State of the catchments 2010

Estuaries and coastal lakes

Technical report series

Monitoring, evaluation and reporting program

Assessing the condition of estuaries and coastal lake ecosystems in NSW

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Summary

This report describes the scientific methodology used to generate the State of the catchments (SOC) 2010 reports on the condition of estuaries in New South Wales and the pressures influencing their condition. This information aims to improve the confidence of government in deciding how to prioritise investment of available financial resources and introduce new policies, strategies or plans to better manage and protect estuary health.

The NSW Government has set a state-wide natural resource management (NRM) target for estuaries that 'By 2015 there is an improvement in the condition of estuaries and coastal lake ecosystems' (NRC 2005). The estuaries target is one of 13 natural resource targets recommended by the Natural Resources Commission (NRC 2005) and, in 2006, adopted by the NSW Government.

Data collected for the SOC 2010 reports provide an initial baseline of estuary condition and pressure against which future change can be assessed and will assist in effective reporting against the state-wide estuaries target. This information will be used to inform decision-making on policy, investment and management priorities.

Four estuary SOC reports have been prepared for the NSW coastline based on the geographic boundaries of the catchment management authorities (CMAs) in NSW. The four reports cover the Northern Rivers, Hunter–Central Rivers, Hawkesbury–Nepean and Sydney Metropolitan (combined) and Southern Rivers CMA regions.

A number of condition indicators were adopted focusing on estuarine biota, as the health of plants and animals reflects the combined effect of pressures acting on the ecosystem. Indicators used were phytoplankton (micro-algae) biomass measured as chlorophyll a; seagrass, mangrove and saltmarsh extent; and fish communities. Turbidity, as a measure of water clarity, was also reported as this has a direct bearing on the biota.

Initially, a comprehensive data trawl was carried out to make best use of available information on estuary condition. Data were sought from NSW Government agencies, local councils, universities, water and power authorities and consultants. Of the 32 coastal councils, two-thirds are actively involved in gathering data on the water quality of estuaries.

Concurrent with the condition data trawl, extensive datasets were collated and compiled on various physical and environmental attributes. These contextual data are essential for developing classification schemes that group estuaries into similar types for the purpose of stratifying any new sampling programs and for developing reference conditions for each estuary type against which health can be gauged. Contextual data are also needed for normalising pressures so that meaningful comparisons can be made of the relative pressures between estuaries.

Estuaries were defined from the 1:25,000 topographic map series available from Land and Property Information (LPI) within the Department of Finance and Services. Waterway areas behind the NSW coastline that are connected permanently or intermittently to the ocean were defined as an estuary and the name confirmed with the Geographical Names Board. Tributaries flowing into ports, bays and harbours were identified as separate estuaries giving a total of 184 systems along the coast. The estuary boundaries were extracted from the LPI map series and merged with maps of seagrass, mangrove and saltmarsh prepared by the Department of Primary Industries (DPI) (Williams et al. 2006). Spatial mapping of catchment boundaries prepared for an earlier stressed rivers assessment project (DLWC 1998) was refined from the topographic maps particularly near estuary entrances.

Raw data from historical hydrographic surveys, gauging of tidal flows, water level recorders, rainfall and evaporation records, earlier classification schemes and the new spatial layers were accessed and used to generate contextual data on geomorphic type and opening regime; estuary perimeter, surface area, depth and volume; and tidal planes, prisms and flushing times. 2CSalt catchment rainfall runoff models were developed for all 184 estuaries calibrated with flow data from 78 gauging stations and used to generate monthly time series of runoff. The capacity of the volume of water in each estuary to dilute catchment inflows was then calculated.

Two of the main factors controlling the estuary phytoplankton response to catchment loads of nutrients and sediments are dilution capacity and flushing time. These two factors were able to be quantified for all estuaries and a chlorophyll response-based classification scheme developed. Estuaries grouped into three main types which were designated as lakes, rivers and lagoons with associated conceptual models of the chlorophyll a response to catchment loads. The 'lake' class included bays, drowned river valleys and lakes either permanently or intermittently open, 'river' included mature barrier river estuaries all of which were permanently open and 'lagoons' included intermittently open lagoons and creeks. A similar classification scheme for macrophytes was not attempted due to lack of data. For fish communities, earlier statistical analysis classified estuaries into three bioregions defined by latitude, and three types: permanently open riverine barrier estuaries and drowned river valleys; large barrier lagoons and predominantly open lakes and lagoons; and predominantly closed lakes and lagoons (Pease 1999). As might be expected, this classification is different to the chlorophyll a response-based classification.

After analysing existing datasets, new field sampling programs were designed for chlorophyll a, turbidity and fish, and implemented in 2007. For all programs estuaries are sampled across the three classification types and across the full disturbance gradient within each type. The water monitoring program involves sampling seven fixed estuaries every year to provide long-term trend data and to track inter-annual variability. A minimum of 27 roving estuaries are selected each year using a stratified random design and are sampled in each of the northern, central and southern parts of the coastline on a three-year rolling program. Fish were sampled for a pilot study in the central bioregion during 2008 and other existing data were used for the northern and southern bioregions. Standard sampling methods and protocols are documented to provide guidance for other parties gathering similar data in the future.

Using data to score the health of an estuary requires definition of what constitutes a healthy system (ie reference condition) and how the extent of deviation from the reference condition can be scored. Ideally, biological or ecological thresholds should be used to separate scoring classes but in their absence, the data distribution is frequently used to divide data up into ranges for scoring. The ranges can be based on equal intervals, equal percentiles, some other multiple of deviation from reference or else expert opinion. A mix of these methods was applied to scoring the SOC condition datasets. Confidence levels were applied to each dataset using set quality criteria.

Pressure data were collated on the basis of their known link to resource condition, availability for all estuaries, potential for gap-filling using empirical relationships, time required for collation and known reference condition. Datasets collated include cleared land, population, sediment and nutrient export change, catchment runoff change, foreshore structures, habitat disturbances, tidal flow change and commercial fishing. Scoring principles similar to those for condition data apply to pressure data.

Condition indicators were combined into an index of condition for each estuary, CMA region and state-wide with rules applied to the minimum number of indicators necessary before an index was calculated. Similarly, pressure indicators were combined into an index of pressure. The assessment found that across NSW, 27 estuaries were in 'very good' condition, 39 in 'good' condition, 23 'fair', nine 'poor', three 'very poor' and 83 had insufficient data to be rated (see Figure S1). For pressures, 48 estuaries rated as being under 'very low' pressure, 47 under 'low' pressure, 78 'moderate', 11 'high' and none as 'very high' pressure (see Figure S2). Within each of these overall state-wide indices, the ratings for individual condition and pressure indicators varied between estuaries and regions.

Data are held in a mix of spatial and tabular formats and are being managed in accordance with the Natural Resource and Environment Information Management Framework. A central element of the framework is metadata which has been prepared and loaded into the NSW Spatial Data Catalogue, which is managed by LPI on behalf of the NSW Government. Public access to the data will be provided.

A series of 42 recommendations has been made to improve the data collection and analysis for the next round of SOC reporting due in 2013. Improvements could be made to estuary definition, catchment hydrology, flushing time, estuary classification, condition data, reference conditions and scoring classes, pressure indicators and indices, and data management. Data collected for the other 12 state-wide NRM targets should be assessed for usefulness in generating pressure data for estuaries, and conversely, using estuarine data to assist with the other targets.

