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Coastal Zone Management Study for Gosford Lagoons

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Gosford Coastal Lagoons Coastal Zone Management Study

Prepared For:	Gosford City Council
Prepared By:	BMT WBM Pty Ltd (Member of the BMT group of companies)

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BMT WBM Pty Ltd BMT WBM Pty Ltd 126 Belford Street BROADMEADOW NSW 2292 Australia PO Box 266 Broadmeadow NSW 2292 Tel: +61 2 4940 8882 Fax: +61 2 4940 8887 ABN 54 010 830 421 www.wbmpl.com.au	***Document :*** R.N1997.001.03 ***Project Manager :*** Michelle Fletcher ***Client :*** Gosford City Council ***Client Contact:*** Tim Macdonald ***Client Reference***

Title :	Gosford Coastal Lagoons Coastal Zone Management Study
Authors :	Michelle Fletcher, Verity Rollason, Philip Haines, Emma Gale
Synopsis :	This document provides a Coastal Zone Management Study for the four coastal lagoons located with the Gosford Local Government Area, namely Wamberal Lagoon, Terrigal Lagoon, Avoca Lagoon and Cockrone Lagoon.

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1 INTRODUCTION AND STRATEGIC CONTEXT

1.1 Why Develop a Coastal Zone Management Plan?

The coastal zone of NSW represents a priceless natural resource that is immensely valuable from an ecological, social and economic perspective. In addition to the open coast beaches and headlands, the NSW coastal zone contains over 130 estuaries that vary in size from small coastal creeks and lagoons to large lakes and rivers. Estuaries contain diverse ecosystems that form the foundation of the coastal food chain. They provide important habitats for a variety of marine and terrestrial plants and animals. These natural systems also provide important recreational and scenic centres for many coastal communities.

The four Gosford lagoons addressed in this study from north to south are Wamberal, Terrigal, Avoca and Cockrone Lagoons. The lagoons are important components of the local landscape from a socio-economic perspective (like the iconic paddle boats in Terrigal Lagoon) as well as a natural perspective (including the various species of flora and fauna that depend upon them).

Under the *NSW Coastal Protection Act 1979*, a Coastal Zone Management Plan may be prepared to address risks to estuary health through management actions to maintain, improve or protect estuary values. Therefore, Gosford City Council (Council) with assistance from the NSW Office of Environment and Heritage (OEH) resolved to prepare the Gosford Coastal Lagoons Coastal Zone Management Plan (CZMP) to 'provide strategic direction and guidance on future actions within the lagoons and their catchments, to preserve, improve or maintain the community and environmental values of the lagoons'.

Once certified, the CZMP shall be used to inform other strategic documents that aim to manage and rationalise human activities and development within the catchments, such as Regional Strategies, Local Environmental Plans (LEPs) and Development Control Plans (DCPs). The CZMP will need to be considered when assessing new developments in accordance with Section 79C of the *Environmental Planning and Assessment Act, 1979*.

The CZMP aims to fulfil Council's requirement for applying the principles of Ecologically Sustainable Development (ESD) to the Gosford Coastal Lagoons and their catchments. The CZMP will also provide an opportunity for future climate change to be considered in the strategic management and planning of the lagoons and surrounding sensitive coastal lands.

Over the past 2 years the NSW Government has introduced various reforms to coastal management, including the release of the *NSW Sea Level Rise Policy Statement (2009)*, reforms to the *Coastal Protection Act 1979* (and other Acts) and new *Guidelines for Preparation of Coastal Zone Management Plans* (DECCW, 2010). The Gosford Lagoons CZMP satisfies the intent and objectives of these new reforms, as well as the fundamental management principles espoused in the *NSW Coastal Policy 1997* and the previous *Estuary Management Policy 1992*. It is noted that under the recent reforms, including the gazettal process, the final document will be officially called a "Coastal Zone Management Plan" (CZMP) for the Gosford Coastal Lagoons, and is largely the same as previous Estuary Management Plans developed for similar waterways.

This document, the Gosford Coastal Lagoons Coastal Zone Management Study (CZMS) provides the preceding step to preparation of the CZMP. It builds upon the information provided in the preceding Coastal Lagoons Estuary Processes Study (Cardno, 2010) to provide a prioritised list of potential management options for the Lagoons, based on input from Council as well as State Agencies, the community and other stakeholders. The management options presented in this Study fundamentally aim to improve, protect or maintain the environmental and community uses and values of Gosford's Coastal Lagoons.

Implementation of the Coastal Zone Management Plan will essentially be facilitated by Council. Other stakeholders including the State Agencies and the general commuinty may also be responsible for the implementation of some actions (indirectly or directly). The community has a keen interest in the future management of the Gosford Coastal Lagoons, and therefore their values and concerns have been considered and addressed as far a reasonable during preparation of this document.

1.2 Area Covered by the Coastal Zone Management Plan

The planning process to which this study applies covers:

- Wamberal Lagoon;
- Terrigal Lagoon;
- Avoca Lagoon; and
- Cockrone Lagoon.

The lagoon catchments are also considered insofar as they influence environmental processes and estuary health. The four lagoons are illustrated in Figure 1-1. The Gosford Lagoons are unique types of estuaries as they have an intermittent connection to the ocean (i.e. they are Intermittently Closed and Open Lakes or Lagoons [ICOLLs], refer Haines, 2008).

The Gosford coastal lagoons featured in this study have natural and acquired similarities and differences. Anthropogenic influences include the developed land within catchments, modification of foreshore areas, and artificial opening of lagoon entrances in order to mitigate flooding of low-lying foreshore areas when the entrances are closed to the ocean. These influences have placed different levels of 'pressure' upon the lagoons, with commensurate impact on their health and condition. ICOLLs naturally have a low tolerance to external pressures compared to other estuary types, so they need to be carefully managed and conserved in order to prevent significant environmental degradation.

1.2.1 Wamberal Lagoon

Wamberal Lagoon is the northernmost lagoon and is largely encompassed within the Wamberal Lagoon Nature Reserve. The extensive riparian vegetation around the lagoon provides a buffer from stormwater runoff and the two largest tributaries that enter the lagoon through Wamberal Park.

The trigger for artificial opening of the entrance (by Council) is when lagoon water levels reach 2.4 metres AHD. This trigger is typically reached three times a year with the entrance remaining open for an average of ten days at a time. The majority of the lagoon is shallow with a slightly deeper section close to the entrance (down to -1.5m AHD).

1.2.2 Terrigal Lagoon

Terrigal Lagoon is a popular recreation location for both locals and tourists, and as a result is subject to community pressure to provide healthy waters and adequate water depths, especially during the summer months.

The waterway area of the lagoon is relatively small and is shallow, with artificial entrance openings initiated when water levels reach 1.23m AHD, primarily to mitigate flooding of residential properties. Historical dredging (with holes down to -3m AHD) occurred in the 1960's for the reclamation of foreshore areas for residential housing.

The trigger for artificial opening of the entrance (by Council) is when lagoon water levels reach 1.23 metres AHD. This trigger is typically reached 12 times a year with the entrance remaining open for an average of eight days at a time.

1.2.3 Avoca Lagoon

Avoca Lagoon is situated between the townships of North Avoca and Avoca. The lagoon has the largest variability in depths across all four Gosford lagoons. It also has the longest shoreline. Artificial entrance openings are triggered when water levels reach 2.09m AHD as a means to alleviate localised foreshore flooding. Openings occur on average 3 - 4 times per year.

Sand was dredged from Avoca Lagoon during the 1980's and continued until the commercial venture failed in the 1990's.

Considerable wetlands exist around the fringes of the lagoon and a large percentage of these are state recognised. The endangered Green and Golden Bell Frog inhabit Bareena wetland on the eastern edge of Avoca Lagoon. The wetland is artificial formed in response to the laying of sewer pipes in the 1980s, a wall of earth and rocks traps fresh water. The wall is semi permeable and saltwater also enters is response to lagoon entrance openings. Water levels within the wetland also respond rapidly to water level changes within the lagoon

1.2.4 Cockrone Lagoon

Cockrone Lagoon is the smallest of the four lagoons, and the least impacted by urban development, with a catchment that is almost 70% forested. Cockrone Lagoon also has the highest of the artificial entrance opening trigger water levels, which is set at 2.53m AHD. Although the trigger level is quite high, the lagoon still experiences on average 2.4 openings per year.

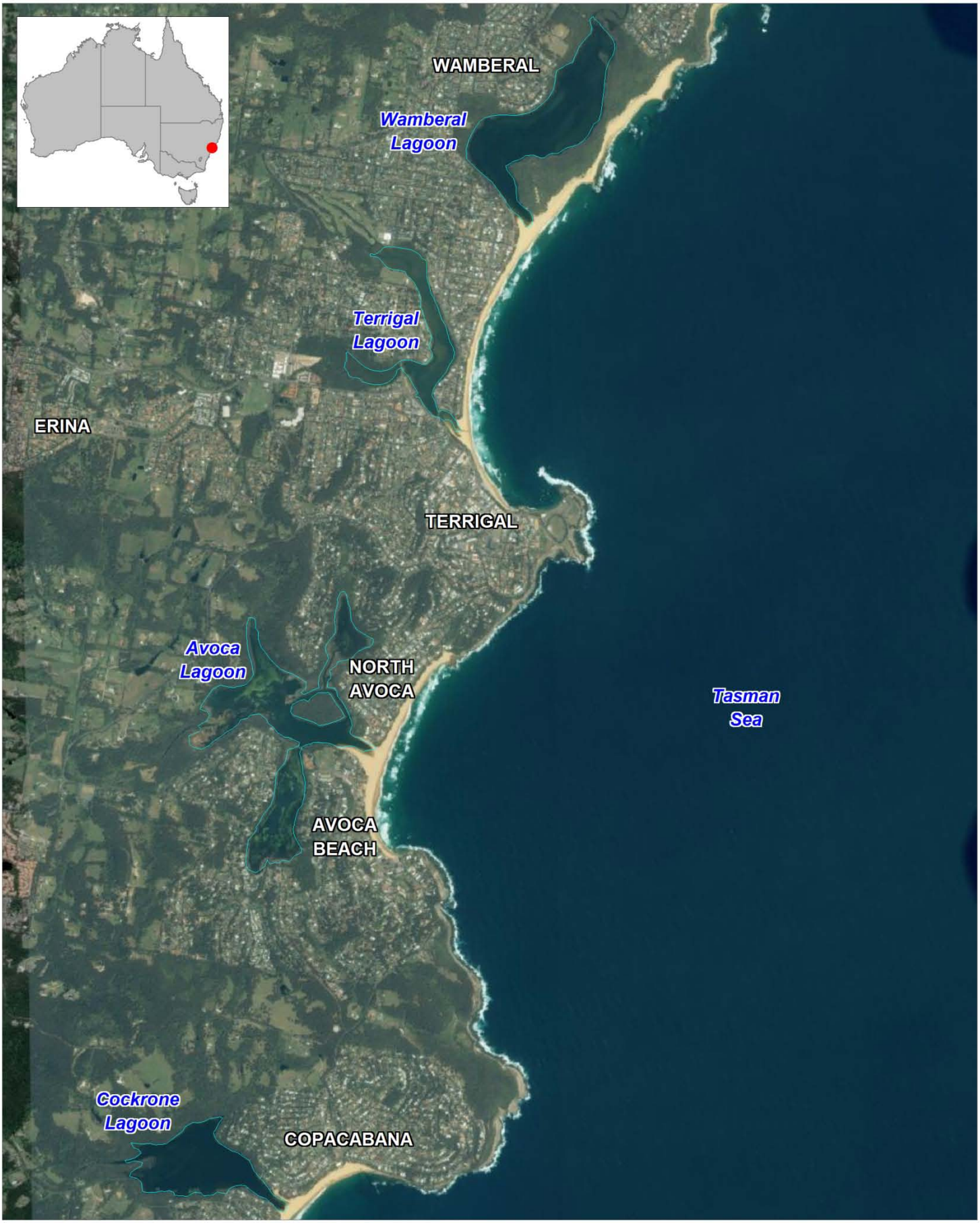
The lowest bed elevation of Cockrone Lagoon is approximately -0.1 m AHD, which is quite shallow, and likely promotes efficient wind driven mixing of waters within the lagoon. It is regarded though that the shallow nature of the lagoon also promotes algal growth due to effective light penetration through to the bed of the lagoon.

1.3 One Plan for Four Lagoons

There are a number of advantages to preparing a single Coastal Zone Management Plan that covers all four Gosford Coastal Lagoons, including:

- The similarities (values, threats) across the four lagoons require the same or similar management responses. That is, many of the management actions are applicable to all four lagoons, and indeed, are valuable actions to be implemented across the entire Gosford Local Government Area;
- Application of actions across a broader area or the entire LGA scale provides greater efficiencies of scale, as well as being more attractive when seeking grant funding to implement works;

Aspects of the four lagoons (including values, threats etc) that are different can still be specifically addressed by separate actions within the one CZMP, ensuring the individuality of the lagoons is not lost, but is being managed appropriately within a streamlined process that is easier for Council to manage.



Title:

Study Area for the four Gosford Coastal Lagoons

Figure: 1-1

Rev: A

N

0 0.75 1.5km

Approx. Scale

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Filepath : K:\N1997 Gosford Lagoons CZMS&P\MI\WOR\DRG_001_120503_ LocalityFig1-1.WOR

1.4 Community Use of the Gosford Coastal Lagoons

The Gosford Coastal Lagoons provide a wealth of opportunities for the community to interact with these unique natural environments. These interactions include a range of passive recreational activities such as bird watching and nature appreciation, as well as more active pursuits, such as swimming, kayaking and paddleboating.

Although not directly appreciable, the community also benefits from the lagoons, and their modified conditions by acting as receiving water for urban runoff. Flooding of surrounding private properties is also mitigated through pro-active management of entrance berm heights of the lagoons.

The purpose of this document is to provide a mechanism for focusing limited funds towards best and highest value works, actions and initiatives, that will ultimately result in improved and sustainable opportunities for use of the lagoons by both the environment and the community.

1.5 Legislative and Strategic Planning Context of the CZMP

1.5.1 NSW Estuary Management Process

Up until recently, the Estuary Management Process in NSW was guided by the Estuary Management Policy (1992) and accompanying Estuary Management Manual (1992). This was replaced in 2011 by the NSW Government's *Guidelines for Preparing Coastal Zone Management Plans* (DECCW, 2010) ('the CZMP Guidelines'). There has also been changes to various legislation and other State policies that supports the recent coastal reform initiatives, including the release of the Sea Level Rise Policy Statement (2009). .

Under the new CZMP Guidelines, estuary management is required to focus on addressing risks to the health of estuaries through practical management actions. Estuary health has become a focus because this is not explicitly investigated or managed through other council or state planning processes.

As outlined in the CZMP Guidelines, a CZMP that addresses coastal ecosystem health management should include the following, which may be commenced in stages:

1. A description of the health status of the estuary, the pressures affecting the estuary health status and their relative magnitude, and projected climate change impacts upon estuary health including consideration of the NSW Sea Level Rise Policy Statement benchmarks, which may be documented in an Estuary Processes Study;
2. Identify the management objectives based on conservation of environmental and community values, and prioritise the issues or threats to those values that require treatment;
3. Preparation of management options to respond to the identified pressures or threats to estuary health and values, which should include an understanding of the existing planning and legislative framework for the CZMP;
4. Assessment of the costs and benefits of the management options, including community acceptability, to select preferred management actions;

5. Prepare an implementation schedule for the preferred management actions, which indicates the timeframe (or trigger), responsibilities and performance measures for implementation as well as potential sources of funding;
6. Present the plan to Council for adoption, then to the Minister for Certification, after which it may be gazetted by Council; and
7. Monitor and review the plan on a regular basis (5-10 years).

Step 1 has been completed for the Gosford Coastal Lagoons (refer Cardno, 2010). This document (the Coastal Zone Management Study) aims to address Steps 2 to 4 of the above list, while the Implementation Schedule (Step 5) will fundamentally form the basis for the formal Gosford Lagoons CZMP. Progress through this process has been co-ordinated by the Gosford Coast and Estuary Management Committee (CEMC), which has representatives from Gosford City Council as well as key state agencies and other stakeholders.

A key doctrine of the CZMP Guidelines is the adoption of a risk-based approach to the management of estuary health. The Risk Management Principles and Guidelines (Australian Standard ISO 31000:2009) have therefore been applied to the development of this document, fulfilling this requirement. A risk-based approach has several key advantages for the management of estuaries, including:

- all risks or threats are assessed and compared equally, ensuring that management efforts are directed towards those areas or issues that post the greatest risk to estuary health and sustainability;
- the process enables better streamlining of the Plan with existing Council operational and strategic plans, as the risk approach inherently requires existing management efforts to be included in the assessment of risk, avoiding the duplication of actions in the CZMP;
- the risk approach identifies the highest priority risks that are not currently being adequately managed through any other process, targeting management resources towards the highest priority issues;
- management options can be designed to reduce the likelihood or frequency of occurrence of the risk (e.g. an adaptation action to raise floor levels to reduce the likelihood of flooding) and / or the consequence of the risk (e.g. an intervention action for the regular cleaning of stormwater treatment devices); and
- where there is a high level of community concern regarding an issue that presents a low risk, monitoring and trigger levels can be set for the risk without absorbing substantial funding resources unnecessarily.

1.5.2 Meeting the Coastal Management Principles

The CZMP Guidelines outline a number of 'Coastal Management Principles' that should be achieved in the preparation of CZMPs. Under Section 733 of the *Local Government Act 1993*, councils are taken to have acted in 'good faith' and receive an exemption from liability of coastal hazards and risks where their actions were done substantially in accordance with the CZMP Guidelines, including the Coastal Management Principles.

The Coastal Management Principles and the manner in which these are addressed through this Gosford Lagoons Coastal Management Study, are described in Table 1-1.

Table 1-1 Coastal Management Principles Addressed by the Gosford Coastal Lagoons CZMS

	Coastal Management Principles (DECCW, 2010)	Addressed by Gosford Lagoons CZMS	Report Section
Principle 1	Consider the objectives of the *Coastal Protection Act 1979* and the goals, objectives and principles of the NSW Coastal Policy 1997 and the *NSW Sea Level Rise Policy Statement (2009)*	The preparation of this CZMS has followed the *Guidelines for Preparing Coastal Zone Management Plans* that is the manual for implementation of the objectives of the Act for CZMPs. In determining the intent for management of the coastal lagoons, the NSW Coastal Policy has been considered. The NSW Sea Level Rise Policy Statement (2009) has been explicitly utilised in determining the threats to the lagoons from sea level rise.	Sec 1.1 & 1.5.1 Sec. 3.6 & Ch 5
Principle 2	Optimise links between plans relating to the management of the coastal zone	By using a risk-based approach, existing controls within existing plans are reviewed and incorporated into the analysis of risk, and also used as starting point for developing risk treatments (i.e. management options).	Sec 5.4
Principle 3	Involve the community in decision-making and make coastal information publicly available.	Comprehensive community consultation has been undertaken throughout the development of this plan.	Sec 1.7
Principle 4	Base decisions on the best available information and reasonable practice; acknowledge the interrelationship between catchment, estuarine and coastal processes; adopt a continuous improvement management approach.	An investigation of the scientific aspects of the four lagoons was conducted. This was combined with community consultation and further investigations to identify the community values and human pressures upon the lagoons. The environmental and community values and threats to the lagoons are based upon these studies and information. The management intent has been based upon each estuaries values and the threat assessment has utilised this information. Both the degree of threat and values for the lagoons was used as the basis for preparing management actions.	Ch 2, 3, 4.3 & 5
Principle 5	The priority for public expenditure is public benefit; public expenditure should cost effectively achieve the best practical long-term outcomes	Cost benefit analysis for management options has recognised the public benefit as priority for management options	Sec. 6.4.2

	Coastal Management Principles (DECCW, 2010)	Addressed by Gosford Lagoons CZMS	Report Section
Principle 6	Adopt a risk management approach to managing risks to public safety and assets; adopt a risk management hierarchy involving avoiding risk where feasible and mitigation where risks cannot be reasonably avoided; adopt interim actions to manage high risks while long-term options are implemented	This plan has been prepared using the ISO 31000:2009 International Standard Risk Management Principles and Guidelines. The risk based approach is an internationally recognised framework for management because it incorporates the best available information and its uncertainty. The adopted Risk Management Framework intrinsically requires ongoing monitoring of risks and review and tailoring of risk treatments (management options).	Ch 5 & 6
Principle 7	Adopt an adaptive risk management approach if risks are expected to increase over time, or to accommodate uncertainty in risk predictions	The Risk Management approach is an internationally accepted standard that intrinsically incorporates both the known and possible frequency and consequence of a threat, thereby incorporating the uncertainty in the occurrence of risks / threats. The Coastal Zone Management Plan will include an ongoing monitoring and evaluation component, linked to an estuary health monitoring program.	Ch 5 & 6
Principle 8	Maintain the condition of high value coastal ecosystems; rehabilitate priority degraded coastal ecosystems	Ability of a management option to provide environmental protection or benefit has formed part of cost benefit analysis of options. Ecological values have been linked to future management intent to allow high value ecosystems to be prioritised for improvement while the objective for other areas is to maintain values at their current level.	Sec 4.3.2 & 6.4
Principle 9	Maintain and improve safe public access to beaches and headlands consistent with the goals of the NSW Coastal Policy	The open coast and rocky headlands are not included in the study area. Public access to lagoon areas has been included.	N/A to Study area
Principle 10	Support recreational activities consistent with the goals of the NSW Coastal Policy	Recreational usage is an important component in determining the values of each lagoon. The management intent for each lagoon has considered the recreational values to a level that is appropriate with the community and environmental uses of the lagoon. This has facilitated the management of recreation activities in a manner that is consistent with the values of each lagoon in accordance with the NSW Coastal Policy.	Sec 4.3.2

1.5.3 State and Commonwealth Legislation and Policies

There are a number of State Parliamentary Acts, Policies and guideline documents that are relevant to the management of the Gosford Coastal Lagoons. The relevant legislative documents are listed below, with detailed review given in Appendix A:

- *Environmental Planning and Assessment Act 1979;*

- *State Environmental Planning Policy (SEPP) No. 71 – Coastal Protection;*
- *SEPP No. 14 – Coastal Wetlands;*
- *SEPP (Infrastructure) 2007;*
- *Coastal Protection Act 1979;*
- *NSW Sea Level Rise Policy Statement 2009;*
- *Threatened Species Conservation Act 1995;*
- *National Parks and Wildlife Act 1974;*
- *Fisheries Management Act 1994;*
- *Local Government Act 1993;*
- *Crown Lands Act 1989;*
- *Water Management Act 2000*
- *Protection of the Environment Operations Act 1997;*
- *Catchment Management Act, 2003;*
- *Natural Resource Management Act, 2003*
- *Environment Protection and Biodiversity Conservation Act 1999;*
- *The NSW Coastal Policy 1997;* and
- *The former Estuary Management Manual 1992.*

1.5.4 Regional and Local Environmental Planning Instruments

The Central Coast Regional Strategy (CCRS) was developed by the NSW Department of Planning (DP) as a long-term land use plan for the region. The Strategy covers the Gosford and Wyong Shire LGAs. It contains policies and actions designed to cater for the region's projected housing and employment growth over the period to 2031 and outlines how and where future development should occur. Significant growth is not expected to occur in the study area.

Until recently the Gosford Planning Scheme Ordinance (GPSO) was the principal planning instrument for Gosford urban areas and Interim Development Order No 122 (IDO 122) was the principal planning instrument for the non-urban areas. However on 11 February 2014 the Minister for Infrastructure and Planning made the Gosford Local Environmental Plan (LEP) 2014 which for large areas of the LGA, replaces the GPSO, the IDO 122 and the Gosford City Centre LEP 2007 (outside of the study area) as the principal planning instrument for Gosford. It was prepared under the direction of the State Government to all local councils, as per the Standard Instrument (Local Environmental Plans) Order 2006 ('the Standard Instrument'). The Standard Instrument Order provides for set land use zonings and definitions of permissible uses that must be used by all NSW councils in preparing their revised

LEPs. In general, the new zonings given to the land parcels in the Gosford LEP 2014 aim to be as closely aligned as possible with the previous land use zonings and definitions. The LEP also sets out provisions such as building height, FSR and lot size, heritage significance etc

The Coastal Open Space System (COSS) does not fit within any of the zonings available for use from the Standard Instrument, but is recognised by both Council and DPI as important for the preservation of environmentally sensitive lands, with substantial positive benefits to the community. As such, until such time as an appropriate land use zoning is available in the standard template, all Council owned and managed Coastal Open Space System (COSS) lands and all privately owned lands zoned Conservation 7(a) and Scenic Protection 7 (c2) located east of the M1 Motorway have been deferred from the LEP. The provisions of the Gosford Planning Scheme Ordinance (GPSO) and Interim Development Order No 122 (IDO No 122) remain in place as they relate to this land.

Gosford Development Control Plan (DCP) 2013 came into effect with the Gosford LEP gazettal. It provides a document that is better streamlined with the new LEP format, and includes additional provisions. For Gosford, this has involved the compilation of many individual DCPs into a single document. In general, the new DCP format provides development controls for land use types (e.g. low density residential), specific areas (e.g. Gosford City Centre) and environmental or risk aspects (e.g. floodplain management). There are aspects of lagoon management that have been incorporated. The DCP has retained the provisions of DCP 89 Scenic Quality which rank different landscapes in terms of their state, regional or local significance, together with describing their scenic conservation issues, development absorption capacities, visual sensitivities and statements of significance. (Gosford Draft DCP Part 2, Chapter 2.2).

1.5.5 Previous Coastal Lagoons Management Plan

The previous Coastal Lagoons Management Plan (CLMP) was adopted by Council in 1995. It was prepared under the guidance of the Coastal Management, Lagoon Management and Coastal Planning Committee (CLP Committee) largely in accordance with the Estuary Management Process. The CLMP describes the issues faced by each of the lagoon at the time of preparation. The CLMP provides a suite of general Lagoon Management strategies as well as a series of individual strategies for each of the lagoons.

Issues identified in the CLMP that are common to all the lagoons include:

- Loss of vegetation;
- Poor Water Quality;
- Acid Sulphate soils;
- Lagoon Water Levels and Opening strategies;
- Extent and type of catchment development;
- Recreational Usage; and
- Threats to habitat values.

Implementation of the previous Estuary Management Plan has not been documented. An understanding of the experience in implementing the former plan would be helpful in designing the present plan. For example it would be useful to know which of the suggested actions were

implemented, the relative success of those implemented, and the reasons for not implementing others. The relevance of actions within the prior Plan is discussed in Section 1.5.5. To help overcome this gap, a rapid audit of implementation of the Gosford Coastal Lagoons Management Plan 1995 was undertaken during the risk assessment workshop conducted as part of this study,.

1.6 Land Tenure

Crown Land is land vested in the Crown and managed by the NSW Department of Primary Industries Catchments and Lands Division (CLD) under the Crown Lands (CL) Act 1989. Crown lands are managed by CLD for public recreation and enjoyment, environmental conservation and heritage conservation purposes. Any land below the mean high water mark (MHWM) is classed as Crown land .

National Parks are dedicated under the National Parks and Wildlife Act 1977 (NP&W Act) and are managed by Office of Environment and Heritage (NPWS). There are three National Parks falling within the bounds of the study area: Wambina Nature Reserve, Wamberal Lagoon Nature Reserve and Bouddi National Park . The *National Parks and Wildlife Act 1974* requires that a plan of management be prepared for each nature reserve. A plan of management is a legal document that outlines how the area will be managed in the years ahead.

There are associated Plans of Management (POM) in place for the Wamberal Lagoon and Wambina Nature Reserves. The Wamberal Lagoon Nature Reserve POM was prepared in 1991, so is in need of revising and updating. For example, the issue of sea level rise is only briefly mentioned in terms of impacts on the water table, so a more up to date and thorough consideration of this threatening process would be of benefit.

Coastal Open Space System (COSS) lands are an important asset that protects the catchments of the Gosford Lagoons. COSS is a network of bushland reserves set aside and managed for their natural beauty and nature conservation values. The COSS was created in 1984, and Council continues to actively purchase identified high nature conservation value land as it becomes available. Funding for purchasing and managing the COSS bushland reserves comes from rates and special contributions made by developers.

COSS lands have been set aside and are actively managed by Council as continuous open space areas in order to achieve multiple objectives relating to nature conservation, ecological connectivity, scenic quality and recreational usage. The lands have either been acquired by or dedicated to Council, and are managed in accordance with Council's Draft COSS Strategy (GCC, 2010). The COSS Strategy has been prepared to provide a strategic planning rationale for the operation and management of the COSS. A number of actions are identified within this strategy that, when implemented, will assist in the operation and management of the COSS (GCC, 2010) Under the COSS the most important lands (environmental and visual qualities of lands) are progressively bought into public ownership.

COSS land acquisition is partially funded under contributions paid for "bonus lot" subdivisions (i.e. smaller than the minimum 2 hectare lot size, but greater than 1 hectare). Council wants to continue these provisions and has included a clause in the draft LEP 2009, with additional matters for consideration in the draft DCP 2009.

Native Title is the recognition by Australian law that Indigenous people have rights and interests in their land that come from their traditional laws and customs. A review of the mapping provided by the Native Title Tribunal indicates that there are no active native title claims within the study area (Cardno, 2008).

1.7 Community Consultation

The development of a Coastal Zone Management Plan requires the involvement of the community, including state agencies, stakeholders groups and directly and indirectly affected residents across the Gosford LGA and greater region who utilise the coastline in many different ways. Community involvement is crucial to the preparation of a plan that is considered acceptable, within financial and technical constraints. A careful and comprehensive consultation process has been conducted to ensure community values and priorities have been incorporated into preparing and selecting the management strategies and actions that will form the Gosford Lagoons CZMP. The following consultation activities have been, and will be, conducted:

- During the preparation of the Gosford Coastal Lagoons Processes Study (Cardno, 2010) consultation was undertaken with a range of stakeholders, community members and the CEMC in the form of direct stakeholder correspondence, a public information session and periodic meetings with the committee;
- For the first stage of the preparation of the CZMS, a series of four community workshops were held in June 2011 (one for each lagoon). The meetings were open invitation and were advertised through local newspapers and on local radio. Over the course of the two hour meetings, community representatives were asked to document values and threats for the relevant lagoon through a series of group activities. Management options that were suggested during this process were also documented for use in the preparation of the options for the CZMS;
- The next stage of consultation involved a one day workshop held on September 1st 2011 to analyse and evaluate the risks to lagoon health, with attendance from 23 representatives of Council, the CEMC and various state agencies. The workshop involved setting objectives for the CZMP and confirming the values identified for the lagoons. A threat assessment was then conducted (primarily for Avoca Lagoon as a case study), in which threats to the lagoons were confirmed by attendees, then analysed in terms of frequency and consequence, to prioritise the threats requiring management attention. Last, a group discussion was held to document the achievements of the previous Gosford Lagoons Management Plan and capture other existing controls;
- The values and management intent for all lagoons were discussed and assessed further at a second internal workshop attended by Gosford City Council and BMT WBM. This second workshop continued the methodology applied at the initial threat assessment workshop;
- Further consultation to be undertaken for this project will include presentation of the management options (within this Study) to the CEMC and community. The CZMP documenting the selected management actions will then be publicly exhibited, for further input from Council, the State Agencies and the broader community.

Through ongoing consultation with the community, it is anticipated that the recommended actions for managing threats to Gosford's Coastal Lagoons will be better understood and therefore accepted by community. This is particularly important where difficult decisions or trade-offs form necessary

actions. Conversely, there will be areas for which little to no action may be needed at the present time, and again, community have and will be involved in determining the level and type of action required to manage the threats to the Gosford Coastal Lagoons.

1.8 Structure of this Document

The information presented in this report ostensibly relates to the future community and environmental uses of the four Gosford Lagoons. Each chapter contributes to the final key outcome, which is a prioritised list of recommended options for detailed documentation within the following CZMP. These recommended options are listed in Chapter 6. The structure of this report is outlined in Figure 1-2 as a flow chart.

Each chapter focuses on a particular component of the flow chart, and is briefly described below. The flowchart demonstrates that the natural lagoon processes define the natural values of the lagoon. These natural values are threatened by external pressures ultimately leading to a modified set of values for the lagoons. It is then these modified values that are utilised by the environment and the community. Management options can focus reducing the threats to the values and/or improving the adaptability of the environment and the community to the modified values set. The difference between the natural values and the modified values that are considered acceptable to the environment and the community is regarded as the acceptable limit of change to the ecosystem processes.

Chapter 2 of this document outlines the ecosystem and other environmental processes of the coastal lagoons. The natural processes include freshwater inputs from catchment rainfall, saltwater influences during periods of open entrance, sediment transport, flora and fauna, and the interactions between these elements. These processes ultimately determine the ecosystem structure and function of the lagoons. The last section of Chapter 2 describes the natural values of the lagoons. These natural values arise from the prevailing coastal and catchment processes, and include feeding and breeding habitat for native fauna, biodiversity, and other intrinsic environmental values.

Chapter 3 details the external pressures imposed on the lagoons and their natural values. The external pressures are mostly human induced such as catchment development. It is the external pressures that threaten and modify the natural values associated with the Gosford Lagoons.

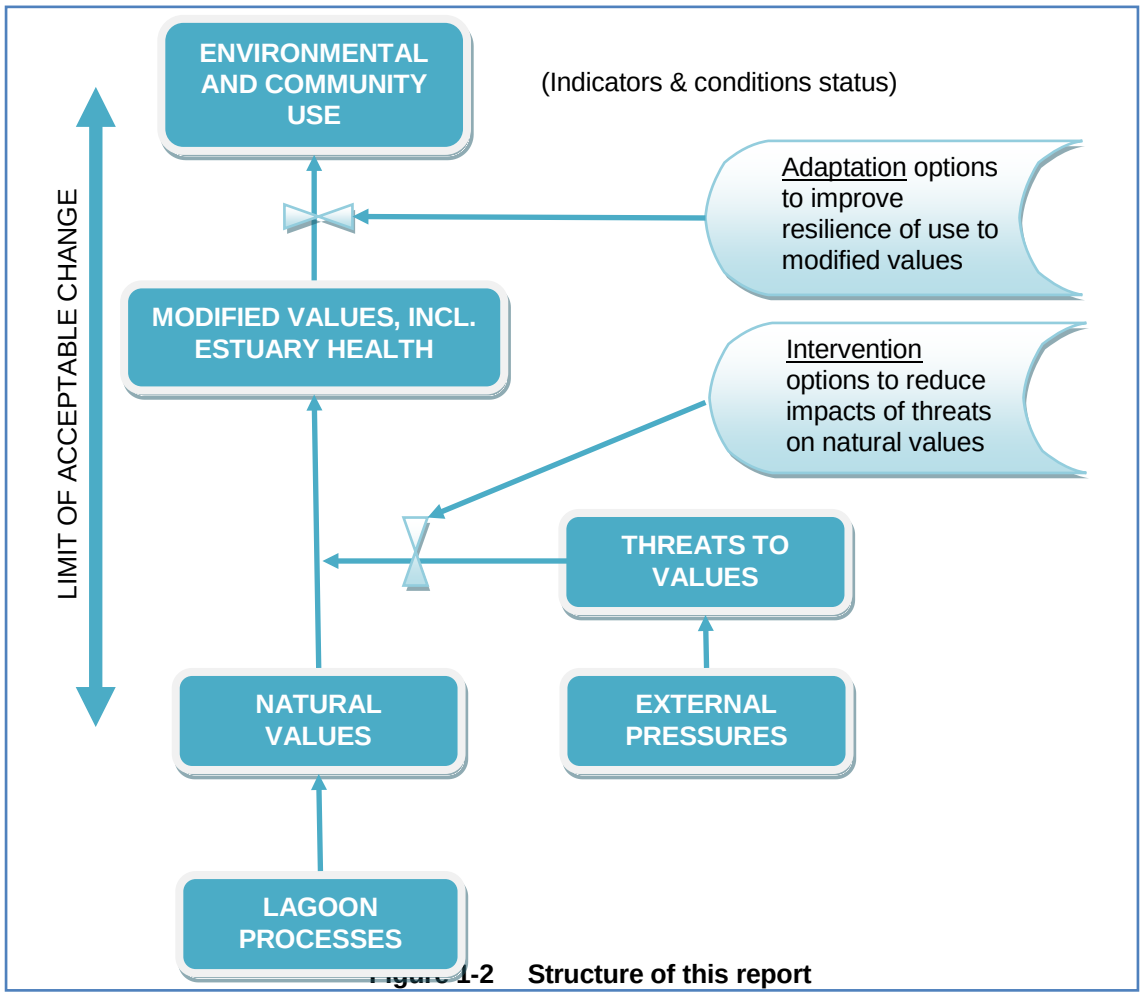

Figure 1-2 Structure of this report

Chapter 4 presents a summary of the resulting modified values of the Gosford Coastal Lagoons, including estuary health. The existing conditions of the lagoons are very different to how they might be in the absence of external pressures, particularly human impacts. The modified conditions of the lagoons therefore lead to a range of 'compromised' uses by the environment and the wider community.

