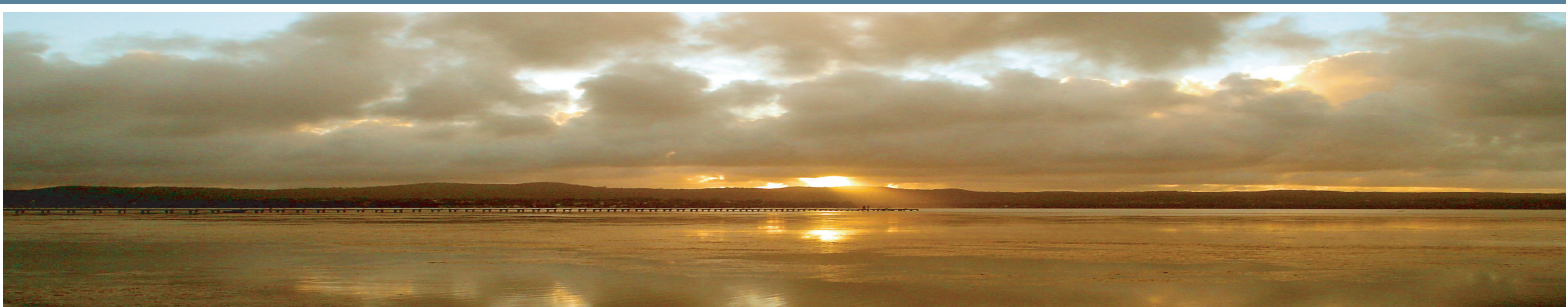


Estuary Management Process

Tuggerah Lakes Estuary Process Study, 2001

Tuggerah Lakes Estuary Management Study, 2005

Tuggerah Lakes Estuary Management Plan



Roberts, D.E. and Dickinson, T.G. (2005).

Tuggerah Lakes Estuary Management Study. Prepared for Wyong Shire Council and Department of Infrastructure, Planning and Natural Resources.
BIO-ANALYSIS: Marine, Estuarine and Freshwater Ecology, Narara

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You can also find information about the Tuggerah Lakes Estuary Processes Study and Estuary Management Study on Wyong Shire Council's web site
www.wyong.nsw.gov.au/environment_home.html

Prepared by



For



Summary

The catchment of the Tuggerah Lakes represents around 80% of the area of the Wyong Shire. The study area, located on the central coast of NSW, is comprised of three shallow coastal lagoons, Tuggerah Lake, Budgewoi Lake and Lake Munmorah. The three lakes are interconnected and open to the sea at The Entrance. The Tuggerah Lakes estuary has always been important to the shire in terms of its value to tourism, recreation and fisheries.

The State Government's Estuary Management Policy is a component policy of the State Rivers and Estuaries Policy of the NSW Government, which in turn comes under the umbrella of Total Catchment Management. The Estuary Management Study builds on the findings of the Tuggerah Lakes Estuary Process Study, adding a managerial framework as a pre-cursor to the development of an Estuary Management Plan.

The Estuary Process Study was completed in 2001 and described physical, chemical and biological patterns (and some processes) and identified management issues that would be the focus of a subsequent management study. The objective of the Tuggerah Lakes Estuary Process Study was to identify data gaps and key estuarine processes so that there was better understanding of how the estuary "worked".

The Tuggerah Lakes estuary was formed some 6,500 years ago when sea levels rose after the last ice age. Most of the geomorphic features of the estuary are no longer active, except for the river deltas of Wyong and Ourimbah Creeks and the tidal delta at The Entrance. Sedimentary processes within the estuary are slow, with no evidence for general depth changes since comprehensive bathymetry studies in the 1970's. There are however, small-scale changes with some places becoming shallower around inflows (e.g. Tumby Creek) whereas other places have become deeper, some due to the effects of mine subsidence. The Tuggerah estuary is one of the slowest infilling estuaries on the NSW coast, and at current rates, would take over 1000 years to fill completely. Tidal flushing contributes very little to circulation and mixing patterns. The bottom sediments within the estuary are relatively "healthy" apart from some small-scale problems in some areas. Investigations on pollutants within the sediments indicated very small amounts of pesticides whilst heavy metals were below those found to cause adverse ecological effects. The sediments within the estuary have significant concentrations of nutrients which are available for plant growth. Nutrient concentrations within the water column are above the water quality guidelines and the estuary can be classified as having a medium nutrient status.

The entrance is now kept open to the sea by a sand dredge, which allows some limited flushing and mixing to occur, however, the overall effects of flushing are small when the size of the estuary is taken into account. As there are no new sources of marine sands entering the estuary, the eastern shorelines have become siltier and in areas where there is continued organic enrichment, "organic oozes" can still be found.

Management of the wider catchment has improved with greater controls on development and farming. The completion of the sewerage scheme has also helped to reduce the amount of nutrients entering the estuary via septic systems and overflows. During heavy rain, nutrients and sediment still enter the estuary from stormwater and from the major tributaries. Symptoms of eutrophication still occur, especially around some of the developed foreshores, as small-scale blooms of drift macroalgae. The processes that drive these blooms are still being examined however their ability to damage the underlying benthic community is without question as is the role the benthic animals play in nutrient cycling.

The turbidity in the estuary has decreased since the 1980's and whether this was due to reduced patterns of rainfall and/or reduced concentrations of suspended material in the water column is unknown. The extent of seagrass habitat within the estuary has not increased since its decline during the 1980's. Anecdotal evidence suggests that there has been some recolonisation of seagrasses into shallow areas around the estuary, which may have been lost. The saltmarshes of the estuary have continued to decline as a result of disturbance and establishing their role in the nutrient cycling process and wrack assimilation is very important.

The process study found that the Tuggerah Lakes estuary was "healthier" than it was during its eutrophic stage in the 1980's and 1990's. The question is whether this level can be sustained with increased future development or whether the system would be pushed over some threshold, returning it to the previous eutrophic state of the 1980's.

In the past, the Tuggerah Lakes estuary has been managed by addressing very specific issues, while maintaining an ongoing programme of water quality/ecology monitoring and entrance management. While these are valid areas of concern to Council and the community, they need to be placed in an overall framework that provides a process for listing, prioritising and resolving issues to ensure that estuarine values are protected. The Estuary Management Study is the first time such a framework has been developed and documented.

Six core principles have been developed to guide the management of the estuary. Of these, five formed the basis for the Central Coast Catchment Blueprint which was developed to manage the catchments of the Central Coast (now being developed into a Catchment Action Plan by the new Hunter Central Rivers Catchment Management Authority). An additional objective was developed to ensure that our knowledge of the estuary continues to improve through time. By linking these documents (the Blueprint and Management Study), estuarine management and catchment management will be contributing to the same vision of managing the natural resources of the area. As these principles are general, it's necessary to focus on important outcomes for the lakes and catchment. There are a number of objectives that focus attention on how the principles could be achieved or protected. The core principles and objectives for managing the Tuggerah Lakes estuary are listed below.

Principles and Objectives for the Tuggerah Lakes Estuary

Principles	Objectives
Water quality and quantity meet community needs and natural ecosystem requirements	Provide adequate environmental flow to sustain estuarine and riverine ecology
	Maintain water quality to protect healthy ecosystem function in the estuary and rivers
	Provide water quality in rivers and the estuary safe for primary human contact
	Maintain flow patterns while minimising flooding threat to life and property
	Provide adequate water for community water supply
	Minimise changes to groundwater flow/stores
The physical structure and vegetation of river, lake and wetland riparian zones are protected (and rehabilitated where required) to sustain healthy ecosystems	Protect, maintain & restore freshwater wetland vegetation
	Protect, maintain & restore aquatic and semi-aquatic estuarine vegetation
	Protect, maintain & restore floodplain vegetation
	Protect, maintain & restore aquatic and riparian riverine vegetation
Conserve the diversity of all native plant and animal species and to protect and assist the recovery of threatened and endangered species	The biodiversity and ecological function of the catchment shall be maintained in a manner that protects the estuary
	Minimise human disturbances that affect ecological function
	Maintain and protect environmentally significant areas and threatened species/communities
	Ensure fishery is sustainable
Human settlement, primary production and other land uses take place while protecting and enhancing Aboriginal cultural heritage, soil, water and ecosystem health	Ensure management of the estuary and catchment protects and enhances indigenous & non-indigenous cultural heritage
	Provide economically and socially justified levels of development whilst containing ecological impacts
	Support forestry, agriculture and other industries in the catchment while viability of downstream ecology is maintained
	Protect and restore soil landscapes and improve understanding of land capability & suitability in the catchment
The coastal zone environment is protected whilst providing for the social and economic needs of the community.	Support existing industry where it is ecologically compatible
	Ensure any new commercial venture is socially and economically justified and is ecologically compatible with the estuary
	Provide for public access and amenity at designated beaches and in designated recreation areas
Improve knowledge of catchment and estuarine systems	Identify extent of information gaps and where appropriate undertake studies to improve understanding
	Ensure community is pro-actively involved in estuarine health and management

Ideally, the objectives could be met easily, ensuring the health of the catchment and estuary. In practice, there are a number of constraints for these objectives. These constraints or problems have been defined as “issues” for the purposes of the Management Study. Traditionally, managing activities that affect the estuary has been done on an issues basis (e.g. foreshore “ooze”, seagrass wrack accumulation). This study relates such issues back to the overall estuarine management objectives that are not being met. A consultation programme was undertaken to obtain a list of issues for estuarine management. This consultation programme canvassed business groups (2 workshops), technical groups from Council and State agencies (3 workshops) and community focus groups (3 workshops). The responses from these groups were compiled and the high priority issues are listed below.

Priority issues for the Tuggerah Lakes estuary grouped by principle

Principles	Prioritised Issues
Water quality and quantity meet community needs and natural ecosystem requirements	1. Increased sediment and nutrient loads from existing landuses affect water quality (WE2)
	2. Increasing population puts an increased demand on water supply (WS1)
	3. Increased sediment and nutrient loads from new development affect water quality (WE3)
	4. Foreshore and streambank erosion adds sediment to waterways (WE7)
	5. Toxic contaminants in runoff could affect aquatic ecology and human health (WE4)
	6. Water supply and irrigation needs get priority over river flow for environmental needs (WF1)
The physical structure and vegetation of river, lake and wetland riparian zones are protected (and rehabilitated where required) to sustain healthy ecosystems	1. No existing plan for identifying, rehabilitating and managing significant foreshore habitats (VE1)
	2. No active monitoring and management of important wetlands (VW1)
	3. Activities in upstream catchments can change downstream wetlands (VW2)
	4. Changes in water quality can affect aquatic and semi-aquatic vegetation (VE2, VR2)
	5. Inadequate understanding of riverine ecological processes and riverine water quality to allow for environmental flow management (VR5)
	6. Invasive species can degrade important habitats (VW3, VF3)
Conserve the diversity of all ecological habitats and viable populations of their constituent species and protect and assist the recovery of threatened and endangered communities and species	1. Loss, fragmentation or degradation of habitat (DC1, DF5)
	2. No ecologically sustainable target for catchment development (DC2)
	3. Protective measures applied to development are difficult to monitor and enforce (DC3)

Principles	Prioritised Issues
	4. Assigning responsibility for managing environmentally significant areas (DS2)
	5. Changes to flow volumes and patterns (DF2)
	6. Human disturbance and built structures can threaten estuarine habitats (DF4)
	7. Some local processes are threatening sensitive ecological communities and species but are not legally defined (DT1)
Human settlement, primary production and other land use take place while protecting and enhancing Aboriginal cultural heritage, soil, water and ecosystem health	1. Difficult to monitor activities of landholders (LA2)
	2. Insufficient programmes in place to investigate and rehabilitate erosion sites (LS2)
	3. Insufficient programmes or plans to determine land capability for the catchment (LS3)
	4. Market forces drive development more than environmental protection (LD4)
	5. Limited funding for works to rehabilitate and manage land (LS4)
The coastal zone environment is protected whilst providing for the social and economic needs of the community	1. Insufficient settlement, employment and conservation strategies (SC1)
	2. Insufficient environmental impact modelling or pre-development ecological assessments (SC2)
	3. Compatibility of businesses with the estuary is not well understood (SE2)
	4. Environmental degradation is difficult to reverse once it has occurred (SE3)
	5. Some amenity issues may be a result of previous land management practices (SP2)
Improve knowledge of catchment and estuarine systems where a clear link to management decisions is evident	1. Community scepticism about available estuarine knowledge, management intentions and management approach (KC2)
	2. Funding and resourcing further studies into estuarine processes, health trends and key management questions (KG1)
	3. Understanding of key estuarine processes is not complete (KG3)
	4. Existing community perceptions about estuarine health (KC1)
	5. General public are not actively informed through the most effective media channels (KC4)

Managing the Tuggerah Lakes estuary will require adopting measures to address the above issues. The options described in the report detail a broad range of potential measures that could be employed at varying scales. By examining the priority issues it was possible to consolidate the options that address them into high priority set of programmes that can be actioned through the management plan. These are presented below.

Item #	Priority Programmes	Components	Issues Addressed	Location	Type	Responsibility
1.	Streambank rehabilitation and erosion protection	<ul style="list-style-type: none"> ▶ Couple with the catchment audit programme to target most affected areas ▶ Incorporate measures to limit activities that cause erosion (boatwash etc) ▶ Link with existing programmes such as Landcare where possible 	WE7, VR3	Catchment streams	Works	WSC, DOL, GWCWA, DIPNR, DPI(Forests), DEC (Parks & Wildlife) Landholders
2.	Stormwater management in new urban areas focussing on sediment and nutrient management, water sensitive urban design and producing more natural flows for downstream environments	<ul style="list-style-type: none"> ▶ Combine with developer partnerships to explore innovative ideas ▶ Set clear, measurable stormwater performance guidelines ▶ Focus on providing natural downstream flow and as close as possible to no net increase in sediment and nutrient load (IWCM and stormwater harvesting can reduce flows) ▶ Place requirements on developers to prove compliance ▶ Link DCP 67 with key stormwater reference material 	WE3, WF1, WG1, VF1, VR1, VR2	Urban	Works	WSC, CMA's, Developers, Community
3.	Retrofit stormwater interventions in existing urban areas focussing on sediment and nutrient management, contaminants and gross pollutants	<ul style="list-style-type: none"> ▶ Couple with the catchment audit programme to target highest polluting catchments ▶ Research models and use to estimate likely loads, calibrate using field data such as GPT sediment collected ▶ Implement treatment train for retrofits. Once priority catchment is identified examine all areas in the catchment for compliance, education and controls 	WE2, WF1, VF1, VR1, VR2	Urban	Works	WSC, Community

