree and Wingham. However, even for the consecutive years 1991 and 1992, the mean spring tidal range for Harrington varied by 100 mm while at Farquhar Inlet there was no recorded change.

Analysis of the data confirms that the tidal response of the estuary is very dependent on the condition of the entrances. Extensive shoaling at both entrances, such as existed between 1988 and early 1990, results in large reductions in tidal range at the entrances due to friction, entrance losses and shallow water effects. The reduction in range is greatest at Farquhar Inlet because it is untrained and generally more heavily shoaled.

The record also shows that moderate flooding in February 1990 increased tidal ranges throughout the estuary, particularly at Farquhar Inlet. The larger increase inside Farquhar Inlet is related to the comparatively wider and deeper channel scoured by the flood at that inlet.

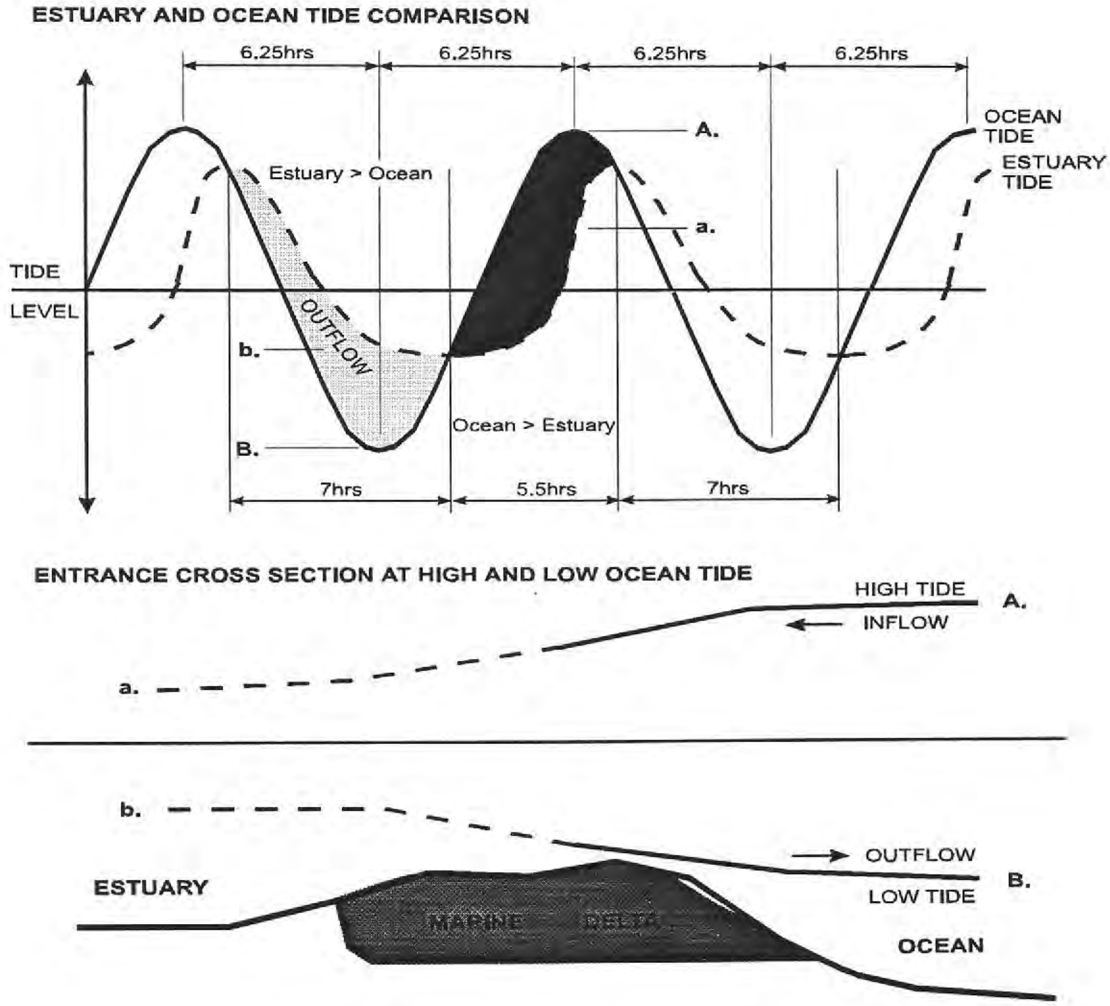
The results of entrance scour during the major 1956 flood can also be seen on the tidal ranges in 1957. The 1957 record shows a comparatively large tidal range at both entrances, as well as amplification of the tidal range between Taree and Wingham. Such amplifications are due to tidal wave reflections and are not uncommon in river estuaries with well defined channels and a distinct tidal limit. The loss of this effect upstream of Taree in more recent gradients is probably related to increased shoaling at the entrances and near Taree. (This shoaling is also responsible for a rise in mean tide level between Taree and Wingham which has also become increasing more evident in the recorded data (PWD, 1990)).

3.2.3 Tidal Flows

Ocean levels also affect tidal flows in the river. Recorded flow data are available for 14 October and 11 November 1981 (PWD, 1985), for 3 March 1983 (GHD, 1983) and for 11 March 1986 (PWD, 1988). These gauging data cover a range of tidal conditions, and give an indication of flows throughout the estuary delta for various entrance conditions.

As is common for all NSW estuaries with shallow entrances, peak tidal flows into the estuary (flood tides) are greater than peak outflow rates (ebb tides) because of shallow water, inertia and friction effects which slow the outflowing tide making it longer and more constant (less peaky) than the inflowing tide, as shown in the diagram below.

Diagram 1: Ocean / Estuary Tides



For the Manning River the outflowing tide will typically flow for around seven hours and the inflowing tide for around 5½ hours. Note however, the total or gross volume of outflows through both entrances must over time equal inflows plus catchment runoff, etc., to achieve a water balance (Section 3.4).

Because the Manning River generally has two entrances, tidal flows are additionally complicated by the relative inflow and outflow proportion through each entrance. When Farquhar Inlet is substantially closed, flows through that inlet are restricted. The restriction affects outflows more than inflows because the ocean tide is lower during outflow and hence there is less depth (more restriction) across the entrance bar (see Diagram 1 above). During inflowing tides the ocean level is higher and the restriction is comparatively less. These shallow water/entrance bar effects are generally greater at Farquhar Inlet because it is generally more restricted than Harrington Inlet.

One result of these different entrance conditions is a nett imbalance in the total tidal volumes entering and leaving from each entrance, although the gross volumes from both entrances are equal. While most tidal waters enter and leave through Harrington Inlet, there is an imbalance with more water leaving than entering. This is balanced by more water entering than leaving through Farquhar Inlet.

3.2.4 Tidal Analysis

Based on the above tidal information it is possible to estimate typical estuary tidal responses for different entrance conditions such as:

Entrance A condition: after a significant period of low catchment runoff and entrance shoaling,

Entrance B condition: following minor flooding and entrance scour,

Entrance C condition: following major flooding and deep entrance scour at both entrances.

A fourth **(Entrance D condition)**, where Farquhar Inlet is closed, also occurs. There are no data on estuarine hydrodynamics for this condition so it has not been possible to produce a corresponding tidal analysis. However, closure of the entrance is generally a progressive process involving a build up from the restricted Entrance A condition. As a result the change in tidal ranges when closure does occur is probably minimal although the change in flow distribution would be significant. To more accurately describe the hydrodynamics when Farquhar Inlet is closed, water level and flow monitoring, or hydrodynamic modelling of the estuary is required.

For the three entrance open conditions for which tidal data is available, the following table gives the estimated tidal ranges at different locations in the estuary. Figure 7 also presents the ranges for the most common, shoaled entrance (Entrance A) condition in graphical format.

Table 4: Estimated Tidal Ranges for Typical Entrance Conditions

Location	Mean Tide Range (m)			Spring Tide Range (m)		
	Entrance A	Entrance B	Entrance C	Entrance A	Entrance B	Entrance C
Ocean	1.0	1.0	1.0	1.4	1.4	1.4
Harrington Inlet	0.7	0.75	0.85	1.0	1.05	1.2
Farquhar Inlet	0.35	0.5	0.7	0.5	0.7	1.0
Taree	0.4	0.5	0.55	0.55	0.7	0.75
Wingham	0.35	0.4	0.6	0.5	0.5	0.8

Clearly, the tidal ranges are conditional upon the actual level of shoaling in the river and particularly at each of the entrances. Shoaling/flood scour also appears to affect the degree of amplification in the upper estuary. However, the table provides a useful assessment of typical tidal responses to significantly different entrance conditions for the purpose of examining tidal processes in the estuary in a general sense.

Based on the typical tidal ranges and the available tidal flow data (Section 3.2), tidal flows can be determined at various locations throughout the estuary for the different entrance conditions. A tide profile, similar to the recorded 1981 tides (PWD, 1985) but with an appropriate volume adjustment, was adopted at each location for the respective entrance condition. No adjustment was made for channel changes or conditions other than for the different entrance conditions.

The following table sets out the estimated tidal volumes and peak tidal flows for a mean (1.0 m) tide with the assumed entrance conditions A, B, and C.

Table 5: Estimated Mean Tide Volumes and Peak Flows

Location	Entrance A		Entrance B		Entrance C	
	Volume Out / In (Mm^3)	Pk Flow Out / In (m^3/s)	Volume Out / In (Mm^3)	Pk Flow Out / In (m^3/s)	Volume Out / In (Mm^3)	Pk Flow Out / In (m^3/s)
Manning R (Harrington)	8.4 / 7.6	400 / 570	8.8 / 8.0	430 / 600	10.2 / 9.6	550 / 700
Manning R (Farquhar)	1.6 / 2.4	100 / 160	2.0 / 2.8	140 / 180	3.2 / 3.8	250 / 300
Manning R (South Ch)	1.2 / 1.8	80 / 130	1.6 / 2.2	100 / 140	2.6 / 3.0	200 / 240
Manning R (Taree)	2.8	180 / 190	2.9	190 / 200	3.3	250 / 260
Scotts Creek	0.2 / 0.4	30 / 60	0.3 / 0.5	35 / 65	0.4 / 0.6	40 / 70
Lansdowne R (Lower)	0.8	45 / 50	0.8	45 / 50	1.0	50 / 55
Dawson R (Lower)	0.3	15 / 20	0.3	15 / 20	0.4	20 / 25

The above table provides an indicative picture of the tidal response of the Manning River under a range of entrance conditions. The table shows that there is a substantial imbalance in flows at Farquhar inlet when the entrance is heavily shoaled (Entrance A conditions), with inflows exceeding outflows by more than 50%. Note, flows in Scotts Creek are also highly variable and dependent on shoaling conditions, with flow reversals occurring throughout a tidal cycle in response to differential water levels between the main channel and south channel.

The Table also shows that even after a major flood (Entrance C conditions) Harrington Inlet remains the main entrance. This result also reflects the rapid infilling of Farquhar Inlet after floods as a result of marine sediment infeed (see Chapter 4).

3.3 Comparison of Fluvial and Tidal Flows

Tables 2 and 5 summarise estimated fluvial and tidal flows for the Manning River estuary under a range of catchment runoff and entrance conditions. Significant points can be drawn from the Tables in relation to the comparison of fluvial and tidal flows.

A comparison of peak tidal flows (for a mean tidal range) with median fluvial flows shows that the tidal flows exceed the fluvial flows at:

- Harrington Inlet by over 20 times,
- Farquhar Inlet by over 25 times,
- Manning River at Taree by over 9 times,
- Lansdowne River (lower) by over 30 times,
- Dawson River (lower) by over 30 times.

These values show that tidal flows far exceed median fluvial flows throughout the lower estuary at the peak of the tide. It is only in the upper reaches of the estuary and tributary streams that fluvial flows begin to dominate.

Comparison of the peak 50% AEP flood flow with peak (mean) tidal flows shows that the fluvial flows exceed the tidal flows at:

- Harrington Inlet by around 2 times,
- Farquhar Inlet by around 2.5 times,
- Manning River at Taree by around 10 times,
- Lansdowne River (lower) by around 1.5 times,
- Dawson River (lower) by around 3 times.

Again it is clear from the data that tidal flows are of the same order as annually occurring fluvial flows throughout most of the lower estuary. It is only in the upper reaches of the river (above Taree) that annually occurring flood flows significantly exceed tidal flows, and it is only during the more severe flooding events (>5% AEP) that peak fluvial flows begin to substantially exceed tidal flows at the entrances.

3.4 Water Balance

The Manning River annual water balance consists of tidal inflows and outflows through both the entrances, catchment runoff including surface water and ground water inflows, direct precipitation into the estuary and evaporation from the estuary. An estimate of these values is set out in the table below (see also Figure 8). Note, for the purposes of the water balance, the shoaled entrance condition (Entrance A) has been adopted.

Table 6: Average Annual Water Balance

Water Balance Component	Volume In (Mm^3)	Volume Out (Mm^3)
Harrington Inlet Tidal Flows	5330	5890
Harrington Inlet Fluvial Flows		1730
Farquhar Inlet Tidal Flows	1680	1120
Farquhar Inlet Fluvial Flows		470
Catchment Inflows	2210	
Direct Precipitation	20	
Evaporation		30
TOTAL	9240	9240

Even with the heavily shoaled entrance condition, tidal flows represented approximately 75% of the average annual water balance for the estuary as a whole. Most of that flow, around 60% of the total balance, passed through Harrington Inlet. Catchment inflows make up the bulk of the remaining 25% of the total water balance.

The above table however does not give a full picture of the estuary water balance. This is because the estuary is predominantly a coastal river, with tidal inflows and outflows at one end (the downstream entrances), and most catchment inflows at the other (upstream) end. The water balance therefore varies throughout the estuary.

For example, upstream of Taree the total water balance is around 3600 Mm^3, of which tidal and fluvial flows represent about 50% each. For the Lansdowne and Dawson Rivers the total water balance is around 650 Mm^3 and 250 Mm^3 respectively, with tidal flows being over 80%.

Further, under a severe drought scenario with very heavy shoaling at Farquhar Inlet, the total estuary water balance would fall to around 5000 Mm^3, consisting mainly (90%) of tidal flows through Harrington Inlet. Catchment inflows and evaporation would represent less than 1% of the balance.

During a wet year with major flooding and scour at both entrances, the water balance could exceed 15000 Mm^3, consisting of around 50% tidal flows through Harrington Inlet, 20% tidal flows through Farquhar Inlet, and 30% catchment runoff.

3.5 Human Impacts

3.5.1 Past Developments

Human development has affected the hydrodynamics of the Manning River estuary in a number of ways. The most identifiable changes are those associated with entrance training works at Harrington Inlet, past channel dredging, current sand and gravel extraction operations, and the construction of the Lansdowne Weir. Other changes, not so obvious but equally as important, are related to catchment clearing.

Construction of the entrance training walls and channel dredging between Harrington Inlet and Wingham earlier this century isolated the Harrington Back Channel and Harrington Lagoon from the main river flow (see Figure 1), and at least initially provided a deeper more hydraulically efficient entrance for the north channel. Ongoing dredging then helped maintain the improved entrance and channel conditions.

The entrance works probably increased flows down the north channel. The effect would be to encourage closure of Farquhar Inlet and to restrict tidal ranges and flows along Scotts Creek and South Channel.

The effects of dredging are no longer likely to be significant in terms of estuarine processes because of extensive natural sediment movement and shoaling in the Harrington entrance area (see Section 4.3). However, it is likely that the entrance training works still improve Harrington entrance efficiency (particularly after floods)

Ongoing sand and gravel extraction operations along the section of river between Tinonee and Mondrook Point have increased the channel width and depth. Numerical modelling of the river undertaken as part of the extractive industry EIS (WBM, 1989) predicted a reduction in peak flood heights at Wingham and Taree Estate of around 0.1 m, but identified negligible changes to tidal flows.

Construction of Lansdowne Weir earlier this century would have moved the tidal limit downstream, but may have slightly increased the tidal range locally by increasing tidal reflections. Tidal flows in the upper Lansdowne River estuary would have been reduced, but changes in the lower and middle estuary would have been very small.

Catchment clearing has also affected the estuary by increasing the volume of catchment runoff. Based on catchment runoff modelling (see Appendix A) and data from similar areas (Mein, 1993), it is likely that catchment clearing has increased runoff in those areas cleared by around 15%, and for the catchment as a whole by around 5%. The greatest impact occurs during minor storms in the lower catchment where clearing is greatest. The impact for extreme storm events and major catchment wide flooding would be minimal.

3.5.2 Greenhouse Effects

In relation to Greenhouse effects there is some consensus that a rise in global ocean water levels will occur, but it remains uncertain as to whether storm activity and rainfall levels will increase or decrease along the NSW coast (see Section 2.4). An increase in rainfall and hence flood frequency would increase the occurrence of post flood entrance B and C conditions (Section 3.2), with a corresponding increase in tidal ranges, and hence tidal flows throughout the estuary. As a result the magnitude of the average annual water balance would be greater both in terms of catchment runoff and tidal flows. If rainfall levels decrease, there would be a corresponding decrease in flood activity and a smaller average annual water balance.

Any increase in ocean mean tide levels would be matched by approximately the same change inside the estuary. Therefore, the predicted best estimate for all tidal planes by the year 2050, would be 0.2 m above existing levels. Such an increase would cause increased tidal and fluvial flooding in some areas and make some low lying pasture land unsuitable for grazing. The increased level could also move the tidal limit 2 km upstream of Abbotts Falls to Basin Ford.

4. SEDIMENT DYNAMICS

4.1 Channel Sediment Distribution

4.1.1 Sediment Types

There are four basic types of bed sediments in the Manning River estuary (Jenks, 1982):

- fluvial gravels and sands,
- fluvial muds and sands,
- reworked coastal sands,
- beach and nearshore sands.

The fluvial gravels are predominantly sedimentary and metamorphic rocks eroded from past fluvial deposits. Originally these fluvial deposits were sourced from the rocks of the New England Geosyncline (Section 2.2). The finer fluvial sediments are a mixture of remnant lithic fragments plus mainly quartz, jasper and feldspar. They have a very high mud content and generally are fairly angular and poorly sorted.

The reworked coastal sands are well sorted, well rounded and mainly quartz. They have a leached appearance and contain grains with organic coatings. The beach and nearshore sands are similar to the reworked sands but have a higher shell content, numerous iron stained grains and an absence of organic coatings.

4.1.2 Sediment Distribution

The distribution of bed sediments throughout the estuary (see Figure 4) is related to their source and the dynamics of the sediment movement processes.

The upper estuary channel sediments are mainly fluvial gravels and large cobbles plus some areas with a higher fluvial sand and silt content. These gravel/sand silt beds continue from above Abbotts Falls downstream to around Dumaresq Island. The river meanders through a floodplain and terrace systems with bedrock barriers on the outsides of bends and deposits of moderately sized gravel forming high point bars on the inside of bends (Resource Planning, 1989). There are a series of rapids or riffles located at Abbotts Falls, Jacksons Falls and above Wingham Brush.

Between Wingham and the Pacific Highway (Martin) bridge at Taree the upper estuary continues meandering through floodplain and terrace systems. There are fewer bedrock bluffs and these are located further apart than up river. The gravel deposits no longer form high point bars on the inside of bends but are more evenly distributed across the whole river cross section (WBM, 1989). There are sandy/muddy deposits along the river bank.

There is a grading of gravel from cobble sized gravels above Tinonee to mixed texture sandy gravel in both passages around Dumaresq Island. Gravel beds form spits at the ends of islands such as Coocumbac Island and at the confluences of creeks (e.g., Browns Creek). There are also gravel shoals at the upstream end of Dumaresq Island. Large shallow muddy shoals are located in the quieter backwaters behind Mondrook Point, the islands and near the confluence of Browns Creek with the Manning.

Downstream of Taree/Dumaresq Island area fluvial muds and sands begin to dominate. These middle reaches are comprised of more or less uniform sandy-mud bottoms with muddy shallows. Within these middle reaches there are areas of hard bottom which have been scoured by flood flows and lined with oyster shells. The fluvial muds and sands extend to within 9 km of Harrington Inlet and 6 km of Farquhar Inlet, after which they are mixed in decreasing amounts over several kilometres with reworked coastal sands from the dune barrier deposits (Section 2.1).

The zone of reworked sands continues to within 4 km of Harrington Inlet and 2 km of Farquhar Inlet. These sands then grade into beach and near shore sands from the marine tidal delta (Roy, 1977).

Because of the differing catchment geology and hydrodynamics, the Lansdowne and Dawson Rivers and the other creeks of the middle and lower estuary have a different sediment distribution to the main river. None of the tributary rivers or creeks have marine sand intrusions and the transitions from upper to middle estuary reaches is far more abrupt.

4.2 Fluvial Sediments

4.2.1 Fluvial Loads

Fluvial sediment inputs are generally examined in two component parts, as bedload and as suspended solids. For most estuaries bedload sediments range from silts through to gravels. Suspended solids are usually fine silts and clay particles, but can also include organic matter.

A Daily Urban Pollution Load Estimation (DUPLE) model was set up as part of this Estuary Processes Study (Appendix C). The model uses daily rainfall records and the Boughton equations to determine catchment runoff (Boughton, 1965). Vegetation and soil parameters from calibrated flows in the Macleay Valley and near Scone plus typical developing urban area values were used as a basis for the model. Runoff was then linked by regression equations to a range of potential pollution inputs such as bedload sediments, suspended solids and nutrients.

Bedload modelling was calibrated against calculations for sediment transport at Killawarra, 6800 to 14 200 tonnes/year (Nanson, 1989) and at Wingham, 8100 tonnes/year (WBM, 1989). These values indicate a low level of sediment transport into the upstream reaches of the river, an assessment which is confirmed by the small volume of flood recharge into the sand and gravel extraction hole between Mondrook Point and Tinonee (pers. com. Readymix Taree).

Parameters for suspended solids derived from the Macleay River and Scone data gave good agreement with water quality monitoring turbidity levels within the upper reaches of the river and tributary streams (Chapter 5).

The following table sets out the estimated bedload and suspended solids load for the catchment on an average annual basis.

Table 7: Estimated Annual Fluvial Sediment Loads

Location	Area km^2	Bedload		Suspended Solids	
		(tonnes)	m^3	(tonnes)	m^3
Manning River (Abbotts Falls)	7300	8000	4500	11000	6100
Taree Urban Area/Browns Creek	10	2600	1450	1400	800
Dawson River	100	400	220	300	170
Lansdowne River	220	600	330	500	280
Other Areas	790	1100	600	900	500
TOTAL	**8420**	**12700**	**7100**	**14100**	**7900**

The total volume of sediments entering the Manning River estuary is not great, around 15 000 m^3/yr, with the volume of suspended solids similar to the volume of bedload sediments. This is much less than the estimated 100 000 m^3/yr in bed sediments alone for the Shoalhaven River (Chapman, 1982), but significantly more than the estimate for bedload sediment movements in the river at Taree of less than 500 tonnes/year (WBM, 1989).

The WBM analysis of sediment movement at Taree does not include inputs from urban runoff but does indicate that the upper estuary areas are significant sites for sediment deposition. The reason for this deposition is the drop in flow velocities (and hence sediment carrying capacity) which occurs in the wider tidal upper estuary reaches, plus the coalescing and settling effects of higher salinities on suspended sediments.

4.2.2 Bank Erosion

Bank erosion is widespread throughout the Manning River estuary, particularly in the lower estuary area. A separate but associated report on bank erosion and sedimentation (WMA, 1996) is concurrently being prepared with this study. The bank erosion study identifies bank clearing and wind generated waves as the major causes of bank loss. Five principal erosion processes are nominated in the report:

- wind generated wave attack,

- water logging and tree collapse,
- cattle denuding and wave attack,
- current scour,
- water logging and current scour.

The bank erosion study not only looks at erosion processes, but also looks at management options including hard structural methods such as rock walls, soft structural methods such as groynes and beaches, and non-structural methods such as buffer zones. The final stage of the study involves preparation of a bank management plan.

Because of the widespread occurrence of bank erosion in the estuary it is very difficult to estimate actual sediment input levels into the system. However, based on sediment grainsize analysis (PWD, 1990) and observations made for the Bank Management Study (WMA, 1996), they are probably of a similar order to catchment inputs, ie. around 15 000 m^3/yr, with around 10% or 1500 m^3/yr as fine silts and clays, and hence as potential suspended sediments.

4.2.3 Deposition

As part of the ongoing erosion and deposition process, fluvial sediments eroded from the catchment or from river banks, are either deposited on the floodplain, or on shoals in response to changed flow patterns. Shoals form on the inside of eroding bends, in the lee of bank or channel training works, and in previously dredged holes.

River bed sediment distribution analysis (Section 4.1) shows that there is limited movement of fluvial bed sediments in the lower reaches of the estuary, even during floods. Hydrographic surveys covering over 100 years also indicate that the level of permanent sediment deposition in the main river channel has been very small (PWD, 1990). (Note, the impact of channel dredging and deposition before and after these surveys has not been included because of the lack of adequate information).

Assuming the deposition of all fluvial sediments (ie. approximately 30 000 m^3/yr) over the middle estuary (as indicated by the sediment distribution), results in an average deposition rate of over 3 mm/yr. While some areas have been infilling at this rate, anecdotal evidence suggests that other areas have not. An average estuary infilling rate of around 1 mm/yr has therefore been adopted with the balance being deposited on the floodplain.

One area of significant fluvial sediment deposition is the dredge area left by the sand and gravel extraction operation between Tinonee and Mondrook Point. However, anecdotal evidence from this area (pers. com. Readymix Taree) suggests that much of the deposited sediments are resuspended during floods.

Another area of identified deposition is along the river bank adjacent to and immediately downstream of Queen Elizabeth Park, Taree. The primary source of sediments is urban runoff via the Pultney Street and Manning Street drains and from Browns Creek. Accretion in this area has reportedly extended depositional lobes some 30 to 40 m into the river and reduced depths along the bank by up to 0.5 m.

4.3 Marine Sediments

4.3.1 Littoral (Beach Zone) Movement

The Data Compilation Study (PWD, 1990) concluded that south-easterly swells were the predominant mechanism for northerly sediment movement in the littoral zone near Harrington and Farquhar Inlets, but that extended periods of easterly and north-easterly swells would also produce southerly movements. The study noted both northerly and southerly movements of both entrances. An attempt to relate storm direction with movement of the entrances failed to find any significant correlation.

Wave energy analyses for the Old Bar Coastal Erosion Study (SKP, 1982) indicated that sediment movement due to waves was greatest in the northerly direction along that section of the beach embayment around Farquhar Inlet. The analysis also indicated a smaller nett northerly movement along the beach near Harrington Inlet and a nett southerly movement along the beach south of Old Bar. The controlling feature was identified as the offshore reef at Old Bar which reduces wave climate at Old Bar and southwards.

Photogrammetric profiling of the beach embayment (SKP, 1982), which included total volume changes and dune escarpment movements between 1940/41 and 1979, identified erosion rates of more than 2 m/yr along Mitchells Island. (Note, an assessment of erosion rates for the period between 1880 and 1940 (SKP, 1987) which was based on anecdotal evidence was not considered reliable and has not been included in this study.)

None of the available studies quantify nett or gross sand movement along the beach embayment. However, the suggested erosion rate equates to a total nett northerly loss due to wave induced movements of some 3 to 4 million cubic metres (or around 100 000 m^3/year) from Mitchells Island beach over the mid 1900's. It should be noted that gross movement rates both north and south which reflect the total wave climate would be at least several times and possibly an order of magnitude greater.

4.3.2 Aeolian Movement

Aeolian or wind blown sand movement was not examined as a significant part of the coastal processes in previous studies. However, observation and analysis of historical aerial photography undertaken for this study suggest that it is a major and possibly the major component of littoral (beach zone) sediment movement along the beach embayment at the entrances.

Observations and aerial photographs from the Data Compilation Study (PWD, 1992) taken when the Harrington Inlet was south of and separated from the northern training wall (years 1965, 1969, 1970, 1972, 1976 and 1996) show that the sand build up on the northern side of the wall is greater than on the southern side. This situation could only exist if the nett volume of aeolian sand moving south at the entrance exceeded the nett volume of littoral surf zone sand moving north.

Note, an assessment of coastal processes based on this deduction provides a more complete explanation of the recorded and observed data. A fuller study of beach erosion/coastal processes which considers aeolian transport is to be the subject of a future study by Council's Estuary and Coastline Management Committee. The study should also include as possible causes of erosion the trapping of some 2 million cubic metes of sand by the breakwall at Harrington in the early 1900's (Section 4.6) and the dredging of 2 to 3 million cubic metres of sand from the marine delta between 1890 and 1950 (Section 4.6).

Construction of the northern breakwall at Harrington created Harrington Lagoon (Section 3.5) as well as a large area of mobile dunes north of the entrance. This area has been partially vegetated over recent years, but still contributes large quantities of aeolian sand to the entrance area particularly during the prevailing summer north easterly winds. Sand from this area mainly moves into the entrance channel and hence onto the marine tidal delta. However, some sand also gets blown into Harrington Lagoon behind the dunes.

Sand blown into Harrington Lagoon is effectively trapped and removed from the entrance/coastal budget. The rate of infilling of the lagoon varies markedly depending on the location of the entrance and the volume of sand trapped both north and south of the breakwall. Historical aerial photography and surveys show that changes to the basic deep water section of the lagoon since 1940 have been minimal. Infilling mainly occurs when the entrance is near its southern limit and aeolian sand enters the lagoon along the eastern and southern shorelines. Over recent years the rate of infilling has increased markedly because conditions at the entrance are optimal.

Based on the available information, an average infilling rate of between 1000 and 2000 m^3 per year would apply, although the maximum yearly rate would be at least an order of magnitude greater. Assuming the average infilling rate continues, the lagoon would be half its current size in about 50 years. Note however, this could be much longer if dune stabilisation significantly reduces aeolian sand transport, or could be much shorter if rapid infilling continues.

4.3.3 Tidal (Marine Delta) Movement

As a result of sediment movement in the beach littoral zone Farquhar and Harrington Inlets both move north and south in response to the prevailing nett sand supply. Some of this sand is also carried into (and out of) the entrances by tidal flows. The volume of sand moved into the entrances by the tides exceeds the volume moved out because of wave stirring and the greater sediment movement capacity of the inflowing tide over the outflowing tide associated with the faster peak inflow velocities (Section 3.2). As a result, both entrances have tidal deltas formed from marine sands (see Figure 4).

The process of tidal delta formation is complex and related to a range of factors including tides, catchment runoff, wave climate, prevailing winds, sediment supply, etc. The Data Compilation Study (PWD, 1990) includes a good description of the processes involved. In summary, there are two basic formation mechanisms. One is associated with a rapid supply of marine sand to the entrance when tidal and fluvial flows are low. This combination tends to build a smaller delta near the entrance. The other is associated with a more gradual supply of marine sand and larger tidal flows. Under these conditions sediments are carried towards the upper limits of the tidal delta and the delta is rebuilt over a wider area.

In practice, the delta forming process is a mix of high and low wave and sediment supply conditions, mixed with varying tides and catchment runoff. Over recent years both entrances have exhibited a buildup of sand at the inland extent of their deltas, i.e. in the vicinity of Harrington Boat Ramp and near the confluence of South Channel and Scotts Creek. This buildup indicates that the marine deltas are now well developed with the volume of marine sand stored in the deltas reaching its maximum.

4.3.4 Fluvial (Marine Delta) Movement

The movement of sand into the entrances (by tidal currents or winds), is over time largely reversed by floods. Floods scour sand from the marine deltas and deposit it in the beach wave zone. This sand is then reworked back onto the beach creating a dynamic equilibrium between the beach and the river entrances/marine deltas. Because of this balance neither entrance acts as a major long term sediment sink, but acts instead as cyclic sediment source and sink. Note, this dynamic equilibrium can be disrupted by human activities such as entrance dredging or the construction of training walls (Section 4.6).

Hydrographic surveys in 1981 and aerial photography before and after the 1978 flood indicate that over 500 000 m^3 of sand was scoured from the marine delta at Harrington Inlet during that flood, with a smaller but similar amount from Farquhar Inlet. Note, the 1978 flood had an AEP of between 1% and 2% (PWD, 1991). Comparison of aerial photographs from other years (PWD, 1990), and estimated flow volumes and velocities for a 50% AEP event (Section 3.1) indicate that smaller floods would scour around 100 000 m^3 and 60 000 m^3 from the respective entrances.