Chapter 5 presents an assessment of the threats to natural values imposed by the external pressures. Specific threats to natural values have been considered for each of the lagoons, driven by external pressures. A risk management approach was adapted for the task. The exercise of identifying and prioritising threats contributes to the selection of a shortlist of options that will best allow ongoing community and environmental uses of the lagoons.

Chapter 6 provides a comprehensive assessment of potential management options aimed at addressing the modified values of the lagoons. The recommended options focus on either improving, protecting or maintaining existing (and potentially modified) values. The terms **improve, protect or maintain** represent a scale of acceptable change to the estuary values from their present condition to a possible future modified condition.

Options for treating threats have been designed to either improve the ability of the estuary to accommodate human activities (adaptation options) or to reduce the impacts of threats in modifying natural values (intervention options).

A short-list of preferred options is provided, giving guidance for development of the CZMP following this document. The short-listed options have been selected from an initial long list of over 100 options.

2 LAGOON PROCESSES

As outlined in the *Guidelines for Preparing Coastal Zone Management Plans* (DECCW, 2010), in order to identify the existing and potential pressures upon estuary health and values, the relationship between the following aspects need to be identified:

- Water quality and sediment quality;
- Flow conditions (including catchment inflows and tidal exchange);
- Sediment transport (sedimentation and erosion); and
- Estuarine biota (including aquatic and terrestrial habitats and species that utilise the estuaries).

The following summary of processes within the four Gosford lagoons is derived principally from the Gosford Coastal Lagoons Processes Study (Cardno, 2010). The document is a detailed scientific assessment of the physical, chemical and biological processes occurring within the lagoons, and the natural values associated with the lagoons.

Catchment processes and entrance condition are the two key drivers of the functioning of intermittently closed and open lakes or lagoons (ICOLLs) (Haines, 2006). Catchment inputs and entrance condition drive estuary hydrodynamics, in terms of rainfall inflows and tidal inflows, respectively. Chemical conditions in the lagoons are also influenced by the catchment land uses, which influence sediment, chemical (nutrients, metals etc) and freshwater inputs, and entrance condition, which controls tidal flushing for lagoon waters. The hydrodynamics and chemical conditions influence the ecology of the estuary.

Cardno (2010) describes catchment characteristics and lagoon processes separately. The summary given in this report outlines the natural processes (geology and topography; hydrodynamics, sediments, water quality, ecology), making note of the influences of the catchment and entrance to each of these aspects together. Likewise, the summary of external pressures described may occur from the catchment influences (e.g. land use) or entrance conditions (e.g. artificial openings).

2.1 Geology, Topography and Estuary Type

The majority of the study area is underlain by bedrock from the Narrabeen Group Terrigal Formation, overlain by the well-known Hawkesbury Sandstone of the Sydney Basin in some areas. Overlying this are Quaternary sediments, particularly alluvium (gravel, silt and clay) within the lagoons, and quartz sands within the barrier dunes and entrance berms.

The bedrock largely controls the catchment topography, while the Quaternary sediments are found in the floodplains and lagoons. Wamberal and Terrigal Lagoons have relatively large floodplains (relative to their catchment size) with lower lying areas situated around the lagoon foreshores. The land surrounding Avoca and Cockrone Lagoons generally rises more steeply from the foreshores, except at the lagoon entrances (Cardno, 2010).

The catchments extend up to 145 m above sea level to the northwest in the Wamberal catchment, 110 m to the south west of Terrigal Lagoon, 190 m to the northwest of Avoca Lagoon and 140 m to the southwest of Cockrone Lagoon (Cardno, 2010). This reflects the relatively prominent headlands

bounding Macmasters Beach for Cockrone Lagoon and forming the southern boundary for Terrigal Lagoon, compared with the less prominent headlands for Avoca and Wamberal.

The four Gosford Coastal Lagoons are classified as wave-dominated type estuaries. That is, the lagoons are characterised by a sand barrier (separating the estuary from the ocean) that may experience wave washover during storms, a narrow tidal inlet and a tidal delta at the entrance. Tidal energy is typically limited, due to the narrow inlet and entrance barrier (Masselink and Hughes, 2003). The Gosford Lagoons are also classified as Intermittently Closed and Open Lakes or Lagoons (ICOLLs), and are typically closed to the ocean (Haines, 2006).

2.1.1 Lagoon Bathymetry

The lagoons are generally broad, shallow basins, with typical bed levels as follows (Cardno, 2010):

- Wamberal Lagoon: -2.05 to 3.07m AHD; predominant depth 0.9-1.0m.
- Terrigal Lagoon: -3.10 to 1.02m AHD; predominant depth 0.5-0.7m.
- Avoca Lagoon: -3.98 to 5.96m AHD (presumably Bareena Island) ; predominant depth 0.8-0.9m.
- Cockrone Lagoon: -1.30 to 2.90m AHD; predominant depth 0.4-0.6m.

2.2 Hydrodynamics

2.2.1 Entrance Conditions

ICOLLs, such as the four Gosford Lagoons, are characterised by sandy berms or bars across their entrances, which close the lagoons off from the ocean. The entrance berm is built by open coastal processes, that is, the action of swell waves, the wind and the tide.

Once the entrance is closed, water circulation within the lagoons is driven by the wind and catchment inputs from rainfall, via creeks, stormwater and groundwater. The process whereby the entrance is opened is termed a ‘breakout’, and involves partial to complete scouring of the sand in the entrance berm and channel, delivering the sand back into the open coast (in the form of a nearshore sand bar). Such breakouts occur naturally when water levels in the lagoon reach a level that exceeds the level of the berm, usually after a significant rainfall event. Following an initial minor breach of the entrance berm, scour of the outflow channel enlarges the breach, eventually creating a substantial entrance channel and open entrance condition. Such breakouts usually take several hours to develop and, depending upon the water level in the lagoon and the adjacent ocean, may significantly drain the lagoons.

During open entrance conditions, tidal exchange with the ocean may dominate water circulation within the lagoons. The coastal processes involved with this tidal exchange also deliver marine sand back into the entrance area, eventually building an entrance berm and closing off the entrance once again. The process of closing the entrance can take days to weeks or even even months, depending upon dominant coastal conditions as well as on-going catchment inputs (whicph helps to self-scour the entrance channel with high outflows).

Thus coastal processes and catchment processes are continually competing for dominance over the entrance condition. For mostly closed lagoons such Gosfords coastal lagoons, the net catchment inputs are less dominant than the action of waves and tide driven currents that deliver sand into the

entrance area. The generally limited tidal exchange of the lagoons impacts the type of estuarine vegetation found within the waterways. Most notably, mangroves are not typically found in closed lagoons such as at Gosford.

When closed (which is the majority of the time), water quality and other environmental processes are dependent upon catchment inputs and wind driven circulation. Indeed when closed, the lagoons are terminal sinks for all runoff and discharges from the catchments.

During periods of drought where catchment inputs are minimal, entrance berms can accrete to levels of 3 m AHD or higher, well above the ocean water level. Sand delivered to the beach berm by waves is transported by Aeolian (wind-driven) processes to continue building berms high.

Given the variability in entrance berm levels, natural entrance openings may occur over a wide range of water levels. The variation in water levels during breakouts for closed lagoons such as those at Gosford can be very important for the ecology, particularly fringing vegetation such as saltmarsh, particularly where tidal exchange is limited.

In the case of the four Gosford coastal lagoons, the entrances are now mostly opened artificially by Council using an excavator. In this case, the frequency of entrance breakouts and hence, the time the entrance remains closed is governed by the artificial opening regime. WMA (1995) report that between 1974 and 1993, only one quarter of the breakouts for the lagoons occurred naturally.

The artificial opening regime limits the potential for water levels to reach their natural peak level, and will have impacts upon aquatic vegetation and fauna and water quality characteristics within the lagoons. For example, the EPS notes that while mangroves have not been previously recordered for any of the lagoons they are now present at Terrigal Lagoon. Artificial opening of the four lagoons is thus noted to be an external pressure in Section 3.2.

2.2.2 Tidal Exchange and Lagoon Water Levels

Lagoon water levels are predominantly controlled by the entrance condition. The entrance berm height governs the maximum potential water level in the lagoon, while the lowest potential water level in the lagoons is also governed by the entrance channel (i.e. after a breakout has occurred) and ocean water levels.

The water levels and patterns of tidal exchange observed in all the lagoons, particularly Terrigal Lagoon, are a result of the artificial management regime, which involves both a trigger opening level and a managed berm height. For the Gosford Lagoons, the berm height is managed by Council specifically to control the maximum potential water level in times of flooding rains where it may not be possible to access the lagoon in sufficient time to initial an artificial opening. The impact of artificial entrance management upon lagoon processes is discussed further in Section 3.2.

The lagoon breakout levels, the average duration of entrance opening, the average yearly breakout frequency and average yearly closure in wet, dry and average rainfall years and overall is presented in Table 2-1. Cardno (2010) undertook modelling to determine tidal flushing times within each of the lagoons, as presented with the average duration of entrance opening in Table 2-2. No catchment flows were supplied to the models that would reduce flushing times by causing a net transport through (i.e. out of) the lagoon. Therefore, the tidal flushing times represent maximum potential flushing rates.

Table 2-1 Lagoon Trigger Levels and Entrance Breakout Characteristics (based on data from 1976 – 2007) (Cardno, 2010)

Lagoon	Trigger level (m AHD)	Managed berm height (m AHD)	Entrance breakouts per year				Days open	Days closed			
			All	Wet	Dry	Mean	All	All	Wet	Dry	Mean
Wamberal	2.4	2.6-2.7	2.7	4.6	1.5	2.9	10	134.5	79.0	247.5	125.2
Terrigal	1.23	1.7	12.6	16.6	9.5	12.9	8	28.6	21.7	37.7	28.0
Avoca	2.09	2.7-2.8	3.2	4.7	2.1	3.5	21	112.7	77.1	172.2	102.9
Cockrone	2.53	3.3-3.5	2.5	4.4	1.4	2.4	9	144.9	81.0	264.0	151.6

Table 2-2 Estimated Flushing Time (from Cardno, 2010)

	Modelled e-folding[1] (flushing) Time (days)		Mean duration of tidal exchange (days)	
	Mean	Maximum	WMA (1995) & Gale *et al*. (2007)	Analysis of historic water level data
Wamberal	4.4	29.9	10	11
Terrigal	2.4	4.5	8	7
Avoca	7.4	35.1	21	12
Cockrone	7.4	40.2	9	9

For all the lagoons, the model results demonstrate that since the average e-folding time is less than the average duration of opening, the majority of the lagoon waterbody would undergo complete tidal exchange during an average entrance opening.

Terrigal Lagoon has the smallest range (i.e. variation from highest to lowest water level) of all the Lagoons, and as it is more frequently open, experiences tidal flows for around 33% of the time (Cardno, 2010). While Terrigal Lagoon experiences longer periods of tidal influence overall, the frequency of entrance breakouts at lower water levels reduces the number of days the entrance remains open. This is because the opening at a lower water level reduces the potential for scour of the entrance, increasing the speed with which the entrance is rebuilt. The low level that Terrigal is already opened at means there is basically no opportunity to reduce the let out level to alleviate the flooding issue in the vicinity of Lake View Road.

Avoca is opened at lower water levels than Wamberal and Cockrone, and remains open for longer than the other lagoons. This most likely relates to the size of the waterbody and relative input from catchment inflows, which will tend to reduce the effectiveness of coastal processes to close the

[1] E-folding time is the time it takes for a conservative constituent to reduce concentration from unity down to a value of 1/e (or 0.368).

entrance. The tidal flushing times indicated by Cardno (2010) suggest Avoca lagoon would be completely flushed after an entrance opening. As there are far fewer breakouts per year, Avoca Lagoon experiences tidal flows for around 10% of the time even though it is open for longer than the other lagoons.

Cockrone and Wamberal Lagoons have a greater range in water levels as consistent with their higher breakout and managed berm levels. Cockrone, with the highest berm height and highest breakout level remains open for only 9 days on average, which is similar to Terrigal Lagoon. Wamberal is similar, with relatively infrequent openings (2-3 per year on average) and remaining open for only 10 days on average, even though it has the second highest breakout level.

The tidal flushing modelling of Cardno (2010) indicates that Cockrone should be completely flushed during an opening event, but there may be times where this does not occur. Wamberal Lagoon has a lower tidal flushing time overall and so is also expected to be completely flushed after entrance opening. Wamberal and Cockrone experience tidal exchange for around 5% of the time (Cardno, 2010), as consistent with their shorter periods for open conditions.

These lagoons are most probably open for shorter periods of time as they have smaller catchments in relation to the lagoon area and volume. Accordingly, there are smaller catchment outflows to overcome the coastal processes that act to close the lagoon entrances. The typically higher breakout level and consequent efficient entrance scour does not seem to prevent their rapid closure.

2.2.3 Catchment Inputs

Catchment inputs are derived from rainfall across the catchment, which is directed into the lagoon waterbodies via the creeks, stormwater system, groundwater and overland flows. Rainfall volumes in any one year are directly related to the natural variability in the climate. Periods of excessive rainfall result in flooding of the creeks and lagoons.

The relative size of the catchment to the lagoon waterway is a very useful measure of the influence of catchment inputs in driving the hydrodynamics, or water movement, within the lagoons. The ratio of annual inflow to lagoon volume and catchment area to lagoon area for the four Gosford Lagoons is presented in Table 2-3. Catchment inputs dominate water movement within the lagoons, due largely to their typically closed entrance conditions (Cardno, 2010).

Major tributaries for the lagoons are also listed in Table 2-3. There are a number of additional creeks draining into the lagoons, however, these drain small sub-catchments (<1km^2) and are un-named, intermittent watercourses (Cardo, 2010). In addition, groundwater inflows (exfiltration) will also be a mechanism for catchment rainfall to reach the lagoons. Groundwater will flow downslope from the typically steep upper catchment areas and, when groundwater levels are higher than the lagoon water level such as after rainfall, flow through (exfiltrate) the banks into the lagoons. There may be some periods of infiltration into the groundwater table when lagoon water levels are higher, such as during droughts, until an equilibrium water level is reached. Occasionally during periods of low rainfall, the lagoon levels drop. This loss of water may be due to evaporation or seepage, or a combination of both.

Table 2-3 Catchment Relative to Waterway Size for the Gosford Lagoons (Cardno, 2010)

Lagoon	Catchment Area (km^2)	Major Tributaries	Average Annual Inflow / Volume	Catchment Area / Lagoon Area
Wamberal	6	Forresters Creek	4.9	12.3
Terrigal	9	North Arm Creek	19.9	32.6
Avoca	10	Saltwater Creek	5.3	17.5
Cockrone	7	Cockrone Creek Merchants Creek	5.7	19.6

2.2.4 Wind Waves and Circulation

Cardno (2010) investigated the potential for wind generated waves within each of the four lagoons under closed conditions using the SWAN nearshore wave transformation model to model wave heights generated by historical records for wind conditions.

The outcomes of the modelling exercise indicated that the largest waves generally occur along the north-eastern and north-western foreshores driven by strong southerly (SE-SW) winds across the water surface where sufficient fetch exists (Cardno, 2010). Not unsurprisingly, the wave model demonstrated that wave generation (height and length) is limited by the short fetch lengths across the lagoons.

Wave-induced bed forces can have the ability to mobilise sediment and organic particles. The SWAN model was used to prepare spatial maps of near-bed velocity and bed shear stress to identify regions where bed forces may be sufficient to initiate re suspension of bed sediments. Sandy regions can sustain greater bed velocities and thus dominate the shallow margins of the lagoons, while muddy or silty areas are found in the deeper sections.

Re suspension of sediments by wind waves and currents is a natural process, to which the existing ecology would be expected to be adapted. Turbidity due to boat waves, uncontrolled stormwater inflows and other human pressures, can impact upon biological function for aquatic flora and fauna, particularly for seagrasses, as they become smothered by the sediments. Re-suspension can also liberate nitrogen and other organic matter locked within the sediments. The unnatural sources or loads of nitrogen and organic matter that cause algal blooms are an issue for management, rather than wind driven re-suspension.

The outcomes of the investigation by Cardno (2010) suggest that seagrasses, located in the deeper parts of the lagoons, are unlikely to be negatively impacted by sediment re-suspension, which is a natural process. Indeed, the shallower margins that are more affected by wind waves and current are likely to be fully exposed after entrance breakouts when the water in the lagoon has drained.

2.3 Sediment Processes

2.3.1 Catchment Soils

The Erina soil landscape is the predominant soil type in the study area, which is classed as an erosional soil type. Erosional soils can be readily mobilised where exposed and may be transported into the lagoon during periods of high winds or rainfall events, as well as high turbidity within the lagoons after rainfall or wind-driven circulation. The erosive nature of the soils may also promote bank erosion where riparian vegetation is in poor condition or absent (Cardno, 2010).

2.3.2 Bed Sediments

The two general categories of sediments in lagoons are:

- fluvial sediments, which are derived from the catchment, entrained in stormwater runoff and flow via the tributary creeks into the lagoon, and will typically remain trapped within the lagoon; and
- marine sediments, which are delivered to the estuary from the open coast by waves and tides, and so are typically sand.

Sediment sampling for the lagoons cited by Cardno (2010) indicated the following:

- Sediments were predominantly sandy in Wamberal Lagoon. Coarse sands likely to be of marine origin have been deposited in deeper parts of the lagoon with coarse silts found in the upper lagoon associated with the outlet of Forresters Creek. Mapping also identifies some rock outcropping in the region of Remembrance Drive and offshore in this location;
- Terrigal Lagoon was found to be a predominantly fine sand environment, with some medium sand sampled from locations near where Lake View Drive and Bundara Avenue run along the foreshore. No rock outcropping was observed;
- Avoca Lagoon sediments comprise primarily fine sand, with some coarse sand sampled from sites located in the upper portions of the northern and western arms of the lagoon. No rock outcropping was observed; and
- Sediments within Cockrone Lagoon typically comprise fine sand, with an accumulation of coarse silts in a delta formation near the outlet of Cockrone Creek. A small area of rock armouring has been placed along the southern bank near the entrance.

2.3.2.1 Sediment Quality

Concentrations of heavy metals in surficial sediment samples reproduced in Table 2-4 are all well below the ANZECC Guidelines Interim Sediment Quality Guidelines Low Trigger Values (ISQG-Low values), except for cadmium. For cadmium, it is suggested that the values represented the lowest limit of reporting for the analytical techniques available at that time, rather than a contamination issue (Cardno, 2010).

Potential sources for contaminated sediments will be catchment derived sediments within stormwater runoff, or associated with contaminated sites such as landfill sites or petrol stations. Contamination of sediments in runoff may also be derived from agricultural land practices, particularly the use of pesticides in the past. The generally low density of development will have limited the potential for

contaminated sediments, compared with high density urban areas and industrial land uses. Potential pollutant sources are described in Section 3.3

Table 2-4 Mean Sediment Pollutant Concentrations (after: WMA, 1995)

Pollutant (mg/kg)	Wamberal Lagoon	Terrigal Lagoon		Avoca Lagoon		Cockrone Lagoon		ANZECC Guideline Values
	(Cheng 1992)	1991	1994	1991	1994	1991	1994	ISQG Low
TP	93.9	48.5	44.7	83.1	35.4	126.3	35.9	
TN	77.8	98.3	37.0	199.1	62.9	797.8	52.8	
Lead	BDL*	30.0		30.0		30.0		50
Copper	7.93	4.84		4.32		9.44		65
Zinc	28.2	9.58		11.18		43.78		200
Cadmium	BDL	3.00		3.00		3.00		1.5
Total Hydro-carbons	52.8	<1,000		<1,000		<1,000		

*BDL = Below Detection Limit

2.3.2.2 Acid Sulphate Soils

The risk of the occurrence of Acid Sulphate Soils (ASS) was determined by Cardno (2010) based upon data provided by Council from OEH.

For Wamberal and Cockrone Lagoons, the high risk ASS areas are confined largely to the defined bed of the lagoon or public foreshore lands. Therefore, the likelihood of disturbance due to excavation is low.

At Terrigal and Avoca Lagoons, areas identified as being high risk for ASS coincide with private development in some locations. There is a possibility that residents may be unaware of the risk and mobilise ASS during the course of some lot-based works. In general, the likelihood of this was considered low due to the requirement for a Development Application for most foreshore activities by private landholders.

2.3.3 Bank Erosion

In simple terms, those areas with good existing vegetation and / or protection works in good condition are less likely to experience bank erosion. Meanwhile, those areas of the foreshore that have limited vegetation (such as grassed or mowed edges) will be more susceptible to erosion under the natural action of wind waves or currents (such as during flood flows).

In general, the lagoon foreshores were found to be stable, with only isolated areas of erosion (Cardno, 2010). Based upon the assessment of foreshore condition (i.e. existing erosion locations), foreshore vegetation, condition of protection works and likelihood of wave impacts, Cardno (2010) categorised the risk of future erosion for the foreshore of all of the lagoons (refer Figures within Cardno, 2010).

Cardno (2010) conducted modelling to determine the potential landward extent of erosion due to wave forces alone. Outcomes of the assessment suggested Terrigal Lagoon was the most susceptible to erosion (maximum of ~ 3 m) relative to the other lagoons, Avoca Lagoon the least susceptible (maximum of ~ 1m) and Cockrone and Wamberal moderately susceptible (maximum of ~ 2m).

The usefulness of the wave erosion assessment for predicting the potential landward extent of erosion is limited because the assessment did not consider other processes that may generate erosion, such as flood flows and currents. The assessment also did not consider the vegetation or protection works in place that may constrain the impacts of waves upon the foreshore areas. Therefore, the results should be considered with caution and used in a relative manner only.

2.3.4 Sedimentation

Cardno (2010) conducted catchment modelling to estimate pollutant loads entering the lagoons, including sediment. Further modelling was then conducted to determine sedimentation, during closed conditions. Again, the model results must be used with caution, because the assessment did not consider periods of high flows (such as flooding flows from tributary creeks entering the lagoons, or outflows of lagoon waters during larger breakout events) during which sediment that had previously settled within the lagoon would potentially be scoured and transported to other parts of the lagoon or even into the ocean.

The range of sedimentation rates given by WMA (1995) and Cardno (2010) suggest:

- ~ 1 – 2 mm/year for Avoca and Cockrone Lagoons;
- ~ 2 mm/year for Wamberal Lagoon; and
- ~ 2 – 3 mm/year for Terrigal Lagoon.

This roughly equates to only 10 – 30 cm of reduced depth due to sedimentation over 100 years in the Lagoons, although there may be localised areas within the lagoons that have experienced higher rates, such as in close proximity to creek and stormwater outlets.

2.4 Water Quality

ICOLLs experience a large variation in water chemistry because they are at times closed from the ocean and at other times open to the ocean (i.e. after a breakout). During closed conditions, water quality is influenced by catchment and groundwater inflows after rainfall and so may be brackish or nearer to fresh water. Catchment inflows are a source of nutrients, which are then mixed and dispersed through the lagoon and taken up by primary producers (e.g. algae). During closed conditions, the lagoon may also become hypersaline during drought conditions when evaporation of the lagoon waters concentrates salts and any existing pollutants within the remaining water.

During open conditions when there is tidal exchange, lagoon water quality may become similar to that in the ocean (subject to the flushing efficiency of the lagoon). The similarity between lagoon and ocean waters will depend upon the time over which the entrance is open and proximity to the entrance (that is, the further from the entrance, the less effective the tidal exchange).

During both open and closed entrance conditions, lagoon water quality is influenced by accumulation (settling) and recycling processes in the sediments, as well as growth and decay of algae (which is linked back to nutrient inputs and settling and recycling of nutrients in the sediments).

The process of entrance closure and entrance breakout is natural for ICOLLs, which means that it is very difficult to define a "typical" water quality within the lagoon, and more importantly, when water quality is "good" or "bad". The ANZECC Guidelines provide default trigger levels for various water quality parameters for South-East Australian Estuarine Ecosystems. The levels stated are guidelines only and have not given specific regard to the unique functioning of ICOLLs (which give rise to significant natural variation in water quality). The ANZECC Guidelines therefore should be considered with caution.

While the ANZECC Guidelines for Primary and Secondary Contact Recreation are important measures for determining if and when recreational uses are safe in the lagoons, as both Terrigal and Avoca Lagoons are an important recreational resource. Council also applies the National Health and Medical Research Council (NHMRC) Guidelines to determine safe recreational use of the lagoons.

Based upon the water quality sampling conducted by Council and reviewed by Cardno (2010), a description of measured water quality in the lagoons is outlined below. Cardno (2010) noted that the measured water quality values represent a limited range of conditions in the lagoons (e.g. samples rarely captured breakout events or open entrance conditions), and so there is potential for greater variability in water quality in the lagoons than reported.

2.4.1 Physico-chemical Parameters

Terrigal Lagoon's turbidity levels tend to exceed the ANZECC guideline value, while values in the remaining three lagoons are generally within the guidelines.

Dissolved oxygen (DO) concentrations in the lagoons were measured in mg/L and hence are difficult to compare with the ANZECC (2000) guideline values, which are in percent saturation. Generally DO concentrations are above 5 mg /L in all lagoons, which is typically accepted as sufficient to support aquatic species such as fish.

Data on pH are within the ANZECC (2000) guidelines for aquatic ecosystem health for all lagoons except Cockrone Lagoon, which regularly recorded values above the upper limit of 8.5 (median pH=8.65, 90^{th} percentile pH=9.59). The cause of the elevated pH levels in Cockrone Lagoon is expected to related to high photosynthesis and primary production (i.e. macroalgal growth).

Measured salinity values (in the dimensionless Practical Salinity Scale, PSS) in the lagoons were:

- Wamberal – range = 4-22 PSS, mean = 8.23 PSS;
- Terrigal – range = 8-22 PSS, mean = 15.43 PSS;
- Avoca – range = 8-33 PSS, mean = 18.79 PSS; and

- Cockrone – range = 11-36 PSS, mean = 20.94 PSS.

Note that seawater is 35 on the PSS. Both Avoca and Cockrone have a higher range and mean salinity compared with the other two lagoons. Interestingly, Avoca has the greatest number of days open per year, while Cockrone is open the least (see Section 2.2.1). It is noted that, given the limitations in the sampling location and sampling time relative to entrance conditions, the potential for a greater range in salinity within all of the lagoons is possible. The results across the lagoons also suggest that higher salinity may occur during both open or closed conditions, depending upon rainfall inputs.

2.4.2 Nutrients

Nitrogen and phosphorous are nutrients that are required for plant growth in all biological systems, both in land and water, including algae. For Nitrogen, the measured concentrations of Ammonia, NOx and TN in all the lagoons generally exceeded ANZECC (2000) guidelines, which suggests susceptibility to algal blooms. Measured concentrations of total phosphorous (TP) are generally within the guideline values, suggesting that phosphorous may be the limiting factor for algal growth.

Cardno (2010) stated that the available data on nutrient concentrations is not sufficient to make meaningful conclusions about water quality processes in the context of nutrient dynamics and algal bloom dynamics. Based upon the limited data on nutrients, Cardno (2010) observed that nutrients in Avoca and Cockrone lagoons tended to increase in concentration with time since entrance closure; for Terrigal Lagoon, nitrogen and phosphorus species generally tended to decrease in concentration with increased time since entrance closure; and nutrient parameters for Wamberal Lagoon tended to be variable.

Both Avoca and Cockrone lagoons are prone to blooms of macro algae The persistence of these blooms suggests nutrient loads in the water column and/or the sediments are sufficient for their sustained existence.

2.4.3 Microalgae

Chlorophyll-a concentrations generally relate to microalgae only, however, the presence of macro-algae may affect the results. The 90th percentile concentration of chlorophyll-a has exceeded the ANZECC (2000) guideline values in all four lagoons, but the median and mean are within the guidelines. Chlorophyll-a concentrations are highly variable from year to year, and may also be seasonably variable within the lagoons, most notably in Avoca and Cockrone.

Concentrations of blue-green algae can on occasion exceed the ANZECC (2000) guidelines for recreational usage. At these times there may be a risk to public health and safety depending on the particular species present. As discussed in ANZECC (2000), toxicity is not necessarily directly related to cell count for blue-green algae and caution should be exercised in relation to problem species even when present at lower cell counts.

2.4.4 Bacteria

Measured data from the lagoons indicates that faecal coliform counts have on occasion exceeded the NHMRC Guidelines for managing risk in recreational waters (2008). While this can represent bacteria

from sewer overflows, animal faeces are also a source of faecal coliforms and may be influencing the sample results.

Enterococci have been monitored since 2010 through the beachwatch partnership program. Enterococci counts have also recorded some exceedences above the ANZECC (2000) guidelines for primary and secondary contact recreation. Enterococci have a higher tolerance to saline waters than faecal coliforms and would therefore be a more reliable risk indicator at those times when lagoon waters are brackish or more saline.

2.5 Ecology

The lagoons provide fringing wetlands and aquatic habitat for a large range of fish, birds and other fauna. ICOLL ecology is typically dynamic due to long periods of closure punctuated by periodic breakout. While some estuarine species may be adapted to a wide range of physical variables, others are not, and rapid changes in estuarine assemblages may occur in response to an entrance breakout (Cardno, 2010). The data presented in the processes study shows that the lagoons have large fluctuations in habitat availability and fish assemblages for the available snapshots.

2.5.1 Fringing Wetlands and Riparian Habitats

The extensive areas of wetland that exist in the Gosford Lagoons (except Terrigal) are considered to be in excellent condition. Vegetation surveys reviewed by Cardno (2010) identified the following types of fringing wetland communities around the lagoons:

- Alluvial Paperbark Sedge Forest;
- Coastal Sand Swamp Forest;
- Estuarine Paperbark Scrub Forest;
- Estuarine Swamp Oak Forest;
- Swamp Mahogany – Paperbark Forest;
- *Phragmites* Rushland; and
- *Baumea* Sedgeland.

Wetlands play important roles in providing breeding areas for fish and habitat for migratory birds and other waders and for trapping nutrients that would otherwise flow into the lagoons.

Saltmarsh and mangroves are largely absent from the four Gosford Coastal Lagoons, and this is likely to be their natural state rather than anthropogenic (i.e. due to human influences). Haines (2008) reports that mangroves in ICOLLS are rare, found in small numbers only and in systems that are mostly open. The vegetation mapping for Gosford (East Coast Flora Surveys 2009) does not identify the mangrove forest occurring in the western section of Terrigal Lagoon, however this is of a significant size and further investigation and mapping should be undertaken.

Likewise, riparian vegetation, while not strictly within the lagoons, is very important to the habitat within the lagoons. Riparian vegetation stabilises the banks of creeks and controls sediment supply thereby directly affecting water quality. It is also important as a habitat for native animals and for providing wildlife corridors (Cardno, 2010).

2.5.2 Aquatic Vegetation

2.5.2.1 Seagrasses

The outcomes of recent surveys of seagrass coverage were reproduced in Cardno (2010), as in Table 2-5. The comparison of results in Table 2-5 with earlier studies suggests significant changes in seagrass coverage. For example, Williams *et al.* (2006) reported 94% cover of *R. megacarpa* in Wamberal and 84% in Cockrone, compared to 60% and 20%, respectively, in Table 2-5. Similarly, in the 1980's, Avoca supported large areas of *Ruppia spiralis* and a fringe of *Z. capricorni*, but in 1991 there was no *Ruppia*, virtually no macroalgae and a small remnant fringe of *Zostera*. By 2006 there were no seagrasses in Avoca at all. The results in 2010 indicate *R. megacarpa* now covers 8% of the lagoon and *Zostera* is also present in small amounts in Avoca.

Variations in the records for seagrasses over time reflect variations in methodology used to record the species to some degree. However, it is likely that the coverage of seagrass within the lagoons is naturally quite variable due to entrance breakout processes, where deeper areas are suddenly reduced in depth or even exposed following a breakout. The number of breakouts may vary from year to year in line with the variability of rainfall, and so, this will necessarily impact upon estuarine vegetation such as seagrasses.

Table 2-5 Aquatic Vegetation (reproduced from Cardno, 2010)

Lagoon	*Ruppia megacarpa*	*Zostera capricorni*
Wamberal	27.67 ha	0.46 ha
Terrigal		
Avoca	8.14 ha	0.68 ha
Cockrone	6.85 ha	

2.5.2.2 Macroalgae

The two main species of macroalgae found in the lagoons are *Enteromorpha intestinalis* and *Cheatomorpha linum* (Cardno, 2010). Avoca and Cockrone Lagoons tend to support larger areas of macroalgae than either Wamberal or Terrigal Lagoons. Indeed, Avoca and Cockrone Lagoons are prone to blooms of the macroalgae. The blooms are a natural feature of the lagoons, and anecdotal evidence suggests the blooms have become more frequent. It is most likely that there is high variability in the occurrence and extent of growth of macroalgae from year to year naturally, just as there is high variability in rainfall and subsequent breakout processes.

Investigations in the Nadgee wilderness area (Scanes *et al*., 2007) suggest there is not necessarily a relationship between the magnitude of catchment disturbance and ambient nutrient concentrations in ICOLLs. This is somewhat similar to the Gosford Lagoons, where Terrigal Lagoon has a more disturbed catchment, but it is the least disturbed catchments of Avoca and Cockrone that exhibit macroalgae blooms. To what extent the macroalgae blooms have been modified (i.e. increased or decreased) by changes to catchment land use is unknown.