Item #	Priority Programmes	Components	Issues Addressed	Location	Type	Responsibility
4.	Undertake a programme of works to restore degraded or threatened habitat through rehabilitation, strategic land protection and active management of invasive species (e.g. weeds)	<ul style="list-style-type: none"> ▶ Use existing Council GIS information to identify habitat ▶ Develop a prioritisation system for remediation ▶ Explore innovative strategies for remediation and future protection ▶ Utilise community and environmental action groups to assist with proposed programmes 	DT1, DC1, VW3, VF3, VR3	Catchment	Works	WSC, DPI (Forests), DEC (Parks & Wildlife), CMA's, Landholders, Community Groups (e.g. Birding NSW)
5.	Foreshore management programme including identification and passive/active rehabilitation of key habitats such as saltmarsh and fringing wetlands, and managing threatening processes on public and private lands	<ul style="list-style-type: none"> ▶ Identify all sensitive and threatened foreshore communities ▶ Appraise effects of recreational and maintenance activity and recommend modifications if necessary ▶ Designate all foreshore areas as recreational zone or passive/active rehabilitation areas ▶ Incorporate an education component for foreshore residents and maintenance workers operating in these areas 	VE1, DT1, VE3, DS1	Foreshore	Works	WSC, DPI (Fisheries), DEC (Parks & Wildlife), Community Groups (e.g. Birding NSW)
6.	Improve facilities in designated recreation areas based on community consultation including additional seating, BBQ's, picnic areas, educational signage, upgraded boat ramps	<ul style="list-style-type: none"> ▶ The aim is to encourage greater use of the foreshore ▶ Undertake some community consultation to determine what improvements are desired ▶ Utilise Maritime Authority WADAMP funding to improve maintenance of boat ramps ▶ Focus on providing facilities that may increase community education (signage) and foreshore interaction (e.g. landscaping) 	SP5, SP1	Foreshore	Works	WSC, Maritime Authority

Item #	Priority Programmes	Components	Issues Addressed	Location	Type	Responsibility
7.	Limit public access to ecologically sensitive areas of the foreshore and estuary where necessary, including saltmarsh (e.g. Tuggerah Bay) and seagrass habitat (e.g. Budgewoi Sandmass)	<ul style="list-style-type: none"> ▶ Determine whether there is an ecological need to do this and if so where it might be appropriate ▶ Examine mechanisms for preventing access if needed ▶ Provide information to the public clearly explaining why the exclusions are necessary (i.e. for rehabilitation or protection) 	DT1, DS1, DF4, VE3, VE4	Foreshore Estuary	Works	WSC, DOL, DEC (Parks & Wildlife), Community Groups (e.g. Birding NSW)
8.	Audit sub-catchments for environmental compliance including sediment/erosion and contaminant controls	<ul style="list-style-type: none"> ▶ Combine with the catchment audit process to target catchments likely to be most pollution ▶ Work through the whole catchment – not just development areas to assess industry and landholders control and compliance measures ▶ Work with people to co-operatively develop solutions rather than fining in the first instance 	LA2, LS2, LS3, WE2, SC3	Catchment	Monitoring	WSC, Industry Community
9.	Develop a catchment audit process for assessing high risk catchments and prioritising interventions	<ul style="list-style-type: none"> ▶ Examine the use of qualitative models to assess likely catchment load contributions ▶ Tie in with the Central Coast Stormwater Monitoring Programme from the Blueprint ▶ Calibrate with field data such as existing water quality information or material collected in GPT's (compare catchment outputs and collection rates) 	WE2, WE4, WH3	Catchment	Monitoring	WSC, CMA's
10.	Continue to monitor faecal coliforms at recreational locations	<ul style="list-style-type: none"> ▶ Continue existing programme ▶ Tie to resolving key management questions about faecal sources in the estuary and target sources 	WH4	Estuary	Monitoring	WSC

Item #	Priority Programmes	Components	Issues Addressed	Location	Type	Responsibility
11.	Monitor key wetlands for degradation and changes in condition	<ul style="list-style-type: none"> ► Identify SEPP 14 wetlands and other key natural wetlands considered important habitats and those performing a water quality improvement function (use GIS) ► Investigate appropriate monitoring programmes including both qualitative and quantitative methods ► Fund and resource an ongoing monitoring programme and develop a series of triggers for action (i.e. undertake Action A when Condition C is reported) ► Adhere to wetlands determination 	VW1	Catchment	Monitoring	WSC, CMA's, Landholders
12.	Develop a population strategy that is based on what environmental changes the estuary, rivers and catchment can sustain rather than on available land	<ul style="list-style-type: none"> ► Investigate appropriate methods for determining what catchment and runoff changes could be absorbed by the rivers and estuary before health suffers ► In particular look to pressures from stormwater quality, water supply extraction and habitat degradation and removal ► Use these limits to set sustainable population, employment and development limits 	SC1, SC2, SE2, SE3, LS3, WP1, VF2, DC2, DF3		Strategy	WSC, GWCWA, DIPNR, DPI (Forests), DPI (Fisheries), DPI (Agriculture), DEC, CMA's, Landholders, Universities, Community
13.	Develop partnerships with universities to get innovative approaches to managing the catchment and estuary in a sustainable manner	<ul style="list-style-type: none"> ► Examine areas of catchment and estuarine management that require some innovation/new ideas and find local universities that can provide technical expertise in these area ► Put together a partnership that enables students and university staff to work with Council on estuarine and catchment issues 	KG1, KG2		Strategy	WSC, Universities

Item #	Priority Programmes	Components	Issues Addressed	Location	Type	Responsibility
14.	Develop partnerships with developers and business operators to get innovative approaches to managing the catchment and estuary in a sustainable manner	<ul style="list-style-type: none"> ▶ Look at ways of using business and operator knowledge to arrive at catchment and estuarine objectives rather than solely using predetermined criteria ▶ Focus on innovative ideas that will clearly provide a better way of managing catchment loads and estuarine health e.g. water reuse ▶ Where new methods are being advocated, there should be provision for assessing their effectiveness before implementing 	LA1, LA2, LD2, LS1, WE3, WP1, DC1, DC3,		Strategy	WSC, Developers, Industry, Landholders
15.	Explore the development of a central body to oversee programmes and expenditure for estuarine management	<ul style="list-style-type: none"> ▶ Gauge community feeling before exploring this option, it is in response to perceptions in the community about a lack of information and transparency regarding estuarine management ▶ Should only be considered after extensive community education has failed to provide confidence to the community ▶ Examine how a central body could work in terms of funding, organisation, reporting, representation and accountability (look at the examples of Lakes Macquarie and Illawarra) ▶ Consider strengthening existing bodies (e.g. giving the Estuary and Coastal Management Committee more power to make decisions and allocate funding) 	KG2, KG1, KC2		Strategy	WSC, DOL, GWCWA, DIPNR, DPI (Fisheries), DEC (Parks & Wildlife), CMA's, Community

Item #	Priority Programmes	Components	Issues Addressed	Location	Type	Responsibility
16.	Develop funding strategies to ensure on-going and dedicated catchment and estuarine management programmes	<ul style="list-style-type: none"> ▶ Examine existing funding arrangements, grant opportunities ▶ Liaise with State/Federal agencies to determine where existing programmes could be used for mutual benefit ▶ Consider approaching the community with a fully costed programme and asking for a general rate rise to fund the works provided they are kept informed of expenditure and can see value for money 	LS4, KG1		Strategy	WSC, CMA's, Community
17.	Develop strategies to identify and manage key remaining catchment habitats	<ul style="list-style-type: none"> ▶ Tie with a sustainable population strategy ▶ Identify priority habitats and strategies for rehabilitation 	VW1, VF2, VR4, DC1, DC2, DC3, DT1, DT2, DS2		Strategy	WSC, DIPNR, DPI (Forests), DPI (Agriculture), DEC (Parks & Wildlife), CMA's, Landholders
18.	Maintain ocean entrance dredging programme	<ul style="list-style-type: none"> ▶ Investigate effects of ocean entrance dredging on physical, chemical & biological processes. ▶ Develop flood, safety and ecological triggers for dredging ▶ Provide funding and resources for an ongoing dredging programme 	WP3, WE6	Estuary	Maintenance	WSC, DIPNR, DPI (Fisheries), DEC, Community
19.	Maintain river mouth dredging on a rolling 5yr programme for Tumbi, Ourimbah, Wyong, and Wallarah/Spring Creeks	<ul style="list-style-type: none"> ▶ Develop triggers to dredge for flooding and navigation ▶ Provide funding and resources for an ongoing dredging programme ▶ Couple with streambank and foreshore erosion programmes and catchment audit programmes and interventions 	WP3, WP2, WF2	Estuary Rivers	Maintenance	WSC, DIPNR, DPI (Fisheries), DEC, Community

Item #	Priority Programmes	Components	Issues Addressed	Location	Type	Responsibility
20.	Continue to maintain stormwater treatment devices ensuring performance data are collected and analysed	<ul style="list-style-type: none"> ▶ Provide funding and resources for maintenance of increasing numbers of devices ▶ Ensure traps comply with OHS legislation ▶ Engage crews in design process to improve ownership ▶ Gather data on quantities of material removed, locations and times 	WE2	Catchment streams	Maintenance	WSC, Community
21.	Designate foreshore recreational areas and manage/encourage maximum recreational use and enjoyment including beach cleaning and wrack management	<ul style="list-style-type: none"> ▶ Investigate areas for rehabilitation and for recreation ▶ In recreation areas, provide for maximum public amenity ▶ Beach cleaning, wrack management, beach nourishment, landscaping 	SP1, SP2	Foreshore	Maintenance	WSC, DOL, DEC (Parks & Wildlife), Landholders, Community
22.	Maintain identified foreshore rehabilitation areas, protect sensitive habitats and educate community about the habitats	<ul style="list-style-type: none"> ▶ Investigate areas for rehabilitation and for recreation ▶ In rehabilitation areas, allocate funding and resources for maximum ecological protection ▶ Provide informative signage for the community to educate them about this environment 	VE3, VE4, DS1	Foreshore	Maintenance	WSC, DOL, DEC (Parks & Wildlife), Landholders, Community Groups (e.g. Birding NSW)
23.	Provide a process for addressing key estuarine process & management questions such as faecal coliform sources, fishery status, bioindicators, groundwater, sea level rise and mixing	<ul style="list-style-type: none"> ▶ Develop a process for continually reviewing and defining key management questions ▶ Consider forming an advisory panel to select important management questions and assist in framing methods for resolving them including resolution of performance indicators ▶ Provide funding for ongoing research as needed 	KG3, KG4, WH1	Estuary	Research	WSC, CMA's

Item #	Priority Programmes	Components	Issues Addressed	Location	Type	Responsibility
24.	Conduct appropriate research into riverine ecological processes and water quality to support environmental flow management	<ul style="list-style-type: none"> ▶ Review the recommendations from the Expert Review Panel and Water Sharing Plans ▶ Investigate the ecology of the streams in order to determine if flow regulation is affecting river and estuarine health (see options WF5b,c,d) ▶ If improving flows to the estuary was thought to be beneficial, examine ways of doing this without impacting on water supply 	WF5, VR5	Catchment Streams	Research	WSC, GWCWA, DIPNR, DPI (Forests), DPI (Fisheries), DPI (Agriculture), CMA's, Landholders
25.	Prepare and implement an ongoing community information and education programme about estuarine health using websites, newspapers, Council columns and field days	<ul style="list-style-type: none"> ▶ Review a range of media for providing this information ▶ Information should be easily understood by the general community ▶ Provide opportunities for the community to get "interactive" with estuarine elements including field trips ▶ Focus specifically on ways of empowering the public to participate in estuarine management, and on improving the image and expectations of the estuary 	KC1, KC2, KC3, KC4, SP4		Education	WSC, CMA's, Community

Item #	Priority Programmes	Components	Issues Addressed	Location	Type	Responsibility
26.	Improve pollution source control through education of community, industry & tourists	<ul style="list-style-type: none"> ▶ Tie with ongoing community education campaign and auditing catchments for compliance ▶ Develop ways for businesses and the community to improve their own contributions to catchment and estuarine health ▶ Provide funding and resources for signage and leaflets at key locations such as The Entrance ▶ Distribute advisories to public information places such as the Tourist Information and DPI (Fisheries) offices 	WE4, WE2, VW3, VE3, VR2, DC3, DT1, SP3		Education	WSC, CMA's, Community
27.	Develop incentives for the community to encourage sustainable use of water and pollutant reduction	<ul style="list-style-type: none"> ▶ Consider a range of incentive schemes from discounting charges to provision of free resources ▶ The aim is to empower the community to make changes at a local level 	WE3, WS1, WG1		Strategy	WSC, GWCWA, CMA's, Landholders, Community

These detailed priority programmes represent the accumulation of preferred possible options as identified by the technical, community and business working groups. The actions in the Estuary Management Plan will form a series of recommendations to federal and state authorities, as well as Council. These will need to be incorporated into plans of management, work programmes, budgets and grant programmes to be carried out, but will have the priority that comes from arising through the comprehensive estuarine management planning process and providing a long term holistic approach to issues affecting the estuary. These programmes will be more thoroughly explored in keeping with the social, economic as well as environmental setting of the Central Coast to establish which options can be funded and actioned to have the greatest impact on maintaining the estuary. The preferred options will then be incorporated into a draft Estuary Management Plan.

Following a review of the draft Estuary Management Study report by the Tuggerah Lakes Estuary and Coastal Management Committee and other stakeholders, the report was submitted to a process of peer review. The comments from this process were incorporated and a final report submitted to Council for endorsement.

The final report and subsequent management plan will become the primary reference documents for directing estuarine management for the Tuggerah Lakes. The Estuary Management Plan will be developed after adoption of the Estuary Management Study. The Plan will provide detailed actions including costs, responsibilities and timeframes for implementation. The Plan would be updated on an annual or bi-annual basis and would use the issues and options provided in the Estuary Management Study to guide the selection of actions. A suggestion for implementing the Estuary Management Plan is to have a number of standalone action plans that are divided along the six principle areas (i.e. a Water action plan, a Vegetation action plan etc.) and are actioned by cross-Council teams. These standalone plans could serve a number of purposes including team development, organisational change and capacity building.

This study is the first step in creating a transparent process for managing activities that affect the estuary that involves and engages the community in helping to protect one of the most valuable natural assets in Wyong Shire.