Based on the above and assuming 3 significant freshes in the river each year, the annual average flood scour at Harrington Inlet would be of the order of 300 000 m^3 and for Farquhar Inlet around 200 000 m^3. Note, this level of movement is somewhat greater than the estimated nett northerly littoral movement of sand due to waves, but is well within the estimated gross movement from both the north and the south.

4.4 Sediment Balance

A summary of the fluvial and marine sediment balance in the Manning River estuary is given in the table below. Note, unlike most estuaries where you would expect to find a nett positive sediment balance due to geological infilling of the system, the Manning River estuary has a small nett negative imbalance. This is because sand and gravel extraction levels exceed catchment and bank erosion inputs and outputs.

Table 8: Average Annual Sediment Balance

Sediment Balance Component	Volume In (m^3)	Volume Out (m^3)
Harrington Inlet Nett Tidal Movement	300000	
Harrington Inlet Nett Fluvial Movement		300000
Farquhar Inlet Nett Tidal Movement	200000	
Farquhar Inlet Nett Fluvial Movement		200000
Harrington Lagoon Aeolian Movement	1000	
Catchment Fluvial Inputs and Flood Deposition	15000	20000
Bank Erosion and Bed Accretion	15000	
Sand & Gravel Excavation		60000
TOTAL	**531000**	**580000**

As with the water balance, the estuary sediment balance is dominated by tidal movement. This is because most movement occurs at the entrances. Beyond the tidal deltas, that is throughout most of the estuary, fluvial processes are also important. For example upstream of Taree the sediment balance is very small, around 10 000 m^3/yr, mainly suspended sediments, with tidal and fluvial movement approximately equal.

4.5 Conceptual Model

A quantified conceptual model of average annual sediment movement in the Manning River estuary based on the findings of the previous sections is presented at Figure 9.

4.5.1 Fluvial Sediments

Fluvial sediments washed in from the catchment tend to settle in the upper reaches of the estuary. This is the result of reduced current velocities and the coalescing effect of salinities at around 6 ppt (or $^1/_6$ ocean levels). Salinities at this level generally occur in the reach upstream of Taree. A similar upper estuary pattern of settlement occurs in the tributary streams.

Over time the catchment sediments are reworked by spring tides and minor freshes to form shoals. Major floods can then resuspend the finer sediments and move the heavier sediments. Movement through the estuary however is limited, with most of the mobilised sediments being deposited in dredged holes, on the floodplain, on the inside of outwardly eroding bends or in cut off meanders, etc. Only very fine suspended sediments are moved out of the entrances to the ocean.

Sediments eroded from the banks of the estuary are subject to a similar process of settlement, reworking and deposition as sediments eroded from the catchment. Wave action generally moves the eroded bank sediments onto shoals along the foreshore. These sediments are then reworked by spring tides and freshes if localised currents are sufficiently strong. During major floods the sediments can be mobilised and deposited on the floodplain or in other low current velocity areas.

4.5.2 Marine Sediments

Sediment dynamics in the marine delta region are determined by a combination of wind, wave and tidal influences as well as fluvial effects. These agents of sediment movement act to form a dynamic interchange of sediments between the beach littoral zone and the marine deltas.

During periods of low catchment runoff from the Manning River system, Harrington and Farquhar Inlets shoal as a result of sediments moving into the entrances from the beach system. The formation of these entrance shoals restricts tidal and fluvial flows. Shoaling and hence the flow restriction tends to be greatest at Farquhar Inlet because of the more active wave climate and gross littoral sand movement, and because of the absence of training walls and a breakwall. As a result Harrington is the dominant river entrance.

During floods most flows initially pass through Harrington Inlet because of the greater conveyance (water transporting capacity) of the Harrington Inlet and the main channel, and because flooding usually occurs from the Lansdowne River first (Section 3.1). As flooding continues the steeper hydraulic gradient between Dumaresq Island and Farquhar Inlet created by the shorter distance and lower ocean levels during storms (Section 3.2) encourages development of this entrance.

Sand scoured from the entrances is not lost to the littoral system but is reworked back onto the beach embayment by waves where it is then again available for transport back into the estuary. Because of this cyclic process there is a dynamic equilibrium between the estuary and the coast. The volume of sand stored in the marine delta may vary, but over time the system is balanced.

4.6 Human Impacts

4.6.1 Past Development

Human development has affected sediment dynamics in the Manning River estuary by increasing catchment inputs and bank erosion, by removing sediments and creating sediment sinks through sand and gravel extraction, by trapping sediments in Lansdowne Weir, and by modifying inlet entrance behaviour through the construction of entrance training walls and past entrance dredging.

Increased Catchment Inputs as a result of clearing and urbanisation have had a significant impact on the volume of sediments entering the estuary. Studies of other areas and catchment modelling for the Manning Valley (Appendix A) indicate that suspended sediment inputs have probably increased three fold and that bedload levels have at least doubled as a result of human development.

Bank erosion, mainly as a result of bank clearing, are equivalent in volume to catchment inputs (WMA, 1996) and contribute significant levels of bedload and suspended load sediments to the estuary. Prior to widespread bank clearing for agriculture and subsequent erosion by waves and currents, the banks of the Manning River estuary were well vegetated and stable (WMA, 1996). There is no evidence to suggest significant bank erosion prior to clearing and so it is probable that input levels from bank erosion have increased many times.

Extractive Industries have removed some 2 Mm^3 of sand and gravel from the river between Taree and Wingham over the last 30 years, at a rate of around 60 000 m^3/yr. This rate far exceeds the infill rate by catchment sediments and has therefore created deep holes which act as sediment sinks for bedload sediments and some suspended sediments, reducing loads in the reach above Taree.

Lansdowne Weir has also created an area of deeper water which acts as a sediment sink for larger bed load particles. Note, the fact that the weir has not infilled indicates that the level of bed load movement from the upper catchment is not great.

The construction of a single northern breakwall at Harrington has limited northerly migration of the entrance, and has affected the formation of the marine delta shoals by making the inlet more hydraulically efficient after floods and so creating a somewhat larger but more stable marine delta. Since completion in 1904 the wall has also progressively trapped over 2 million cubic metres of marine sand in the beach dunes north of Harrington and on the expanded delta. As a result the entrance works may at least in part be responsible for the beach erosion recorded along Mitchells Island beach during the mid 1900's.

Artificial opening of Farquhar Inlet, which is occasionally undertaken to improve water quality in Scotts Creek and the South Channel, also has the potential to change natural flow conditions and hence to have an impact upon bank erosion by encouraging greater flow down South Channel or along Scotts Creek. Again however, because of the high level of sediment movement in the entrances, and the fact that the entrance closures and openings also occur naturally, it is impossible to quantify the impact of artificial openings on bank erosion.

There has been a suggestion that northerly opening of the entrance results in accelerated erosion of the beach along Mitchells Island (SKP, 1982). The evidence to support this assumption was based on a less complete record of the entrance than is currently available, and the conclusion that the entrance when open acted as a continuous sediment sink. In reality, within a short period of flood scour (generally less than a few months) most littoral zone sediment movement would bypass the entrance and any ongoing diversion onto the marine delta would be substantially balanced by sediments scoured from the entrance moving back onto the beach system (see Section 4.3).

4.6.2 Greenhouse Effects

The most likely effect of the predicted greenhouse increases in mean ocean levels would be to raise the height of the entrance shoals by an amount similar to the water level rise. Such changes would increase the volume of sand stored in the marine deltas by around 200,000 m^3 at Harrington Inlet and 150 000 m^3 at Farquhar Inlet. This sand would come from erosion of the beach between Old Bar and Harrington. Using the current best estimate increase of 0.2 m by 2050 (Section 2.4), and on the basis of an upward and landward translation of beach profiles, the increased level would result in a localised landward open coast recession of 12 m (Evans, 1996).

Changes due to increased or reduced storminess and flooding as a result of greenhouse effects (see Section 2.4) would respectively either increase or decrease the volume of sediments moving in and out of the entrances. The change in sediment flux would also probably be associated with a nett change in the size of the marine deltas. Changes in catchment runoff and possibly bed and bank erosion would also add to or reduce fluvial loads in the estuary. The result would be either a respective overall increase or decrease in the size of the average annual sediment budget for the estuary and some minor changes to open coast recession in the vicinity of the entrances.

5. WATER QUALITY

5.1 Pollutant Sources

The Manning River estuary has a substantially rural catchment with a large regional urban service centre, but no major heavy industries. As is usual for such catchments, most water pollutants are associated directly with human use such as treated and untreated sewage discharges, and urban and rural runoff.

For the Manning River estuary the most common pollutants are excessive nutrients, increased turbidity, and additional biochemical oxygen demand which can cause deoxygenation. There is also a potential problem associated with the release of untreated or partially treated faecal material from septic tanks, the sewerage system, dairy (or piggery) wash and boats. The other major pollutants are acid sulphate leachate which results from the draining of swampy soils with high pyrites content, and turbidity from bank and bed erosion.

5.1.1 Sewerage System Discharges

There are four sewage treatment plants in the lower valley/estuary area, these being the Taree, Wingham, Dawson and Harrington STPs. In March 1994 most of the effluent from the Taree plant, which had previously flowed into Browns Creek, was directed to the Dawson plant. Since the diversion about 280 ML/yr of effluent, or about 20% of the volume of the Taree plant, has been discharged into Browns Creek during wet weather.

Under the existing system, most sewage from the Taree area receives full secondary treatment at the Taree plant and is then pumped to the Dawson plant for further treatment including extended aeration and pond disinfecting. The wet weather discharge into Browns creek is diluted, screened, and treated or partially treated sewage which has similar characteristics to normal sewage effluent, but with somewhat higher faecal coliform levels.

Sewage from the eastern part of Taree and the effluent pumped from the Taree plant receives secondary treatment at the Dawson plant. The process includes continuous extended aeration and pond disinfection. Based on a comparison of average influent and effluent characteristics there is 75% nitrogen and 65% phosphorus removal during the treatment process.

Effluent from the Dawson plant is discharged to the Manning River North Passage between Taree and Cundletown (see Figure 10). About 3% or 70 ML of effluent are discharged each year from the Dawson plant direct to the Dawson River near the railway bridge during or following heavy rain. These discharges have passed more quickly than normal through the treatment plant but have generally undergone a fairly high level of treatment.

The Wingham plant discharges treated effluent directly into the upper estuary of the Manning River just downstream of Wingham. Plant operations and outputs are similar to the Taree/Dawson plants although significantly smaller in scale.

Augmentation of the Harrington treatment plant was completed in 1995 and capacity is currently adequate for anticipated peak holiday loadings until 2011. Treatment includes continuous extended aeration, with approximately half the discharges going to sand dunes west of Harrington and half to Harrington Swamp. Based on a recent vegetation studies (Wetlands, 1996) very little if any discharge enters the river.

As a result of recent changes/upgrading of the sewerage system, particularly the diversion of flows from Taree STP to Dawson STP in 1994, analysis of estuary water quality in relation to the existing sewerage system has been restricted to data from the last few years. The transfer of most effluent discharges from Browns Creek to the North Passage has changed the entire pattern of effluent dispersal in the estuary. Furthermore, the total load of pollutants entering the estuary has been substantially reduced because the Dawson plant produces better quality effluent than the old Taree plant.

The table below summarises water quality parameters for treatment plant discharges over 1995-96 based on recorded data and compares them with typical licence conditions. The estimated value for discharge quantity and quality is based on Council data (GTCC, 1996, and Appendix B).

Table 9: Sewage Effluent Discharge Quality 1995-96

Parameter	Units	Typical Licence Conditions	Manning R at Wingham	Browns Ck	Manning R North Passage	Dawson R
Volume	ML/yr	NA	450	280	2130	70
TP	mg/L	NA	6.9	15.0	4.7	5.8
TN	mg/L	NA	8.1	19.0	5.2	5.9
TON	mg/L	NA	5.6	12.0	3.1	3.7
TKN	mg/L	NA	2.5	7.0	2.1	2.2
Ammonia	mg/L	<5	3.0	5.0	1.3	1.4
BOD	mg/L	<20	5.0	14.0	6.9	13
SS	mg/L	<30	5.8	16.8	8.1	8.8
pH	units	>6.5 & <8.5	7.0	7.3	7.6	7.4

TP - Total Phosphorus
TN - Total Nitrogen (TON + TKN)
TON - Total Oxide Nitrogen (NO_X)
TKN - Total Kjeldahl Nitrogen (Ammonia + dissolved organic nitrogen)
BOD - Biochemical Oxygen Demand (at five days)
SS - Suspended Solids
pH - Acidity / Alkalinity

Based on the above sewage effluent quantities and qualities, the quantities of phosphorus and nitrogen discharged into the Manning River estuary from the sewerage system were around 18 tonnes and 20 tonnes respectively. Approximately 60% of inputs were from the Dawson STP direct to the Manning River via the North Passage outlet. Most of the remaining inputs were into Browns Creek or the main river at Wingham. Discharges from the Dawson STP direct to the Dawson River only represent 2% of the total inputs.

The level of BOD inputs into the estuary were approximately 22 tonnes and the level of suspended solids around 25 tonnes. Again, these inputs are mainly derived from the Dawson STP, but discharges into both Browns Creek and the main river near Wingham were also significant. Discharges from the Dawson STP direct to the Dawson River only represent between 2% to 5% of the total inputs from the sewerage system.

In addition to the above water quality parameters there is also the potential for estuary waters to be polluted by faecal material from the sewerage system, particularly during or just after wet weather. There is very little information on wet weather discharges relating to faecal material and the levels of faecal coliforms entering the estuary. However, faecal coliform levels in Browns Creek near the sewerage system outflow are known to be high after rain. Similarly, but far less frequently, faecal coliform levels in the Dawson River near the Dawson STP can be high. Whether these levels are associated with the discharge of partially treated sewage, or are related to other urban or rural runoff, has not been established.

5.1.2 Urban Runoff

As mentioned in Section 2.5, approximately 23 000 residents or 50% of the catchment population live in the Taree-Wingham urban area, with a further 15 000 living in villages and small farms around the estuary. The Taree urban area is therefore by far the most significant source of urban pollutants in the catchment. To date, there is very little recorded data on catchment runoff quality, although GTCC has proposed to undertake a survey of stormwater runoff from the Wingham-Taree urban area (GTCC, 1995_b).

Because of the lack of recorded data, values from other urban areas have been adopted for this study. Runoff water quality modelling indicates that the estimated 10 km^2 of urban development would have a runoff of approximately 7.1 Mm^3/year (Appendix A). The modelling also includes regression equations for suspended sediments, Total Phosphorus and Total Nitrogen based on calibrated findings from the Macleay River and a catchment near Scone.

Comparison with SPCC values for urban runoff (SPCC, 1989) and values used for the Harrington Waters Estate EIS (Oceanics, 1983) (modified for the areas and runoff volumes involved) are given in the following table.

Table 10: Estimated Urban Runoff Pollutant Loads

Parameter	Units	SPCC 1989	Oceanics 1983	Adopted Values
Volume	ML/yr	NA	NA	7100
TP	mg/L	0.1 to 1.5	0.56	0.45
TN	mg/L	0.5 to 3	1.4	1.5
BOD	mg/L	10 to 60	5.6	15
SS	mg/L	150 to 650	-	200
pH	units	NA	NA	7.1

The results of the analysis indicate that the annual inputs of phosphorus and nitrogen from urban areas to the estuary are of the order of 3.2 tonnes and 10.5 tonnes respectively. The level of BOD input into the estuary is around 110 tonnes per year and the level of suspended solids is around 1400 tonnes.

Note, SPCC investigations also showed that urban runoff has faecal coliform levels approaching those of raw sewage (SPCC, 1989). The source of the bacteria is generally assumed to be animal faeces. There is no data on general pathogen levels in urban runoff, but very high faecal coliform levels indicate that pathogens may also be a problem.

5.1.3 Rural Runoff

The results from the recent Streamwatch data collection exercise (Appendix B) and the earlier SPCC water quality survey (SPCC, 1987) were combined to give an assessment of the quality of the water entering from the catchment. This information was then used in the catchment runoff modelling and the results compared with the values adopted from calibrated catchments. The results of the analysis gave good agreement for suspended solids, Total Phosphorus and Total Nitrogen. The adopted values for these parameters and for BOD and pH are given in the following table.

Table 11: Estimated Rural Runoff Pollutant Loads

Parameter	Units	SPCC 1987	Streamwatch 1996	Adopted Values
Volume	ML/yr	NA	NA	M. Valley 2200 000
TP	mg/L	0.03 to 0.04	0.026	0.03
TN	mg/L	0.28 to 0.37	low	0.34
BOD	mg/L	NA	NA	2
SS	mg/L	3 to 5	NA	6
pH	units	7.5 to 8.2	NA	7.9

Note, the SPCC values give a low, medium and high flow range which was converted into a weighted average for this study.

The results of the analysis indicate that annual inputs of phosphorus and nitrogen into the estuary from the total Manning River Valley including tributaries are of the order of 66 tonnes and 750 tonnes respectively. Further, the level of BOD input into the estuary is around 4400 tonnes per year and the level of suspended solids is around 13 000 tonnes. Note, some 85% of the above inputs are via the main river. Inputs from tributary streams such as the Dawson and Lansdowne Rivers are much smaller because although pollutant load concentrations are similar, flows volumes are much smaller (Section 5.5).

In addition to the above pollutants there is increasing evidence from areas such as the Wallis and Myall Lakes, that semi urban/rural developments can contribute high levels of faecal contaminants to waterways from septic tanks and poorly maintained onsite treatment plants. Identified problem areas are villages and tourist developments such as caravan parks and camping grounds, particularly those adjacent to the estuary or tributary streams.

On the basis that most people living in small villages and farms rely on septic tank systems, there would be around 10 000 permanent residents and over 1000 visitors during summer using this form of waste disposal. There have been numerous reports of residents pumping out septic tanks into surface waters (pers. com. Council Officers) and Council has recently prepared a technical report looking at control measures to address the problem of failing septic tanks.

Potential problem areas in the lower estuary, where there are oyster leases in close proximity to development, are being monitored as part of the oyster growers' quality assurance program. To data there is not enough available information to quantify the extent of the problem, or to differentiate between septic tank seepage and other sources such as urban runoff, sewerage system discharges, or dairy wash.

5.1.4 Acid Soil Leachate

A large part of the Manning River floodplain has been identified as having a high acid leachate potential (Section 2.3) and large areas have been drained to facilitate the growth of pasture. Most of these areas have the potential to produce acid leachate. Water quality monitoring by Council, and by the Consultants for this study, has identified the Lansdowne River and particularly the Great Swamp and the Ghinni Ghinni Creek areas as producing a significant level of acid waters (Section 5.4 and Appendix B).

The extent of the problem has only recently become a matter of public knowledge and concern. Because of this, adequate investigation has yet to be undertaken and land use practices have not yet been fully implemented to mitigate or prevent the problem. However, farmer education and modified land use practices are being pursued through Council and the various Drainage Unions and Landcare Groups in the lower valley. Council has only recently introduced a draft Development Control Plan covering activities in acid soil areas. As a result of these works and measures, there is an expectation that the acid leachate situation will improve over the next few years (pers. com. Lower Manning Landcare Group).

5.1.5 Bank Erosion

Bank erosion has been identified along with catchment erosion as one of the main sources of suspended solids in the Manning River estuary (WMA, 1996). Large sections of banks have been denuded of vegetation and hence exposed to erosion. Waves and currents not only attack and erode banks which have been cleared of vegetation, they also remobilise fine sediments and other particulate matter which have settled in shallow water. This is a particular problem along the estuary foreshores downstream of Taree where bed sediments have a high (10%) silt and clay content (Section 4.1).

During windy conditions turbidity levels are visibly much higher along the banks and in the shallows. Estuary currents tend to move in a bank parallel direction, retaining the turbid waters near the banks. However, some mixing with channel waters does occur, resulting in increased turbidity levels throughout the estuary.

5.1.6 Industry Wastes

Industry wastes have in the past been identified as possible significant pollutant sources. The main concerns related to:

- point source discharges from the two dairy factories in Taree,
- untreated waste discharges from numerous dairies located along the banks of the estuary,
- turbid water discharges from sand and gravel extraction operations upstream of Tinonee,
- boat wash (both commercial and recreational vessels).

Wastes from the Dairy Factories have been diverted to the sewerage system for treatment since 1989. Based on estimates made by the SPCC (SPCC, 1989), the treatment of dairy factory discharges would have reduced inputs of phosphorus and nitrogen to the estuary by about one tonne and nine tonnes respectively, and reduced BOD and suspended solids by about 300 and 100 tonnes respectively.

Dairy Waste recycling has been encouraged over recent years by the NSW Dairy Corporation. Advice from the Corporation is that there are some 50 dairies within 200 m of the estuary, milking nearly 3000 cows. Only a few dairies continue to discharge significant quantities of effluent into the waterway (pers. com. NSW Dairy Corporation). These dairies are mainly located along the Lansdowne River.

Faecal coliform testing by GTCC from areas in the lower estuary along the South Channel and Scotts Creek and regular testing for faecal coliforms by oyster producers generally show very low levels of faecal contamination (Sections 5.4 and 7.2, and Appendix B). Occasional high levels have been recorded after rain in the Lansdowne River and throughout the main River. The contribution of dairy runoff to this problem is unknown, but may well be significant in some areas such as the Lansdowne given the low potential from other sources.

Sand and Gravel Extraction Operations between Tinonee and Mondrook Point have in the past been identified as a source of increased turbidity. The level of suspended sediments in water down flow from the extraction works has been elevated above background levels during low flow conditions (SPCC, 1987). Since the late 1980's measures have been implemented to reduce the escape of fine sediments and in recent years there have not been any identifiable increases although some localised increase in suspended solid levels is an inevitable outcome of the dredging process.

Boat Wash has been suggested as a source of increased bank erosion and turbidity. Water skiing along the Dawson River has reportedly been responsible for increased erosion and hence turbidity levels in the river (GTCC Estuary and Coastline Management Committee delegate). However, while boat wash probably does contribute to increased erosion and turbidity (WMA, 1996) it is not a significant contributor because of the low level of boating activity in the estuary. There is no evidence from other parts of the Manning that boat activities are significantly adding to bank erosion or turbidity.

5.1.7 Summary of Pollution Sources

The main sources of pollution into the Manning River estuary are associated with human use of the catchment and include:

- sewage effluent discharges, particularly from Taree STP into Browns Creek and from Dawson STP into the North Passage near Cundletown,
- urban runoff from the Taree/Wingham urban area, much of which enters the estuary via Browns Creek,
- rural runoff, from both the 80% of the catchment above the tidal limit at Abbotts Falls, and from the local floodplain area,
- acid leachate from drained low lying swampy ground, mainly from the Lansdowne River and Cattai Creek catchments,
- bank erosion from excessive clearing and destabilisation of the river banks.

Note, there are now no licenced trade waste disposal sites directly into the estuary. It has therefore been assumed that all trade waste discharges are now included for consideration as part of general urban runoff and sewage discharges.

Based on the preceding analysis the following summary table has been prepared for the total input to the estuary of most of the "main" pollutants associated with the above pollution sources, ie.

nutrients, BOD and SS. A summary for pH and faecal contamination has not been given because these are concentrations which can not readily be expressed as total amounts/volumes.

Table 12: Summary of Main Pollutant Inputs

Parameter	Units	Sewage Effluent	Urban Runoff	Rural Runoff (Mean)	Rural Runoff (Median)
Volume (Manning Valley)	ML/yr	2630	7100	2 200 000	660 000
TP	tonnes/yr	18	3.2	66	20
TN	tonnes/yr	20	10.5	750	225
BOD	tonnes/yr	22	110	4400	1300
SS	tonnes/yr	25	1400	13 000	4000

Based on the above table, it is clear that most of the "main" pollutants enter the Manning River estuary from the catchment above the immediate estuary/floodplain area. This conclusion varies significantly from past assessments by Council (GTCC, 1994) and the SPCC (SPCC, 1987) which have assumed sewage inputs and urban runoff to be the primary sources of estuary pollutants.

Although rural catchment runoff undoubtedly does provide the greatest volume of "main" pollutants, most of these pass directly through the estuary during floods. For example an analysis based on median rather than mean flows (which represents typical catchment runoff conditions rather than average conditions which include major floods) would reduce the volume of rural catchment inputs by 70%. On this basis the level of phosphorus input is divided approximately equally between effluent discharges and catchment inflows.

Further, the concentration of pollutants in rural catchment runoff is substantially less than for urban runoff or sewage discharges. Therefore, for both these reasons, urban runoff and sewage discharges are important determinants of estuarine water quality.

5.2 Export and Assimilation Rates

Pollutants which enter the Manning River estuary can be taken up by plants or animals and enter the biological system, or they can be washed out to sea, deposited on the floodplain, decay, or be incorporated into bed sediments. Pollutants which are incorporated into bed sediments can be remobilised under certain conditions and can then be taken into the biological system, lost to the estuary or again returned to the sediments.

5.2.1 Natural Decay

Oxygen levels are an important indication of the capacity of the waterway to sustain aquatic animal life. Excessive amounts of organic material with a high biochemical oxygen demand (BOD) can reduce dissolved oxygen levels as a result of bacteria oxidising the organic matter. Provided sufficient oxygen is available, domestic sewage is usually about 65% oxidised after five days.

Nutrients, particularly nitrogen compounds, are also broken down naturally. Complex organic nitrogen proteins, acids and urea oxidise to form ammonia nitrogen, which in turn can then be oxidised to form nitrites and finally nitrates. The oxidisation products are more readily available for take up by plants. Under anaerobic conditions nitrogen compounds can be broken down to form free nitrogen.

It should also be noted that most human pathogenic organisms die off when exposed to estuarine conditions. However, under most conditions bacteria such as faecal coliforms die off more quickly in receiving waters than do enteric viruses and most parasites.

5.2.2 Hydrodynamic Exchange

The movement and exchange of water through the ocean entrances is a major component of the estuarine water quality process. Pollutants which enter the waterway do not necessarily remain in the estuary but can be exchanged for ocean waters by tides or flushed from the system during floods.

Tidal exchange is highly dependent on both the level of tidal flows and on the mixing rates between polluted catchment inflows and ocean waters. As discussed in the section on tidal hydrodynamics (Section 3.2), the level of tidal flows is related to flow condition of the ocean entrances. The greater the shoaling the lower the flows. The mixing of estuary waters with ocean tide waters inside the estuary is a more complex problem which depends upon a range of factors such as relative water densities, flow velocities, channel shape, bed conditions, side storages, wind generated currents, etc. These factors, and particularly the fact that the different waters tend to stratify, makes analysis of this problem difficult (Section 5.6).

Fluvial flushing is mainly dependent on the volume of water entering the estuary from the catchment during a particular flood/flushing event, although for smaller events the degree of stratification/mixing is also be an important factor. Assuming no mixing of runoff waters and estuary waters, a flood event which equalled in volume the volume of the estuary (Section 3.1) would provide complete flushing. A more realistic scenario would allow some increase in the volume of runoff water to allow for mixing and flow bypassing due to stratification (Section 5.6).

5.2.3 Sediment Transfers

Fine sediments are an important part of water quality processes because not only do they act as pollutants themselves in the form of suspended solids, but they also act as a carrier for other pollutants, particularly nutrients, heavy metals and chemicals such as pesticides. The movement and deposition of fine sediments throughout the estuary is therefore of interest when determining pollution export rates.

There is very little information on the quality of bed sediments in the Manning River estuary. However, based on data from other estuaries with similar development levels it is reasonable to assume that the sediments generally will not contain high levels of pollutants (other than possibly nutrients) above the guideline levels proposed by the Australian New Zealand Environment and Conservation Council for contaminated site investigations (ANZECC, 1992_a).

The quantity of fine sediments entering the estuary from the catchment or from bank erosion is small, less than 10 000 m^3/yr in total (Section 4.2). The most likely source of contaminated sediments would be the Taree/Wingham urban area. However, less than 1000 m^3 of the total comes from this area. Most of the fine sediments which enter the waterway are eventually deposited on the floodplain during floods, although some accumulates along the foreshores, in previously dredged areas, on the inside of eroding bends, or is washed out to sea.

5.2.4 Biological Cycling

Nutrients in the estuary are often recycled. Nutrients taken up by plants can be returned to the water as animal waste after being eaten and expelled by aquatic animals. Alternatively the plants will eventually die and the nutrients released as the plant matter breaks down.

Nutrients attached to fine bed sediments can be released when conditions at the bed become anoxic. These conditions usually develop in deep holes under stratified water layers where the BOD is sufficient to lower the levels of dissolved oxygen. Nutrients released from bed sediments become available for plant growth.

5.3 Water Quality Data

Physical, chemical and biological water quality data for the Manning River estuary is available from a number of sources including:

- an ongoing monitoring program by Greater Taree City Council,
- previous studies by Council related to sewage effluent disposal,
- a mid 1980's study by State Pollution Control Commission and Public Works,
- recent Streamwatch data collection through Manning River Landcare Groups/Catchment Committee,
- previous studies by other agencies and industries,
- data collected by the Consultants for this study.

5.3.1 Council Data

Greater Taree City Council has been collecting water quality data at eight sites in the upper estuary (Manning River, Dawson River and Browns Creek), plus treated effluent discharge from the Wingham, Taree and Dawson STPs, since May 1989 (see Figure 12 and Appendix B). More recently, collection has been expanded to include a further seven sites.

The original data collection was directed towards assessing the impacts of treated sewage disposal. Samples were only taken once or twice a year and testing concentrated on those water quality parameters normally associated with organic pollutants. A report on the data from 1989 to 1994 was prepared for Council (GTCC, 1994).

More recently sampling from 1992 has been undertaken approximately five times per year. A range of nutrients plus faecal coliforms, pH, turbidity and chlorophyll-a are taken. Temperature, salinity and dissolved oxygen depth profiles are also taken. Some additional analysis and comment on this data is available in GTCC's State of the Environmental Report (GTCC, 1995).

As part of a separate water quality investigation for the Lansdowne STP, Council collected samples at four locations along the Lansdowne River estuary, and at two sites upstream (Tuft, 1996). Testing was undertaken for a wide range of water quality parameters mainly related to organic pollution (Appendix B).

5.3.2 SPCC/PWD Data

Between June 1984 and March 1986 the SPCC undertook a water quality survey of the Manning River (SPCC, 1987). The survey was part of a wider investigation involving several NSW coastal rivers. The Manning River data included testing and sampling at 27 sites throughout the estuary. Depth profiles were taken for temperature, salinity, acidity, dissolved oxygen and suspended solids. Water clarity, chlorophyll-a and nutrients were also taken.

In conjunction with the SPCC survey the PWD undertook a tidal gauging exercise in March 1986 (PWD, 1988). This exercise included a limited amount of current metering plus some temperature and salinity profiles. Dye tracing was also undertaken in the upper estuary near Taree to examine tidal excursion and mixing (Williams, 1987).

5.3.3 Landcare/Catchment Committee

Since November 1994 the Manning River Catchment Management Committee has been coordinating a Streamwatch program of monthly recordings by Landcare Groups throughout the Manning Valley. The information collected includes turbidity, conductivity, and some nutrient (nitrogen and phosphorus) data and a comment on flow levels. Twenty two sites have been sampled, including the lower non-tidal reaches of the Manning River, Dingo Creek, Cedar Party Creek and the Lansdowne River (see Figure 12 and Appendix B).

The Catchment Committee/DLWC have also collected some information on acid sulfate leachate from waterways and drains around the lower estuary(see also Figure 12).

5.3.4 Other Data

In addition to the above water quality information there are also a number of other data sources including some suspended sediment, temperature and salinity measurements taken by the PWD during the 1977 and 1981 current metering exercises (PWD, 1979) and (PWD, 1985).

Data and analysis are also available for specific studies associated with proposed developments. Canal development proposals near Harrington included some limited data collection in the entrance area (Laxton, 1982) (Oceanics, 1983). Proposals to upgrade sewage and trade waste disposal included some nutrient and organic pollutant assessments (Nix, 1990), (SKP, 1988) and (PWD, 1979), and a sand and gravel extraction EIS has some upper catchment runoff water quality measurements (Nanson, 1989). Oyster farmers in the lower estuary area also take regular samples and test for faecal coliforms.

Data collection was also undertaken specifically for this study by the consultants over a three day period commencing on 20 May 1996. The aim of the exercise was to provide specific information on acidity levels in the lower estuary and Lansdowne River area, as well as general information on water quality during the period of the biological survey (see Chapter 6). Temperature, salinity, acidity and turbidity profiles were measured at 12 locations (see Figure 10 and Appendix B).