The macroalgae *E. intestinalis* and *C lignum* have relatively low salinity tolerances, and where these macroalgal species are present in the lagoon at the time of a breakout, they will suffer die-back due to

both the increase in salinity and drop in water levels, as the lagoon volumes typically decrease by 50%. In Cockrone Lagoon, the die off of macroalgae following a sustained period of entrance closure and subsequent opening has been associated with oxygen depletion and fish kills (Cardno, 2010), as discussed further in Section 2.5.7.

The complex biogeochemical processes that influence the nutrient cycling within the lagoons are not well documented. An understanding of these processes would assist in understanding the extent to which the sediments act as a store of nutrients and contribute to algal blooms (Cardno, 2010).

Council is presently contributing to funding of a PhD through the University of Newcastle to document temporal and spatial dynamics of algal blooms in Avoca and Cockrone Lagoons and to identify all species of algae that contribute to the 'blooms'. The project will also aim to identify main factors that cause algal blooms and to assess the implications of the opening regime on this. If possible the team will develop a biomass dynamics mathematical model that could be used in predictions of macroalgal blooms at various environmental conditions.

2.5.3 Terrestrial Vegetation

While not strictly within the lagoons, there are up to eight Endangered Ecological Communities (EECs) across the four lagoon catchments, including (Cardno, 2010):

- Freshwater Wetlands on Coastal Floodplains*;
- Kincumber Scribbly Gum Forest, Littoral Rainforest;
- Lowland Rainforest, River-flat Eucalypt Forest on Coastal Floodplains;
- Swamp Oak Floodplain Forest*;
- Swamp Schlerophyll Forest on Coastal Floodplains*; and
- Umina Coastal Sands Woodland.

Those EECs marked with an asterix are likely to form key components of the fringing vegetation around the lagoons.

2.5.4 Avifauna

The Gosford Coastal Lagoons support a wide variety of bird life, particularly migratory birds that utilise the lagoons for food and shelter. Birds are an important part of the overall biodiversity of estuaries and lagoons and may also be valued for their functional role in ecological processes such as nutrient cycling, seed dispersal and population regulation (including both predation and herbivory) (Cardno, 2010). The study area is on the route of the East Asian-Australasian Flyway which is used by shorebirds to move between Australia / New Zealand, East Asia and the Arctic region of the northern hemisphere.

A search of the Birds Australia database conducted by Cardno (2010) on 7/12/2009 found records for 207 bird species in the general study area, including:

- 15 species protected under the *Threatened Species Conservation Act 1995*;
- 65 species listed marine species under the *Environment Protection and Biodiversity Conservation Act 1999*;

- 17 species protected under Japan-Australia Migratory Bird Agreement (JAMBA);
- 17 species protected under China-Australia Migratory Bird Agreement (CAMBA); and
- 12 species protected under Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA).

The maintenance of water quality and habitat extents greatly assists in supporting the resident and migratory birdlife who utilise the lagoons. For example, the periodic exposure of areas of mudflats, as occurs after entrance breakouts, provides important foraging opportunities for a number of bird species (Cardno, 2010).

2.5.5 Amphibians and Reptiles

Cardno (2010) provide records for at least 13 amphibian and reptile species within the study area, some of whom would be resident, others travelling through from time to time (e.g. turtles). The full list of species is provided in Cardno (2010).

Of particular interest, there is a Green and Golden Bell Frog resident population of about 100 adults, in North Avoca in Bareena Wetland. Pressures upon this population particularly relating to entrance management are outlined in Section 3.2.2.

2.5.6 Fish, Prawns and Crustaceans

There is a wide diversity of fish species that inhabit coastal lagoons. Resident species may spend their entire lives in the lagoon. Marine estuarine dependent species will need to utilise the estuaries at some point over their life cycle, for example, as juveniles and during part of their adult stages, then as adults migrating out to sea to spawn. Haines (2008) reports that ICOLLs tend to exhibit lower fish species diversity when compared to permanently open estuaries. This is particularly evident following extended periods of closure.

Surveys of fish and prawns undertaken by NSW Fisheries between 1986 and 2008, as cited by Cardno (2010), collected a total of 72 species of fish over the sampling period. Terrigal had the highest diversity of species, and this was attributed by the authors to the frequency of lagoon openings (permitting biological exchange) rather than habitat availability or water quality.

Sampling undertaken by Newcastle University in 2009 and cited by Cardno (2010) found that Terrigal Lagoon had the greatest diversity of fish (23 species), followed by Avoca (15 species), Wamberal (13 species) and Cockrone (12 species) (Cardno, 2010). Again, the diversity appears to be correlated to opening frequency, with the more frequently open the lagoon, the greater the fish diversity.

In terms of abundance of fish, an opposite correlation between opening frequency and abundance was observed (Cardno, 2010). Comparing the lagoons, Wamberal had the highest abundance of fish and Terrigal the lowest (Edwards and Gladstone, 2009), likely due to the low habitat diversity of this lagoon. While there were substantial changes in the abundance and diversity of larval and juvenile fish in all the lagoons over time, there was no evidence that these changes were associated with lagoon openings. It was generally found that both the diversity and abundance of fish in Wamberal, Avoca and Cockrone Lagoons (which opened at approximately the same time) decreased after entrance openings.

Few prawns or other crustaceans were recorded in the surveys by NSW Fisheries between 1986 and 2008, as cited by Cardno (2010).

Shellfish are relatively rare in the Gosford Lagoons with pipis (*Donax deltoides*) being most abundant at Avoca, but only one sample with a single individual was found at Wamberal and none in the other lagoons. Shellfish inhabiting hard substrata, such as rock or mangrove roots and trunks, are rare as these habitats are not well represented in the lagoons (Cardno, 2010).

Since the completion of the EPS, McCormack (2010) has published information regarding aquatic surveys undertaken for Avoca and Cockrone lagoons in late August and early September 2010, while Terrigal and Wamberal lagoons were surveyed in May and June 2010 (during flood conditions). Biological surveys were undertaken as part of both the broad Australian Crayfish Project and the Australian Aquatic Biological Survey and a targeted sub-project on Gosford LGA.

Within the Terrigal lagoon catchment aquatic biodiversity & population densities were rated as low. Very few native fish and no freshwater snails or shellfish were found.

The Wamberal catchment was in very good condition and contained a large number of native fish species with large numbers of Gudgeons identified as well as exotic Gambusia. Some of the largest freshwater snails ever collected by ACP & AABS were found within the catchment. A new native species of Gramastacus crayfish was discovered as well as an invasive Cherax freshwater crayfish species was found to be proliferating within the lagoon.

For the Avoca Lagoon Catchment McCormick (2010) reported finding that the aquatic biodiversity and population densities of freshwater shrimp and snails were good. Relatively good numbers of native fish were also reported. While freshwater cray fish were not found, anecdotal indications of their presence warrant further investigations.

Within the Cockrone Lagoon Catchment, numbers of native fish and overall aquatic biodiversity and population densities were poor.

2.5.7 Fish Kills

Fish kills have been observed in Cockrone Lagoon on several occasions. Investigations of two events suggest that the fish kills occurred due to a rapid decrease in dissolved oxygen that results when blooms of macroalgae decompose immediately following a lagoon breakout.

Council staff have also advised that fish kills occur in Wamberal Lagoon following breakout.

Water levels decrease significantly after a break out event and large expanses of the lagoon (if not the entire waterbody) drain to dry. The result is rapidly declining and persistent low dissolved oxygen levels following the death of significant amounts of algae along the previously unexposed shoreline. Decomposition of this organic matter consumes most of the oxygen from the water. In addition, the low water levels also limit the availability of refugia for fish, further contributing to the fish kill as they cannot escape the low oxygen water. It should be noted that fish kills are not observed after every breakout event, nor after every macro algae bloom.

2.5.8 Macrobenthic Invertebrates

A benthic community is the assemblage of bottom dwelling species occurring in a particular location at a particular time. Infaunal benthic invertebrates are divided into groups based on their size: being micro- (<0.04mm), meio- (0.04-0.1mm), macro- (0.5-2.0mm) or megafauna (>2.0mm). These can be very diverse communities representing a range of different phyla of animals.

Field surveys of benthic macroinvertebrates by Freewater and Gladstone (2010) as reported in Cardno (2010) collected a total of 412 individuals including seven mollusc species, five families of polycheates, six families of crustaceans and three families of insects.

Macrobenthic assemblages in each of the lagoons were different. In the central basin in Wamberal capitellid polychaetes and exoedicerotid crustaceans were found. Capitellids were most abundant in Terrigal, and were not significant in Cockrone. There were no statistically significant differences between Terrigal and Avoca or between Avoca and Cockrone (Cardno, 2010).

Diversity and abundances of macrobenthic invertebrates were greatest in the central mud basin of the lagoons and least in the beach berm regions. This is likely due to lower rates of disturbance in the deeper parts of the lagoons. Of particular interest was the finding that when comparing assemblages before lagoon breakout to when the lagoon has re-established, there were no significant difference in assemblage structure in any of the lagoons. These results indicate that the effects of artificial opening are short-lived and that the benthos recovers rapidly in the entrance barrier (Gladstone *et al*., 2006).

2.5.9 Zooplankton

Surveys of zooplankton in the Gosford Coastal Lagoons in 1996, 1997 and 1999 (Laxton, 1997 and 1999 as cited in Cardno, 2010) indicated the presence of large numbers of copepod crustaceans and gastropods, as well as the eggs, larvae and juveniles of fish in Wamberal. In Terrigal and Avoca, copepods and amphipods were the most numerous animals in seagrass beds (present in Terrigal at that time), but fish, molluscs and polycheates were also common. In Cockrone, large numbers of small gastropods were caught over Ruppia seagrass beds and high densities of copepods were caught in open water. Fish and crustacean larvae were also caught in Cockrone.

2.6 Natural Values

Based upon the above discussion of lagoon processes, the following natural environmental and community values are summarised for the Lagoons:

- Native vegetation in the catchment, which provides habitat and moderates water quality inputs to the lagoons;
- Areas of fringing vegetation including wetlands, which also provides habitat and reduces the likelihood of bank erosion. Furthermore, natural wetlands act as ‘filters’ for catchment runoff before entering the lagoons;
- Aquatic vegetation and associated habitats that support a variety of birdlife and estuarine aquatic life;
- Scenic views associated with the vegetated backdrops and natural waterways; and

- Natural variations in water levels and entrance conditions, which allow for a wide range of habitat conditions that support various birdlife (through exposure of mudflats) and aquatic life within the lagoons (through allowing fish species to enter and exit the lagoons as needed as part of their life cycles).

Modifications to the natural environmental and community values that are associated with the external pressures on lagoon processes are detailed in Chapter 4.

3 EXTERNAL PRESSURES

For the Gosford Coastal Lagoons, external pressures arise largely from human influences, including direct human uses of the lagoons and their catchments, as well as indirect anthropogenic influences such as climate change.

The pressure index utilised in the State of the Catchments report (OEH, 2010) lists the following as key pressure indicators for NSW estuaries:

- Cleared land within the catchment;
- Population within the catchment;
- Sediment input (modelled);
- Nutrient input (modelled);
- Disturbed habitat (based on foreshore structures, aquaculture and in the future will also include foreshore vegetation);
- Tidal flows (based on opening levels in the case of the Gosford Coastal Lagoons); and
- Fishing (both recreational and commercial).

This list provides a broad scale consideration of the pressures potentially influencing the Gosford Lagoons. A summary of key pressures most relevant to modifications to lagoon processes and associated values is given below.

3.1 Changes in Catchment Land Use

Changes in catchment land use from their pre-developed state have had flow-on implications for most other pressures discussed in this chapter. The current catchment land uses, broadly described as rural, residential and forested, for each of the four lagoons is given in Table 3-1. From the earliest available aerial photograph in 1954 to the present, the catchment land use has shifted from a predominantly rural land use to an increasingly residential land use. Prior to 1954, it is assumed that all the catchments were predominantly forested. It is noted that there are no significant commercial or industrial land uses within the catchments of the four lagoons (Cardno, 2010).

Table 3-1 Current land use for the Gosford Lagoon Catchments (Cardno, 2010)

Lagoon	Total Catchment area (km^2)	Urban (%)	Rural (%)	Forested (%)	Waterway (%)
Wamberal	6	31	36	24	9
Terrigal	9	36	44	16	3
Avoca	10	25	21	45	9
Cockrone	7	9	16	69	6

Both the shift from forested to rural land uses and then from rural to residential land uses would have negatively influenced sediment and nutrient inputs to the lagoons, and thereby affected water quality, aquatic vegetation (particularly algae) and aquatic fauna. This is in addition to the direct changes in fringing vegetation that would have occurred due to land clearing.

The former rural land uses would have comprised of clearing of forested areas, resulting in an increase in sediment and nutrient loads to the lagoons. Fertilisers and pesticides used in agricultural activities would also have discharged into the lagoons, adversely affecting water quality and ecology (Cardno, 2010).

The shift to residential land use (from both rural and forested land uses) would have placed further pressure upon the lagoons. In particular, the area of impervious surfaces increased, which would have increased the quantity of stormwater and with it, the quantity of sediment and nutrient inputs to the lagoons. The construction phase for such residential development would have particularly increased sediment inputs, as there were no formal erosion and sediment controls for construction sites unlike the present day.

A more recent positive shift in the catchments has been the change from onsite sewage systems to a reticulated sewage system since the 1990s, which would have reduced nutrient and pathogen loads to the lagoons, which is important for both ecological health and human health.

The increase in residential development around the fringes of the lagoons has also influenced the need for artificial entrance management. Low-lying lands were filled and developed for residential properties but at levels below the potential height of natural entrance openings, particularly around Terrigal Lagoon. This has led to a requirement for artificial entrance openings in order to avoid periodic flooding from the lagoon. The pressure upon lagoon processes and values in relation to artificial entrance management is discussed further in Section 3.2.

In the future, there is not expected to be substantial change in the current ratio of rural, residential and forested land uses in the catchments of the lagoons (Cardno, 2010). Therefore, future inputs to sediments and nutrients and water volumes are expected to remain similar, but there may be some minor implications for water quality during redevelopment of existing properties, particularly during the construction phase when sediment loads in runoff may be increased. There may also be longer term impacts on hydrology due to an increase in the area of and connectivity of hardstand impermeable areas, unless there is planning controls upon the ratio of pervious to impervious area for such re-developments.

The subsequent pressures relating to the change in catchment land use is discussed in greater detail in the sections below.

3.2 Artificial Entrance Management

Each of the lagoons is mechanically opened by Council when water levels exceed a prescribed trigger level. This intervention has been undertaken by Council for about forty years. Council's artificial entrance management approach can comprise either mechanical opening of the entrance by an excavator (based on trigger water level), or "scraping" of the berm by an excavator to the desired level in order to maintain a maximum potential flood level before a natural breakout is induced. The

opening entrance water levels and maintained berm heights for each of the lagoons are given in Table 2-1

Berm scraping is undertaken so that, in the case where lagoon water levels increase too rapidly for Council to undertake an artificial opening, a natural breakout will be initiated at a level that does not cause foreshore flooding. In managing lagoon entrances and associated breakouts and berm scraping, Council considers rainfall forecasts, tidal conditions and even school holidays (especially for public safety reasons as breakouts tend to attract youths that ride the outflowing water on boards). Indeed some breakouts in the past have occurred illegally by community members – a scenario that is repeated at a number of coastal lagoons along the NSW coast. As a result, opening levels for the lagoons marginally exceed the trigger levels from time to time. The ability of Council to artificially open coastal lagoon entrances may be limited by risk factors to equipment and personnel during extreme weather.

Artificial entrance opening has had an impact upon lagoon entrance dynamics and therefore a range of physical, chemical and ecological processes. This is because the artificial opening level is fundamentally lower than the breakout level that would occur naturally. This is particularly the case at Terrigal Lagoon. Where the entrance opening occurs at a lower level, the potential for scour of the entrance area is reduced. In turn, the extent of time for which the lagoon remains open is potentially reduced and likewise the potential for tidal flushing. As less volume of sand has been displaced by the lagoon opening, less time is required for the sand to be replaced and rebuild the entrance berm. The implication is that more frequent entrance breakouts at lower than natural levels may reduce the potential for tidal flushing over time, which may affect water quality.

Natural openings in fact occur over a range of levels, and this can be important for lagoon processes. Although not by design, it appears that there is still some variability in lagoon opening levels due to the logistics of artificial entrance management. A range of opening heights under certain conditions could be considered by Council in reviewing their opening policy.

Estimated maximum berm heights that may occur if artificial management was ceased were provided in Cardno (2010, citing AWACS, 1994) based on surveys of back beach areas undertaken by the former Public Works Department:

- Wamberal and Avoca Lagoons - berm levels of 3.0m AHD are common, with a level 3.5m AHD achievable over time;
- Terrigal Lagoon – berm levels of 2.5m AHD could be expected, with a level of 3.0m AHD achievable over time; and
- Cockrone Lagoon – berm level of 3.5m AHD likely and a level of 4.0m AHD is possible.

These potential berm height levels demonstrate the potential maximum water levels that may have occurred in the lagoons, prior to artificial intervention.

3.2.1 Changes in Lagoon Ecology

Artificial entrance management is expected to have affected the extent of fringing wetlands within the lagoons. Artificial management reduces the potential range of water levels, particularly the higher levels. Wetland species such as saltmarshes require infrequent inundation at such levels to proliferate. Without this inundation, the extent of saltmarshes and other fringing wetland species is

likely to have reduced over time in the lagoons (primarily been overgrown/outcompeted by more terrestrial species).

Frequent openings in Terrigal Lagoon are likely to have increased the percentage of time for which the lagoon is open to the ocean, and this can result in a change in species towards more marine types. Indeed, a few mangrove stands have been observed in Terrigal Lagoon. As well as providing a pathway for mangrove seeds to enter the lagoon, more 'open' conditions in Terrigal Lagoon help to somewhat stabilise water levels, with only a relatively narrow range of levels achievable. Typically for other ICOLLs, the large range of water levels means that at time when the lagoon is 'full', the mangrove pneumatophores (peg roots) are entirely submerged, effectively 'drowning' the trees.

Cardno (2010) suggested that artificial lagoon openings in Cockrone and Avoca Lagoons could be used to manage macro algae blooms. This would need to be considered very carefully, as openings within these lagoons under the influence of macroalgae has led to fish kills in the past (Cardno, 2010). This would be the result of detrital algae within the waterbody utilising dissolved oxygen to meet the needs of the decay process. Thus, the most likely time for fish kills is after the entrance has re-closed after a breakout event, when there is no further marine flushing of the waterway.

In most cases, lagoon openings for reasons other than to alleviate flooding, such as for lagoon water quality, have not been proven to have positive outcomes. Furthermore, lagoon systems naturally have highly variable water quality conditions, so introducing saline waters more frequently may indeed adversely affect predominant lagoon ecosystem processes.

3.2.2 Impact on Green and Golden Bell Frogs in Avoca Lagoon

Avoca Lagoon is one of only two habitats on the NSW Central Coast for the Green and Golden Bell frog, *Littoria aurea*. Green and Golden Bell Frogs inhabit the Bareena Wetland on the eastern edge of Avoca Lagoon. The wetland formed in response to the laying of sewer pipes in the 1980s along with a wall of earth and rocks, forming a weir between the wetland and the remaining lagoon waterbody. The wetland traps fresh water inputs and as the weir is semi permeable, saltwater also enters the wetland. As water levels within the wetland respond rapidly to water level changes within the lagoon, the salinity of the wetland is somewhat controlled by lagoon openings. .

The frog breeding habitat at North Avoca appears to be confined to the Bareena Wetland, and includes several urban yards adjacent to the wetland that contain native shrubs such as *Lomandra* spp. and at least two yards also have ponds.

The Bareena Wetland is not necessarily a reliable breeding site for the Green and Golden Bell Frog, as it can often be too salty for tadpole survival. Interestingly, however, the Green and Golden Bell Frogs tend to prefer habitats that have a degree of salt, as it reportedly kills off a Chytrid fungus that otherwise limits tadpole survival. It is reported that salt levels of up to 8 ppt are tolerated by Green and Golden Bell Frog tadpoles.

When the lagoon water level drops below 1.4 m AHD, Bareena Wetland may become dry. Depending upon the season for such drying events, it can be either beneficial or detrimental for the Green and Golden Bell Frog. If the wetland dries out during spring or summer, it is fatal to tadpoles and an entire breeding season may be lost. If drying occurs during autumn or winter, this may help prevent colonisation of the wetland by the predatory mosquito fish *Gambusia*. *Gambusia* are present

elsewhere in Avoca Lagoon and are identified by NSW Government as a key threatening process to the Green and Golden Bell Frogs. The relationship between drying and positive or negative impact upon the Green and Golden Bell Frogs suggests there is potential for entrance management to be modified to increase the breeding potential for this species.

3.3 Pollutant Inputs

3.3.1 Sewerage Systems

Overflows and leakages from the reticulated sewerage system are identified as point sources for pollution in the lagoon. Overflows typically occur during wet weather, as illegal connections and infiltration result in higher volumes of flows. Sewerage pumping stations within the lagoon catchments that have the potential for overflow have been connected to a telemetry system by Council (Cardo, 2010). The system provides early warnings of failures, to enable Council to act quickly to minimise the impacts of overflows, should they occur.

Furthermore, a major upgrade to the wastewater treatment network is currently underway, involving a $30 million upgrade to construct a 6.5 km pipeline between North Avoca, Avoca and Kincumber to the Kincumber Wastewater Treatment Plant. The pipeline shall improve the reliability, performance and capacity of the system, thereby reducing the likelihood of failures (Cardno, 2010).

In 1996, Council required all onsite sewage systems to connect to the reticulated network, although there are approximately 915 properties still using onsite sewage systems. A Council based audit of these systems' performance and risk categorisation determined only two properties within the Lagoons that were identified as high risk, due to the age of the systems and increased need for management. None of the systems in the LGA were found to be failing (Cardno, 2010). Therefore, the risk pollution from such systems may be considered as low.

3.3.2 Stormwater

The volume of stormwater is a function of catchment size, land use (i.e. the ratio of pervious to impervious surfaces) and rainfall. Thus more developed catchments, which have a higher percentage of hard surfaces and so experience less infiltration of surface water into the soil, have a higher net volume of runoff to the lagoons in the form of stormwater. More developed catchments also have higher pollutant concentrations in the stormwater.

Computer modelling of stormwater runoff was undertaken for each of the four lagoon catchments to estimate potential pollutant loads (Cardno, 2010). Key results from the modelling are as follows:

- Terrigal Lagoon had the highest pollutant loads given by the modelling. It has the second largest catchment area with 80% of the catchment developed, for rural or urban land uses. Given it also has the largest catchment relative to waterway area, the modelling therefore suggests Terrigal Lagoon to have the highest potential for poor water quality relative to the other lagoons;
- Wamberal Lagoon model results showed relatively high pollutant loads, not dissimilar to Avoca Lagoon. Wamberal Lagoon is the smallest, but has a higher proportion of development (67%) compared with Avoca Lagoon, which has a lower proportion of developed land (46%) and much more forested land (46%);

- Cockrone Lagoon, with its small catchment size and high proportion of forested land (69%) was shown in the modelling to have the lowest pollutant loads and runoff volumes.

Pollutants in stormwater typically comprise sediments and nutrients. Thus, for more developed catchments, there is likely to have been an increase in the rate of sedimentation due to the increased delivery of sediments. This is reflected in the rates of sedimentation for each of the Lagoons given in Section 2.3.4. Sedimentation rates in Terrigal Lagoon are around double that of the less developed Avoca and Cockrone Lagoons, with Wamberal also slightly higher than those lagoons.

In addition to sediments and nutrients, stormwater may also deliver litter and garden debris (termed gross pollutants) into the lagoons. The garden debris may contain environmental weeds and their seeds. Other pollutants such as heavy metals and hydrocarbons may also wash off roadways into stormwater, and so the lagoons (CEN 2007), while agricultural practices and some urban land management (eg recreational facilities) may also lead to organo-pollutants (e.g. pesticides), which would mostly be attached to fine sediment,

3.3.3 Other Potential Pollutant Sources

There are currently no licenced discharges of pollution to the air, soil or waterway in any of the lagoon catchments that have an Environment Protection Licence issued under the *Protection of the Environment Operations Act 1997* (Cardo, 2010).

The register of notices issued under the *Contaminated Land Management Act 1997* does not list any notices for any land in the lagoon catchments. The register of contaminated lands held by Council suggested only one known site, in the Terrigal Lagoon catchment. The risk-based assessment for potential contaminated lands cited by Cardno (2010) suggests up to four high risk sites and two medium risk sites across the four lagoons, including a former landfill (high), two existing motor engineers and repairs shops (medium), and four service stations / garages (high) (Cardo, 2010). The landfill site may potentially be contributing nutrients to the groundwater, and the service station and other motor engineering sites may potentially be contributing heavy metals and hydrocarbons to the groundwater and to surface water runoff (stormwater) after rainfall.

The sites have been identified as high risk of potential contamination. Without an investigation of the actual contamination at the sites, the nature and extent of their contribution to pollutant loads in the lagoons is unknown. Mapping of the potential contaminated sites given in Cardno (2010) suggests the sites are very small relative to the waterway and catchment areas of the lagoons.

3.4 Land Management Practices

Land management practices such as clearing, the construction of foreshore protection structures (seawalls), and the introduction of environmental weeds have directly impacted upon fringing vegetation (wetlands and riparian habitats). Fringing vegetation in Terrigal Lagoon in particular has been heavily modified by such actions.

3.4.1 Foreshore Land: Public Access and Private Ownership

Fringing native vegetation has been impacted by deliberate removal by community members to enhance views and/or provide foreshore access (CLT, 2008). Uncontrolled public access further damages the foreshore vegetation. Constant mowing of grassed areas also prevents the

regeneration of native vegetation, including foreshore and wetland vegetation such as rush and sedge species, and Broad-leaved Paperbark (*Melaleuca quinquenervia)*.

Mowing also provides conditions conducive to the growth of environmental weeds, especially short-lived species which can flower and seed between mowing events (CEN 2007). Weeds observed around the lagoons included Bitou Bush, Asparagus Fern, Lantana and Morning Glory, and records suggest there may be 47 introduced species within the study area (Cardno, 2010).

Aside from the ecological impacts, the removal and damage of foreshore vegetation enhances the likelihood of bank erosion, and will also impact upon water quality.

3.4.2 Modifications to Creeks

Urbanisation has resulted in significant changes to the tributary creeks. Changes have included channelisation (i.e. where the natural bed is replaced by concrete), removal of snags, and construction of roads, culverts and bridges. The removal of native vegetation for such works has also enabled the proliferation of weeds in and adjacent to the creeks. This will have significantly impacted upon the fish and other fauna who live in or move into the creeks from the lagoon.

3.5 Sediment Extraction and Reclamation Works

Historic extraction and reclamation works for Terrigal and Avoca Lagoons has changed the morphology and distribution of sedimentary environments. There are no records for such works in either Wamberal or Cockrone Lagoons (Cardno, 2010).

In Terrigal Lagoon, the triangular-shaped area bounded by Leumeah Avenue, Ocean View Drive and Lake View Road, part of Ogilvie Street, Lions Park Rotary Park is said to be reclaimed land, using material dredged from the lagoon. Foreshore reclamation is thought to have occurred over 3,500 m of the 4,700 m lagoon perimeter, with the primary source of fill being dredged material.

Dredging works have covered approximately 15%, or 4ha, of the bed area to a depth of approximately -0.3mAHD, with some dredge holes to -3.0mAHD also occurring (WMA, 1995). This represents around 40,000-60,000 m^3 of sediment.

In Avoca Lagoon, a lease for dredging was active between approximately 1981 and 1994. The dredging is thought to have been undertaken in the central portion of the lagoon around Bareena Island and, to some extent, up the north-eastern arm of the lagoon. The estimated extent of dredging is 10%, or 7.5 ha, of the bed surface with levels taken to -2 to -3m AHD, equating to around 100,000 m^3. Some foreshore reclamation occurred west of the Avoca Drive Bridge in relation to the land-based activities of the dredging operation (WMA, 1995).

There are no active leases or permissions for dredging or reclamation in any of the lagoons.

3.6 Climate Change

3.6.1 Projections

Current Climate

The general climate of the study area is warm temperate, with late summer to early winter becoming generally wet and humid and the late winter- spring period is mild and dry. Average annual rainfall for the study area is around 1,300 mm/yr. The wettest time of the year is around February-March, while the driest is around July-October (Cardno, 2010).

Projected Climate Change

Sea level rise is the most accepted of the predictions associated with future climate change. To provide a consistent benchmark for use in all coastal assessments, the NSW Government released a *Sea Level Rise Policy Statement* (2009), which recommends adoption of a 0.4 m rise above 1990 sea level by 2050 and 0.9 m by 2100. The projections are based upon the most recent work from IPCC (2007) and CSIRO (2007) that are relevant to the NSW coastline.

Projections of potential climate change impacts were identified for the Hunter, Central and Lower North Coast region of New South Wales as an initiative of the Hunter & Central Coast Regional Environmental Management Strategy (HCCREMS). The Regional Climate Change Project completed in 2009 provides regional scale projections of climate change by establishing relationships (i.e. shifts and changes) between key synoptic types (based on projected monthly sea-level pressure field output from the CSIRO Mk3.5 Global Climate Model (GCM)) and regionally specific climate data measured by the Bureau of Meteorology (BoM).

The projections for key climate variables are presented by HCCREMS (2009) in terms of three regional climate zones, namely the Western Zone, Central Zone and Coastal Zone. For the present study, key climate change impacts relevant to coastal hazards for Gosford Coastal Lagoon are based on downscaled predictions obtained for the Coastal Zone.

A summary of key findings from the HCCREMS project for the 2020 to 2080 period as described in Cardno (2010) are as follows:

- average temperature is likely to increase;
- maximum temperatures are likely to increase by ~1° C in autumn and winter and decrease ~ 0.5° C in summer and spring;
- rainfall patterns are likely to remain within the boundaries of existing climate variability, although the climate will shift into the wetter and more variable phase of known climate;
- for wind climate, the seasonal shifts are predicted to cancel out such that there is no change annually;
- the frequency of extreme storm events was considered likely to increase, particularly a higher probability of east coast low weather systems (that produce the highest rainfall and wave heights on the NSW coast) during autumn and winter was predicted;
- higher rainfall events are predicted to increase in frequency in summer and autumn and decrease in winter and spring; and
- extreme temperature days were considered likely to increase in summer and autumn.

3.6.2 Potential Impacts of Climate Change

3.6.2.1 Entrance Berm Heights and Flooding

For ICOLLs, sea level rise may have impacts upon both the entrance morphology and the extent of inundation during both open and closed conditions.

The height of the entrance berm is expected to increase by a roughly equal amount as the rise in sea level (Hanslow *et al*., 2000; Haines and Thom, 2007; Wainwright and Baldock, 2010), that is, by 0.4 m by 2050 and 0.9 m by 2100 at the NSW Governments sea level rise benchmarks. As described by the Bruun Rule concept of the movement upward and landward of the beach profile with sea level rise, coastal entrances would also increase in height and move further landward to reach equilibrium with the new mean sea level, as shown in Figure 3-1,. With an increase in berm height at typically closed entrances, there is a corresponding increase in available storage volume within the lagoon waterway (i.e. water behind the berm). Entrance breakouts would thus become less frequent because more rainfall is required to fill the lagoon to a level that will overtop the berm. The entrance berm height controls the lagoon water level, and so, the potential extent of flooding will increase with sea level rise.

During open entrance conditions, the higher sea level will also affect flooding within the lagoon waterway, because the ocean water level acts as a barrier to the outflow of water from the lagoon (i.e. the hydraulic gradient between the lagoon water level and ocean water level is reduced with sea level rise, and so the water won't flow out). Where this occurs with a high tide and storm surge in the ocean, the impact upon upstream flooding will be further worsened. The impact of sea level rise upon flood extents both with and without the elevated ocean water levels due to tide and storms is best defined during a flood study, where advanced modelling is applied to investigate the flooding. As foreshore flooding is already an issue on the northern side of Terrigal Lagoon, this situation is expected to worsen.

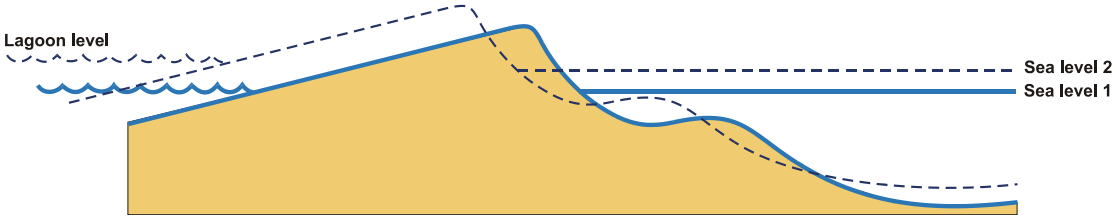

Figure 3-1 Shoreline response to increasing sea level (Hanslow *et al*., 2000)

3.6.2.2 Artificial Entrance Management

The natural response of the entrance berm to a rise in sea level poses a significant complication for maintaining artificial entrance management at the current levels. Under the existing breakout levels for each lagoon, as sea level rises, the gradient between the lagoon water level and the sea level reduces, as shown in Table 3-2. This in turn reduces the extent to which lagoon waters will outflow and scour the entrance, and so, the length of time for which the entrance remains open. In turn, tidal flushing and ecological processes may be affected (such as discussed in Section 3.2.1). In essence, maintaining the same breakout level while sea levels rise by 1m is equivalent to progressively lowering breakout levels by 1m under a static sea level condition.

For Terrigal Lagoon, the existing breakout level clearly cannot be sustained into the future, as the breakout level would be within the normal tidal range of the lagoon (refer Table 3-2). For Terrigal Lagoon, the time between acceptable change and the period approaching unacceptable change is far shorter than the other lagoons and difficult and costly actions to enable higher breakout levels in the future will be required.

For Avoca lagoon, while the existing breakout level is likely to still be effective by 2050, it is unlikely to remain effective by 2100. Existing breakout levels for Wamberal and Cockrone lagoons could potentially be maintained for 100 years into the future to control flooding of foreshore land. There will still be some impacts, however, from an increased ocean water level entering the lagoons that will affect the extent of tidal inundation and range within the lagoons when breakouts occur.

There may also be implications for managing the entrance berm height, most notably, that the heights applied at present will be more readily overtopped by waves. Further, the longer present breakout levels are maintained in light of sea level riseprojections, staff and equipment will be increasingly placed at risk from coastal processes during breakout procedures.