Table of Contents

SUMMARY	3
1 FRAMEWORK	25
1.1 The Estuary Management Planning Process	25
1.1.1 Status of the Estuary Management Plan	25
1.1.2 Scope of the Estuary Management Study	27
1.1.3 Estuary Management Plan	28
1.2 Managers of the Catchment and Estuary	29
1.2.1 Community	29
1.2.2 Wyong Shire Council	29
1.2.3 Catchment Management Authorities	30
1.2.4 NSW Government	32
1.2.5 Federal Government	35
1.3 Legislative Instruments	35
1.4 Catchment Planning Instruments	36
1.4.1 Wyong Local Environment Plan	36
1.4.2 Development Control Plans	37
1.4.3 Regional Environment Plans	39
1.4.4 State Environmental Planning Policies	39
1.5 Policy Guides	40
1.5.1 Councils Management Plan	40
1.5.2 Ecologically Sustainable Development (ESD)	41
1.5.3 Stormwater Management Plan	42
1.5.4 Healthy Rivers Commission and Coastal Lakes	43
1.5.5 Central Coast Catchment Blueprint	45
1.5.6 Water Reform Package	46
1.5.7 Coastline Management Plans	46
1.5.8 Floodplain Management Plans	47
1.5.9 Regional Vegetation Management Plans	48
2 MANAGEMENT STATUS	49
2.1 Estuary Process Study	49
2.2 Features, Activities, Uses and Conflicts	53
2.2.1 Tuggerah Lakes Restoration Project	54
2.2.2 Power Station	55
2.2.3 Sediments and Nutrients	56
2.2.4 Catchment Management	57
2.2.5 Environmental Flows	60
2.2.6 Urban Stormwater Management	64
2.2.7 Sewerage Management	68
2.2.8 Hydrodynamics	68
2.2.9 Foreshore Management	81
2.2.10 Conservation and Fisheries	91
2.2.11 Tourism and Recreation	106
2.2.12 Monitoring	110
2.3 Existing Management Strategies	111
2.3.1 Tuggerah Lakes Adaptive Management Strategy	111
	18

2.3.2	Environment Business Plan	113
2.3.3	Regional Environmental Management Strategy	114
2.3.4	Water Sharing Agreements	115
2.4	Ongoing Research	116
2.4.1	Bio-indicators	116
2.4.2	Mixing and Algal Growth	119
2.4.3	Saltmarsh Rehabilitation and Wrack Management	120
3	DEVELOPING A STRATEGY FOR THE FUTURE	124
3.1	Important Considerations	124
3.1.1	Importance of Catchment Management	124
3.1.2	Organisational Considerations	124
3.2	Key Steps Completed	126
3.2.1	Initial Consultation	126
3.2.2	Consolidating Input and Strategy	126
3.2.3	Establishing a Framework with the Committee	127
3.2.4	Further Consultation	127
4	WATER QUALITY AND QUANTITY	128
4.1	Introduction	128
4.1.1	Principle	128
4.1.2	Elements	128
4.2	Environmental Flows	129
4.2.1	Issues & Threats	129
4.2.2	Options	133
4.3	Water Quality for Ecology	136
4.3.1	Issues & Threats	137
4.3.2	Options	142
4.4	Water Quality for Human Health	149
4.4.1	Issues & Threats	149
4.4.2	Options	151
4.5	Flow Patterns and Flooding	153
4.5.1	Issues & Threats	153
4.5.2	Options	156
4.6	Water Supply	161
4.6.1	Issues & Threats	161
4.6.2	Options	164
4.7	Groundwater	167
4.7.1	Issues & Threats	167
4.7.2	Options	169
4.8	Recommendations	173
4.8.1	Issues Identified by Reference Groups	173
4.8.2	Additional Priorities	173
4.8.3	Suggested Programmes	173
5	VEGETATION MANAGEMENT	175
5.1	Introduction	175

5.1.1	Principle	175
5.1.2	Elements	175
5.2	Freshwater Wetland Vegetation	176
5.2.1	Issues & Threats	176
5.2.2	Options	178
5.3	Aquatic and Semi-Aquatic Estuarine Vegetation	184
5.3.1	Issues & Threats	185
5.3.2	Options	188
5.4	Floodplain Vegetation	196
5.4.1	Issues & Threats	196
5.4.2	Options	198
5.5	Riverine and Riparian Vegetation	203
5.5.1	Issues & Threats	203
5.5.2	Options	206
5.6	Recommendations	211
5.6.1	Issues Identified by Reference Groups	211
5.6.2	Suggested Programmes	211
6	DIVERSITY AND THREATENED SPECIES	212
6.1	Introduction	212
6.1.1	Principle	212
6.1.2	Elements	213
6.2	Catchment Ecology	213
6.2.1	Issues & Threats	213
6.2.2	Options	215
6.3	Human Disturbance	218
6.3.1	Issues & Threats	218
6.3.2	Options	219
6.4	Environmentally Significant Areas and Threatened Species/Communities	221
6.4.1	Issues & Threats	222
6.4.2	Options	224
6.5	Sustainable Fisheries	226
6.5.1	Issues & Threats	226
6.5.2	Options	229
6.6	Recommendations	233
6.6.1	Issues Identified by Reference Groups	233
6.6.2	Additional Priorities	233
6.6.3	Suggested Programmes	233
7	LAND USE AND HUMAN SETTLEMENT	235
7.1	Introduction	235
7.1.1	Principle	235
7.1.2	Elements	235
7.2	Cultural Heritage	236
7.2.1	Issues & Threats	236
7.2.2	Options	237
		20

7.3	Development Activity	239
7.3.1	Issues & Threats	239
7.3.2	Options	241
7.4	Agriculture and Forestry	245
7.4.1	Issues & Threats	245
7.4.2	Options	247
7.5	Soil Landscapes	249
7.5.1	Issues & Threats	249
7.5.2	Options	251
7.6	Recommendations	255
7.6.1	Issues Identified by Reference Groups	255
7.6.2	Suggested Programmes	255
8	SOCIAL AND ECONOMIC NEEDS	256
8.1	Introduction	256
8.1.1	Principle	256
8.1.2	Elements	256
8.2	Existing Industry	257
8.2.1	Issues & Threats	257
8.2.2	Options	259
8.3	New Commercial Ventures	264
8.3.1	Issues & Threats	264
8.3.2	Options	266
8.4	Public Access	269
8.4.1	Issues & Threats	269
8.4.2	Options	271
8.5	Recommendations	276
8.5.1	Issues Identified by Reference Groups	276
8.5.2	Additional Priorities	276
8.5.3	Suggested Programmes	276
9	KNOWLEDGE GAPS	277
9.1	Introduction	277
9.1.1	Principle	277
9.1.2	Elements	277
9.2	Managing Knowledge Gaps	278
9.2.1	Issues & Threats	278
9.2.2	Options	280
9.3	Community Education and Involvement	284
9.3.1	Issues & Threats	284
9.3.2	Options	286
9.4	Recommendations	288
9.4.1	Issues Identified by Reference Groups	288
9.4.2	Suggested Programmes	288
10	DISCUSSION AND RECOMMENDATIONS	289

10.1	Establishing Priorities	289
10.2	Priority Programmes	290
10.3	Reporting	299
10.3.1	Community	299
10.3.2	External Agencies	299
10.3.3	Reporting Using Indicators	300
10.4	Linking with Key Documents	300
10.4.1	Catchment Action Plans	300
10.4.2	Departmental Business Plans	300
10.4.3	Relevant Agency Plans	301
11	ESTUARY MANAGEMENT PLAN	302
11.1	Preparation of the Plan	302
11.1.1	Developing and Implementing Action Plans	302
11.1.2	Consultation with Stakeholders and Representative Groups	302
11.1.3	Securing Funding	303
11.1.4	Measuring Performance	303
11.2	Periods of Review	304
12	ACKNOWLEDGEMENTS	305
13	REFERENCES	311
14	GLOSSARY	322
15	INDEX	325

List of Figures

Figure 1. Estuary management planning process (after DLWC, 1992).	26
Figure 2. Information flows for the Estuary Management Study.	28
Figure 3. Hunter-Central Rivers Catchment Management Authority boundaries (HCRCMA, 2005).	31
Figure 4. Tuggerah Lakes and the Wyong Shire local government area.....	50
Figure 5. Bloom of macroalgae growing along Chittaway Bay.....	57
Figure 6. Streambank erosion on Wyong River.	58
Figure 7. Streambank erosion in Tumbi Creek.....	59
Figure 8. Streambank erosion before rehabilitation.	59
Figure 9. Streambank after rehabilitation.	60
Figure 10. Mangrove Creek Dam.	62
Figure 11. The weir on Ourimbah Creek.	62
Figure 12. A causeway road crossing.	63
Figure 13. Railway bridge and culvert on Spring Creek.....	63
Figure 14. Stormwater drain entering the estuary.	66
Figure 15. Example of water sensitive urban design.....	67
Figure 16. Constructed wetland at the end of a stormwater drainage system.....	67
Figure 17. The entrance to Tuggerah Lakes.	69
Figure 18. Maintenance dredging at the entrance.....	71
Figure 19. The entrance to Tumbi Creek and the existing dredged channel.	80
Figure 20. The plug of sediment at the mouth of Tumbi Creek.....	80
Figure 21. Backhoe sampling sediment at the mouth of Tumbi Creek.	81
Figure 22. Unmodified foreshore with saltmarsh and fringing wetland.	83
Figure 23. Saltmarsh with fringing wetland replaced by houses.	83
Figure 24. Modified foreshore with saltmarsh and fringing wetland replaced by houses and exotic lawns.	84
Figure 25. Highly modified foreshore with saltmarsh and fringing wetland replaced by houses, exotic lawns and seawalls.	84
Figure 26. The weed harvester used to collect floating algal and seagrass wrack from shallow water around the estuary.....	86
Figure 27. Removing stranded wrack from the shallows using the beach cleaner.	87
Figure 28. The damage done to the foreshore as a result of beach cleaning.....	88
Figure 29. Example of mowing of saltmarsh.	89
Figure 30. The seagrass <i>Zostera capricorni</i>	94
Figure 31. The saltmarsh <i>Sarcocornia quinqueflora</i>	96
Figure 32. Seagrass meadows, mud flat and saltmarsh in Tuggerah Bay.	98
Figure 33. The relic tidal delta or Budgewoi Sandmass.....	98
Figure 34. The sponge <i>Suberites</i> may be threatened within the Tuggerah Lakes.	100

Figure 35. Fishing within the estuary.....	103
Figure 36. Sailing is a popular activity on Tuggerah Lakes.....	109
Figure 37. Tuggerah Lakes Adaptive Management Strategy (WSC, 2001).....	112
Figure 38. The growth of saltmarsh in a wracked plot after 6 months.	122
Figure 39. Wracked plots at the same site at the end of the study in December 2002 (note unwrapped plot in foreground marked by a stake).	123
Figure 40. Application of seagrass wrack over large bare areas.	123
Figure 41. Suggested review periods for various measures in the estuarine management planning process	304

List of Tables

Table 1. Wyong Council expenditure on key management responsibilities (WSC, 2003).	30
Table 2. Development Control Plans and importance for managing catchment.....	37
Table 3. Overarching objectives for principal activities in the Management Plan.	41
Table 4. Coastal lakes statement of intent (HRC, 2003).....	44
Table 5. Foreshore development around the Tuggerah Lakes estuary	82
Table 6. Percentages of failure to comply with water quality guidelines for faecal coliforms for primary contact recreation at lake beaches (as a % of sampling times).....	110
Table 7a. Flow classes for creeks with Water Sharing Plans	116
Table 7b. Environmental water provisions for plans.....	116
Table 8. Impact of lake level change on exposed foreshore area (after Wallace, 1999).....	155

1 Framework

The Tuggerah Lakes estuary is composed of three interconnected coastal lagoons. Historically, it has been managed by an array of managerial strategies, government policies, engineering measures and community sentiment. The estuarine management planning process is an opportunity to bring all these elements together to produce a cohesive, sustainable strategy. This study ties catchment management with estuarine management to focus attention on protecting the natural features of the estuary and into improving community understanding and ownership.

1.1 THE ESTUARY MANAGEMENT PLANNING PROCESS

The State Government's Estuary Management Policy is a component of the Rivers and Estuaries Policy of the NSW Government, which comes under the umbrella of the Total Catchment Management framework. The Estuary Management Study builds on the findings of the Tuggerah Lakes Estuary Process Study (Roberts, 2001), adding a managerial framework as a pre-cursor to the development of the Estuary Management Plan.

1.1.1 Status of the Estuary Management Plan

The NSW State Government's estuarine management process required a management plan for the Tuggerah Lakes estuary to be prepared. An Estuary and Coastal Management Committee was formed to assist in the formulation of this plan. The committee was comprised of representatives from community groups, industry, State Government agencies and Council staff. The Estuary and Coastal Management Committee's main objective was to promote ecologically sustainable development through the formulation of an Estuary Management Plan, which accounted for all stakeholders (Roberts, 2001).

The process of forming an Estuary Management Plan is detailed in the Estuary Management Manual (DLWC, 1992), which outlines a process leading to the implementation of the plan based on principles of ecologically sustainable development and management of the catchment. Having established the Estuary and Coastal Management Committee, the second stage in the process was to undertake a review of literature and to compile relevant data; these were, to some extent, done as part of the Adaptive Environmental Assessment and Management Programme (Walkerden and Gilmour, 1996) for Wyong Shire Council (Roberts, 2001).

The third stage, the process study, examined the following key processes as part of the scientific basis for an Estuary Management Study (Roberts, 2001):

- Hydrodynamic and sedimentary processes operating in the estuary
- Water quality variables of importance to the "health" of the estuary and their mixing and flushing behaviours
- Interactions between physical, chemical and biological processes
- Ecological and biological processes and characteristics of importance to the estuary
- Location and nature of significant natural, cultural, physical and scientific sites
- Extent to which human activities have modified or disturbed processes
- Additional data and studies necessary to aid in preparing the subsequent stages of the Estuary Management Study and Plan

The Estuary Management Study represents the fourth stage in the development of the plan as part of the overall process (Fig. 1).

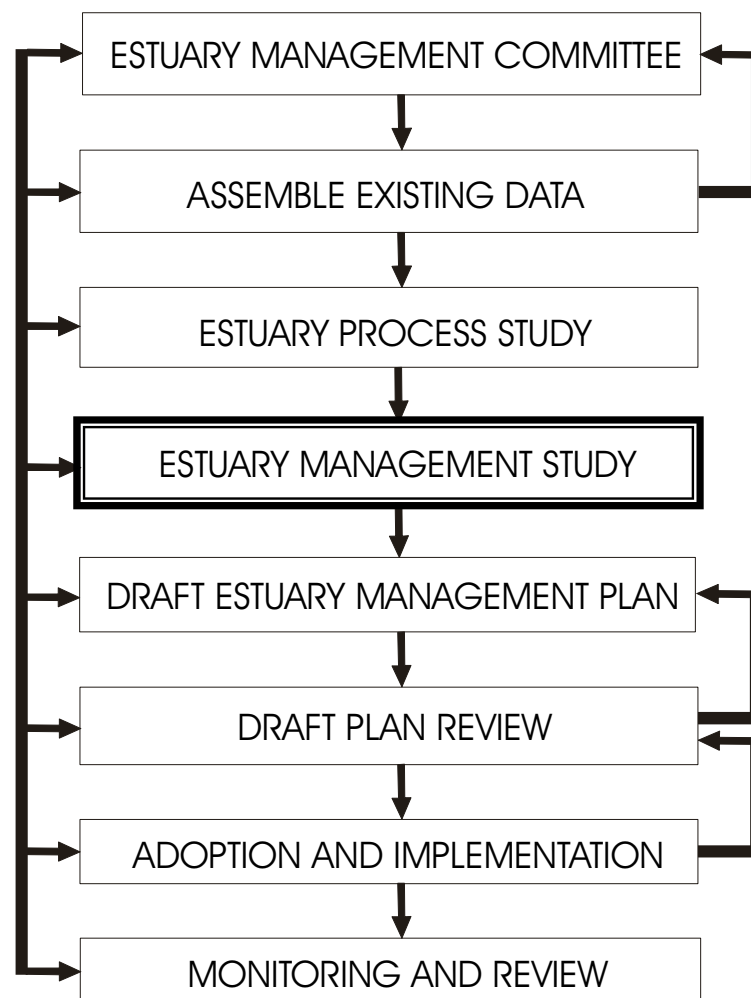


Figure 1. Estuary management planning process (after DLWC, 1992).