5.4 Water Quality Parameters

A summary of available water quality data for the Manning River estuary has been presented in Section 5.1 and any data not already published has been listed at Appendix B. The following section reviews this data concentrating on the period since March 1994 when most sewage treatment and disposal was transferred from Taree STP and the Browns Creek outfall to the Dawson River STP and the Manning River outfall.

The review compares the available Manning River estuary data with guidelines as set out in the Australian Water Quality Guidelines for Fresh and Marine Waters (ANZECC, 1992_b). These guidelines examine water quality in terms of physical, chemical and biological properties or parameters.

5.4.1 Physical Parameters

- Temperature

Water temperatures follow a regular seasonal pattern with mean winter temperatures of about 13 °C in July and mean summer temperatures of about 24 °C in January. Temperatures were consistent throughout the estuary and varied only slightly at different sites and at different depths. The difference between surface and bottom temperatures was generally less one degree warmer in summer and one degree colder in winter. There was no apparent relationship between temperature and runoff volumes.

ANZECC Guidelines allow for a maximum increase in natural temperature of 2 °C. Although natural changes exceed this level there are no human activities causing such changes.

- Salinity

During periods of low to median catchment runoff, estuary salinity levels varied from essentially marine (>35 ppm) in the lower estuary to fresh (<1.0 ppm) in the upper estuary. A significant vertical salinity gradient was also present in the middle estuary area around Taree and along the middle reaches of the Dawson and Lansdowne Rivers.

At Harrington (Pelican Point), in Scotts Creek (near the bridge) and in the South Channel near Bohnock salinity levels averaged around 35 ppm and there was no salinity gradient. In the main channel between Ghinni Ghinni Creek and Tinonee levels averaged around 20 ppm and there was generally a salinity gradient with bottom levels around 25 ppm and surface levels around 12. Near Wingham levels were rarely above 12 ppm and averaged less than one ppm with no salinity gradient.

During periods of higher than average catchment runoff salinity levels throughout the estuary fell to below 12 ppm and were generally less than one. Under the lower salinity conditions there was no stratification.

ANZECC Guidelines restrict salinity changes to less than 5% from background levels. Given the large natural variation in background salinity levels in the estuary this requirement is difficult to apply, but based on the available data neither sewage discharges nor overflows appear to break this requirement.

- Acidity (pH)

The pH of the Manning River estuary excluding the Lansdowne River (Dickensons Creek, Cattai Creek) system was very stable with an average of around 7.7 and a total variation of less than 0.2 pH units. Readings from the Lansdowne River show a significant variation from the estuary average with measurements of less than pH 5.0 recorded in the lower reaches after moderate rain. There have also been numerous reading below pH 3 taken from drains flowing into the Lansdowne River and Cattai Creek.

ANZECC Guidelines require that pH values do not vary by more than 0.2 units from normal values, and should not be outside the range of 6.5 to 9.0. Clearly acid runoff into the Lansdowne River does not meet this requirement. It is also possible that acid leachates affect other areas of the estuary, but there is insufficient data available.

- Dissolved Oxygen

In the past dissolved oxygen measurements showed a considerable drop in the river near Taree. This pattern is still discernable, although the low point has moved downstream to the vicinity of the Dawson River and the difference is generally less than 1 mg/L. DO reading in the Dawson River and Browns Creek are generally much lower than elsewhere in the estuary.

Over recent years surface mean dissolved oxygen levels in the main river and the Lansdowne River have averaged over 7.0 mg/L or 90%, with supersaturated values of over 9.5 mg/L or 115% occurring occasionally during late summer and autumn (after rain when salinity levels were low). Conversely, following extended dry periods levels have fallen to around 6.0 mg/L or 65%.

Bottom mean dissolved oxygen levels in the main river have averaged around 6.0 mg/L or 80%. Occasionally during extended dry periods, levels have fallen to around 5.0 mg/L or 65%.

In the Dawson River and Browns Creek dissolved oxygen levels average around 5.0 and 4.0 mg/L (65% and 50%) respectively, with surface waters exceeding bottom waters by 20 to 30%. DO levels in these waterways were never supersaturated, but levels did fall to below 2.5 mg/L, or less than 30%, on some occasions.

ANZECC Guidelines require dissolved oxygen concentrations of not less than 6.0 mg/L or 80 to 90%.

Dissolved oxygen levels within the study area except in Browns Creek were generally found to be above this level and hence should be sufficient to support a fish population. However, most DO readings were spot measurements taken during the day when DO levels are naturally high. It is therefore likely that DO levels at the bottom of the Dawson River, and in the main river during dry periods, fall below acceptable limits.

- Biochemical Oxygen Demand

Mean near surface Biochemical Oxygen Demand (BOD) levels were generally constant throughout the middle and upper estuary area and in the Lansdowne River, with an average value of around

4.5 mg/L. The maximum average value was around 9.0 mg/L and the minimum value around 1.7 mg/L. Values of 2.0 mg/L or less occurred on approximately half the reading days.

BOD measurements were developed for use in sewage treatment and have limited applicability in natural waterways. There are no Australian standards for BOD levels. US standards for marine and estuarine waters recommend BOD levels below 2.5 mg/L, whilst European standards recommend levels below 4 mg/L (GTCC, 1994).

Based on the above standards, and noting the limits of their applicability, BOD levels were only acceptable for approximately 50% of time. To provide a more accurate measure of organic carbon and potential oxygen demand, Council has since January 1996 replaced the BOD test with a Total Organic Carbon (TOC) test. This test is considered more reliable for estuary waters. However, to date there has not been enough data collected to draw any firm conclusions.

- Clarity

Secchi disc readings throughout the estuary generally were found to vary between 0.5 m following moderate rain and 3 m during extended dry periods. Occasional lower readings of less than 0.5 m were recorded near the Browns Creek and Dawson River STP's after sewage overflows. Browns Creek also receives a substantial proportion of Taree urban runoff.

Mean Secchi disc values were 2.0 m between Wingham and Taree, and 1.4 m between Taree and Ghinni Ghinni Creek. The mean depths near Wingham and Taree were both 1.6 m, as were values in the Lansdowne River. Depths in the river near Harrington averaged around 2.0 m.

ANZECC Guidelines require that the "natural euphotic depth" should not be change by more than 10%. As with salinity, given the large natural variation in background clarity in the estuary, this requirement is difficult to apply. However, it is possible that both urban and sewage discharges into Browns Creek, and increased catchment runoff and bank erosion, have created conditions which exceed the 10% limit.

- Turbidity/Suspended Solids

Measurements of turbidity in nephelometric turbidity units (NTU) since late 1994 show a mean reading of around 6.0 NTU over the middle and upper estuary area, with slightly lower readings in the section above Taree and somewhat higher reading in Browns Creek. Values vary from zero to 32 in the main river and in the Lansdowne River, and up to 64 in the Dawson River with the highest values occurring after moderate rain.

Measurements of suspended solids in mg/L over the estuary generally (and prior to 1994) ranged from very small through to over 200 mg/L. However, locations with high values tended to be consistently high and vise-versa. Mean values increased substantially as you moved down the estuary. Mean values near Wingham were around 12 mg/L while at Taree they were around

90 mg/L. Further downstream, between Cundletown and Ghinni Ghinni Creek, they were around 160 mg/L. Levels in the Dawson River were also around 90 mg/L. The high levels for the lower estuary are probably a result of testing techniques which allowed crystallised salt to be included in the readings.

The change in suspended solid values at each sampling location, although high and dependent on runoff conditions, was not as variable as NTU values. ANZECC Guidelines for turbidity and suspended particulate matter require that the seasonal mean should not change by more than 10%. As with salinity and clarity, given the large natural variation in background turbidity levels throughout the estuary, this requirement is difficult to apply. However, it is likely that both increased catchment runoff and bank erosion as a result of human development have created turbidity levels which exceed the 10% limit.

5.4.2 Chemical Parameters

The ANZECC Guidelines provide suggested concentrations for the more readily biologically available nutrients, orthophosphate, ammonia and nitrate. However, the guidelines also predicate these limits with a statement which recommends site specific studies to determine the appropriate concentration limits for individual estuaries. Site specific studies are beyond the scope of this processes study, but are expected to provide limits higher than the suggested ANZECC limits.

- Phosphorus

The highest total phosphorus (TP) levels were measured in the Dawson River and along the main river between Taree and Ghinni Ghinni Creek where mean levels were around 0.045 mg/L. Levels then decreased both upstream and downstream. Mean total phosphorus concentrations were found to be around 0.03 mg/L near Wingham and Harrington, and 0.02 mg/L in the Lansdowne River.

Dissolved reactive phosphorus (DRP) follows the same concentration pattern as TP. Mean levels along the main river between Taree and Ghinni Ghinni Creek were around 0.025 mg/L. Levels then decreased both upstream and downstream. Mean DRP concentrations were found to be around 0.018 mg/L near Wingham and Harrington, and 0.012 mg/L in the Lansdowne River.

ANZECC Guidelines do not recommend specific TP or DRP concentration limit, but do suggest an indicative range limit for DRP of between 0.005 and 0.015 mg/L for estuaries. Nowhere in the main river estuary meets these suggested phosphorus levels, although conditions in the Lansdowne River do and conditions at Wingham and the entrances come close.

Like the situation prior to the transfer of Taree sewage to the Dawson STP in 1994, upper catchment runoff and the additional high concentration discharge from the Taree/Wingham urban area still creates a noticeable impact on phosphorus levels. Elevated phosphorus levels still exist in the middle estuary centred around the Taree/Cundletown area although the impacts are now more widespread and diffused.

- Nitrogen

Mean total nitrogen (TN) levels in the form of Total Oxide Nitrogen (TON) plus Total Kjeldahl Nitrogen (TKN) were found to vary between 0.2 and 1.0 mg/L, with the lowest measurements at the entrances and along the Lansdowne River, and the highest in the Dawson River. Values in the main river between Cundletown and Wingham were around 0.5 mg/L.

The highest TON levels (nitrate plus nitrite) were measured in the main river between Taree and Ghinni Ghinni Creek and around Wingham, where mean levels were around 0.08 mg/L. Mean TON concentrations were found to be around 0.02 mg/L near Harrington, and 0.06 and 0.03 mg/L in the Dawson and Lansdowne Rivers respectively.

TKN levels followed a similar concentration pattern as TON. The highest TKN levels were measured in the main river between Taree and Ghinni Ghinni Creek and around Wingham, where mean levels were around 0.5 mg/L. Mean TKN concentrations were found to be around 0.2 mg/L near Harrington and along the Lansdowne River. The highest concentrations were recorded in the Dawson River with a mean level of 0.9 mg/L.

ANZECC Guidelines do not recommend specific TN concentration limits, but do suggest an indicative range limit for TON of between 0.01 and 0.1 mg/L. Nowhere in the estuary do mean TON levels exceed the suggested upper value, but neither do they fall below the lower value.

- Ammonia

Ammonia is both a nutrient for aquatic plants and a toxicant for aquatic animals. Ammonia levels followed the same concentration pattern as TKN. Mean levels along the main river between Taree and Ghinni Ghinni Creek were around 80 *u*g/L. Levels then decreased both upstream and downstream. Mean ammonia concentrations were found to be around 40 *u*g/L near Wingham and Harrington. Levels in the Lansdowne and Dawson Rivers were around 80 *u*g/L.

ANZECC Guidelines conservatively suggest that ammonia levels in estuarine waters should not exceed 5 *u*g/L. Nowhere in the estuary do the recorded levels come close to meeting this suggested limit.

- Heavy Metals and Organic Compounds

There is only very limited data on heavy metal and organic compound pollution levels in Manning River estuary waters. Based on this information and analysis from other estuaries with similar levels of catchment development, these substances should not exceed ANZECC Guideline limits.

5.4.3 Biological Parameters

- Chlorophyll-a

Chlorophyll-a levels are a measure of the free floating algae in the upper water column. In the Manning River estuary they follow a similar concentration pattern to TP levels. Mean levels along the main river between Taree and Ghinni Ghinni Creek were around 3.0 *u*g/L. Levels then decreased both upstream and downstream. Mean chlorophyll concentrations were found to be around 1.8 *u*g/L near Wingham and 2.6 *u*g/L near Harrington and in the Lansdowne River. Levels were highest in the Dawson River at around 4.0 *u*g/L.

ANZECC Guidelines recommend chlorophyll-a concentration limits of between one and 10 *u*g/L. Nowhere in the estuary do mean chlorophyll-a levels exceed the suggested upper value, but neither do they fall below the lower value.

- Faecal Coliforms

Testing for faecal coliforms indicated a continuing impact from both the Taree and Wingham urban areas. Faecal coliforms levels in the main river had a median of level of 10 cfu/100 mL and a mean below 50 cfu/100 mL. Following moderate to heavy rain there were occasional average levels in the Lansdowne River and throughout the Manning River of around 300 cfu/100 mL, with maximums near Browns Creek of around 600 cfu/100 mL. Median and mean coliform levels in Browns Creek were 120 and 220 cfu/100 mL respectively, while in the Dawson River median and mean levels were 10 and 140 cfu/100 mL. In both these waterways occasional levels above 1000 occurred following rain.

ANZECC Guidelines for the production of edible fish, crustacea and shellfish require that the median faecal coliform concentration should not exceed 14 cfu/100 mL, with no more than 10% of the samples exceeding 43 cfu/100 mL. On this basis the waters of Browns Creek and possibly those of the Dawson River would not be suitable for the production of edible food.

ANZECC Guidelines also require faecal coliform levels of less than 150 cfu/100 mL for primary contact such as swimming. To meet this requirement five samples need to be taken at least once a month. Although sufficient sampling is not undertaken in the Manning most of the estuary, with the clear exception of Browns Creek, appears to meet this requirement. Note, the Dawson River appears close to the limit.

- Pathogenic Organisms

There is no data on the levels of pathogenic organisms in the waters of the Manning River estuary. Recent data clearly shows the connection between disease outbreaks and water contamination by faecal material (WMA, 1996_b). Human enteric viruses such as enteroviruses (polioviruses, Coxsackie-A), hepatitis A, adenoviruses and rotaviruses have all been associated with estuarine water borne illnesses such as paralysis, hepatitis and eye infections. Human parasitic protozoa such as *Crypto sporidium parium* and *Giardia lamblia* also result in gastrointestinal disease in swimmers (Long, 1994). ANZECC Guidelines require that there be less than 35 enterococci organisms/100 mL and no free living pathogenic protozoans in primary contact waters.

5.5 Water Quality Assessment

Because the Manning River estuary is the downstream portion of a river system (rather than a lake system) it is subject to extreme variations in some water quality parameters such as salinity, clarity and turbidity even under natural conditions. However, human development has and is having a significant impact on water quality. As mentioned in Section 5.1, the identified main pollution sources are:

- rural catchment runoff,
- treated and semi treated sewage discharges from the Taree/Wingham urban area,
- stormwater runoff from the Taree urban area,
- acid sulphate leachate, particularly in the Lansdowne River area,
- fine sediment loads from catchment runoff and bank/bed erosion.

The following assessment of water quality in the Manning River estuary has largely been based on data collected since 1994 because of the substantive changes to inputs associated with the transfer in March 1994 of sewage effluent discharges from the Taree STP and Browns Creek outlet, to the Dawson River STP and North Passage outlet. This upgrading of treatment and change in outlet location appears to have reduced peak pollution concentrations throughout most of the estuary, but it has increased organic pollution in the Dawson River.

- North Channel (main river)

Water quality in the main river generally appears to have improved over recent years, mainly around Taree, although there has been a drop in quality along the North Passage and downstream to Ghinni Ghinni Creek for some parameters, probably as a result of the concentration of sewage effluent discharges in this area.

Phosphorus levels throughout the channel and particularly in the middle and upper estuary are generally higher than recommended ANZECC Guideline limits, and nitrogen levels are generally sufficiently high to be of concern. Chlorophyll-a levels are also high in the middle (Taree to Ghinni Ghinni Creek) estuary although they do not exceed the maximum guideline value. However, epiphytic (attached) algal growth appears to be limited, possibly due to the high turbidity levels along the foreshores in the middle estuary caused by bank and bed erosion and stirring by waves. On some occasions dissolved oxygen levels become supersaturated.

- South Channel and Scotts Creek

There is only a limited amount of water quality information for the lower estuary, South Channel, Scotts Creek, and the Harrington and Farquhar Inlet areas. The available information indicates that water quality in this area is generally adequate. Faecal coliform levels are low and the physical water quality parameters are within guideline limits. Phosphorus levels at Harrington are slightly above ANZECC guidelines, reflecting the high input volumes into the estuary from the upper catchment and the Taree/Wingham urban area.

- Browns Creek

Despite most sewage effluent discharges being transferred from Browns Creek to the main river, Browns Creek still has the worst water quality in the estuary. Sewage effluent and urban runoff combine to produce faecal coliform levels sufficiently high to make the creek unsuitable for the production of edible food and also usually unsafe for swimming. The creek also has nutrient levels well above recommended ANZECC guidelines and has poor clarity and high turbidity. Dissolved oxygen levels are often below those sufficient to support aquatic animals.

- Dawson River

Water quality within the Dawson River has deteriorated over recent years as a result of sewage effluent discharges during wet weather combined with low flushing rates. Based on the limited data available the Dawson River may not be suitable for the production of edible foods, and possibly may not be suitable for swimming or other forms of primary contact. Dissolved oxygen levels are occasionally close to the limit for the support of fish populations and bed levels often drop below acceptable limits at night. Nutrient and chlorophyll-a levels are always high, although chlorophyll levels do not ever exceed the ANZECC Guideline upper limits.

- Lansdowne River

In the Lansdowne River water quality is generally within guideline limits except following rain when pH values can drop to around 5, and drainage inflow levels to 3. pH values below 5 indicate a significant acid sulphate leachate problem which could result in excessive stress on fish, fish kills, and habitat degradation (SCS, 1995).

5.6 Conceptual Model and Nutrient Budget

Both the SPCC (SPCC, 1987) and Council (GTCC, 1994) have previously identified that water quality processes in the Manning River estuary are controlled by density stratification, partial mixing and fluvial flushing. This is a conclusion supported by this study.

Catchment fluvial inflows occur at a median rate of around 21 m³/s (or 1.8 Mm³/day) and at a mean rate of around 70 m³/s (or 6.0 Mm³/day) (Section 3.1). Further, the total volume of runoff during a 50% AEP flood is about 350 Mm³ and the total volume of water in the estuary is of the order of 70 Mm³.

Tidal flows through the entrances under "Entrance Type A Conditions" (Section 3.2) average around 16.0 Mm³/day and 4.0 Mm³/day for Harrington Inlet and Farquhar Inlet respectively. There is however a substantial 1.6 Mm³/day imbalance of inflows over outflows at Farquhar Inlet (and the reverse at Harrington Inlet).

Based on the above flow and salinity data it is reasonable to assume that water exchange near the entrances is close to 100% each tidal cycle. Further into the estuary (along the main river channel from Harrington to the Scotts Creek confluence, from Farquhar Inlet along Scotts Creek, and along South Channel to around Bohnock) there is probably close to total tidal exchange every 4 to 7 days during periods of low to median catchment runoff. However, upstream of Scotts Creek on the main river, and Bohnock on the South Channel, there is generally a significant bottom to surface salinity gradient which causes density stratification and prevents efficient mixing. Therefore, in the middle and upper estuary areas water quality relies on gradual mixing at the stratification barrier and on fluvial flushing.

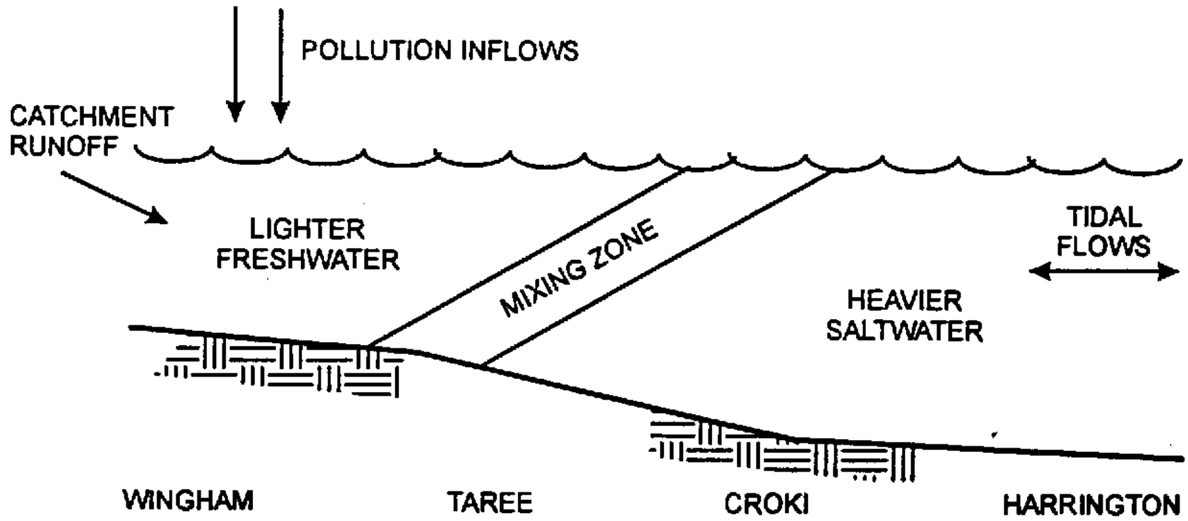
5.6.1 Density Stratification

Density stratification is associated with fresh water catchment inflows moving over heavier saline tidal waters which enter the estuary through the ocean inlets. For the Manning estuary under low to median flows this density layering develops in the middle reaches of the river as well as in the middle reaches of the Dawson and the Lansdowne Rivers.

The zone over which stratification occurs varies depending on the level of catchment inflows and the state of the tide. Gauging and dye tracing undertaken by SPCC and PWD in 1984 to 86 (SPCC, 1987) indicated that during a tidal cycle the stratification zone moved some 5 to 10 km at the surface and 2 to 3 km at the bed. Analyses of more recent data collected by Council shows that during low flows the stratification zone moves upstream of Tinonee towards Wingham, and that during extended dry periods the layers breakdown and the estuary becomes well mixed. Alternatively, during higher than average runoff the stratification zone can be flushed from the system.

The formation of density stratification in the middle estuary substantially reduces the capacity of the system to exchange or remove pollutants which enter at the upper or upper middle level. Pollutants which enter in this area are trapped by the stratification barrier at least partially, causing a build up of pollutants . Some mixing of the waters and dispersion of the pollutants does occur at the stratification interface, but generally the buildup continues until the system is flushed by catchment runoff.

Diagram 2: Density Stratification



5.6.2 Tidal Exchange and Partial Mixing

Mixing of catchment and ocean waters at the interface of the layers occurs as a result of turbulence caused by tidal flows and wind generated currents. As a result bottom waters at the layer boundary tend to be around 65% to 80% marine and surface waters around 30% to 40%.

In the lower estuary along Scotts Creek the main channel and South Channel to Bohnock the waters are generally close to fully oceanic except during periods of above average catchment runoff. Pollution levels in the lower estuary are lower because of the flushing effect of the tides and the low nutrient and BOD level of the ocean waters. Flushing in this area is assisted by the predominant tidal movement along Scotts Creek from Farquhar Inlet to Harrington Inlet (see Section 3.2.3).

Waters in the upper estuary around Wingham are usually less than 10% to 15% oceanic, although bottom waters can rise to above 50% oceanic during dry periods. Pollution levels in the upper estuary are generally low because of the lower concentration of nutrients and BOD in the water entering from the upper catchment. With no catchment inflows the rate of mixing is slow, and total mixing in the upper estuary, if reliant on tidal exchange alone, would probably take many months and probably more than a year.

The level of mixing between upper estuary and lower estuary waters is not sufficient to prevent the build up of pollutants, particularly nutrients and BOD, in the middle estuary near the major input sources. This problem is greatest in the Dawson River where tidal flows and mixing at the density interface are comparatively lower than in the wider main river.

5.6.3 Fluvial Flushing

Under median inflow conditions it would take one to two months for the volume of catchment runoff to equal the volume of water in the estuary. For average catchment flows this reduces to one to two weeks.

Assuming no mixing of fluvial inflows with estuary waters, and based on the 50% AEP flood volume, a flood event/fresh which replaced all the water in the estuary could be expected several times (3 to 4 times) each year. However, the presence of density stratification, as is evidenced in most river water quality profiles (Section 3.4 and Appendix B), significantly reduces the effectiveness of any fluvial flushing events by allowing lighter surface waters to shortcut the flushing process.

Based on the available water quality data, fluvial flushing of the entire estuary would appear to occur less than once per year. However, runoff events which bring significant levels of catchment pollutants into the estuary occur far more frequently. After catchment runoff has stopped the lower estuary quickly returns to near oceanic conditions and a salinity gradient is re-established along the middle estuary reaches. Much of the pollutants washed into the estuary then become "trapped" by the stratification barrier.

5.6.4 Nutrient Budget

The water balance figures provided in Table 6 and the water quality results presented above have been used to calculate nutrient budgets for Total Phosphorus and Total Nitrogen. The budgets are shown in the following table and on Figures 11 and 12. Mean ocean water TP and TN concentrations of 0.02 mg/L and 0.2 mg/L respectively have been adopted based on averaged values (MPR, 1995). Rainfall concentrations of 0.005 mg/L and 0.1 mg/L were also assumed based on typical values. Average TP concentrations of 0.03 mg/L were adopted for outflows at Harrington Inlet and 0.025 mg/L at Farquhar Inlet. Average nitrogen concentrations of 0.26 mg/L were adopted for outflows at Harrington Inlet and 0.022 mg/L at Farquhar Inlet.

Table 13: Average Annual Total Phosphorus and Total Nitrogen Budgets

Source/Sink	TP Input (tonnes)	TP Output (tonnes)	TN Input (tonnes)	TN Output (tonnes)
Rain and Evaporation	0		2	
Upper catchment Inflows	57		640	
Taree/Wingham Urban Runoff	3		10	
Taree/Wingham Sewage Effluent	18		20	
Dawson River Catchment Inflows	2		20	
Lansdowne River Catchment Inflows	3		35	
Floodplain Inflows/Outflows	4	12	55	300
Harrington Inlet Inflows/Outflows	110	180	1070	1500
Farquhar Inlet Inflows/Outflows	33	30	348	250
Balance Retained in Estuary	-	8		150
TOTALS	230	230	2200	2200

The above Total Phosphorus budget indicates that approximately 230 tonnes of phosphorus are cycled through the estuary on average each year. Over half the budget comes from the ocean, a quarter from upper catchment areas and the remainder from the local urban/floodplain area (mainly from sewage effluent discharges). Of the Total Phosphorus entering the system, an estimated 8 tonnes/yr is retained by estuary plants and bed sediments and 12 tonnes/yr is temporally held in estuary sediments prior to being distributed across the floodplain during flood events. Note, the latter figures are indicative only as they are the remainder after subtracting much larger estimated figures and so contain an inherently high degree of error.

The Total Nitrogen budget indicates that approximately 2200 tonnes of nitrogen are cycled through the estuary on average each year. Nearly two thirds of the budget comes from the ocean, over a quarter from upper catchment areas and the remainder from the local urban/floodplain area. Of the Total Nitrogen entering the system, an estimated 150 tonnes/yr is retained in by estuary plants and bed sediments and 300 tonnes/yr is temporally held in estuary sediments prior to being broken down to free nitrogen or distributed across the floodplain during flood events. Note again, the latter figures contain an inherently high degree of error.

Based on the above, the N:P ratio for the estuary is about 10:1, which is less than the 20 to 16:1 ratio usually nominated as the balanced level between nitrogen and phosphorus for plant growth (ANZECC, 1992_b). Nitrogen therefore appears to be the controlling nutrient in the estuary. It should be noted, that some phytoplankton species including toxic cyanobacteria can fix atmospheric nitrogen and under nitrogen limited conditions these species have a competitive advantage.

The estuary's nutrient budget is largely determined by factors external to the immediate estuary area, that is by ocean and upper catchment inputs, and the system is relatively insensitive to localised estuary inputs. However, this does not mean that the identified middle estuary inputs of urban runoff and sewage effluent discharges are not important in determining water quality in the estuary. As already discussed, the formation of density stratification in the middle estuary has a major determining factor on estuary water quality. Further, as with the hydrodynamic and the sediment dynamic budgets, the balance of the budget varies depending upon where the boundaries are drawn. A nutrient budget for the estuary upstream of Taree would be much smaller and dominated by catchment inflows rather than by ocean inputs.

5.7 Human Impacts

5.7.1 Past Development

Human development has been identified as the principal source of pollutants in the estuary (see Section 5.1). These main pollutant sources are associated directly with human use such as:

- treated and semi treated sewage effluent discharges,
- urban runoff,
- rural runoff,
- acid sulphate leachate from drainage areas,
- turbidity from bank and bed erosion.

The volumes of sediments and the levels of nutrients entering the estuary from the catchment prior to extensive land clearing and development is unknown. Adopting values from relatively similar undeveloped catchments on the NSW coast (EPA, 1996) indicates that suspended solids, total phosphorus and total nitrogen concentrations in runoff waters may have been around 3, 0.03 and 0.05 mg/L respectively. Based on these estimates and numerical modelling (see Appendix A) the following comparisons between pre and post catchment development were determined.

Table 14: Changes to Pollutant Inputs as a Result of Catchment Development

Pollutant Source	Bedload (tonnes) pre/post	Suspend Solids (tonnes) pre/post	TP Input (tonnes) pre/post	TN Input (tonnes) pre/post
Manning River Upper Catchment	5000/8000	5400/11 000	50/57	90/640
Taree/Wingham Urban Area	10/2600	10/1400	- /3	- /10
Taree/Wingham Sewage	-	- /25	- /18	- /20
Dawson River Catchment	250/400	170/300	2/2	3/20
Lansdowne River Catchment	380/600	270/500	3/3	4/35
Floodplain/Delta Area	660/1100	450/900	5/4	8/55
TOTAL	6300/12700	6300/14100	60/83	105/780

Although the changes are only based on assumed catchment conditions they do indicate that there has been a significant increase in all the principal estuary pollutants as a result of human development. The level of sediments entering the estuary from the catchment has approximately doubled and there has been an estimated 7 times increase in nitrogen levels. The increase in phosphorus has been about 50%.

5.7.2 Greenhouse Impacts

The impacts of increased greenhouse gas levels and consequent increased ocean water levels and changes to storm occurrence (Section 2.4) is likely to be minimal on estuary water quality. There may be some reduction in acid sulphate leachate as a result of a higher water table. Changes to storm occurrence and the possibility of either runoff levels increasing or decreasing would have some effect on tidal flushing of the estuary, but whether this has a positive or negative effect will depend on the magnitude and direction of the changes.

6. FLORA AND FAUNA

Habitat distribution within an estuary is significantly dependent upon:

- catchment characteristics (morphology, geology, soils, climate, etc.),
- the flow and mixing of fluvial and marine waters,
- bed sediments and their quality,
- temporal and spacial changes in water quality.

For the Manning River estuary these matters have been addressed in the previous chapters. As can be seen from these chapters, the Manning River provides a wide variety of estuarine conditions which then produce a range of habitat types. These in turn result in a biota (sum of all living things) which ranges from free swimming micro plankton and algae through to mangrove forests, aquatic birds and dolphins.

The composition (species presence, diversity and abundance) of the aquatic biota of the available habitats is seldom static. It is subject to variation as the biota react to long and short term variations in the physical and chemical characteristics of the habitat, e.g., seasonal changes, reactions to prolonged dry periods, or flood events. The biota variations arising from environmental changes then lead to even more complex variations in the composition of the biota as a result of interactions between the biota (e.g. competition and predation).

6.1 Description of Habitats

The first and principal habitat determinant in the Manning River estuary is the division between land and water. The habitats directly influenced by estuarine waters are deemed the Estuarine habitats and the fringing habitats not in direct contact with the estuary are called Riparian habitats.

Estuarine habitats may be further sub-divided into the sub-tidal and inter-tidal habitats. The sub-tidal habitats include the water column itself and the estuary bottom. Substratum type and depth are important determinants of estuarine habitat and thus the estuarine bottom habitats may be further sub-divided into deep sandy or gravel bottoms, shallow shoals (either sandy, muddy or gravel bottoms), and submerged rocky reefs (deep or shallow).

The intertidal habitats form the interface between the truly estuarine and riparian terrestrial ecosystems. In the intertidal habitats plants and animals need to be adapted to periodic inundation by tidal waters of varying salinity. These habitats may be subdivided into the drying shoals and intertidal fringing areas. Again, substratum type is important and the habitats are thus sub-divided into muddy, gravely, rocky or sandy habitats.