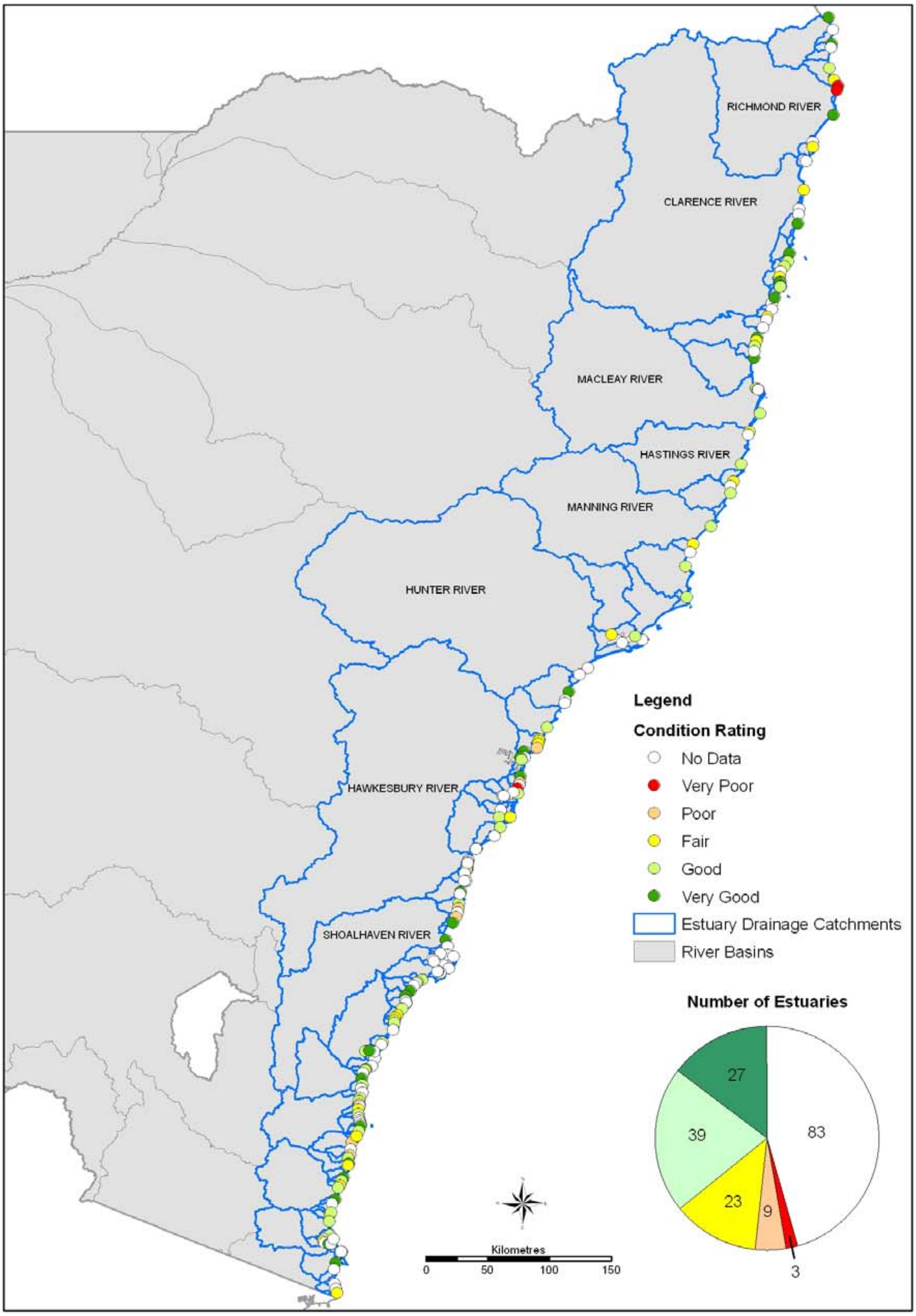


Figure S1: Condition ratings for NSW estuaries

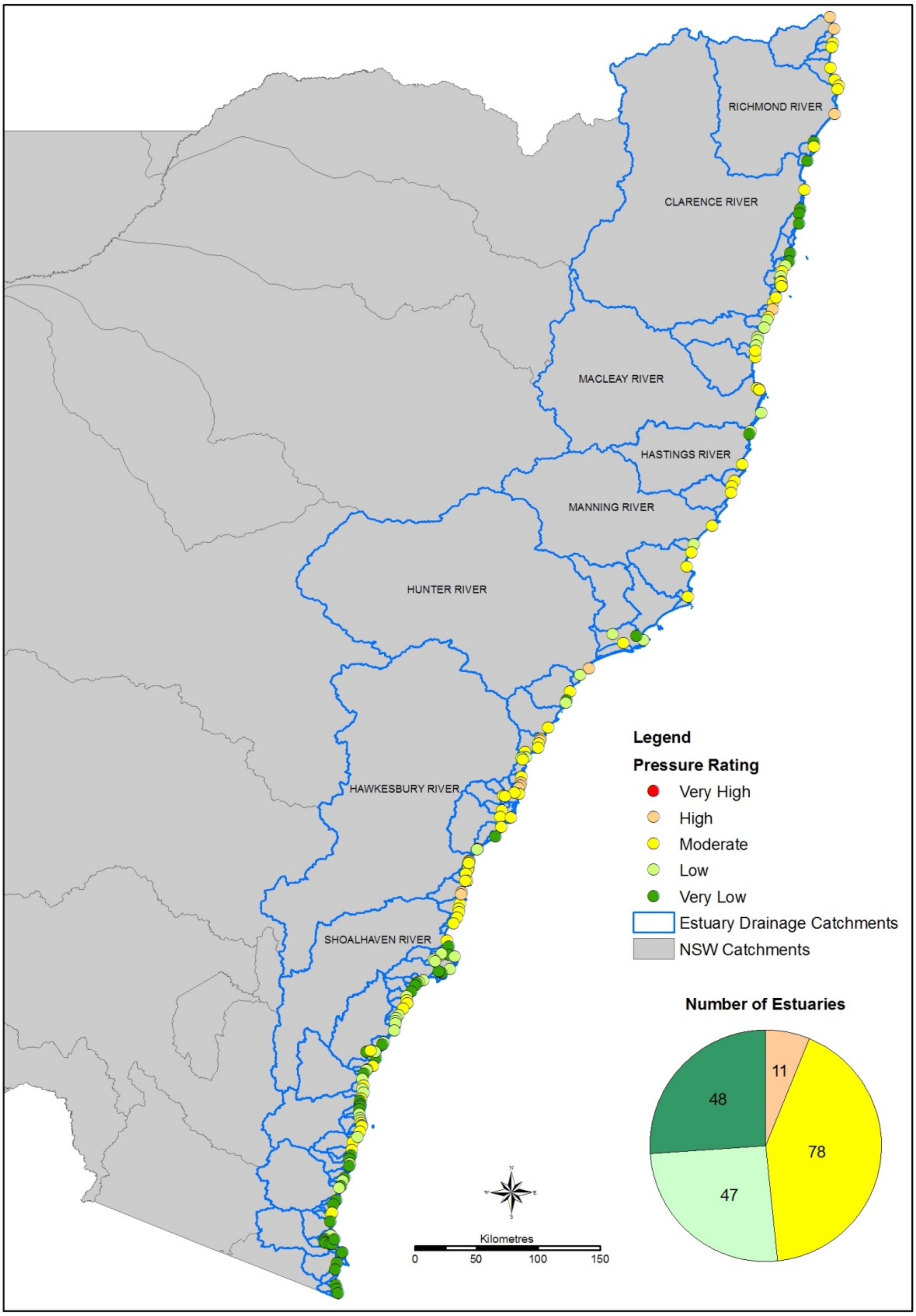


Figure S2: Pressure ratings for NSW estuaries

1. Introduction

This report is the technical document underpinning SOC reports on NSW estuary condition and pressures. The SOC reports are based on the geographic boundaries of regional CMAs in NSW. In the case of estuaries there are four SOC reports covering five coastal CMA regions: Northern Rivers, Hunter–Central Rivers, Hawkesbury–Nepean and Sydney Metropolitan combined, and Southern Rivers. This technical document and the SOC reports are a collaborative effort between NSW Government agencies and the CMAs and represent the first regionally based assessment of estuary condition and pressures along the coastline.

A number of new field sampling programs were initiated in 2007 that strategically targeted data collection critical to the reporting process. As such, the reports present an initial baseline of estuary condition and pressure against which future change can be assessed. The monitoring programs established are ongoing to inform future SOC reports on a three-yearly cycle. This will enable reporting against the following state-wide NRM target set by the NSW Government:

'By 2015 there is an improvement in the condition of estuaries and coastal lake ecosystems'.

This target is one of 13 natural resource targets recommended by the Natural Resources Commission (NRC) in a standard and targets document published in September 2005 (NRC 2005).

1.1 NSW natural resources MER strategy

The MER strategy was prepared by the Natural Resources and Environment (NR&E) CEO Cluster of the NSW Government in response to the NRC standard and targets and was adopted in August 2006. The purpose of the strategy is to refocus the resources of NSW natural resource and environment agencies and coordinate their efforts with CMAs, local government, landholders and other natural resource managers to establish a MER system on natural resource condition (NR&E CEOs 2006).

A NSW MER system for natural resources should provide access to resource condition data, and periodic formal reports evaluating that data, to inform the policy, investment and best practice management decisions made by natural resource managers across NSW.

The strategy specified that SOC reports be prepared to provide a preliminary assessment of the condition of natural resources in each catchment. For estuaries, this will enable comparison of the condition of the state's estuaries to each other as well as regionally and state-wide. The strategy also required SOC reports to:

- inform investment decisions within and between CMA regions
- inform other natural resource managers' investment decisions in each region
- assess progress towards catchment targets.

These multiple objectives of condition assessment, investment priorities and target reporting provided the basis for the monitoring design process.

1.2 Natural Resources Commission

1.2.1 Indicators

A number of indicators for assessing progress towards the state-wide estuaries and coastal lakes target were proposed by the NRC and subsequently modified through a series of pilot studies in collaboration with government agencies (eg Scanes et al. 2007). The indicators focused on estuarine biology as the monitoring endpoints in preference to stressors and pressures which influence condition. A mix of indicator groups was finally adopted representing elements of the structure, function and composition of estuarine ecosystems and included:

- eutrophication
  - microalgal abundance, measured as phytoplankton chlorophyll a
  - macroalgal abundance
  - water clarity as turbidity
- habitat availability
  - extent of seagrass
  - extent of mangroves
  - extent of saltmarsh
- fish assemblages
  - species diversity and composition (four metrics)
  - species abundance (two metrics)
  - nursery function (four metrics)
  - trophic integrity (four metrics).

1.2.2 Background

Input to the NRC for development of the indicators was provided by an Independent Scientific Expert Working Group reporting directly to the NRC (ISEWG 2005).

In response to the NRC standard and targets report, the NR&E CEO Cluster Group requested implementation plans setting out actions to monitor each NRC target be prepared by inter-agency Indicator Working Groups (IWGs). These IWGs generally concurred with the indicators recommended by the NRC with minor modifications and progressed to the stage of costing the required data collection for methods development and five years of monitoring.

To check the efficacy of designs, the NR&E Cluster Group established three Scientific Peer Review Panels comprised of recognised experts from across Australia. The Review Panels raised a number of concerns across all IWG plans including the need for:

- visual conceptual models
- complementary pressure and stressor indicators for early warning of change and for causality inference
- consideration of scale issues including spatial, temporal and biological organisation
- specification of data collation, analysis, interpretation and reporting methods and the influence of effect size detection on costs (Abal et al. 2005).

Issues raised by the Review Panels that were specific to the estuaries and coastal lakes theme included the following:

- Indicators should reflect short- and long-term trends, as well as state-wide and catchment-wide
- There is a need to recognise high variability in estuarine systems and consider the different types of catchment, estuary geomorphic and marine environments and temporal factors influencing variability
- The definition of 'unacceptable' condition needs to be made explicit
- A suite of freshwater, estuary and marine indicators is required as adopted for the South East Queensland Ecosystem Health Monitoring Program.

1.2.3 National processes

At the national level, the Intergovernmental Coastal Advisory Group (ICAG) coordinated a process of reaching national agreement on a set of resource condition indicators in association with the (former) National Land and Water Resources Audit (NLWRA) and the (former) Department of Environment and Heritage. A national workshop was held in February 2006 from which emerged a number of key themes which included the following (Thorman 2006):

- Clarity is required as to what the policy and management questions are, and what information is needed to provide answers
- There is a need to document the extent of existing information
- Further work is required to develop social and economic or pressure indicators to provide context for the resource condition indicators.

The issue of 'contextual' data was also raised in a report commissioned by the NLWRA (BTG 2004a). While being broadly defined by the Beaten Track Group as data commonly needed for interpretation, aggregation and/or mapping, contextual data for this technical report is taken to mean variables that assist in either:

- defining a resource's classification in accordance with a recognised system
- stratifying sampling designs to reduce statistical variability and costs of data
- interpreting any causal linkages between condition and the forcing variables describing drivers, pressures and stressors or else between condition and variables describing impacts eg socio-economic.

In response to the MER strategy and these wide-ranging external reviews and processes, the NRC worked with inter-agency theme teams to develop a number of pilot SOC reports. These teams were drawn from across the former NSW Government Departments of Environment and Climate Change, Water and Energy, and Primary Industries over a two-year period from August 2006. One of the pilots was for estuaries and coastal lakes, from which the final products described in this report have been derived.

1.3 Purpose of this report

The purpose of this report is to present a broad baseline picture of the condition of estuaries within NSW as at January 2009 and to describe the methods for collecting, analysing and interpreting the data used to derive the condition. In addition, the main human-induced pressures acting on each estuary are detailed to provide insight into the possible causes driving the condition. The report uses a mix of existing and newly collected data to compare the condition and pressures between estuaries, as well as between regions and across the state. When monitoring is at a fine enough scale, comparisons are feasible between tributaries or specific sites within an estuary.

As the intent behind monitoring is to illuminate decision-making, the program has been designed to test the response of estuaries to the key pressures or stressors driving condition wherever possible, for example land-use. If relationships can be established between drivers and response, predictions can be made about the condition of those estuaries without monitoring data. The predictive models can then be used for setting priorities for action across all estuaries and at a scale (state-wide to site-specific) appropriate to the resolution of the data and size of the issue.

This testing of *a priori* management hypotheses can be complemented by multivariate statistical analysis of potential stressor-response relationships as more monitoring data become available. Most stressors and responses are not one-to-one but are interdependent so that multiple stressors act and interact to affect different elements of an estuary's biota and ecology. Stressors will act at different spatial and temporal scales which need to be accounted for in any analysis as well as in the design of any accompanying management action.

In NSW an integral component of the NRM framework has been the establishing of targets by the NSW Government requiring an improvement in the condition of estuarine ecosystems by 2015. In addition to informing decision-making, another aim behind monitoring of estuary condition is therefore to enable reporting of progress towards the state-wide trend target.

1.4 Report format

Chapter 2 of this report sets out the objectives of the monitoring program after reviewing comparable overseas programs, and the management questions that the program is designed to answer.

Chapter 3 details the coastal waterbodies in NSW that were defined as estuaries, their location and extent and how they were compiled into an inventory.

Chapter 4 presents the physical and environmental contextual data required to develop classification schemes, interpret resource condition and normalise pressures for comparison between estuaries. Contextual data are provided on geomorphology, hydrodynamics, catchment characteristics and hydrology.

Chapter 5 reviews the purpose of classification into estuary types and the range of existing schemes. The methods adopted to classify estuaries by their response of each of the eutrophication, habitat and fish indicators to anthropogenic stress, particularly nutrient inputs and catchment disturbance, are described.

Chapter 6 presents the results of an extensive trawl for resource condition data and how the data were used to design sampling programs. The designs are detailed together with sampling methods and protocols.

Chapter 7 describes how the data collated and collected were used to generate reference conditions and develop scoring classes for assessing the extent of deviation of condition from reference.

Chapter 8 presents the results of the sampling programs initiated for the SOC reporting, together with any historic data used in the assessment process.

Chapter 9 reviews potential sources of data on estuary pressures and criteria for selecting pressures for which data collection was to be initiated. The results of the data compilation are summarised, scoring classes defined and estuary pressures rated using those classes.