1.1.2 Scope of the Estuary Management Study

The Estuary Management Manual (DLWC, 1992) lists the aims of an Estuary Management Study. In general, it should seek to:

- Identify the significance of the estuary in terms of broader coastal planning issues
- Identify essential features of the estuary, be they physical, chemical, biological, aesthetic, social or economic
- Document current uses and conflicts of use in the estuary
- Identify possible future land-uses and assess their impact on the “essential features”
- Assess the need for nature conservation and remedial measures
- Identify and assess management objectives
- Assess planning controls, works and other strategies to achieve these objectives

The management study has been prepared to adhere to this scope of works. In addition it needed to address a number of specific concerns and knowledge gaps raised by the community and the Estuary and Coastal Management Committee. These included:

- Ecologically sustainable management of estuarine beaches, foreshores and seagrass meadows
- Protection of ecologically sensitive habitats, eg. Budgewoi Sandmass and Tuggerah Bay
- Managing potentially elevated nutrient and sediment loads to the estuary from increased urbanisation and development in the catchments
- Identification and management of those nutrients responsible for excessive aquatic plant growth
- Implications of periodic dredging of rivers and the tidal delta at The Entrance
- Practical and ecological implications of a second entrance and/or break walls, to alter existing estuarine mixing and flushing
- The management of both recreational and commercial fisheries
- Potential ecological effects of mine subsidence
- The feasibility of using “Bio-indicators” to quantify whether management targets for the estuary have been attained

The Estuary Management Study was presented for both peer-review and public exhibition in draft form. It was hoped that sufficient public interest would be generated to engender a sense of participation in the process and ownership over the final plan. The basic information flows for the development of the management study are shown in Figure 2.

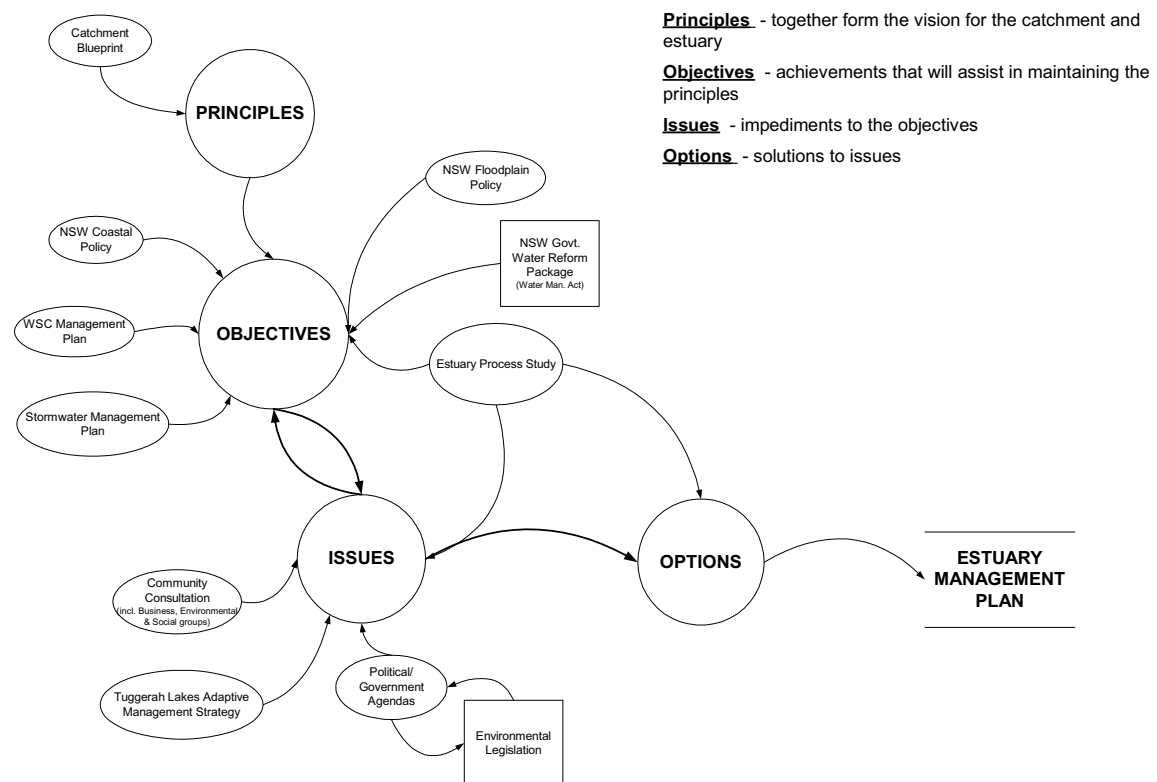


Figure 2. Information flows for the Estuary Management Study.

1.1.3 Estuary Management Plan

The options identified in this study will be referred back to stakeholders as part of the exhibition process. The draft Management Plan will be prepared following agreement between stakeholders on management actions, costs and timelines for implementation stemming from this study. The draft plan will be both peer reviewed and exhibited publicly prior to its finalisation and adoption.

1.2 MANAGERS OF THE CATCHMENT AND ESTUARY

The estuary is managed by a number of different governments and their agencies. The historic lack of a defined estuarine management plan or overall managing entity for the estuary creates a situation where transparency is not obvious for either the individual managers/operators or the community. It was hoped that by articulating the roles and responsibilities of the main stakeholder groups, the plan could explicitly target the correct stakeholder for appropriate actions.

1.2.1 Community

The Estuary Management Manual (DLWC, 1992) recognised that “the catchment of an estuary is an attractive place in which to work, live and play, and it is not surprising that 75% of the State’s population live in the immediate proximity of estuaries and that many major urban areas are sited adjacent to these waterbodies”. The manual also recognised that the community had a right to use the resources of the estuary however this should be done in an integrated, balanced, responsible and ecologically sustainable way.

The Tuggerah Lakes Estuary Process Study (Roberts, 2001) identified patterns of decline in some of the ecological components of the estuary and related them to human activity in the catchment, tributary creeks and the receiving waters. It was generally accepted that the activities of the community in the catchment continue to affect the estuary. The community funds the management and maintenance of the estuary through payment of taxes, rates and licence fees.

As such, an important part of the Estuary Management Process is community involvement and action. There is a perception and expectation within the community that improvements to the estuary and the catchment is the responsibility of government alone. In the past, a large proportion of the disturbances to the estuary have been reported as being produced by small, seemingly insignificant disturbances by the community and other land holders. These include fertilisation of lawns, washing cars on impervious surfaces, mowing to the edge of the estuary, septic seepage or overflows. There needs to be a strong commitment by the community to make improvements at small spatial scales. This could be strengthened by a robust communication strategy and an open and transparent management planning and review processes.

1.2.2 Wyong Shire Council

Wyong Shire local government area (LGA) encompasses approximately 99% of the Tuggerah Lakes catchment (around 690km²). Wyong Shire Council (WSC) employs approximately 1200

staff and operates on a budget of around \$175 million annually. Council manages five key areas of responsibility and budget (Table 1).

Table 1. Wyong Council expenditure on key management responsibilities (WSC, 2003).

Responsibility	2002/03 March Review (‘000)	2003/04 Budget (‘000)	2004/05 Forecast (‘000)	2005/06 Forecast (‘000)
Society	36,358	47,809	33,490	42,078
Economy	7,234	4,388	4,262	4,057
Environment	5,114	5,517	4,470	4,466
Infrastructure	87,702	104,738	98,495	99,735
Organisation	36,554	35,543	34,631	34,563
<i>Total Expenditure</i>	172,962	197,995	175,348	184,899

As the largest land manager in the catchment, WSC has the ability to manipulate catchment activities and influence riverine and estuarine health. Council's legal responsibility for the estuary ends at the high water mark. Inland waterways are the responsibility of the State Government. For more than 50 years WSC has undertaken works to provide and protect the amenity of the estuary. This work has included maintenance dredging, rivers and foreshore improvements, seagrass wrack harvesting and water quality monitoring. The State Government frequently provides partial funding for some works in the estuary (eg. 50/50 funding for dredging works).

In recent decades, the focus of estuarine management has shifted more toward trying to understand and influence the ecology of the estuary. The estuary management planning process is an example of this shift and there has been increased understanding of estuarine patterns and some processes (Roberts, 2001). At present, Council spends approximately \$3 million per annum on catchment and estuarine management which includes a number of multi-purpose programmes (Fawcett pers com., 2004).

1.2.3 Catchment Management Authorities

The Hunter-Central Rivers Catchment Management Authority (HCRCMA) is one of 13 new catchment management authorities (CMA's) that have been declared by the State Government. These CMA's replace the existing catchment management boards/trusts, regional vegetation committees and water management committees as the primary administrative body for managing water, land and vegetation in NSW catchments. CMA's will operate under the auspices of the *Catchment Management Authorities Act 2003*.

The HCRCMA will amalgamate the areas previously covered by the Lower North Coast Catchment Management Board, Hunter Catchment Management Trust and Central Coast Catchment Management Board (Fig. 3). An interim CMA establishment team has been put in

place by the Minister to manage the transition from catchment management boards and trusts, to the new CMA (HCRCMA, 2003).



Figure 3. Hunter-Central Rivers Catchment Management Authority boundaries (HCRCMA, 2005).

At this stage, the Department of Infrastructure, Planning and Natural Resources will continue to oversee the estuary, coastal and floodplain management processes (thereby keeping them within State government). The new HCRCMA will be funded from a range of government and private sources including the Commonwealth Government's Natural Heritage Trust. For 2003/04, the funding is \$2.1 million, with a total package of \$18.7 million being made available for the 04/05, 05/06, 06/07 financial periods. The office for the CMA is based in Paterson, with satellite offices in Gosford and Taree.

Funds have been allocated on the basis of 3-year investment strategies for each of the board areas. This means that programmes recommended by the Central Coast Catchment Blueprint will continue to be funded until the CMA is fully operational. The CMA will prepare an Annual Implementation Plan that will outline the investment from all sources including government and private sources. The expenditure of Natural Heritage Trust investment will be specifically guided by a 3-year rolling Investment Strategy. Each CMA will be required to submit a 10-year Catchment Action Plan (CAP) which outlines programmes and costs.

As the principal catchment management body now representing the Tuggerah Lakes catchment, it is important to engage this organisation from the outset to ensure that any catchment action plan involves a programme of works that directly benefits the catchment and ultimately the estuary.

1.2.4 NSW Government

1.2.4.1 Department of Conservation (Parks and Wildlife Division)

The Department of Environment and Conservation's Parks & Wildlife Division has responsibility for a number of reserve areas throughout NSW. Within the Tuggerah Lakes catchment, there are two reserves that are actively managed by DEC (Parks & Wildlife); Wyrrabalong National Park (WNP) and Munmorah State Conservation Area (MSCA).

DEC (Parks & Wildlife) administers plans of management for each of these two reserves. These plans assist in managing the catchment and estuary as they make provision for the prevention of soil erosion, sedimentation and excess runoff as well as rehabilitation of land through weed control and bush regeneration (Conyers, 2004).

While the DEC (Parks & Wildlife) is not a signatory to any catchment or estuarine management agreements, they are an organisation committed to managing our natural resources. DEC (Parks & Wildlife) was a key stakeholder in the Tuggerah Lakes Urban Stormwater Management Plan and in the Estuary Process Study. The organisation considers involvement in committees (such as the Estuary and Coastal Management Committee) as the most appropriate mechanism for developing activities and programmes to cooperatively manage the catchment and estuary.

DEC (Parks & Wildlife) is likely to become more involved in foreshore management around Tuggerah Lakes with the recent determination from the NSW Scientific Committee that coastal saltmarsh be listed as a threatened ecological community (discussed in detail in section 2).

1.2.4.2 Department of Environment and Conservation (EPA)

The Department of Environment and Conservation has had significant involvement in the Tuggerah Lakes estuary with a number of important pieces of scientific research done as part of the Estuary Process Study (Roberts, 2001). In 1998/99, the then Environment Protection Authority (EPA) also allocated grant funding to a number of stormwater projects including the Stormwater Management Plan (Dickinson, 1999) and funding for a number of innovative stormwater research projects that were developed in collaboration with WSC (Roberts, 2001). Council continues to submit State of the Environment reports to the DEC. These annual reports present a snapshot of the state of Wyong Shire's environment in several key areas.

It is hoped that Council and the DEC will continue to have a strong relationship; researching the processes of the estuary, investigating better methods of managing development, and funding programmes that are vital to protecting the estuary.

1.2.4.3 NSW Maritime Authority

NSW Maritime Authority (formerly NSW Waterways) aims to provide safe and responsible use of navigable waters and provision of appropriate maritime infrastructure throughout New South Wales. The Central Coast region provides residents with access to rivers, estuaries and the ocean. Access to these waterways is important to residents for recreational use, such as boating, sailing, fishing and amenity. NSW Maritime Authority (Lynch, 2004) has provided the following 2003 statistics for boat ownership/licensing on the Central Coast.

- Residents owning boat licences 24,157
- Residents owning registered vessels 19,671

The Maritime Authority currently operates “No-wash” zones and speed restricted areas in some locations including Wyong River, Ourimbah Creek, Wallarah Creek, Spring Creek, Canton Beach, around Budgewoi Channel and around The Entrance channel. If further areas were required for say environmental protection (perhaps Budgewoi Sandmass or Tuggerah Bay), these would need to be put through a consultation process (Lynch, 2004) including the public and the major stakeholders (such as commercial operators and government authorities).

In terms of management of the Tuggerah Lakes estuary, the Maritime Authority is active in a number of ways including:

- Examining specific environmental and recreational issues in Wyong River and Ourimbah Creek with Council, Department of Lands, DIPNR and DPI (Fisheries).
- Providing funding to Council for the development and improvement of boating infrastructure via the Waterways Asset Development and Management Programme. This is a 50/50 grant programme for use on boat ramps, jetties and dinghy storage throughout NSW.
- Consulting with Wyong Shire Council regarding dredging of The Entrance Channel.
- Maintaining and installing navigational aids.

Council should investigate accessing the WADAMP programme for part funding the maintenance of boating facilities around the estuary (Lake Macquarie and Brisbane Waters having received upgrade grants of \$135,000 and \$210,000 respectively). Any co-operative opportunities for Council and the Authority to work together should also be pursued.

1.2.4.4 Department of Infrastructure, Planning and Natural Resources

The Department of Infrastructure, Planning and Natural Resources (DIPNR) drives, coordinates and streamlines land-use and transport planning, infrastructure development and natural resource management in New South Wales. In its previous form (Department of Land and Water Conservation - DLWC), this organisation had a strong involvement in catchment and estuarine management.

In April 2004, there were significant changes made to the role that DIPNR plays in managing both the catchment and the estuary. At this stage, it is difficult to assess the exact implications of these changes, however it is understood that significant responsibilities have been devolved both to local governments and to catchment management authorities. The apparent intention of this restructure is to provide more localised environmental management opportunities with the CMA's while DIPNR focuses on a support and risk management role (Kelleher pers com., 2004).

1.2.4.5 Department of Primary Industries (Fisheries)

The Department of Primary Industries (Fisheries) is the State's lead agency in the conservation and management of fisheries resources (formerly NSW Fisheries). The agency is responsible for the administration of the Fisheries Management Act 1994, which provides a comprehensive framework for the protection of fish and fish habitat.

Within Tuggerah Lakes, DPI (Fisheries) has a number of areas of responsibility however there is no overall plan for managing the fish stocks in the estuary. DPI (Fisheries) licenses a number of commercial fishers to harvest from the estuary. Recreational fishing is also administered by DPI (Fisheries) and while the local offices (Toukley and The Entrance) issue recreational licenses, they are not area specific, as distinct from commercial fishing. This makes it difficult to monitor recreational fishing in Tuggerah Lakes.

DPI (Fisheries) has a strong role in monitoring compliance with the Fisheries Management Act. The protection and management of seagrass habitat in Tuggerah Lakes is an area where DPI (Fisheries) responsibilities can be harnessed for estuarine management. Currently, the Estuary and Coastal Management Committee is the most appropriate forum for Council to discuss issues and improve collaboration with Fisheries.