The riparian habitats are strictly terrestrial. That is they are not subjected to periodic (i.e., regular) inundation by estuarine waters. However, by virtue of the proximity to the estuary, either along the bank or on the river flood plain, they are subjected to periodic flooding. The major sub-division for riparian habitats is one of proximity. The riparian bank habitats form a direct link between the intertidal habitats and communities on the land. They are by definition found as a fringe along the waterways which consist the estuary. Because of the proximity to the estuary, the riparian habitats may form portions of the niches of some estuarine fauna (e.g., aquatic birds and mammals).

Floodplain habitats make up the remaining riparian habitat type and this habitat may be subdivided on the basis of drainage. Well drained habitats generally support fully terrestrial woodlands. Poorly drained habitats generally support heath, freshwater wetlands or mono specific swamp forests, depending on the degree of standing water and the influence of salinity (either via ground water or by flood inundation).

6.1.1 Estuarine Habitats

The broad distribution of estuarine habitats in the Manning River estuary is shown in Figures 13 (A, B & C). Because mangrove and saltmarsh communities in the lower estuary and reed beds in the upper estuary are important elements of intertidal muddy habitats, these communities are also shown. Similarly, seagrass and freshwater aquatic plant beds are generally associated with shallow subtidal muddy shoals and these have also been shown.

There is a longitudinal component to the distribution of most of the habitats, and the estuary may be sub-divided into upper, middle and lower reaches. The upper estuarine habitats in the Manning River (between the tidal limit at Abbotts Falls and the Wingham/ Mondrook Point area) are controlled by the low salinity regime imposed by the inflowing catchment waters and the presence of coarse bed sediments such as gravels and large grained sands plus the existence of rapids and bedrock bluffs. The Wingham Brush rapids are always submerged by tidal waters but Jacksons Falls and Abbotts Falls are more typically freshwater rapids with tidal influence being a function of river flow and tide cycle.

Between Wingham and Taree the gravel deposits become lower and are distributed across the whole river cross section and there are also increasingly large sandy/muddy deposits along the river bank and in the quieter backwaters. Below Taree the middle reaches of the Manning estuary comprise more or less uniform sandy-mud bottoms and muddy shallows. Within these middle reaches there are areas of hard bottom which have been layered with oyster shells.

From an estuarine biota perspective the estuarine lower reaches comprise the areas of marine sand intrusion from Harrington and Farquhar Inlets (see Section 4.1). Marine sands form deep and shallow shoals plus sandy beaches.

The Lansdowne and Dawson Rivers and the other creeks of the middle and lower estuary principally have muddy bottoms with muddy shallows. None of the tributary rivers or creeks have marine sand intrusions and the transition from upper to middle estuary reaches is far more abrupt.

6.1.2 Riparian Habitats

The riparian bank habitats vary with topography, saline intrusion and tidal influence. In the upper and mid Manning, Dawson and Lansdowne Rivers there are a variety of freshwater riparian habitats such as gallery rainforest and tall scrubland along water course and creek banks. Open forest and closed grasslands are found on the point-bar river flats.

In the middle reaches of the river much of the original bank vegetation has been cleared and the intertidal/riparian zone is characterised by fringing reed beds, riparian river oaks and large areas of grasslands along the river flats. The riparian habitats along the lower reaches of the river comprise small remnants of the former lowland forest habitat plus planted grasslands where the lowland forests have been cleared.

The lowland forest remnants generally consist of a fringe of swamp oaks. These remnants are generally located behind the remaining mangrove fringes. Wingham Brush and Coocumbac Island are the only significant examples of low land rainforests left along the Manning River estuary.

6.1.3 Floodplain Habitats

The floodplain habitats in the Manning estuary comprise the extensive freshwater swamps and sedge lands of the middle reaches of the Manning and of the Lansdowne and Dawson Rivers and the extensive fresh/saline swamps of the lower Manning River around the tidal deltas of the inlets and to the north and west of Harrington.

The middle reach swamps are located around the creek mouths and in the low areas of old river beds running parallel to the present river alignment. The lower reach floodplain swamps comprise mainly the extensive swamps located north of the main river and west of the Dawson. These drain to the Manning via Cattai Creek.

6.2 Aquatic and Riparian Vegetation

Aquatic vegetation of the Manning estuary may be sub-divided on the basis of habitat (location and salinity tolerance) to the following categories:

- the submerged vegetation - algae and submerged or fringing rooted plants seagrass and freshwater macrophytes),
- saltwater wetlands (saltmarsh, mangroves, sedges, rushes, etc.),
- riparian and floodplain vegetation (coastal swamps and forests).

Whilst phytoplankton form a major food source for many estuarine biota and are important to oysters (and therefore the oyster industry) there have been no studies of the phytoplankton communities of the Manning estuary.

6.2.1 Submerged Vegetation

The water based vegetation of the Manning River estuary consists of algae and submerged aquatic macrophytes (true vascular grass-like plants which are attached to the substratum via proper root systems and which produce flowers). Aside from the mapping of seagrasses there have been no studies of the community structure or floristics of the algae or aquatic macrophytes of this estuary.

Algae

The algae comprise free-floating microscopic forms (phytoplankton), larger semi-attached floating or stringy forms and larger more robust attached forms (macro-algae). The phytoplankton and semi-attached forms are characterised by fast growth rates and large seasonal population fluctuations. The macro-algae are slower growing and are generally located in well defined areas in the lower estuary.

All waterways support phytoplankton and semi-attached algae populations and the biomass of these populations is generally held in check by limitations in essential elements (in the form of nutrients - nitrogen and phosphorus), by temperature and by available light for photosynthesis. For some phytoplankton groups such as the diatoms which secrete a silicon shell, dissolved silicon can also be limiting. In estuaries affected by agricultural development or urban runoff (i.e., where there can be greater than normal inputs of plant nutrients), the natural check on phytoplankton and semi-attached algae growth arising from limiting nutrients may be removed leading to phytoplankton algae blooms or blooms of attached nuisance algae (see also Chapter 5).

Biomass of phytoplankton is generally estimated indirectly by a measurement of the concentration of chlorophyll-a, a plant pigment common to most phytoplankton species. Whilst there have been few if any reports of algae blooms in the Manning River estuary there have been reports of both elevated nutrients and elevated chlorophyll-a concentrations. Algae blooms in the middle Manning River estuary may be limited by available light which itself is limited by excessive turbidity arising from excessive bank erosion (Chapter 5).

The macro-algae, being larger and more robust, require some form of firm attachment. They are therefore limited to areas which provide hard attachment structures and materials (rocks, shell beds, oyster lease structures). The macro-algae are generally associated with the marine end of the estuary with a decrease in attached plants along an upstream salinity gradient.

The principal attached macro-algae along the Manning River seawall are kelp, *Ecklonia radiata* and *Sargassum spp*. *Sargassum* and a few other green algae species may occur seasonally on shallow rocky shores or reefs up to about Taree. A number of salinity tolerant freshwater species may colonise shallow reefs at the upper reaches of the rivers. There are also semi-attached forms (long brown and green weeds) which form large patches of nuisance algae at certain times of the year. These may occur in any parts of the estuary, right up to the tidal limit.

The smaller members of the macro-algae can attach to other plant substrata such as mangrove aerial roots and seagrass leaves. Algae which grow on other aquatic plants are called epiphytes. The estuarine epiphytic algae are generally associated with the saltwater aquatic angiosperms (such as *Zostera capricomi*). Epiphytic algae, like the phytoplankton, can generally respond quickly to increases in plant food supply. In eutrophic (nutrient rich) conditions the growth of epiphytic algae on seagrass may be prolific and lead to smothering and shading of the seagrasses to the extent that the seagrass can be adversely affected. There were no instances of prolific epiphytic algae growth observed during the field studies for this project and there have been no reports of such growth for the Manning.

Submerged aquatic macrophytes

The salt tolerant aquatic macrophytes (seagrasses) are found in shallow beds downstream of Tinonee and are concentrated along the lower reaches of the river. Whilst the Manning estuary is the third largest water area on the north coast (about 28 km^2) it supports only 33 ha of seagrass. In contrast, the Hastings River estuary supports 114 Ha of seagrass and the Camden Haven estuary supports 634 Ha of seagrass (which includes extensive beds of *Ruppia spp*). Unlike the Manning both these adjacent estuaries have extensive shallow lagoon systems on their floodplains.

Of the total seagrass species reported from the north coast (West, 1985), two occur in the Manning River (Figure 13B). *Zostera capricomi* (eelgrass or silky weed) commonly occurs on the mudflats and in the shallows along the shores of the Manning River below Taree, in the Harrington back channel and around the seaward ends of Scott's Creek and the South Channel (Farquhar Inlet). Paddle weed, *Halophila ovalis*, occurs as sparse patches in shallow waters along the river edges, in the Harrington back channel and in Farquhar Inlet. *Heterozostera tasmanica* has been reported from deeper waters of the Harrington Inlet (WBM, 1983), but this species was not found in the same study area during a 1993 study nor was it found in the present survey.

A freshwater macrophyte, ribbon weed (*Vallisneria sgiganteus*) occurs upstream of Wingham (Figure 13A), in shallow muddy bed habitats similar to seagrass habitats downstream. In the gravel beds at the top of the estuary, ribbon weed and pond weed (*Elodia canadiensis)* have been reported (WBM, 1983) and were observed during the field survey for this project. Resource Planning (RP, 1989) also reported several other freshwater species; perfoliate pondweed (*Potamogeton perfiolatus*), water nymph (*Najas tenuifolia*) and a polygonia *Polygonum sp.*, from the section of river at the transition between freshwater and saltwater (Jacksons Falls to Abbotts Falls).

Between Wingham and Mondrook Point there is a mixed fringe of ribbon weed and *Ruppia sp.*, a more salt water tolerant submerged macrophyte. *Zostera* was reported growing among freshwater plant affinities in the upper Manning between Jackson's and Abbotts Falls (RP, 1989). This would seem an unlikely occurrence even though the study was undertaken in April 1983, following a severe drought which affected river flows and allowed saline intrusion much further upstream than normal. It is noted that no *Vallisneria* was reported and it may be that the reported *Zostera* was in fact *Vallisneria*.

Comparison of the mapping of seagrasses undertaken for the present study and that undertaken by West in 1984 would indicate that in broad terms there have not been significant changes in the distribution of seagrass within the estuary. However, there are certainly seasonal and longer-term variations in distribution for individual seagrass beds. This is indicated in the detailed analysis of seagrass distribution around the Harrington Back Channel provided in Mitchell McCotter (1993) where long term variation in distribution has been attributed in part to movement of marine sand bars.

6.2.2 Emergent Plants

Salt tolerant emergent plants such as mangroves and a host of saltmarsh plants fringe the lower estuary and cover the mud flats of the lower estuary. River reeds line the banks of the mid and upper estuary.

Mangroves and Saltmarsh

Figures 13A to 13 C show the main coastal wetland associations (saltmarsh and mangroves) in the Manning estuary and Figure 5 shows the distribution of saltwater wetlands throughout the lower estuary. Most of these wetlands have been afforded zoning protection either under Council's 7a or 8a zoning or under specific SEPP14 Wetlands zoning. The area of Manning estuary saltwater wetlands is comparable to adjacent northern river estuaries. The Manning supports 358 Ha of mangroves and 72 Ha of saltmarsh. By contrast the Hastings River estuary supports 207 Ha of mangroves and 80 Ha of saltmarsh and the Camden Haven supports 87 Ha of mangroves and 78 Ha of saltmarsh.

Two species of mangrove are commonly found in the Manning estuary, the grey mangrove (*Avicennia marina*) and the river mangrove (*Aegiceras corniculatum*). The grey mangrove is dominant in the lower and mid Manning estuary (up to Tinonee) and often form large stands or forests in the lower estuary, especially at the heads of shallow muddy bays such as Pelican Bay. The river mangrove generally forms a fringe along the river side of the grey mangrove and penetrates a little further up the main river to Tinonee. Both mangrove species fringe the estuarine portions of the Dawson and Lansdowne Rivers.

A third mangrove species, the milky mangrove (*Exoecaria agallocha*) has been reported from the lower Manning River (West, 1985) and is at the southern most point of its range. Whilst this species was not sighted for this project it could still be present. If present, it would be found in the lower estuary as an uncommon and fringing associate of swamp forest where swamp forest merges into saltmarsh/mangrove forest.

Comparison of mapping of mangroves and saltmarsh habitats undertaken for the present study and that undertaken by West in 1984 would indicate that in broad terms there have not been significant changes in the distribution of these habitat types within the estuary. However, there are certainly instances of loss of both saltmarsh and mangrove habitat to developments (e.g. drainage works, sewage treatment works, bridge works) plus losses due to wanton destruction (e.g. cutting of mangroves in Harrington Back Channel).

River Reeds

The mid Manning River estuary is a transition zone between the mainly freshwater upper estuary and the distinctly marine lower estuary. The bank vegetation of this zone is characterised by prolific reed beds fringing the river from just above the Pacific Highway (Martin) bridge upstream to just above Mondrook Point (Figure 13A).

The lower section of reed beds (from the bridge to Andrews Reserve, Tinonee) consists of a narrow fringe of river mangroves and salt rush (*Juncus kraussii*). Above Andrews Reserve there is a mixed salt rush and reed (*Phragmites australis*) community. These reed beds do not cease abruptly at the limits described above but continue as smaller and thinner strips or clumps both up and down stream, as shown in Figure 13A.

The introduced rush *Juncus acutus acutus* has been reported in saltmarsh areas near Old Bar Park and is thought to be spreading and displacing local species. This species may also occur in Harrington Lagoon saltmarsh.

6.2.3 Riparian and Floodplain Vegetation

Riparian habitats have been mapped and described in general terms by the National Parks and Wildlife Service (NPWS, 1995) and are summarised in the Taree 1995 State of the Environment Report. The terrestrial/riparian vegetation systems are shown in Figure 5 of this report.

As noted in Sections 6.1.2 and 6.1.3 above, the riparian and flood plain vegetation of the Manning estuary generally has been much reduced by urbanisation and agricultural development. Bank erosion is widespread throughout the Manning River estuary and clearing of riparian vegetation has been identified as one of the main contributing factors (Section 4.2.2 above). Much of the remaining middle and lower Manning River riparian vegetation has subsequently been lost to additional river bank erosion. Further details regarding the condition and weed infestations of the riparian and floodplain vegetation components are contained in the Taree 1995 State of the Environment Report (GTCC, 1995_b).

Resource Planning (RP, 1989) described the riparian vegetation of the Manning River between Jackson and Abbots Falls; i.e., at the head of the estuary, and provided detailed species lists. Their description of vegetation alliances and their species lists are adequate to describe the riparian flora along the upper estuary from Abbot's Falls to Mondrook Point. "Tall scrubland and closed grasslands occur on the river flats with terrestrial affinities (mainly dry open forest) on the higher ground. Gallery rainforest vegetation occupies a narrow strip along the water's edge and is generally open to domestic stock."

There are only a few remnants of the once extensive sub-tropical rainforest remaining in the Manning Valley (Williams, 1990). The most significant riverine rainforest portion on the Manning is Wingham Brush, located just south of Wingham. Williams also described two other significant areas of riverine rainforest, both on the Lansdowne River. One, the Lansdowne Recreation Reserve is about 4 Ha in size and is crown reserve. It is located on the tidal portion of the river and the riparian portion of the vegetation includes river mangroves and she-oaks *Casuarina glauca*. It is more closely associated with littoral rainforest. Williams noted that management problems at the Reserve were substantial with weed infestation, walking trails and fire damage around the fringes. The second portion of riverine rainforest is located in a gully on private land above the estuary and the weir at Lansdowne.

In the middle reaches of the river the riparian banks are characterised by fringing reed beds, river oaks and large areas of grasslands along the river flats. There are isolated pockets of riparian lowland rainforest in the middle reaches of the river. The most significant of these is located on Coocumbac Island (Williams, 1990). There are also isolated areas of riparian (gallery) rainforest along a number of smaller watercourses in the mid to lower estuary. Gallery rainforests generally form narrow bands fringing creeks and minor watercourses. In the mid Manning they often pass through cleared agriculture land and thus provide important wildlife corridors and buffer zones between the cleared lands and the water.

The cleared riparian habitats along the lower reaches of the river comprise large sections of planted grasslands (mainly for fodder)with some remnant patches of swamp oaks, generally located behind remnant mangrove fringes.

In the lower estuary there are larger swamp forest remnants behind the river mangrove fringe (MPR, 1990) and (MMc, 1993 & 1994). These remnants are typically dominated by swamp oaks (*Casuarina glauca*), which may reach to 14 m in height. There are few shrub understorey species. Lantana (*Lantana camara*), often occurs in patches and coastal morning glory (*Ipomoea cairica*) occurs as a scrambler. Ground cover is generally sparse with sedges (the salt rush *Juncus kraussii*) and salt couch (*Sporobolus virginicus*) being the most common. Kikuyu and buffalo grass also occur.

The riparian sedge lands of the lower flood plain are a complex of fresh and salt water affinities. For example, the Great Swamp is described as 1,100 Ha of fresh meadow, 400 Ha of seasonal fresh swamp and about 500 Ha of saltwater sedge lands. Around Cattai creek there are large tracts of Melaleuca swamp (LMP 1980). The fresh to brackish water sedge lands are dominated by saltwater sedge (*Baumea juncea*) or twig rushes (*B. rubiginosa*). The salt to brackish water sedge lands comprise a mosaic of saltwater sedge and rushes (*Juncus kraussi* and *Phragmites australis*) plus saltmarsh dominated by samphire (*Sarcocornia quinqueflora*) and salt couch (*S. virginicus*).

There are pockets of littoral rainforest, coastal heath and coastal shrub along the coastal fringe with some of these elements extending down to water courses and along estuary margins (e.g., at Harrington, Manning Point and in Old Bar Park, Old Bar).

6.3 Aquatic Fauna

Aquatic fauna of the estuary may be subdivided into the following main groups:

- the invertebrate fauna, zooplankton, benthic invertebrates (pippies and worms) and larger mobile invertebrates (prawns, etc.),
- fish and marine mammals,
- aquatic birds.

6.3.1 Invertebrates

The smaller invertebrate fauna includes the zooplankton and the benthic (bottom dwelling) invertebrates of the estuary.

Zooplankton

There have been no studies of the zooplankton of the Manning River estuary. The zooplankton comprises a group of small and microscopic free-living invertebrate organisms which reside in the water column and feed off phytoplankton or attached algae, or prey on other zooplankton. The zooplankton fauna also includes larvae and eggs of many of the larger invertebrate organisms and fish. In a riverine estuary the zooplankton may also include freshwater or brackish water plankton brought down the estuary in the freshwater invertebrate drift. Zooplankton are important in grazing and controlling mild algae blooms. They also comprise a significant food resource for many estuarine fish species.

Benthic Fauna

The benthic (bottom dwelling) fauna of an estuary constitutes the most important food source for a majority of estuarine fish species and for a large number of aquatic birds, principally the wading birds. A large proportion of this component of the aquatic fauna resides in the bottom sediments of the estuary and, as the benthos is essential non-mobile, is susceptible to adverse water quality conditions. A study of the benthos will therefore give both an indication of the overall worth of the estuary as a fisheries and aquatic bird habitat, and an indication of bottom water quality.

There have been three studies published on the benthos of the Manning River; two surveys of the benthos in the upper Manning estuary (WBM, 1989 and RP, 1989) and a survey of the benthic fauna of the lower Manning estuary in and adjacent to Harrington Inlet (Oceanics, 1985). There have been no studies of the (critical) middle reaches of the estuary. However, in spite of the limitations of the available studies, observations on habitat health made for the present study support the conclusion that the Manning River upper and lower estuary sections probably support a diverse and healthy benthic fauna in comparison with other estuaries (e.g. Botany Bay (SPCC, 1981), or the Bellinger River (MPR, 1993)).

Upper Estuary Benthos

The WBM (1989) study collected benthic fauna from six sites; one from an upper estuary site adjacent to Wingham and five sites ranging down the upper estuary from Mondrook Point to Tinonee. The sample substratum ranged from highly mobile sand to coarse gravels. Species diversity and abundance were low as would be expected on mobile, coarse substrata.

For the Wingham site there were five mainly freshwater species, an annelid worm, two molluscs and two insect larvae. None of these species, with the exception of one of the molluscs (*Fluviolanatus amarus,* a bivalve), occurred downstream. *F.amarus* is generally found in brackish waters (as at sites 2 and 5 downstream from Wingham) and its presence at site 6 would indicate that bottom waters at Wingham were not altogether fresh. This is consistent with water quality sampling which showed that a tidal saltwater wedge can form up to Wingham (Chapter 5).

Seven estuarine species were collected from the five sites downstream of Mondrook Point, four polychaete worms, two bivalve molluscs and an amphipod crustacean.

Resource Planning (1989) sampled the Manning between Jacksons and Abbotts Falls. Sampling was undertaken in February 1983 prior to the breaking of a prolonged drought, and in April 1983 following good rains and restoration of "more normal" river flows. They described the invertebrate fauna as "oligohaline, i.e., mildly resistant to salinity, not truly representative of the freshwater species and with few affinities to the marine biota."

Lower Estuary Benthos

A survey of the benthic fauna of the lower Manning estuary in and adjacent to Harrington Inlet was undertaken by Oceanics Australia in 1984 (Oceanics, 1985). A total of 10 stations were sampled. Bottom substrata varied from bare marine sands to deep estuarine muds and shallow *Zostera* beds.

Three major taxonomic groups were recorded in the results, molluscs (8 bivalves, 9 gastropods), polychaete worms (15 species) and crustaceans (6 species). Over the complete study area there was a mean of 4.5 molluscs, 5.7 polychaete worms and 1.3 crustacean species per sample. Mean abundance over the complete study area were 24 molluscs, 13.8 polychaetes and 9.6 crustaceans per sample.

The single *Zostera* site supported the second highest number of taxa (16 taxa) and the largest abundance (170 individuals). The single muddy site supported the least taxa (4 taxa) and the lowest abundance (7 individuals). All other sites were reasonably diverse and supported between 7 and 17 taxa and between 24 and 72 individuals.

There was little difference between predominantly sandy and silty-sand sites; mean number of taxa on both was 11.5 taxa per site. Mean number of individuals was slightly greater on sandy sites (mean 48 individuals on sandy and mean of 38 individuals per site on silty-sand sites).

6.3.2 Fish and Larger Crustaceans

There have been no studies of the fish and crustaceans of the Manning estuary but a number of fish lists have been complied (Oceanics, 1983), (WBM, 1989), (Nix, 1990) and (P&S, 1993). These lists were amalgamated into a single list (MMC, 1993). Table 15 reproduces that list plus two additional species included as part of this study. Detailed information on life histories and seasonal occurrences of many of the listed fish and invertebrates, particularly those of commercial and recreational importance, may be found in a report on the ecology of fish in Botany bay (SPCC, 1981).

The updated list includes the recreationally important migratory Australian bass which transits the upper estuary on its migrations to the middle estuary from freshwater sections of the river. Another recreationally important species, the estuarine perch was also not included on the original list. This fish also migrates to its breeding grounds in the middle estuary above Taree in autumn-winter each year (EPA, 1995).

Table 15: Fish Species Observed in the Manning River Estuary

Common Name	Scientific Name	Category **
Flathead, Dusky	Platycephalus fuscus	A
Perch, Estuary	Macquaria colonorum	A
Bass, Australian	Macquaria novemaculeata	-
Leatherjacket, Fan-bellied	Monacanthus chinensis	A
Whiting, Sand *	Sillago ciliata	B
Bream, Yellow-finned *	Acanthopagrus australis.	B
Luderick	Girella tricuspidata	B
Mullet, Sea *	Mugil cephalis	B
Snapper	Chrysophrys auratus	C
Flounder, Small-toothed	Pseudorhombus jenynsii	C
Flounder, Large-toothed	Pseudorhombus arsius	C
Groper, Western Blue	Achoerodus gouldii	C
Mulloway	Argorosomus hololepidotu	C
Tarwhine	Rhabdosargus sarba	C
Pilchard	Sardinops neopilchardus	C
Garfish, Eastern Sea	Hyporhamphus australis	D
Herring Southern	Harengula abbreviata	D
Anchovy, Australian	Engraulis australis	D
John Dory	Zeus faber	E
Salmon, Eastern Australian	Arripis trutta	E
Tailor	Pomatomus saltator	E
Yellowtail	Trachurus novaezelandiae	E
Flathead, Northern Sand	Platycephalus arenarius	E
Jack, Mangrove	Lutjanus argentimaculatus	B
Trumpeter	Pelates quadrilineatus	C
Whiting, Trumpeter	Sillago macaluta	C
Goby, Krefft's	Bathygobius krefftii	A
Sole, Lemon Tongue	Paraplagusia unicolor	C
Toadfish	Tetractenos hamiltoni	B
Jewfish/Mulloway	Argyrosomus hololepidotus	C
Cowtail Ray	Pastinachus sephen	B
Blue-eye	Pseudomugil signifer	A
Perchlets	Velambassis jacksoniensis	B
Fortescue	Centropogon australis	B
School Prawns	Metapenaeus macleayi	B
Schrimp	Palaemon debilis	A
Blue Swimmer Crab	Portunus pelagicus	B
Mud Crab	Scylla serrata	A

NOTES:

- * Indicates commercially important species.
- ** Estuarine dependancy.
- A Dependant on estuarine habitat for all needs.
- B Dependant on estuarine habitat for all needs except spawning.
- C Live in estuaries as juveniles but in open sea or coastal areas as adults.
- D Common outside estuaries but spawn in estuaries.
- E Common outside estuaries but also found in estuaries.

Several additional fish species have been noted in the upper Manning between Abbotts and Jacksons Falls (PR, 1989). These include the bully mullet (*Mugil cephalus*) and short-finned eel (*Anguilla australis*) plus three freshwater species, the Mitchellian hardyhead (*Craterocephalus fluviatilis*), a striped gudgeon (*Gobiomorphus australis*) and the introduced mosquito fish (*Gambusia affinis*).

Lower estuarine habitat requirements of some of the fish listed in Table 15 have been taken from the State Fisheries' Botany Bay study (SPCC, 1981). Shallow estuarine habitats in general and seagrass beds plus mangrove creeks in particular have been found to be important as nursery areas for commercial species of fish and prawns. A similar range of habitat preferences may be established for the other listed estuarine fish. As noted above, additional estuarine perch nursery and spawning areas have been identified upstream from Taree. These areas are utilised during the autumn/winter breeding season.

SPCC (1981) concluded that post larvae and small juveniles of commercial species demonstrate relatively specific habitat preferences which are probably related to their specific shelter and feeding requirements. With increasing size most species utilise a wider variety of habitats. This behaviour is attributable mainly to their feeding requirement, the spawning behaviour of adults and a reduced necessity for shelter to provide protection from predators. Crustaceans and polychaetes were identified as the major food items. However, substantial differences frequently existed in the diet of a given species in different habitats. This is true for both large and small size classes and indicates that most species are relatively opportunistic. Significant seasonal differences in diet are common within any one year and frequently correspond to temporal changes in habitat preferences.

In terms of habitat importance the study indicated that mangrove and seagrass habitats were critically important habitats in the lower estuary. The study also found that a number of the listed fish and crustaceans utilise shallow sandy habitats (shoals) on a temporary or transient basis. Adults and juveniles of these species utilise the habitat for feeding and most are non seasonal. As noted above, the estuarine perch breeding grounds above Taree are critical habitat during the autumn-winter breeding season.

6.3.3 Marine and Aquatic Mammals

The mammal fauna of the estuary may be sub-divided into the true marine mammal fauna of the lower estuary which consists of the cetaceans (dolphins and whales) and the terrestrial based mammals which make use of the waterway, such as the swamp rat *Rattus lutreolus* (a common inhabitant of sedge and rush lands and the water rat *Hydromys chrysogaster*.

Two dolphins, the common and bottle-nose dolphins (*Delphinus delphis* and *Tursiops truncatus*), are known from the lower and mid estuary. A Bryde's whale, Balaenoptera edeni, became inadvertently stranded inside the river for almost four months (August to November 1994) before being towed out to sea and released. The Bryde's whale probably became trapped inside the river following its initial stranding on sand bars at the river mouth. The swamp rat has been listed as occurring in the region (GTCC, 1995) but the water rat was not listed. It is however reported by locals to be common along the water front of Manning Point.

Sea turtles have been reported by locals from the lower estuary but the species are unknown. For the upper estuary/freshwater transition Resource Planning (1989) reported two riparian/aquatic reptiles, the eastern water dragon (*Physignathus lesueurii*) and a tortoise (*Emydura signata*).

6.3.4 Aquatic Birds

Estuaries are important habitat for wading birds, for birds dependant on riparian vegetation and for fishing birds. The GTCC State of the Environment report (GTCC, 1995) contained a comprehensive bird list for the region but did not make any distinction about occurrence or habitat utilisation. A number of specific aquatic bird lists have been complied for the estuary and Mitchell McCotter (1993) amalgamated these lists into a single list for the lower estuary. This list was used as a base for Table 16.

Table 16: Aquatic Birds Utilising the Manning River Estuary

Common Name	Scientific Name	Feeding * Methods	Habitat?				
			C	IS	SB	MS	UF
Darter, Australian	Anhinga melanogaster	Fisher	X				X
Heron, Mangrove	Ardeola striatus	Wader/Fish				X	X
Heron, Rufous Night	Nycticorax caledonicus	Fisher					X
Heron, Striated	Butorides striatus	Wader/Fish					
Heron, White-faced	Ardea novaehollandie	Wader/Fish		X	X		X
Bittern, Black	Ixobrychus flavicollis	Fisher				X	X
Egret, Great	Ardea alba	Wader/Fish		X	X		
Egret, Intermediate	Ardea intermedia	Wader/Fish		X	X		
Egret, Eastern Reef	Ardea sacra	Wader/Fish		X	X		
Egret, Little	Ardea garzetta	Wader/Fish		X	X		
Oystercatcher, Pied	Heamatopus longirostris	Wader/Benthos		X	X	X	
Stilt, Black-winged	Himantopus himantopus	Wader/Benthos		X	X	X	
Godwit, Bar-tailed	Limosa lapponica	Wader/Benthos		X	X		
Cormorant, Great	Phalacrocorax carbo	Diver	X				X
Cormorant, Little Pied	P. meclanoleucos	Diver	X				X
Cormorant, Little Black	P. sulcirostris	Diver	X				X
Cormorant, Pied	P. varius	Diver	X				X
Spoonbill, Yellow-billed	Platalea flavipes	Wader/Benthos		X	X		
Spoonbill, Royal	Platalea regia	Wader/Benthos	X	X	X		
Ibis, Sacred	Threskiornis aethiopica	Wader/Benthos		X		X	
Ibis, Straw-necked	T. spinicollis	Wader/Benthos		X	X		
Sandpiper, Common	Tringa hypoleucos	Wader/Benthos		X	X		
Greenshank, Common	T. nebularia	Wader/Benthos		X	X		
Turnstone, Ruddy	Arenaria interpres	Wader/Benthos		X	X		
Curlew, Eastern	Numenius madagascarien	Wader/Benthos		X	X		

Common Name	Scientific Name	Feeding * Methods	Habitat?				
			C	IS	SB	MS	UF
Lapwing, Masked	Vanellus miles	Wader/Benthos		X		X	
Lapwing, Masked	Vanellus miles	Wader/Benthos		X	X		
Duck, Pacific Black	Anas superciliosa	Shallows	X			X	
Teal, Chestnut	Anas castanea	Shallows	X				
Osprey	Pandion haliaetus	Diver	X				
Sea-eagle, White-breast	Haliaeetus leucogaster	Diver	X			X	
Kite, Whistling	Milvus sphenurus	Diver	X			X	
Tern, Caspian	Hydropogne caspia	Diver		X	X		
Tern, Little	Sterna albifrons	Diver		X	X		
Tern, Common	Sterna hirundo	Diver		X	X		
Tern, Crested	Sterna bergii	Diver		X	X		X
Pelican, Australian	Pelicanus conspicillatus	Shallows/Div	X				X
Gull, Silver	Larus novaehollandiae	Wader/Shallows	X		X		X
Jabiru	Xenorhynchus asiaticus	Shallows		X	X		X
Swan, Black	Cygnus atratus	Shallows		X	X		
Moorhen, Dusky	Gallinula tenebrosa	Shallows					X
Swamphen, Purple	Porphyrio porphyrio	Shallows					X
Coot, Eurasian	Fulica atra	Shallows					X

NOTES:

* Feeding Methods
Fishing & Diving birds generally dive for mobile prey.
Wading birds prey on mobile species (fish), probe for invertebrate animals in the substratum (benthos) or feed ib benthic vegetation.
Shallows birds feed on benthic vegetation or animals.