Chapter 10 covers the development of an initial set of indices for condition and pressure to enable comparisons to be made at estuary, regional and state-wide levels. Confidence levels were assigned to each dataset.

Chapter 11 details the management of data and information including metadata and public access.

Chapter 12 gives recommendations for improving datasets, data analysis, classification and reference systems, index development and integration across themes.

Chapter 13 lists references followed by appendices of various tables, maps and protocols.

2. Monitoring program objectives

2.1 Comparable monitoring programs

In the course of developing a conceptual basis and monitoring objectives for the NSW estuary monitoring program, a number of similar programs elsewhere in the world were reviewed, focusing on the USA and Europe. A snapshot of these programs includes the following:

- The **State of the Nation's Ecosystems 2008** (Heinz Center 2008) takes the approach of reporting on condition and trend of ecosystems in the USA using publicly-available data and only comparing condition with a standard where it already exists. It is restricted to a presentation of scientific data and does not attempt to rate condition on a comparative basis, present pressures or link condition to management
- The **National Estuary Program Coastal Condition Report** (US EPA 2008) presents the condition of estuaries across the USA. Data sources are from an unbiased, quality-assured monitoring program implemented nationally by the Environmental Protection Agency (EPA) as well as from individual National Estuary Programs (NEPs) which are estuary-specific monitoring programs run by local partnerships. For the national program, a number of water and sediment quality, benthic and fish tissue contaminant indicators are allotted into the categories 'good', 'fair' or 'poor', based on biological or ecological thresholds wherever possible and by coarse scale regions. Indices of water, sediment, benthos and fish are reported for each estuary as well as an overall condition rating. Comparisons are then made between estuaries and regions. Population density is reported but no other pressures or management action. For the individual NEPs, local responses are reported together with likely stressors
- The **National Estuarine Eutrophication Assessment** (NEEA) in the USA uses the Assessment of Estuarine Trophic Status (ASSETS) methodology to report on four indices describing the pressures taking into account natural system susceptibility (*Overall Human Influence*), a symptoms-based evaluation of eutrophic state (*Overall Eutrophic Condition*), expected ecological response from future pressures (*Definition of Future Outlook*) and a synthesis combining each of pressure, state and future ecological response into an overall colour-coded classification grade of 'high', 'good', 'moderate', 'poor' or 'bad' (Bricker et al. 1999; Bricker et al. 2003; Bricker & Ferreira 2008). The overall eutrophic condition is based on five indicators: chlorophyll a, macroalgae, dissolved oxygen, seagrass distribution and nuisance/toxic algal blooms. The concept of susceptibility is introduced by using estuary dilution and flushing characteristics as 'filters' to modulate the pressure and expected future response indices. State is assumed to respond to pressure but modulated by estuary typology. Other filters could include the light regime (Devlin et al. 2007).

  More recent developments for the NEEA program are type classification based on physical and hydrologic characteristics that influence the expression of nutrient-related impacts such as phytoplankton blooms (Whitall et al. 2007) and the introduction of socio-economic costs linked to eutrophication impacts.

  The stated objective of the ASSETS approach is to provide relevant information on status, causes of observed problems and probable future changes in condition, to facilitate making appropriate management decisions. The ASSETS method recognises that the information provided can be used at a range of scales. At large continental and regional scales, management and research can be prioritised thereby maximising cost efficiency in the use of limited resources. At smaller scales the approach can be used in conjunction with other models to gain insight into system behaviour and predict potential problems before they occur. The NEEA program managers believe that the combination of better type classification and socio-economic cost evaluation will provide an even stronger basis for successful management of estuaries in the USA as well as Europe and Asia (Bricker & Ferreira 2008)

- The **European Water Framework Directive** (WFD) establishes a framework for the protection of groundwater, rivers, lakes, estuaries and coastal waters. It has the objective of achieving at least Good Ecological Status (on a scale of 'high', 'good', 'moderate', 'poor' and 'bad') for all waters by 2015. Member States must establish monitoring plans to determine Ecological Status through the assessment of a range of Biological Quality Elements (BQEs) and Supporting Quality Elements (SQEs). BQEs include phytoplankton, macroalgae, aquatic plants (seagrass and saltmarsh), benthic invertebrates and fish (Best et al. 2007). SQEs include physico-chemical (transparency, thermal conditions, oxygen conditions, salinity and nutrient concentrations) and hydromorphological (eg freshwater flow) attributes.

  Status is assessed by comparing the state of the quality elements with reference conditions in a pristine waterbody of the same typology. Expert rules can be used to integrate the individual quality element scores into an overall assessment of Ecological Status (Borja et al. 2009) although some interpretations of the WFD imply that the lowest of the quality element assessments should determine the overall Ecological Status (Borja et al. 2008). Should Ecological Status be assessed as moderate, poor or bad, Member States are to implement programs to achieve Good Ecological Status by 2015. The WFD also requires assessment of Heavily Modified Water Bodies which are ones with irreversible changes to their hydrogeomorphological character (eg a harbour). Status is to be assessed in terms of Good Ecological Potential (Borja & Elliot 2007).

Each of these assessment methods was reviewed and the most promising elements incorporated into the NSW estuary monitoring program. Management-oriented hypotheses have been used to drive the sampling design and develop predictive modelling frameworks that will aid policy, investment, planning and management decision-making at a range of appropriate scales.

2.2 Surveillance monitoring

Unless dramatic change occurs in catchments, very few ecological variables exist that will show significant change in less than several years (Nichols & Williams 2006). A monitoring period spanning up to ten years has been suggested as a minimum sensible target for detecting change in most ecological monitoring programs (Field et al. 2007). In traditional long-term surveillance monitoring, many different species, ecological characteristics or locations are monitored to satisfy many different purposes. Action is generally triggered following statistical confirmation of an adverse trend. This action can be immediate conservation efforts or a study into the cause of the decline. In either event, a problem arises with time lags between trend detection and management action which may mean irreversible damage and lost opportunities for early intervention.

2.3 Management-oriented monitoring

The alternative to surveillance monitoring is to use management-oriented hypotheses to drive the monitoring design (Nichols & Williams 2006). Steps involved will include collating and analysing existing data for patterns, processes and responses to the various stressors and pressures acting on the system. Best practice is to build conceptual models to facilitate understanding by scientists and managers of the key factors and interactions driving ecological responses. Classification into ecosystem types, each with their own conceptual model, is often required to represent significant differences in system processes and response to stress.

On the basis of a thorough assessment of the existing data, research literature and scientific/community expert opinion, hypotheses on how ecosystems will change under existing and future pressures can be developed. Monitoring design can then proceed with the best possible knowledge of the direction and extent of change to be detected. Data generated by monitoring should be analysed promptly and used to adaptively refine the sampling regime (Field et al. 2007).

The NRC and the MER strategy direct that any monitoring is to be explicitly linked to decision-making at as many scales as is practically feasible. Constraints to achieving this objective are those common to all monitoring programs which are the trade-offs required between the statistical certainty of the program and the available budget. Such constraints will necessarily influence the scale at which the data can be reliably interpreted and applied.

2.4 Management questions

2.4.1 Strategic level

At the strategic level, the questions for natural resource managers can be broadly grouped into the following (Brooks et al. 2006):

- How big is the problem (ie where is the resource and what is its condition)?
- Is it getting better or worse (ie which way is the trend going)?
- What is causing it (and is it natural or human-induced)?
- What can be done to fix the problem (ie how can we improve the health of the impaired system and what level of health can be maintained given current social choices on resource use)?
- Once action is taken, is management making a difference?
- How can any of the above be communicated to the community?

Brooks et al. (2006) proposed a taxonomy or hierarchy of indicators and grouped the types of management questions into the following categories:

- **Condition assessment/state**: snapshot of the current state of the ecosystem
- **Performance evaluation**: evaluating the effectiveness of management actions
- **Stressor diagnosis**: identification of factors causing a change in condition and demonstration of clear relationship between cause and condition
- **Communication to the public**: encouraging comprehension of condition in a clear and understandable form
- **Futures assessment**: estimating the probable trend in condition, or assessing the vulnerability of a system to a particular event or activity.

In addition to the management question, two other primary elements of the hierarchy were scale (spatial and temporal) and context (ie social choice of land-use). By specifying the appropriate management questions being asked, the spatial and temporal scale being reflected and the social choices being addressed, natural resource managers can choose indicators appropriate for their decision-making. A range of potential indicators was identified by Brooks et al. (2006) and then categorised according to how well they met each of the three elements of the hierarchy.

2.4.2 Operational level

Within these broadly based strategic management questions lie a more detailed sequence of inter-linked operational management and scientific questions that correspond to various decision points in an NRM cycle. Questions in an approximate chronological order in the cycle could include the following:

Asset mapping

- Where is the resource and what is the extent of its assets?
- How can the assets be classified into groups exhibiting similar characteristics?

Condition assessment

- How do biological, chemical and physical processes affect the condition?
- What is the condition of the resource compared to standards, benchmarks or reference sites?
- What are the limits of acceptable change or ecological thresholds and how close is the current condition to a threshold?
- Is the condition changing and what is the direction and size of the trend?

Risk assessment

- What is the natural vulnerability of the resource to degradation?
- What pressures and stressors appear to be responsible for harm or deterioration?
- What pressures and threats are likely to arise in the future and how will they affect condition?
- What are the most significant threats that need to be addressed?

Management response

- What are the vision, biophysical and societal values and landscape use expectations of the community, industry and government?
- What are the objectives for management?
- What are appropriate targets for management to achieve?
- What options are available to achieve targets?
- How will the resource respond to the options?
- What are the benefits, costs and impacts of options and what tradeoffs are required?
- What is an acceptable option mix?

Performance review

- What indicators should be monitored to reflect option performance?
- Were the management objectives and targets achieved?
- To what extent did the management options contribute to target achievement?

- What was the influence of external factors?
- How can we improve the current management response mix?
- How can report findings be best presented?

Long-term surveillance monitoring programs generally target indicators of condition at the top of this sequence. Management-oriented monitoring of resource condition will select indicators across other elements of the management cycle to facilitate diagnosis of the causes of impairment, develop a predictive modelling capability and improve the effectiveness and timeliness of management decision-making. Performance monitoring may result in a different set of indicators being monitored to suit the management objectives of the activity being assessed.

2.4.3 Estuary monitoring program

The management questions for the NSW estuary monitoring program are:

1. Which coastal water bodies are defined as estuaries for inclusion in the monitoring program design?
2. What is the physical extent of estuaries in NSW?
3. Are existing estuary conceptual models and classification systems appropriate to NSW estuaries and if not, how should they be modified?
4. What constitutes good and poor condition?
5. What is the current condition of estuaries?
6. Is the condition changing and in what direction and at what rate?
7. What broad pressures and stressors appear to be responsible for the condition?
8. How do physical, chemical and biological processes affect the condition?
9. What makes some estuaries more vulnerable to degradation than others?

These questions address all the asset mapping and condition assessment stages of the NRM cycle. They also address some parts of each of the risk assessment and management response stages. If these questions are posed together, they will address the multiple objectives specified in the MER strategy requiring condition assessment, informing investment priorities at scales appropriate to the data and reporting progress towards state-wide targets. Reporting against CMA catchment targets will be feasible to the extent they align with the state-wide condition and trend targets of the NRC, which they tend to do for estuaries as shown by the following list of catchment targets:

Northern Rivers CMA: By 2016 there is an improvement in the condition of Coastal Zone natural resources.

Hunter–Central Rivers CMA: By 2016 improve or maintain the estuarine environments of the Hunter–Central Rivers CMA region.

Hawkesbury–Nepean CMA: Estuary marine condition – By 2016, there will be no decline, and where appropriate improvement, in estuarine and marine ecosystem functioning as reflected in a range of indicators that potentially includes:

- extent and condition of estuarine vegetation, freshwater inflows, algal blooms, water quality, soil condition (for estuarine)
- rocky reef spp, sewage discharges, industry groups implementing EMS, marine debris, extent of Marine Protected Areas (MPA) (for marine).