1.2.4.6 Department of Primary Industries (Forests)

The Department of Primary Industries' Forests Division undertakes forestry operations in Wyong Shire in three designated State Forests. Olney, Ourimbah and Wyong State Forests are located within the catchments of Ourimbah Creek and Wyong River.

Approximately 35% of the Tuggerah Lakes catchment is under the care and control of DPI (Forests). This makes them a significant catchment manager. The operations of DPI (Forests) have particular relevance to freshwater streams within and downstream of forestry areas.

Consultation between WSC and DPI (Forests) occurs on an as needs basis, often when relevant projects have overlapping areas of concern such as with the Gosford-Wyong Joint Water Supply operations. There is potential for the links with the Regional Manager to be formalised via inclusion of DPI (Forests) in relevant Council advisory committees (such as the Estuary and Coastal Management Committee).

1.2.4.7 Department of Lands

Department of Lands is the primary administrator for State Land tenures and unallocated State Lands. Department of Lands administers an area of approximately 12.7 million hectares. It is responsible for the professional management of some 72,600 licences and permits state wide, along with 14,800 leases. Department of Lands also manages the development, marketing and sales of State Lands not required for public purposes.

As the landowner of most of the foreshores and the bed of the estuary, Department of Lands authorises management activities including: dredging, waterfront occupations; commercial; grazing and agriculture; residential; sporting; community purposes; tourism; and industrial (Signor pers com., 2004).

1.2.5 Federal Government

The Department of the Environment and Heritage is responsible for environmental management and policy in Australia. It is also responsible for Australia's participation in a number of international environmental agreements. The new Catchment Management Authorities (discussed in detail in Section 1.2.3) will be supported by DIPNR, but funded by programmes such as the Natural Heritage Trust. The Trust is a Federal Government programme that provides funding to various environmental initiatives. This marks a shift in the funding of local/regional environmental programmes, which have traditionally been funded by the State.

1.3 LEGISLATIVE INSTRUMENTS

There are a number of pieces of legislation that are either in use, or available to be used for catchment and estuarine management. Changes to these can significantly alter the management framework. For example, the creation of the Water Management Act altered the way water resources are managed in the catchment, affecting the environmental flows available to the estuary (see Sections 1.5.6 and 2.3.4 for more detail).

The following are the more important pieces of State government legislation relevant for the Tuggerah Lakes and catchment.

- *Protection of the Environment Operations Act 1997*
- *Catchment Management Authorities Act 2003*
- *Water Management Act 2000 (incorporates Rivers and Foreshores Improvement Act)*
- *Soil Conservation Act 1938*
- *Mining Act 1992*
- *Fisheries Management Act 1994*
- *Threatened Species Conservation Act 1995*
- *Environmental Planning Assessment and Approvals Act 1979*
- *Crown Lands Act 1989*
- *Heritage Act 1977*
- *National Parks and Wildlife Act 1974*
- *Forestry Act 1916*
- *Native Vegetation Act 2003*
- *Forestry and National Parks Estate Act 1999*

1.4 CATCHMENT PLANNING INSTRUMENTS

1.4.1 Wyong Local Environment Plan

The Wyong Local Environment Plan (LEP) covers the Wyong Shire local government area. It is used to define certain landuse types, confine them to desirable areas and subject them to requirements in keeping with the location of the landuse. The landuse zonings in Wyong are diverse and include rural, residential, business, tourist, industrial, roadways, open space, scenic protection, conservation, environmental protection, wetlands management, national parks and special uses (schools, churches, community facilities). For each of these zonings, objectives outline the intended development types that are permitted. Development applications (DA's) allow the consent authority (Wyong Council in the first instance) to review proposals and impose conditions on the development that protect features of the site and/or the local environment.

In recent times, Wyong Council has used the LEP to protect significant natural areas within the shire including wetlands and significant ridgeline vegetation. There is scope for provisions within the LEP to be used to strengthen estuarine and catchment management programmes.

1.4.2 Development Control Plans

Development Control Plans (DCP's) are often more specific than other environmental planning instruments such as SEPP's, REP's and LEP's. Although not absolutely binding in development application decisions, DCP's provide a strong set of guidelines and provisions for those applying for consents and those assessing the DA's. There are a number of DCP's in Wyong that could be used to strengthen estuarine and catchment management.

Table 2. Development Control Plans and importance for managing catchment.

DCP	Focus	Potential importance for catchment management
13	Protection of Potential Conservation Areas	This DCP was originally prepared as a pre-cursor to a "Conservation Strategy". It was intended to be a temporary measure to ensure that whilst a conservation strategy was being developed additional lands/habitats/communities were not lost. Without a conservation strategy this DCP will continue to provide a baseline guide to the assessment of impacts of development in the catchments of the estuary.
14	Tree/Vegetation Management	This document sets clear guidelines for tree removal, land clearing, undesirable & noxious species, and for the protection of endangered/vulnerable communities. This DCP strengthens the ability of Council to maintain viable catchment ecology, in turn buffering the estuary and providing habitat for species that use both environments.
30	Wetland protection in Wyong Shire	DCP 30 was developed to compliment the formulation of the 7g zoning under the Wyong LEP. This zoning was added to cover the approximately 28 wetlands located in the shire that fall under the protection of SEPP 14. The objectives and guidelines in the DCP are specific and relate to the protection of habitat, biodiversity, hydrology and water quality within these wetland areas. There are no prescriptive criteria within the DCP (presumably due to the variability of wetland environments and the difficulty in applying generic standards to such systems). This DCP is an example of the type that could be used to outline clear objectives for estuarine management via strong catchment management and foreshore management controls.
36	North Wyong Industrial Estate	The DCP sets out design criteria primarily related to the provision of infrastructure and ensuring that the development minimises impact on the surrounding residents (particularly in relation to air quality). While mention is made of the need to consider the proximity of this development to sensitive nearby environs (including Porters Creek wetland), there are no prescriptive criteria aimed at negating impacts.
49	Development in Warnervale & Wadalba	This DCP is primarily concerned with the layout and co-ordination of development in the Warnervale/Wadalba areas. While some consideration is given to the construction of roadways and reserves to minimise impacts on green corridors, the focus is on the quality of urban development. Much of the significant environmental planning for this area was addressed in the Warnervale Floodplain Environmental Management Strategy, where the focus was on minimising impacts on Porters Creek Wetland.
64	Medium and High Density Residential Development in the shire	The DCP provides developers/builders with requirements that must be considered when constructing this type of development. In terms of estuarine impact, there are two areas of interest; car washing and shading. The DCP insists that basement washing facilities be connected to sewer, while outdoor washing be directed to grass or landscaped areas sized to treat the wash off. Shading diagrams are requested for this type of development, however this could be strengthened by insisting that the shading take into account effects on estuarine ecology such as seagrasses.

DCP	Focus	Potential importance for catchment management
65	Disposal of Wastewater in Non-Sewered Areas	This plan provides technical details for managing household sewage in areas that are not connected to Councils sewer system. It is thought that poorly installed/maintained septic systems have had significant impacts on the estuary over time possibly responsible for the macroalgal blooms of the late 1980's. These systems have been replaced with sewer and the blooms have not been as prevalent since. Moving forward, this document could be of use for developments that are not sewered and are close to sensitive habitats, where strong controls over septic installation & maintenance are required e.g. upper catchment streams.
66	Design of New Subdivisions in Wyong Shire	There is significant scope for this document to provide strategic direction in key areas of catchment management. As the principal document for designing layout and facilities in subdivisions, this plan is used throughout the shire for guiding the development of new subdivisions. It covers areas such as soil & water management, stormwater, vegetation management, open space planning, lot design/layout, street layout & heritage. Currently, the overwhelming focus is on the provision of services and aesthetics in new subdivisions. There is the potential for stormwater and vegetation management to be strengthened and provided with prescriptive criteria to aid catchment and water management in the development area.
67	Technical Engineering Design Guidelines for all development in the shire	<p>This document provides all technical and design details for DA's in the shire. It contains highly prescriptive design criteria and advice for various aspects of a development. These include design & construction of: roads, pavements, stormwater, earthworks, kerb/guttering, concrete works, bitumen surfaces, water reticulation, and sewerage. Strong consideration is also given to construction controls and environment, vegetation & heritage protection. In terms of content, there are two areas where the inclusion of specific criteria would aid the estuary and catchment. These are for stormwater and for the control of construction activities.</p> <p>Stormwater quality is considered in this document however it uses a number of limiting criteria. Treatment standards are based on the 1997 EPA Council Handbook, rather than on Council or catchment established criteria that can be frequently updated. If the handbook standards are out of date, then so are the standards applied to new development in Wyong Shire. The document does not make explicit requests for measuring removal efficiencies of devices post implementation. This allows a methodology or treatment to be employed that may not reduce pollutants as required, yet satisfies criteria because the use of a method forms the criteria.</p> <p>Construction controls and guidelines for construction are a focus for this document. Where construction materials or activities are thought to be impacting the estuary, this document could be used to obtain compliance in areas such as sediment and erosion control, as well as the use of fill material.</p> <p>Council could improve the structure and operation of this document by referencing frequently updated internal and external documents. This would ensure that the most up-to-date information was being incorporated into new developments, rather than waiting for an update of the overall DCP.</p>
69	Waste Disposal requirements for Large Waste Generating Development	The DCP is not likely to be relevant for the estuary except where a significantly sized waste generating activity has the potential to introduce pollutants into the estuary. An explicit statement of this type within the document would be a useful "flag" during consideration of a development.
72	Farm Dams and Rural Earthworks	This is a technical document, which provides guidance for property owners who intend to construct farm dams or undertake significant reshaping of earth on their property. While consideration is given to the impact a dam will have on the rights of surrounding water users, none is given to the impact that dams have on environmental flows. While it is understood that dams and irrigation are often necessities for rural development, these resources should be managed in a way that minimises the effect on these environmental flows.
75	Requirements for Industrial Development in the shire	This DCP provides guidance for the design of individual industrial premises in Wyong Shire. The document places requirements on developers to ensure that the proposed development does not contribute to the degradation of environmental quality in the surrounding area, or of the Tuggerah Lakes estuary. This plan references DCP 67 for all prescriptive criteria related to stormwater management. Given the limitations in the current structure of DCP 67 in relation to stormwater, industrial development may not be adequately containing stormwater impacts.

DCP	Focus	Potential importance for catchment management
83	Commercial Hydroponic & Horticultural Development in the shire	This type of development is a concern for surface water runoff and groundwater infiltration. These types of development can generate significant levels of nutrients and pesticides. Generally, stormwater and discharge waters from these developments are not permitted to enter nearby receiving waters under the DCP. Nutrient rich water must be disposed of off-site, while all stormwater must be contained within dams on-site to prevent degradation of receiving waters. This DCP appears to adequately manage potential impacts for the estuary.
100	Providing Environmentally Sensitive Housing in the shire	The DCP aims to improve both the quality of new housing in the shire, and its net environmental impact. Considerations such as energy efficiency, sustainable building materials, site layout, building design and water sensitive design are all addressed for new residential development. One of the most significant features of this plan is the requirement for water efficiency. The use of rainwater tanks, AAA devices, porous paving and native vegetation is encouraged and in some cases required under the plan. The effect of this is to delay the need for further water supply augmentation, which in turn allows for water saved to be channelled into environmental flows for the streams and estuary. These actions also aid in protecting natural flow patterns for water receiving stormwater runoff from new development. Generally, developing a catchment results in changed flow patterns and increased volumes of water for downstream environments, which can have significant impacts on the ecology of these areas.

In addition to these DCP's, there are a number of potentially important DCP's that are in draft stage, and are therefore unavailable for comment at this time. Some of these include:

- DCP 82 – Turf Farming
- DCP 91 – Natural Areas Management
- DCP 100 – Water Sensitive Urban Design

1.4.3 Regional Environment Plans

Regional Environmental Plans (REP's) are developed to provide planning guidance at a regional level. There is one current plan that potentially could be significant for the catchment and estuary, Sydney REP 8 – Central Coast Plateau Areas. This plan regulates agricultural and development activity for agricultural lands on plateaus in the Central Coast Area. The application of this plan in the Tuggerah Lakes catchment occurs on the Kulnura Plateau. Regulating these types of development in the upper catchment provides an opportunity to mitigate future impacts on upper catchment streams.

1.4.4 State Environmental Planning Policies

State Environmental Planning Policies (SEPP's) are administered by the State Government, and are used to apply state-wide principles in landuse planning. There are a number of SEPP's that are relevant to the catchment and receiving waters. These include:

- SEPP 14 – Protection of wetlands. SEPP 14 is of significance to the catchment and the estuary as it provides for the protection of wetlands in the catchment such as those lands zoned 7(g) and Porters Creek wetland. Without these valuable

ecosystems, a large buffer between catchment runoff and receiving waters would be lost. In addition, these ecosystems form unique and important habitats for a number of species, and in some locations are a link between the estuary and the catchment.

- SEPP 35 – Maintenance dredging of tidal waterways. This policy is designed to streamline the planning process for determining permissibility of maintenance dredging in tidal waterways.
- SEPP 45 – Permissibility of mining. This SEPP is relevant to the estuary, as it guarantees that a Local Environment Plan (LEP) cannot regulate underground activity. This means that if a Council were to ban all mining with an LEP, SEPP 45 can override and provide a planning instrument that permits mining.
- SEPP 71 – Protection of the Coastal Zone. This policy has been established to refer development in the Coastal Zone to the State for consent. It is intended to provide a check mechanism to ensure that local governments take coastal protection matters into consideration during development assessment. There are instances within NSW where disputes have arisen about the definition of the extent of the Coastal Zone and its boundaries.
- SEPP (Building Sustainability Index: BASIX) – The BASIX programme is a new development assessment technique that will be introduced as a SEPP. The policy will require new development to complete the BASIX assessment as part of a development application. The risk for Wyong Shire, in terms of catchment and estuarine management, is that the local LEP/DCP planning controls may be more rigorous and/or appropriate than guidelines being developed for the whole State. The application of less rigorous assessment procedures may weaken Council's ability to ensure only appropriate development is permitted.

1.5 POLICY GUIDES

All forms of government in Australia have a role in developing environmental policy. Wyong Shire Council has been working on catchment and estuarine management for many years whilst the State Government has a number of initiatives and policies in place. In terms of estuarine and catchment management, it is important to work towards these policies where appropriate, and lead the way where the policies do not go far enough to protect local resources. The Federal government also develops environmental policy. One of the most far-reaching examples is the policy of ecologically sustainable development (ESD).

1.5.1 Councils Management Plan

Wyong Shire Council's Management Plan is the principal document used to direct Council activities on an annual basis. The spending allocations in any year are based around

Council's aims and objectives for each of its activity areas (society, economy, environment, infrastructure and organisation) (see Table 3). While priorities in an activity area may shift from year to year, the objectives must always be satisfied. For this reason, it is important to articulate Council's commitment to managing Wyong Shire and the 99% of the Tuggerah Lakes catchment contained within it.

Table 3. Overarching objectives for principal activities in the Management Plan.

Principal Activity	Management Objective
Society	To provide an enhanced quality of life supported by human services and facilities commensurate with the needs of the growing population of the shire
Economy	To expand and strengthen the economic base of the shire by actively encouraging sustainable, employment generating development
Environment	To protect and enhance the natural environmental qualities of the area
Infrastructure	To provide enhanced physical infrastructure to support social, economic and environmental objectives
Organisation	To provide an efficient and effective Council organisation to facilitate achieving social, economic and environmental objectives

Wherever possible estuarine management planning should be structured in a way that will allow actions to be integrated into Councils Management Plan. This will improve the ability of estuarine management activities to be addressed through the principal management document.