Habitats
- C — Channels and submerged intertidal shallows.
- SB — Seagrass beds
- IS — Intertidal sand banks and shores
- MSM — Mangroves and/or Saltmarsh
- UF — Upper estuary/freshwater riparian

The following additional species were reported to the Consultants as also occurring. Note that species names have been standardised against the Slater Field Guide (1993): Black Bittern *(Ixobrychus flavicollis)*, Beach Thick-knees *(Esacus magnirostris)*, Sanderling *(Calidris alba)*, Brahminy kite *(Milvus indus)*, Comb-crested jucana *(Jucana gallinacea)*, Varied or Mangrove Honeyeater *(Lichenostomus versicolor)*, Sacred kingfisher *(Todiramphus sancta)*, Hardhead or white-eyed duck *(Aythya australis)*, Wood or Maned duck *(Chenonetta jubata)*, Grey teal *(Anas gracilis)*.

Two bird species lists were compiled for the upper estuary; one as part of the Wingham Environmental Study (GTCC, 1987) and one for a study of the portion of river just above Abbotts Falls. Both have been incorporated into Table 16. Fifteen birds were listed as utilising the upper estuary and 11 of these were also identified from the lower estuary. The remaining 4 are generally associated with freshwater; dusky moorhen, eastern swamphen, coot and the rufous (or nankeen) night heron. The whistling kite, whilst it is not strictly an aquatic bird, is known to hunt for fish over rivers and estuaries, much like the sea eagle.

There are a number of listed (endangered) aquatic bird species which are dependant on the Manning estuary for food or shelter/nesting. The little tern (*Sterna albifrons*) has important nesting sites on the sandspit on the northern side of Manning River mouth at Harrington and on the northern side of Farquhar Inlet (Smith, 1990). Potential nesting sites have been identified on the southern side of the Manning River mouth at Manning Point. The osprey (*Pandion haliaetus cristatus*) has important nesting trees in the lower estuary (Clancy, 1991). Two sites are known from Harrington, one from Cundletown and one from Old Bar. All these sites were active in 1990 and the Old Bar site was observed to be active during field work for the present report (in 1997).

Under the Japan-Australia Migratory Bird Agreement (JAMBA) and its Chinese equivalent (CAMBA) Australia agrees to protect birds which migrate between China and Japan and Australia, plus their habitats. In NSW these treaty obligations are administered by the National Parks and Wildlife Service. The lists includes 38 NSW wader species, a number of which visit the Manning estuary. The Manning estuary does not contain sufficient wader habitat to warrant inclusion of particular sites in the schedules of protected habitat.

6.4 Human Impacts

Estuarine ecology is governed by physical processes (tides, floods and river hydraulics) and by land and waterway uses (rural and urban land use, oyster farming, fishing, gravel extraction and water based recreation). Ecology may be governed by direct impacts (bank erosion, marine sand intrusion) or indirectly via adverse water quality arising from land use practices.

Natural Physical Processes

The physical processes governing the Manning River estuary are detailed in Chapters 3, 4 and 5.6 of this report. There are several underlying natural processes which impact on estuarine ecology. The interaction between saline intrusion and freshwater flows is greatly dependant on drought/flood cycles. During drought conditions freshwater flows can be very low and saline intrusion may reach as far as Jacksons Falls. As noted above this can alter the range and type of benthic and fish populations of the river.

The interaction of freshwater inflows and marine tidal waters leads to density stratification under medium to high freshwater flows (Section 5.6.1). Density stratification develops in the middle reaches of the Manning, Dawson and Lansdowne Rivers and the extent of stratification varies with runoff. During extended dry periods stratification may extend from Croki to the tidal limit. During higher than average runoff there may be no stratification for the length of the river.

The effect of density stratification can be to trap pollutants in the upstream layer and so impede flushing of the pollutants to the sea. These are then more generally available for take up by bottom organisms. Stratification can also lead to deoxygenation of the bottom waters. Depletion of oxygen is a factor of the time elapsed between successive freshwater discharge events

(Williams, 1987). Deoxygenation can lead to the death of benthos and to fish kills when fish are trapped by deoxygenated layers and can also lead to the release of nutrients from bottom sediments with consequent uptake by algae to form nuisance algae growths or phytoplankton algae blooms.

The flood/drought cycles also impact on the hydraulics of the entrances which in turn may influence water quality. Farquhar Inlet and the estuary leading down to it are potentially susceptible to changing water quality as a direct consequence of alterations to the entrance of the inlet. Principally the proportion of tidal and freshwater flows along Scotts Creek and the South Passage may be altered with consequent changes in the length of time lower salinity is experienced through the lower estuary. The alteration in flows may also result in the alteration of the location and time of trapping by stratification of polluted bottom waters. This is of particular concern to oyster farmers in the South Passage and Scotts Creek. Currently there are insufficient water quality data to test the above suggestion.

Fish kills may result from the sudden release of "black waters" to the river or to adjoining creeks from swampy areas. After prolonged rainfall, pools of water collect in swampy areas and may go stagnant over weeks or months with consequent drop of dissolved oxygen levels to zero. When subsequent rainfall occurs this oxygen depleted water may be flushed out into an adjoining creek or river trapping fish which suffocate.

Land Use Practices and Water Quality

Land use practices can (and do) have a profound impact on aquatic biota. Direct impacts such as habitat destruction (clearing of mangroves, alterations of saltwater sedge lands and saltmarsh to freshwater meadow, dredging of shoals) limit the amount of space, shelter and food available for aquatic plants, invertebrates and fish. Fish may also be limited by the decrease in specific nursery habitat. Aquatic bird populations are consequently limited by the decrease in food supply and by decrease in nesting or roosting space.

The life cycles of many estuarine fish and crustaceans is dependent on the size and frequency of minor flooding events and on the invertebrate drift food brought down to the estuary from the freshwater sections by these floods. Construction of dams and weirs at the estuary head generally limit the interaction of fish and invertebrate drift up and down stream.

The Manning River estuary and its tributaries (with the exception of the Lansdowne River) has a direct connection to the freshwater portion of the river without intervening weirs or dams and thus provides the important minor flood and invertebrate drift triggers for many of the estuarine fish and crustacean. This also has important consequences for fish (such as Australian Bass and eels) which migrate up the estuary to freshwater habitats.

There are a number of dams and weirs on freshwater tributaries of the Manning located well above the estuary and these probably have negative consequences for freshwater fish and invertebrate migration in their locality. Isolation of fresh waters from estuarine waters by a weir at the head of the estuary has been implicated as a reason for the decline of fish both above and below the weir at Lansdowne (unpublished report, NSW Fisheries). NSW Fisheries have recommended immediate breaching and eventual removal of the Landsdowne weir to facilitate migration of fish between the estuary and the freshwater sections of the river.

Drainage and flood mitigation works on the lower flood plain also limit the movement of biota from the river to the productive channel and watercourse habitats and to the flood plain sedge lands and freshwater swamps which these water courses connect. NSW Fisheries data indicate a number of problems with fish passage due to road or drainage works; four creeks where culvert diameters are too small, two creeks and a stormwater drain where culvert inverts are set too high and three creeks where causeways have no openings.

NSW Fisheries data also indicate that there are more than seven sets of flood gates which impede water movement on waterways leading into the Manning, at least 13 flood gates on the Landsdowne River and six on Ghinni Ghinni Creek. All these structures should be examined with a view to improving fish passage. Given the comparative low area of estuarine wetlands habitat along the main river banks compared with the wetland habitat isolated by flood mitigation works, this could be a significant limit on aquatic production in the Manning estuary.

Most indirect impacts on aquatic biota arising from land use practices are mediated by the effects of land use practices on water quality. The interaction of land use practices and water quality is detailed in Chapter 5.

The review of water quality presented in Chapter 5 indicates a number of significant gaps in the data. Notwithstanding these gaps the review concluded that water quality in the main channel appears to have improved over recent years with a number of exceptions:

- the north passage downstream to Ghinni Ghinni showed higher nutrient concentrations and consequent high chlorophyll-a concentrations,
- the lower estuary water quality appears to be generally adequate, at least under dry weather conditions,
- Browns Creek water quality is generally inadequate as a consequence of sewage effluent discharges and urban runoff,
- Dawson River water quality has deteriorated, possibly as a result of sewage effluent discharges combined with low flushing rates,
- Lansdowne River water quality is generally good, at least during dry weather. Following rain there are significant acid sulphate leachate problems leading to low pH conditions.

With respect to the estuarine biota and human health the main pollutants in the Manning estuary are high siltation loads, excessive nutrients, high faecal coliform loads and low pH/ waters. Most are associated with catchment land use practices and most are associated with runoff during wet weather (mediated by natural physical processes, as detailed above).

Upland native bushland in the wider catchment is a significant source of sediment, faecal and nutrient load to the estuary and the basic nature of the estuarine aquatic ecosystem is governed by these natural pollutant loads. The main sources of water pollution over and above this natural background are agricultural and urban runoff which contribute further suspended solids, nutrients and faecal coliforms.

Pollution from agricultural runoff arises from inadequate control of intensive farming practices and inadequate stock control within the riparian zone. Urban runoff is contributed by inadequate control of road runoff, by sewage treatment plus sewage overflow from the two main townships, by septic groundwater or runoff from the smaller townships and by individual rural dwellings plus packet sewage treatment plants associated with tourist development.

Bank erosion throughout much of the Manning estuary has been exacerbated following clearing of riparian vegetation, clearing of mangroves and by excessive stock movements within riparian zone vegetation. Bank erosion results in greater silt loads being carried down stream, and the silts are often a major source of nutrients. Submerged aquatic plant life may be limited to shallower depths due to lower light penetration. Whilst algae blooms may be stimulated by the excess nutrient supply, the higher turbidity resulting from the silt loads may limit plant growth by inhibiting available light for photosynthesis.

Direct nutrient input by cattle increases in the freshwater sections of the catchment during low or drought flow conditions when more cattle travel to the rivers for water. These increased nutrient inputs plus decreased flushing during lower flow conditions have been implicated in observed high algae growth in other similar Northern river systems (MMc, 1993).

A significant additional source of pollution on the lower flood plain is acid soil runoff from drained freshwater marshes. NSW Fisheries have identified three sets of agricultural drains (on Cattai Creek, Ghinni Ghinni Creek and in the Landsdowne River) which produce acid soil runoff. Acid runoff has been implicated in fish kills and red spot disease reported from various parts of the lower river (and in particular from the Lansdowne River). Other acid runoff "hot spots" have been identified in and around Cattai Creek and have been reported from Scott's Creek.

In summary, the type, area and quality of habitats are important indicators of the type and abundance of aquatic organisms likely to be found in an estuary. For example, the abundance and diversity of fish will be high if there exists a diversity of fish habitats in close proximity to one another and these habitats are linked together by a waterway with good water quality and unfettered connections with the upstream freshwaters, the lower stream creeks and channels, the adjacent flood plain salt and freshwater swamps and with the ocean.

Whilst many of these conditions would appear to be met to a large degree in the Manning estuary there are a sufficient number of questions regarding land use practices and water quality to warrant caution. Indeed, there have been concerns raised about dwindling fish stocks in the Manning estuary. The Manning Valley Draft Strategic Plan (MCMC, 1996) noted that "the number of species and the populations of individual species of estuary and freshwater fish appear to be declining." A number of submissions have been made to this study by recreational fishing groups which attest to a "dramatic decline in numbers and size of fish caught in the Manning River over the past ten years" (Taree West Bowling Club Fishing Club).

In particular, NSW State Fisheries, in conjunction with local angling clubs, noted an alarming trend of failed recruitment of Australian bass to the Manning over a number of years in the early 1990's. This was initially attributed to the combined impacts of drought and habitat degradation. A comparative study of Australian bass stocks in the Manning, Hastings and Macleay Rivers over the drought period indicated a decline in the Manning and Hastings stock but flourishing populations in the Macleay thus implicating habitat degradation as the most likely cause. Habitat destruction was attributed to possible loss of freshwater aquatic weed habitat (and food supply) following exacerbated siltation from mis-management of riparian lands during the drought period (i.e., clearing practices and stock management).

In the short term, Taree NSW Fisheries office, the NSW Fisheries Research Institute and the Wingham Anglers Club combined resources to catch broodstock of the Manning River Bass for artificial propagation and have released 20,000 fingerlings back into the system. The success of this venture is expected to be judged by a netting program in 1997/98 (pers. comm, Taree NSW Fisheries).

The Manning Valley Draft Strategic Plan (MCMC, 1996) also suggested that increased fishing pressure may have contributed to the decline in fish species and abundance, and there has been recent controversy in the local media over possible over-fishing arising from commercial fishing. This topic is canvassed further in Section 7.9.1 which considers the impacts of both commercial and recreational fishing pressure on Manning River fish stocks.

6.4.1 Greenhouse Effects

As noted in Section 3.5.2, there is some consensus that a rise in global water levels will occur and there is uncertainty as to what impact this would have on rainfall and tidal levels along the NSW coast. Given the complex relationship between the estuarine biota and the hydrodynamic parameters of the present estuary it can only be said with certainty that alterations to mean rainfall and/or to tidal levels would, in the short term, advantage some portions of the estuarine ecosystem whilst disadvantaging others. Further than that, the impacts on the estuarine biota would, to a large degree depend on the reaction of humans to the changing situation. Left to itself the estuary ecosystem would, in the long-term, adjust to the new conditions and recover some sort of equilibrium. However, it is probably more likely that major public works will be undertake to protect existing property rights and uses, and these could result in major deleterious alterations to the estuarine ecosystem.

In the absence of the impacts of public restoration works, the nature of the Australian estuarine ecosystem is such that they would be expected to cope with variations in frequency and magnitude of average rainfall. That is, the Australian estuarine ecosystem has evolved to cope with unpredictable periods of drought and flood and has the resilience to adjust in reasonably short time.

In summary, rainfall increases would increase the frequency and possibly the magnitude of floods and could have beneficial effects for the estuarine biota by imposing some greater regularity on the present flood/drought cycles. However, if increases in the frequency of large magnitude (scouring) floods was such that estuarine ecosystems did not have time to recover there could be long-term adverse impacts. If these floods were combined with increases in mean tide levels there could be large scale losses of valuable riparian and intertidal habitats. This would be particularly so if bank protection works (dams and levees) were built to protect the hinterland.

Decreases in the average rainfall would probably send the estuary to the drought condition where the mean salinity of the estuary would increase and salinity would penetrate up stream for a longer time, allowing a more marine flora and fauna to develop up-stream. However increased droughts would probably lead to increased pressure for upstream damming and freshwater abstractions which could have dire impacts on both the estuarine biota, which depend on frequent flooding for food and migration stimulus, and on the freshwater biota which need to move between the estuary and the freshwater habitats of the river.

7. WATERWAY USAGE

7.1 User Groups

Waterway use of the Manning River is not extensive when compared with many other estuaries on the NSW coast (pers comm. Waterways Authority Boating Officer). The waterway is however used by a number of different groups for a variety of purposes, including fishing, aquaculture, gravel extraction, commercial boating, recreational boating, swimming and picnicking. Each of these groups tend to utilise discrete areas as shown on Figure 16.

Manning River estuary also has a valuable Aboriginal and early European heritage. Evidence of past Aboriginal occupation can be found and the area still contains sites which are significant to the Aboriginal community. The remains of European settlement such as early wharfs and factory buildings are also located along the foreshore.

7.2 Fishing & Aquaculture

The principal fishing activities in the Manning estuary are commercial and recreational fishing for fin-fish, crustaceans and molluscs. The principal aquacultural activity is oyster farming. Apart from the oyster industry there is no saltwater aquacultural industry in the district. There are a number of fledging freshwater aquacultural industry based on hatching and grow-out of silver and golden perch, Australian bass, freshwater catfish and yabbies within the total catchment area.

7.2.1 Oyster Farming

Current and historical oyster catch and farming details for the Manning estuary plus comparisons between the Manning and other Northern River estuaries are shown in Appendix A.

Oyster farming based on the cultivation of the Sydney rock oyster *Saccostrea cuculata* is a valuable industry in the Northern Rivers and the Manning estuary is one of the top producers . In 1994/95 Manning estuary oyster production ranked 2nd in the Northern Rivers and 7th in the state. The 1994/95 production value was estimated as Million $11.151. There is no cultivation of gigas or pacific oysters and the estuary is still relatively free of wild gigas stock.

Figure 15 shows the location of the oyster growing areas and the main oyster harvesting techniques. Spat collection (catching) leases are utilised in years of good spat settlement. When spat sticks have collected sufficient spat they are moved to depot or growing leases (to prevent over-collection of spat). In the depot leases the spat sticks are kept in cages to prevent predation by fish and are kept growing on the lease for up to 18 months. When the oysters have gained a size which inhibits predation, the oysters are again moved to other leases for fattening. There are also bottle oyster leases along the river training walls. These leases support naturally settled oysters which are harvested from time to time. As the crop is a natural one there is generally a variety of oyster grades in any harvest which is therefore used for bottle oysters. There are also dredge oyster leases along the shallows of the main river at Harrington, along the north-western bank of Mitchells Island and along the middle of the South Channel. Dredging is undertaken on an opportunistic basis when oysters are available.

In 1993/94 there were 225 foreshore leases along 62 km of river shoreline and 132 off-shore leases covering 99 Ha of the estuary. In terms of foreshore length and area covered, the Manning ranked first in the Northern Rivers. In 1994/95 the Manning estuary produced 23.2 % of the Northern Rivers production and 3.8 % of the total state production.

Rack and tray grow-out was by far the most important cultivation technique in 1994/95. Rack/basket grow-out and raft cultivation the next most important. The older method of rack/stick cultivation produced only a minor proportion of total production. The river also yielded a small harvest of bed oysters. Float-stick and rock cultivation were minor cultivation techniques for the Manning estuary oyster production.

Inter-estuary transfers are an important component of the Manning River industry and the above production figures relate only to oysters marketed directly from the Manning. The Manning River oyster industry also produces seed stock, catching sticks, growing sticks, oyster trays and spat bags for transfer to other estuaries. Part of the state importance of the Manning River oyster industry is based on the spat collection and oyster production activities for inter-estuary transfer. In particular, the limited occurrence of Pacific or gigas oyster (*Crassostrea gigas*) in the Manning River make clean spat collection areas such as occur in the lower Manning highly important for the general NSW industry (Lands, 1990).

In 1994/95 the Manning estuary produced 16.5% of the total state all-in spat bags and about 10% of the catching sticks for inter-estuary transfer. Most of the catching sticks were dispatched to Merimbula and most of the spat bags went to Wallis Lakes. The Manning produced 5.6% of the state's oyster trays for transfer, with all production going to Brisbane Waters. There was some transfer of culled spat bags, both into and out of the estuary in 1994/95; 245 culled spat bags were transferred into the estuary from the Camden Haven and 90 bags were transferred out, to Brisbane Waters and Wallis Lake.

Pease and Grinberg (P & G, 1995) produced a compilation of long-term commercial fisheries statistics including annual oyster production from 1941 to 1992. The annual oyster production for the Manning over this period has ranged from 73,000 to 466,000 kg. The average production for that period was 240,000 kg per year.

There were several clear cycles of production. Between 1940 and 1957 production fluctuated considerably with annual production generally below the long-term average. There were further dips over the periods 1972 to 1975 and from 1987 to 1990. The main trend in the data is to stability with annual yields closer to the long-term average from the mid 1960's onwards.

As recent events in Wallis Lake have demonstrated, estuarine water quality is an important determinant of the health of the oyster industry and there is a clear connection between disease outbreaks and water contamination by human faecal material (Section 5.2). Currently faecal pollution in waters is estimated by measurement of faecal coliforms concentrations. ANZECC guidelines specify that the median faecal coliform concentration in estuarine waters where oysters are grown should not exceed 14 cfu/100 ml with no more than 10 % of the samples exceeding 43 cfu/100 ml. Faecal contamination data for the oyster growing areas of the Manning are currently not collected.

Following problems with contaminated oysters in the 1970's the NSW oyster industry now uses purification plants to cleanse oysters prior to sale. The National Food Authority has set the standard for E.coli as 2.3 counts per gm of oyster flesh.

The Manning River oyster growers have high concerns about water quality in the river and in particular they are concerned about water quality in the southern arm of the Manning where they believe that poor tidal exchange is responsible for maintenance of high pollution levels. Therefore, in addition to the use of the statutory purification plants, the Manning River oyster growers have instituted their own quality assurance programme (QAP). The oyster growing area of the Manning River has been divided into five harvesting zones as follows:

Zone A	Harrington Inlet and Pelican Bay.
Zone B	Manning River main channel up to Cattai Creek.
Zone C	Manning River main channel above Cattai Creek and the upper portion of Scott's Creek.
Zone D	Lower portion of Scott's Creek and northern portion of Farquhar Inlet.
Zone E	Manning River South Channel and Farquhar Inlet.

Voluntary closures by all growers in each of the affected zone are instigated if river salinity drops below an acceptable level (generally 18 p.p.t.) or if levels of faecal coliform contamination exceeds the industry standard of 1 E.coli count per gm of oyster flesh (at the pre-purification stage). Oysters are collected and tested from all harvest areas on a weekly basis. Closures may also be instigated if there is local heavy rain, if river levels rise or if Council informs the co-ordinator of larger than normal sewage discharges arising from plant breakdowns or overloads.

The QAP has been operating since December 1993. Results of oyster testing up to August 1996 have been made available for this report and summary statistics of the results re presented in Appendix A. The data would appear to bear out the oyster grower's contention regarding conservation of pollutants in the southern arms of the Manning. Based on the limited data available to date it would appear that pollutants brought down the main river are accumulated in the main arm (Zone C) and the south arm-Farquhar Inlet (Zone E) to a greater extent than in Scott's Channel (Zone D) and that there is little or no accumulation in the lower North Channel and Harrington Inlet (Zones B and A). This result is supported by hydrodynamic and water quality tidal exchange and mixing processes as identified in Sections 3.2.3 and 5.6.2).

7.2.2 Commercial Fishing

The Fish Co-Op at Taree handles most of the fish and prawns caught in the Manning River. Some are also processed through the Wallis Lake Co-op. The river fisheries is relatively small producing an average of 128 tonnes of commercial fish, crustaceans and molluscs per year. The fishery has been reasonably stable over the years. In 1980 there were 75 licensed fishermen in the district of whom only about 20 were actively fishing the estuary (LMP, 1980). In 1991/92 the fishery produced 167 tonnes of fish product with 21 full time fishermen operating (EPA, 1993). In 1996 there were 17 full-time fishers producing about the same yield (168 tonnes).

The fishery, as are most NSW estuarine fisheries, is currently regulated via a number of closures including time restrictions (week-end and public holiday closures, seasonal breeding closures), gear restrictions (types and sizes of nets) and total closures on important portions of the estuary. Thus for example, the estuarine entrances at Harrington and Old Bar are closed to all net fishing (commercial and recreational) to protect the fish which congregate in these areas during their spawning or breeding runs into or out of the estuary.

Commercial fisheries data and statistics have been compiled for this report and are summarised in Appendix A. The main sources of commercial fishing data are the published annual summaries of the NSW Commercial Fishery. These have been published for 1990/91 (P & S, 1993), for 1991/92 (P & S, 1994) and for 1992/93 (S & K, 1996). In addition, the NSW Fisheries Research Institute (FRI) has compiled a summary of annual commercial fisheries data for the period 1940 to 1992 (P & G, 1995).

The published data sources are particularly valuable because they allow for a comparison of all NSW estuary fisheries. These summaries distinguish between ocean and estuarine fisheries and are based on the locations from which fish are caught rather than on where fish are landed.

Analysis of the Manning River commercial fishery returns for the later periods of 1993/94, 1994/95 and 1995/96, is based on preliminary, non-published data supplied by FRI for this project. FRI staff stress that these data are still being cross-checked and validated. It therefore must be stressed here that the conclusions drawn from these data are preliminary and implications drawn about the commercial fishery of the Manning River for this latter period must be viewed in this light.

The Manning River fishery was typical of north coast estuarine fisheries. The fishery is based on a number of estuarine fishing methods:

Fish and Crab Traps	target species are blue swimmer crabs mangrove crabs and bream. Gear restrictions apply (trap numbers and dimensions).
Mesh Nets	bully (or sea) mullet, fantail mullet, bream, whiting, flathead, luderick, tailor, tarwhine and crabs. The mainstay target fish are bully mullet and luderick.

	Flathead mesh nets are prohibited in the Manning. Various gear, method, time and location closures apply. Estuary mouths are closed to all nets. All waters upstream from Martin Bridge are closed to mesh net setting. There is a total net closure at Wingham. Splash only closures apply seasonally. There are weekend and public holiday day-time meshing closures.
Prawn Hauling Nets	school and greasy-back prawns. Various gear, method, time and location closures apply. Trawling is illegal. The fishery is closed during June, July and August.
Eel Traps	Short and long-finned eels, silver eel, common pike eel and grass eel. Location and gear closures (see below).
Bait collecting	small bait prawns (school and greasy-back), pipis and beach worms (ocean beaches only). The prawns form part of the estuary prawn fishery described above. Whilst the pipis and beach worms are caught from the ocean beaches they are often processed through the Taree Co-op and therefore feature in the Manning Estuary annual returns.

Of the nine main northern river-based estuarine fisheries (i.e., from the Tweed to the Manning), the Manning commercial fishery ranked 4th overall for both 90/91 and 91/92 and ranked 3rd in 1992/93. Annual tonnage of production ranged from 173 tonnes in 91/92 to 162 tonnes in 92/93.

The estuary ranking held for the fin fish component of the catch and the Manning produced the 4th highest catch in 90/91 (137 tonnes) and the 3rd highest fin fish catch for both 91/92 and 92/93 (144 & 124 tonnes). For all estuaries except the Clarence the fin fish production was lowest in 1992/93.

Sea (or bully) mullet was the single most important species in the fin fish catch accounting for more than 50% of the catch for 5 of the 6 years between 1990 and 1996. Luderick was the second most important species (between 10% and 20% of the catch). Other important species include dusky flathead, sand whiting, fantail mullet and bream. Minor species include shark, pilchards, river garfish, tailor, mulloway and sand mullet.

Eels always ranked in the first eight for the period 1990 to 1996 and were the second most important species in 1995/95. The eel fishery in NSW is growing as the demand for eels for the live export market increases. Trapping of eels from inland waters (e.g., above Abbot's Falls on the Manning, above Lansdowne Weir on the Lansdowne) is prohibited and commercial fishers must have permits to take eels from designated fish farm dams. A number of estuarine fishers trap eels from the middle and upper estuary for the export trade using regulated traps (designs and numbers). The short and long-finned eels (*Anguilla australis* and *A. remhardfil*) are prime targets with silver eel, common pike eel and grass eel also being taken.

The Manning crustacean fishery (predominantly prawns) was more variable, with the Manning ranking 3rd in 90/91, 5th in 91/92 and 2nd in 92/93. This reflects the fickle nature of the fishery which depends greatly on climatic conditions months before the season begins. Good rains are required mid-year to make conditions conducive for feeding and good growth (NSW Fisheries Taree). In 92/93 the Manning was the only estuary to produce an increased crustacean catch on the previous year.

Prawns were the most important crustacean species by weight. In the Manning River the prawn season runs from September to May and is closed from June to August each year. The main estuarine species (the school prawn *Metapenaeus macleayi*) and the main off-shore target species (eastern king prawn *Penaeus plebejus*) utilise the seagrass beds of the river as feeding and nursery habitat. King prawns, greasy back prawns make up minor components of the prawn fishery. Two crab species, the blue swimmer *Portunus pelagious* and the mud crab *Scylla serrata* are caught commercially in the Manning. Both species are caught over shallows and in mangrove creeks in the estuary.

Apart from oysters, molluscs are not important constituents of the northern river estuary fisheries. Octopus was the most frequent mollusc catch in the Manning River between 1990 and 1996.

The annual total catch varied between 61 and 226 tonnes with a mean of 128.6 tonnes. Annual production was generally below the mean between 1954 and 1980 with annual catches generally above the mean from 1980 onwards.

The fin-fish annual catch accounted for the major weight landed each year (generally about 80% of the total production) so the variation in annual fin-fish catch more or less mirrors the variation in total catch. Annual fin-fish landings varied between 56 and 191 tonnes with a long term annual mean of 103 tonnes. The most notable difference from the annual catch variation is that between 1955 and 1986 the annual fin-fish catch was generally less than the long-term mean, indicating that for the period 1980 to 1986 the increase in total catch shown in the total catch analysis was made up by an increased crustacean catch.

There were no mollusc catches prior to 1972/73. From that time on the commercial catches started to include squid and octopus for local and off-shore markets.

The long-term data are useful for indicating the long-term sustainability of the fishery. The three most abundant species of the fin-fish catch over the long term (based on comparisons of long-term means) were the sea mullet, flat-tail mullet and luderick. These three species accounted for about 75% of the long-term catch. The sea mullet accounted for almost 50% the long-term catch with about 14% for the flat-tail mullet and 11% for luderick.

A detailed analysis of the long term variation in annual landings of individual species and species' groups is shown in Appendix A.

This survey indicates that the fishery has been sustainable over the long-term. Particular long-term or cyclic trends shown for a number of species/groups (e.g., eels, shark, river garfish and bream) may reflect short and long-term changes in the commercial fishery and therefore may warrant further investigation with regard to future implications. This is discussed further in Section 7.9.1 below.

7.2.3 Recreational Fishing

Recreational fishing is important in the Manning River estuary. Most activity is during holiday periods and is highest over the Christmas/New Year period (NSW Fisheries Taree). Highest fishing intensity is through mid to late summer during the peak holiday period when popular species of fish and crustaceans are targeted. All public holidays throughout the year are popular fishing days for most anglers. There are 10 fishing clubs in the region, most catering for blue-water fishing. A number of the clubs cater for freshwater fishers.

The keener fishers target certain species throughout the year and adjust their gear and localities to suit. Over summer whiting and flathead are popular targets. Some prawning occurs in season. In autumn travelling bream are targeted, mainly from the ocean beaches and from breakwaters.

There are a number of closures affecting recreational fishers. Harrington Backwater is closed to bait collecting (worms and nippers). Whilst there is a total closure to all commercial nets near the mouth of the river, recreational fishers are allowed some nets. There is a spear fishing closure over Harrington Inlet (up river to Mangrove Creek), Harrington back-water and Harrington swimming lagoon.

Shore based fishing is the most popular form of angling in the Manning with all beaches, jetties, breakwalls and other vantage points utilised. The Harrington Inlet training walls provide numerous locations for both boat and shore based angling for Bream, mulloway, flathead, whiting and luderick. Old Bar is popular with boat fishers who target whiting, flathead, prawns and crabs.

NSW Fisheries and local angling clubs combine resources each year around February-March to conduct a "Bass catch event". The concept is to catch, measure and release as many Australian bass as possible to provide information on local stocks. The event was instrumental in showing alarming declines in recruitment in the early 1990's. Subsequently NSW Fisheries plus the Wingham Anglers Club combined to catch broodstock of Manning River bass for artificial propagation and the release into the Manning system of 20,000 fingerlings marked with salt solution for later identification.

Other popular fishing competitions are the Ashley Nix Memorial Competition (run on the October long weekend for young fishers) and the Manning Classic. This latter competition was held for the first time in early February 1996.

7.3 Industries

7.3.1 Sand and Gravel Extraction

Over two million cubic metres of gravel and sand have been extracted and processed from the river upstream of Taree since 1965 (WMA, 1996_a). Most of this material has been extracted from the river bed between Tinonee and Mondrook Point. The current rate of extraction is around 60 000 m^3/year.

Uncontrolled gravel extraction in the past may have contributed to bed instability and exacerbated erosion along the Manning River (SPCC, 1987). However, more recent reviews of gravel extraction practices, (WBM, 1989) and (WMA, 1996_a), concluded that the main impact of gravel extraction and processing upstream of Taree was on water quality (Section 5.1), by slightly increasing the level of suspended solids.

There have also been several proposals for sand extraction from the lower estuary entrance areas, most of which have not proceeded because of the likely adverse impacts on sediment dynamics (Chapter 4). There is an existing proposal by land developers to dredge the Harrington Back Channel and to use the excavated material for land fill. The proposal aims to increase the depth of water along the Back Channel and so facilitate boating access, improve tidal flushing and enhance the overall recreational amenity of the area. An EIS is being prepared.