Table 3-2 Risk Likelihood of Sea Level Rise and Foreshore Flooding

Year	Water Level	Terrigal	Avoca	Wamberal	Cockrone
Present	Artificial Breakout Level	1.23	2.1	2.4	2.53
2050	Potential Berm height (0.4 m SLR)	>1.63	>2.5	>2.8	>2.93
	Breakout Level minus Mean Sea Level (average hydraulic gradient)	0.83	1.7	2.0	2.13
	Breakout Level minus HAT (worst case hydraulic gradient)	-0.07	0.8	1.1	1.23
	Effectiveness of artificial breakout	Poor	Good	Good	Good
2100	Potential Berm height (0.9 m SLR)	>2.13	>3.0	>3.3	>3.43
	Breakout Level minus Mean Sea Level (average hydraulic gradient)	0.13	1.2	1.5	1.63
	Breakout Level minus HAT (worst case hydraulic gradient)	-0.57	0.3	0.6	0.73
	Effectiveness of artificial breakout	Very Poor	Poor	Reasonable	Reasonable

3.6.2.3 Impacts on Lagoon Ecology

The expected increase in water levels within the lagoon, both due to higher entrance berm heights and tidal water level, will result in additional inundation of lagoon foreshores. In response to this, fringing vegetation will migrate landward, to remain in its preferred location relative to water level. As low water levels will increase in line with sea level rise, aquatic vegetation will be squeezed into the shallower foreshore areas, while intertidal vegetation will be pushed upslope by the rise in low tide levels. If the 'high' water levels of the lagoons are not affected (i.e. there is no commensurate upward shift in entrance breakout levels), then the intertidal and fringing wetland vegetation will be squeezed to fit within the narrower water level range.

Vegetation adjacent to existing development has a reasonable likelihood of being lost, as there is little opportunity for upslope migration of species.

Within the lagoon itself, depending upon how the shift in entrance berm height is translated to breakout frequency and height, there may also be shifts in lagoon species. For example, where breakouts become less frequent and lagoon water levels are more influenced by freshwater inputs from the catchment, there may be a shift in estuarine species to more freshwater species. Conversely, if artificial entrance breakouts are conducted more frequently, then species may shift to more marine.

Unfortunately, current projections for shifts in temperature and changes to rainfall patterns (annual, seasonal, extreme) are inconclusive. Furthermore, the understanding of the threshold for severe impacts to the range of species and habitats that exist around the lagoons is even less well understood.

Given the high uncertainty in the response of ecology to climate change, methods to build the resilience of key habitats such as enhancing and protecting foreshore vegetation in areas where migration is possible and enabling habitat migration through the effective application of buffers around lagoon foreshores may provide for adaptation of lagoon ecology to climate change impacts.

3.6.2.4 Loss of Cultural Heritage Sites

The LALC is concerned about the potential impacts of climate change on Aboriginal sites and has worked on a project with the CMA regarding erosion of midden sites (CLT 2008). With respect to the lagoons, there are frequently Aboriginal sites surrounding coastal lagoons, such as middens, which would potentially be inundated by future sea level rise.

3.6.2.5 Changes to local water table

Exchange between the lagoon waters and the local groundwater can occur. Since Sea level rise is expected to result in low tide not getting as low as it does under existing conditions, this will potentially elevate the local water table level around the lagoons. This could further exacerbate the flooding issues.

3.7 Spatial Mapping of Issues

During the consultation processes, a series of spatial maps were generated listing specific locations for issues around the lagoons (refer to Figure 3-2, Figure 3-3, Figure 3-4 and Figure 3-5). The

locations listed were supplied by participants of the various workshops and Council staff. The spatial mapping of issues provides a visual indication of the modifications to the lagoons that have resulted from estuary pressures. The mapping identified for example, sites of sediment build up in coastal creeks, stormwater devices such as Gross Pollutant Traps that are frequently overloaded, nesting and foraging sites for birds and access points. The spatial mapping includes all issues identified during consultation with each management issue assessed through the threat assessment described in Section 5.3. It must be noted that these management issues may not directly result in management action due to the degree of threat and / or is being addressed through other management activities (i.e. Item No.18 of Table 3.6).

The maps were used extensively throughout the threat assessment and options development. It will also form a useful bench marking tool for assessing the success of the Coastal Zone Management Plan in the future.

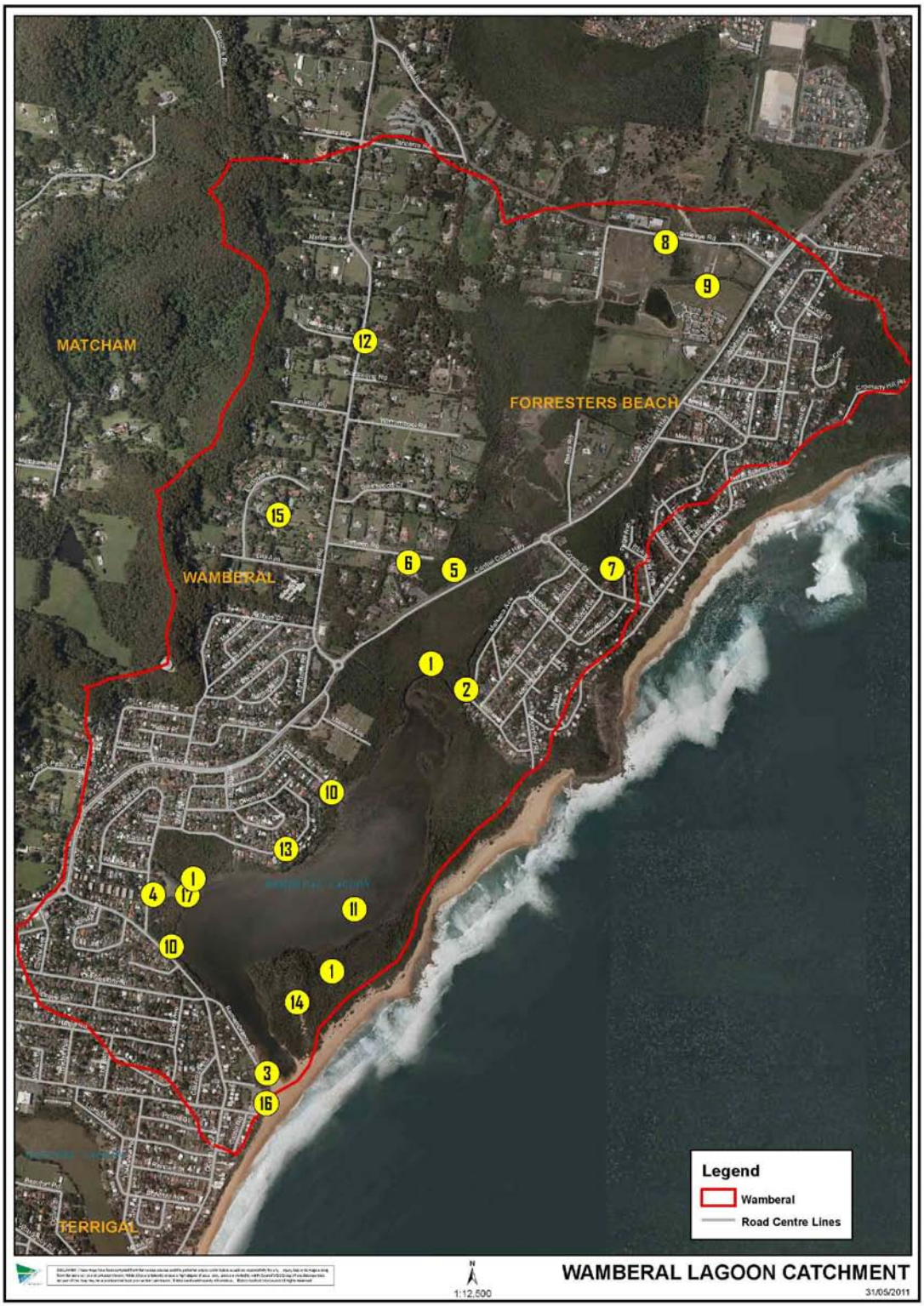

Figure 3-2 Spatial issues mapping based on community consultation for Wamberal Lagoon

Refer to Table 3-3 for brief descriptions of the issues.

The issues identified on the map shown in Figure 3-2 through the community consultation are described in Table 3-3.

Table 3-3 Management issue description key for spatial mapping of Wamberal Lagoon developed through the community consultation process.

Item No.	Management Issue Description
1	High Value vegetation (bush care site)
2	Stormwater Runoff issues & scour of creek bank
3	Erosion and need for controlled access. Revegetation required.
4	Retain informal track network.
5	Die back of trees.
6	Potential sediment/nutrient source
7	Encroachment.
8	Threatened species - *Eucalyptus camfieldi* and Endangered population *Eucalyptus oblonga*. This site may also have been an uncontrolled tip site in the past which may be a source of pollutants.
9	Encourage WSUD and sustainable living if developed
10	Stormwater runoff/pollutant source.
11	Migratory Bird habitat - e.g. Bar-tailed Godwit.
12	Encourage planting of endemic vegetation to enhance green corridors.
13	Encroachment. Also a sewer pumping station with potential for overflow during breakdowns etc.
14	Significant sand dune.
15	Sediment control needed.
16	Rabbits in dune vegetation.
17	Dog off-leash area, is this a suitable site?

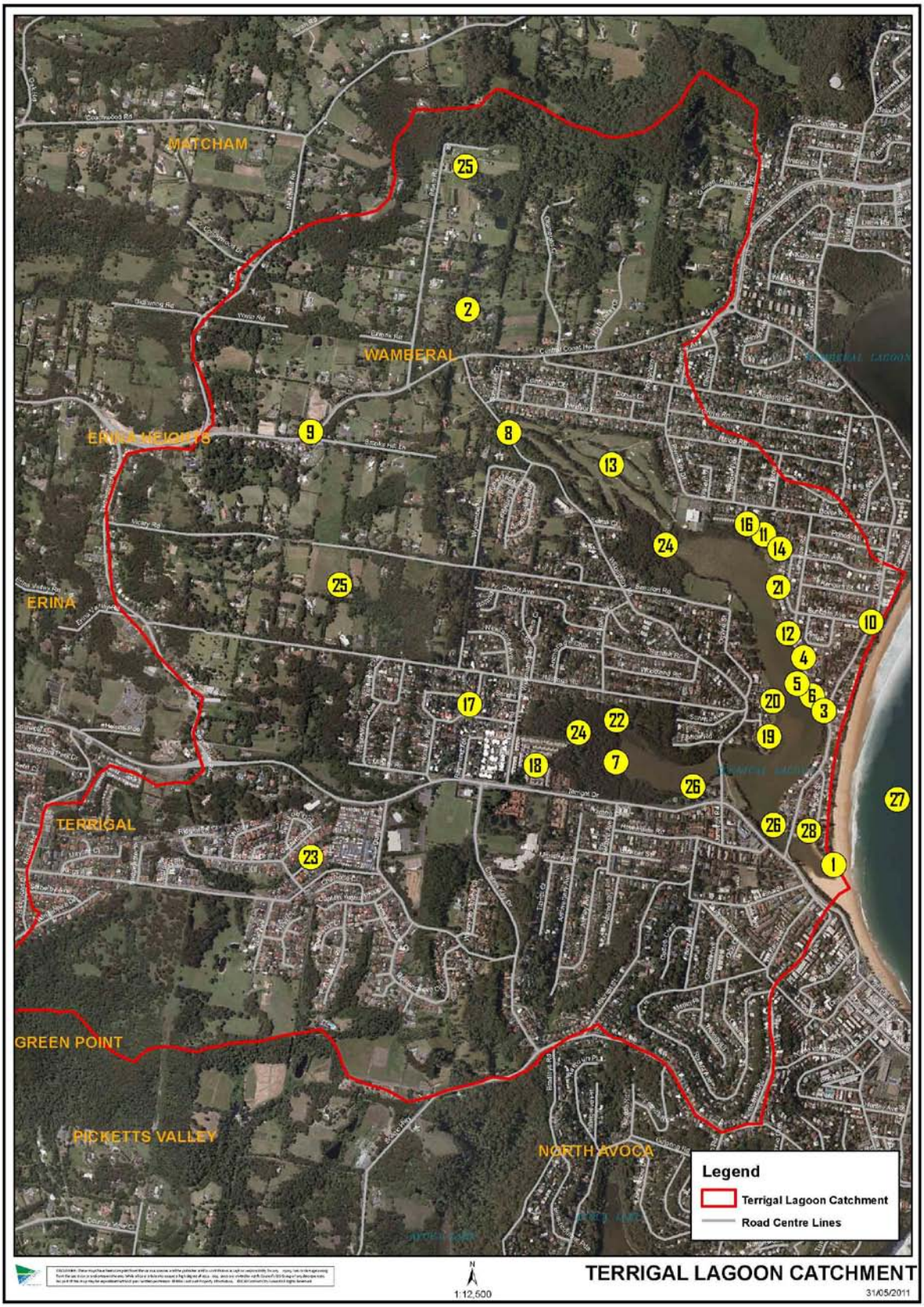

Figure 3-3 Spatial issues mapping based on community consultation for Terrigal Lagoon

Refer to Table 3-4 for brief descriptions of the issues.

The issues identified on the map shown in Figure 3-3 through the community consultation are described in Table 3-4

Table 3-4 Management issue description key for spatial mapping for Terrigal Lagoon developed through the community consultation process.

Item No.	Management Issue Description
1	Sand accumulation at entrance creates usability issues for families
2	Sedimentation of creek line and drains - requires maintenance
3	Weed growth (lantana), rubbish and uncontrolled access issues
4	Flooding of foreshore Road and adjacent properties
5	Lack of depth as a result of sedimentation
6	Access issues and foreshore erosion. Model boat club seeking improved/formalised water access point
7	Important bird habitat
8	Sedimentation of creek line and drains - requires maintenance
9	Sedimentation of creek line and drains from road works - requires maintenance
10	Sub-catchment requires improved drainage and stormwater management (Dover Road to Arilla Avenue)
11	Blocked drainage system requires maintenance
12	Opportunity for improved access for kayaks and recreational users
13	Sedimentation of creek line and drains. Potential nutrient input from Golf Course.
14	Problem with sewage overflows and potential lack of capacity in sewerage system.
12-14	Seawall or levee potential option to overcome inundation issues from lagoon water levels and to improve foreshore access
16	Siltation and Loss of depth leading to flooding issues
17	Concern over development intensification throughout catchment
18	Stormwater pollution issues
19	Restricted foreshore access and encroachment
20	Foreshore clearing by residents. Rabbit problem
21	Need for improved access along entire foreshore coupled with expansion of vegetation communities. Need to change maintenance regime to encourage revegetation.
22	Stormwater runoff issues exacerbated by land clearing along Hastings Road
23	Need for improved creek management, revegetation, stormwater controls
24	High quality vegetation should be protected and enhanced
25	Encourage planting of native vegetation to enhance connectivity and green corridors
26	Need to improve foreshore vegetation to address erosion issue
27	Look at long term land use and option to purchase properties to minimise flood risk (SLR)
28	Sand relocation option to be periodically reviewed to replenish scoured section at the end of Pacific Street. Access issue and threat exists on northern side of lagoon entrance.
	Commercial use of the lagoon and access issues at the end of Pacific Street and off Terrigal Rotary Park

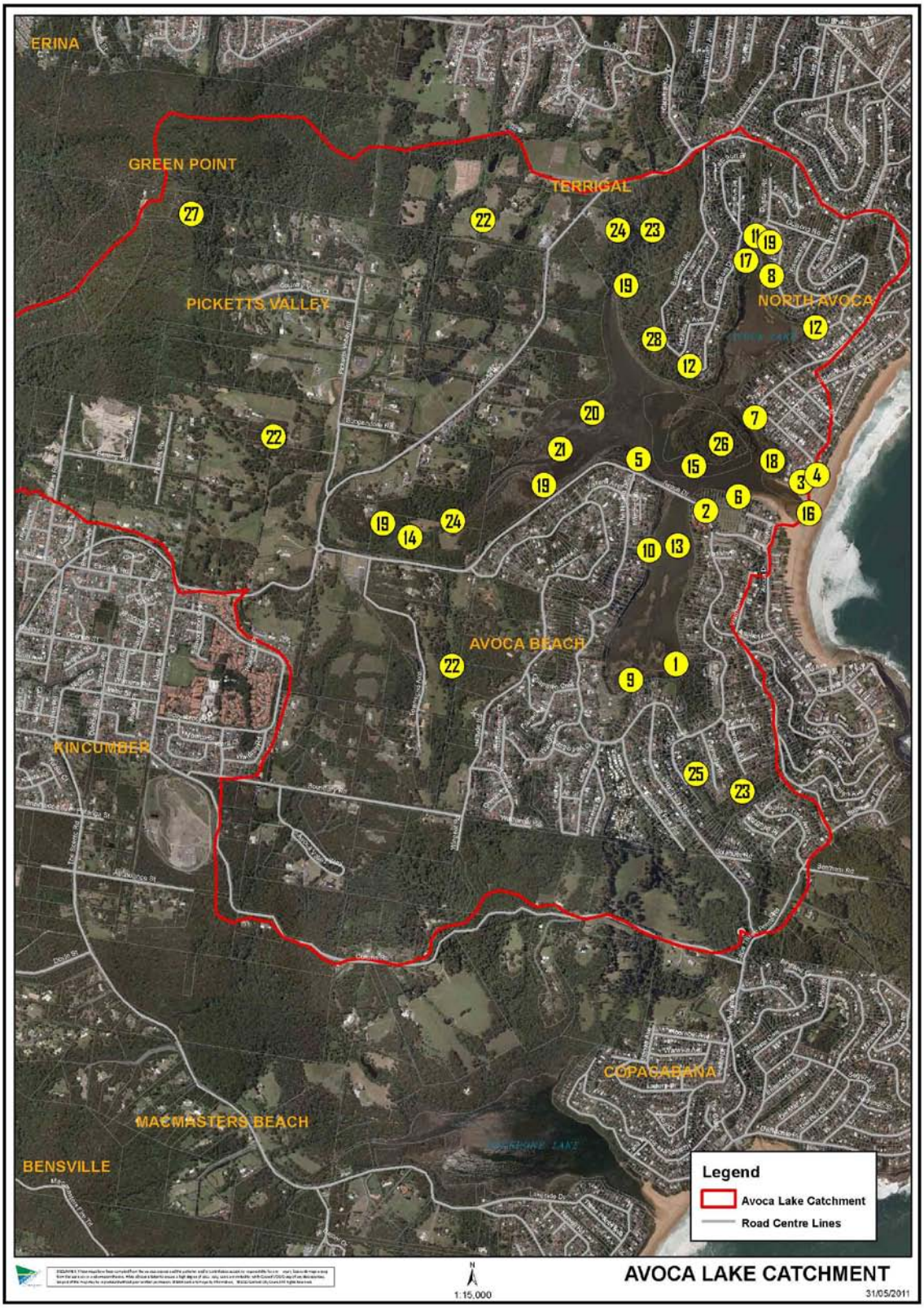

Figure 3-4 Spatial issues mapping based on community consultation for Avoca Lagoon

Refer to Table 3-5 for brief descriptions of the issues.

The issues identified on the map shown in Figure 3-3 through the community consultation are described in Table 3-5

Table 3-5 Management issue description key for spatial mapping for Avoca Lagoon developed through the community consultation process.

Item No.	Management Issue Description
1	Sedimentation and general stormwater pollution problems apparent at pipe outlet.
2	Concern over potential pollution from Service Station at this location. Pollutant problems may be from hard stand area which lacks bunding and potentially underground tanks.
3	Shoreline recession has restricted access on northern foreshore of Lagoon entrance. This has led to uncontrolled access through dunes and led to damage of dune vegetation. Contributing factor may be SPS and stormwater infrastructure.
4	Signage for off-leash dog area is considered to be unclear and may need review (in numerous locations).
5	Sedimentation and general stormwater pollution problems apparent at pipe outlet.
6	Need for reestablishment of foreshore vegetation as stormwater outlet (from car park) is eroding foreshore. Uncontrolled access at this location may also be a contributing factor.
7	Over-enthusiastic mowing of Tramway Reserve (contractors and residents) is impacting on EEC communities.
8	Sedimentation and general stormwater pollution problems from stormwater outlet. Specific problem with blue metal entering stormwater syst6em from road and adjacent lands.
9	Sedimentation and general stormwater pollution problems apparent at pipe outlet.
10	Presence of illegal structures/encroachment on public lands. Chicken Coops and garden beds may be sources of nutrients and contribute to weed infestation/algal blooms.
11	Sedimentation and general stormwater pollution problems apparent at creek/ outlet.
12	Need to improve access by extending and improving existing walking track further around lagoon foreshore.
13	Macroalgal blooms are recognised as an important ecological and aesthetical problem. Large amounts of fast growing algae deplete dissolved oxygen and cause anoxic onditions and consequent death of animals and plants. Masses of rotting algae on the shore significantly reduce the recreational value of the lake.
14	Need for education of property owners in relation to best practice land management relating to pollution/nutrient minimisation.
15	Petrol outboard motors are restricted for use on lagoon. Is the use of electric motors permitted?
16	Entrance management – needs to consider ecological processes (i.e. breeding cycle of the Green and Golden Bell Frog population, wetland vegetation at western end of lagoon etc).
17	Need for improved education to residents in relation to resident Grey headed Flying Fox population.
18	Green and Golden Bell Frog population and migratory bird habitat (i.e. Latham's snipe) – Tramway Reserve needs to be protected.
19	Need to verify extent of Melalueca biconvex community and implement measure to protect/enhance.
20	Important water bird habitat.
21	Investigate species of grass establishing on sand islands and determine risk to foreshore vegetation communities if exotic.
22	Encourage vegetation enhancement program to enhance green corridors
23	Need to manage weed infestations.
24	Feral deer identified in bushland.
25	Problem with stream bank erosion.
26	Need to manage weed infestations.
27	Need to protect yellow-bellied glider population.
28	Bradleys Reserve – need to verify boundary of EEC in this Reserve, threats to vegetation communities and implement measure to project and enhance.

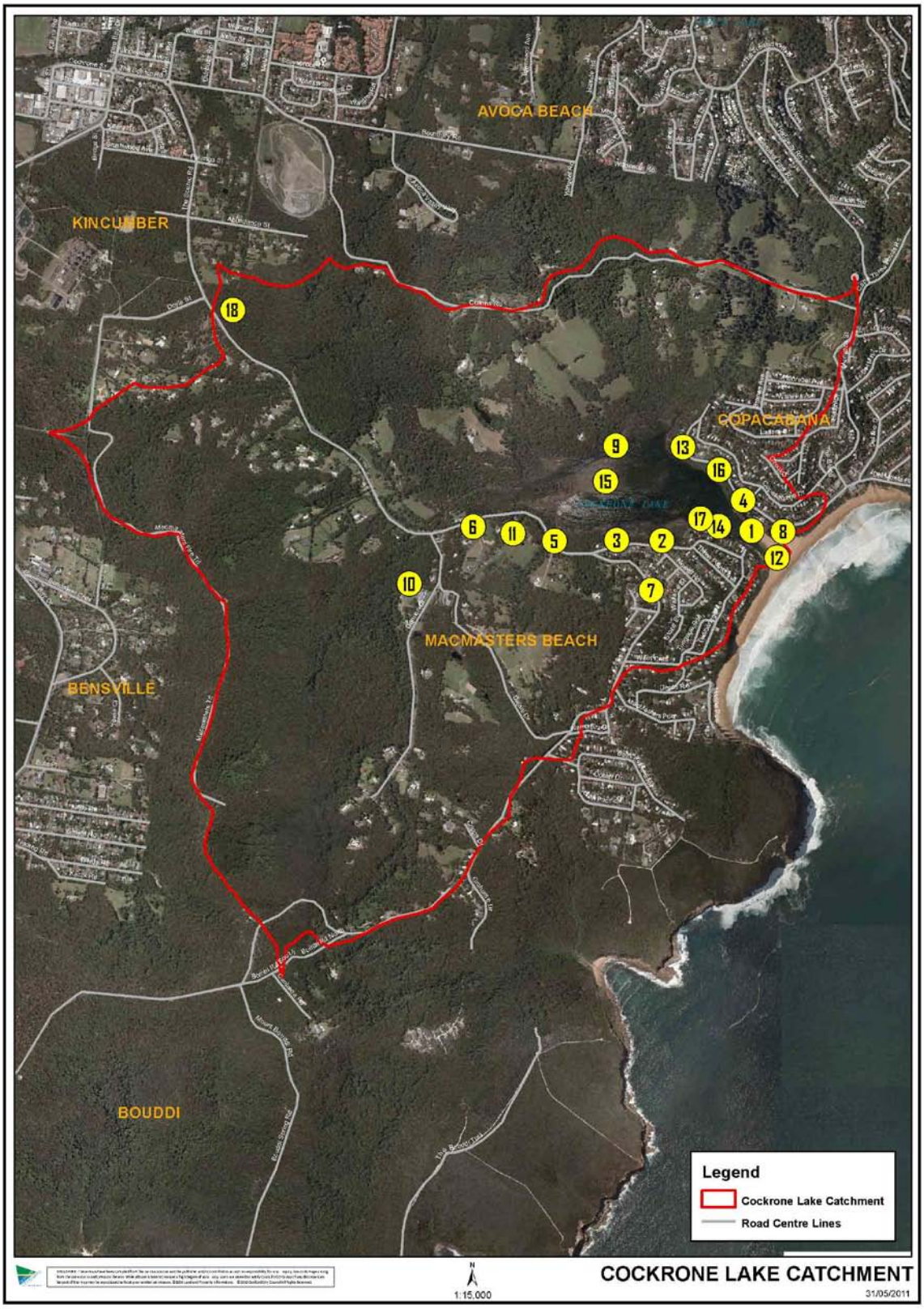

Figure 3-5 Spatial issues mapping based on community consultation for Cockrone Lagoon

Refer to Table 3-6 for brief descriptions of the issues.

The issues identified on the map shown in through the community consultation are described in Table 3-6

Table 3-6 Management issue description key for spatial mapping for Cockrone Lagoon developed through the community consultation process.

Item No.	Management Issue Description
1	Need to ensure regular and adequate flushing of lagoon entrance for ecological/water quality purposes
2	Stormwater drain and piping is unsightly with an inadequate Gross Pollutant Trap. Weeds and siltation problems
3	Problems with stormwater pollution, siltation, weed plumes and gross pollutants
4	Problems with stormwater pollution, siltation, weed plumes and gross pollutants
5	Problems with stormwater pollution, siltation, weed plumes and gross pollutants. Localised erosion issues
6	Potential nutrient source from agricultural practices
7	Road verges are experiencing erosion from high velocity flows down slope
8	Need for beach raking after lagoon opening events
9	High value vegetation on north and west foreshore/riparian zones (SEPP 14). Need to ground truth vegetation communities to enable better management and protection
10	Weed infestation with privet
11	Potential source of nutrients and pathogens from livestock and uncontrolled runoff
12	Opportunity to improve access path between beach and lagoon foreshore
13	Weed and encroachment problems with species including lantana, noogoora burr
14	Encroachment of private property into public foreshore lands
15	High value migratory bird habitat
16	Need to ensure regular maintenance of sediment gross pollutant trap
17	Dinghy and kayak storage impacting upon valuable Endangered Ecological Community
18	Kincumber Scribbly gum Forest identified as a Critically Endangered Ecological Community

4 EXISTING ESTUARY HEALTH AND OTHER MODIFIED VALUES

4.1 Identifying the Status of Estuary Health

As stated in the CZMP Guidelines (DECCW, 2010), the assessment of the health of estuaries should be evaluated against applicable 'estuary health' targets, for example, the NSW Government's Water Quality and River Flow Objectives (DEC, 2006). In reality, all estuaries and especially coastal lagoons, are highly dynamic systems with complex and varied ecosystems. Conditions that define a "healthy" status can therefore vary greatly between ecosystems, or even between locations within an ecosystem. Estuaries are an ecotone between salt and fresh water environments. Given the potential variability of chemical, biological and hydrodynamic conditions within estuaries, applying a single definition or scale for estuary health can be problematic as well as misleading.

Complicating any measure of estuary health is the availability of data to assess health status. Our understanding of these complex systems is generally poor, although improving. Indeed Golley (1993) stated that "ecosystems are not only more complex than we think, they are more complex than we can think". In addition to the availability of data, or lack thereof, it is possible that historical data are now unreliable (due to inaccuracies in measurement techniques or laboratory analysis), or indeed focused on parameters that are now considered unsuitable as indicators of estuary health.

A good example of the difficulty in defining a "healthy" estuary is the recent work by Scanes *et al.* (2011) assessing data collected from lagoons and estuaries in the Nadgee Nature Reserve, including Nadgee Lake, which have had virtually no impact by humans. These estuaries represent an opportunity to study a predominantly closed ICOLL in its complete natural state. The work in the Nadgee wilderness area confirmed earlier work by Scanes *et al*. (2007) that there does not appear to be a relationship between the magnitude of catchment disturbance and ambient nutrient concentrations in estuarine waters. That is, elevated nutrient concentrations still occur in these lakes that have not been impacted by catchment development. The results indicate that some or all of the existing preconceptions about the chemical and algal dynamics of infrequently opened coastal lagoons may need to be re-examined.

The CZMP Guidelines suggest an initial assessment of estuary health be undertaken based on existing information, which may include the National Land and Water Resources Audit (2008) and the State of the Catchments Reports (OEH, 2010). Bearing in mind the complications in assessing estuary health status, the outcomes of these two broad scale (NSW-wide) assessments of estuary health that have included the Gosford Coastal Lagoons are presented in the following sections.

Unfortunately, neither of these assessments give results that are considered to be reflective of the actual status of estuary health for the four Gosford Coastal Lagoons. The reports in fact illustrate the difficulties in applying measures of health to ecosystems as diverse as the estuaries of NSW, and particularly in assessing ICOLLs with a standard set of parameters and thresholds that cover all estuaries.

It is recommended that, instead of focussing upon the outcomes of these reports that may or may not reflect the true status of health in Gosford's Lagoons (and further, may not reflect the values associated with these systems to the community as well as the environment), a program of monitoring to reflect the key parameters of interest to defining changes in environmental and / or

community values be developed. Monitoring as a future management option is discussed further in Chapter 6.

4.1.1 The National Land and Water Resources Audit (NLWRA, 2008)

The National Land and Water Resources Audit (the NLWRA Audit) was funded by the Australian Government through the Natural Heritage Trust. It was set up in 1997 to improve land, water and vegetation management by providing better information to resource managers. The Audit ended on 30 June 2008. The audit included an estuary assessment, which collated information on 979 estuaries and was undertaken to:

- assess the condition of Australian estuaries;
- develop a process-based understanding of estuaries and their diversity across Australia; and
- contribute to an information base that can underpin and inform estuarine management.

The classification scheme used in the audit considered:

- dominant processes (based on estuary type and size);
- catchment characteristics such as land use and hydrology;
- tidal regime;
- condition of the floodplain;
- estuary use;
- pests and weeds; and
- estuarine ecology.

The assessment adopted a pressure, state, response approach.

From the NLWRA Audit, Terrigal Lagoon and Avoca Lagoon are considered to have 'modified conditions', while Wamberal Lagoon and Cockrone Lagoon are considered to have 'extensively modified' conditions. Without detailed appraisal of the Audit methods and associated data, it is not possible to rationalise how these categories were assigned to the Gosford Coastal Lagoons.

4.1.2 State of the Catchment Reports

The NSW Natural Resources Commission has set 13 state-wide targets for natural resource management. The target for estuaries is: "By 2015 there is an improvement in the condition of estuaries and coastal lake ecosystems". Outcomes of the NSW Natural Resources Monitoring and Evaluation Reporting Strategy (MER) were used to compile the 2010 State of the Catchments (SOC) Reports for each catchment management authority region in NSW. Protocols for the assessment of the condition of estuaries and coastal lakes to derive outcomes for the 2010 SOC Reports is documented in Roper *et al.* (2011).

Wamberal, Terrigal, Avoca and Cockrone Lagoon are all included in the SOC Report (noting the Gosford Coastal Lagoons fall within the Hunter Central Rivers Catchment Management Authority region).

The SOC report uses two indices for estuaries, being estuary condition and pressure. Each indicator has been scored relative to a reference or least impaired condition. A number of methods have been employed to develop scoring classes on a five-colour scale of 'very good', 'good', 'fair', 'poor' and 'very poor' to represent the extent of deviation from the reference condition.

The indicators of estuary condition used in the SOC Reports were:

- eutrophication: chlorophyll a, macroalgae and turbidity (microalgae may also be included in the future);
- habitat distribution: change in seagrass, mangrove and saltmarsh (macrophytes) extent;
- fish assemblages: species diversity and composition, species abundance, nursery function and trophic integrity (food web).

The key pressure indicators for the pressure index in the SOC Report (OEH, 2010) provided a broad scale listing of the pressures on the Gosford Coastal Lagoons, as reported in Chapter 3.

The indicators selected, paucity of data and comparison to large permanently open estuaries are problematic for small ICOLLs and the results are again not considered reflective of the actual conditions of the Gosford Coastal Lagoons. Thus, for the Hunter Central Rivers SOC report Cockrone Lagoon is the only estuary rated as 'poor'. Yet within the Gosford basin, Cockrone Lagoon would be amongst the most pristine systems as it has the least catchment disturbance. For the pressure index, the results for the four Gosford Coastal Lagoons are a category of moderate pressure for Wamberal, Avoca and Cockrone Lagoons and High pressure for the Terrigal Lagoon. Terrigal Lagoon is agreed to be under high pressure, although it is arguable that the remaining three lagoons would be considered under only moderate pressure.

4.2 Heritage and Human Demands on the Lagoons

4.2.1 Aboriginal Heritage

The Gosford area has traditionally been inhabited by the Kuringai and Darkinjung people. The earliest known site in the Gosford region is the Loggers Shelter at Mangrove Creek dating to 11,050 BP (Before Present). Given this length of history, the location (and function) of many Aboriginal heritage items within the study area can vary significantly (i.e. Aboriginal sites identified may have been utilised when sea level was up to 120 metres below present day level). The arrival of Europeans within these communities from 1788 is known to be associated with rapid declines in Aboriginal populations through disease (e.g. small pox) and conflicts over land settlement (Cardno, 2010).

A summary of information relating to Aboriginal sites in the area provided by Cardno (2010) noted:

- 30 known sites/items have been identified in the Gosford Coastal Lagoons Catchment. By comparison, some 274 items have been identified within the catchment of Brisbane Water to the south-west of the study area (Cardno, 2008b);
- The majority of these 30 known sites are rock engravings, middens or shelters with middens indicating the dominant activities of the Aboriginal people at that location in the past;
- A number of highly sensitive burial sites are also found in the region;

- 25 of the items are located along the beachfront, at the mouths of lagoons, or along the related tributaries. To protect these items, site locations are not provided;
- Avoca Lagoon Catchment was observed to have the highest density of sites, with a similar number within the Wamberal Catchment;
- Given the high level of development immediately surrounding many of the lower reaches of the estuaries, the probability of discovering previously unresolved Aboriginal items in these areas is lower than in the upper reaches of the estuary, where there is a high probability of discovering further Aboriginal items.

4.2.2 Non-Indigenous Heritage

The greater Gosford area was not significantly settled by Europeans until 1823. Use of the Central Coast first developed after the establishment of a penal colony in Newcastle in 1804. However, it was not until James Webb established a property in Brisbane Water in 1823 and the distribution of land grants that development within the region established itself (predominantly agricultural in nature) (Cardno, 2010).