1.5.2 Ecologically Sustainable Development (ESD)

Ecologically Sustainable Development was given global significance during the Earth Summit in Rio de Janeiro in 1992. It coincided with movement already underway in Australia to develop a guiding set of principles for managing the environment in a sustainable way, while providing for future development. The Inter-governmental Agreement on the Environment (Commonwealth Govt, 1992) provided the commonly accepted doctrine for ESD in Australia. It contains the four principles that form the basis for many environmental policies and strategies. These principles are a legislative requirement under the Local Government Act, 1993 when considering development applications.

- **The precautionary principle:**

Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.

In the application of the precautionary principle, public and private decisions should be guided by:

- (i) careful evaluation to avoid, wherever practicable, serious or irreversible damage to the environment; and

(ii) an assessment of the risk-weighted consequences of various options.

- **Intergenerational equity:**

The present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations.

- **Conservation of biological diversity and ecological integrity:**

Conservation of biological diversity and ecological integrity should be a fundamental consideration.

- **Improved valuation, pricing and incentive mechanisms:**

Environmental factors should be included in the valuation of assets and services:

- polluter pays i.e. those who generate pollution and waste should bear the cost of containment, avoidance, or abatement.
- the users of goods and services should pay prices based on the full life cycle costs of providing goods and services, including the use of natural resources and assets and the ultimate disposal of any wastes.
- environmental goals, having been established, should be pursued in the most cost effective way, by establishing incentive structures, including market mechanisms, which enable those best placed to maximise benefits and/or minimise costs to develop their own solutions and responses to environmental problems.

1.5.3 Stormwater Management Plan

In April 1998, the NSW EPA issued Wyong Shire Council with a direction under the Protection of the Environment Administration Act to prepare a Stormwater Management Plan for urban areas within both the Tuggerah Lakes and Lake Macquarie catchments. In response, Council produced a plan in collaboration with Gosford City Council, Lake Macquarie City Council, the then NSW State Forests, RTA and the then NPWS, that examined current stormwater management activities and provided future direction for management practices (Dickinson, 1999).

The plan is a framework for applying a consistent standard of stormwater management throughout the catchments across a range of stormwater managers and stakeholders. Council is the largest stormwater manager in the catchment and as a reflection of this and the unique responsibilities of various departments of Council, it was decided that individual departments would be recognised as distinct stormwater managers. On this basis, the plan established a series of actions and timelines for their implementation. These actions included new strategies, corrective works, operational changes and stormwater management studies and were combined with a rigorous review process.

The plan is reviewed every 2 years to ensure that the various stormwater managers are undertaking the agreed actions, and where possible providing feedback based on the experiences they have had implementing the various actions. The most recent review was completed by Wilcox (2003) with the following observations:

- The 1999 action plan is largely implemented. Some actions are intended to be ongoing, evolving with changes in policy, technology and legislation.
- The control of nutrient flow to the estuary continues to be of concern. There is an identified knowledge gap in terms of which areas of the catchment provide the largest nutrient contributions and how stormwater flow mixes with the near and off-shore water. It is expected that the answer to these questions will drive funding of future programmes.
- Suggested focus areas for future management plans include:
 - Management system audits – combined with catchment investigations to provide an indication of stormwater management status. Environmental Systems will undertake maintenance audits of stormwater treatment devices.
 - Capacity building / training for outdoor workers in constructed wetlands – this would require an assessment of current staff skill levels, increased priority for maintenance activity in works schedules, increased visibility during establishment phase and reinforcing the importance of feedback to management.
 - DCP revisions to include WSUD features – to incorporate both water sensitive urban designs into relevant DCP's and include periodical revisions on existing DCP's.

While the Stormwater Management Plan is an important environmental management document for Council, it may not be effective because it is not linked to key internal Council documents. For example, the plan lists prescriptive criteria for sediment/nutrient removal and flow management yet it is not referenced within DCP 67 – Engineering Requirements for Development. While many departments make agreements about implementing actions, these agreements are not tied into departmental business plans to assess likely funding and implementation. The Estuary Management Plan and Stormwater Management Plan should both be strongly linked to Council's Management Plan and Departmental Business Plans to ensure implementation.

1.5.4 Healthy Rivers Commission and Coastal Lakes

The Healthy Rivers Commission was involved with an independent inquiry into Coastal Lakes for the NSW Government. The final report built on earlier Government decisions relating to other Commission Inquiries (HRC, 2003). The Coastal Lakes Strategy incorporates:

- Principles for managing coastal lakes.
- A classification for each of the 91 coastal lakes in NSW into four protection categories, each category denoting the level of protection required and the kinds of management strategies necessary for achieving this level.

- Requirements for preparing sustainability assessments and management plans for each coastal lake, which identifies lake-specific actions to be taken by relevant parties to achieve the level of protection required for maintaining or improving the health of each lake.
- Implementation arrangements including formalisation of the management actions for each coastal lake through a State Environmental Planning Policy.
- A range of supporting initiatives.

Under this strategy, Tuggerah Lakes was assessed as requiring “Targeted Repair”. The recommended management approach for estuaries requiring “Targeted Repair” is shown in Table 4.

Table 4. Coastal lakes statement of intent (HRC, 2003).

Action: Prepare and implement a sustainability assessment and strategy for each coastal lake and its catchment <ul style="list-style-type: none"> • Specify any other outcomes for each coastal lake that are consistent with creating a preferred condition through rehabilitation • Determine the few targeted rehabilitation measures necessary to achieve the intended outcomes • Determine the capability and limitations of a lake/catchment to sustain any new development (i.e. permitted or encouraged, permitted subject to conditions, not permitted pending further investigations, not permitted). Determine opportunities to harness new development to offset the impacts of existing development • Select and design the most appropriate set of management tools • Specify the responsibilities, timing and resources for each action 	
Intended Outcomes Primary Outcomes Habitat conditions for selected key species established Other Possible Outcomes <ul style="list-style-type: none"> • Frequency of algal blooms reduced • Existing urban areas retained and/or expanded within defined limits • Aesthetic value/amenity maintained 	Indicative Actions – those most likely to be necessary and effective <ul style="list-style-type: none"> • Design rehabilitation measures for nominated areas and modified ecosystem values (such as protecting selected species, opening a lake entrance, aerating a lake water body, implementing stormwater controls). These should be designed to close the gap progressively between actual and intended conditions. • Apply and enforce controls for any new development to keep their impacts on lake/catchment health within tolerable limits.

As a first stage, the NSW Government will trial a small group of lakes to pilot the preparation of sustainability assessments and management strategies. Following completion of this first stage, the Government will receive and consider a report on the outcomes of the first stage and options for applying the Coastal Lakes Strategy to other coastal lakes across NSW, taking into account a detailed cost benefit analysis for each option (HRC, 2003). While not active for Tuggerah Lakes, this strategy should be consulted when determining appropriate plans of action for the estuary.

1.5.5 Central Coast Catchment Blueprint

The Central Coast Catchment Management Board was established in late 1999. The Board's principal function was to develop an Integrated Catchment Management Plan or Blueprint to set out natural resource objectives, targets and prioritised management actions for the Board's area. The Blueprint was to provide a framework for the strategic direction of investment in natural resource management in the Board's area over the next 10 years (CCCMB, 2003).

There were three critical themes that guided the Board's approach:

1. The strategies must not only prevent deterioration of our natural resources, but also provide positive examples of ecologically sustainable development.
2. Reducing the pressures on our natural resources can only be achieved by changing behaviour, and gaining commitment to implementing the prioritised management actions identified in this Blueprint. Key stakeholders need to have the knowledge, the will, the skills and the resources to make change happen.
3. Natural resource planning must demonstrate respect for aboriginal cultural heritage.

With these themes in mind, the CCCMB developed five key objectives that provided a statement of the community's values about the desired state and functioning of the area's natural resources. It is important that the principal catchment management document be linked with the estuarine management planning process. This was achieved in the study by ensuring that estuarine management seeks the same overarching principles as the Blueprint. As such, the objectives from the Blueprint form the basis for the objectives, issues and options for this Estuary Management Study. The common objectives were:

- Water quality & quantity meet community needs and natural ecosystem requirements.
- The physical structure and vegetation of river, lake and wetland riparian zones are protected (and rehabilitated where required) to sustain healthy ecosystems.
- Biodiversity and ecological integrity are maintained and enhanced.
- Human settlement, primary production and other land uses take place while protecting and enhancing Aboriginal cultural heritage, soil, water and ecosystem health.
- The coastal zone environment is protected whilst providing for the social and economic needs of the community.

In keeping with these objectives, the CCCMB came up with a number of targets against which the success of the Blueprint can be measured. These targets are divided into management and catchment targets and are grouped into four natural resource areas; aquatic ecosystems, land capability, terrestrial biodiversity and native vegetation.

With the dissolution of Catchment Management Boards and Trusts, Catchment Management Authorities (CMA's) will now become the primary vehicle for implementing the Action Plans contained in the Blueprint. This was discussed in Section 1.2.3 however it is worth noting that the level of funding is uncertain in this new environment.

1.5.6 Water Reform Package

The NSW government announced a water reform package to improve the management and health of rivers and groundwater. It included:

- Establishing a framework for community based planning and management of our rivers and groundwater.
- Strengthening water access and use rights for water users.
- Improving the health of rivers and groundwater.
- Funding a significant package to encourage industry to use water more efficiently.
- Making it easier to buy and sell water to encourage regional development.
- Regularly monitoring and auditing the scientific and socio-economic impacts of the reforms.
- Establishing interim river flow and water quality objectives for the State's rivers.
- Establishing a groundwater and weirs policy.

The water reform package has produced two changes to the way water will be managed in the Tuggerah Lakes catchment, with the establishment of Catchment Management Authorities and the development of Water Sharing Plans. It is important to recognise the intent of the package outlined above, as it is likely to continue to influence water and catchment management in Wyong Shire into the future.

In terms of actual changes to management, the package has resulted in the development of three water-sharing plans for the catchment. These are discussed along with other existing managerial approaches in Section 2.3

1.5.7 Coastline Management Plans

The Coastline Hazard Policy aims to reduce the impact of coastal hazards on individual owners and occupiers, and to reduce private and public losses resulting from natural coastal forces. DIPNR has set out the following policy objectives for managing coastline hazards:

- the impact of coastal forces on existing developed areas shall be reduced by works and measures and by the purchase of property on a voluntary basis, where appropriate.

- the potential for coastal damage in respect of any proposed coastline development shall be contained by the application of effective planning and development controls by local councils.
- a merit approach to all development and building decisions that takes account of social, economic and ecological as well as oceanic process considerations, shall be followed by local councils and developers.

A Coastline Management Plan is being prepared for Wyong Shire Council to ensure that these policy objectives are met. The Plan is in its early stages of development but it is expected to be completed in 2005.

As there are a number of overlaps between the Coastline Management Plan, the Estuary Management Plan and indeed the Floodplain Management Plans (mentioned below), it is important that the objectives and actions of the plans be as complimentary as possible. This will allow catchment and estuarine managers to maximise the use of limited funding and produce a cohesive approach to managing land use and its impacts on the estuary.

1.5.8 Floodplain Management Plans

The NSW Government released the Floodplain Management Manual in 2001 to support its Flood Prone Land Policy. The primary objective of the policy was:

To reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property, and to reduce private and public losses resulting from floods, utilising ecologically positive methods wherever possible

The main mechanism for achieving this objective is the preparation of a Floodplain Risk Management Plan (FRMP). The formulation process of this plan is directly linked to Council's strategic planning processes.

The plans take into account other environmental concerns such as erosion and natural processes. Dredging is one of the most significant overlaps between flood and estuarine management. For example, the management of The Entrance channel has at times been justified as being necessary for flood control. It is understood that the risk of flooding for some properties will increase where floodwaters do not have an unimpeded flow path out of the estuary to the ocean (i.e. where the entrance is constricted or closed). The ecology of the estuary is also highly likely to be affected by flood and entrance management. As such, the Estuary Management Plan and the FRMP should ensure that recommendations are not to the detriment of objectives contained in either plan.

1.5.9 Regional Vegetation Management Plans

Regional Vegetation Management Plans (RVMP's) are 10-year plans being developed under the *Native Vegetation Conservation Act 1997* that provide for the protection and conservation of native vegetation based on regional needs. Because of their close relationship with land-use planning, RVMP's have been developed on local government boundaries (DLWC, 2002).

Reforms being implemented under the Native Vegetation Act 2003 have seen the RVMP's replaced with criteria for classing native vegetation types (regrowth, remnant or protected regrowth) and a clear vegetation planning mechanism (property vegetation plan) that operates at a property rather than regional level. The draft Native Vegetation Regulation (2004) will be used as the regulatory tool for the Native Vegetation Act. These reforms are in their infancy, and their ability to protect the catchment and riparian/floodplain vegetation of the Tuggerah Lakes estuary is not yet understood. These reforms will be administered under the new Catchment Management Authorities, which represents a decentralisation in native vegetation management for the catchment.

2 Management Status

2.1 ESTUARY PROCESS STUDY

The Tuggerah Lakes are a series of three interconnected shallow coastal barrier lagoons (Roy et al., 2001) that are open to the sea at The Entrance (Fig. 4). An Estuarine Process Study was done as part of the NSW State Government's estuarine management programme (Roberts, 2001). The Estuary Process Study described the physical, chemical and biological patterns and some processes operating within the estuary and identified management issues that would be the focus of the subsequent management study. In the past, community concerns about deteriorating environmental quality within the estuary had led to scientific studies and a number of management actions. Many of the studies were not done at appropriate spatial and/or temporal scales and were generally focused on issues surrounding the operation of the Munmorah Power Station and its effects on the estuary. The Tuggerah Lakes restoration programme was a direct result of community and political pressure to do something about eutrophication within the estuary. The results of that particular management action have and continue to be questioned by the community and technical experts from various disciplines. The lakes restoration programme was considered a "bandaid solution" because it treated only the symptoms and not the actual cause of the problem.

The objective of the Tuggerah Lakes Estuary Process Study was to identify data gaps and key estuarine processes so that there was better understanding of how the estuary "worked". All the relevant scientific studies that had been done were examined so that a generalised description of the processes within the estuary could be used to assist with managing environmental issues. It became clear that many of the previous studies were inadequate for describing estuarine processes because they failed to evaluate their findings at appropriate spatial and or temporal scales. To help overcome this, a number of studies were done aimed at describing the estuary in terms of its important physical, chemical and biological components. Many of these studies were funded by Wyong Shire Council independent of external funding (e.g. water quality, macroalgae and phytoplankton monitoring). These programmes were reported in the Council's annual State of the Environment Reports, technical reports and in the broader scientific literature.