7.3.2 Other Industries

The dairy industry has in the past been a major user of the estuary both for the transport of milk products and for the disposal of wastes. Use of the river for transport is no longer economic because of the efficiency of road transport, but a number of old wharves and buildings remain. Further, the river is no longer used for the direct disposal of milk/butter factory waste products, which since 1994 have been treated at the Dawson River STP before disposal into the river (Section 5.1). Most dairy wash waste is also recycled onto pasture, although some dairies (mainly along the Lansdowne River) still wash down directly into the estuary.

7.4 Commercial Boating

7.4.1 Cruise Boats

Cruise boats operate on the estuary between Wingham and Manning Point. Between approximately September and July each year there are two routine cruises, Taree to Wingham, and Taree to Manning Point. Special cruises are also available.

Access to the cruise boat mooring on the right bank of the river opposite Taree CBD is difficult. The cruise boat therefore uses the public jetty near Fotheringham Park (Taree). The cruise boat also uses the public wharf at Wingham. There is no suitable public landing structure at Harrington.

7.4.2 House Boats

House boats of various sizes can be hired for use on the waterway throughout the year. These boats are based in Browns Creek and have prescribed limits of travel although they range extensively throughout the estuary, including the Dawson and Lansdowne Rivers. The infrastructure for mooring and accessing the house boats in Browns creek is inadequate, and navigation within the creek is difficult.

House Boats on the Manning River are potentially a cause of water pollution due to garbage and sewage disposal directly into the estuary. The main problem is the release of untreated sewage which creates a very bad visual impact. The problem is worst in confined areas such as the houseboat mooring area in Browns Creek. The sewage disposal problem highlights a need for pumpout facilities in the estuary.

7.5 Recreational Boating

Recreational boaters and sailors are one of the main waterway user groups. Taking only the local population into account the number of locally registered vessels is less than 1 500 (including motor vessels >4 watts and/or sailing boats >5.5 m). On this basis use of the river is proportionally lower than most other large north coast estuaries. However, smaller craft sailing and rowing/sculling is very popular at Taree.

7.5.1 Power/ Ski Boats

Power boating (other than for fishing) in the estuary tends to be confined to the stretch of river upstream of Dumaresq Island, generally during the months of September through to April. The Manning River Power Boat Club has around 30 members and 15 boats, and holds two or three race meetings each year on a registered race course between Dumaresq Island and the Pacific Highway (Martin) bridge at Taree (Hassell, 1990). The main meeting, the Manning Aquatic Power Boat Carnival, is usually in November. In past years the Club has also held the Taree Aquatic Carnival during the Easter holiday period. This carnival, which included the National Power Boat Titles, has not been held for several years.

Water skiing tends to concentrate in areas where ramp access is good, and where there are suitable landing areas adjacent to sheltered straight river reaches. As a result water skiers also tend to confine themselves to the stretch of river upstream of Dumaresq Island, mainly in the Tinonee (Andrews Reserve) to Wingham area, where the popularity of "drag-ski" racing is increasing. Some skiing is also undertaken on the Dawson and Lansdowne Rivers and in Scotts Creek. Water skiers mainly use the estuary between September and June.

7.5.2 Sailing and Sailboarding

The river near Taree is well known within sailing circles for its excellent conditions. Organised sailing activities are associated with the Manning River Sailing Club (juniors) and the Taree Aquatic Club (seniors). Most sailing is undertaken in the area around Taree, between the South Channel and the Pacific Highway (Martin) bridge, opposite Queen Elizabeth Park. Boats are generally stored at the clubs and launched from the nearby ramps although sailing is undertaken throughout the estuary.

During the latest season the MRSC regularly hosted 22 Sabots, 7 Lasars, 5 VJ's, and 3 Flying Ants. The TAC had 15 NS Fourteens, 4 Manly Graduates, and 10 Trailer Yatchs. Competitive sailing is undertaken weekly from September to March and once a month from April to August. A regional regatta such as the Mid North Coast Championships is held each year with around 80 boats. Parts of the NSW State Championships (heats or finals) are also often held on the river with up to 100 boats.

Non competitive sailing is concentrated in the Taree area, mainly utilising the same launching and rigging areas as the competitive sailing. Cruising is undertaken throughout the estuary particularly during the summer holiday period. In early January the Manning River Sailing Marathon is held between Manning Point and Taree.

Sailboarding is undertaken throughout the estuary but is also concentrated around Taree. Sailboarding is most popular between the months of September and May. About 30 sailboarders are affiliated with MRSC. These members conduct races on Wednesday evenings during the daylight saving period each year. Participants use the earth ramp and rigging area adjacent to the MRSC clubhouse and set courses in the river near the club. Non competitive sailboarding is also popular at Farquhar Inlet.

7.5.3 Rowing and Canoeing

Rowing is centred around the rowing club at Endeavour Place near the Taree CBD. As with sailing, rowing/sculling is very popular on the river and the club has over 150 members, mainly juniors. Approximately 200 days per year rowers can be found using the waterway, generally between September and July.

The club has two competition courses, a 2000 m course from the Cundletown bridge to the club, and a 1000 m course from near the Pacific Highway (Martin) bridge to some 50 m past the club. Boats are launched at a concrete ramp adjacent to club house and members consider the facilities equal to the best in NSW (Hassall, 1990). In addition to regular training and competition sessions, the club also has an annual regatta day with over 60 boats and 250 competitors (plus as many spectators), and regional race days involving 20 to 30 boats and 80 competitors.

There are many canoeing opportunities (rapids, etc.) in the non-estuary upper reaches of the Dawson and Lansdowne Rivers. Canoe adventure/exploring activities are also increasing on the estuary reaches (pers comm. Waterways Authority Boating Officer).

7.6 Passive Recreation and Swimming

7.6.1 Swimming

Swimming and wading is undertaken at a number of locations throughout the estuary where access and conditions are conducive. One of the more popular locations is in Harrington Lagoon near the camping ground during the summer holiday period. There is also some summer swimming/wading from sandy beach areas along Harrington Back Channel, across the river at Manning Point where there is a swimming enclosure, and at Farquhar Inlet. Further up the river there is a swimming enclosure at Croki near the confluence of the river North Channel and Scotts Creek.

At Taree swimming/wading occurs in association with sailing and rowing activities near the Endeavour Place Boat Ramps, and at the Taree Jetty near Fotheringham Park. Each year in November the Taree Triathlon includes a swim leg in the main river at Taree. Swimming is also popular at Andrews Reserve (Taree Estate) adjacent to the boat ramp, in the upper reach of the river near the Wingham boat ramp and wharf, and in the upper reaches of the Lansdowne River near the old wharf. The river upstream of the Wingham boat ramp has been closed to boating to protect the swimmers.

Faecal coliform levels in Browns Creek indicate that this body of water is not suitable for swimming much of the time. There has also been a couple of high readings for the Dawson River near the STP which suggest that this waterway may not be suitable for swimming on some occasions. However, the available data is for one location only and far to infrequent for any firm conclusions to be drawn.

7.6.2 Parks and Reserves

There are a number of public reserves and parks used for picnics and other forms of passive recreation associated with the estuary. Although there are no data available, Queen Elizabeth Park near the Taree CBD would probably be the most used area. Council are currently undertaking improvements in this park to improve access further. Other foreshore areas, such as the Wingham Brush, Harrington seawall, Andrews Reserve, Croki swimming pool reserve, Farquhar Inlet and Lansdowne Brush are also popular.

7.7 Heritage

7.7.1 Aboriginal Heritage

The Manning River Estuary and foreshore areas contains a number of Aboriginal heritage sites. The locations of these sites has not been shown for protection. The majority of the sites are middens which are found both along the edge of the rivers and in the coastal dunes. Aboriginal sacred sites and burial sites are also present and stone artefacts have been found throughout the area.

National Parks and Wildlife Service records show a number of sites which have now been destroyed by development as well as by erosion. Many of the present sites are threatened. This is particularly the case along coastal dunes where vehicle induced erosion threatens the middens.

7.7.2 Early European Development

There are several wharves and building associated with river transportation during the early part of this century and the dairy industry which still remain along the river. Two old timber wharves on the Lansdowne River (near Coopernook and Lansdowne) have been classified by the National Trust. The wharf at Wingham has a long history dating back to the early timber cutters, but has been extensively modified structurally to keep it in working order.

There are also old wharves and building associated with the dairy industry. Of particular interest are the Old Milk Factory, the Peters Wharf and a vessel wreck near the Peters Wharf.

7.8 User Facilities

7.8.1 Boat Launching Ramps

Boat launching facilities are essential infrastructure for most waterway users. On the Manning River estuary there are nearly 20 recognised boat launching ramps and several informal ramps which provide a range of access conditions. Despite the large number of ramp sites, boat launching facilities generally (including such considerations as ease of use, parking, landing/loading wharves, etc) are poor when compared with most other large popular NSW estuaries.

The following summary of the main ramps and ramp conditions is based on an earlier review of waterway infrastructure (Hassall, 1990) which has been updated to current conditions (see also Figure 16):

- Wingham Brush ramp is within a foreshore reserve. Facilities and conditions at the ramp are good given the localised level of use.
- Andrews Reserve (Taree Estate) has a three lane ramp with good facilities. Parking is informal. Use levels are high which can create conflicts with other reserve users (Section 7.9).
- Tinonee (Hutchinson Street) ramp is a steep ramp which originally was a car ferry approach. Facilities and usage is limited.
- Tinonee (Peverill Street) ramp is also a steep ramp with limited use.
- Taree CBD has three ramps off River street opposite Fotheringham Park. These ramps are restricted in use by a deep drop off at the ends, their proximity to the CBD, and consequent parking and access problems.
- Taree Aquatic Club ramp has limited access and is only suitable for small dinghies.
- Endeavour Place, Taree Rowing Club and VJ Club ramp is very popular with a wide range of waterway users because it has good parking, adequate facilities and is adjacent to the sailing and rowing clubs.
- Cundletown ramp has one lane, a steep grade and no facilities. Because of these problems the ramp is not well used.
- Oxley Island Ferry ramp has one lane and restricted vehicle access.
- Croki ramp provides waterway access to the Lansdowne River/Scotts Creek area of the estuary. Although small with restricted vehicle access there are other user facilities which make this ramp comparatively well used.
- Coopernook ramp has a gravel surface and no facilities. Use is limited.
- Cattai Creek ramp has a steep gravel surface and limited use.
- Harrington upstream ramp has good facilities but waterway access is restricted by sand shoals in the channel near the ramp.
- Harrington downstream ramp has a single lane, no formal parking, is near the business area and has restricted waterway access.
- Manning Point ramp has a single lane. Conditions are good for the localised level of use.
- Bohnock ramp is the only ramp on the South Channel and hence is popular for this reason. Parking is informal and there are no facilities.

7.8.2 Wharves and Jetties

There are only two public wharves and six jetties on the Manning River estuary. Generally, these facilities are not up to the public standard provided on most other major NSW north coast rivers. The following summary is based on an earlier review of waterway infrastructure (Hassall, 1990) which has been updated to reflect current conditions:

- Wingham wharf is a historical structure which has been extensively modified to keep it in a functional condition. The wharf is near the Wingham Brush Reserve and boat launching ramp and so caters for passive users of the area as well as swimmers, skiers, and the river cruise vessel. Dredging is proposed by Council to improve depths.

- Taree jetty adjacent to Fotheringham Park is used by the river cruise vessel as well as by swimmers and park visitors.
- Pampoolah jetty is located in a reserve at the end of Redbank Road. The reserve has good facilities and is a popular picnic area and stop over lunch site for the river cruise.
- Coocumbac Island jetty provides access to the island nature reserve.
- Croki wharf is part of the Croki swimming enclosure and has good facilities although vehicle access is restricted. Use is mainly by passive users, swimmers and recreational boaters.
- Manning Point jetty is upstream of the boat ramp and is used by recreational boaters for loading and unloading. Depths are too shallow for the cruise boat at low tides.

7.8.3 Mooring and Other Facilities

There are no public moorings in the Manning River for either short term or long term stay. Visitors to the estuary therefore either lie at anchor or make arrangements with the owners of private berths.

There is one slipway in the estuary near the Aquatic Club in Taree. This slipway is operated by a private company but is available to the public. Vessels of up to 30 tonne can be slipped.

7.9 Conflicting Users

7.9.1 Commercial & Recreational Fishing

A question was raised earlier (in Section 6. 4) regarding the perceived reduction of fish stocks in the Manning River estuary. It was suggested that alleged reductions in stock may have been attributable to drought effects, loss of habitat, over fishing or a combination of these reasons. Whilst there was indisputable evidence for recruitment failures of the Manning River Australian bass stocks there were no studies on other estuarine fish stocks to support or refute the allegation of widespread declines in estuarine fish stocks.

The remaining reason proffered for the possible reduction in estuarine fish stocks was related to fishing pressure. However, based on a full analysis of the commercial fish returns (presented in Section 7.2.2 above) it would appear that there has been no significant reduction in estuarine fish stocks ; at least for the species commonly targeted by both the recreational and commercial fishing sectors.

As with many coastal communities along the NSW coast there is a perceived conflict between recreational and commercial fishers. Recreational fishers accuse the commercial fishers of over-exploiting the resource, damaging fish habitat and damaging juvenile fish stock caught and killed as part of by-catches. Recreational fishers are accused of over exploitation of bait species;

nippers and worms and of use of illegal nets. Fishers of this estuary are no different and these accusations are frequently heard. In fact, there is sufficient evidence available to demonstrate that both these sectors of the fishing industry are significant harvesters of the estuarine fish stock of NSW and any evaluation of the impacts of human impacts on the estuarine biota must consider the fishing impacts of the total fishing industry, not just of one sector.

Commercial fishing in NSW is a significant coastal industry and the fishing industry of the Taree district is estimated to be worth $ 3 Million annually (NSW Fisheries Taree). The Taree Co-op contributes an annual $ 500,000 of this sum and currently services 17 estuarine commercial fishers plus three full-time staff of its own. Recreational fishing in NSW estuaries is high. There are an estimated 1.75 million anglers in NSW. At peak holiday time the recreational fishing population of the Manning is significant. Based on the observation that there is currently an increase in the Manning River bait fishery, it would appear that the district recreational fishing effort may be increasing. Whether this increase is in the off-shore or in-shore component is not known. However, any increase in off-shore fishing impacts on the estuary during adverse off-shore weather conditions when off-shore fishers remain in the estuaries to fish.

As noted above, with the exception of the Australian bass studies there have been no detailed local studies of the relative impact of fishing on stocks and habitat in the Manning estuary. Recent in-depth analysis of commercial fishing returns by the Fisheries Research Institute (as extended and summarised by us above) have partially quantified the impact of the commercial fishing sector on the Manning estuary. Studies of the comparative impact of the commercial and recreational sectors on selected estuaries elsewhere along the NSW coast indicate that the recreational fishery may be (and often is) bigger than the commercial fishery (e.g., Sydney Harbour). NSW Fisheries' research over a number of estuaries indicate that estuarine recreational anglers take a significant proportion of the total catch of popular angling species such as bream, flathead, snapper, mulloway (jewfish) and whiting (Lynch, 1993).

An extensive comparison of the commercial and recreational fisheries in the Richmond and Clarence Rivers (West, 1994) found that the recreational fishery matched the commercial fishery in tonnage of fish landed by each sector and that for some species the recreational fishers caught more than the commercial fishers. Thus, for example in 1989/90 the recreational catch of yellowfin bream in the Richmond River was between 12 and 19 tonnes and the commercial harvest was 1 tonne (West, 1994). In the Manning over the same period the commercial catch of bream was 3.5 tonnes. Anglers took between 5 to 10 tonnes of dusky flathead and commercial fishers landed 2 tonnes from the Richmond in 1989/90. In the Manning that year commercial fishers landed 10 tonnes of dusky flathead.

Given the similarity between the Richmond and Manning estuary commercial fisheries (as shown in Section 7.2.2 above) and if the Manning River recreational fishery is similar to that studies in the Richmond River it may be concluded that the Manning River recreational fishing sector is likely to be catching about the same tonnage of fish annually as the commercial fishing sector and that recreational fishers may be taking up to the same amount of flathead and significantly more bream than the commercial fishing sector. Anecdotal information indicates that the Manning River estuarine fishery is smaller than that reported for the Richmond River and could therefore be expected to land a smaller tonnage of fish than reported for the Richmond.

This conclusion, namely that both sectors of the estuary fishing industry are taking similar proportions of fish should not come as a surprise, as both sides of the fishing industry have known about these sorts of conclusions since the earlier reviews published in the late 1970's (R&H, 1977). In fact, the perceived conflict has unintended consequences which were foreseen in the 1977 Ruello and Henry paper:

> *"A sad consequence of the friction and conflict between amateur and commercial fishermen is that it diverts the attention of both groups of fishermen, the general public and the press from the real dangers to the fish resource - the detrimental changes to an estuary and its catchment."*

In practice NSW Fisheries has reduced conflict between the two sectors by reducing the hours and areas open to the commercial sector, increasing the minimum sizes of individual species which may be caught and proscribing particular fishing methods and gear. Most commercial fishing methods are now detailed in terms of gear dimensions and methods of usage.

In recognition of the impact of recreational fishing NSW Fisheries have also progressively tightened up the recreational fishing regulations. In 1993 new recreational angling laws were brought in covering size and bag limits plus recreational fishing methods.

The question thus remains as to what impact estuarine fishing as a whole is having on the estuarine ecosystem. Given that the recreational fish catch is at least as significant as the commercial catch, the long-term annual commercial fish returns provide some measure of overall fishing impact. On this basis, the previous conclusion, viz., that the fishery has been sustainable over the long-term may be reasonable expected to hold.

Notwithstanding this conclusion, it must also be noted that this review of estuarine flora and fauna has raised a number of uncertainties regarding the viability of the estuary ecosystem for the future. These relate to direct losses of riparian and inter-tidal habitat from agricultural and urban developments plus indirect impacts arising from water quality deterioration in the estuary. Both these issues warrant further investigation. In particular it is the recommendation of this report that further targeted and specific water quality studies are required to ascertain the impacts of adverse water quality on the oyster industry and on human health.

Further, the conclusions regarding these impacts on estuarine fauna are, in the main, based on arguments from inference and not on well resourced particular surveys of the fish and benthic populations of this estuary. Given the documented problems found with Australian bass recruitment, it is recommended that a specific survey of the Manning estuary fish populations and fishing industry should be undertaken to test the conclusions of this report. It is also recommended that this survey should be complimented by a field survey of the benthic populations of the estuary, in particular the benthic populations of the middle estuary where the major water quality problems are thought to be manifest.

7.9.2 Swimmers and Boating

Swimming occurs at a number of locations in the estuary which are exposed to or even the focus of boating activities. River foreshore reserves and access locations such as wharves, jetties, sand beaches and boat ramps attract swimmers as well as boaters. The boat traffic is potentially extremely dangerous to swimmers.

Protected swimming areas are available at Wingham (upstream of the boat ramp), at Croki and Manning Point (in the swimming enclosures) and at Harrington Lagoon. Additional swimming controls are also required at some of the other more popular swimming locations, especially at Endeavour Place, Andrews Reserve and Wingham wharf.

7.9.3 Other Conflicting Users

The estuary has a limited number of good quality boat launching areas, wharves and jetties. Most waterway users require these facilities and so the shortage leads to conflicting interests, congestion and competition for space. This in turn limits the number of users.

Parking at waterway access points is also an area of conflict. Swimmers, boaters, picnickers, people on cruises and even shoppers often all use the same parking areas. The available parking is usually inadequate and informal which highlights the conflict. This problem is particularly evident at:

- Wingham, where swimmers, water skiers, power boaters, the cruise boat and Wingham Brush visitors all use the same area.
- Andrews Reserve (Taree Estate) where swimmers, water skiers, power boaters and picnickers all congregate.
- Taree CBD adjacent to Fotheringham Park, where swimmers, the cruise boat, house boats, the occasional power boats and shoppers mix.
- Taree near the rowing club ramp, where rowers, sailors, power boaters, club patrons and shoppers all park.
- Croki where swimmers, picnickers, boaters and sometimes a flying boat utilise the area.

Oyster farmers and recreational boaters come into conflict in the lower Manning particularly in more accessible areas such as around Manning Point. These conflicts generally relate to the waterway access problems experienced by boaters as a result of oyster industry activities, or of damage or the theft of oysters by recreational boaters.

Power boats conflict with the natural environment in many places along the river. The wash made by power boats acts to increase the erosion of the riverbank, and engine noise particularly from jet skis. Limiting the power boats area of use and controlling their activities will lessen this effect.

7.10 Human Impacts

7.10.1 Catchment Development

Catchment development has affected human use of the estuary in a general sense by, increasing the overall size of the population, and through the provision of improved roads and services. However human development and particularly expansion of the urban area of Taree/Wingham has increased the level of pollutants entering the estuary from the catchment (Chapter 5).

Urban runoff contributes elevated suspended solids loads, gross pollutants, nutrients, BOD and faecal matter to the estuary. This leads to a loss of water quality and "swimmability". Urban development also increases the volume of sewage (treated or partially treated) which reaches the waterway. Sewage effluent discharges, particularly during wet weather, contribute high suspended solids, nutrients, BOD and faecal coliform loads to the main river around Wingham and Taree and to Browns Creek and the Dawson River (from the treatment plants). The Harrington Sewage Treatment plant discharges into adjacent freshwater swamps which take up most excess nutrients into aquatic plant biomass thus contributing negligible excess nutrients to the lower estuary.

7.10.2 Greenhouse Effects

The projected increase in mean ocean levels would affect waterway use by improving the low tide water depths at most of the existing infrastructure. However, inundation may also make some facilities difficult to use during very high tides. This may lead to structural modifications in some areas such as the raising of access ways or the building of small levees and improved drainage.

8. SIGNIFICANT ISSUES AND RECOMMENDATIONS

8.1 Significant Issues

Chapter 1 - Introduction, includes a listing of the concerns raised by the community over recent years. These concerns cover a range of estuary problems which can be classified under the following headings:

- Water Quality,
- River Bank Erosion,
- Sedimentation,
- Entrance Conditions,
- The Fishery,
- Waterway Access,
- Nature Conservation.

Chapters 2 to 7 detail the physical, chemical and biological processes of the estuary as well as the impacts (and requirements) of human usage. These chapters provide both a generalised understanding of estuarine processes and a more detailed assessment of the factors associated with the above concerns.

The next step in the estuary management process, as set out by the NSW Government's Estuary Management Policy, is to undertake an Estuary Management Study and Plan which addresses the identified significant issues. To assist this process the following sections set out more clearly the issues of significance for management of the estuary.

8.2 Water Quality

8.2.1 Issue

The principal water pollutants in the Manning River estuary are nutrients, suspended sediments and organic matter with a high oxygen demand. Acid leachate is also a problem in the lower estuary, particularly around the Lansdowne River and Cattai Creek areas.

Most pollutants enter the estuary in a diluted form from the upper catchment via the main river. However, concentrated pollutant input from the Taree-Wingham urban area, such as urban runoff and sewage effluent inflows, significantly raise pollution levels in the upper and middle estuary.

Because of the flow conditions which exist in the Manning River estuary, under normal flows, density stratification develops along the middle estuary reaches. This stratification inhibits the mixing of the lighter, less saline and more polluted catchment runoff with ocean waters. Pollutants which enter upper estuary waters become partially trapped in the middle and upper estuary until they are flushed from the river by floods or freshes.

As a result of the above processes, water quality in the estuary often does not meet generally accepted Australian guidelines (ANZECC, 1985) for a number of water quality parameters. Of particular concern are phosphorus, nitrogen, BOD or TOC, and suspended solids levels throughout most of the middle and some of the upper river reaches, and acid levels in the Lansdowne River and Cattai Creek areas.

8.2.2 Objectives

The principle objectives of any actions to address water quality problems in the estuary would include:

- improve water quality in the estuary to a standard where it maintains ecological, recreational and aesthetic values (in accordance with ANZECC guidelines),
- reduce nutrient levels sufficiently to prevent algal blooms or excessive growth of epiphytic algae on seagrasses,
- increasing water clarity to encourage seagrass growth and improve the visual appearance of the water.

8.3 River Bank Erosion

8.3.1 Issue

Bank erosion within the estuary is a major issue. Because of this bank and bed erosion has been addressed in a separate but associated study "Manning River Bank Management Study, Draft" (WMA, 1996). This study found that erosion was widespread throughout the lower and middle estuary. The study also found that there are no longer any areas of particularly severe erosion threatening infrastructure or a major loss of productive land. Gravel and sand extraction from the bed of the upper estuary is not linked to bank erosion.

8.3.2 Objectives

The objectives of the Management Plan are to:

- identify all areas of erosion and accretion along the river banks,
- provide practical and cost effective solutions to the problems,
- convey the findings of the study to groups most affected.

8.4 Sedimentation

8.4.1 Issue

Investigations for this Estuary Processes Study identified a relatively low rate of sediment infeed from the catchment. The investigations also found that much of the material causing sedimentation problems in the middle estuary was sourced from bank erosion, or the remobilising and deposition of existing bed sediments. In the lower estuary entrance areas, sedimentation was associated with the natural buildup of marine sands on the marine deltas. This sand is brought into the estuary by tides.

Sedimentation in both the middle and lower estuaries is largely a natural process which can be related to a range of natural and human factors such as:

- the lack of major floods over recent years,
- the level of bank erosion and sediment inputs from the catchment,
- the cessation of dredging for and navigation by milk boats,
- etc.

8.4.2 Objectives

The objectives of any planning policies with regards to sedimentation would be to reduce the rates at which sediments entered the waterway, and to limit or remove sediments which are deposited in areas which adversely affect the ecology of the estuary or human use.

8.5 Entrance Conditions

8.5.1 Issue

The Manning River estuary is unique on the NSW coastline because it has two natural, predominantly open entrances. These entrances have a major influence on flows and hence tidal exchange in the estuary. However, this influence varies significantly, and in different ways depending upon the degree of shoaling at each of the entrance.

Shoaling at the entrances is a natural process. The northern training wall at Harrington Inlet and artificial opening of Farquhar Inlet does have some impact on the location and operation of the entrances. However, by far the most important factors are:

- the occurrence or otherwise of major floods which scour the entrances,
- the rate of entrance infilling and shoaling which is connected to coastal processes (waves, winds, tides and sand movement, etc).

Shoaling is currently a problem at both entrances because there has not been a major flood event since 1990, and this has allowed the buildup of marine sands in the entrances. This situation will persist, or even get worse, until there is a substantial flood (or until major temporary dredging works are undertaken).

8.5.2 Objectives

The objectives of any works undertaken under a Management Plan would be to improve waterway depths and tidal flushing at the entrances without adversely affecting beaches near the entrances.

8.6 The Fishery

8.6.1 Issue

The Manning River estuary is a major supplier of oysters and an important supplier of finfish and prawns. Recreational fishing activities are concentrated at the ocean entrance where they are a significant part of the local tourist industry. The level of the recreational fish catch is unknown but is expected to be significant, but slightly less than similar other major river estuaries on the NSW north coast such as the Tweed or the Richmond Rivers.

The Manning River estuary does not have large shallow broadwater areas with seagrasses and inter-tidal wetlands. It does have several structures such as the Lansdowne Weir and a number of flood gates and drainage culverts which limit fish access to potentially valuable habitat areas. The estuary also has high nutrient, suspended sediment and organic carbon inputs to the upper estuary, and distinct density stratification under most flow conditions which retains these pollutants in the upper estuary. There are problems with faecal contamination in some areas, particularly Browns Creek, and possibly also in the Dawson River on some occasions. In the Lansdowne River and the lower estuary there is a significant problem with acid leachate. All the above factors combine to reduce fishery productivity in the estuary.

Because of the lower than expected levels of fishery production from the estuary there is a degree of conflict between commercial and recreational fishers over catch levels. This conflict has led to repeated calls for commercial fishing to be banned or significantly limited.

8.6.2 Objectives

The objectives of any planning policies would be to implement actions which improve fishery productivity in the estuary. A secondary objective would be to ensure that the fish catch does not exceed the sustainable production capacity of the estuary and to find a balance between recreational and commercial fishing requirements.

8.7 Waterway Access

8.7.1 Issue

The level of boating activity on the Manning River downstream of Taree is low compared with most other north coast estuaries. In contrast there is a high level of activity at or near Taree for both smaller sailing boats and rowing. The reaches between Taree and Wingham are also reasonably well utilised for water skiing and power boating.

There are no major launching facilities on the river with properly laid out parking, turning areas, loading jetties, etc. Associated facilities, such as beaches, safe swimming areas, picnic areas, amenities, etc are also virtually non existent. The most used reaches of the river are associated with the best of the available ramps, but because of the restricted access opportunities, there is unnecessary conflict between waterway users.

8.7.2 Objectives

The objectives of the management plan in relation to waterway access would be to upgrade public boating facilities and foreshore picnic/swimming areas to facilitate public access and reduce user conflicts.

8.8 Nature Conservation

8.8.1 Issue

The major nature conservation issue associated with the estuary is loss of estuarine foreshore, inter-tidal and riparian habitats as a result of general land/bank clearing and degradation. This is coupled with the need to preserve (and expand) the remaining areas of significant natural habitat such as Coocumbac Island, the Wingham Bush, the Lansdowne Brush and the limited foreshore mangrove, reed and seagrass strips.

8.8.2 Objectives

The objectives of any future management plan could be:

- to protect and restore estuarine and foreshore habitats and ensure that human development and use does not further degrade important natural habitat areas,
- to preserve the natural abundance and diversity of estuarine flora and fauna.

8.9 Recommendations

On the basis of the findings of the Estuary Processes Study the Consultants would recommend that Council proceed with the preparation of an Estuary Management Study and Plan which addresses the issues raised in the preceding section.

The Consultants would also recommend that Council expand the existing water quality monitoring program to include more data collection and analysis in the lower river and in the Dawson and Lansdowne Rivers, and Cattai Creek.

The review of previous coastal processes studies identified substantial differences and inconsistencies between the reports, and with the observed data. Coastal erosion and river entrance stability are significant issues relating to many of the problems. A coastal processes study leading to a Coastal Management Plan is therefore recommended.

A numerical modelling investigation of the entrances would provide a better understanding of the entrances, and of the impacts of entrance training works, artificial entrance opening and channel dredging on both estuarine and coastal processes.

As with all NSW estuaries there is insufficient data on the fishery to make conclusive recommendations about specific management issues. Council should request that NSW Fisheries undertake detailed studies of the fishery.