Sydney Metropolitan CMA: Estuaries and lakes – By 2016, there is an improvement in the condition of estuaries and coastal lake ecosystems.

Southern Rivers CMA: By 2016 the condition of coasts, estuaries and the marine environment is maintained or improved through active management, best management practice and strategic research.

Two of the five coastal CMAs, Northern Rivers and Southern Rivers, have initiated pilot programs testing indicators for reporting against their estuarine catchment targets. The indicators being investigated are similar to the state-wide targets but with the addition of other indicators of estuary structure, function or composition. The Hawkesbury–Nepean CMA has proposed a range of potential indicators of structure, function and composition in their catchment target and have specifically identified ecosystem functioning as a key element in that target.

3. Estuary definition

There are a number of definitions in the literature of what constitutes an estuary (see Edgar et al. 1999). The definition provided in the NSW Estuary Management Manual (NSW Govt. 1992) is 'any semi-enclosed body of water having an open or intermittently open connection with the ocean, in which water levels vary in a predictable, periodic way in response to the ocean tide at the entrance'.

There are many waterways shown on the 1:25,000 topographic map series from LPI that lead to the Tasman Sea. One estimate suggests that there are over 950 of these features (Williams et al. 1996), although hundreds of them are ephemeral in nature, draining only under wet conditions. On the basis of previous studies (West et al. 1985; Roy et al. 2001), between 130 and 150 waterways were thought to be large enough to retain standing water and therefore fell within the definition of an estuary.

For the purpose of the MER program, a waterway was identified as an estuary if it was shown as an area feature adjacent to the coastline in the 1:25,000 topographic map series for NSW. Any drainage lines adjacent to the coast that appeared only as line features were excluded. Waterway area features adjacent to the coastline that did not have either a permanent or intermittent connection to the ocean were also excluded.

3.1 Downstream boundary

The seaward limit of an estuary has various definitions. For example, NSW Govt. (1992) suggests there is a hydraulic boundary where topography ceases to affect tidal behaviour. This boundary may be difficult to define in the entrance of drowned river valleys where sill development is limited. Salinity distribution has also been used to define where the salinity of the transitional waters is substantially lower than the adjacent ocean water. For larger rivers, plumes may extend some distance offshore (WFD 2002).

For NSW estuaries where freshwater flows are relatively low and bar development is limited, the downstream boundary has been taken as the 'line between the land masses on each side of the entrance to an estuary' (Ketchum 1983). This line is provided on the LPI map series as a coastal Mean High Water mark, but was checked on-screen and adjusted where necessary to better reflect this definition.

For ports, bays and harbours where individual estuarine systems drain to a semi-enclosed waterway, each tributary and the semi-enclosed waterway has been defined as a separate estuary. Nine ports, bays and harbours with inflowing tributaries were identified (see Appendix 1 for maps):

- Port Stephens – Myall River and Lakes, Karuah River, Tilligery Creek
- Broken Bay – Brisbane Waters, Hawkesbury-Nepean River, Pittwater
- Port Jackson – Lane Cove River, Middle Harbour Creek, Parramatta River
- Botany Bay – Cooks River, Georges River
- Port Kembla Harbour – Allans Creek
- Jervis Bay – Callala Creek, Cararma Creek, Currambene Creek, Moona Moona Creek, Wowly Gully

- Ulladulla Harbour – Millards Creek
- Batemans Bay – Clyde River, Cullendulla Creek
- Twofold Bay – Boydtown Creek, Curalo Lagoon, Fisheries Creek, Nullica Creek, Shadrachs Creek, Towamba River.

3.2 Upstream boundary

Tidal and mangrove limits have been defined through the collection of field data over a ten-year period from 1996 to 2005 (DNR 2006). The tidal limit was defined as the point along the estuary at which the water level no longer responded to the ocean tide. While vertical tidal movement must be present, this point can experience minimal salinity if freshwater flows are significant. For some upstream sites, vertical movement is constrained by structures such as weirs.

Mangroves occupy the fringe of intertidal shallows and grow in marine, estuarine and, to a limited degree, fresh water (DPI 2008). The mangrove limit is always downstream of the tidal limit. Mangroves are usually not found in estuaries with intermittently open entrances where water levels can be constantly elevated for extended periods of time.

3.3 Lateral boundary

NSW Govt. (1992) defines lateral boundaries in ecological terms rather than the hydraulic basis used for the downstream and upstream boundaries. The definition includes all wetlands inundated during extreme tidal or flood events. The 1:25,000 topographic map series from LPI will usually include seagrass in the waterway area, but mangrove and saltmarsh to varying degrees depending on water levels at the time of aerial photographs and operator interpretation. To address this issue, the waterway areas from the topographic map series were merged with maps of mangrove and saltmarsh produced over the last five years by DPI (Williams et al. 2006).

3.4 Estuary surface area

3.4.1 GIS operations

A detailed report is available on the GIS operations used to generate the composite data layer (see metadata on Estuaries in the NSW Spatial Data Catalogue). In summary:

- the water surface boundaries were derived from the LPI 1:25,000 topographic map polygons, which are assumed to approximate the high water mark
- the downstream boundary was defined as the line across the entrance mouth
- upstream estuary boundaries were extended up to the tidal limits defined by Manly Hydraulics Laboratory on the basis of DNR (2006). A nominal 1 m width was assigned to tributaries depicted as line features on the LPI maps to generate a single polygon for estuary area
- the DPI seagrass, mangrove and saltmarsh polygon layers were reconciled and merged with the LPI water surface layer so as to create consistent layers of water, seagrass, mangrove and saltmarsh. The combined area of water and macrophytes was defined as the total estuary surface area
- some portions of the coast are necessarily excluded as they drain directly to the Tasman Sea.

A total of 184 estuarine water surface polygons were found and digitised from the LPI map series.

3.4.2 Comparison with other inventories

There are a number of other inventories of NSW estuaries that have been prepared over the last 30 years. These inventories have generally contained estimates of estuary water surface area but have been prepared using a number of different mapping methods. The inventories include:

- an environmental inventory prepared for estuaries and coastal lagoons in NSW (Bell & Edwards 1980)
- an estuarine inventory for NSW prepared for the former Department of Agriculture (West et al. 1985)
- an Australian Estuarine Database prepared for the Commonwealth Government (Digby et al. 1998). The data are derived from a former inventory prepared by Bucher & Saenger (1989)
- a report prepared for the NLWRA containing a national geoscience database (Heap et al. 2001). Landsat TM satellite imagery with a spatial resolution of 25 m was used to map estuary geometry including area, perimeter, total length, maximum width, entrance width and entrance length
- a database maintained by the former Department of Land and Water Conservation (DLWC 1997). The main source of data on estuary water surface areas was the LPI 1:25,000 topographic map series.

A comparison was made between the areas calculated from the detailed mapping of 48 estuaries under the MER program and the previous five inventories as shown in Figure 1.

For the purposes of clarity, only 38 estuaries up to 20 km^2 in area (79 per cent of the 48 estuaries) have been shown. The 48 estuaries selected for the comparison are those for which bathymetry was available and gridded as discussed in Section 4.1.1. The mapping conducted for the MER program has generated areas mostly above those from previous inventories as it has included all areas of mangrove and saltmarsh mapped by DPI. Saltmarsh is known to colonise typically from Mean High Water up to Highest Astronomical Tide level. Also plotted as a single black line is the estuary area excluding saltmarsh which produces areas more consistent with previous inventories.

The most accurate source of information on estuary areas is that available through photogrammetry routinely conducted by Office of Environment and Heritage (OEH) since 1992. Photogrammetry is undertaken to sub-metre positional accuracy using the most recent aerial photography available, usually at a scale of 1:25,000, to produce a baseplan of the estuary being surveyed. Prior to 1992, a shoreline plot was generally generated using the LPI 1:25,000 topographic maps with a potential positional error of up to ±25 m.

A majority of estuaries have been the subject of photogrammetric analysis but the data have not been accessed for the MER program. However, it would be valuable for future SOC reporting to compare photogrammetric data with the areas derived for the MER program which were based on a merging of 1:25,000 waterbody areas from LPI and macrophyte areas from DPI.

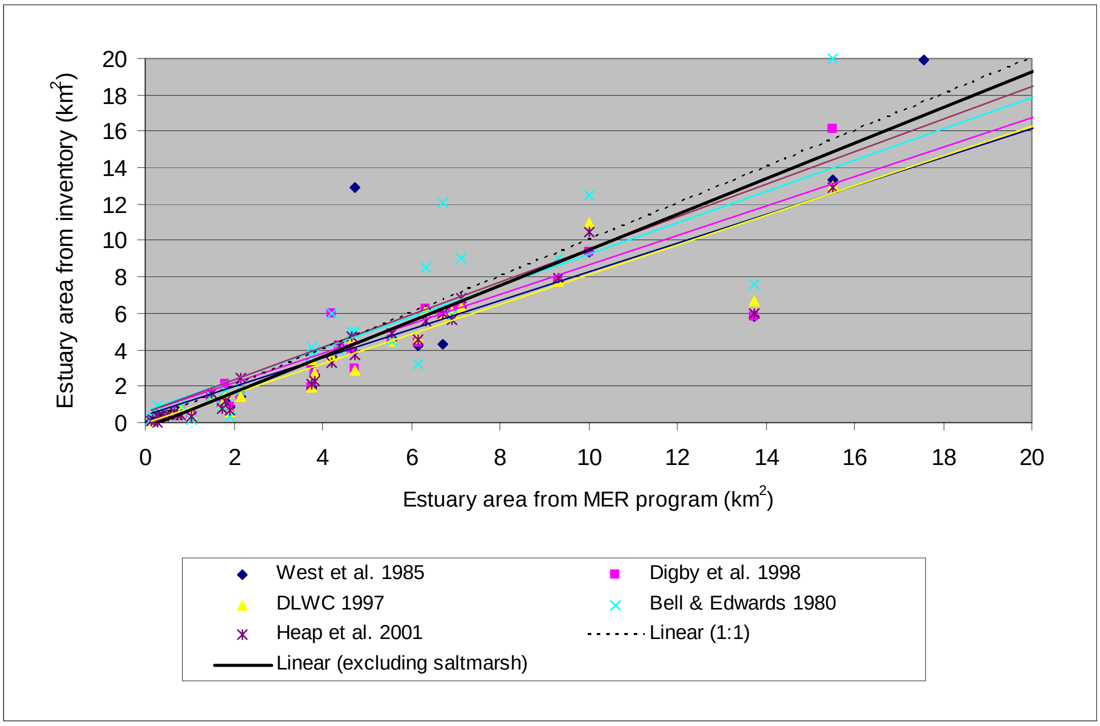


Figure 1: Comparison of estuary surface area from six inventories

3.5 Estuary catchments

NSW coastal catchments have been previously digitised from the 1:25,000 topographic map series for the stressed rivers assessments produced for the NSW water sharing plans (WSPs). However, small estuaries adjacent to larger systems were often combined into a single catchment. In addition, the connection of the catchment boundary to the coastline was made between adjacent estuary entrances so as to fully cover the entire coastal land surface.

Using the catchments defined in the stressed rivers assessments as a starting point, on-screen digitising was employed to redefine and separate each individual estuary catchment down to the entrance. Any errors detected in catchment boundaries away from the entrance were also corrected.

The National Oceanic and Atmospheric Administration (NOAA) of the United States Department of Commerce further divide estuary catchments into those areas draining directly to the estuary (also known as the Estuarine Drainage Area [EDA]) and those draining to the catchment rivers and streams above the estuary tidal limits (also known as the Fluvial Drainage Area [FDA]) (Burgess et al. 2004). It is thought that inputs from the EDA affect estuary health to a greater extent than those from the FDA. This may not hold if the EDA is relatively small (NOAA 1990). Barton (2006) found a strong correlation between estuarine drainage area land-use and estuarine water and sediment quality in south-east Australian estuaries.