The Tuggerah Lake estuary was formed some 6,500 years ago when sea levels rose after the last ice age. Most of the geomorphological features of the estuary are relic (i.e. they are no longer active), except for the river deltas of Wyong and Ourimbah Creeks and the tidal delta at The Entrance. Sedimentary processes within the estuary were generally found to be slow, with no evidence for depth changes since the early bathymetry studies in the 1970's (Dickinson, 1997). There were, however, small-scale changes, with some places becoming shallower around inflows, whereas other places had become deeper due to the effects of subsidence from mining. The Tuggerah estuary is one of the slowest infilling estuaries on the

NSW coast, and at current rates, would take over 1000 years to fill completely (Roberts, 2001). The flushing and mixing characteristics of the estuary were examined and tidal flushing contributed very little to its circulation and mixing patterns (Roberts, 2001). Overall, the bottom sediments within the estuary were relatively “healthy” apart from some small-scale problems in some urbanised areas. Investigations on pollutants within the sediments indicated very small amounts of pesticides whilst heavy metals were below those found to cause adverse ecological effects. The sediments within the estuary had large concentrations of nutrients. Sediment/nutrient fluxes were positive which meant that they were biologically available. Nutrient concentrations within the water column were found to be above ANZECC (1998) guidelines and the estuary was classified as being mesotrophic (i.e. medium nutrient status).

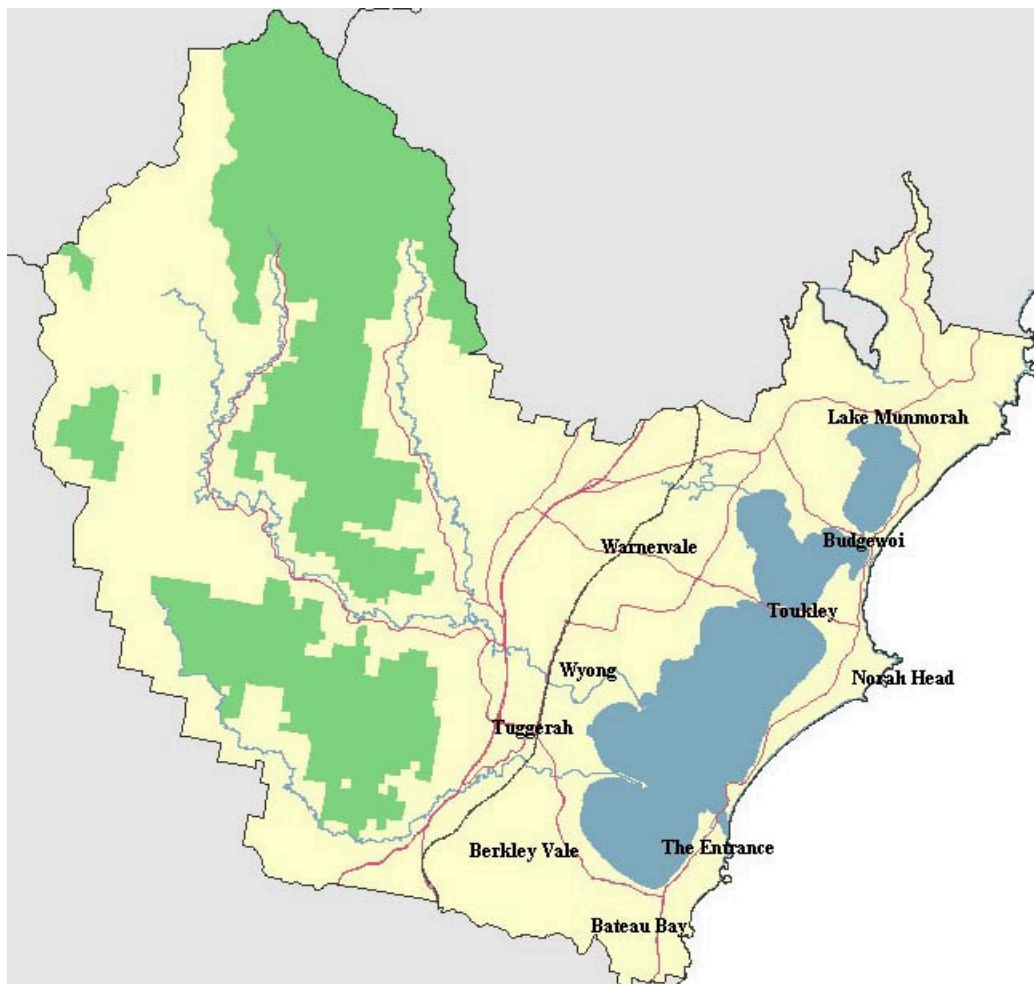


Figure 4. Tuggerah Lakes and the Wyong Shire local government area.

NUTRIENT-POOR ESTUARY

The patterns that have been documented for the Tuggerah Lakes estuary can be summarised by saying that the estuary has passed through three recent historical stages. In the first stage, prior to large-scale development in the 1950's, the estuary was considered to have been nutrient poor (oligotrophic). Although this sounds negative, it was the natural state of things and the plants and animals of the estuary were adapted to it.

In these early days the entrance was not dredged. The action of long-shore drift moved sand across the entrance forming a barrier, which often closed the estuary to the sea. This sand bar was only removed after heavy flooding or high seas. At these times, the estuary would be “flushed” and “estuarine-dependent” fish and prawns would enter and leave.

There were extensive □ saltmarshes fringing the estuary that provided significant habitat for a range of birds and invertebrates. The large catchment provided the necessary freshwater, nutrients and sediments, which made the estuary a productive ecosystem. Flows of freshwater and nutrients from the catchments were not substantially altered by artificial structures such as weirs and water reclamation for the use of humans. Naturally eroded sediments from the catchments were deposited into the relatively shallow mud basin of the estuary and in areas of lower energy (e.g. seagrass habitats). These silty sediments were often remobilised by wind induced mixing and the estuary was generally turbid under these conditions. Generally, however, water clarity was high and the light regime within the estuary was not limiting the growth of plants.

Marine based sand entered the estuary through the actions of tides and storms. The nutrients required by the primary producers (algae and seagrasses) were recycled amongst the physical, chemical and biological components of the estuary. These biological components included fish, crustaceans and benthic and pelagic invertebrates. Apart from natural disturbance, which changed these patterns from time to time, the estuary was considered “balanced” with natural processes occurring at various spatial and temporal scales. There were abundant seagrass habitats that were consistent with the geomorphology and quality of the water of the estuary at this time. By all accounts there was a plentiful supply of fish, crabs and prawns as well as an abundance of benthic and pelagic organisms. The amount of tidal flushing was limited because of the overall shape of the estuary and its constricted ephemeral entrance.

At the entrance to Tuggerah Lake and at places close to it, the local community considered the lakes to be “healthy”. At certain places around the estuary, “blooms” of drift macroalgae sometimes occurred and the floating detached leaves of seagrasses (wrack) were often washed up onto the shoreline. These wind and wave deposited wracks were quickly recycled through the actions of □ saltmarshes and those invertebrates and grazers that lived within them. Whilst there were still some human influences on the estuary, the threshold required to drastically alter natural patterns had not yet been reached.

NUTRIENT-RICH ESTUARY

After the 1950's, greater pressure was placed on the Tuggerah Lakes as the region primarily changed to a major "holiday resort" and then towards suburban development. The flows of nutrients and sediments from the sub-catchments increased, whilst freshwater flows from the wider catchments were reduced as more and more water was taken from the rivers for the use of the larger human population. The rainfall during this period was, on average, greater than what it had been in previous years so there was the potential for increased loads of nutrients and sediments.

Rapid urbanisation and sewage discharges from septic tanks and treatment works increased the amount of nutrients (especially nitrogen and phosphorus) entering the estuary. In this stage, the estuary became eutrophic (nutrient enriched) causing increased occurrences of blooms of drift macroalgae. Increased sediment inflow also had the effect of reducing the amount of light available for photosynthesis of submerged aquatic plants and extensive areas of seagrasses disappeared.

In the shallow seagrass areas close to the shoreline, drift macroalgae began to form extensive floating mats which deoxygenated the underlying water and caused the death of benthic invertebrates and seagrasses. This resulted in a breakdown of the natural nutrient cycling processes in these shallow habitats. Many of the drift macroalgal species found in estuaries are ephemeral and therefore "bloom" and eventually die. Under normal conditions their organic remains are recycled back into the system through the actions of bacteria and benthic invertebrates. Under eutrophic conditions, the normal recycling mechanisms of the benthos are disrupted and once the macroalgae die they decompose slowly, producing anoxic conditions within the sediments. This can lead to increased concentrations of organic nutrients within the sediments and the production of so-called "organic ooze" which the Tuggerah Lakes experienced during the 1980's. Add to this, the significant reduction in the recycling capacity of extensive areas of fringing saltmarsh and the continued disturbance of seagrass habitats and sediments through activities such as development of foreshores, dredging and reclamation, and it was not surprising that some threshold was crossed in the ecology of the estuary.

At this time, the shallow sediments near the dunes on the eastern side of the lakes received increased silt, and fish and prawns were apparently less abundant. Although it was never documented, the abundance of phytoplankton may have increased during this period, which would have added to the turbidity within the estuary.

MEDIUM-NUTRIENT ESTUARY

Today the estuary could be classed as mesotrophic (medium nutrient status). The entrance is kept open to the sea by a sand dredge, which allows some limited flushing and mixing to occur, however, the overall effects of flushing are small when the size of the estuary is taken

into account. The shape and depth of the estuary has not changed appreciably since the 1960's although there are some areas where depth has decreased due to siltation. As there are no new sources of marine sands entering the estuary, the eastern shorelines have become siltier and in areas where there is continued organic enrichment, "organic oozes" can still be found.

Management of the wider catchment has improved with greater controls on development and farming. The completion of the sewerage scheme has also helped to reduce the amount of nutrients entering the estuary. During heavy rain, nutrients and sediment still enter the estuary from stormwater and from the major tributaries. Symptoms of eutrophication still occur, especially around some of the developed foreshores, as small-scale blooms of ephemeral drift macroalgae. The processes that drive these blooms are still being examined, however their ability to damage the underlying benthic community is without question (Cummins et al., 2004). The role of this benthic community in nutrient cycling and as a major food source for higher order consumers is also without question.

The turbidity in the estuary has improved since the 1980's and whether this was due to lower patterns of rainfall and reduced concentrations of suspended material in the water column cannot be answered. The spatial extent of seagrass habitat within the estuary has not increased since its decline during the 1980's. Anecdotal evidence suggests that there has been some recolonisation of seagrasses into very shallow areas around the estuary, which may have been lost as a result of earlier processes of eutrophication. The □ saltmarshes of the estuary have continued to decline as a result of disturbance, and establishing their role in the nutrient cycling process is now being done (Roberts and Chapman, 2003).

In summary, the Tuggerah Lakes estuary was considered to be "healthier" than it was during its eutrophic stage in the 1980's and 1990's. The key question remained whether this level could be sustained with increased future development or whether the system would be pushed over some threshold, returning it to the previous eutrophic state of the 1980's.

2.2 FEATURES, ACTIVITIES, USES AND CONFLICTS

The primary aim of the Estuarine Process Study was to describe the patterns and some processes occurring within the estuary and to identify potential management studies, including features, uses and conflicts that may need to be resolved. A number of "scoping workshops" were run within the monthly Estuary and Coastal Management Committee meetings. Input from community meetings was also used to help guide the identification of issues that would need to be addressed in the development of the Estuary Management Study. They were summarised into the following key points, in no particular order of priority, and were incorporated into the scope of the Estuary Management Study:

- Ecologically sustainable management of estuarine beaches, foreshores and seagrass meadows.
- Protection of ecologically sensitive habitats, e.g. Budgewoi Sandmass and Tuggerah Bay.
- Managing potentially elevated nutrient and sediment loads to the estuary from increased urbanisation and development in the catchments.
- Identification and management of those nutrients responsible for excessive aquatic plant growth.
- Implications of periodic dredging of rivers and the tidal delta at The Entrance.
- Practical and ecological implications of a second entrance and/or break walls, to alter existing estuarine mixing and flushing.
- The management of both recreational and commercial fisheries.
- Potential ecological effects of mine subsidence.
- The feasibility of using “Bioindicators” to quantify whether management targets for the estuary are attained.

2.2.1 Tuggerah Lakes Restoration Project

The Tuggerah Lakes Restoration Project was established by the NSW State Government and Wyong Shire Council in response to community pressure to “clean up” Tuggerah Lakes (WSC, 1998a). The programme involved dredging to keep the entrance open, foreshore reclamation and removal of nutrient laden sediments from within the shallow seagrass meadows, and the construction of stormwater treatment zones around the estuary (Patterson Britton & Partners, 1992). The impacts of the actual works on physical, chemical and biological processes within the estuary were never evaluated. The restoration programme and its value to the estuary have been questioned by environmental managers and there are mixed feelings within the general community as to its overall worth as a solution to the problems. Overall, it is difficult, if not impossible to assess the positive or negative impact of the restoration project on the estuary, because no quantitative data were ever collected either before or after the works. There were many reports of fish kills associated with the physical works and the dredging did cause disturbance to acid sulphate soils. The restoration project has been termed a “bandaid solution” to what was considered human disturbance from the catchment. Nutrients delivered to the estuary from the wider catchment and from local sub-catchments were considered to be the cause of eutrophication in the first place. The source of the nutrient problem in the restoration programme could not be addressed as the brief for the project stipulated that all work had to be done in the estuary (Roberts, 2001).

2.2.2 Power Station

The Munmorah Power Station (MPS) was commissioned in 1967 with four generating units, and obtains its cooling water from Lake Munmorah and discharges into Budgewoi Lake (Roberts, 2001). There have been numerous studies and investigations into the effects of the Power Station on the ecology of the Tuggerah Lakes estuary (Powis 1973; Higginson, 1971; Henry and Virgona, 1981). Batley et al. (1990) and Thresher et al. (1993) reviewed the effects of power station operations on the ecology of the estuary. It was considered that the power station had substantial ecological impacts in Budgewoi Lake within one kilometre of the outfall, causing changes to sediments, benthos, macrophytes and water quality (Thresher et al., 1993). Elevated temperatures of surface waters in Budgewoi Lake were obvious, but there were insufficient data to assess whether the station has caused effects on the growth of seagrasses. It was recommended that experiments be done to ascertain effects associated with increased temperature. Light, salinity and sediment composition were not affected by the power station, but it was thought that increased water temperature could lead to increased nutrient release (fluxes) from the sediments, although this is not thought to have a large effect on the overall ecology of the lakes. Particulate ash from the station was high in Lake Munmorah whilst zinc, lead, copper and antimony were also high although within ANZECC guidelines (Roberts, 2001). There was no evidence of bioaccumulation in seagrass or other biota (Batley et al., 1990).

MPS currently operates two generating units of the original four that were commissioned. Present conditions mean that only one unit operates for a few months of the year, supplying 400GWh per year (about 2% of company supply and 0.6% of the State grid). The power station, while not providing large proportions of the State grid, serves an important backup role in times of high demand. System demand is expected to increase in the next five years and will see MPS take on more of a generating role. The power station is a major local employer with some 200 people employed at a cost of \$3 million/year.

The power station monitors its operations in accordance with its DEC licence conditions and spends approximately \$40,000 annually reviewing variables such as air and water quality. MPS also occupies a significant tract of land that is largely untouched, and in addition to providing green corridor value it contains significant remnant vegetation communities. While Council does not have administrative control over the power station or its operations, there is a history of strong dialogue between the two organisations.