Cardno (2010) identified seven heritage sites within the four lagoon catchments. The items have local heritage significance, except for the Wamberal Lagoon Nature Reserve, which has National heritage significance. Only three of the sites are located along the estuary foreshores. The seven sites are:

- Wamberal Cemetery (Wamberal foreshore);
- Wamberal Lagoon Nature Reserve (Wamberal foreshore);
- Allen MacMaster's Gravestone (Cockrone catchment);
- "The Gunyah" historical cottage (Terrigal foreshore);
- "Seville" home (Terrigal catchment);
- Former Uniting Church (Terrigal catchment); and
- Erina Heights Public School (Terrigal catchment).

4.2.3 Scenery and Views

The topographical variation and vegetated ridgelines and upper slopes of the Gosford Coastal Lagoons catchments have long been recognised for their scenic amenity and value to the region. As such, they are protected through planning controls to preserve the natural visual backdrop of Gosford City.

4.2.4 Public Access

Access to the southern foreshore of Wamberal Lagoon is limited by the dense vegetation, but this should remain to preserve the foreshore vegetation from inappropriate public access and disturbance. Restricting public access is consistent with maintaining this area as a nature reserve.

Much of the Terrigal Lagoon foreshore is abutted by private property. Those areas that are accessible to the public are highly modified and managed for passive recreation, and are therefore easily accessible. As a result, Terrigal Lagoon is more readily accessible to the general public than the other lagoons (Cardno, 2010).

Avoca Lagoon foreshores are also dominated by private ownership, which limits public foreshore access and confines access to only a few areas.

For Cockrone Lagoon, Crown lands are confined to the coast and do not include any lagoon foreshores, however, there are some stretches of Community Land along the foreshores of the lagoon where public has access.

4.2.5 Recreational Usage

Land-based recreational uses include:

- Picnics and barbeques (with numerous facilities provided);
- Walking and jogging;
- Fishing;
- Bird-watching and nature appreciation;
- Stand-up paddleboards,
- Dog exercising (in designated areas); and
- Cycling.

Water based recreation involves passive watercraft such as canoes, kayaks, paddle-boats and sailboards for wind-surfing and sailboarding, particularly at Avoca and Terrigal. There are a few small commercial operators providing hire of these craft at Avoca and Terrigal. Sailing of model boats is also undertaken. Motorised boating is not permitted at any of the lagoons. In general, Cockrone and Wamberal Lagoons are suited to informal, water-based activities.

There are no formal boat ramps at any of the lagoons, however, there are some informal watercraft launching facilities used at the lagoons (e.g. for canoe and kayak launching).

Swimming is concentrated in the entrance area of all of the lagoons, as it is relatively safe compared with the adjacent open ocean beaches. For this reason the entrance areas are popular with small children and families.

Passive recreational uses of the lagoons are generally compatible with preserving the natural values. Swimming, canoeing and sail boarding are discouraged from areas of high current flow and from sensitive seagrass beds and wetland areas within the lagoons. There are also some restrictions on recreational fishing within the lagoons, namely, fishing by any method involving the use of a holift net, a hand-hauled prawn net, a push or scissors net (prawns), a crab trap, or a lobster trap (Cardno, 2010). The main pressure arising from recreational usage has been the disturbance of foreshores by public access. This is discussed in Section 3.4.

4.3 Modified Estuary Values

The modified estuary values comprise the natural values that have been retained within the lagoons (in spite of external pressures) plus the community values for the lagoons, which includes both human-influenced aspects and the existing natural aspects (modified or otherwise) that are appreciated by the community. The combination of the environmental and community values is outlined below.

4.3.1 Values of the Lagoons Identified by the Community

Values for the lagoons were identified during the community workshops held separately for each lagoon, and are summarised in Table 4-1. The data collated during the workshops is provided in Appendix B. Table 4-1 has been presented to highlight the similarities and differences in values across the lagoons. Generally, values for the lagoons held by the community include:

- the human-influenced aspects such as foreshore access and recreation on land and in the waterways; and
- the natural aspects of the lagoons, such as good water quality, biodiversity and bird and fish life, which also provide aesthetic beauty and a sense of naturalness.

Table 4-1 Values of the Lagoons Identified by the Community

Wamberal	Terrigal	Avoca	Cockrone
Passive recreational opportunities	Recreational use and public access to the foreshore	Access around the lagoon	Community focal point for passive recreation
Good water quality	Good water quality	Good water quality	Good water quality
	Aesthetic beauty	Aesthetic beauty	Aesthetic beauty
Naturalness		Naturalness	
Biodiversity			Biodiversity
	Ecology including fish and birds	Bird and fish life	
			Riparian vegetation
The protected catchment.			
Educational opportunities			
	Consistent depths		

4.3.2 Modified Values and Management Intent

A list of existing, modified, estuary values was compiled based upon the existing environmental processes and conditions of the lagoons, as well as the values highlighted by the community, as given in Table 4-3. It was recognised that while the lagoons all possess similar values, the extent to which the values are critical for environmental or community use and the extent to which the natural values have been modified is different for each lagoon. Inherently, these differences allow for a difference in management priorities across the four lagoons.

A methodology for determining the management intent for the values at each lagoon was developed and applied as part of the risk assessment workshop. The risk assessment workshop (involving CEMC, state agencies and Council staff) focussed upon Avoca Lagoon as a case study, as it was considered to have a broad range of values and threats representative of the four lagoons. The remaining lagoons were then assessed during a smaller internal workshop involving key study team members and Council officers, applying the same methodology as for Avoca Lagoon.

For each of the specific values listed, participants were asked to determine if the management objective should be to 'maintain', 'protect' or 'improve' the value. The description of the 'maintain', 'protect' or 'improve' intentions for management is given in Table 4-2.

Ascribing an intent to 'maintain', 'protect' or 'improve' a particular value requires a decision regarding whether the aim is to:

- return the value to its natural condition (improve);
- preserve the current value and ensure it is not diminished over time, and possibly improved where possible (protect); or
- maintain the status quo, or essentially take a "do nothing" approach to the value (maintain).

The prioritisation essentially focuses on the strengths of each lagoon. This methodology highlights those values that are more important at each lagoon which then become the management intent and priority for future actions. The management intents essentially form the objectives of the Coastal Zone Management Plan for the four lagoons.

The outcomes of the management intent for the estuary values for each lagoon are given in Table 4-3. Natural values such as natural bushland and riparian vegetation are the focus for improvement at Wamberal and Cockrone Lagoons, while tourism is a major focus for Terrigal Lagoon. This reflects the different extents to which the lagoons have been modified, with both Cockrone and Wamberal retaining high quality riparian habitats and bushland that can be further supported through management, compared with Terrigal at which the foreshores and catchment have been heavily modified by development and public access. Indeed, Terrigal has higher water based and access values than Wamberal and Cockrone, reflecting the ease of access to the waterway and foreshore that are in fact a result of human modification and pressure.

Interestingly, water quality was highlighted as a high priority for management ('improve') across all four lagoons. Water quality supports both recreational uses for the more modified lagoons and ecological values in the more natural lagoons.

Table 4-2 Scale for Management Intent

Scale	Condition
I	The current condition of the value should be maintained and actively managed to improve the condition over time – high priority for management
P	The management objective is to protect this value over time (and enhance where possible) – priority for management
M	The maintenance of the value is desirable but not essential and does not drive management decisions

Table 4-3 Environmental & Community Values and Management Intent for the Lagoons

Value	Wamberal	Terrigal	Avoca	Cockrone
Water Quality	I	I	I	I
Natural Bushland/Riparian Vegetation	I	M	I	I
Presence of Threatened Species – flora or fauna	P	M	P	P
Aquatic/marine vegetation (seagrass, etc.)	P	M	P	P
Supports species at a Critical Life Stage – (nesting, breeding, spawning habitat)	M	M	P	M
Wetland Fauna – Fish and other aquatic fauna habitat values	P	P	P	P
Wetland Fauna – Waterbird habitat (migratory or resident)	I	M	P	P
Primary Contact – Recreation (Swimming)	M	P	P	P
Secondary Contact – Recreation (Boating, Fishing)	M	M	M	M
Aesthetic Beauty	M	M	M	M
Public Access around Lagoon	M	M	M	M
Educational resource	P	P	M	M
Tourism	M	P	P	M
Flood Mitigation/entrance management	M	P	M	M
Historic or indigenous cultural heritage significance	M	M	M	P

I = Improve, P = Protect, M = Maintain – see Table 4-2.

5 ASSESSMENT OF THREATS TO ESTUARY VALUES

5.1 Application of a Risk-based Threat Assessment to Estuary Management

A risk-based framework is a robust methodology for dealing with outcomes that are uncertain or have limited data, or for impacts with uncertain timeframes. A key step towards improving, protecting or maintaining the estuary values is identifying the risks that may threaten those values. The use of a risk-based approach for managing coastal hazards is a requirement of the new CZMP Guidelines, and accords with current international best practice for natural resource management.

A risk-based approach is particularly applicable to the impacts of projected sea level rise, where there is considerable uncertainty regarding when and if impacts will manifest, and for ICOLLs such as the Gosford Coastal Lagoons, how such impacts may manifest. But in the case of the coastal lagoons, given the historical, ongoing and future pressures upon the lagoons, such 'risks' may already be occurring.

The standard risk management approach defines the magnitude of risk as a combination of 1) the likelihood of a risk event occurring, and 2) the consequence if such an event does occur. For this project, a variation on the standard risk approach has been adopted to address management of existing threats that already have a 'frequency' of occurrence, as opposed to future / unrealised risks that have a 'likelihood' of occurrence. Essentially, a threat or risk assessment process is the same, only threats are described in terms of their frequency, compared with risks that are described in terms of their likelihood. In both cases, the consequence of the threats that have (or may) occur or of the risks that may occur forms the second variable in calculating the magnitude of the threat/risk.

The Threat Assessment process utilised for the Gosford Coastal Lagoons Coastal Zone Management Study is adapted from the Australian Standard Risk Management Principles and Guidelines (AS/NZS ISO 31000:2009), and is described below and presented schematically in Figure 5-1.

- **Establish the Context –** the requirements and scope of a coastal zone management plan for estuaries set by NSW Legislation and Guidelines provides the context for the threat assessment and intended outcomes. The purpose and context for the Gosford Lagoons CZMP is outlined in Chapter 1. Each of the coastal lagoons has distinct community and environmental values that need to be improved, protected or maintained (see Section 4.3.2), and this forms the objectives for the Plan and therefore the Threat Assessment;
- **Identify the Threats –** the threats arise from the pressures upon lagoon processes that subsequently modify the lagoons' values. Pressures may be historical, they may be occurring at present, or they may arise in the future such as due to sea level rise. A combination of scientific assessment and community inputs assisted to identify the external pressures upon the lagoons and therefore threats to each of the four Gosford Lagoons;
- **Analyse the Threats –** the threats to lagoon values need to be qualified in terms the **frequency** with which they occur and the **consequence** of their occurrence, so that an appropriate management response to intervene or adapt to the threat can be identified. That is, the level or degree of threat (extreme, high, medium or low) is the product of *frequency X consequence;*

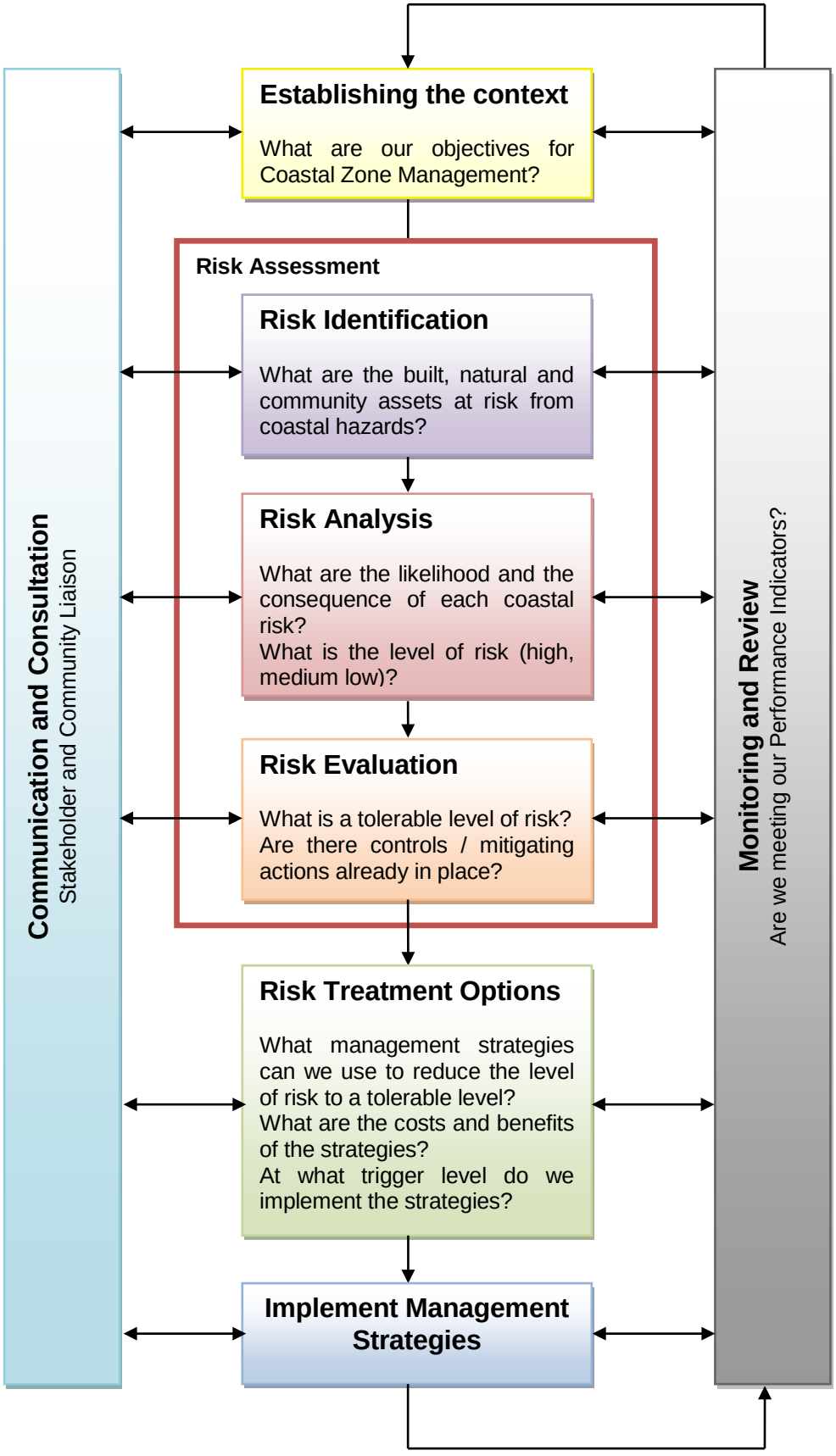

Figure 5-1 Risk Management Framework (ISO 31000:2009) adapted to Coastal Zone Management

- The *frequency* of occurrence for the threats aims to qualify the existing threats that are already occurring as well as the potential future threats such as the impacts of sea level rise;
- The *consequence* relates to the impact of the threats upon the values of the lagoon, particularly the environmental values. The values and therefore the management objectives differ across the four lagoons. Determining the consequence to the a particular lagoon's values ensures that those aspects that are specific to the lagoon are captured by the Threat Assessment and managed appropriately for each lagoon;
- The frequency and consequence are then combined to determine the level or *degree of the threats* to each lagoon. The product of frequency and consequence are specified within a Threat Matrix. The level of threat is listed for each identified threat in each lagoon, which is then used to assist in the identification and prioritisation of management actions, with management options that treat the greatest threats given priority. A register of the threats listed in ranked order from greatest to least threat at each lagoon is given in Section 5.3.3;
- **Evaluate the Threats –** in consultation with Council and other stakeholders (from the CEMC, state agencies and others), the threat assessment and threat criteria were checked to ensure a reasonable and consistent outcome. The existing controls that may manage any of the identified threats was investigated and included in the development of management options where appropriate (see Section 5.4);
- **Manage the Threats –** the process of developing coastal management options is directly related to managing the threats to lagoon values. Management options may be designed as intervention actions to improve or protect lagoon values and therefore eliminate extreme or high threats; or adaptation actions to maintain, protect or improve lagoon values and therefore reduce extreme or high threats and incidentally eliminate medium or low threats where possible;
- The management options were considered based upon the technical viability of implementation in the study area. A cost benefit analysis for the options was conducted to consider a range of factors. A key component of this analysis was to score the options based upon the level of threat treated by the option, i.e. options that treated extreme threats are weighted more highly than those treating low threats. Another key component of the cost-benefit analysis was the values and therefore key management objectives addressed by the option at a particular lagoon. In this manner, the prioritisation of management options is tied directly to the threat assessment and the management intent (through values at individual lagoons). Management options are outlined and analysed in Chapter 6; and
- **Implement Management Strategies (Risk Treatments) –** The Coastal Zone Management Plan provides the forum to detail how the recommended management options (risk treatments) shall be implemented (costs, timeframes etc.) and funded. Ongoing monitoring and review of both the threats and management options is also detailed. The Coastal Zone Management Plan outlining the preferred actions for implementation shall be compiled subsequent to finalisation of this Coastal Zone Management Study.

5.2 Identifying the Threats to Estuary Values

A first pass list of threats to estuary health for each of the lagoons was developed by the study team using:

- The Estuary Processes Study (Cardno, 2010); and
- The threats identified by the community during the four workshops, as summarised in Table 7-1 (Appendix B).

The first pass list of threats was refined through:

- The threat assessment workshop, involving a broader range of Council, CEMC, state agencies and other stakeholder representatives;
- The smaller internal workshop with Council and key study team members; and then
- Circulation of the list of threats to relevant Council staff.

The initial list of threats is presented in Appendix C. The final list of threats is listed in Table 5-4 to Table 5-7, presented separately for each lagoon. For example, at Wamberal Lagoon, the community is very concerned about the occurrence of myrtle rust, which is seen to be resulting in defoliation and a loss of tree species and abundance and therefore a loss of naturalness. This threat was subsequently removed from the final list as Council advised that it is already being addressed through a separate process.

Likewise at Avoca Lagoon, there is considerable concern that fruit bats living around the lagoon may be stripping trees of vegetation, which is then being assumed to increase light in the lagoon and so the occurrence of algal blooms. There does not appear to be any scientific data supporting this assumption, and further, Council staff have advised that a CZMP is not an appropriate mechanism for addressing such a threat.

5.3 Threat Assessment Results

The assessment of the level of threat requires consideration of both the frequency of the event and the consequence if and when the event occurs. As for risk, the level of threat = frequency x consequence.

In order to qualify both the frequency and consequence of the threat, and the combination of these factors, a set of scales was developed specifically for this Gosford Lagoons threat assessment. Based upon these scales, the frequency and consequence for each of the threats at each lagoons was ascribed:

- for Avoca Lagoon, during the Threat Assessment Workshop:
- for the remaining lagoons during the subsequent internal workshop; and
- then re-checked by Council staff for all lagoons.

The scales and outcomes of their application to the threats identified for the Gosford Lagoons is detailed below.

5.3.1 Frequency of Threats

A frequency scale has been developed that reflects the varying level of prevalence of the identified threats (Table 5-1). The scale is based upon the frequency range of the known threats to the Gosford Lagoons, that being from 'almost never' to 'often or continuous'. The frequency ascribed to each of the threats at each lagoon, based upon the workshops and further refinement by the study team, is provided for reference in Appendix C.

Table 5-1 Frequency Scale Adopted for the Threat Assessment

Scale	Frequency Descriptor
1	Almost Never
2	Rare
3	Infrequent
4	Occasionally
5	Often / continuous

5.3.2 Consequence of Threats

The threat assessment was linked back to the management intent by adopting a consequence scale that related to the environmental values of the lagoons. The consequence scale that was developed focuses specifically on how the consequence may affect the environmental and / or community values of the lagoons, since it is the improvement, protection or maintenance of these values that forms the management intent for the Plan. The consequence scale used in the threat assessment is provided in Table 5-2. The final consequence value ascribed to each threat for each lagoon, based upon both the threat assessment and internal workshops and Council review, is provided in Appendix C. For example the threat of pollutants entering the lagoon via stormwater as a result of existing catchment activities was a threat for each of the lagoons with varying consequences dependent upon catchment land uses and management intent for relevant environmental values.

Table 5-2 Consequence Scale Adopted for the Threat Assessment

Scale	Consequence
1	No or negligible impact to the environmental value
2	Small but measurable impact to environmental value but impact is temporary and value is maintained at current level over time
3	Moderate impact to environmental value; impact is still temporary and recovery is likely over time
4	Major impact to environmental value; impact will occur for period of months/years. Recovery is possible in the long term
5	Permanent Loss of Value; recovery unlikely or irreversible

5.3.3 Level of Threat for Each Lagoon

A threat matrix was developed to provide the overall threat level from the combination of consequence and frequency, as given in Table 5-3. The matrix was developed bearing in mind that

many of the threats are already being experienced across the four lagoons, but with varying frequency and / or consequence. The matrix was designed to ensure that the combination of frequency and consequence was a reasonable reflection of the level of threat or risk that may already be occurring.

The degree or level of threat from the combination of the frequency and consequences ascribed for each threat at each lagoon is outlined in Table 5-4 to Table 5-7. The level of threat was used as a key component in assessing the applicability of the management options in Chapter 6, through use of a scoring system for the level of threat treated by the management option.

Table 5-3 Threat Matrix Defining the Level of Threat

		Consequence				
		Negligible (1)	**Small but measurable (2)**	**Moderate (3)**	**Major (4)**	**Permanent (5)**
Frequency	**Often / Continuous (5)**	**low**	**medium**	**high**	**extreme**	**extreme**
	Occasionally (4)	**low**	**medium**	**high**	**high**	**extreme**
	Infrequent (3)	**low**	**medium**	**high**	**high**	**high**
	Rare (2)	**low**	**low**	**medium**	**medium**	**high**
	Almost never (1)	**low**	**low**	**medium**	**medium**	**medium**

5.3.4 Threats to Wamberal Lagoon

Threats to Wamberal Lagoon, as determined through the processes described above, as summarised in Table 5-4.

Table 5-4 Ranked Threats to Wamberal Lagoon

Threat	Threat Level
Inappropriate dumping of residential garden waste resulting in weed invasion	extreme
Impacts of sea level rise on foreshore inundation	extreme
Pollutants entering the lagoon via stormwater as a result of existing catchment activities	high
Disturbance of native wildlife as a result of recreational usage	high
Displacement of native species by exotics resulting in loss of biodiversity within the lagoon	high
Faecal contamination leading to impacts on recreational opportunities and increased nutrients	high
Impacts of sea level rise on environmental values	high
Increased density of development into the future and reduction in undeveloped land contributing to increased runoff to the lagoon	medium
Insufficient habitat protection as a result of inadequate management resources and funding leading to a decline in total protected catchment area	medium
Erosion of sand dunes and loss of dunal vegetation due to recreational use	medium
Algal blooms as a result of nutrient inputs resulting in a decline in recreational opportunities	medium
Loss of vegetation and increased erosion as a result of bushfires leading to degradation of the protected catchment area and sedimentation of waterway	low
Reduced depths within the estuary due to opening regime	low
Decreased extents of Melaleuca forests as a result of land clearing for development leading to a loss in biodiversity	low

5.3.5 Threats to Terrigal Lagoon

Threats to Terrigal Lagoon, as determined through the processes described above, as summarised in Table 5-5.

Table 5-5 Ranked Threats to Terrigal Lagoon

Threat	Threat Level
Faecal contamination of the estuary leading to impacts on human and estuary health.	extreme
Loss of foreshore habitat value due to removal of foreshore vegetation, weed invasion, mowing and trampling leading to a decrease in ecological health	extreme
Impacts of sea level rise on foreshore inundation	extreme
Foreshore erosion around the lagoon due to pedestrian and vehicle access	high
Pollutants entering the lagoon via stormwater as a result of existing catchment activities	high
Increased density of development into the future and reduction in undeveloped land contributing to increased runoff to the lagoon	medium
Displacement of native species by exotics resulting in a loss of biodiversity within the lagoon	medium
Inappropriate dumping of residential garden waste resulting in weed invasion	medium
Infestations of weeds due to introduced plant species around the lagoon resulting in a decline in plant diversity.	medium
Impacts of sea level rise on environmental values	medium

Threat	Threat Level
Disturbance of native wildlife as a result of recreational usage	**medium**
Loss of recreational access due to low water levels following entrance opening	**low**
Changes in water chemistry and enhanced sand ingress due to opening policy leading to shifts in the ecology	**low**

5.3.6 Threats to Avoca Lagoon

Threats to Avoca Lagoon, as determined through the processes described above, as summarised in Table 5-6.

Table 5-6 Ranked Threats to Avoca Lagoon

Threat	Threat Level
Smothering of vegetation due to soil erosion from construction sites resulting in loss of natural bushland	**extreme**
Loss of native riparian vegetation due to mowing of tramway reserve resulting in reduced habitat potential for frogs and migratory birds	**extreme**
Contamination by sewage in lagoon waters due to sewer system overflows resulting in declining water quality	**extreme**
Impact of sea level rise on coastal inundation	**extreme**
Impacts of sea level rise on environmental values	**high**
Pollutants entering the lagoon via stormwater	**high**
Water pollution due to nutrient enrichment resulting in a decline in water quality	**high**
Restrictions to recreational access around the lagoon due to vegetation overgrowth, high lagoon water levels and unauthorised land use (fencing, jetties, car parking) resulting in a loss of amenity	**high**
Unpleasant odours from decaying algae resulting in complaints	**high**
Low abundance of birds due to presence and actions of domestic animals leading to a reduction in bird and fish life.	**high**
Low concentrations of dissolved oxygen within lake waters due to increased algal decay resulting in declining water quality	**high**
Reduction in flushing and circulation within the upper reaches of the lagoon due to excessive algal growth leading to declining water quality	**high**
Sedimentation resulting in low water depths leading to enhanced water temperatures and algal blooms	**high**
Dune erosion due to opening events leading to loss of access around lagoon.	**high**
Increased nutrient inputs due to chicken coops and garden beds on public lands resulting in water pollution	**high**
Faecal contamination of the estuary leading to impacts on human and estuary health	**high**
Disturbance of native wildlife as a result of recreational usage	**medium**
Increased frequency of lower lake water levels due to illegal openings resulting in a loss of aesthetic beauty	**medium**
Prograding mud flats due to siltation leading to loss of aesthetic beauty	**medium**
Loss of tadpoles from Bareena wetland due to artificial entrance opening leading to reduction in abundance of Green and Golden Bell Frogs	**medium**

Threat	Threat Level
Deterioration of fauna and flora due to increased presence of nutrients and contaminants from agricultural runoff resulting in a decline in water quality	**medium**
Inappropriate dumping of residential garden waste	**medium**
Illegal dumping of garbage e.g. car parts, shopping trolleys, and unauthorised car parking around lagoon resulting in degradation of foreshore areas and loss of access to lagoon waters.	**low**
Displacement of native species by exotics resulting in loss of biodiversity within lagoon	**low**
Destruction of native vegetation due to human activities resulting in a loss of natural bushland as well as bird and fish life.	**low**
Loss of habitat due to urban development leading to reduction in bird and fish life	**low**

5.3.7 Threats to Cockrone Lagoon

Threats to Cockrone Lagoon, as determined through the processes described above, as summarised in Table 5-7.

Table 5-7 Ranked threats to Cockrone Lagoon

Threat	Threat Level
Inappropriate dumping of residential garden waste resulting in weed invasion	**extreme**
Impacts of sea level rise on foreshore inundation	**extreme**
Pollutants entering the lagoon via stormwater as a result of existing catchment activities	**high**
Erosion of beach berm due to illegal openings of the lagoon leading to a reduction in amenity	**high**
Disturbance of native wildlife as a result of recreational usage	**high**
Infestations of weeds due to introduced plant species around the lagoon resulting in a decline in plant diversity.	**high**
Faecal contamination leading to impacts on recreational opportunities and increased nutrients	**high**
Impacts of sea level rise on environmental values	**high**
Displacement of native species by exotics resulting in a loss of biodiversity within the lagoon	**high**
Increased density of development into the future and reduction in undeveloped land contributing to increased runoff to the lagoon	**medium**
Impacts of catchment development on landscape character	**medium**
Insufficient habitat protection as a result of inadequate management resources and funding leading to a decline in total protected catchment area	**medium**
Erosion of sand dunes and loss of dunal vegetation due to recreational use	**medium**
Damage to flora and fauna diversity due to increased human access around pristine sections of the lagoon leading to a reduction in aesthetic beauty	**medium**
Impacts on bird populations due to predation from feral animals resulting in a loss of diversity	**medium**
Abundant numbers of ducks due to hand feeding increasing nutrients and reducing aesthetic beauty	**low**
Reduced depths within the estuary due to opening regime	**low**
Algal blooms resulting in a decline in amenity	**low**

Threat	Threat Level
Visual pollution due to excess signage around the lake leading to a decline in aesthetic beauty.	low
Threat to pristine and tranquil qualities of the lagoon environment should commercial development be allowed, resulting in loss of aesthetic beauty	low

5.4 Existing Controls

Existing controls such as provisions in the LEP or DCPs, POMs, works or other actions, including the opening policies and water quality monitoring program need to be incorporated into the assessment of threats, as such existing controls may (theoretically) reduce the level of existing threats (frequency and / or consequence) (if indeed these existing controls are effective). Existing controls were documented under four categories that align with Council's areas of operation, being planning, works, compliance, research/monitoring and education. The range of existing controls has been reviewed and incorporated where possible within the assessment of threats to specific values.

The preparation of management options (refer to Section 6) includes recommended changes to existing controls that may better address threats to lagoon values.

A summary listing of existing controls is outlined in Table 5-8 while a discussion of key existing controls that potentially affect the Gosford Coastal Lagoons is provided below.

Table 5-8 Existing Controls to Threats

Planning				
Lagoon opening policy (R0.14)	Councils Response to communities affected by emergencies (H3.05)	Native Vegetation of Lagoons (R0.16)	Disposal of Injured, Diseased or Dangerous Animals (D1.07)	Flood Plain Risk Management Committee Policy (D2.10)
LEP	Access through Reserves (R0.03)	Wetlands Management Policy (R0.17)	Dob in a Dumper Program (D1.09)	Climate Change Policy (D2.11)
Threatened species recovery plans	Use of Public Reserves (R0.04)	Biodiversity Management Policy (R0.18)	Regional Vegetation / Vegetation Vandalism (D1.10)	Bush Fire Management (D6.37)
Aquatic habitat protection policy guidelines	Bareena Island Care and Control (R0.05)	Dog Exercise Area (R3.06)	Environmental Policy (D2.07)	Landscape and vegetation Management Policy (D6.44)
Biodiversity strategy	Natural Area Bushland (R0.13)	Prohibiting Power Boats on Lagoon (R3.07)	Flood Management (D2.08)	Nutrient Control for Development (D6.45)
Setback Policy – Creeks, Rivers & Lagoons (D6.47)	Erosion Sedimentation Control (D6.46)	Tree Distribution (T1.13)	Flood Management (NSW govt. policy) (D2.09)	
Rainforest (D6.49)	DAMP (drainage asset	Existing EMP	Water Cycle Management	

	management Plan – identifies all devices)		Strategy	
Works				
Lagoon Opening Procedure	Drainage work, control scouring, address minor flood issues, resizing culverts,	Improvements to sewerage network to prevent leakage	No mow zones	Habitat rehabilitation / resilience building
Stormwater maintenance (SQIDs) (need to prioritise for maximum benefit)	Bush care	Sewage pump station improvements to reduce the chance of overflow	Present project for sand relocation at Avoca Lagoon moving channel further south trial to prevent erosion)	
Compliance				
EPA conditions (Environmental protection licence)	Signage – warning / hazard	Construction and post construction		
Research / monitoring				
Algal bloom research	WQ sampling (monthly ambient, bacterial weekly)	Water level monitoring and basic warning system	Climate change research through HCCREMS and CSIRO,	State govt, projects such as these
Education				
Protection of habitats and biodiversity (lagoon info sheets, habitat type fact sheets – ready to be updated)	DEET	Bush care program	CEN (including rehab plans),	Marine discovery centre
Signage – interpretative				

5.4.1 Previous Management Plan

The extent to which the 1995 Coastal Lagoons (Estuary) Management Plan (CLMP) has been implemented is unknown. The outcomes of the present CZMP will be maximised through having an understanding of the success and challenges of implementing the actions in the previous management plan. As some of the participants at the workshop were directly involved in implementing the previous plan, the opportunity was taken to undertake a rapid audit of the implementation and success of the CLMP. A table listing each of the actions recommended for Avoca Lagoon in the previous study was circulated. Participants then added information relevant to the implementation of these actions. Information included:

- If the action had been partially or fully implemented;
- If it had been implemented, a comment on the success of the action in meeting the objective; and
- Where it had not been implemented, any known reason for this (e.g., lack of funding, lack of community support, resources etc.).

5.4.2 Planning Controls: COSS

The Coastal Open Space System (COSS) has been in operation since the early 1980's, and maintains the environmental and visual qualities of these lands by progressively bringing such lands into public ownership. Privately owned elevated and vegetated lands are managed to support the environmental and scenic qualities of the lands. The protection of the COSS and management of other areas of remnant vegetation, habitat and foreshore areas plays a key role in lagoon catchment protection.

Proposed zonings under Draft Gosford Local Environmental Plan 2009 continue to recognise the importance of both COSS and other environmentally sensitive lands, and draft Gosford Development Control Plan has further specific provisions to ensure these qualities are protected.

5.4.3 *Planning Controls: Dual Occupancy*

Dual occupancy is not allowed for Urban Areas under the GPSO. The GPSO states that "Consent must not be granted for the carrying out of development for the purpose of a dual occupancy;

(b) on land within Zone No. 2(a) which is within the lagoon catchment of Wamberal or Terrigal Lagoons, or Avoca or Cockrone Lakes, or is within the locality of Pearl Beach or Patonga"

This is considered to be a significant conservation initiative for the Gosford Lagoons.

Dual Occupancy is also not allowed, with development consent for non urban areas under IDO 122, which states:

"Consent must not be granted for the carrying out of development for the purpose of a dual occupancy: on land within Zone No. 7(c2) or 7(c3) which is within the lagoon catchment of Wamberal or Terrigal Lakes, or Avoca or Cockrone Lakes, or is within the locality of Pearl Beach or Patonga, as defined by the Geographical Names Board"

5.4.4 Draft LEP

As with other local Councils across NSW, Gosford Council is in the process of converting its current principal planning instrument to a standard instrument LEP. One Standard Instrument LEP will replace all existing LEPs in each local government area (LGA). It is not yet finalised how existing controls such as the COSS Lands reservation will be carried over into the new template LEP. The state wide standard zonings include just 3 categories for private lands with environmental values. These are:

- Environmental Conservation E2;

- Environmental Management E3; and
- Environmental Living E4.

Gosford Council is negotiating with the state Government to introduce a new zone E5 Public Conservation, to better reflect the intention and function of the existing COSS Lands. These lands might otherwise be zone RE1, however, this would reduce the current conservation level applied to these lands.

6 MANAGEMENT OPTIONS

6.1 Introduction

Management options have been designed to improve the condition of the lagoons and to facilitate and support environmental and community uses. *Limits of Acceptable Change* have been defined by the decision to "improve, protect or maintain" the estuary values identified.