Digitising the extent of NSW estuarine catchments above and below the tidal limits has been completed to facilitate exploratory analysis of links between catchment land-use and estuary health. These data and analyses will be available for the next SOC reports.

Excluding small catchments that drain directly to the Tasman Sea (eg Bondi Beach), estuarine catchments in NSW (Figure 2) cover a total area of 127,154 km^2 (Table 1) or 15.8 per cent of the area of NSW. This portion of the state contains 82.1 per cent of the population (from 2006 Census – see Section 9.7.3).

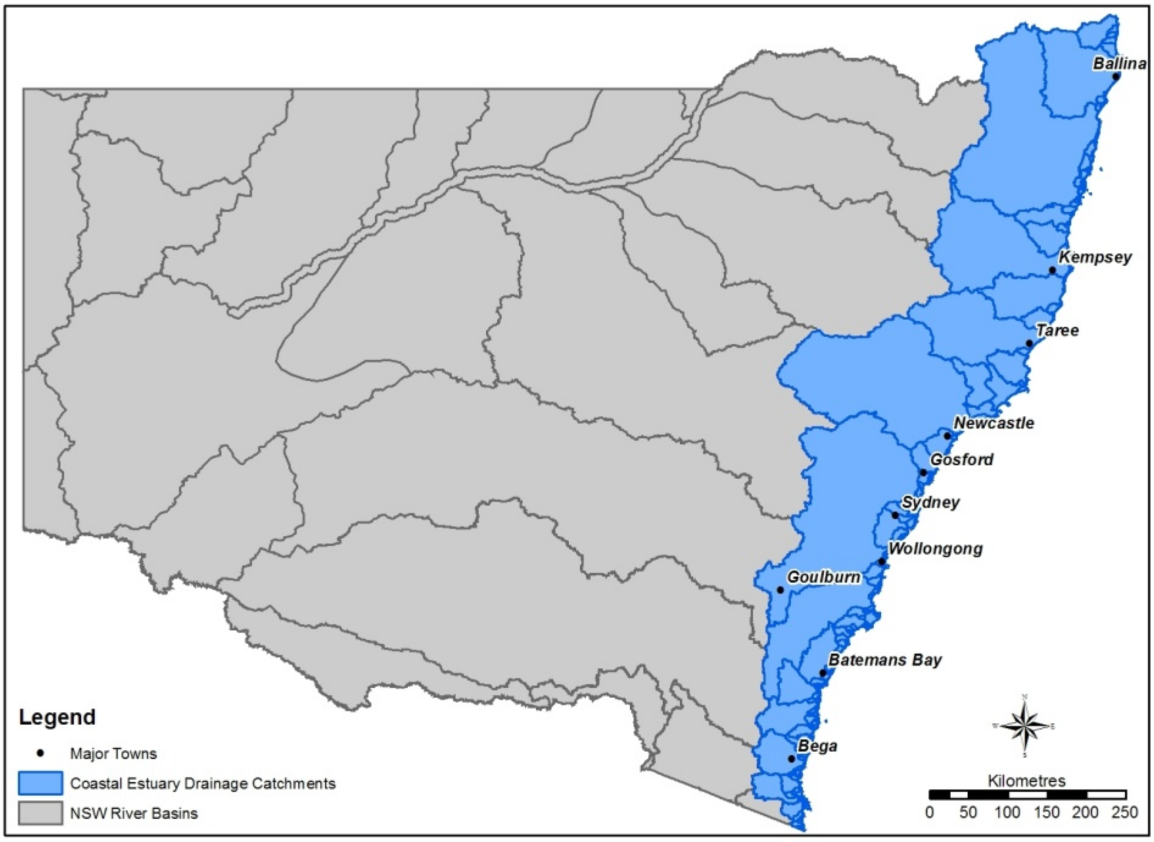


Figure 2: Location of the estuary catchments of NSW

3.6 Location and identifier

Each estuary location has been mapped as a point feature representing the latitude and longitude at the midpoint of the line drawn across the estuary entrance.

An additional numbering system from one to 184 has been used to identify estuaries from north to south. Tributaries entering a port, bay or harbour have been numbered in an anti-clockwise direction with the port, bay or harbour as the last number in the group. Sorting estuaries using the north-south numbering from one to 184 will result in a different order to sorting by latitude.

The names assigned to individual estuaries were sourced from the Geographical Names Board. Table 1 shows the 184 estuaries in NSW by name, latitude and longitude, north-south identifier number, estuary and catchment areas, CMA and local government areas (LGAs). Ports, bays and harbours and their tributaries are shaded grey.

Table 1: Estuaries in NSW

Estuary	Entrance location		Nth-sth no.	Estuary area [1] (km²)		Catchment area [2] (km²)	Total area [3] (km²)	CMA	LGA(s)[4] covering estuary waterway
	Latitude (ºS)	Longitude (ºE)		Saltmarsh excluded	Saltmarsh included				
Tweed River	-28.1693	153.5562	1	21.95	22.72	1054.76	1077.48	NR[5]	Tweed
Cudgen Creek	-28.2564	153.5847	2	2.10	2.15	68.61	70.76	NR	Tweed
Cudgera Creek	-28.3596	153.5780	3	0.41	0.48	60.55	61.03	NR	Tweed
Mooball Creek	-28.3877	153.5700	4	0.52	0.53	109.14	109.68	NR	Tweed
Brunswick River	-28.5379	153.5581	5	3.28	3.59	226.34	229.93	NR	Byron
Belongil Creek	-28.6251	153.5916	6	0.19	0.27	30.41	30.68	NR	Byron
Tallow Creek	-28.6673	153.6216	7	0.12	0.12	5.34	5.46	NR	Byron
Broken Head Creek	-28.6968	153.6135	8	0.05	0.05	1.12	1.17	NR	Byron
Richmond River	-28.8766	153.5910	9	37.78	38.38	6861.84	6900.22	NR	Ballina, Byron, Lismore, Richmond Valley
Salty Lagoon	-29.0771	153.4376	10	0.16	0.16	3.57	3.73	NR	Richmond Valley
Evans River	-29.1128	153.4373	11	2.30	2.66	75.84	78.50	NR	Richmond Valley
Jerusalem Creek	-29.2145	153.3919	12	0.32	0.32	48.32	48.64	NR	Clarence Valley
Clarence River	-29.4268	153.3721	13	129.42	132.32	22055.11	22187.42	NR	Clarence Valley
Lake Arragan	-29.5651	153.3383	14	0.97	0.97	9.28	10.25	NR	Clarence Valley
Cakora Lagoon	-29.6007	153.3330	15	0.23	0.36	12.33	12.69	NR	Clarence Valley
Sandon River	-29.6728	153.3325	16	2.14	2.62	131.52	134.14	NR	Clarence Valley
Wooli Wooli River	-29.8878	153.2683	17	3.08	3.75	180.00	183.74	NR	Clarence Valley
Station Creek	-29.9494	153.2587	18	0.25	0.26	21.36	21.62	NR	Coffs Harbour
Corindi River	-29.9805	153.2318	19	1.32	1.90	146.44	148.34	NR	Coffs Harbour
Pipe Clay Creek	-30.0223	153.2069	20	0.01	0.01	1.63	1.64	NR	Coffs Harbour
Arrawarra Creek	-30.0582	153.1973	21	0.11	0.12	17.82	17.95	NR	Coffs Harbour
Darkum Creek	-30.0959	153.2004	22	0.06	0.06	6.11	6.17	NR	Coffs Harbour
Woolgoolga Lake	-30.0987	153.1993	23	0.16	0.16	21.02	21.18	NR	Coffs Harbour
Flat Top Point Creek	-30.1286	153.2047	24	0.02	0.02	2.57	2.59	NR	Coffs Harbour
Hearns Lake	-30.1320	153.2025	25	0.10	0.15	6.60	6.75	NR	Coffs Harbour
Moonee Creek	-30.2122	153.1614	26	0.28	0.41	41.11	41.52	NR	Coffs Harbour
Pine Brush Creek	-30.2516	153.1423	27	0.02	0.02	7.34	7.35	NR	Coffs Harbour
Coffs Creek	-30.2965	153.1391	28	0.46	0.46	24.04	24.50	NR	Coffs Harbour
Boambee Creek	-30.3546	153.1062	29	0.96	0.99	48.48	49.48	NR	Coffs Harbour
Bonville Creek	-30.3760	153.1004	30	1.50	1.66	113.47	115.13	NR	Coffs Harbour
Bundageree Creek	-30.4313	153.0758	31	0.00	0.00	10.12	10.13	NR	Coffs Harbour
Bellinger River	-30.5017	153.0313	32	8.02	8.16	1100.32	1108.49	NR	Bellingen
Dalhousie Creek	-30.5232	153.0281	33	0.07	0.08	6.26	6.33	NR	Bellingen
Oyster Creek	-30.5633	153.0175	34	0.14	0.14	16.78	16.92	NR	Bellingen, Nambucca

Estuary	Entrance location		Nth-sth no.	Estuary area [1] (km^2)		Catchment area [2] (km^2)	Total area [3] (km^2)	CMA	LGA(s)[4] covering estuary waterway
	Latitude (ºS)	Longitude (ºE)		Saltmarsh excluded	Saltmarsh included				
Deep Creek	-30.6010	153.0116	35	1.08	1.72	89.80	91.53	NR	Nambucca
Nambucca River	-30.6483	153.0105	36	11.37	12.64	1298.93	1311.57	NR	Nambucca
Macleay River	-30.8729	153.0259	37	27.39	31.64	11287.03	11318.67	NR	Kempsey
South West Rocks Creek	-30.8831	153.0379	38	0.83	0.94	3.67	4.61	NR	Kempsey
Saltwater Creek (Frederickton)	-30.8831	153.0428	39	0.28	0.28	11.11	11.40	NR	Kempsey
Korogoro Creek	-31.0536	153.0561	40	0.24	0.28	9.51	9.79	NR	Kempsey
Killick Creek	-31.1870	152.9784	41	0.28	0.29	7.93	8.22	NR	Kempsey
Goolawah Lagoon	-31.2093	152.9683	42	0.13	0.13	3.95	4.08	NR	Kempsey
Hastings River	-31.4259	152.9168	43	28.09	29.96	3658.57	3688.53	NR	Hastings, Kempsey
Cathie Creek	-31.5495	152.8598	44	7.86	13.75	105.50	119.25	NR	Hastings
Duchess Gully	-31.5871	152.8403	45	0.02	0.02	10.59	10.62	NR	Hastings
Camden Haven River	-31.6357	152.8375	46	31.39	32.16	588.99	621.15	NR	Greater Taree, Hastings
Manning River	-31.8767	152.6959	47	32.27	34.72	8124.50	8159.22	HCR[5]	Greater Taree
Khappinghat Creek	-32.0100	152.5656	48	1.03	1.19	90.73	91.92	HCR	Greater Taree
Black Head Lagoon	-32.0704	152.5449	49	0.01	0.01	1.99	2.00	HCR	Greater Taree
Wallis Lake	-32.1734	152.5109	50	92.80	98.70	1196.90	1295.61	HCR	Great Lakes, Greater Taree
Smiths Lake	-32.3954	152.5196	51	10.01	10.01	27.97	37.98	HCR	Great Lakes
Myall River	-32.6710	152.1457	52	112.53	115.20	818.74	933.93	HCR	Great lakes, Port Stephens
Karuah River	-32.6656	151.9719	53	14.12	17.88	1448.42	1466.30	HCR	Great Lakes, Port Stephens
Tilligerry Creek	-32.7280	152.0519	54	20.45	20.45	114.77	135.22	HCR	Port Stephens
Port Stephens	-32.7071	152.1953	55	123.75	134.38	296.77	431.14	HCR	Great Lakes, Port Stephens
Hunter River	-32.9143	151.8013	56	41.83	47.03	21366.95	21413.99	HCR	Dungog, Maitland, Newcastle, Port Stephens
Glenrock Lagoon	-32.9627	151.7383	57	0.05	0.05	7.37	7.42	HCR	Lake Macquarie, Newcastle
Lake Macquarie	-33.0855	151.6620	58	113.21	114.10	604.39	718.48	HCR	Lake Macquarie, Wyong
Middle Camp Creek	-33.1461	151.6368	59	0.01	0.01	5.01	5.03	HCR	Lake Macquarie
Moonee Beach Creek	-33.1666	151.6328	60	0.00	0.00	3.48	3.48	HCR	Wyong
Tuggerah Lake	-33.3447	151.5032	61	80.63	80.76	714.47	795.23	HCR	Wyong
Wamberal Lagoon	-33.4299	151.4489	62	0.52	0.52	5.82	6.34	HCR	Gosford
Terrigal Lagoon	-33.4427	151.4436	63	0.28	0.28	8.94	9.22	HCR	Gosford
Avoca Lake	-33.4642	151.4365	64	0.67	0.67	10.77	11.44	HCR	Gosford
Cockrone Lake	-33.4939	151.4288	65	0.33	0.33	6.85	7.18	HCR	Gosford