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FIGURES

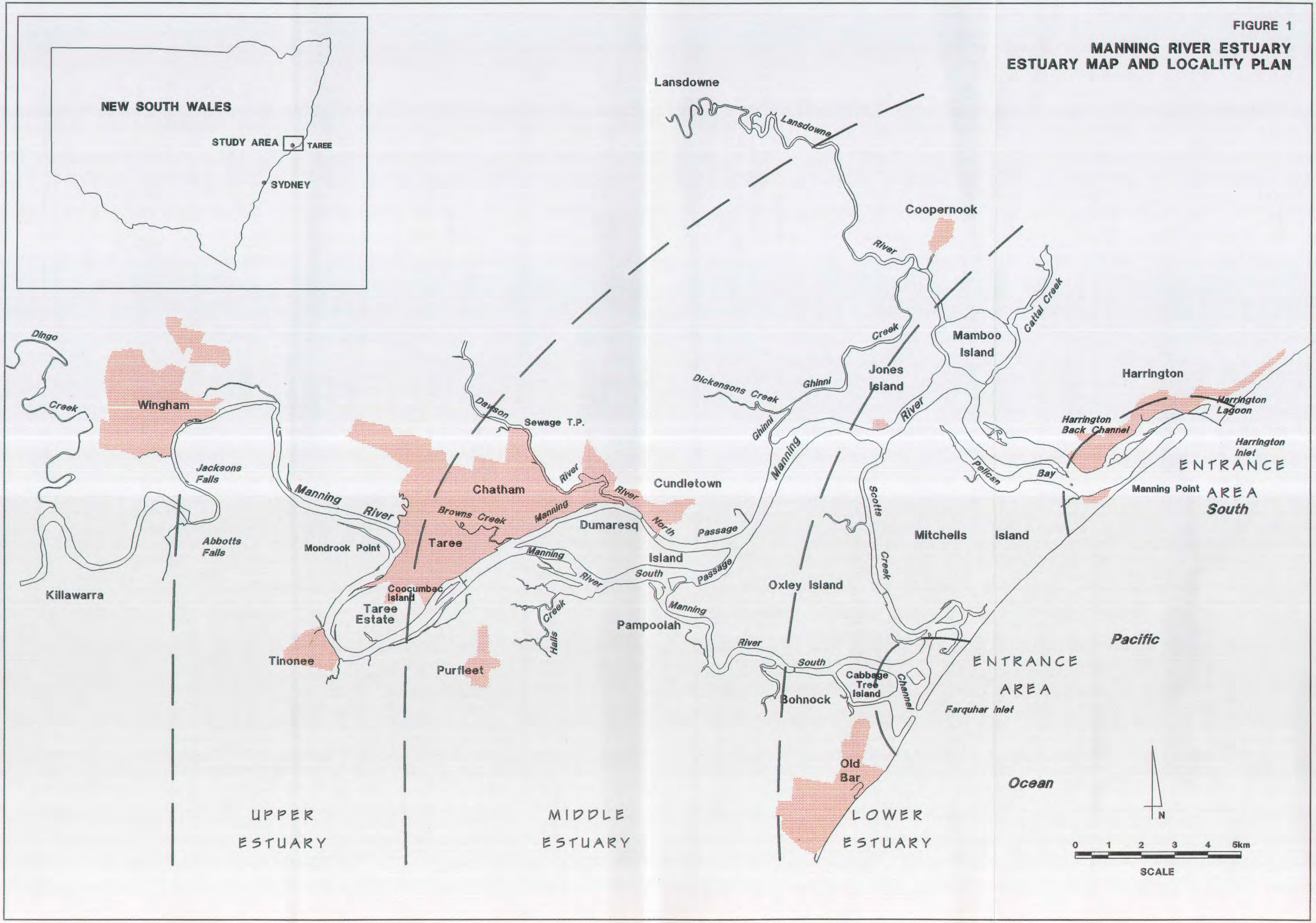


FIGURE 1
MANNING RIVER ESTUARY
ESTUARY MAP AND LOCALITY PLAN

FIGURE 2
CATCHMENT MAP

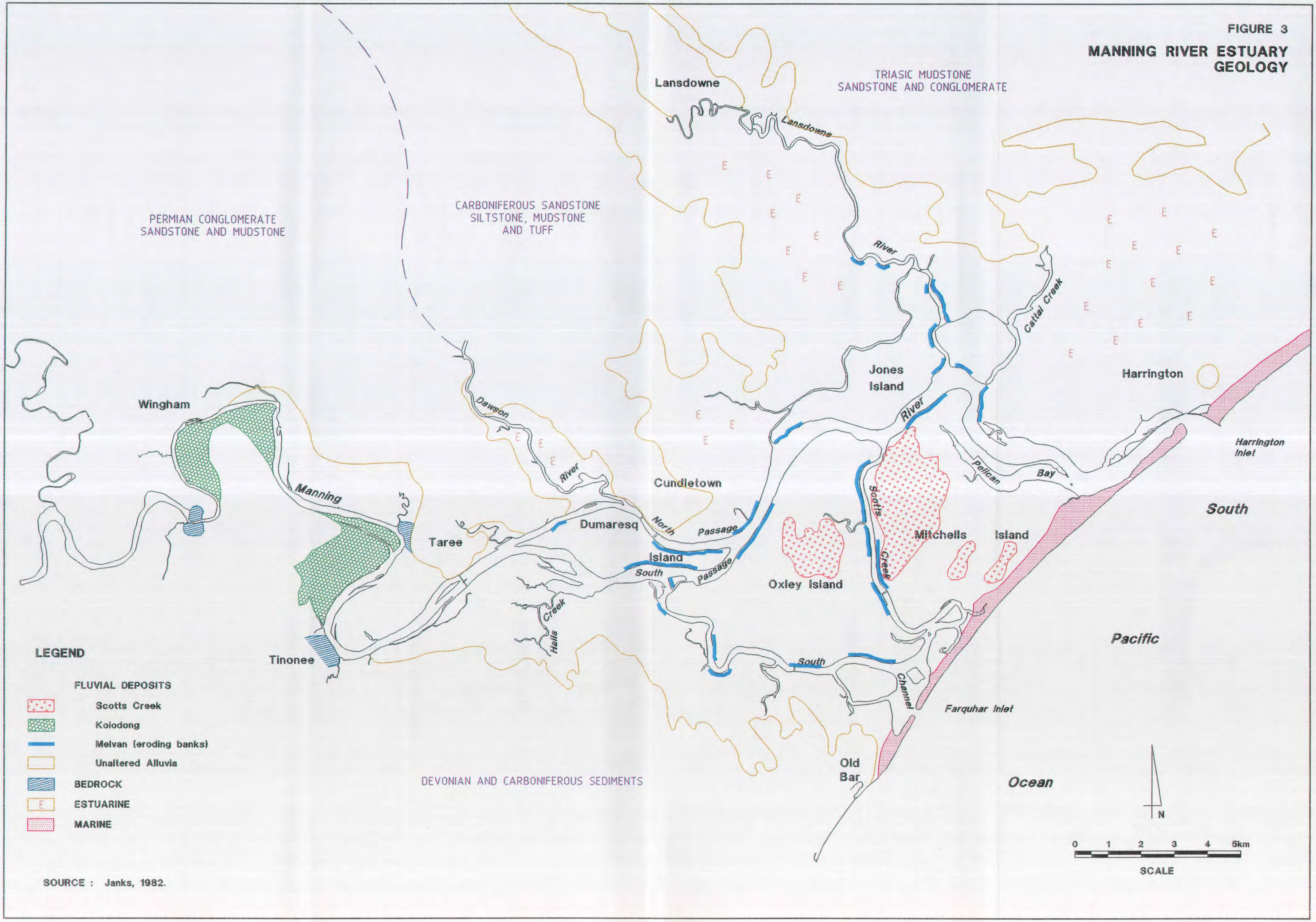


FIGURE 3
MANNING RIVER ESTUARY GEOLOGY
TRIASIC MUDSTONE SANDSTONE AND CONGLOMERATE
Lansdowne
Lansdowne
River
CARBONIFEROUS SANDSTONE SILTSTONE, MUDSTONE AND TUFF
PERMIAN CONGLOMERATE SANDSTONE AND MUDSTONE
Cattai Creek
Jones Island
Harrington
River
Harrington Inlet
Wingham
Dawson
River
Pelican
Bay
Manning
Cundletown
South
Dumaresq
North
Passage
Scotts
Mitchells
Island
Taree
Island
South
Passage
Creek
Oxley Island
Creek
Halls
Pacific
LEGEND
Tinonee
South
Channel
FLUVIAL DEPOSITS
Scotts Creek
Koiodong
Melvan (eroding banks)
Unaltered Alluvia
BEDROCK
ESTUARINE
MARINE
Farquhar Inlet
Old Bar
DEVONIAN AND CARBONIFEROUS SEDIMENTS
Ocean
N
0 1 2 3 4 5km
SCALE
SOURCE : Janks, 1982.

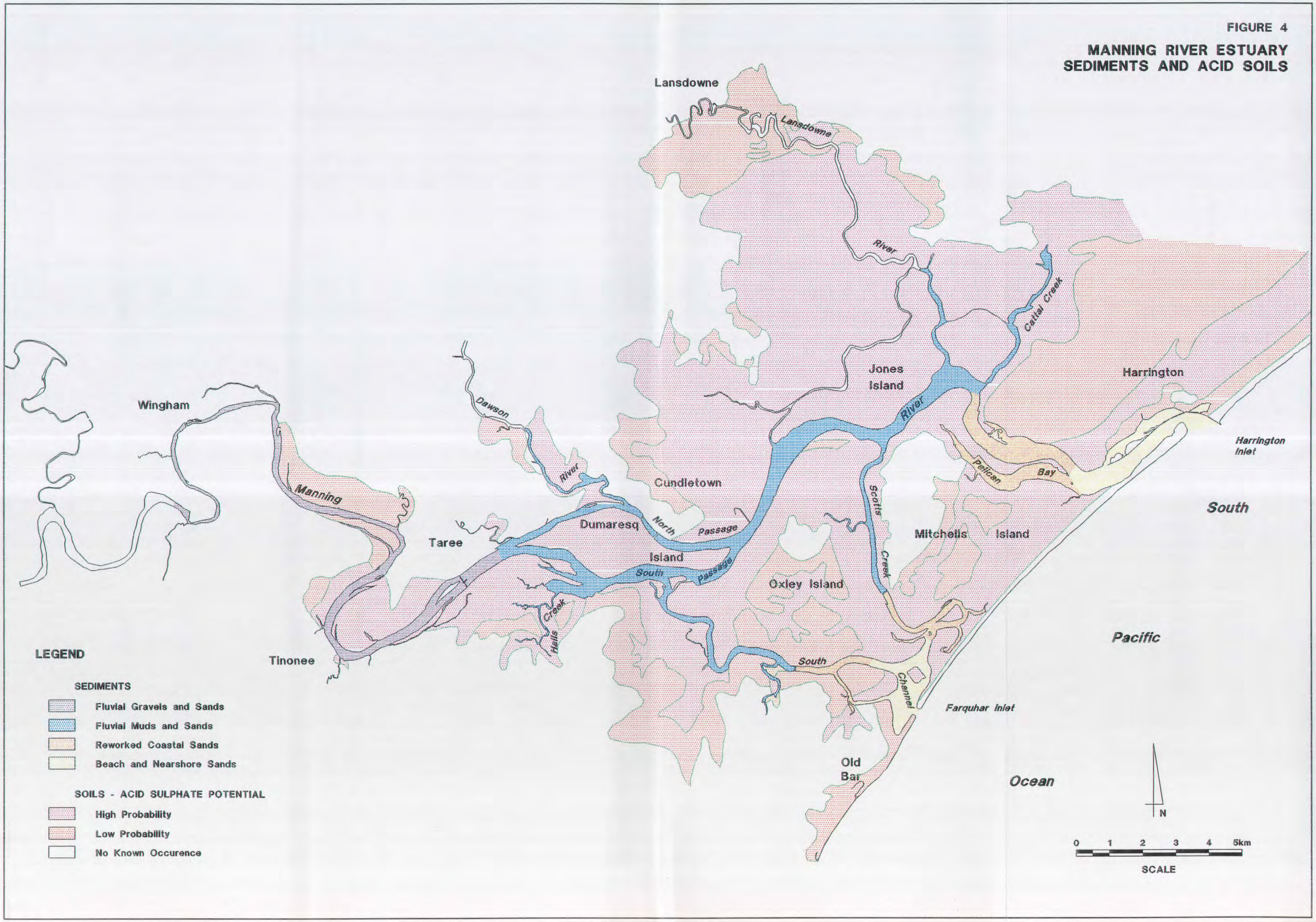


FIGURE 4
MANNING RIVER ESTUARY
SEDIMENTS AND ACID SOILS
Lansdowne
Lansdowne
River
Cattai Creek
Jones
Island
Harrington
River
Wingham
Dawson
River
Manning
Cundletown
Pelican
Bay
Harrington
Inlet
Scotts
Creek
Dumaresq
North
Passage
Taree
Island
South
Passage
Mitchells
Island
Oxley Island
South
Creek
Hallis
Tinonee
South
Channel
Pacific
Farquhar Inlet
Old
Bar
Ocean
LEGEND
SEDIMENTS
Fluvial Gravels and Sands
Fluvial Muds and Sands
Reworked Coastal Sands
Beach and Nearshore Sands
SOILS - ACID SULPHATE POTENTIAL
High Probability
Low Probability
No Known Occurence
N
0
1
2
3
4
5km
SCALE

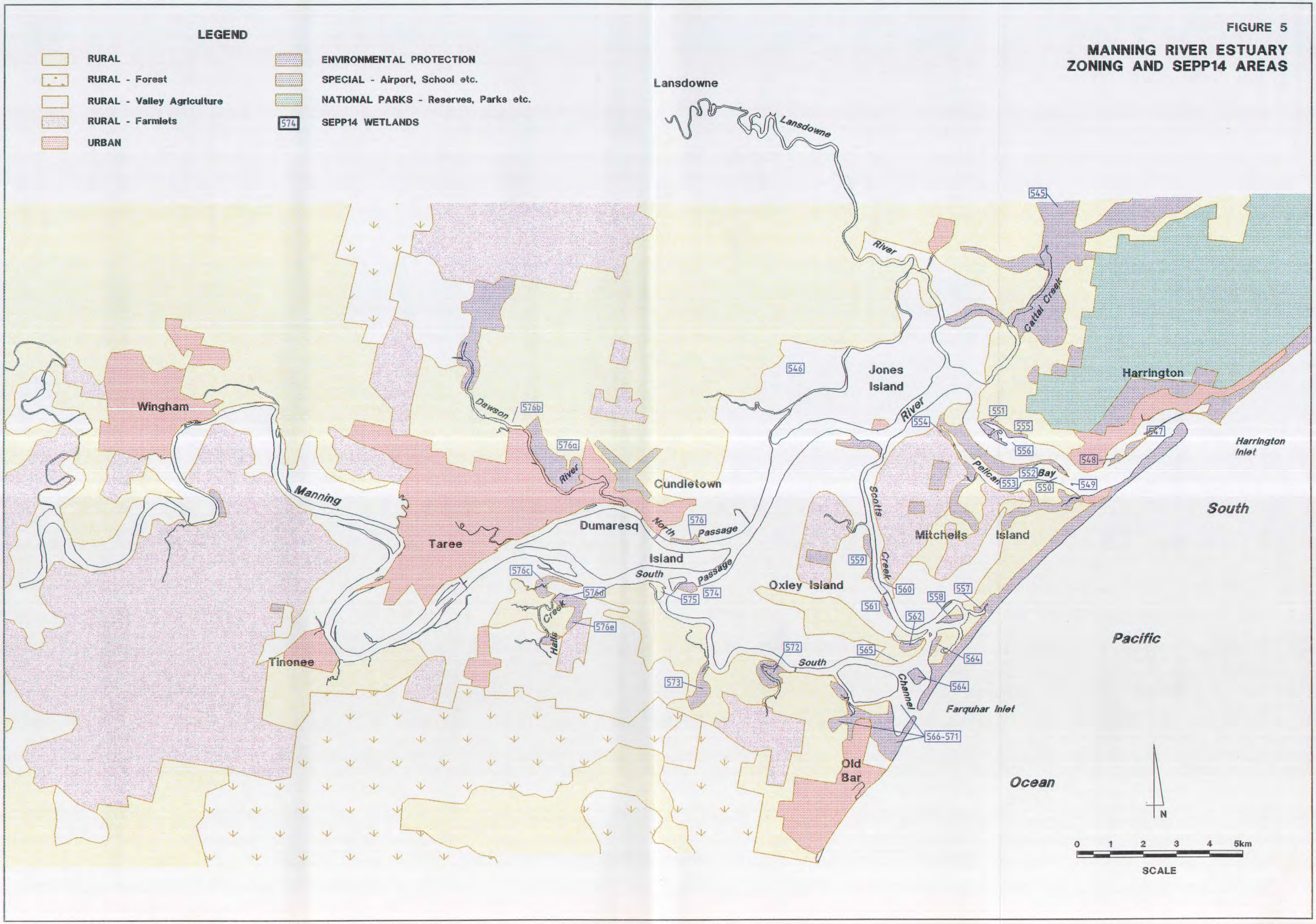


FIGURE 5
MANNING RIVER ESTUARY ZONING AND SEPP14 AREAS

FIGURE 6

MANNING RIVER ESTUARY FLUVIAL AND TIDAL FLOWS

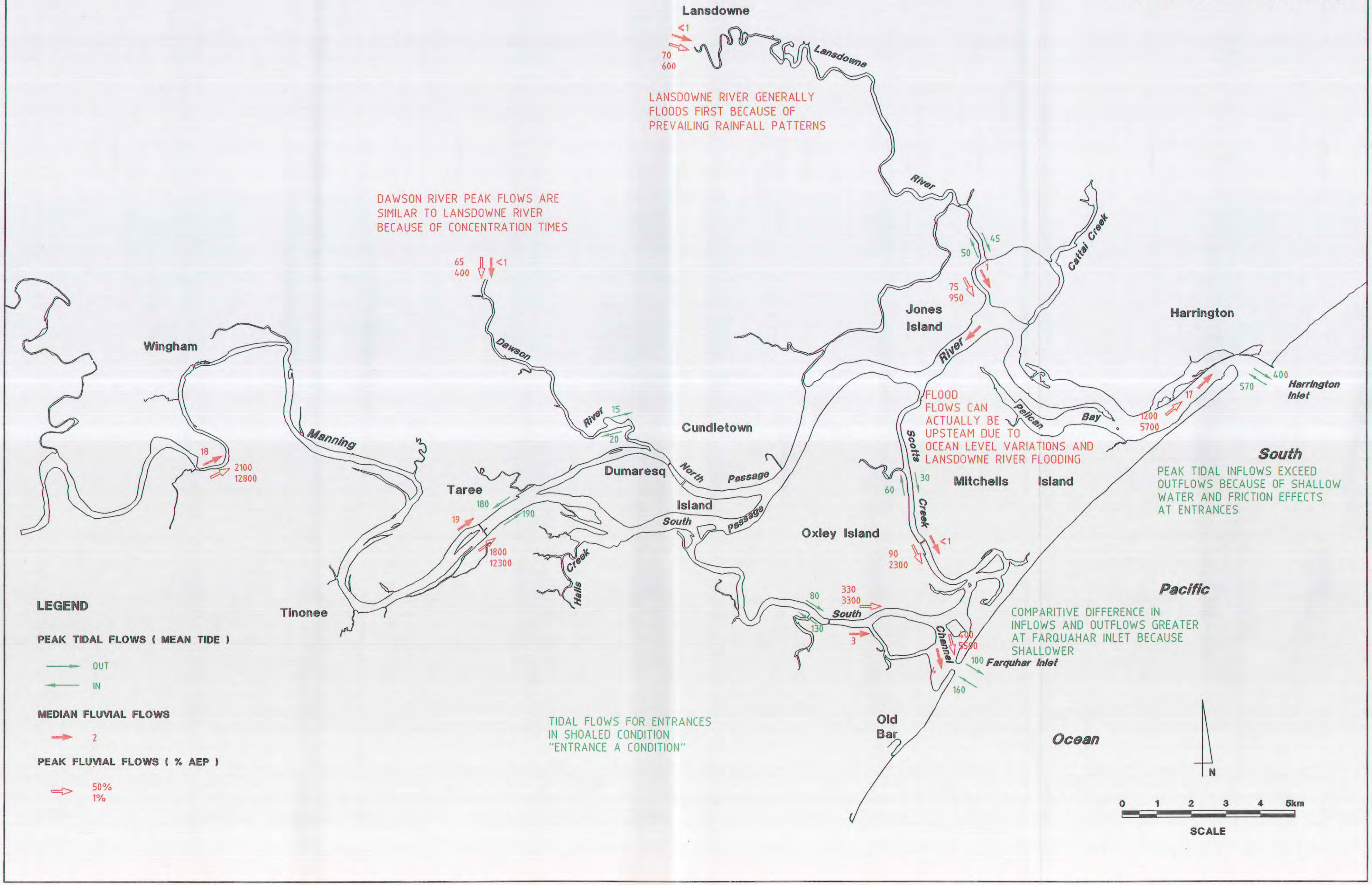


FIGURE 7

MANNING RIVER ESTUARY ESTIMATED TIDAL RANGES

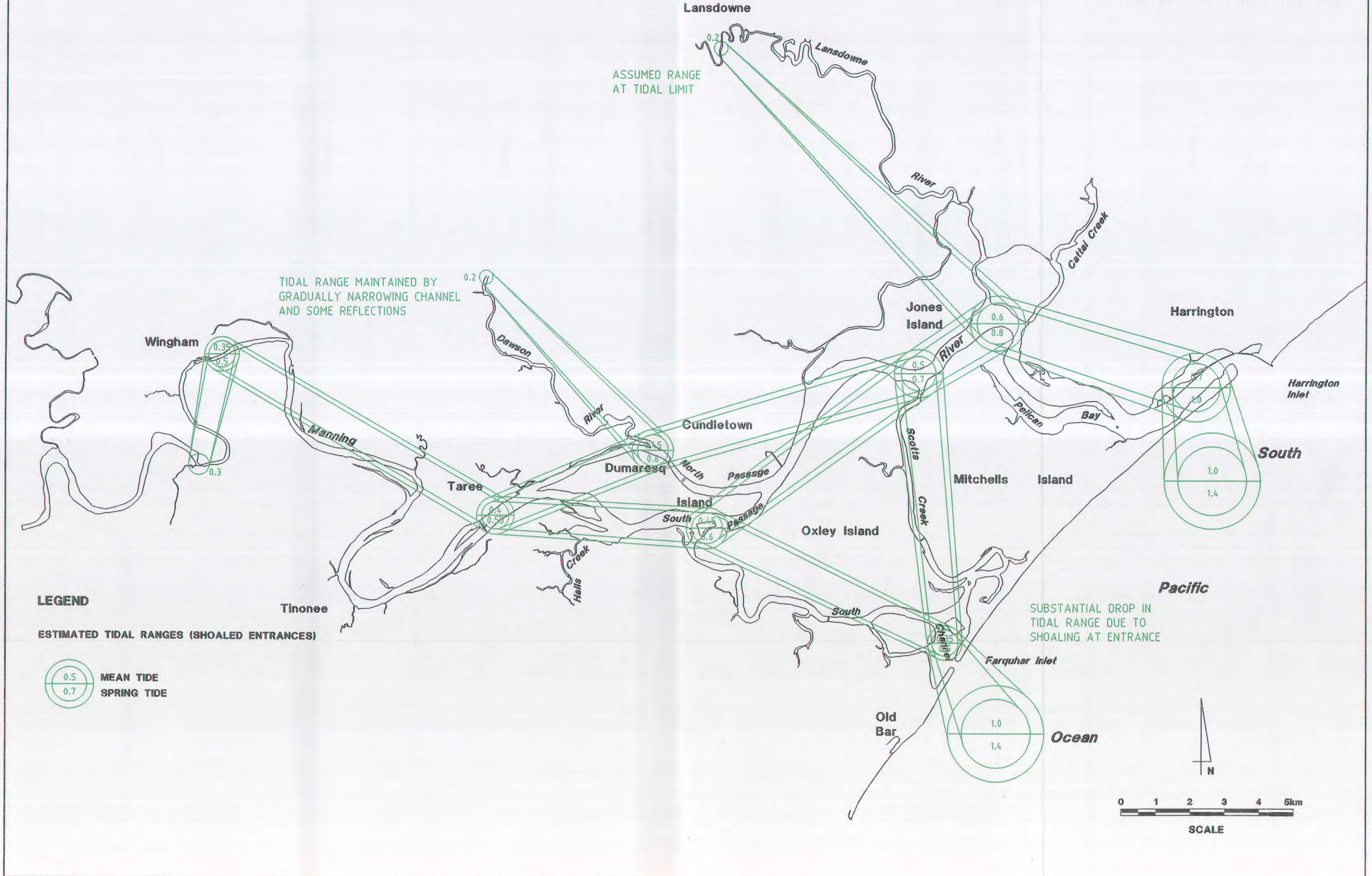
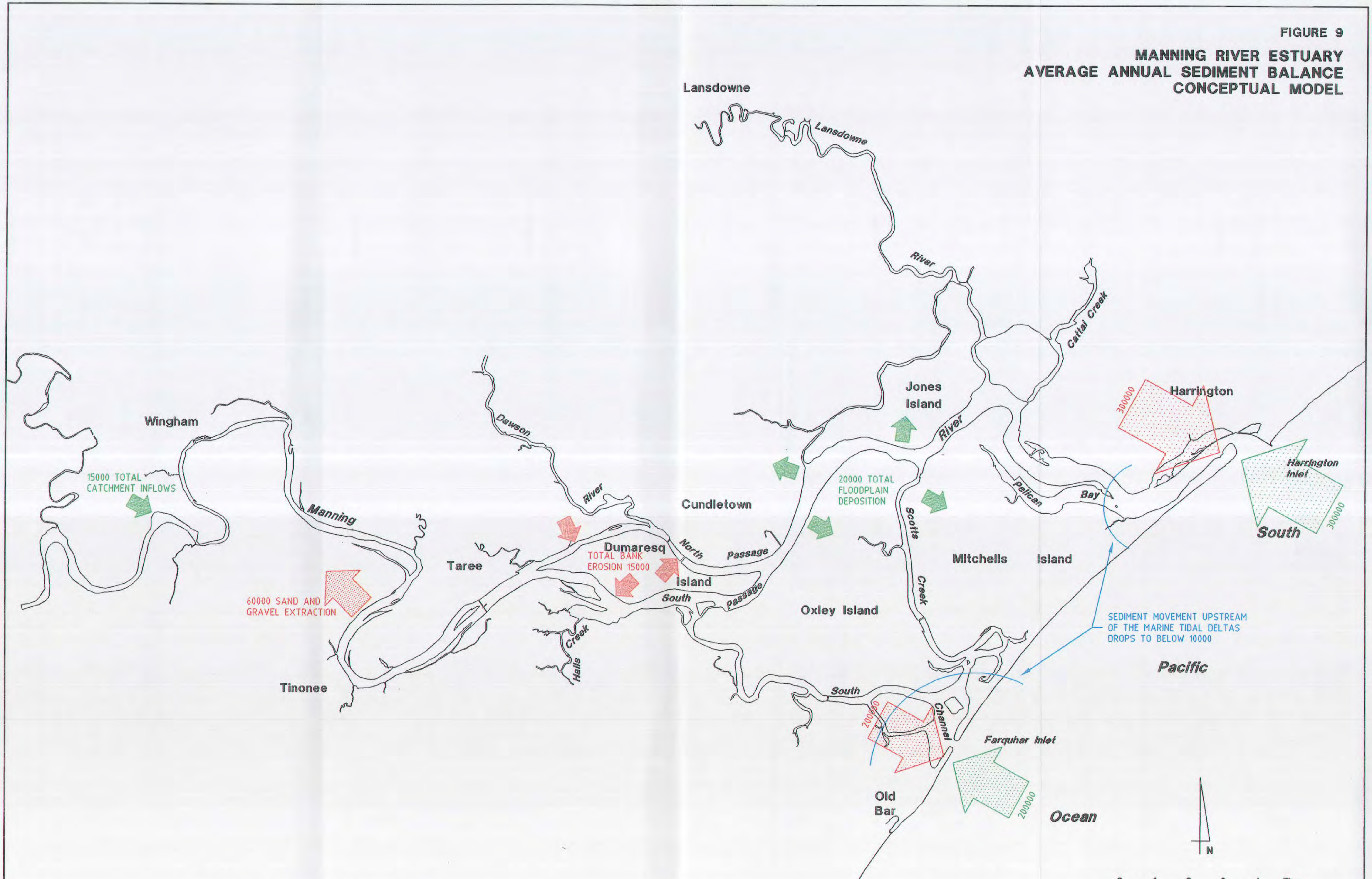


FIGURE 8

MANNING RIVER ESTUARY
AVERAGE ANNUAL WATER BALANCE
CONCEPTUAL MODEL

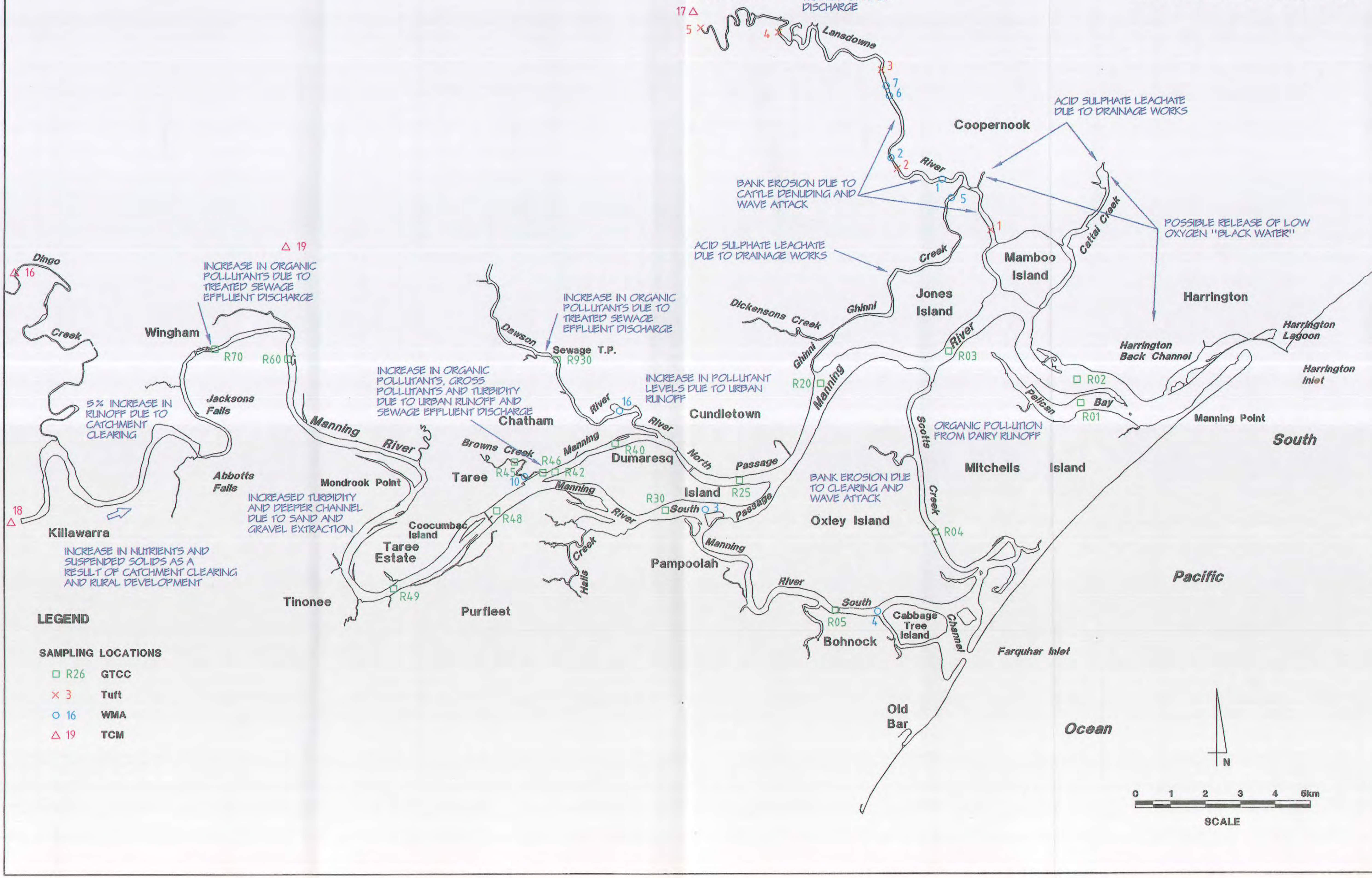
NOTE : FLOW VOLUMES ARE IN Mm^3 / YEAR



NOTE : SEDIMENT MOVEMENTS ARE IN m^3 / YEAR

FIGURE 10

MANNING RIVER ESTUARY
WATER QUALITY POLLUTANT SOURCES
AND SAMPLING LOCATIONS



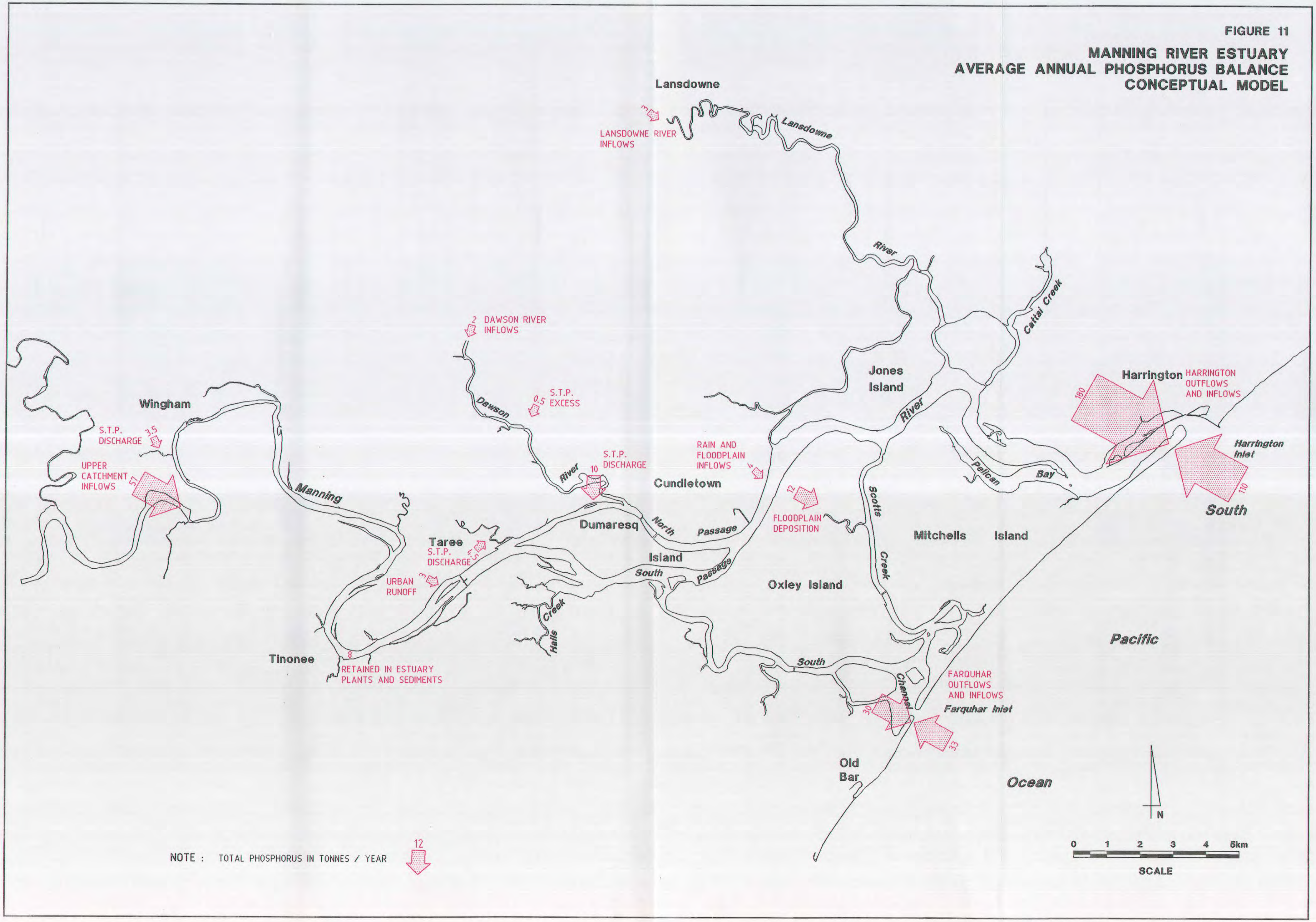


FIGURE 11
MANNING RIVER ESTUARY
AVERAGE ANNUAL PHOSPHORUS BALANCE
CONCEPTUAL MODEL
Lansdowne
3
LANSDOWNE RIVER INFLOWS
Lansdowne
River
Cattai Creek
2 DAWSON RIVER INFLOWS
0.5 S.T.P. EXCESS
Dawson
River
10
S.T.P. DISCHARGE
Jones Island
River
Harrington
HARRINGTON OUTFLOWS AND INFLOWS
180
Harrington Inlet
110
South
Wingham
S.T.P. DISCHARGE 3.5
UPPER CATCHMENT INFLOWS
57
Manning
RAIN AND FLOODPLAIN INFLOWS
4
Cundletown
12
FLOODPLAIN DEPOSITION
Pelican
Bay
Scotts
Creek
Dumaresq
North
Passage
Island
South
Passage
Taree
S.T.P. DISCHARGE
5
3
URBAN RUNOFF
Mitchells Island
Oxley Island
Creek
Hells
Tinonee
8
RETAINED IN ESTUARY PLANTS AND SEDIMENTS
South
Channel
30
FARQUHAR OUTFLOWS AND INFLOWS
Farquhar Inlet
33
Pacific
Old Bar
Ocean
N
0 1 2 3 4 5km
SCALE
NOTE : TOTAL PHOSPHORUS IN TONNES / YEAR
12