2.2.3 Sediments and Nutrients

Nutrients (nitrogen and phosphorus) and sediments enter the estuary by various pathways, including riverine sources, urban runoff (stormwater), groundwater, atmospheric deposition (nitrogen), and ocean exchange. The Tuggerah Lakes estuary has a constricted entrance to the ocean, which allows only limited water and nutrient exchange. Modelling was used to calculate the flow and nutrient loads entering from the surface catchment surrounding the estuary as part of the Estuary Process Study (Roberts, 2001). An average annual flow of 311,500 ML and nutrient load of 60 and 219 tonnes of phosphorus and nitrogen were identified, respectively (Garofalow, 1998). The immediate sub-catchments (urban areas) contributed approximately 37% of the total phosphorus and 43% of the total nitrogen load to the estuary under normal flows whereas high flows from the rivers contributed almost 90% of the total nutrient load. Groundwater may also contribute significant quantities of nutrients, particularly during periods of low rainfall, however there was insufficient data to estimate its load at this time (Garofalow, 1998).

The estuary was subjected to high levels of nutrient enrichment (eutrophication) in the past, from septic systems and poor land-management-practices. Large-scale blooms of macroalgae were common during the 1980's leading to the Lakes Restoration Programme (Roberts, 2001). Wyong Shire Council currently monitors the ambient concentrations of nutrients within the estuary and at the major river inflows at a number of spatial and temporal scales (Cummins et al., 1999). Groundwater contributions have also been examined (Kerry, 1998), as well as the flux rates of nutrients between the sediments and the water column (Bourgues et al., 1998). Blooms of macroalgae still occur at small-scales, generally in shallow vegetated seagrass meadows in close proximity to stormwater drains (Cummins et al., 2000). A stormwater management plan, which incorporated the catchments draining to the Tuggerah Lakes estuary was developed by Wyong Shire Council (Dickinson, 1999).

Managing nutrient inputs to the water column may assist in reducing the frequency and scale of blooms of macroalgae (Fig. 5). While circumstantial evidence suggests that the removal of septic systems has been largely responsible for this response in macroalgal patterns, it should be noted that the nutrients sustaining the growth could have come from a number of other sources. Appropriate controls on these other sources are required to minimise the chances of returning the estuary to a eutrophic state. Council is currently looking at sediment and nutrient modelling of the Porters Creek catchment to manage increased loads from development.



Figure 5. Bloom of macroalgae growing along Chittaway Bay.

2.2.4 Catchment Management

The rehabilitation of degraded stream-banks and riparian zones within the freshwater sections of the tributary creeks entering the Tuggerah Lakes estuary has received some attention and funding (although this is mostly confined to areas above the weirs in the water supply catchment). Erosion of riverbanks due to natural and human disturbance has received considerable attention from environmental managers over the past few years. Rivers naturally meander across their floodplains and consequently natural erosion of the stream-bank occurs. The process of erosion takes place over large geological time-scales, however disturbance due to increased runoff from development in the catchment can accelerate this erosion (Figs. 6 and 7). It was generally agreed that there was an urgent need to assess and restore where possible riparian habitats within the freshwater and estuarine sections of Wallarah Creek, Spring Creek, Tumby Creek, Ourimbah Creek and Wyong River. Both riparian and in-stream aquatic plants are recognised as being important in reducing the erosion of stream-banks. Due to deteriorating water quality however, many species of in-stream aquatic macrophytes have disappeared from our river systems, whilst clearing, cattle, development etc. have disturbed riparian vegetation (Roberts and Cummins, 2001).

Wyong Shire Council and DIPNR have done some preliminary studies on the extent of stream-bank erosion in the estuarine sections of Wyong and Ourimbah Creeks. This involved detailed site inspections and ranking of urgency and costs for work. Wyong Shire Council encourages community groups such as Landcare and landowners to play a role in

rehabilitation of streambanks within the shire (Figs. 8 and 9). Active rehabilitation of major sources of erosion and creek bed degradation has also been funded by council and the State Government. The newly formed Hunter and Central Rivers Catchment Management Authority (CMA) will also be directing funds towards riparian zone management through the Catchment Action Plan and the three year investment strategy. Commonwealth funding for on-the-ground riparian works in Ourimbah, Wyong and Jilliby are presently being distributed to individuals and volunteer networks.



Figure 6. Streambank erosion on Wyong River.



Figure 7. Streambank erosion in Tumbi Creek.



Figure 8. Streambank erosion before rehabilitation.



Figure 9. Streambank after rehabilitation.

2.2.5 Environmental Flows

Urbanisation and development of catchments has caused major disturbances to aquatic systems in NSW. The impacts associated with human disturbance generally include the loss of aquatic habitat and reduced biodiversity (Gehrke and Harris, 1996; Gehrke, 1997). Examples of these disturbances include water pollution and eutrophication and in many systems, river regulation and abstraction. The native aquatic organisms that inhabit rivers, streams and wetlands in Australia have adapted to millions of years of cycles of drought and flood, which provide natural variability to river ecosystems. The variation in water flows helps to maintain the natural biodiversity within aquatic systems and human disturbance has the potential to reduce this variability (Gehrke and Harris, 1996). The composition and abundance of macroinvertebrates within coastal streams is controlled by flow regime, food supply, water quality, biotic interactions and habitat structure (Cummins et al., 1997; Growns and Growns, 1997). The distribution and abundance of macroinvertebrates can be affected by changes in the flow intensity and pattern (Growns and Growns, 1997), pollution (Wright et al., 1995), and differences in habitat and structure (Kay et al., 1999). Significant differences have been found between assemblages found in riffle zones and those found along the edges of creeks. Furthermore, upstream and downstream differences can occur due to obstructions (man-made and natural) and between assemblages found in aquatic macrophytes and overhanging riparian vegetation (Cummins et al., 1997).

Environmental flows are important to estuaries as a source of fresh water and to many migratory fish species. As part of the Healthy Rivers Commission, Gosford Wyong Councils Water Authority (GWCWA) prepared a report on environmental flows, which included Wyong River and Ourimbah Creek (Muston, 2000). There was very little data on the instream ecology of creeks in NSW coastal regions. The habitats that exist within these creeks were generally a result of the basic streambed geomorphology of the creek. In the higher elevated headwaters of these creeks, this usually consisted of a series of stretches of deeper water or pools, which ended in shallow riffle zones or boulder fields. The edges of these creeks can have both overhanging vegetation and submerged and emergent aquatic macrophytes. Diatoms and algae growing on submerged boulders and rock shelves and in many places fallen logs and trees (woody debris) provide habitat for a range of aquatic organisms such as macroinvertebrates, fishes and small vertebrates such as platypus. Once these creeks reach the floodplain they tend to meander and become deeper and wider, and closer to the estuary they are generally influenced by tidal saline waters. Major disturbances to creek systems in NSW have included water pollution and eutrophication, and in some systems river regulation. This includes the building of weirs, dams and other structures that alter the natural flow regimes, which can lead to adverse changes to the ecology of the river or creek system (Figs. 10-13). Inter-basin transfers also occur between the rivers and dams, which have the potential to transmit pests and pathogens as well as cause ecological disturbances associated with thermal pollution, and alter flow regimes.

The tributary creeks entering the Tuggerah Lakes provide freshwater input to the estuary. These creeks have suffered from human disturbance such as water regulation. The GWCWA engaged the services of an Environmental Flows Expert Panel to assess the ecological implications of its water supply activities and to make recommendations on environmental flow management strategies (TEL, 1999). A series of expert panel workshops were run and a discussion report (Muston, 1999) and final report were produced which detailed the expert panels' recommendations (Muston, 2000). Recommendations by the expert panel included the development of a water supply operations monitoring programme, which included sampling of water quality and biological communities. The monitoring programme of the GWCWA required the sampling of macroinvertebrates as well as physical and chemical variables. All further monitoring was to be linked with flow regimes and water supply activities. Since those recommendations, quantitative data on both water quality and instream macroinvertebrates have been collected to establish baseline conditions on the ecology of the tributary creeks. The aim of this work was to be in a position to assess the effects of water supply activities and environmental flows on the ecology of the tributary creeks (Roberts, 2004). The strategy for environmental flows will therefore be developed over the next few years primarily by the GWCWA. The needs of the Tuggerah estuary will be considered as part of any strategy developed by the supply authority.



Figure 10. Mangrove Creek Dam.



Figure 11. The weir on Ourimbah Creek.



Figure 12. A causeway road crossing.



Figure 13. Railway bridge and culvert on Spring Creek.

2.2.6 Urban Stormwater Management

2.2.6.1 New Urban Areas

There are a number of areas in the catchment targeted for substantial development in the future. Much of the “damage” has already been done with respect to sediment and nutrient mobilisation from the catchment, with years of development not subjected to any form of control (Fig. 14). In order to prevent future disturbance, development must be subjected to effective sediment and nutrient control. Areas that have the potential to be significant sources include Warnervale/Wadalba and Bushells Ridge. WSC has delegated authority under the Protection of Environmental Operations Act 1997 (POEO) to manage and enforce erosion and sedimentation control.

Nutrients cannot be removed completely from stormwater discharge using current technology. At the level of the urban lot there are few programmes for limiting nutrients other than through education (Figs. 15 and 16). For sub-catchments, the preferred treatment method for removing nutrients from urban runoff is to install constructed wetlands (examples of which can be found in Bluehaven, Berkeley Vale, Tumbi Umbi and Warnervale). These systems are costly in terms of capital and maintenance, and variable in terms of performance. At best, it is believed that they can remove between 40 and 75% of total phosphorus and nitrogen from runoff, given adequate size and detention time. There is little monitoring available for most of the constructed wetlands of the shire, and given the variability in performance, it is not possible to determine their effectiveness, except to say that it is likely to be better than sending untreated urban runoff into the estuary, rivers or natural wetlands. Additional efforts will be needed to research the most appropriate systems for the catchments of Tuggerah Lakes.

Sediments can be removed using a number of means at various locations within the catchment. At the lot level, vegetating exposed soils, and erecting sediment barriers (fences, hay bales) are effective at controlling the rate of erosion and confining the eroded material to the lot. At the subdivision level, sediment basins, swales, hay bales and gross pollutant traps are all effective means of limiting sediment movement downstream. Enforcement at the lot and subdivision level is another method that is currently minimising sediment transfer. At the sub-catchment level, constructed wetlands and larger gross pollutant traps, collect and remove water borne sediments from the stormwater system. The removal efficiency varies depending on the design of the device and its maintenance regime. Constructed wetlands are being installed in developing areas to remove sediments as well as nutrients. The efficiency of the wetlands in removing sediment is also variable however this is in the high range, generally removing between 80 to 95% of the total suspended solids (TSS) load (EPA, 1997). Some soils in the catchment are highly dispersive which make settling an inefficient way of removing sediment from runoff.

A number of policies/documents have been developed either by or for Wyong Shire to help protect “ecological health” in the face of new development, through the removal of sediments and nutrients. These include:

- Quality Housing DCP 100
- Water Sensitive Urban Design DCP (draft)
- Stormwater Management Plan
- Central Coast Catchment Blueprint
- Porters Creek Wetland Management Plan
- Warnervale Floodplain Environmental Management Strategy

2.2.6.2 Existing Urban Areas

Council has a drainage infrastructure upgrade programme that aims to spend approximately \$300,000 annually on drainage from existing urban areas to improve the removal of sediments and nutrients. Constructed wetland retrofits have been completed in Canton Beach, Berkeley Vale, Gorokan and Killarney Vale.

The Gorokan retrofits were part of an ecological experiment (SUTLE) with the Centre for Ecological Impacts of Coastal Cities (EICC) from the University of Sydney. The aim of this study was to measure the response of the aquatic ecology when existing drainage lines were upgraded with constructed wetlands. The study tested the hypothesis that by improving stormwater treatment, the ecology around the discharge area would respond in a positive measurable way. Another study by Council is comparing the use of multiple low cost treatment devices in the upper catchment, with singular high cost treatment devices in the lower catchment. Available space for stormwater retrofits is limited in urban catchments, and it is hoped that using numerous smaller devices rather than downsizing a larger device, will maximise the overall pollutants removed. This project (LOCOST) is an ongoing collaboration with the DEC's Stormwater Trust.

To date there has been little monitoring done on the stormwater from the existing urban catchment. Monitoring is difficult due to the variability of catchments, resource intensiveness and cost. DIPNR (funded by NHT) funded a review of stormwater monitoring and data collection by the three councils responsible for the Lake Macquarie, Tuggerah Lakes and Brisbane Waters estuaries. The aim was to design a rigorous monitoring programme for the entire central coast (Dickinson et al., 2005). This may also help to determine the size of the contribution from existing urban areas. Recognising the cost of retrofits for existing urban stormwater treatment, Council has, on a number of occasions, launched education campaigns to try and limit the inflows of sediment and nutrients from the catchment. Without consistent monitoring it is difficult to gauge whether these campaigns have been effective, however the general improvement in awareness would undoubtedly be having flow on effects.

Council's Environment Business Plan identifies the focus of nutrient and sediment management improvements for Council in a given year. For 2002/03, more than \$500,000 had been earmarked for projects related to reducing sediment and nutrients from existing urban areas.



Figure 14. Stormwater drain entering the estuary.



Figure 15. Example of water sensitive urban design.



Figure 16. Constructed wetland at the end of a stormwater drainage system.

2.2.7 Sewerage Management

The reticulated sewerage system of Wyong Shire is generally confined to the urban areas, with septic systems being used in the rural areas. The reticulated system has built-in failure points where sewage can overflow in case of pump failure, or similar problems. Generally, the overflow points will be adjacent to stormwater systems or a waterway. Given that sewage is high in nutrients and turbid, it can have a significant impact on downstream environments. Septic systems, if well contained and frequently serviced, do not necessarily increase sediment and nutrient loads. However, poorly maintained systems can overflow or fracture, leaching nutrients and sediment into surface and groundwater flows.

The reticulated system overflows relatively infrequently. However, it should be remembered that the reticulated system is composed of both a domestic sewerage line and trade waste line. Both lines have an overflow capacity, which allows discharge into the stormwater system. A significant overflow to Tumby Creek occurred in May 2003, which saw 72,000L of effluent discharged following a combined pump/power failure at a pumping station (WSC, 2003a). Although unintentional and quickly rectified, this kind of discharge can have significant nutrient impacts on downstream environments. Four non-significant sewage overflows occurred in the Wyong system during 2001/02. Two were due to blockages of mains and two due to power failure at pump stations (WSC, 2002). The overflow points are sometimes located adjacent to sensitive environmental areas. For example, the overflow at Fishburn Drain can discharge sewage and trade waste to the Porters Creek wetland.

There have been a number of positive steps taken to limit the contribution of sewage to sediment and nutrient loads to the estuary, wetlands and rivers. The Charmhaven Sewerage Treatment Plant is no longer discharging secondary treated wastewater to Wallarah Creek (it is discharged off Norah Head). Septic systems that were common in urban areas fringing the estuary have been replaced with the reticulated system. The water and sewerage network of Wyong Shire has an extensive telemetry system that alerts base monitoring stations in the event of a pump failure or large change in flow conditions. As part of Y2K planning, many major pump stations were fitted with backup generators. Although not the design intention, the generators assist in minimising overflows that occur during power outages. Council also has an active maintenance programme to minimise the occurrence of network failures and subsequent sewer overflows.

2.2.8 Hydrodynamics

The hydrodynamics (circulation, mixing and flushing) of an estuary are a function of its geomorphological characteristics such as shape, width, depth, and tidal regimes. The Tuggerah Lakes system is comprised of three coastal lagoons, which are open to the sea at the tidal delta at the entrance (Fig. 17). The estuary process study (Roberts, 2001) examined the hydrodynamics of the estuary and generally found that tidal flushing contributed very little