Estuary	Entrance location: Latitude (ºS)	Entrance location: Longitude (ºE)	Nth-sth no.	Estuary area [1] (km²): Saltmarsh excluded	Estuary area [1] (km²): Saltmarsh included	Catchment area [2] (km²)	Total area [3] (km²)	CMA	LGA(s)[4] covering estuary waterway
Brisbane Water	-33.5225	151.3341	66	27.22	28.34	152.55	180.89	HCR	Gosford
Hawkesbury River	-33.5644	151.3090	67	111.63	114.50	21624.06	21738.56	HN[5]	Baulkham Hills, Blacktown, Gosford, Hawkesbury, Hornsby, Ku-Ring-Gai, Penrith, Pittwater, Warringah
Pittwater	-33.5799	151.3169	68	18.36	18.39	50.77	69.16	HN	Pittwater
Broken Bay	-33.5625	151.3410	69	17.14	17.14	12.93	30.07	HN	Gosford
Narrabeen Lagoon	-33.7037	151.3081	70	2.31	2.32	52.41	54.73	SM[5]	Pittwater, Warringah
Dee Why Lagoon	-33.7469	151.3037	71	0.24	0.30	4.27	4.57	SM	Warringah
Curl Curl Lagoon	-33.7673	151.2992	72	0.07	0.07	4.65	4.72	SM	Warringah
Manly Lagoon	-33.7864	151.2891	73	0.10	0.10	17.25	17.34	SM	Manly, Warringah
Middle Harbour Creek	-33.8188	151.2572	74	6.11	6.11	76.98	83.09	SM	Ku-Ring-Gai, Manly, Mosman, North Sydney, Warringah, Willoughby
Lane Cove River	-33.8427	151.1778	75	2.98	2.98	95.36	98.33	SM	Hunters Hill, Ku-Ring-Gai, Lane Cove, Ryde, Willoughby
Parramatta River	-33.8449	151.1873	76	13.74	13.74	252.36	266.10	SM	Ashfield, Auburn, Canada Bay, Hunters Hill, Lane Cove, Leichhardt, Marrickville, Parramatta, Ryde, Strathfield
Port Jackson	-33.8283	151.2901	77	28.97	29.06	55.74	84.81	SM	Leichhardt, Mosman, North Sydney, Sydney, Woollahra
Cooks River	-33.9494	151.1688	78	1.20	1.20	110.57	111.77	SM	Botany Bay, Burwood, Canterbury, Marrickville, Rockdale, Sydney
Georges River	-33.9975	151.1554	79	25.75	26.59	930.91	957.50	SM	Bankstown, Canterbury, Fairfield, Hurstville, Kogarah, Liverpool, Rockdale, Sutherland
Botany Bay	-34.0013	151.2337	80	38.79	39.55	54.87	94.42	SM	Botany Bay, Randwick, Sutherland
Port Hacking	-34.0725	151.1628	81	11.57	11.70	165.34	177.04	SM	Sutherland, Wollongong
Wattamolla Creek	-34.1379	151.1182	82	0.03	0.03	8.05	8.08	SM	Sutherland
Hargraves Creek	-34.2297	150.9914	83	0.00	0.00	2.02	2.02	SR[5]	Wollongong
Stanwell Creek	-34.2328	150.9878	84	0.01	0.01	7.69	7.69	SR	Wollongong
Flanagans Creek	-34.3156	150.9290	85	0.00	0.00	2.02	2.02	SR	Wollongong
Woodlands Creek	-34.3251	150.9244	86	0.00	0.00	2.00	2.01	SR	Wollongong
Slacky Creek	-34.3355	150.9251	87	0.00	0.00	3.08	3.08	SR	Wollongong
Bellambi Gully	-34.3652	150.9228	88	0.02	0.02	6.46	6.47	SR	Wollongong
Bellambi Lake	-34.3768	150.9223	89	0.03	0.03	1.31	1.34	SR	Wollongong
Towradgi Creek	-34.3833	150.9165	90	0.04	0.04	8.56	8.60	SR	Wollongong
Fairy Creek	-34.4099	150.9022	91	0.11	0.11	20.65	20.76	SR	Wollongong
Allans Creek	-34.4638	150.9003	92	1.16	1.17	50.46	51.63	SR	Wollongong
Port Kembla	-34.4648	150.9116	93	1.37	1.37	6.25	7.63	SR	Wollongong

Estuary	Entrance location		Nth-sth no.	Estuary area [1] (km²)		Catchment area [2] (km²)	Total area [3] (km²)	CMA	LGA(s)[4] covering estuary waterway
	Latitude (ºS)	Longitude (ºE)		Saltmarsh excluded	Saltmarsh included				
Lake Illawarra	-34.5436	150.8750	94	35.53	35.83	238.43	274.27	SR	Shellharbour, Wollongong
Elliott Lake	-34.5606	150.8699	95	0.08	0.08	9.97	10.05	SR	Shellharbour
Minnamurra River	-34.6280	150.8611	96	1.53	1.86	117.33	119.19	SR	Kiama, Shellharbour
Spring Creek	-34.6642	150.8545	97	0.05	0.05	5.83	5.88	SR	Kiama
Munna Munnora Creek	-34.6924	150.8538	98	0.00	0.00	3.63	3.63	SR	Kiama
Werri Lagoon	-34.7287	150.8394	99	0.14	0.14	16.48	16.63	SR	Kiama
Crooked River	-34.7728	150.8157	100	0.26	0.28	31.99	32.27	SR	Kiama
Shoalhaven River	-34.8979	150.7662	101	29.84	31.89	7085.83	7117.72	SR	Shoalhaven
Wollumboola Lake	-34.9425	150.7772	102	6.33	6.33	34.13	40.46	SR	Shoalhaven
Currarong Creek	-35.0147	150.8215	103	0.03	0.03	12.33	12.37	SR	Shoalhaven
Cararma Creek	-35.0020	150.7776	104	2.39	2.39	6.80	9.19	SR	Shoalhaven
Wowly Gully	-34.9953	150.7287	105	0.16	0.16	6.02	6.19	SR	Shoalhaven
Callala Creek	-35.0067	150.7182	106	0.01	0.01	19.79	19.79	SR	Shoalhaven
Currambene Creek	-35.0375	150.6714	107	2.22	2.22	160.02	162.24	SR	Shoalhaven
Moona Moona Creek	-35.0499	150.6780	108	0.14	0.14	28.57	28.71	SR	Shoalhaven
Flat Rock Creek	-35.1241	150.7041	109	0.01	0.01	6.88	6.89	SR	Shoalhaven, Commonwealth
Captains Beach Lagoon	-35.1264	150.7115	110	0.05	0.05	3.14	3.19	SR	Commonwealth
Telegraph Creek	-35.1363	150.7254	111	0.01	0.01	4.28	4.29	SR	Commonwealth
Jervis Bay	-35.1039	150.7872	112	122.41	123.89	32.39	156.28	SR	Shoalhaven, Commonwealth
St Georges Basin	-35.1852	150.5938	113	40.76	40.91	315.75	356.66	SR	Shoalhaven, Commonwealth
Swan Lake	-35.2023	150.5598	114	4.68	4.68	26.38	31.06	SR	Shoalhaven
Berrara Creek	-35.2108	150.5484	115	0.26	0.26	35.04	35.30	SR	Shoalhaven
Nerrindillah Creek	-35.2276	150.5326	116	0.07	0.07	17.22	17.29	SR	Shoalhaven
Conjola Lake	-35.2687	150.5078	117	6.69	6.72	139.09	145.81	SR	Shoalhaven
Narrawallee Inlet	-35.3027	150.4740	118	0.86	1.04	80.92	81.96	SR	Shoalhaven
Mollymook Creek	-35.3356	150.4743	119	0.01	0.01	2.72	2.72	SR	Shoalhaven
Millards Creek	-35.3546	150.4757	120	0.00	0.00	4.50	4.51	SR	Shoalhaven
Ulladulla	-35.3556	150.4784	121	0.09	0.09	0.30	0.39	SR	Shoalhaven
Burrill Lake	-35.3950	150.4474	122	4.14	4.38	60.74	65.12	SR	Shoalhaven
Tabourie Lake	-35.4427	150.4106	123	1.45	1.49	46.14	47.63	SR	Shoalhaven
Termeil Lake	-35.4623	150.3944	124	0.57	0.57	14.05	14.62	SR	Shoalhaven
Meroo Lake	-35.4829	150.3915	125	1.37	1.37	19.27	20.64	SR	Shoalhaven
Willinga Lake	-35.5006	150.3914	126	0.31	0.31	13.59	13.90	SR	Shoalhaven