An initial 'long-list' of possible Management Options was developed, under each Management Aim. This 'long list' of options is provided in Appendix D. The source of these options include recommendations from the Estuary Processes Study (Cardno, 2010) (refer Section 6.3), community input through the workshop process, suggestions from agency representatives and other stakeholders from the threat assessment workshop, best practice approaches used elsewhere and tailored strategies developed by the Study Team. The long list contained over 100 separate potential management options.

The possible Management Options identified utilise a variety of implementation mechanisms that can act at different levels, or on different aspects of the problem. Types of Management Options considered include:

- planning controls and policies;
- economic incentives and cost sharing arrangements;
- regulation and compliance;
- on-ground works and rehabilitation;
- investigation;
- monitoring;
- research; and
- education and public relations.

It is not practical or affordable for Council to implement all of these options, therefore a methodology for prioritising options was developed. The result is a list of recommended options to achieve the management objectives within an affordable and realistic framework.

6.2 Types of Options: Intervention vs Adaptation

In accordance with a risk management approach, Management Options are designed to reduce the frequency of a threat occurring or to reduce the severity of the consequence of the threat occurring or both. In this regard options have been categorised as either an *intervention option* or an *adaptation option*.

Intervention options are those designed to reduce impacts of threats on natural values. These are typically options that address issues at the source.

Adaptation options are options to improve resilience of use (by the environment or the community) to modified values. These options typically address issues by improving the estuaries capacity to accommodate threats.

6.3 Recommendations from the Estuary Processes Study

The Estuary Processes Study (Cardno, 2010) makes a range of recommendations for consideration by the Coastal Zone Management Study. These recommendations are compiled below and have been incorporated into the development of potential management options for the Gosford Coastal Lagoons:

- Where possible, improve catchment management practices to reduce impacts on the lagoons;
- Look at opportunities to implement WSUD (Cardno [2010] says target Terrigal in the first instance as this is worst affected – it could be argued, however, that the first focus should be on the catchments of the lagoons with the most potential for rehabilitation);
- Where contaminated sites are identified, the potential for migration via stormwater into the lagoons should be considered;
- Ongoing protection for foreshore vegetation and maintenance of existing protection works;
- Management of recreational activities to ensure ongoing stability of lagoon banks;
- Catchment based control to reduce sediment input including planning controls, compliance monitoring, community education and the implementation of WSUD features;
- Consider management of lagoon water levels and algal build up with a view to minimising the incidence of these water quality issues following breakout;
- Acknowledgement that existing opening regime has been in place for 40 years and will have already changed lagoon ecology and that pragmatic management approach should be adopted that seeks to maintain and enhance the lagoon ecology within the parameters of the existing framework;
- Consider developing an ecological monitoring strategy;
- There is a high probability of sea level rise exposing further Aboriginal items. Any management actions likely to impact upon or regarding aboriginal heritage should be developed in consultation with local Aboriginal people;
- Consideration should be given to the impacts of climate change on heritage items;
- Foreshore access needs to be managed to minimise impacts to vegetation and foreshores – may require an educational component;
- Areas currently experiencing bank erosion and instability and areas vulnerable to this in the future should be addressed;
- Council and CLD should capitalise on any opportunities to acquire additional foreshore lands, bringing them into public ownership to maximise opportunities to improve and enhance public access and foreshore ecological values;
- Water quality monitoring for public recreation;

- Reduce risks to public safety during breakout; and
- More strategic water quality monitoring.

6.4 Evaluation of Management Options

A two stage approach was applied to the initial long list of options. Firstly, options passed through a coarse filter wherein management options that were clearly "no regrets" actions were 'fast-tracked' to a short-list of options. For all remaining options, a fine filter was used to evaluate the benefits and costs of the options. Options that score well in the fine filter (over a relative score of 20) were also included in the final short-list. Options that did not get short-listed would still potentially have merit and therefore have been included in Appendix D of this document for future reference.

6.4.1 Coarse Filter

A coarse filter was initially adopted to identify 'no regrets' options. 'No regrets' refers to options that are clearly beneficial to the lagoons, the broader community, and involve little or no trade-offs. These options should be pursued irrespective of the specific aims and objectives of this CZMP.

No regrets options involve on-going compliance, education and further investigations, aimed at improving resilience to threats imposed on lagoon health now and in the future. In general, implementation of all 'no regrets' options should be pursued as part of normal day-to-day duties by Council and other relevant management authorities.

6.4.2 Fine Filter

A multi-criteria rapid assessment tool was developed to assess the positive and negative costs and benefits of the various options. These costs and benefits consider more than the technical merits of the options, by including aspects such as the degree of the threats addressed, implementation cost (capital and on-going), timeframe, community acceptance, ease of implementation and effectiveness (in terms of the management intent of the value that the option addresses).

The fine filter assessment tool is based on a "traffic light" colour system for a range of variables, to clearly display if an aspect of an option should be cause to "stop" and reconsider, "slow" to proceed with caution or "go" with few trade-offs expected. The assessment has been conducted for each possible Management Option. It is aimed at presenting quickly and clearly the benefits and trade-offs of a particular option, to assist in the selection of a short-list of management options.

Each of the options has a final score based on this traffic light assessment. The criteria that were scored on are given in the Table 6-1. In the scoring system used, green coloured traffic lights were given 3 points, orange 2 and red scored 1. This gave each option an overall score out of 21, per lagoon. Where an option scored 20 or higher for a lagoon, it was included in the short list. Most of the options that scored high enough to be shortlisted for one lagoon also scored twenty or higher for the other lagoons. There are exceptions to this, where, for example, a threat was lagoon specific or the management intention of the value addressed was to *Improve* the value for one lagoon and to *Maintain* for another lagoon. The score also informs the geographic focus for the management plan.

Table 6-1 Fine Filter (Traffic Light) Assessment Criteria – refer Appendix D for application

	Degree of Threat addressed	Effectiveness / Risk Reduction Potential (RRP)	Time frame	Cost	Practicality / Legal	Community Support	Effect on Management Intent
STOP & reassess	Low	Option does not provide an effective and long term solution. Risk reduction potential is relatively low	LONG Term (> 5-10yrs before tasks can commence). Requires prior commitment of funds, resources or other tasks to be completed first	High ($300K to millions)	LOW: Will require approval to implement and significant community engagement. There is a residual risk that approval will not be able to be obtained for the proposed works/strategy. Works may also require significant resources that are presently unavailable	LOW: Unlikely to be acceptable to community and politically unpalatable. Extensive community education, endorsement by Minister(s) and Council required.	The management intent for the value addressed by this option is to **Maintain**
SLOW	Medium	Option is considered worthwhile, but does not necessarily help with long term sustainability and estuary health.	MEDIUM Term (> 2 – 5yrs before tasks can commence). Requires prior commitment of funds, resources or other tasks to be completed first	Medium (e.g. $30,000 - $300,000)	MEDIUM: May require approvals to be implemented, but works are generally supported. Generally these approvals would likely to be granted assuming requirements are met. May require some resources that would require redistribution of existing tasks and duties by officers.	MEDIUM: Would be palatable to some, not to others (50/50 response). Briefing by Councillors, GM and community education required	The management intent for the value addressed by this option is to **Protect**
GO	Extreme or High	Option provides an effective long term solution	SHORT Term (tasks can commence within approximately 2 years). Generally can be completed without too many barriers	Low (< $30,000)	HIGH: No or minimal approvals or other impediments required to implement. No significant additional resources required (can be done as part of normal duties)	HIGH: Is very politically palatable, acceptable to community. Minimal education required	The management intent for the value addressed by this option is to **Improve**

6.5 Short-listed Management Options

6.5.1 No Regrets Options

The No Regrets Management Options identified through the evaluation processes are detailed in Table 6-2. These Options should be pursued irrespective of specific CZMP aims because they meet broader environmental and community needs and Council responsibilities.

Table 6-2 Short-listed No Regrets Management Options

Ref	Option	Expanded Description	Council Division /Authority	Geographic Focus
6	Develop and implement a Water Sensitive Urban Design (WSUD) Development Control Plan (DCP)	This should be consistent with Gosford City Council Integrated Water Management Sub-Plan (refer Section 6.7)	Planning	All Lagoons. WSUD and other sustainability initiatives will need to be incorporated into any development of the land within Wamberal catchment bounded by the Central Coast Hwy and Bellevue Road
2	Ensure that present planning and development controls allow for sea level rise and if possible a gradual reduction in lagoon opening by progressively increasing floor heights	Redevelopment of houses within the flood zones of the lagoons should require increased floor heights to minimise the impacts of sea level rise (particularly for Terrigal Lagoon).	Planning	All Lagoons
46	Work with Aboriginal groups for any management actions likely to impact upon or regarding aboriginal heritage	There is a potential for sites to be revealed in response to sea level rise. Similarly many management options have the potential to impact known and unknown sites (e.g. bush regeneration works, erosion control). This option involves active involvement of representatives of the Aboriginal community wherever possible. Build on and utilise work through the CMA project *Aboriginal Culturally Significant Landscapes Project.*	Environment	All Lagoons and catchments
61	Update Lagoon fact sheets and distribute with Rates notices to increase general community appreciation and awareness. Also make available at visitor information centres, accommodation providers etc.	The lagoon fact sheets are a great resource that would benefit from an update with new information given in the EPS. The fact sheets are read by a large range of people and offer a quick snap shot of the lagoons.	Environment and Education	All Lagoons
70	Actively support the continuation of Bush care to assist with revegetation works on Public and Private Lands	Council should continue to support Bush care. It is also important that the work undertaken through this program is consistent with the intent of the CZMP. For example, Bush care volunteers should be aware of	Works	All Lagoons

Ref	Option	Expanded Description	Council Division /Authority	Geographic Focus
		the possibility of uncovering Aboriginal items and have an understanding of what to do in this circumstance.		
80	Acknowledgement that existing opening regime has been in place for 40 years and will have already changed lagoon ecology and that pragmatic management approach should be adopted that seeks to maintain and enhance the lagoon ecology within the parameters of the existing framework.	This recommendation from the Estuary Processes Study (Cardno, 2010) is an attempt to focus Coastal Zone Management on managing the manageable. While much effort could be expended on understanding the impacts of the opening regime on ecology, the regime is largely driven by flood mitigation and this allows very little room for changing the levels and frequency of artificial openings.	Environment	All Lagoons
101	Continual documentation of implementation of CZMP including challenges (funding, logistics, community concerns etc.), achievements and failures to inform adaptive management.	To make sure Council and stakeholders (including the community) are in the best position in 5-10 years to have an effective Coastal Zone Management Plan for the Lagoons, documentation of the plan's implementation, achievements and failures should be undertaken.	Environment	All Lagoons
106	Council continue to support University researchers to undertake studies on the ecology of lagoons and to describe potential impacts caused by development in order to develop improved management practices for the fauna associated with the coastal lagoons.	There is much about ICOLL function, ecology and nutrient dynamics that we still do not understand well. Improving the scientific understanding of these aspects, particularly establishing cause and effect is essential to better future directing management effort. It is important that Council is aware of all research being undertaken on the lagoons and that this information is actively informing management, where appropriate.	Environment	All Lagoons
	Provide funding and support to the Gosford Wetland Strategy and use the resulting wetland prioritisation to inform priorities for wetland rehabilitation, commercial licence applications, recreation and foreshore use planning.	This project will provide crucial information for protecting lagoon health.		
Avoca Lagoon Only				
	Investigate opportunities for harvesting microalgae for use as a fertiliser	This option should be informed by the University of Newcastle research into causes of algal blooms. This has been successfully undertaken in Tuggerah Lake and Lake Illawarra.	Environment and Works	Avoca Lagoon
Wamberal Lagoon Only				
5	Prepare updated National	NP POM's contain information on the	OEH	Wamberal Lagoon

Ref	Option	Expanded Description	Council Division /Authority	Geographic Focus
	Parks Plan of Management (NP POM) for Wamberal Lagoon to complement CZMP	natural environments, Aboriginal heritage, history, and recreational opportunities in a park. They are legal documents, explaining how a park will be managed. The previous National Parks POM (1990) is considered to be out of date. An updated plan, consistent with this CZMP would contribute to integrated and appropriate management across agencies. It would also contribute to appropriate resource allocation. Example of where updating is required is the implications of sea level rise on estuarine vegetation which is not considered in the POM, but is now a key threatening process. Entrance management is a lagoon activity that needs to be included in a new POM		Nature Reserve
		Cockrone Lagoon Only		
57	Education in high schools regarding artificial entrance opening- to be trialled for Cockrone Lagoon and if successful rolled out for Avoca Lagoon as well.	Anecdotal information given at the Cockrone Lagoon Community Workshop indicated that in the past (approximately ten years ago), an education program was undertaken at McMasters High School where a teacher with an interest in the coast spoke at assemblies about the importance of coastal lagoons and the potential impacts of artificial lagoon openings. It is understood that this resulted in a dramatic reduction in unofficial openings. This low cost option has other benefits such as increased appreciation for lagoon ecology and significance. The information could be presented by a teacher, if one is available / interested or possibly by a member of Councils Environment Team. The message should include: how the lagoon works, what the lagoon opening procedure is and why unofficial openings are harmful.	Education	Cockrone Lagoon
		Terrigal Lagoon Only		
	Council to address flooding in Lake View Road through the flood management program. Consideration should be given to the installation of tidal flaps where appropriate	The entrance to Terrigal Lagoon is already opened at a relatively low level so there isn't the option of letting it out lower to alleviate the flooding issue.	Planning	Terrigal

6.5.2 Intervention Options

The Intervention Management Options identified through the evaluation processes are detailed in Table 6-3. Intervention options aim to reducing the occurrence of threats on values.

Table 6-3 Short-listed Intervention Management Options

Ref	Option	Expanded Description	Council Division /Authority	Geographic Focus
18	Identify potential sources of nutrients (e.g. Golf courses and agricultural lands and liaise directly with land owners/ managers to reduce nutrient and sediment inputs	This option would benefit from involvement by the CMA. There are a number of resources available that could be utilised for this option. One such resource is the (former) Department of Environment and Climate Change Guideline Improving the environmental management of NSW Golf Courses. The manual and workshops would address the key environmental issues for golf course management such as water management, pesticides and fertiliser management and other related practices. The Terrigal Memorial Country Club is located at the limit of the North Arm of Terrigal Lagoon. End of line stormwater treatment would be limited by space, however, there are some operational actions that could minimise the impacts on Terrigal Lagoon such as timing releases, planting vegetation on the lee side of water courses to assist in nutrient uptake and other source control steps. A key component of this initiative was a training program run for a selection of NSW Golf Courses.	Environment and Works	Potential large scale sources of nutrients within the lagoon catchments would include: Golf Course at Terrigal Memorial Country Club Agricultural areas along The Scenic Road in Cockrone Lagoon Catchment Rural land holders in Avoca Lagoon Catchment Rural Land Holders in Wamberal Catchment
25	Undertake an intensive engagement program for works staff involved in sediment and erosion control and workers from roads and maritimes services within the catchment to raise the profile of best practice erosion and sediment control, assist staff with new policies and procedures and track improvements in performance.	A program such as this was successfully implemented at Great Lakes Council. The first steps would be to assess staff awareness levels around sediment and erosion control policies and opportunities to improve practices. The target for the program would be works staff with erosion and sediment control responsibilities within the catchment to raise the profile of best practice erosion and sediment control assist staff with new policies and procedures and track improvements in performance. Council has an erosion and sediment control policy, D6.46 Erosion and sediment control. This is due for review in 2013. Implementing the present strategy and assessing its performance would	Environment and works	All Lagoons

Ref	Option	Expanded Description	Council Division /Authority	Geographic Focus
		be useful information for the review.		
49	Prepare and implement a holistic Foreshore Access Plan including consideration of water based recreation and commercial operators	This should be consistent with the management intent identified for the present study for each of the lagoons. The plan should balance social and economic needs whilst ensuring that natural shoreline habitats and their ecological function are not impacted. This plan needs to address habitat conservation and ecosystem services in the face of potential climate change. It should consider the advantages of raising floor levels in conjunction with planned retreat as a strategy to conserve and protect ecosystem. This plan could have trade-offs, high conservation foreshores of Wamberal and Cockrone could have precedence over higher tourism and access for Terrigal. Note that the community suggested that the plan identify specific locations for foreshore access and rehabilitate the areas in between with appropriate foreshore vegetation. Preparation should include mapping of unauthorised encroachment to public land.	Environment, planning and works	For Wamberal Lagoon erosion and access issues in the vicinity of the lagoon entrance near Remembrance Drive (refer to Foreshore stability mapping in EPS) For Avoca Lagoon address informal access through dunes at northern side of foreshore entrance. Option to formalise access on southern side of entrance near Ficus Avenue. Address presence of private structures encroaching on public lands. Consider formalising the walking track in the vicinity of Lake Shore Drive. For Cockrone Lagoon this should generally prioritise conservation over access. Issues to be considered include requests for improved access by model boat enthusiasts, improved access near and to the south of the entrance Lakeside Drive.
10	Restrict any rezoning of land within the catchments that increases runoff or pollutant inputs	A key measure that has contributed to existing health of the lagoons has been the protected nature of the catchments over the past 20 years (despite the level of existing development they contain). This aspect should be maintained to prevent future degradation. Ensure planning instruments incorporate best practice: including sediment, erosion and stormwater controls (e.g. construction controls plans and WSUD); use of water reduction devices and maximum permeable surfaces, landscaped area calculations: protection of native vegetation; restriction of landscaping and gardens to endemic species;	Planning	All Lagoons
16	Undertake adequate and appropriate maintenance	GPT's such as those on Warakei Rd Wamberal and Adjacent to	Works	All Lagoons

Ref	Option	Expanded Description	Council Division /Authority	Geographic Focus
	of existing WSUD devices to maintain their effectiveness, in particular GPTs and other stormwater quality improvement devices.	Terrigal Drive. In order to undertake adequate maintenance this option may need to start with an audit to determine relevant stormwater devices, sizes, monitoring techniques etc.		
23	Enforce implementation and maintenance of effective sediment controls during the subdivision and building phases of all developments (including infrastructure projects) by undertaking regular audits of development during construction.	This option is related to option 25 above	Compliance	All Lagoons
71	Maintain and reinstate vegetation along all major drainage lines	This option should be informed by the foreshore assessment and stormwater input mapping undertaken for the EPS (where creeks are included.) Protection of native vegetation along these creeks will improve water quality and bank stability. It will also provide habitat and act as a corridor to native species	Works	All Lagoons

6.5.3 Adaptation Options

The Adaptation Management Options identified through the evaluation processes are detailed in Table 6-4. Adaptation options aim to improve resilience of the lagoon ecosystem and the community to the consequences of identified threats.

Table 6-4 Short-listed Adaptation Management Options

Ref	Option	Expanded Description	Council Division /Authority	Geographic Focus
59	Provide information to private landholders that have key habitat and vegetation communities on their properties to describe the community, its importance to the estuary and options for its protection and management	Correspondence should be targeted to each land holder, letting them know specifically what is on their property, describing its conservation significance and describing actions that should or should not be taken. This option could also be supported by the No Regrets Option 61 to update the lagoon fact sheets. This should include a section on what landholders can do.	Environment and Education	The priority for this action should be placed upon Wamberal, Avoca and Cockrone Lagoons. For Wamberal Lagoon, most estuarine vegetation is in nature reserve, although there is an issue along Forresters Creek (eastern shoreline). For Avoca Lagoon, a particular focus for the Avoca catchment would be Tramway

				Reserve. For Cockrone Lagoon, along Lakeside Drive
72	Identify sites where there is the potential for landward migration of estuary vegetation and prioritise these for rehabilitation works	To be informed by wetland mapping undertaken for EPS and the Wetland Assessment Project currently underway for Gosford which aims to describe and prioritise all wetlands within Gosford LGA.	Environment and planning	All lagoons
74	Implement an intensive garden escapee weed management program	Garden escapees were ranked as the highest threat to Wamberal and Cockrone Lagoons and inappropriate foreshore management (including mowing of Tramway Reserve) was considered a high threat to Avoca Lagoon. A multifaceted, intensive garden escapee weed management program should be developed. Elements may include: • Use of resources from the Grow Me Instead initiative (http://www.growmeinstead.com.au/) • "Unintended Garden" signage such as that implemented at the Bega Shire at garden escape infested sites for walkers to see, where possible incorporate this into existing walking routes • Intense sweeps of lagoons to "weed blitzkrieg" • articles in local papers	Environment, Education and works	For Wamberal Lagoon, western shore and Forrester's Creek For Avoca Lagoon, Tramway Reserve would be a key focus
81	Reconsider triggers and options for entrance management with recreational and ecological benefits	The practical entrance management occurring is already counter to the opening procedure in some regards. For example trimming berms may need to be reconsidered. Terrigal berm is checked approximately monthly and trimmed within about a week if it is too high (often rebuilds in days). During big seas, waves apparently wash into Terrigal over a lowered berm. For the other three lagoons, the berm maintenance is not routinely undertaken and may just serve to encourage unofficial openings. For Cockrone and Avoca, it could be possible to permit let out at lower levels following a period of significant build-up of algae. At Avoca, improved liaison between Construction Operations and Natural Open Space regarding opening times and Green and Golden Bell frog breeding would be an advantage.	Environment	This option would not be viable for Terrigal Lagoon as the adopted let out level is only 0.15m higher than HAT making it susceptible to ocean inundation. When opening Terrigal Lagoon, where possible, relocate sand to replenish scoured section at the end of Pacific Street.
	Improve mapping of bird	Facilitates adaptation, by identifying	Environment	Wamberal only

	habitat	priority sites for conservation and rehabilitation.		
	Investigate options to provide additional freshwater breeding sites for Green and Golden Bell Frogs within Tramway Reserve	Alternative freshwater breeding habitat may provide some buffering to the impacts of lost tadpoles due to entrance opening.	Environment and Works	Avoca
12	Undertake bank erosion works in areas currently experiencing bank erosion and instability and areas vulnerable in the future	EPS bank condition assessment showed lagoon foreshores are relatively stable with isolated areas of erosion. Potential for bank erosion to occur highlights the need for ongoing protection of foreshore vegetation and maintenance of any protection works. In the short term, shoreline erosion is more likely to occur in relation to human activities where, for example, people access the banks and/or waterways. Therefore, management of recreational usage of the lagoons is key to ensuring the ongoing stability of the lagoon banks. It is better to invest in revegetation works in vulnerable locations now than to react to erosion of these areas in the future	Environment and Works	Terrigal is the first priority as this was a high level threat – informed by mapping in EPS
50	Council and Crown Lands capitalise on any opportunities to acquire additional foreshore lands, bringing them into public ownership to maximise opportunities to improve and enhance public access and foreshore ecological values	This option could function as both an intervention and adaptation option. It is included here despite its low weighting, which was a consequence of its potential to be very expensive. This is because of its very high potential to have significant benefit for the estuary. This was also recommended in the EPS.	Crown Lands Council (property)	Priority should be placed on high value conservation areas, areas suitable for allowing migration of estuarine vegetation under sea level rise scenarios and areas that may be used for retrofitting stormwater treatment options (artificial wetlands etc.)

6.6 Recommendations and guidance for recreational uses

The Coastal Zone Management Plan may also be used to provide direction to decision makers in regard to recreational activities and commercial licensing.

Based on the information provided within this report, it is recommended that decisions of this nature prioritise lagoon health and protect the existing ecological values (particularly for the more natural lagoons, namely, Wamberal and Cockrone). Activities likely to disrupt or impact upon native wildlife (particularly shore birds), should be discouraged for Wamberal, Avoca and Cockrone Lagoons, as wetland fauna and particularly waterbirds were highly valued for these lagoons. This would include dog exercising and use of motorised remote controlled boats.

While recreational use of Terrigal Lagoon, and to a lesser extent Avoca Lagoon, is envisaged into the future, care should be taken not to issue new licences for activities that will increase pressure to dredge the lagoons.

The value prioritisation presented in 4.3.2, should be used as a guide for decision making.

6.7 Integration with Gosford IWCM

Gosford City Council, in partnership with Wyong Shire Council, has developed an Integrated Water Cycle Management (IWCM) Strategy within a broader regional (Central Coast) context. As part of the overall IWCM strategy, each Council has developed a separate IWCM sub-plan to fit within WaterPlan 2050. Gosford City Council's IWCM Sub-Plan explores options for sustainably managing the provision of water supply, sewerage and stormwater services.

Suggested options for urban stormwater within the Sub Plan are:

- Stormwater treatment ponds/wetlands for existing areas;
- WSUD DCPs for new developments;
- Retrofit of WSUD to key existing areas;
- Enhanced erosion controls during and after construction;
- Smart sewers (low inflow and infiltration) for new developments; and
- Gross pollutant traps.

Appendix F of the document sets out recommendations for General Guidance for Consideration for an IWCM/WSUD DCP (one of the recommendations of this CZMS).

One of the key options recommended for the CZMP is improved adoption and implementation of WSUD, and thus aligns well with this existing Council initiative.

6.8 Where to from here?

The final list of options selected to treat threats shall be decided in consultation with Council and based upon the outcomes of the next stage of community consultation. This will enable community review, assessment and input as to preferred management options.

The recommended management options will then be provided with implementation details for Council as to timeframe or trigger for action, responsibilities, estimated costs etc, to form a Plan for implementation in and around the lagoons and catchment areas.

7 REFERENCES

Biosphere Environmental Consultants (2006) *Plan of Management Green and Golden Bell Frogs North Avoca and Davistown*. February.

Cardno (2010), *Gosford Coastal Lagoons Processes Study*, prepared for Gosford City Council, July 2010.

NLWRA (2008). The National Land and Water Resources Audit 2002 – 2008. Achievements and Challenges. NLWRA Canberra.

Cook,P and Holland,D 2008 *Interactions between phytoplankton dynamics, nutrient loads and the biogeochemistry of the Gippsland Lakes* A report prepared for the Gippsland Lakes Taskforce August 27, 2008 published by Water Studies Centre

Sacnes, P., Dela-Cruz, J., Coade, G., Haine, B., McSorley, A.,van den Broek, J. Evans, L. Kobayshi, T. and O'Donnell, M. (2011) Aquatic Inventory of Nadgee Lake, Nadgee River and Merrica River Estuaries. *Proceedings of the Linnean Society of New South Wales* **132** 169-186.

DEC (2006) *Local Planning for Healthy Waterways – using NSW Water Qulaity Objectives*. Department of Environment and Conservation, Sydney.

Department of Environment and Climate Change (2007) *Improving the environmental management of NSW Golf Courses* ISBN 978 1 74122 658 4

DECCW (2009a), *NSW Sea Level Rise Policy Statement*, October 2009.

DECCW (2009b), *Derivation of the NSW Government's sea level rise planning benchmarks*, Technical Note, October 2009.

DECCW (2010), *Guidelines for Preparing Coastal Zone Management Plans*, December 2010.

DP (2010), *NSW Coastal Planning Guideline: Adapting to Sea Level Rise*, State of NSW Department of Planning, August 2010.

Golley, F. B. (1993) A history of the ecosystem concept in ecology: More than the sum of the parts, Yale University Press, New Haven

Masselink, G. and Hughes, M.G. (2003), *Introduction to Coastal Processes and Geomorphology*, Oxford University Press, London, pp 347.
McCormack, R.B, 2010. Avoca Lagoon Catchment Aquatic Biological Survey 2010. Australian Aquatic Biological for Gosford City Council, Gosford NSW.

Roper T, Creese B, Scanes P, Stephens K, Williams R, Dela-Cruz J, Coade G, Coates B & Fraser M 2011, *Assessing the condition of estuaries and coastal lake ecosystems in NSW*, Monitoring, evaluation and reporting program, Technical report series, Office of Environment and Heritage, Sydney, December 2011.

WMA, 1995 – FROM COASTAL LAGOONS STUDY

APPENDIX A: LEGISLATIVE AND POLICY FRAMEWORK

Environmental Planning and Assessment Act 1979 (EPA Act)

The *Environmental Planning and Assessment Act 1979* (EPA Act) is the key NSW legislation for planning and land use. The Act provides a system of environmental planning and assessment for NSW, and involves developing plans to regulate competing land uses, through 'environmental planning instruments'.

The Act establishes three types of environment planning instruments (EPI):

- Local Environmental Plans;
- Regional Environmental Plans (now deemed as SEPPs); and
- State Environmental Planning Policies.

The objectives of the EPA Act are to encourage:

- proper management, development and conservation of natural and artificial resources, including agricultural land, natural areas, forests, minerals, water, cities, towns and villages for the purpose of promoting the social and economic welfare of the community and a better environment;
- promotion and co-ordination of the orderly and economic use and development of land;
- protection, provision and co-ordination of communication and utility services;
- provision of land for public purposes;
- provision and co-ordination of community services and facilities;
- protection of the environment, including the protection and conservation of native animals and plants, including threatened species, populations and ecological communities, and their habitats;
- ecologically sustainable development;
- the provision and maintenance of affordable housing;
- promotion of the sharing of the responsibility for environmental planning between the different levels of government in the State;
- provision of increased opportunity for public involvement and participation in environmental planning and assessment.

Approval processes for "development" and "works" in NSW are provided for in Part 4, Part 5 and Part 5A of the EPA Act. Key provisions are outlined briefly below.

Part 4 – Development Assessment

Part 4 of the EPA Act lays out the legislative regime for the standard process for lodgement and consideration of development applications. Part 4 processes essentially apply where the local authority (Council) is the consent authority. The majority of land based development within the Newcastle study area will fall within Part 4 of the EPA Act.

The controls and permissibility for development of particular sites and / or uses are found in the Local Environment Plan (LEP) and Development Control Plan (DCP) that cover Council's Local Government Area (LGA).

Section 79C under Part 4 of the *Environmental Planning and Assessment Act 1979* outlines matters for consideration for a consent authority (typically Council) in determining a development application to include the provisions of any coastal zone management plan (within the meaning of the *Coastal Protection Act 1979*) that apply to the land to which the development application relates.

Part 5 – Environmental Assessment

Part 5 outlines the requirements for determining authorities to consider the environmental impact of activities, through an environmental assessment for the proposed activity. The environmental assessment shall outline the effect of the activity on critical habitat, endangered fauna, vulnerable species, conservation agreements (under the *National Parks and Wildlife Act 1974*), plans of management, wilderness areas (under the *Wilderness Act 1987*) and joint management agreements and bio-banking agreements under the *Threatened Species Act, 1995*, and any other legislation pertaining to the proposed activity.

Part 5 of the Act applies to proposed activities that are permissible without development consent under Part 4 of the EPA Act but require approval from a Minister or Public Authority, or is proposed to be carried out by a Minister or Public Authority (and Council is classified as a Public Authority).

Part 5 obliges the "determining authority" for the proposal to consider the environmental impact of any activity. A determining authority is the public authority which is required to approve an activity, and can also be the public authority proposing to carry out the activity. For example, Council is permitted to undertake certain environmental management activities under SEPP (Infrastructure) 2007 without development consent, however will still need to complete an environmental assessment (typically, a Review of Environmental Factors) under Part 5 of the EPA Act. In certain cases where an activity is considered to be "designated development", an Environmental Impact Statement (EIS) is required.

Part 5A (Development by the Crown) essentially provides a legislative regime for consideration of Development Applications made by, or for and on behalf of, the Crown.

The remaining parts of the EPA Act relate to: Part 6 – Implementation and Enforcement; Part 7 – Finance and Part 8 – Miscellaneous.

State Environmental Planning Policies

SEPP No. 71 – Coastal Protection

State Environmental Planning Policy No. 71 – Coastal Protection (SEPP 71) aims to protect and manage the natural, cultural, recreational and economic attributes of the New South Wales coast. SEPP 71 aims for development in the NSW coastal zone to be appropriate and suitably located, in accordance with the principles of the Ecologically Sustainable Development (ESD). The policy provides for: the protection of and improvement to public access compatible with the natural attributes coastal foreshores; and protects and preserves Aboriginal cultural heritage, visual amenities of the coast, the beach environment and amenity, native coastal vegetation, marine environment of New South Wales, and rocky platforms.

SEPP 71 applies to all lands within the coastal zone of NSW, which is defined on gazetted maps under the SEPP. Therefore, SEPP 71 applies all of the land in the study area for this CZMP. SEPP 71 provides matters for consideration in clause 8 that are to be taken into account: by a council when preparing its LEP for land within the coastal zone; and by a consent authority (e.g. council) when determining a development application on land within the coastal zone.

SEPP 71 also outlines the conditions for which the Minister for Planning becomes the consent authority for 'significant coastal development', that is, development on land within 100 metres of and below mean high water mark of the sea, a bay or an estuary. Development applications received by Council on such lands must be sent to the Director-General of Planning, and Council is required to take any additional matters specified by the Director-General into account when determining the application (in addition to the 'matters for consideration' given in Clause 8).

SEPP 71 also outlines development controls in Part 4 for which consent cannot be granted to applications that, in the opinion of the consent authority:

- will or is likely to impede or diminish to any extent the physical, land based right of access of the public to or along the coastal foreshore;
- where effluent is proposed to be disposed of by means of a non-reticulated system, will or is likely to have a negative effect on the water of the sea or any nearby beach, or an estuary, a coastal lake, a coastal creek or other similar body of water, or a rock platform; or
- will or is likely to, discharge untreated stormwater into the sea, a beach, or an estuary, a coastal lake, a coastal creek or other similar body of water, or onto a rock platform.

A master plan is to be adopted by Minister for Planning (or otherwise waived by the Minister as per Clause 18), prior to Council granting consent for subdivision of land:

- within a residential zone or rural residential zone if part or all of the land is in a 'sensitive coastal location'; or
- within a residential zone that is not within a 'sensitive coastal location' into more than 25 lots, or 25 lots or less, if the land proposed to be subdivided and any adjoining or neighbouring land in the same ownership could be subdivided into more than 25 lots; or
- within a rural residential zone that is not identified as a 'sensitive coastal location' into more than 5 lots.

SEPP71 defines 'sensitive coastal location' to mean land within:

- 100 metres above mean high water mark of the sea, a bay or an estuary;
- a coastal lake, or within 100 m of the water's edge of a coastal lake;
- a declared Ramsar Wetland, or within 100 m of a declared Ramsar Wetland;
- a declared World Heritage Property, or within 100 m of a declared World Heritage Property;
- a declared aquatic reserves under the *Fisheries Management Act 1994*, or within 100 m of such;
- a declared marine park under the *Marine Parks Act 1997*, or within 100 m of a marine park;
- coastal lakes (which includes all four of Gosford's Coastal lagoons), Ramsar wetlands and World Heritage areas;

- marine parks and aquatic reserves under the *Fisheries Management Act*; land within 100 metres of any of the above;
- within 100 m of land reserved under the *National Parks and Wildlife Act 1974*;
- within 100 m of SEPP 14 Coastal Wetlands; and
- residential land within 100 metres of SEPP 26 Littoral Rainforests.

SEPP No. 14 – Coastal Wetlands

State Environmental Planning Policy (SEPP) 14 – Coastal Wetlands (SEPP14) was designed to protect and preserve coastal wetlands for the environmental and economic interests of the State. The policy provides protection to specific wetland areas that have been mapped and gazetted by Department of Planning. Development that involves the following activities is not allowed to be carried out unless consent (as 'designated development') is provided by local council or the Director General of Planning: clearing of land, construction of levees, draining of land, and filling of land. If this development is to be carried out, an Environmental Impact Statement first needs to be prepared.