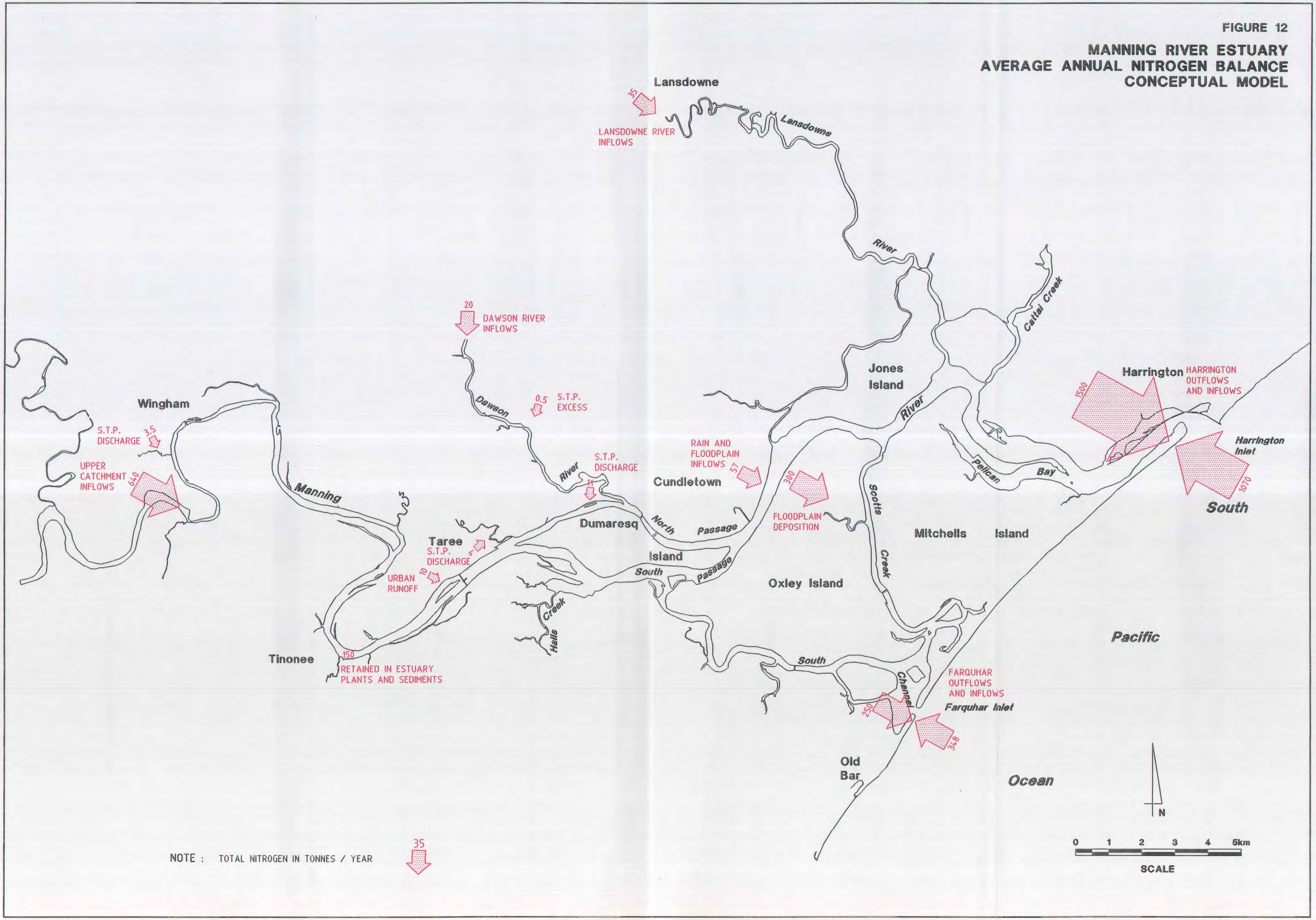


FIGURE 12
MANNING RIVER ESTUARY
AVERAGE ANNUAL NITROGEN BALANCE
CONCEPTUAL MODEL
Lansdowne
35
LANSDOWNE RIVER INFLOWS
Lansdowne
River
20
DAWSON RIVER INFLOWS
0.5
S.T.P. EXCESS
Wingham
S.T.P. DISCHARGE
3.5
UPPER CATCHMENT INFLOWS
640
Manning
Dawson
River
S.T.P. DISCHARGE
11
RAIN AND FLOODPLAIN INFLOWS
57
300
FLOODPLAIN DEPOSITION
Cundletown
Dumaresq
North Passage
Island
South Passage
Taree
S.T.P. DISCHARGE
4
URBAN RUNOFF
10
Creek
Hells
Tinonee
150
RETAINED IN ESTUARY PLANTS AND SEDIMENTS
Jones Island
River
Cattai Creek
Harrington
HARRINGTON OUTFLOWS AND INFLOWS
1500
Harrington Inlet
1070
South
Pelican Bay
Scotts Creek
Mitchells Island
Oxley Island
South Channel
FARQUHAR OUTFLOWS AND INFLOWS
Farquhar Inlet
250
348
Old Bar
Pacific
Ocean
N
0 1 2 3 4 5km
SCALE
NOTE : TOTAL NITROGEN IN TONNES / YEAR
35

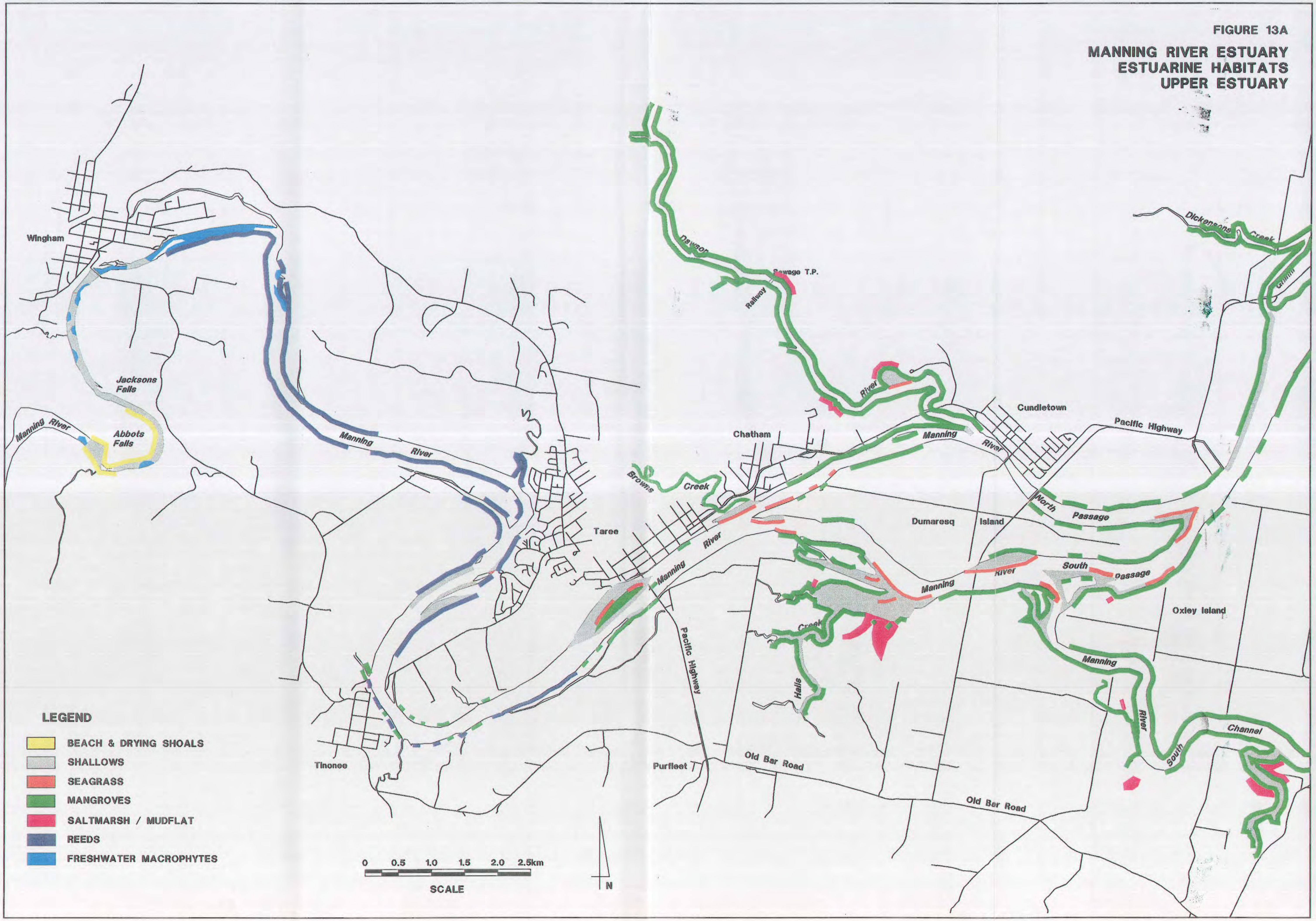


FIGURE 13A

MANNING RIVER ESTUARY
ESTUARINE HABITATS
UPPER ESTUARY

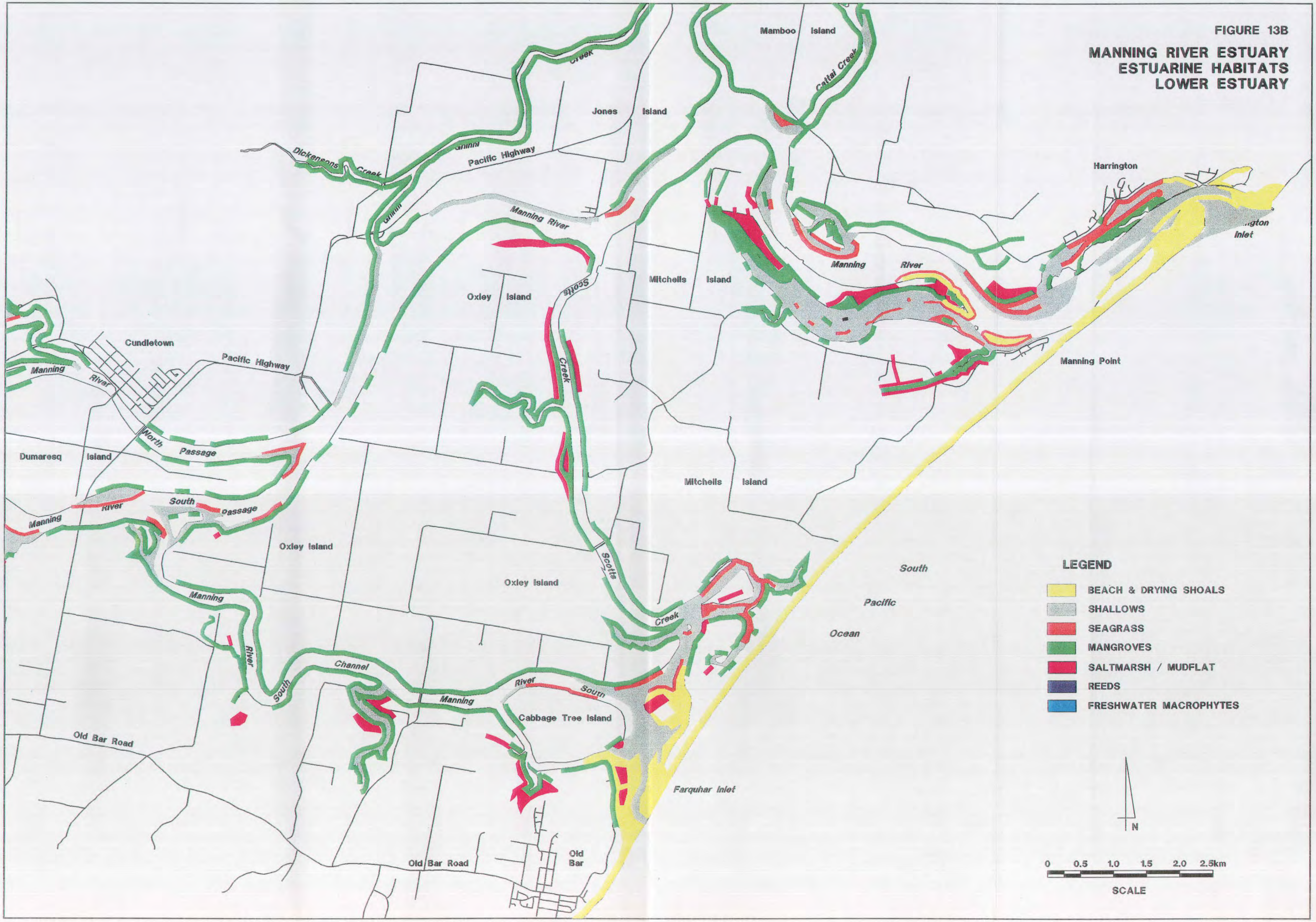


FIGURE 13B

MANNING RIVER ESTUARY
ESTUARINE HABITATS
LOWER ESTUARY

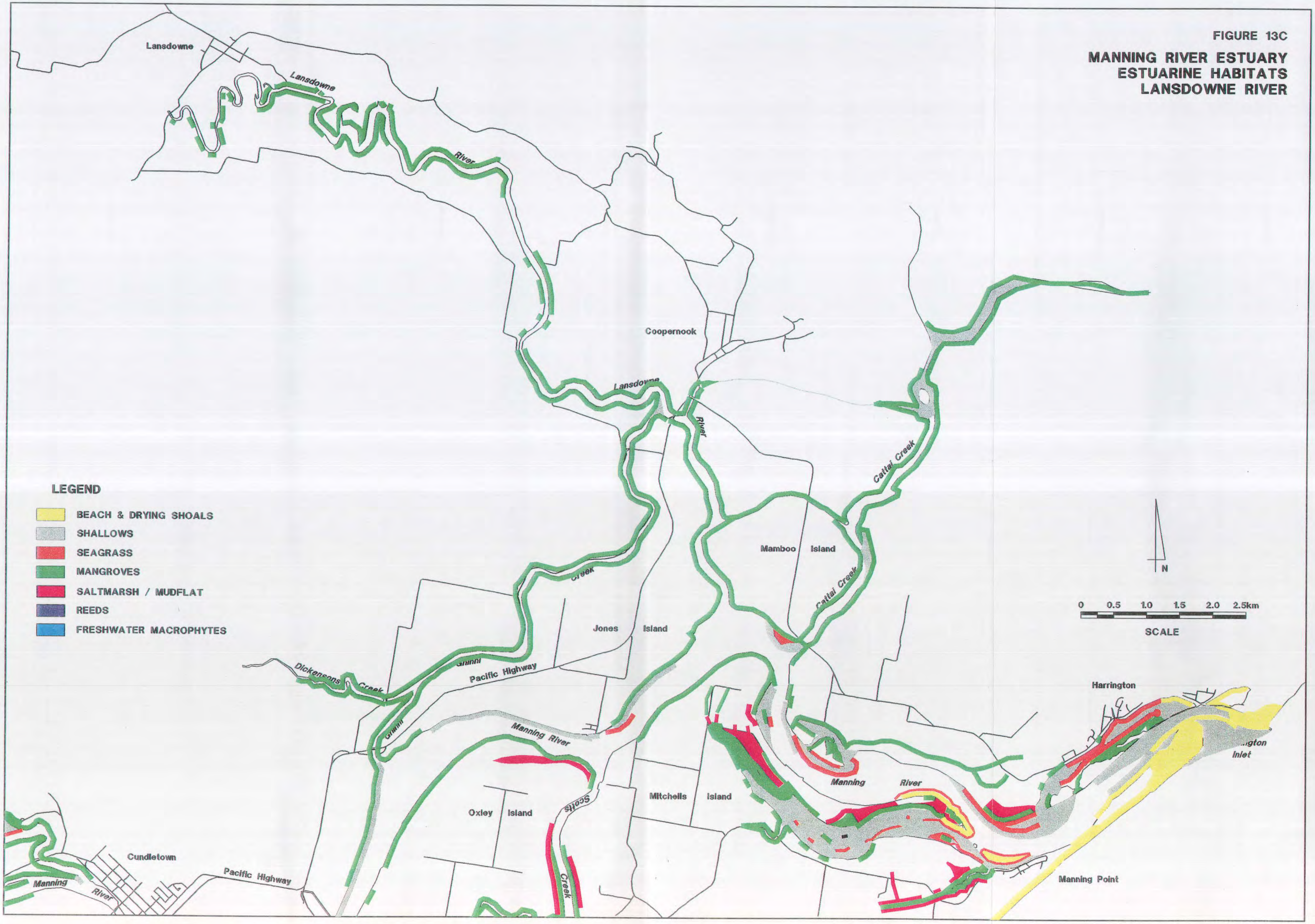
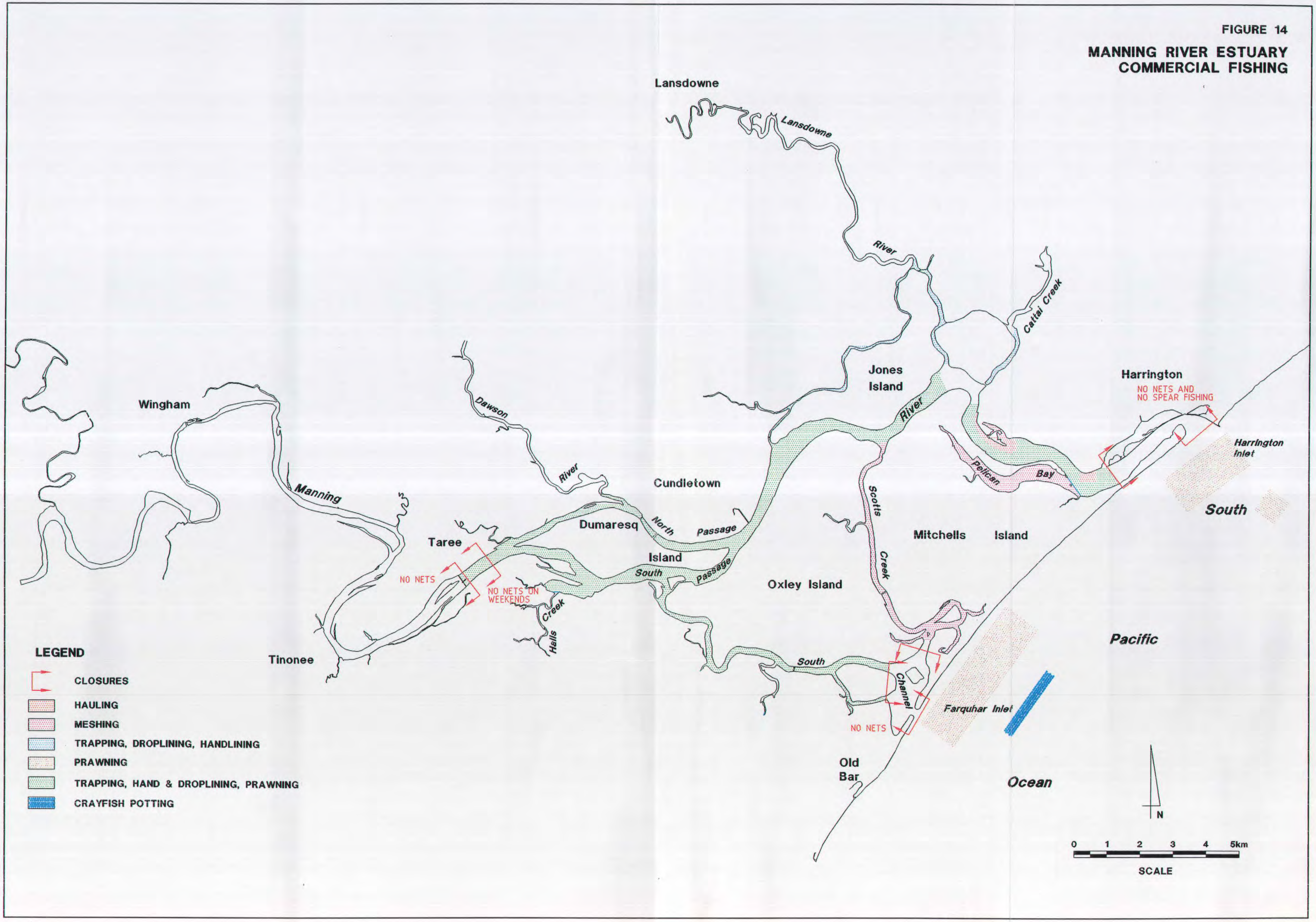


FIGURE 13C
MANNING RIVER ESTUARY
ESTUARINE HABITATS
LANSDOWNE RIVER
LEGEND
BEACH & DRYING SHOALS
SHALLOWS
SEAGRASS
MANGROVES
SALTMARSH / MUDFLAT
REEDS
FRESHWATER MACROPHYTES
N
0 0.5 1.0 1.5 2.0 2.5km
SCALE
Lansdowne
Lansdowne River
Coopernook
Lansdowne River
Cattai Creek
Mamboo Island
Cattai Creek
Jones Island
Dickensons Creek
Pacific Highway
Manning River
Harrington
Inlet
Manning River
Mitchells Island
Oxley Island
Scotts Creek
Cundletown
Pacific Highway
Manning River
Manning Point



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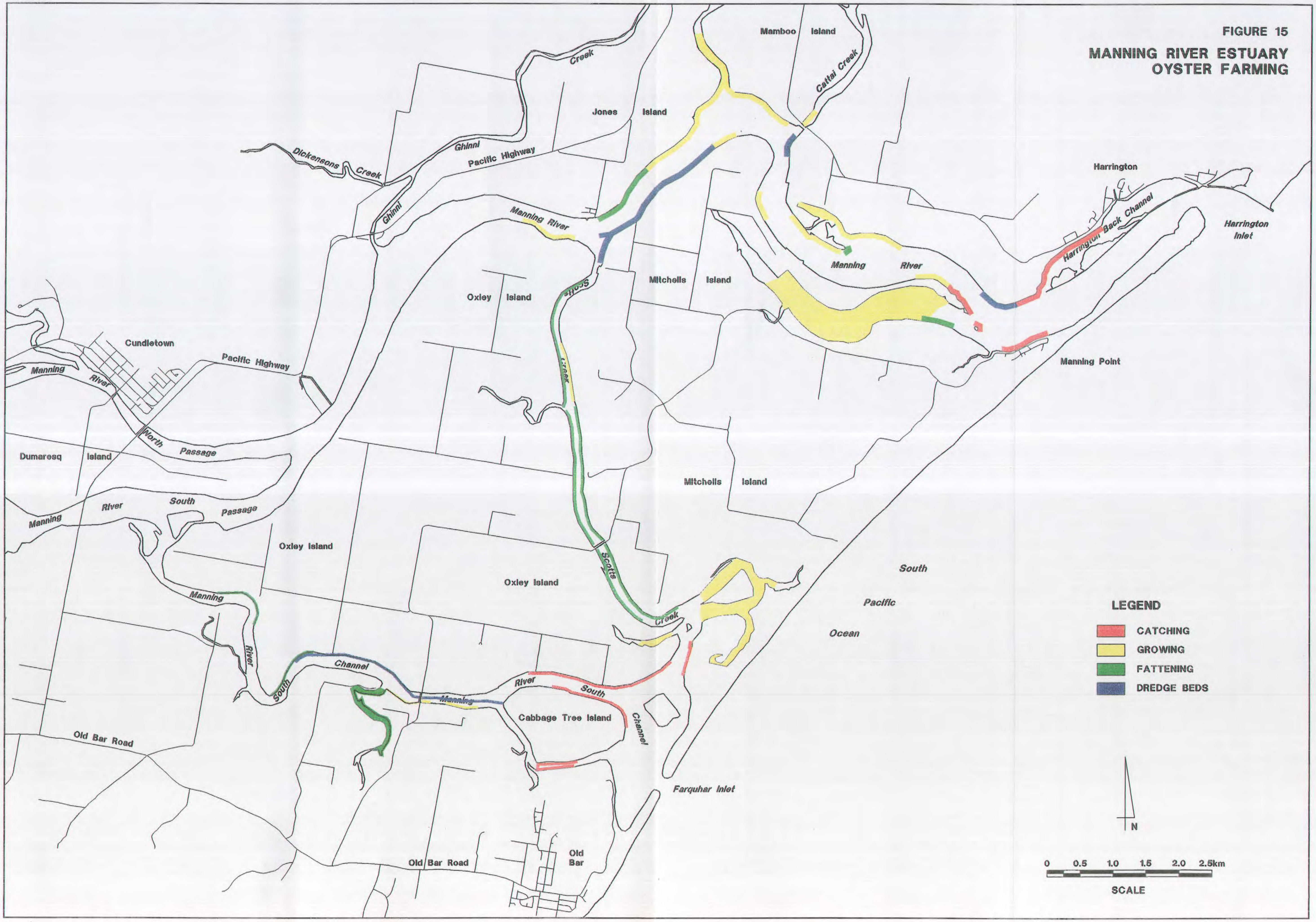

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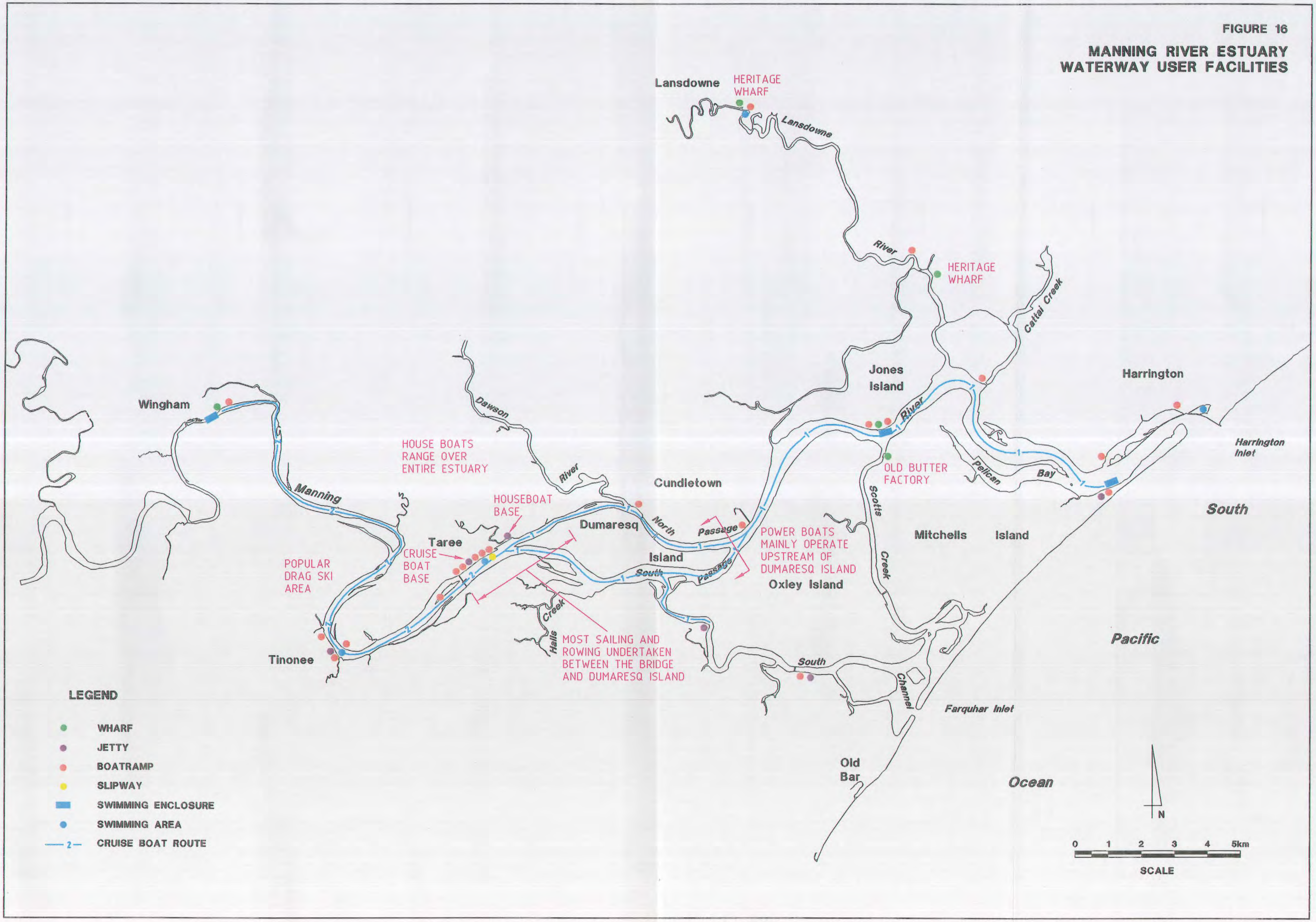
FIGURE 16

MANNING RIVER ESTUARY WATERWAY USER FACILITIES



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