Estuary	Entrance location: Latitude (ºS)	Entrance location: Longitude (ºE)	Nth-sth no.	Estuary area [1] (km^2): Saltmarsh excluded	Estuary area [1] (km^2): Saltmarsh included	Catchment area [2] (km^2)	Total area [3] (km^2)	CMA	LGA(s)[4] covering estuary waterway
Butlers Creek	-35.5522	150.3827	127	0.03	0.03	3.06	3.09	SR	Shoalhaven
Durras Lake	-35.6418	150.3054	128	3.60	3.77	58.38	62.15	SR	Eurobodalla, Shoalhaven
Durras Creek	-35.6576	150.2971	129	0.02	0.02	5.92	5.94	SR	Eurobodalla
Maloneys Creek	-35.7094	150.2437	130	0.03	0.03	8.17	8.20	SR	Eurobodalla
Cullendulla Creek	-35.7022	150.2095	131	1.12	1.29	15.16	16.45	SR	Eurobodalla
Clyde River	-35.7069	150.1818	132	17.03	17.55	1722.91	1740.46	SR	Eurobodalla, Shoalhaven
Batemans Bay	-35.7572	150.2500	133	34.48	34.48	28.00	62.49	SR	Eurobodalla
Saltwater Creek (Rosedale)	-35.8122	150.2259	134	0.00	0.00	2.82	2.82	SR	Eurobodalla
Tomaga River	-35.8374	150.1852	135	1.35	1.81	91.90	93.71	SR	Eurobodalla
Candlagan Creek	-35.8424	150.1802	136	0.13	0.20	24.12	24.31	SR	Eurobodalla
Bengello Creek	-35.8679	150.1632	137	0.01	0.01	16.32	16.33	SR	Eurobodalla
Moruya River	-35.9058	150.1518	138	5.35	6.14	1423.67	1429.82	SR	Eurobodalla
Congo Creek	-35.9536	150.1601	139	0.12	0.13	43.19	43.32	SR	Eurobodalla
Meringo Creek	-35.9785	150.1511	140	0.07	0.08	5.29	5.38	SR	Eurobodalla
Kellys Lake	-36.0065	150.1574	141	0.06	0.06	2.11	2.18	SR	Eurobodalla
Coila Lake	-36.0486	150.1416	142	6.77	7.12	47.64	54.76	SR	Eurobodalla
Tuross River	-36.0667	150.1344	143	14.70	15.50	1813.78	1829.28	SR	Eurobodalla
Lake Brunderee	-36.0935	150.1372	144	0.19	0.21	5.72	5.93	SR	Eurobodalla
Lake Tarourga	-36.1052	150.1356	145	0.33	0.33	5.99	6.31	SR	Eurobodalla
Lake Brou	-36.1280	150.1264	146	2.37	2.45	41.64	44.09	SR	Eurobodalla
Lake Mummuga	-36.1621	150.1266	147	1.63	1.65	25.76	27.41	SR	Eurobodalla
Kianga Lake	-36.1921	150.1330	148	0.17	0.17	7.50	7.67	SR	Eurobodalla
Wagonga Inlet	-36.2095	150.1348	149	6.91	6.94	93.28	100.22	SR	Eurobodalla
Little Lake (Narooma)	-36.2243	150.1411	150	0.10	0.10	2.17	2.27	SR	Eurobodalla
Bullengella Lake	-36.2421	150.1447	151	0.15	0.15	0.59	0.74	SR	Eurobodalla
Nangudga Lake	-36.2519	150.1444	152	0.60	0.74	9.47	10.21	SR	Eurobodalla
Corunna Lake	-36.2897	150.1312	153	2.08	2.13	29.74	31.87	SR	Eurobodalla
Tilba Tilba Lake	-36.3281	150.1156	154	1.02	1.17	17.09	18.27	SR	Eurobodalla
Little Lake (Wallaga)	-36.3396	150.1025	155	0.12	0.13	2.37	2.51	SR	Eurobodalla
Wallaga Lake	-36.3697	150.0799	156	9.14	9.31	263.84	273.14	SR	Bega Valley, Eurobodalla
Bermagui River	-36.4224	150.0731	157	1.99	2.16	83.46	85.62	SR	Bega Valley
Baragoot Lake	-36.4641	150.0668	158	0.47	0.55	12.61	13.16	SR	Bega Valley
Cuttagee Lake	-36.4880	150.0551	159	1.24	1.35	53.12	54.47	SR	Bega Valley
Murrah River	-36.5254	150.0581	160	0.68	0.84	195.76	196.60	SR	Bega Valley

	Entrance location			Estuary area [1] (km^2)		Catchment	Total		
Estuary	**Latitude (ºS)**	**Longitude (ºE)**	**Nth-sth no.**	**Saltmarsh excluded**	**Saltmarsh included**	**area [2] (km^2)**	**area [3] (km^2)**	**CMA**	**LGA(s)[4] covering estuary waterway**
Bunga Lagoon	-36.5402	150.0555	161	0.11	0.14	11.55	11.68	SR	Bega Valley
Wapengo Lagoon	-36.6285	150.0209	162	3.17	3.67	68.50	72.18	SR	Bega Valley
Middle Lagoon	-36.6505	150.0092	163	0.51	0.56	27.32	27.88	SR	Bega Valley
Nelson Lagoon	-36.6857	149.9940	164	1.19	1.35	26.98	28.33	SR	Bega Valley
Bega River	-36.7018	149.9830	165	3.31	3.84	1934.83	1938.67	SR	Bega Valley
Wallagoot Lake	-36.7900	149.9600	166	3.87	3.98	26.52	30.50	SR	Bega Valley
Bournda Lagoon	-36.8202	149.9389	167	0.08	0.08	34.50	34.58	SR	Bega Valley
Back Lagoon	-36.8833	149.9307	168	0.36	0.38	31.35	31.74	SR	Bega Valley
Merimbula Lake	-36.8957	149.9228	169	4.99	5.58	37.90	43.48	SR	Bega Valley
Pambula River	-36.9469	149.9170	170	4.36	4.72	296.46	301.18	SR	Bega Valley
Curalo Lagoon	-37.0469	149.9223	171	0.71	0.80	28.22	29.03	SR	Bega Valley
Shadrachs Creek	-37.0768	149.8787	172	0.01	0.01	13.23	13.24	SR	Bega Valley
Nullica River	-37.0911	149.8729	173	0.32	0.33	54.77	55.11	SR	Bega Valley
Boydtown Creek	-37.1029	149.8819	174	0.02	0.02	3.86	3.87	SR	Bega Valley
Towamba River	-37.1118	149.9132	175	1.91	2.04	1026.17	1028.21	SR	Bega Valley
Fisheries Creek	-37.1107	149.9289	176	0.05	0.09	6.45	6.54	SR	Bega Valley
Twofold Bay	-37.0775	149.9481	177	30.73	30.73	11.01	41.74	SR	Bega Valley
Saltwater Creek (Eden)	-37.1685	150.0030	178	0.06	0.06	17.19	17.24	SR	Bega Valley
Woodburn Creek	-37.1706	150.0052	179	0.05	0.05	13.51	13.56	SR	Bega Valley
Wonboyn River	-37.2497	149.9662	180	3.69	4.21	335.44	339.64	SR	Bega Valley
Merrica River	-37.2966	149.9519	181	0.12	0.12	60.54	60.66	SR	Bega Valley
Table Creek	-37.4063	149.9541	182	0.06	0.06	17.29	17.35	SR	Bega Valley
Nadgee River	-37.4381	149.9661	183	0.19	0.27	58.79	59.07	SR	Bega Valley
Nadgee Lake	-37.4688	149.9729	184	1.20	1.20	13.70	14.90	SR	Bega Valley
Total				**1718.51**	**1791.23**	**127153.76**	**128944.99**		

Estuaries draining to a port, bay or harbour have been numbered in a clockwise direction with the port, bay or harbour as the last number in the group.

Notes

1. Estuary water surface area is measured at approximately Mean High Water or about 0.6 m AHD. Two areas are given, the first is the water surface area including seagrass and mangrove which are usually submerged at Mean High Water. The second area includes saltmarsh which typically occurs between Mean High Water and Highest Astronomical Tide.
2. Catchment area excludes the estuary water surface and macrophyte areas.
3. Total area is the sum of estuary water surface, macrophyte and catchment areas.
4. LGA is local government area.
5. NR is Northern Rivers, HCR is Hunter–Central Rivers, HN is Hawkesbury–Nepean, SM is Sydney Metropolitan, SR is Southern Rivers.

4. Contextual data

Additional data are often required to interpret the condition of a natural resource and the pressures and threats acting on that asset that influence its condition. For example, systems for classifying estuaries into types with similar characteristics generally require data on a range of morphometric, hydrodynamic, catchment and hydrologic variables. Pressures also often have to be normalised to facilitate meaningful comparisons between estuary systems, for example, by catchment or estuary area.

The issue of contextual data was discussed in some detail in a report commissioned by the NLWRA (BTG 2004b). The report suggested that data were commonly required for interpretation, aggregation and/or mapping of an indicator. Contextual data were identified as either 'critical' or 'useful' in compilation or interpretation of an indicator:

- Data that are 'context-critical' were defined as those essential for interpreting 'protocol' or condition data and thus necessary to the proper understanding of the indicator
- Data that are 'context-useful' can add value to the process but are not essential.

Arundel & Mount (2007), in a background paper prepared for the NLWRA, focused on the need for contextual data identified in a number of consultant reports commissioned by the NLWRA and from pilot projects contracted to various state agencies. A conceptual model of three information domains was introduced covering:

- Asset Context: system typology, system trajectory, vulnerability (susceptibility) and pressures (drivers)
- Human Aims: ecosystem and human use vales and management objectives
- Asset Monitoring: resource condition.

Arundel & Mount (2007) argue that contextual information from the Asset Context and Human Aims information domains is essential to interpreting resource condition data. They suggest the credibility and value of resource condition assessments is reduced if information on mapping and inventories, asset typologies (classifications), pressures, vulnerabilities, ecosystem and human use values and management objectives is not available.

National indicator guidelines and protocols setting out recommended methods for collecting, collating and reporting information on condition and pressure indicators for national, state/territory and regional application are available at www.lwa.gov.au/products/tags/2437 and www.lwa.gov.au/products/tags/2438. Sections on interpretation include factors influencing indicator values.

Likewise, the Australian and New Zealand Environment Conservation Council water quality guidelines (ANZECC 2000) refer to ecosystem-specific modifiers that can act to reduce the biological effects of individual stressors. As an example, chlorophyll a modifiers can include (depending on ecosystem type) hydraulic retention time (flows and volume of waterbody), mixing regimes, light regime, turbidity, temperature, suspended solids (nutrient sorption), grazing rates and type of substrate.

All the condition, pressure and stressor datasets potentially available for the SOC reports together with the contextual data that were considered for collation or collection to aid interpretation and whether they were 'context-critical' or 'context-useful' are shown in Table 2.

Table 2: Potential data types and indicators available for reporting

Dataset used | Dataset accessed but not used | Dataset not accessed

Data type	Attribute	Indicators	Units	Database [1]	Data source	Custodians	No. [2]	NRC C.I. [3]	Context [7] Crit.	Context [7] Usef.
Condition data										
Biology	Chlorophyll	Annual chlorophyll a statistics	µg/l	Local	Sample	OEH, Ccls, Unis	Some	✓		
	Macroalgae	Macroalgae distribution and abundance	m^2	Local	Observation	OEH	None	✓		
	Seagrass	Seagrass extent and distribution	m^2	DPI	Aerials, satellite	DPI	All	✓		
	Epiphytes	Seagrass epiphyte coverage	% cover	Local	Observation	OEH	Few	✓		
	Mangrove	Mangrove extent and distribution	m^2	DPI	Aerials, satellite	DPI	All	✓		
		Distance from entrance to mangrove limits	km	OEH	Observation	OEH	All			✓
	Saltmarsh	Saltmarsh extent and distribution	m^2	DPI	Aerials, satellite	DPI	All	✓		
	Fish assemblages	Species diversity, abundance, nursery function, trophic integrity	various	Estuarine fish ecology database	Sample	DPI	Many	✓		
	Shore birds	Shore birds fledgling success rate	no.	Local	Observation	OEH	South			✓
	Invasive species	Estuary area infested with *Caulerpa Taxifolia*	m^2	DPI	Aerials	DPI	Some			✓
Water clarity	Turbidity	Annual turbidity statistics	NTU	Local	Probes	OEH, Ccls, Unis	Many		✓	
	Secchi depth	Annual secchi depth statistics	m	Local	Observation	OEH, Ccls, Unis	Some			✓
Pressure data [4]										
Demographics	Population	Catchment density	head/km^2	Local	Census collection district pop^{n}	ABS, OEH	All		✓	

Data type	Attribute	Indicators	Units	Database [1]	Data source	Custodians	No. [2]	NRC C.I. [3]	Context [7]	
									Crit.	Usef.
Catchment	Land-use	Catchment land-use types	m^2	Enterprise DataBase	Aerials	OEH	All		✓	
	Sewerage	Licensed discharge loads	kg/yr	ISEMS	Load based licensing records	OEH	All		✓	
		Area with no reticulated sewerage	m^2	Local	Town sewerage schemes	OEH	All			✓
	Soils	Soil erosion hazard	t/ha/yr	Local	Soil types, slope, models	OEH	All			✓
		Acid sulfate soils drainage	km^2 drained	Local	Flood drain maps, aerials	OEH	All			✓
Fluvial System	River health	Riparian woody vegetation extent	% absent	Local	Satellite imagery	OEH	All			✓
		River style geomorphic condition	class	Local	Survey	OEH	Some			✓
		Macroinvertebrate assemblages	O/E SIGNAL	Local	Survey	OEH	Some			✓
		Adjacent land-use	m width	Local	Aerials	OEH	All			✓
		Fish barriers	no.	DPI	Survey	DPI	All			✓
	Extraction	Water extraction entitlements	m^3/yr	LAS	Licence database	NSW Office of Water (NOW)	All		✓	
Foreshore use	Foreshore structures	Waterway structures	m	Crown Lands Division (CLD)	Licence records	CLD	All		✓	
	Moorings	Piles and marina licence area	m^2	CLD	Licence records	CLD	All			✓
	Aquaculture	Areal aquaculture extent	m^2	DPI	Licence records	DPI	All		✓	
Waterway use	Entrance	Presence of training walls or breakwaters	presence	Estuaries	Aerials	OEH	All		✓	
		Artificial entrance opening level	m AHD	Local	Council records	Ccls, OEH	All		✓	
	Dredging	Dredging volumes for navigation etc	m^3/yr	CLD	Licence records	CLD	All			✓