The Director General of Planning must consider a number of matters prior to agreeing to the proposed development including:

- The environmental effect of the proposed development;
- Whether adequate safeguard and rehabilitation methods are proposed;
- Whether the development is consistent with the aims of the policy; and
- Whether any feasible alternatives have been considered and if so, the reason for choosing the proposed development.

All four of Gosford's coastal lagoons contain areas of SEPP 14 wetlands.

SEPP (Infrastructure) 2007

SEPP (Infrastructure) 2007 provides a consistent planning regime for infrastructure and the provision of services across NSW, including consultation with relevant public authorities during the assessment process. The intent of the SEPP is to support greater flexibility in the location of infrastructure and service facilities along with improved regulatory certainty and efficiency for the State.

Division 25 of the SEPP outlines development permitted with and without consent for the purpose of 'waterway or foreshore management activities', which are defined as:

'(a) riparian corridor and bank management, including erosion control, bank stabilisation, resnagging, weed management, revegetation and the creation of foreshore access ways, and

(b) instream management or dredging to rehabilitate aquatic habitat or to maintain or restore environmental flows or tidal flows for ecological purposes, and

(c) coastal management and beach nourishment, including erosion control, dune or foreshore stabilisation works, headland management, weed management, revegetation activities and foreshore access ways, and

(d) coastal protection works, and

(e) salt interception schemes to improve water quality in surface freshwater systems, and

(f) installation or upgrade of waterway gauging stations for water accounting purposes.

Development for the purpose of waterway or foreshore management activities may be carried out by or on behalf of a public authority (i.e. Council) without consent on any land, which may include:

- construction works;
- routine maintenance works;
- emergency works, including works required as a result of flooding, storms or coastal erosion (noting that this excludes emergency coastal protection works within the meaning of the Coastal Protection Act 1979);
- environmental management works.
- new coastal protection works on the open coast or entrance to a coastal lake (despite Clause 129A, see below), provided the public authority considers the provisions of any adopted CZMP relating to the land on which the works are proposed, or if there is no CZMP, notify the NSW Coastal Panel and take into consideration any response received from them within 21 days of notification. The 'new coastal protection works' excludes beach nourishment or sand placement, presumably so that councils can undertake beach nourishment without requiring such action to be a stated action in the CZMP or gaining approval from the Coastal Panel.

Under Clause 129A, development for the purposes of a sea wall or beach nourishment may be carried out by any person with consent on the open coast or entrance to a coastal lake. In determining the application, the consent authority (e.g. Council) must consider the provisions of any CZMP relating to the land on which the works are proposed, the matters stated in Clause 8 of SEPP 71, and any guidelines for assessing and managing the impacts of the works issued by the Director-General (noting that preconditions for granting consent for coastal protection works are stated in Section 55M of *the Coastal Protection Act*). Where there is no CZMP, the NSW Coastal Panel shall determine such applications.

SEPP (Infrastructure) 2007 formally repeals SEPP 35 – Maintenance Dredging of Tidal Waterways (among others). As noted above, Council and other public authorities may undertake dredging for environmental purposes (i.e. aquatic rehabilitation). In addition, Under Division 13 (Clause 68) development for the purpose of wharf or boating facilities may be carried out by or on behalf of a public authority without consent on any land, except for land reserved under the *National Parks and Wildlife Act 1974* such development may be carried out if it is authorised by or under that Act. Such development in connection wharf or boating facilities permitted without consent includes:

a) construction works (including dredging and land reclamation, if it is required for the construction of facilities), or

(b) routine maintenance works (including dredging, or bed profile levelling, of existing navigation channels if it is for safety reasons or in connection with existing facilities).

Thus, dredging for the purpose of safe navigation may also be undertaken without consent by Council under SEPP (Infrastructure) 2007.

Council may undertake waterway or foreshore management activities or activities for wharf and boating facilities without consent, provided they undertake a Review of Environmental Factors (REF) (under Part 5 of the EPA Act) and gain any approvals / licences required under other relevant Acts (e.g. *Crown Lands Act 1989*, *Fisheries Management Act 1994*, *Water Management Act 2000* etc). Dredging proposing the removal of greater than 1,000 cubic metres is 'designated development' under Clause 77A of the EPA Act and therefore requires the preparation of an Environmental Impact Statement (EIS).

Coastal Protection Act 1979

The NSW *Coastal Protection Act 1979* (the CP Act) provides guidance on the use, occupation and development of the coastal zone in NSW. The CP Act was amended in 1998 to extend the coastal zone to include estuaries, coastal lakes and lagoons, islands and rivers in recognition of the strong connection between estuaries and the open coast. The CP Act was again amended in 2002 to better reflect the purpose of the NSW Coastal Policy (1997) and to incorporate the principles of ecologically sustainable development.

The CP Act allows the Minister for the Environment to direct a council with land within the coastal zone to prepare a Coastal Zone Management Plan, and gives directions as to how such Plans shall be prepared, approved, gazetted and amended where necessary. This Coastal Zone Management Plan is being prepared in accordance with the *Coastal Protection Act 1979*, including the objectives of the Act as below. The CP Act also requires Coastal Zone Management Plans to provide for the unobstructed access to the coastline by the public (beaches, headlands, waterways, including lakes and lagoons).

The objects of the CP Act are to provide for the protection of the coastal environment of the State for the benefit of both present and future generations and, in particular:

- to protect, enhance, maintain and restore the environment of the coastal region, its associated ecosystems, ecological processes and biological diversity, and its water quality;
- to encourage, promote and secure the orderly and balanced utilisation and conservation of the coastal region and its natural and man-made resources, having regard to the principles of ecologically sustainable development;
- to recognise and foster the significant social and economic benefits to the State that result from a sustainable coastal environment, including
- benefits to the environment, and
- benefits to urban communities, fisheries, industry and recreation, and
- benefits to culture and heritage, and
- benefits to the Aboriginal people in relation to their spiritual, social, customary and economic use of land and water;
- to promote public pedestrian access to the coastal region and recognise the public's right to access;

- to provide for the acquisition of land in the coastal region to promote the protection, enhancement, maintenance and restoration of the environment of the coastal region;
- to recognise the role of the community, as a partner with government, in resolving issues relating to the protection of the coastal environment; and
- to ensure co-ordination of the policies and activities of the Government and public authorities relating to the coastal region and to facilitate the proper integration of their management activities.

Amendments to the CP Act 1979 were recently implemented as part of the *Coastal Protection and Other Legislation Amendment Act 2010* (now repealed). Of relevance to this estuary-based CZMP are:

- amendments to Part 2A of the CP Act establishing a joint state-local body called the NSW Coastal Panel, which shall act as a consent authority for coastal protection development applications where a council does not have a certified CZMP and / or requires further technical assistance in assessing such development applications, and the Panel shall also assist the Minister when requested, such as for reviewing CZMPs; and
- amendments to Section 55M of the CP Act and SEPP (Infrastructure) 2007 (refer above) that enable Council to construct coastal protection works without consent or any person to construct protection works with consent at the entrances to coastal lakes, provided such works are consistent with the adopted CZMP, or otherwise approved by the NSW Coastal Panel; and
- amendments to the *Local Government Act 1993* (Section 553B) to allow local councils to levy a Coastal Protection Service Charge to maintain and repair coastal protection works or to manage the impacts of coastal protection works.

The NSW Sea Level Rise Policy Statement

The NSW Sea Level Rise Policy Statement (2009) (the Policy Statement) sets the planning standards for projected sea level rise over the next century that are to be adopted in all forms of coastal assessment, from development applications to coastal hazards definitions studies and coastal zone management plans.

The NSW Government has adopted benchmarks of 0.4 m rise in sea level by 2050 and 0.9 m by 2100 as the best national and international projections for the NSW Coast (at the present time). These benchmarks were used to prepare the Newcastle Coastal Hazards Definition Study and hazard lines.

The Policy Statement also provides guidance on the risk-based assessment approach recommended by the NSW Government, and the support the state intends to provide to coastal communities to prepare and adapt to the medium to long term social, economic and environmental impacts of sea level rise. The NSW Government has stated a commitment to:

- promoting risk-based assessment approaches to sea level rise and coastal planning;
- providing guidance to councils to support adaptation planning initiatives;
- encouraging appropriate development on land at risk from sea level rise;
- providing continued emergency management support for damaging storms and floods; and

- providing ongoing updated information to the public about sea level rise and projected impacts.

The NSW Government intends to support local councils through funding assistance for voluntarily purchasing of property or for protection works, provided such actions are based upon thorough assessments (such as a CZMP) that outline the magnitude of the hazard risk, cost-effectiveness of the action including maintenance costs, ability to adequately protect from sea level rise, and the genuine hardship of coastal residents and benefiting landholders.

When allocating funding assistance to local councils for coastal protection works, the NSW Government will give priority to public safety and protecting valuable publicly-owned assets, and then to private land. Where assistance is provided to reduce the impacts of coastal hazards, the Government does not assume any responsibility for these hazards.

The Sea Level Rise Policy Statement (2009) supersedes the 1988 Coastline Hazards Policy with respect to managing sea level rise. The Policy Statement is to be used in conjunction with the existing legislation and policies for coastal management.

Threatened Species Act 1995

The *Threatened Species Conservation Act 1995* (the TSC Act) aims to conserve biological diversity and promote ecologically sustainable development, by providing for the identification, protection and recovery of threatened species, populations, endangered ecological communities and their critical habitats. The TSC Act also aims to eliminate or manage processes that may threaten the survival of threatened species, populations or ecological communities.

Within the TSC Act:

- Schedule 1 lists endangered species, endangered populations, endangered ecological communities, species presumed to be extinct and critically endangered species and ecological communities (Schedule 1A);
- Schedule 2 lists vulnerable species and vulnerable ecological communities; and
- Schedule 3 lists key threatening processes.

The TSC Act has established a committee that is responsible for determining species, populations, ecological communities or threatening processes that should be included in Schedules 1, 2 or 3, or such can be listed upon request by the Minister (for the Environment, Climate Change and Water who administers this act).

The TSC Act does not include fish or marine vegetation as defined within Part 7A of the FM Act, i.e., such threatened species are covered by the FM Act. However, there is some overlap between the acts, and where a plant or animal may inhabit a terrestrial environment at some stage during its biological development, in concurrence with the Minister administering the FM Act, it may be listed in the TSC Act.

It is an offence under the TSC Act (and the *National Parks and Wildlife Act 1974* (NPW Act)) to harm, damage or pick an animal or plant that is, is part of, is critical habitat for, or is habitat for a threatened species, population or ecological community, unless a licence has been obtained under the TSC Act or NPW Act.

One example of an endangered ecological community located within the study area is coastal saltmarsh.

National Parks and Wildlife Act 1974

The objectives of the *National Parks and Wildlife Act 1974* (NPW Act) are:

- the conservation of nature, including habitats, ecosystems, ecosystem processes, biological diversity at the community, species and genetic levels, landforms of significance including geological features and processes, and landscapes and natural features of significance including wilderness and wild rivers;
- the conservation of objects, places or features (including biological diversity) of cultural value within the landscape, including of Aboriginal significance, of social value to the people of NSW and of historic, architectural or scientific significance;
- fostering public appreciation, understanding and enjoyment of nature and cultural heritage and their conservation; and
- providing for the management of land reserved under the NPW Act.

The objectives of the NPW Act are to be achieved by applying the principles of ecologically sustainable development (ESD).

The NPW Act was responsible for the establishment of the NSW National Parks and Wildlife Services (NPWS) which is now part of OEH. The officers are responsible for administering the NPW Act including national parks and other lands under this act, and also administration of the *Wilderness Act 1987* and the TSC Act 1995.

It is an offence under the NPW Act to damage, deface or destroy items of Aboriginal heritage (places, objects) without approval from the Director-General for OEH.

Fisheries Management Act 1994

The aim of the *Fisheries Management Act 1994* and *Fisheries Management Amendment Act 1994* (the FM Act) is to conserve, develop and share the fishery resources for the state's benefit for present and future generations. The FM Act applies specifically to aquatic flora and fauna, primarily fish, invertebrates and some algae. The FM Act promotes ecologically sustainable development, including conservation of biological diversity.

The FM Acts protects marine vegetation, including mangroves, saltmarsh and seagrass. Under the FM Acts, a permit is required to destroy or damage marine vegetation such as mangroves, seagrass, and saltmarsh. The Act also includes schedules of endangered aquatic species, populations and ecological communities, which must be considered in the same manner as species listed under the *Threatened Species Conservation Act 1995*.

All developments under the EPA Act must also be consistent with the objectives and permissible uses of aquatic reserves as contained within the FM Act and any management plans where they exist for the aquatic reserve.

Dredging and reclamation activities also fall under the FM Act. Reclamation of land in the waterway shall be managed so as to conserve the biodiversity of fish, aquatic vegetation and fish habitat and be consistent with the principles of ecologically sustainable development. Persons (i.e., not a public or local authority) must have a permit issued by the Minister for Fisheries before they may proceed with reclamation or dredging activities.

Under the FM Act it is an offence to harm or cause damage to (by an act or an omission) any fish, marine vegetation or habitat of a threatened species, population or ecological community, or critical habitat. This includes damage caused in the act of carrying out a development or as a failure to comply with a development consent or approval. Licences to cause harm or damage will only be granted for: scientific purposes; the welfare of fish or marine vegetation; or where there is threat to life or property.

The FM Act also includes and allows for the preparation of Habitat Protection Plans. Those plans relevant to the study area include:

Habitat Protection Plan No. 1 General

This is an advisory document summarising various protective measures in relation to dredging and reclamation activities, fish passage requirements, and the protection of mangroves, other marine vegetation and snags.

Habitat Protection Plan No. 2 Seagrasses

The Plan deals specifically with the protection of seagrasses across NSW, and discusses activities which impact on seagrasses, including the construction of jetties, wharves, and bridges, dredging and reclamation, and the collection of seagrasses.

Local Government Act 1993

The *Local Government Act 1993* (the LG Act) creates local governments and grants them the power to perform their functions, which involve management, development, protection, restoration, enhancement and conservation of the environment for the local government area. The functions of the local government are to be performed in a manner that is consistent with and promote the principles of ecologically sustainable development.

The service functions of local councils (defined in Chapter 6 of the Act) includes the classification, use and management of public land, including the objectives for management of the Community Land owned by Council (i.e. that is not Crown Land).

Plans of Management for Community Land need also to be prepared under Section 35 of the Act. Section 35 of the act provides that community land only be used in accordance with the plan of management applying to the parcel of community land; any law permitting the use of the land for a specified purpose or otherwise regulating the use of the land; and the provisions of Division 2 Chapter 6 of the Act.

Community land can be categorised into a range of categories under Section 36 of the Act, and each of these categories have their own core objectives specified under the Act. The categorisation of community lands is important as the Act requires Council to only grant a lease, licence or another

estate (other than in respect of public utilities) for a purpose consistent with the core objectives of the category of that community land.

Section 733 of the LG Act offers exemption of liability to Council with respect to coastal and floodplain lands providing that Council acts in 'good faith' and manages the lands in accordance with Government guidelines and manuals. In respect to coastal lands, the relevant Government manual is the CZMP Guidelines. Consequently, the development of this CZMS and subsequent CZMP is considered to be acting in good faith and in accordance with the appropriate guidelines, and as such, when the CZMP is gazetted, Council can assume the liability exemption.

Crown Lands Act 1989

The *Crown Lands Act 1989* (the CL Act) provides for the administration and management of Crown land for the benefit of the people of NSW. The CL Act provides principles for the proper assessment, development, reservation or dedication and conservation of Crown Lands.

Waterbodies such as beaches and foreshores and estuaries / creeks / lagoons below the mean high water mark are designated as Crown Land and managed by the Department of Primary Industries Crown Lands Division (CLD). In addition to this, there are other Crown reserves in the catchments of the Gosford Lagoons for which Council is the is the reserve trust manager or trustee appointed by the Minister for Lands to care, control and manage the land in accordance with its public purpose and the principles of Crown Lands management (Section 11 of the Act).

The principles of Crown Land management as defined in Section 11 of the Act are: environmental protection principles be observed in relation to the management and administration of Crown land; natural resources of Crown Land (including water, soil, flora, fauna and scenic quality) be conserved wherever possible; public use and enjoyment of Crown lands be encouraged; where appropriate, multiple uses of Crown land be encouraged; and where appropriate, Crown Land be used and managed in such a manner that the land and its resources are sustained in perpetuity.

In addition to these principles, the objectives of the Coastal Crown Lands Policy 1991 apply to Crown lands within the coastal zone. The policy sets specific objectives for conserving the environmental and cultural qualities of coastal Crown Land, retaining in public ownership coastal lands that are environmentally sensitive and / or required for public purpose, and providing use of coastal crown lands for recreation, tourism, residential and commercial development with due regard to the nature and consequences of coastal processes.

For all Crown land reserves, a Plan of Management (POM) is required to be prepared and adopted (in accordance with Division 6 of the *Crown Lands Act 1989*). The POM shall identify the key attributes and values of the area, general physical improvements to enhance the values and specify the permissible uses for the reserve.

The CL Act requires a land assessment to be undertaken prior to the reservation, dedication, exchange, vesting or sale of Crown land, or the granting of easements, leases or licences in respect of such land. The process for land assessment is specified by the Act and the *Crown Lands Regulation 2000*. It requires the physical characteristics of the land to be identified, the land's capabilities to be assessed and suitable uses identified. A draft land assessment is publicly exhibited for 28 days for comment. The exhibited draft may indicate a preferred use or uses.

Under the CL Act Crown lands may be:

- Held under tenure (lease or licence) for public purposes;
- Community managed reserves;
- Reserved for environmental purposes;
- Crown public roads; or
- Managed reserved lands.

Where an individual or organisation proposes to undertake an activity, build a structure or use Crown land, they are required to apply for tenure from CLD. This includes the issue of domestic waterfront licences for the use of submerged and tidal Crown land where there is direct access to Crown land. This type of licence would cover facilities such as jetties, boatsheds or boat ramps. There are three general types of arrangements under which Crown land may be held under tenure:

- Lease – form of tenure generally for exclusive occupation and use of Crown land for a specific term and under specific conditions as outlined under the provisions of the CL Act. Leases are designed with terms to suit the purpose of the lease. A lease may be forfeited for non-compliance of conditions, or may expire because the term has lapsed. A lease is also transferrable with the consent of the Minister. Generally, leases will require land assessments.
- Licence – provides the right to occupy or use Crown land under the provisions of the CL Act. A licence may not necessarily confer exclusive use by a licensee. It is not transferrable and may be revoked at the will of the Minister without compensation.
- Permissive Occupancy (PO) – PO agreements with the Minister are pursuant to the CL (Continued Tenures) Act 1989. Under the CL Act, only leases or licences will be issued in the future and permissive occupancies will be progressively terminated in favour of a licence or lease.

Water Management Act 2000

The *Water Management Act 2000* (the WM Act) seeks to promote the integrated and sustainable management of the States waters for the benefit of both present and future generations. Of key relevance to the Study area, the Act aims in particular "to protect, enhance and restore water sources, their associated ecosystems, ecological processes and biological diversity and their water quality". The Water Management Act 2000 replaced the Rivers and Foreshores Improvement Act 1948 (RFI Act 1948) in February 2008.

The WM Act outlines those activities for which a 'controlled activities approval' is required for works on waterfront land. The WM Act defines waterfront land as all land between the bed of a watercourse and a distance of 40 m from: the top the highest bank of a river (including creeks); shores of a lake; or, mean high water mark of an estuary or coastal waters (including lakes and lagoons). Therefore, controlled activities approval is required for the following activities on all foreshores of the Study area within 40 m of the mean high water mark:

'(a) the erection of a building or the carrying out of a work (within the meaning of the EPA Act), or

(b) the removal of material (whether or not extractive material) or vegetation from land, whether by way of excavation or otherwise, or

(c) the deposition of material (whether or not extractive material) on land, whether by way of landfill operations or otherwise, or

(d) the carrying out of any other activity that affects the quantity or flow of water in a water source.'

Exemptions from the WM Act are defined in Clause 39A of the Water Management (General) Regulation 2004 and include exemptions for government authorities, with the exception of Landcom.

Protection of the Environment Operation Act 1997

The Protection of the Environment Operations Act regulates water pollution, land pollution, air pollution and noise pollution in New South Wales. The Act enables the Environment Protection Authority, an agency within the OEH and Council, to issue pollution licenses and notices, to take legal action to enforce the law and to create a range of pollution offences and penalties. The Act also enables members of the public to take legal action to enforce laws.

Under the POEO Act it is considered an offence to pollute water without an environmental protection licence. Water pollution is the placement of any matter in a position where pollution enters or is likely to enter the water. Pollution of a waterway is allowed if an environmental protection license is held, however, there are conditions of a licence.

Other activities that require a licence under the Act are dredging or extractive activities where more than 30,000 m^3 per year is being removed, for re-use or resale (refer Schedule 1).

Catchment Management Act 2003

The purpose of the *Catchment Management Act 2003* is to establish catchment management authorities that would carry out certain natural resource management functions in their regions. There are thirteen catchment management authorities in New South Wales. The four Gosford coastal lagoons fall within the Hunter Central Rivers Catchment Management Authority (HCRCMA) area. The Act repealed the Catchment Management Act 1989 and amends various other Acts.

The objectives of the Act are:

- To provide natural resource planning on a catchment level;
- To ensure that the decisions about natural resources take into account appropriate catchment issues;
- To ensure that catchment level decisions take into account state standards and involve the Natural Resource Commission in catchment planning;
- To make use of the communities' knowledge and expertise and to involved them in decision making;
- To ensure proper management of natural resources from the social, economic and environmental issues; and

- To provide financial assistance and incentives to landholders in connection with natural resource management.

Under the Act each catchment management authority prepared a Catchment Action Plan (CAP). Through the CAP, the HCRCMA aimed to improve the health of our estuaries by protecting and enhancing wetlands, better managing stormwater and nutrient run-off, improving foreshore and riparian vegetation and increasing tidal flushing. Implementation of this CZMP will help achieve the aims of the CAP for estuaries in the catchment management area. The catchment management authorities are currently reviewing the implementation of CAP management targets and revising the CAPs for 2012.

Natural Resource Management Act 2003

The *Natural Resource Management Act 2003* is responsible for the creation of the Natural Resources Commission. The objectives of the Act are:

- To establish a sound scientific basis for the informed management of natural resources in regards to the social, economic and environment interests of the State;
- To enable the adoption of State-wide standards and targets for natural resource management issues; and
- To advise in the circumstance where broad-scale clearing is regarded to be an improvement or maintenance of environmental outcomes for the purpose of the *Native Vegetation Act 2003*.

The Natural Resource Commission consists of a full time Commissioner and Assistant Commissioner. The role of the Commission is to provide the government with independent advice on natural resource management, in addition to recommending state-wide targets for natural resource management, approval of catchment action plans, and commenting on the effectiveness of these plans. The commission would also undertake natural resource management assessments, and would control investigations and inquires into natural resource management issues and research of the issues.

Environment Protection and Biodiversity Conservation Act

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) is the main Commonwealth Law responsible for the protection of flora and fauna. The Act applies to:

- Flora and fauna within areas controlled or owned by the Commonwealth;
- Flora or fauna that may be harmed by the actions of a Commonwealth agency; and
- Actions that may have a significant effect on species on the national threatened species list.

The EPBC Act requires approval by the Commonwealth Minister for the Environment for actions that may have a significant impact on matters of national environmental significance. The EPBC Act defines matters of national environmental significance as: Ramsar wetlands, listed threatened species and communities, World Heritage properties, listed migratory species, the Commonwealth marine environment and nuclear actions (including uranium mining). The EPBC Act was amended in 2003 to include protection of National Heritage. This amendment involved, including 'national

heritage' as new matter of national environment significance, and the establishment of a national heritage list.

The EPBC Act also requires Commonwealth approval for certain actions on Commonwealth land.

Estuary Management Policy 1992

The NSW Estuary Management Policy was one of a suite of policies under the former NSW State Rivers and Estuaries Policy. The Estuary Management Policy was developed in response to the State Government's recognition of the social and economic importance of estuaries. The specified general goal of the policy is "to achieve an integrated balance responsible and ecologically sustainable use of the State estuaries which form a key component of coastal catchments".

The Estuary Management Manual (1992) was replaced by the *Guidelines for Preparing Coastal Zone Management Plans* (DECCW, 2010), in which the coastal and estuary management processes were combined. This Gosford Lagoons Coastal Zone Management Plan has taken consideration of the objectives and relevant guidance for estuaries given in the former Manual.

NSW Coastal Policy 1997

The aim of the New South Wales Coastal Policy 1997 is to promote the ecologically sustainable development of the New South Wales coastline. To achieve this, the policy sets out various goals, objective and actions. This policy applies the coastal zone, as defined by the area that extends to:

- three nautical miles seaward of the mainland and offshore islands;
- one kilometre inland of the 'open coast' High Water Mark;
- one kilometre around all the bays, estuaries, coastal lakes, lagoons and island; and
- in relation to tidal rivers, one kilometre around the tidal waters of the river to the limit of mangroves or the tidal limit (whichever is closer to the sea).

Wamberal, Terrigal, Avoca and Cockrone Lagoons and their foreshores are within the defined coastal zone; therefore the Coastal Policy has been considered in the preparation of Gosford Coastal Lagoons Coastal Zone Management Plan.

The relevance of the Policy to future development is that the council is required to implement the policy when making local environment plans applying to land within the coastal zone and to take the provisions of the policy into consideration when determining development applications in the coastal zone.

As the NSW Coastal Policy 1997 applies to Wamberal, Terrigal, Avoca and Cockrone Lagoons, Council is required to reflect the principles of ecologically sustainable development in planning and management decisions. Also, Council is committed to the principles of ecologically sustainable development through the *Local Government Act 1993* (amended 1997), which are embodied within Council's Environmental Policy 2002.

The Coastal Policy has nine goals, each underpinned by objectives that are to be achieved by strategic actions. Responsibilities for these actions have been assigned to appropriate agencies,

councils and other bodies. OEH is wholly or partly responsible for nearly half of the strategic actions in the Coastal Policy, with many of these involving a partnership with local councils.

The nine goals of the NSW Coastal Policy 1997 are:

1. To protect, rehabilitate and improve the natural environment;
2. To recognise and accommodate natural processes and climate change;
3. To protect and enhance the aesthetic qualities;
4. To protect and conserve cultural heritage;
5. To promote Ecologically Sustainable Development;
6. To provide for ecologically sustainable human settlement;
7. To provide for appropriate public access and use;
8. To provide information to enable effective management; and
9. To provide for integrated planning and management.

Ecologically Sustainable Development

The four principles of Ecologically Sustainable Development (ESD) are:

1. The precautionary principle: The lack of full scientific evidence should not be used as a justification for the postponement of the introduction of measures to prevent or mitigate environmental degradation. This principle is fundamental to adaptive management. Monitoring and prevention are central to the precautionary principle – monitoring to measure progress, and prevention to minimise costs and risks. Decisions can and should be refined as ongoing monitoring and research provides better understanding.

2. Intergenerational equity: Each generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for future generations. This principle points to institutional and community responsibilities for integrated management, to ensure quality of life is maintained and enhanced.

3. Conservation of biological diversity and ecological integrity: Measures should be taken to prevent and protect against the extinction or loss of viability of plant and animal species due to human activities.

4. Improved valuation and pricing of environmental resources: The quality and value of environmental resources should be maintained and enhanced through appropriate management and pricing, preventing degradation and damage.

APPENDIX B: COMMUNITY WORKSHOP OUTPUTS

The key outputs for the community consultation workshops were details on values, threats and management options for each of the lagoons.

Table 7-1 Threats to the Lagoons Identified by Community During Workshops

Threat	Wamberal	Terrigal	Avoca	Cockrone
Stormwater inputs	✓	✓	✓	✓
Development within the catchment	✓	✓	✓	
Domestic animals (including dogs)	✓		✓	✓
Loss of riparian vegetation		✓	✓	
Algal blooms			✓	✓
Opening policy		✓		
Illegal openings				✓
Inappropriate foreshore management (eg. Mowing and chicken coops)			✓	
Flying foxes			✓	
Duck feeding				✓
Litter				✓

APPENDIX C: THREAT ASSESSMENT WORKSHEETS

Threats to Avoca Lagoon	Primary underlying cause	Frequency (overall)	Consequence (overall)	Level of Threat	Notes from Community Consultation	Notes from processes study	Threat Included in Final List ?
Smothering of vegetation due to soil erosion from construction sites resulting in loss of natural bushland	Urban land use	5	4	extreme	Approximately 10% of the area around the Lake.		Yes
Loss of native riparian vegetation due to mowing of tramway reserve resulting in reduced habitat potential for frogs and migratory birds	Foreshore management	5	4	extreme	from issues list - e.g. Latham's snipe		Yes
Contamination by sewage in lagoon waters due to sewer system overflows resulting in declining water quality	Other sources of pollution	5	4	extreme	This primarily occurs in the Northern and Southern reaches and typically occurs twice/year	Coastal Carrier System upgrade?	Yes
Impacts of sea level rise on environmental values		3	5	high			Yes
Water pollution due to nutrient enrichment resulting in a decline in water quality	Urban land use	4	3	high		Generally good, Some anzecc exceedences (for nutrients), When entrance open WQ expected to fall within guidelines, Very rapid changes following breakout – odour – low do – algal die off (short lived). Majority of lagoon volume completely flushed during an average opening. (av e-fold 7.4 days, max e-fold 35.1	Yes
Restrictions to recreational access around the lagoon due to vegetation overgrowth, high lagoon water levels and unauthorised land use (fencing, jetties, car parking) resulting in a loss of amenity	Foreshore management	4	3	high	Chicken coups have been seen on the 10-15% of the foreshore regions of the lake. Locations shown on issues maps. In the southern arm of the lake private fencing of properties has extended onto areas of public land and access ways and public use of the land is lost. This has increased in the last decade. Poor access western edge of the southern arm of the lake and near scout hall, North eastern corner of the southern arm of the lake. Particularly around the South Arm there has been lawn mowing to the edge of the lake resulting in a loss of natural vegetation e.g.. reeds & rushes		Yes
Unpleasant odours from decaying algae resulting in a loss of aesthetic beauty	?	3	3	high	Around the whole of the lagoon		Yes
Low abundance of birds due to presence and actions of domestic animals leading to a reduction in bird and fish life.	Human recreational use and access	3	3	high			Yes
Low concentrations of dissolved oxygen within lake waters due to increased algal decay resulting in declining water quality	?	3	3	high		Supports the theory that fish kills are in response to depleted dissolved oxygen following algal die off. This is a natural process that may have been exacerbated by catchment nutrient inputs.	Yes
Reduction in flushing and circulation within the upper reaches of the lagoon due to excessive algal growth leading to declining water quality	?	4	4	high			Yes
Sedimentation resulting in low water depths leading to enhanced water temperatures and algal blooms	Urban land use	3	3	high			Yes
Increased nutrient inputs due to chicken coops and garden beds on public lands resulting in water pollution	Foreshore management	4	3	high			Yes
Algal and weed growth due to nutrient enrichment from stormwater runoff resulting in a loss of aesthetic beauty		4	2	medium	This primarily occurs in the shallower reaches of the lagoon, especially in the Southern Arm, and typically occurs once per year	Algal processes not well understood - it is believed that the persistence of elevated water for long periods of time contribute to increased algal biomass and subsequent wq issues. It is estimated that for the large mudflat areas, a depth of 1.1 metres is associated with shading and die off. Groundwater sources of trace limited minerals are being investigated.	Yes
Increased frequency of lower lake water levels due to illegal openings resulting in a loss of aesthetic beauty	Human recreational use and access	3	2	medium	Estimated by community to Occur about 25% of the time	Limited information on unofficial openings	Yes
Prograding mud flats due to siltation leading to loss of aesthetic beauty	Urban land use	3	2	medium	Near inlets and lake edges approximately 2mm/yr, stormwater sources of sedimentation shown on issues maps	Siltation rate estimated at 2.1mm / year, modeling shows locations (primarily near entrance of Saltwater Creek)	Yes
Dune erosion due to opening events leading to loss of access around lagoon.	Artificial entrance management	3	2	medium	Focus at the mouth of the lake, and has increased in last 3 years. Issues list indicates that shoreline recession has restricted access on the northern foreshore - resulting in access through dunes		Yes
Loss of tadpoles from Bareena wetland due to artificial entrance opening leading to reduction in abundance of Green and Golden Bell Frogs	Artificial entrance management	3	2	medium		If the lagoon level drops below 1.4 metres AHD, Bareena wetland may become dry. The drying of the wetland can have significant negative impact if it occurs during spring or summer as it would be fatal to tadpoles and an entire breeding season may be lost. However, if drying occurs during autumn or winter, this may help prevent colonisation of the wetland by Gambusia, which inhabit the Avoca Lagoon, are a key threatening process to the Green and Golden Bell Frogs and are not adapted to surviving drying. Chytrid fungus spores are killed by exposure to salt and it is possible that the fluctuating salinity levels of the Bareena Wetland help to minimise its impact on this population.	Yes

Threats to Avoca Lagoon	Primary underlying cause	Frequency (overall)	Consequence (overall)	Level of Threat	Notes from Community Consultation	Notes from processes study	Threat Included in Final List ?
Deterioration of fauna and flora due to increased presence of nutrients and contaminants from agricultural runoff resulting in a decline in water quality	Agricultural land use	3	2	medium			Yes
Illegal dumping of garbage e.g. car parts, shopping trolleys, and unauthorised car parking around lagoon resulting in degradation of foreshore areas and loss of access to lagoon waters.	Human recreational use and access	2	1	low			Yes
Displacement of native species by exotics resulting in loss of biodiversity within lagoon	?	2	2	low	Lots of introduced plants - Camphor laurel, Lantana, particularly on the left going into Western Avoca and around South Arm	Lists weeds as an issue for the lagoons, gambusia are present, rabbits may impact on riparian areas	Yes
Destruction of native vegetation due to human activities resulting in a loss of natural bushland as well as bird and fish life.	Human recreational use and access	2	2	low			Yes
Loss of habitat due to urban development leading to reduction in bird and fish life	Urban land use	1	2	low			Yes
Increased disturbance and drying of soils due to flow modifications in Saltwater Creek resulting in activation of acid sulphate soils and release of acid waters	?	5	4	extreme		High risk ASS areas coincide with private development so some chance of exposure. Activities would require a DA so risk is considered low.	No - existing controls (activities require a DA) effectively treat the threat.
Destruction of foliage at tree tops due to increased numbers of flying foxes resulting in a change to understorey vegetation		3	3	high	Particularly in the Northern Arm of the lake.		No - not found to be sufficient scientific evidence regarding assumption and not considered applicable to a CZMP
Damage to property due to increased flood inundation from climate change resulting in loss of housing, valuables and possibly life		2	4	medium	Threat added by workshop attendee		No - already covered by other threats
Increase in Greenfield releases and zoning changes due to changes in government resulting in a loss of natural catchment.					Threat added by workshop attendee		No - already covered by other threats and not considered applicable to a CZMP
Loss of heritage sites due to uncertainty of heritage values resulting in a loss of cultural heritage					Threat added by workshop attendee		No - already covered by other threats and not considered applicable to a CZMP
Warmer water temperatures due to warmer air temperatures from climate change resulting in the potential for higher frequency of algal blooms					Threat added by workshop attendee		No - already covered by other threats and not considered applicable to a CZMP
Low dissolved oxygen values in lagoon waters due to lower water levels and warmer waters due to climate change resulting in a decline in water quality					Threat added by workshop attendee		No - already covered by other threats and not considered applicable to a CZMP
Hazards to marine life due to urban pollution, including plastic debris, resulting in a loss of fauna					Threat added by workshop attendee		No - already covered by other threats and not considered applicable to a CZMP
Extension of urban footprint due to housing intensification of new and existing land resulting in a loss of natural bushland					Threat added by workshop attendee		No - already covered by other threats and not considered applicable to a CZMP
Inadequate management of catchment and waterway due to unclear management responsibilities resulting in a decline in estuary health					Threat added by workshop attendee		No - already covered by other threats and not considered applicable to a CZMP
Channelisation of flows and stormwater runoff due to urbanisation resulting in modified flows					Threat added by workshop attendee		No - already covered by other threats and not considered applicable to a CZMP
Modification of foreshore banks and riparian vegetation due to development pressure resulting in a decline in amenity and estuary health					Threat added by workshop attendee		No - already covered by other threats and not considered applicable to a CZMP
Erosion of feeding creeks		1	1	low	Threat added by workshop attendee	Shoreline erosion assessment indicated very few areas of existing erosion, however increased boat activity or removal of riparian veg have the potential to increase vulnerability	No - already covered by other threats and considered a low degree of threat.

Threats to Wamberal Lagoon	Primary underlying cause	Frequency (overall)	Consequence (overall)	Level of Threat	Notes from Community Consultation	Notes from processes study	Threat Included in Final List ?
Inappropriate dumping of residential garden waste resulting in weed invasion	Urban land use	5	4	extreme			Yes
Impacts of sea level rise on foreshore inundation		5	5	extreme			Yes
Pollutants entering the lagoon via stormwater as a result of existing catchment activities		5	3	high	10% of whole of catchment , particularly Blue Bell Dr. & Upper catchments	Wamberal has the smallest catchment but 67% is developed (urban or rural). Measured WQ is generally good, Some anzecc exceedences (for nutrients), When entrance open WQ expected to fall within guidelines, spikes after rainfall, Very rapid changes following breakout. Majority of lagoon volume completely flushed during an average opening. (av e-fold 4.4 days, max e-fold 29.9, av duration of opening 10 days)	Yes
Disturbance of native wildlife as a result of recreational usage	Human recreational use and access	5	3	high	Close to sand dunes, edges of lagoon, dog off leash area		Yes
Faecal contamination leading to impacts on recreational opportunities and increased nutrients	Other sources of pollution	5	3	high		Coastal carrier system upgrade? The beach watch data provides existing monitoring for this	Yes
Impacts of sea level rise on environmental values		5	3	high			Yes
Increased density of development into the future and reduction in undeveloped land contributing to increased runoff to the lagoon	Urban land use	2	3	medium	Low but continued pressure over whole of catchment - 10% - retirement proposal at north side of catchment	Protected catchment 31% urban, 36% rural, 24% forested, 9% waterway	Yes
Insufficient habitat protection as a result of inadequate management resources and funding leading to a decline in total protected catchment area		5	2	medium	also includes poisoning of trees particularly in the foreshore area of the reserve		Yes
Erosion of sand dunes and loss of dunal vegetation due to recreational use	Human recreational use and access	4	2	medium	Is happening at present (access to dunes) particularly on the ocean side of the Nature Reserve		Yes
Algal blooms as a result of nutrient inputs resulting in a decline in recreational opportunities	?	1	3	medium		Algal processes not well understood - it is believed that the persistence of elevated water for long periods of time contribute to increased algal biomass and subsequent wq issues.	Yes
Loss of vegetation and increased erosion as a result of bushfires leading to degradation of the protected catchment area and sedimentation of waterway	?	2	2	low	Variable particularly in the nature reserve and bushland		Yes
Reduced depths within the estuary due to opening regime	Artificial entrance management	2	1	low			Yes
Decreased extents of Melaleuca forests as a result of land clearing for development leading to a loss in biodiversity	Human recreational use and access	2	2	low			Yes
Defoliation, loss of tree species and abundance due to increased occurrence of myrtle rust resulting in a loss of naturalness	?	?	?		newly described fungus - May result in plant death, affect plants belonging to the family Myrtaceae including Australian natives like bottle brush (Callistemon spp.), tea tree (Melaleuca spp.) and eucalypts (Eucalyptus spp.).		No - threat already managed through existing process.
Phosphate runoff from agricultural lands	Agricultural land use						No - already covered by other threats
Pollution of lagoon waters with pesticides due to residential use resulting in a decline in water quality and impacts on ecology	Urban land use						No - already covered by other threats
Water pollution as a result of urban runoff from roads and pools leading to a decline in water quality	Urban land use						No - already covered by other threats
Loss of seagrass as a result of increased siltation and changes in salinity leading to poor water quality	Urban land use					Decline when comparing between 2006 and 2010, although different methodology used.	No - already covered by other threats
Loss of birds and vegetation as a result of domestic and feral animals leading to a decline in biodiversity							No - already covered by other threats
Off leash dog area encouraging domestic animals to nature reserve							No - already covered by other threats

Threats to Terrigal Lagoon	Value	Primary underlying cause	Frequency (overall)	Consequence (overall)	Level of Threat	Notes from Community Consultation	Notes from processes study	Threat Included in Final List ?
Faecal contamination of the estuary leading to impacts on human and estuary health.	Recreational, Social uses & Public Access to Foreshores	Other sources of pollution	5	4	extreme		Coastal Carrier upgrade?	Yes
Loss of foreshore habitat value due to removal of foreshore vegetation, weed invasion, mowing and trampling leading to a decrease in ecological health	Ecology including fish/birds & Foreshore Vegetation	Foreshore management	5	4	extreme		Illegal clearing of foreshore veg to facilitate access	Yes
Impacts of sea level rise on foreshore inundation		Natural variability and or future climate change	5	5	extreme			Yes
Foreshore erosion around the lagoon due to pedestrian and vehicle access	Recreational, Social uses & Public Access to Foreshores	Human recreational use and access	5	3	high			Yes
Pollutants entering the lagoon via stormwater as a result of existing catchment activities			5	3	high			Yes
Increased density of development into the future and reduction in undeveloped land contributing to increased runoff to the lagoon	Ecology including fish/birds & Foreshore Vegetation	Urban land use	4	2	medium		Protected catchment 36% urban, 44% rural, 16% forested,3% waterway	Yes
Infestations of weeds due to introduced plant species around the lagoon resulting in a decline in plant diversity.			5	2	medium			Yes
Impacts of sea level rise on environmental values			5	2	medium			Yes
Loss of recreational access due to low water levels following entrance opening	Recreational, Social uses & Public Access to Foreshores	Artificial entrance management	2	2	low			Yes
Changes in water chemistry and enhanced sand ingress due to opening policy leading to shifts in the ecology	Ecology including fish/birds & Foreshore Vegetation	Artificial entrance management	2	2	low			Yes
Siltation of the lagoon due to catchment runoff impacting on water quality, benthic ecology and aesthetic beauty	Aesthetic Beauty	Urban land use					Siltation rate estimated at 0.35mm/year	No - already covered by other threats
Nutrient inputs to the lagoon as a result of catchment activities resulting in a decline in water quality	Good Water Quality	Urban land use					Highest pollutant loads of the lagoons	No - already covered by other threats
Gross pollutants, including litter entering the lagoon through stormwater and direct dumping	Good Water Quality	Human recreational use and access						No - already covered by other threats

Threats to Cockrone Lagoon	Primary underlying cause	Frequency (overall)	Consequence (overall)	Level of Threat	Notes from Community Consultation	Notes from processes study	Threat Included in Final List ?
Inappropriate dumping of residential garden waste resulting in weed invasion	Urban land use	5	4	**extreme**			Yes
Impacts of sea level rise on foreshore inundation	Natural variability and or future climate change	5	4	**extreme**			Yes
Pollutants entering the lagoon via stormwater as a result of existing catchment activities	Urban land use	5	3	**high**		Lowest pollutant loads of any of the lagoons. Measured WQ is generally good, Some anzecc exceedences (for nutrients), Majority of lagoon volume completely flushed during an average opening. (av e-fold 7.4 days, max e-fold 40.2, av duration of opening 9 days)	Yes
Erosion of beach berm due to illegal openings of the lagoon leading to a reduction in amenity	Artificial entrance management	3	3	**high**	illegal openings estimated to occur around 60% of the time		Yes
Disturbance of native wildlife as a result of recreational usage	Human recreational use and access	5	3	**high**	includes impacts on duck numbers from hand feeding Numbers have already increased approximately 50% and ducks can be found all over the lake particularly along southern boundary.		Yes
Infestations of weeds due to introduced plant species around the lagoon resulting in a decline in plant diversity.		3	3	**high**			Yes
Faecal contamination leading to impacts on recreational opportunities and increased nutrients	Human recreational use and access	5	3	**high**			Yes
Impacts of sea level rise on environmental values		5	3	**high**			Yes
Increased density of development into the future and reduction in undeveloped land contributing to increased runoff to the lagoon	Urban land use	2	3	**medium**	On the foreshore where houses have been built at Copacabana & MacMasters Beach. Typically covering 10% of lagoon area.	Protected catchment 9% urban, 16% rural, 69% forested, 6% waterway	Yes
Impacts of catchment development on landscape character		4	2	**medium**			Yes
Insufficient habitat protection as a result of inadequate management resources and funding leading to a decline in total protected catchment area	Urban land use	5	2	**medium**			Yes
Erosion of sand dunes and loss of dunal vegetation due to recreational use	Human recreational use and access	4	2	**medium**	Illegal openings frequent		Yes
Damage to flora and fauna diversity due to increased human access around pristine sections of the lagoon leading to a reduction in aesthetic beauty	Human recreational use and access	4	2	**medium**		Crown land just around entrance. Some community land elsewhere but privately owned land dominates foreshore. Fencing limits access on western foreshore	Yes
Impacts on bird populations due to predation from feral animals resulting in a loss of diversity	Human recreational use and access	4	2	**medium**			Yes

Threats to Cockrone Lagoon	Primary underlying cause	Frequency (overall)	Consequence (overall)	Level of Threat	Notes from Community Consultation	Notes from processes study	Threat Included in Final List ?
Abundant numbers of ducks due to hand feeding increasing nutrients and reducing aesthetic beauty	Human recreational use and access	2	2	low	includes impacts on duck numbers from hand feeding Numbers have already increased approximately 50% and ducks can be found all over the lake particularly along southern boundary.		Yes
Reduced depths within the estuary due to opening regime	Artificial entrance management	2	1	low			Yes
Algal blooms resulting in a decline in amenity	?	2	2	low			Yes
Visual pollution due to excess signage around the lake leading to a decline in aesthetic beauty.	Foreshore management	5	1	low			Yes
Threat to pristine and tranquil qualities of the lagoon environment should commercial development be allowed, resulting in loss of aesthetic beauty	Human recreational use and access	1	2	low			Yes
Sediments entering the lagoon via stormwater leading to reduced depths, smothering of vegetation and decreased water quality	Urban land use						No - already covered by other threats
Gross pollutants including litter entering the lagoon through stormwater and illegal dumping	Urban land use						No - already covered by other threats
Unpleasant odours after opening events due to decay of algal blooms in shallow or non existent waters resulting in a loss of aesthetic beauty	Artificial entrance management						No - already covered by other threats
Loss of birds, fish and plant life due to declining water quality	Urban land use						No - already covered by other threats
Limited opportunity for recreational swimming in the lagoon due to increased presence of a high tide residue around the lagoon resulting in a loss of community focal point.	Natural variability and or future climate change						No - already covered by other threats
Pollution of lagoon waters with pesticides due to residential use resulting in a decline in water quality and impacts on ecology	Urban land use						No - already covered by other threats
Depleted dissolved oxygen due to large algal biomass die off after entrance opening resulting in fish kills	?					Algal processes not well understood - it is believed that the persistence of elevated water for long periods of time contribute to increased algal biomass and subsequent wq issues. It is estimated that for the large mudflat areas, a depth of 1.1 metres is associated with shading and die off . Groundwater sources of trace limited minerals are being investigated.	No - insufficient scientific evidence regarding threat
Illegal openings impacting on lagoon ecology, entrance dynamics and aesthetics	Artificial entrance management				Illegal openings have been observed to occur approximately 60% of the time, and typically occurs when the lagoon waters are high.		No - already covered by other threats
Input of nutrients from agricultural land uses	Agricultural land use						No - already covered by other threats

APPENDIX D: LONG LIST OF OPTIONS

The fine filter assessment of the long list of options is presented below. For a description of the assessment process, please refer to Section 6.4.2

Ref	Option	Threat Level Wamberal	Threat Level Terrigal	Threat Level Avoca	Threat Level Cockrone	Risk Reduction Potential	Timeframe	Cost	Practicality	Community Support	Management Intent - Wamberal	Management Intent - Terrigal	Management Intent - Avoca	Management Intent - Cockrone	No Regrets?	Score Wamberal	Score Terrigal	Score Avoca	Score Cockrone
106	Council continue to support University Researchers to undertake studies on the ecology of lagoon fauna and to describe potential impacts caused by development in order to develop improved management practices for the fauna associated with the coastal lagoons.	3	3	3	3	3	3	3	3	3	3	3	3	3	3	21	21	21	21
29	Liaise with Gosford/ Wyong Council Water Authority when private and public sewers are observed to be causing water quality problems, this will remain important during coastal carrier system upgrade and beyond.	3	3	3	3	2	3	3	3	3	3	3	3	3	3	20	20	20	20
70	Actively support the continuation of Bush care to assist with revegetation works on Public and Private Lands	3	3	3	3	3	3	3	3	3	3	2	3	3	3	21	20	21	21
61	Update Lagoon fact sheets and distribute with Rates notices to increase general community appreciation and publication of awareness. Also make available at visitor information centres, accommodation providers etc.	3	3	3	3	2	3	3	3	3	3	2	3	3	3	20	19	20	20
6	Develop and implement a Water Sensitive Urban Design (WSUD) Development Control Plan (DCP)	3	3	3	3	3	3	3	3	3	3	3	3	3		21	21	21	21
14	Where possible, improve catchment management practices to reduce impacts on the lagoons	3	3	3	3	3	3	3	3	3	3	3	3	3		21	21	21	21
18	Identify potential sources of nutrients (e.g.. Golf courses and agricultural lands) and liaise directly with land owners/ managers to reduce nutrient and sediment inputs	3	3	3	3	3	3	3	3	3	3	3	3	3		21	21	21	21
25	Undertake an Intensive engagement program for works staff involved in sediment and erosion control within the catchments to raise the profile of best practice erosion and sediment control, assist staff with new policies and procedures and track improvements in performance.	3	3	3	3	3	3	3	3	3	3	3	3	3		21	21	21	21

Ref	Option	Threat Level Wamberal	Threat Level Terrigal	Threat Level Avoca	Threat Level Cockrone	Risk Reduction Potential	Timeframe	Cost	Practicality	Community Support	Management Intent - Wamberal	Management Intent - Terrigal	Management Intent - Avoca	Management Intent - Cockrone	No Regrets?	Score Wamberal	Score Terrigal	Score Avoca	Score Cockrone
63	Provide education for agriculturalists within the catchment - now combined with 18)	3	3	3	3	3	3	3	3	3	3	3	3	3		21	21	21	21
10	Restrict any rezoning of land within the lagoon catchments that increases density of development.	3	3	3	3	3	3	3	3	2	3	3	3	3		20	20	20	20
13	Catchment based control to reduce sediment input including planning controls, compliance monitoring, community education and the implementation of WSUD features	3	3	3	3	3	3	2	3	3	3	3	3	3		20	20	20	20
16	Undertake adequate and appropriate maintenance of existing WSUD devices to maintain their effectiveness, in particular GPTs, nutient filters and other stormwater quality improvement devices.	3	3	3	3	3	3	2	3	3	3	3	3	3		20	20	20	20
17	Council develop a Management Practice for the regular inspection and clearing of trash racks, sediment traps and nutrient filters. - now combined with 16	3	3	3	3	3	3	2	3	3	3	3	3	3		20	20	20	20
23	Enforce implementation and maintenance of effective sediment controls during the subdivision and building phases of all developments (including infrastructure projects) by undertaking regular audits of developments during construction	3	3	3	3	2	3	3	3	3	3	3	3	3		20	20	20	20
49	Develop a Foreshore Access Plan designed to minimise impacts to vegetation, wildlife and foreshores – (may require an educational component.)	3	3	3	3	3	3	3	3	3	3	2	3	3		21	20	21	21
59	Provide information to private landholders that have key habitat and vegetation communities on their properties to describe the community, its importance to the estuary and options for its protection and management	3	3	3	3	3	3	3	3	3	3	2	3	3		21	20	21	21
71	Maintain and reinstate vegetation along all major drainage lines.	3	3	3	3	3	3	2	3	3	3	3	3	3		20	20	20	20

Ref	Option	Threat Level Wamberal	Threat Level Terrigal	Threat Level Avoca	Threat Level Cockrone	Risk Reduction Potential	Timeframe	Cost	Practicality	Community Support	Management Intent - Wamberal	Management Intent - Terrigal	Management Intent - Avoca	Management Intent - Cockrone	No Regrets?	Score Wamberal	Score Terrigal	Score Avoca	Score Cockrone
74	Implement an intensive garden escapee weed management program	3	3	3	3	3	3	3	3	3	3	2	3	3		21	20	21	21
103	More strategic water quality monitoring	3	3	3	3	2	3	3	3	3	3	3	3	3		20	20	20	20
105	Consider developing an estuary health monitoring strategy	3	3	3	3	3	3	2	3	3	3	3	3	3		20	20	20	20
8	When undertaking reviews of strategic planning initiatives (including LEPs and DCPs) ensure consistency with the objectives of the CZMP	2	2	3		3	3	3	3	3	3	3	3	3	3	20	20	21	18
15	Retrofit appropriate WSUD in existing urban areas including measures such as artificial wetlands, vegetated swales	3	3	3	3	3	2	2	2	3	3	3	3	3		18	18	18	18
39	Incorporate the lagoons into a revised Foreshore Reserves Plan of Managment	3	3	3	3	3	3	3	3	3	3	2	2	2		21	20	20	20
50	Council and the CLD capitalise on any opportunities to acquire additional foreshore lands, bringing them into public ownership to maximise opportunities to improve and enhance public access and foreshore ecological values	3	3	3	3	3	3	1	3	3	3	2	3	3		19	18	19	19
72	Identify sites where there is the potential for landward migration of estuary vegetation and prioritise these for rehabilitation works	3	3	3	3	3	3	3	3	3	3	2	2	2		21	20	20	20
104	Water quality monitoring for public recreation	3	3		3	3	3	3	3	3	3	3	3	3		21	21	18	21

Ref	Option	Threat Level Wamberal	Threat Level Terrigal	Threat Level Avoca	Threat Level Cockrone	Risk Reduction Potential	Timeframe	Cost	Practicality	Community Support	Management Intent - Wamberal	Management Intent - Terrigal	Management Intent - Avoca	Management Intent - Cockrone	No Regrets?	Score Wamberal	Score Terrigal	Score Avoca	Score Cockrone
2	Ensure that present planning and development controls allow for sea level rise and if possible a gradual reduction in lagoon opening by progressively increasing floor heights	3	3	3	3	2	2	3	2	2	3	2	2	2	3	17	16	16	16
28	Where contaminated sites are identified, the potential for migration via stormwater into the lagoons should be considered and mitigating measures implemented	3	3	3	3	2	2	2	2	3	3	3	3	3		17	17	17	17
69	Remove then contain growth of weeds through Councils, bush care groups, local clean up initiatives	3	3	3	3	3	2	2	2	3	3	2	3	3		18	17	18	18
58	Include lagoons in "Clean up Australia"	3	3		3	2	3	3	3	3	3	2	3	3		20	19	17	20
66	Improve mapping of bird habitat	3	3	3	3	3	3	2	3	3	3	1	2	2		20	18	19	19
26	Promote and undertake compliance on unauthorised use and development on riparian and estuarine vegetation areas	3		3	3	2	3	3	3	3	3	1	3	3		20	15	20	20
81	Reconsider triggers and options for entrance management with recreational and ecological benefits	3	3		3	3	3	3	3	3	3	2	2	2		21	20	17	20
45	Management of recreational activities to ensure ongoing stability of lagoon banks		3	3		3	3	3	3	3	3	2	3	3		18	20	21	18
73	Encourage the planting of appropriate species to enhance connectivity, green corridors and succession of desired adult trees (e.g. M. quinquenervia)		3	3		3	3	3	3	3	3	2	3	3		18	20	21	18
43	Ongoing protection for foreshore vegetation and maintenance of existing protection works		3	3		3	3	2	3	3	3	2	3	3		17	19	20	17

Ref	Option	Threat Level Wamberal	Threat Level Terrigal	Threat Level Avoca	Threat Level Cockrone	Risk Reduction Potential	Timeframe	Cost	Practicality	Community Support	Management Intent - Wamberal	Management Intent - Terrigal	Management Intent - Avoca	Management Intent - Cockrone	No Regrets?	Score Wamberal	Score Terrigal	Score Avoca	Score Cockrone
12	Undertake bank erosion works in areas currently experiencing bank erosion and instability and areas vulnerable to this in the future		3			3	3	3	3	3	3	2	3	3		18	20	18	18
24	Have rangers police the area regularly & make the fines for having dogs off leash higher.	3		3	3	3	3	2	2	2	3	1	2	2		18	13	17	17
53	Encourage bank and foreshore erosion control techniques that maximise the use of riparian and estuarine vegetation		3			3	3	3	3	3	3	2	3	3		18	20	18	18
3	Do not allow any further development within lagoon catchments			3		3	2	3	1	2	3	3	3	3		14	14	17	14
5	Prepare updated NP POM for Wamberal Lagoon to compliment CZMP	3	0	0	0	2	3	3	3	3	3	1	1	1	3	20	15	15	15
9	Ensure identified and unidentified Aboriginal heritage sites are protected through developing heritage management plans	1	1	1	1	2	3	3	3	3	1	1	1	2	3	16	16	16	17
42	Discourage public access along the lagoon foreshore to limit vegetation trampling and bank erosion		3			2	3	3	2	2	3	2	3	3		15	17	15	15
36	Facilitate and encourage public access to Terrigal Lagoon	3	1	3	3	2	3	3	3	2		2				16	16	16	16
62	Education about littering	3	3	3	3	1	3	3	3	3	3	3	3	3		19	19	19	19
4	Extend ban on dual occupancy to non urban lands through modifying Interim Development Control Order 122	3	3	3	3	2	2	3	2	3	2	2	2	2		17	17	17	17

Ref	Option	Threat Level Wamberal	Threat Level Terrigal	Threat Level Avoca	Threat Level Cockrone	Risk Reduction Potential	Timeframe	Cost	Practicality	Community Support	Management Intent - Wamberal	Management Intent - Terrigal	Management Intent - Avoca	Management Intent - Cockrone	No Regrets?	Score Wamberal	Score Terrigal	Score Avoca	Score Cockrone
55	Limit Public access to Wamberal Lagoon to protect and enhance natural values	3				3	3	3	3	3	3				3	21	15	15	15
57	Education in high schools regarding artificial entrance opening				3	3	3	3	3	3				3	3	15	15	##	21
21	Council to use the sand rake especially after a lagoon opening			3		1	3	2	3	3	2	2	2	2		14	14	17	14
46	Work with Aboriginal groups for any management actions likely to impact upon or regarding aboriginal heritage					3	3	3	3	3	1	1	1	2	3	16	16	16	17
99	Skimming & harvesting algae from the water body and shoreline to reduce odour and aesthetic impacts			3		2	3	2	3	3	1	3	1	1		14	16	17	14
37	Limit public access to Wamberal Lagoon	3				3	3	3	3	3	3					21	15	15	15
51	Better waste facilities for Terrigal Lagoon		3			3	3	3	3	3		3				15	21	15	15
35	Limit public access to Cockrone Lagoon				3	3	3	3	3	3				2		15	15	15	20
41	Discourage public access on Southern side of Avoca Lagoon, improve access on eastern side			3		3	3	3	3	3			2			15	15	20	15
44	Work with Aboriginal groups and OEH to determine management options for existing or revealed heritage sites.					3	3	3	3	3	1	1	1	2		16	16	16	17

Ref	Option	Threat Level Wamberal	Threat Level Terrigal	Threat Level Avoca	Threat Level Cockrone	Risk Reduction Potential	Timeframe	Cost	Practicality	Community Support	Management Intent - Wamberal	Management Intent - Terrigal	Management Intent - Avoca	Management Intent - Cockrone	No Regrets?	Score Wamberal	Score Terrigal	Score Avoca	Score Cockrone
77	Consider management of lagoon water levels and algal build up with a view to minimising the incidence of these water quality issues following breakout			3		2	3	3	2	3			2	2		13	13	18	15
78	Improve entrance management policy to include better communication with frog managers					3	3	3	3	3			2		3	15	15	17	15
80	Encourage the review of the NP POM to include Entrance Management					2	3	3	3	3	3				3	17	14	14	14
89	Use an automated warning system connected to a real time water level monitoring station to trigger opening events					3	3	3	3	3	1	2	1	1		16	17	16	16
38	Limit access to Avoca Lagoon	2				3	3	3	3	3			2			17	15	17	15
40	Remove mats of algae along those public use foreshore areas prior to the onset of peak seasonal holiday periods, in order to minimise any impacts on the amenity of the lagoon. Council develop a policy that considers removal and disposal procedures. Damage to the lagoon bed should be minimised.			3		2	3	3	3	3			2			14	14	19	14
48	Identify recreational activities that are more suited to the environmental variation					3	3	3	3	2	1	2	1	1		15	16	15	15
52	Repair fencing, signs, noticeboard explaining need for vegetation around Terrigal Lagoon		2			2	3	3	3	3		3				14	19	14	14
47	Investigate alternative locations for paddle boats on Terrigal Lagoon during low water					1	3	3	3	3	1	2	1	1		14	15	14	14

Ref	Option	Threat Level Wamberal	Threat Level Terrigal	Threat Level Avoca	Threat Level Cockrone	Risk Reduction Potential	Timeframe	Cost	Practicality	Community Support	Management Intent - Wamberal	Management Intent - Terrigal	Management Intent - Avoca	Management Intent - Cockrone	No Regrets?	Score Wamberal	Score Terrigal	Score Avoca	Score Cockrone
67	Rehabilitate foreshore around Terrigal Lagoon to have a continuous Green Belt		3			3	3	1	3	3		2				13	18	13	13
83	Acknowledgement that existing opening regime has been in place for 40 years and will have already changed lagoon ecology and that pragmatic management approach should be adopted that seeks to maintain and enhance the lagoon ecology within the parameters of the existing framework.					3	3	3	3	3					3	15	15	15	15
84	Reduce risks to public safety during breakout					3	3	3	3	3					3	15	15	15	15
101	Continual documentation of implementation including challenges (funding, logistics, community concerns etc.), achievements and failures to inform adaptive management.					3	3	3	3	3					3	15	15	15	15
88	long term movement toward a zero intervention policy for Avoca, Wamberal and cockrone					3	1	3	3	3	1	1	1	1		14	14	14	14
64	Combine message onto one or two Discreet signs					1	3	2	3	3	1	1	1	1		13	13	13	13
30	Better maintaining of drains that bring heavy run off after rain	3	3	3	3	3	3	3	3	3	3	3	3	3		21	21	21	21
33	Raise the kerb and guttering of Lake View Road Terrigal (between nos. 16-26) from the corner of Minell Close near house number 16 to the corner at No. 26. To prevent road flooding					1	3	2	3	3		2				12	14	12	12
60	Educate and encourage residents to plant reeds and rushes on shoreline so does not detract from their view.					3	3	3	3	3	1	1	1	1		16	16	16	16

Ref	Option	Threat Level Wamberal	Threat Level Terrigal	Threat Level Avoca	Threat Level Cockrone	Risk Reduction Potential	Timeframe	Cost	Practicality	Community Support	Management Intent - Wamberal	Management Intent - Terrigal	Management Intent - Avoca	Management Intent - Cockrone	No Regrets?	Score Wamberal	Score Terrigal	Score Avoca	Score Cockrone
75	Stabilise the north side of the Avoca Lagoon bank at the rear of Bareena Avenue where erosion to the bank has occurred and the pathway disappeared.					2	3	2	3	3			2			13	13	15	13
79	Use of a submersible pump set at a level of 1 metre and pumped to ocean. The pump and supports could be located adjacent to the stormwater street crossing near 38 Ocean Drive Wamberal.		3			2	2	1	1	1	1	2	1	1		8	12	8	8
86	Maintain berm height for Terrigal Lagoon only					3	3	3	3	3						15	15	15	15
102	Annual reporting of plan progress to committee and community.					3	3	3	3	3						15	15	15	15
19	Gross pollutant traps at stormwater outlets to the lagoon. Manage sediment and nutrient load of Pickets Valley and Kincumber on western side of Scenic High way/Avoca Drive. Dredge to improve the depth of the upper reaches.	•	•	3	•	3	3	2	3	3	•	•	2	•		##	##	19	##
54	Conduct audit of existing seawall structures to determine their current condition and effectiveness and future protection potential		3								3	2	3	3		3	5	3	3
82	Council investigate the practicability and desirability of mechanically assisting the closure of the lagoon where the lagoon has been open for more than one week.					2	3	2	1	2	1	1	1	1		11	11	11	11
97	Construct a control structure to allow manipulation of water levels in Bareena wetland during green and golden bell frog breeding times					3	2	2	2	3			2			12	12	14	12
32	Upgrade North Avoca major SPS at Tramway Road. Raise gravity MHS lids around perimeter of the lagoon. Line the gravity sewer mains around the perimeter of the lagoon to reduce infiltration and reduce the load on the SPS's during wet weather.					3	3	1	3	3									

Ref	Option	Threat Level Wamberal	Threat Level Terrigal	Threat Level Avoca	Threat Level Cockrone	Risk Reduction Potential	Timeframe	Cost	Practicality	Community Support	Management Intent - Wamberal	Management Intent - Terrigal	Management Intent - Avoca	Management Intent - Cockrone	No Regrets?	Score Wamberal	Score Terrigal	Score Avoca	Score Cockrone
68	Fill deep dredge holes to reinstate a bathymetry closer to natural conditions and to eliminate WQ issues associated with deep dredge holes					2	2	2	2	2						10	10	10	10
85	Consider implementation of structures for Terrigal in the longer term		3			1	1	1	1	1		2				5	10	5	5
95	Construct control structures in Terrigal Lagoon to allow a permanently open entrance		3			1	1	1	1	1		2				5	10	5	5
87	Reduce the opening level to 1 metre					1	3	3	1	1						9	9	9	9
92	Dredge the lagoon to give greater depth and allow greater storage					1	2	2	2	2						9	9	9	9
11	Carry out works to address diffuse sources of pollution (e.g.. Stormwater, acid sulphate soils, stormwater, bank erosion)																		
20	Better containment of street run off at Cass Place																		
22	Enforce regulations (e.g. erosion and sediment control, septic tanks, illegal clearing)	3	3	3	3	2	3	3	3	3	3	3	3	3	3	20	20	20	
27	Manage point source water pollution* (contaminated sites, spills)																		
31	Improve infrastructure design (e.g. sewer overflows, road crossings)																		

Ref	Option	Threat Level Wamberal	Threat Level Terrigal	Threat Level Avoca	Threat Level Cockrone	Risk Reduction Potential	Timeframe	Cost	Practicality	Community Support	Management Intent - Wamberal	Management Intent - Terrigal	Management Intent - Avoca	Management Intent - Cockrone	No Regrets?	Score Wamberal	Score Terrigal	Score Avoca	Score Cockrone
34	Improve foreshore management (including public access, stock access and erosion control)																		
56	Conduct public education programs																		
65	Rehabilitate habitat																		
76	Manage coastal lake entrances																		
90	Manage sediment movement within or into the estuary (e.g. dredging, groynes)	1	0	3	1	2	2	2	2	2	2	2	2	2		13	12	15	13
91	traps stormwater filtration etc.																		
93	Reduce sediment flow into the Lagoon																		
94	Remove or reduce barriers and restrictions to natural movement of water																		
96	Protect fish nursery areas																		
98	Eradicate or manage aquatic weeds																		

Ref	Option	Threat Level Wamberal	Threat Level Terrigal	Threat Level Avoca	Threat Level Cockrone	Risk Reduction Potential	Timeframe	Cost	Practicality	Community Support	Management Intent - Wamberal	Management Intent - Terrigal	Management Intent - Avoca	Management Intent - Cockrone	No Regrets?	Score Wamberal	Score Terrigal	Score Avoca	Score Cockrone
100	Monitoring and evaluation																		
1	Implement planning and development controls																		

BMT WBM Brisbane
Level 8, 200 Creek Street Brisbane 4000
PO Box 203 Spring Hill QLD 4004
Tel +61 7 3831 6744 Fax +61 7 3832 3627
Email bmtwbm@bmtwbm.com.au
Web www.bmtwbm.com.au

BMT WBM Denver
8200 S. Akron Street, Unit 120
Centennial Denver Colorado 80112 USA
Tel +1 303 792 9814 Fax +1 303 792 9742
Email denver@bmtwbm.com
Web www.bmtwbm.com.au

BMT WBM Mackay
Suite 1, 138 Wood Street Mackay 4740
PO Box 4447 Mackay QLD 4740
Tel +61 7 4953 5144 Fax +61 7 4953 5132
Email mackay@bmtwbm.com.au
Web www.bmtwbm.com.au

BMT WBM Melbourne
Level 5, 99 King Street Melbourne 3000
PO Box 604 Collins Street West VIC 8007
Tel +61 3 8620 6100 Fax +61 3 8620 6105
Email melbourne@bmtwbm.com.au
Web www.bmtwbm.com.au

BMT WBM Newcastle
126 Belford Street Broadmeadow 2292
PO Box 266 Broadmeadow NSW 2292
Tel +61 2 4940 8882 Fax +61 2 4940 8887
Email newcastle@bmtwbm.com.au
Web www.bmtwbm.com.au

BMT WBM Perth
Suite 6, 29 Hood Street Subiaco 6008
Tel +61 8 9328 2029 Fax +61 8 9484 7588
Email perth@bmtwbm.com.au
Web www.bmtwbm.com.au

BMT WBM Sydney
Level 1, 256-258 Norton Street Leichhardt 2040
PO Box 194 Leichhardt NSW 2040
Tel +61 2 9713 4836 Fax +61 2 9713 4890
Email sydney@bmtwbm.com.au
Web www.bmtwbm.com.au

BMT WBM Vancouver
401 611 Alexander Street Vancouver
British Columbia V6A 1E1 Canada
Tel +1 604 683 5777 Fax +1 604 608 3232
Email vancouver@bmtwbm.com
Web www.bmtwbm.com.au