Data type	Attribute	Indicators	Units	Database [1]	Data source	Custodians	No. [2]	NRC C.I. [3]	Context [7]	
									Crit.	Usef.
	Wild harvest fisheries	Annual commercial fish, prawn, mollusc catch	tonnes/yr	DPI	Licence records	DPI	All		✓	
		Estuary extent open to recreational or commercial fishing	% area	DPI	Licence records	DPI	All			✓
	Fish barriers	Barriers to tidal flow	no.	DPI	Observation	DPI	All			✓
Stressor data [5]										
Catchment exports	Suspended solids	Total suspended solids (TSS) diffuse source inflow	t/year	Local	Catchment modelling	OEH	All		✓	
		Point source TSS discharges	kg/yr	ISEMS	Licence records	OEH	All		✓	
	Nitrogen	Total nitrogen (TN) diffuse source inflow	t/year	Local	Catchment modelling	OEH	All		✓	
		Point source TN discharges	kg/yr	ISEMS	Licence records	OEH	All		✓	
	Phosphorus	Total phosphorus (TP) diffuse source inflow	t/year	Local	Catchment modelling	OEH	All		✓	
		Point source TP discharges	kg/yr	ISEMS	Licence records	OEH	All		✓	
Contextual data [6]										
Geography	Identifier	Estuary name	name	Estuaries	Geographical Names Board	OEH	All		✓	
		Estuary number (latitude)	6 digit ID	Local	Estuary polygon	OEH	All		✓	
	Location	Latitude, longitude	ºS, ºE	Estuaries	Estuary polygon	OEH	All		✓	
	Boundary	CMA, LGA, IMCRA	name	EDB	CMA polygon	OEH	All		✓	
Geomorphology	Classification	Geomorphic group, type, maturity	class	Local	Roy et al. 2001	OEH	Most		✓	
	Area	Estuary surface area	m^2	Estuaries	Aerials and bathymetry	OEH	All		✓	
	Depth	Mean estuary depth	m	Local	Bathymetry	OEH	Some		✓	
	Volume	Estuary volume	m^3	Local	Bathymetry	OEH	Some		✓	
	Perimeter	Estuary perimeter	km	Local	Aerials and bathymetry	OEH	All		✓	

Data type	Attribute	Indicators	Units	Database [1]	Data source	Custodians	No. [2]	NRC C.I. [3]	Context [7]	
									Crit.	Usef.
	Length	Distance from entrance to tidal limits	km	EDB	Survey	OEH	All		✓	
Sediments	Unvegetated	Habitat type	m^2	OzCoasts	Aerials	Geoscience Aust.	Most			✓
	Vegetated	Intertidal area (flats+saltmarsh+mangrove)	m^2	OzCoasts	Aerials	Geoscience Aust.	Most			✓
Inlet channel	Inlet morphology	Inlet channel dimensions	m	Local	Aerials	OEH	Few			✓
	Entrance	Entrance opening regime	days	Local	Opening records and aerials	Ccls, OEH	Some		✓	
		Mean natural berm height	m AHD	Local	Survey	Ccls, OEH	Few			✓
		Entrance dimensions	m	Local	Aerials and bathymetry	OEH	Few			✓
Oceanography	Ocean tides	Water level statistics	m AHD	MHL	Water level recorders	OEH	All		✓	
	Waves	Mean wave height, period	m	OzCoasts	Wave stations	Geoscience Aust.	Most			✓
	Temperature	Sea surface temperature	ºC	MHL	Satellite imagery	Various	All			✓
	Sediment transport	Mean gross longshore transport	m^3/yr	Local	Wave climate, offshore bathymetry, particle size	OEH, Royal Australian Navy	Few			✓
Hydrodynamics	Estuary tides	Water level statistics	m AHD	MHL	Water level recorders	OEH	Some		✓	
		Tidal planes	m AHD	MHL	Water level recorders	OEH	Some		✓	
		Tidal prism	m^3	MHL	Flow gauging	OEH	Many		✓	
	Flushing	Entrance exchange efficiency	%	Reports	Salinity records, models	OEH	Few		✓	
		Tidal flushing	days	Local	Derived	OEH	Most		✓	
		Freshwater flushing	days	Local	Derived	OEH	All		✓	
Water quality (physical)	Salinity	Annual salinity statistics	ppt	MHL	Probes	OEH, Ccls, Unis	Some			✓
	Temperature	Annual temperature statistics	ºC	MHL	Probes	OEH, Ccls, Unis	Some			✓
	Dissolved oxygen	Annual dissolved oxygen statistics	% sat.	MHL	Sample	OEH, Ccls, Unis	Some			✓

Data type	Attribute	Indicators	Units	Database [1]	Data source	Custodians	No. [2]	NRC C.I. [3]	Context [7]	
									Crit.	Usef.
Water quality (nutrients)	Nitrogen	Annual TN statistics	µg/l	Local	Sample	OEH, Ccls, Unis	Some			✓
	Phosphorus	Annual TP statistics	µg/l	Local	Sample	OEH, Ccls, Unis	Some			✓
Catchment	Area	Catchment surface area	m^2	LPI	Aerials	LPI	All		✓	
	Topography	Elevation, slope statistics	m AHD	Local	DEM	OEH	All		✓	
	Geology	Regolith stability	class	SALIS	Soil type polygons	OEH	All			✓
	Soils	Landscape, type	class	SALIS	Survey	OEH	All			✓
Climate	Air temperature	Annual air temperature statistics	ºC	Local	Temp. stations	BoM	All			✓
Hydrology	Rainfall	Catchment rainfall patterns	mm/yr	Local	Rainfall stations	BoM, SILO	All		✓	
	Runoff	Catchment runoff statistics	m^3/yr	Local	Runoff model	OEH	All		✓	
	Evaporation	Pan evaporation rate, pan factor	mm/yr	Local	Evaporation pan	BoM, SILO	All		✓	
	Dilution	Freshwater dilution of total estuary volume	ratio	Local	Bathymetry and runoff model	OEH	All		✓	

1. Local database means not corporate database system. ISEMS = Integrated Statutory Environmental Management System. LAS = Licencing Administration System. MHL = Manly Hydraulics Laboratory. SALIS = Soil And Land Information System.
2. No. is the number of estuaries for which data are available ranked as few, some, many, most, all (184 in total).
3. NRC C.I. is Natural Resources Commission resource Condition Indicator.
4. Pressures refer to human activities influencing the environment.
5. Stressors refer to physical, chemical or biological components of the environment that transfer the impact of a pressure onto resource condition.
6. Contextual data refers to physical or environmental data necessary for interpretation of resource condition data.
7. 'Context critical' data are essential for interpretation of condition; 'Context useful' data add value to interpretation but are not essential.

Shown in Table 3 are contextual data identified by the estuaries theme team as the minimum necessary for interpreting estuary condition and pressure indicators used in the SOC reports. The rationale by the estuaries theme team for their collection is listed under 'Intended uses' together with how any gaps in existing datasets were filled.

Table 3: Contextual data required for interpretation of indicators

Attribute	Intended uses	Data gap-filling
Morphometry		
Tidal limits	Establish upstream extent of area	
Estuary surface area	Normalise pressures Potential scaling factor for catchment loads	Map from LPI 1:25,000 topographic series
Estuary volume	Input for dilution and flushing	Establish correlations with other physical factors eg area
Estuary depth	Potential scaling factor for catchment loads	Establish correlations with other physical factors eg area
Estuary perimeter	Normalise pressures	Map from LPI 1:25,000 topographic series
Catchment		
Area	Normalise pressures Input to catchment hydrology	
Topography	Input to catchment hydrology	
Hydrology		
Rainfall	Catchment hydrology model Direct input onto estuary surface	
Runoff	Input to estuary for flushing	Regionalise calibrated model parameters
Evaporation	Catchment hydrology model Direct loss from estuary surface	
Hydrodynamics		
Tidal prism	Input to tidal flushing	Use tidal range and estuary area
Tidal range	Input to tidal flushing	Use default values for each classification type
Tidal flushing	Classification variable Potential scaling factor for catchment loads	Use default tidal range, estuary area and exchange efficiency values
Dilution	Classification variable Potential scaling factor for	

Attribute	Intended uses	Data gap-filling
	catchment loads	
Classification		
Entrance condition	Needed for response classification Opening level/training as pressure	Local government records
Geomorphology	Correlation variable for gap-filling data	Aerial photograph interpretation
Chlorophyll response	Stratify sampling design Basis for reference conditions	Utilise factors available for all estuaries

In the following sections, the data sources, analysis and interpretation for each contextual dataset listed in Table 3 are described.

4.1 Morphometry

4.1.1 Estuary volume

Hydrographic surveys of the bathymetry of NSW estuaries have been conducted by the NSW Government over the last 100 years, with many of those in the last 30 years. Surveys are available for 80 estuaries, mostly in digital format since 1992 but with some of the older surveys still in paper form. The paper surveys are being converted to digital format as resources permit. A full listing of hydrographic surveys is included in Appendix 2.

Of the 80 surveys, 49 were in a form suitable for gridding into a Digital Elevation Model (DEM) with a horizontal resolution of generally 12.5 m. In addition, a single DEM with a spatial resolution of 25 m is available to describe topography over all NSW coastal catchments. The bathymetric and topographic models were merged so that a continuous surface could be created up to at least 1.6 m Australian Height Datum (AHD) which is above Mean High Water Spring tide for NSW estuaries. The procedure used for generating merged DEMs is described in DECC (2009a).

Gridded bathymetry was prepared for the following 49 estuaries: Cudgen Creek, Clarence River, Wooli Wooli River, Corindi River, Moonee Creek, Deep Creek, Macleay River, Saltwater Creek (Frederickton), Killick Creek, Hastings River, Cathie Creek, Wallis Lake, Smiths Lake, Myall River, Lake Macquarie, Tuggerah Lake, Wamberal Lagoon, Avoca Lake, Brisbane Water, Narrabeen Lagoon, Dee Why Lagoon, Lake Illawarra, Werri Lagoon, Crooked River, Wollumboola Lake, Jervis Bay, St Georges Basin, Swan Lake, Conjola Lake, Narrawallee Inlet, Burrill Lake, Tabourie Lake, Willinga Lake, Durras Lake, Clyde River, Tomaga River, Moruya River, Coila Lake, Tuross River, Kianga Lake, Wagonga Inlet, Nangudga Lake, Wallaga Lake, Bega River, Back Lagoon, Merimbula Lake, Pambula River, Curalo Lagoon and Wonboyn River.

The DEMs for the 49 estuaries were used to calculate the underwater horizontal area at vertical intervals of between 0.1 and 0.2 m, starting at the deepest point in each estuary (hypsometry). The hypsometry was then converted to total water volumes below elevations of 0.0, 0.2, 0.4 and 0.6 m AHD.

In addition, the NSW Maritime Authority has calculated water volumes for Parramatta River, Lane Cove River, Middle Harbour Creek and Port Jackson at Mean High Water Mark (MHWM – defined as 1.48 m above zero level on the Fort Denison Tide Gauge) and at zero Fort Denison Tide Gauge, and the area, perimeter (including island foreshore) and depth all at MHWM.

An example of the bathymetric and topographic contours and the hypsometry calculated for Smiths Lake is shown in Figure 3.

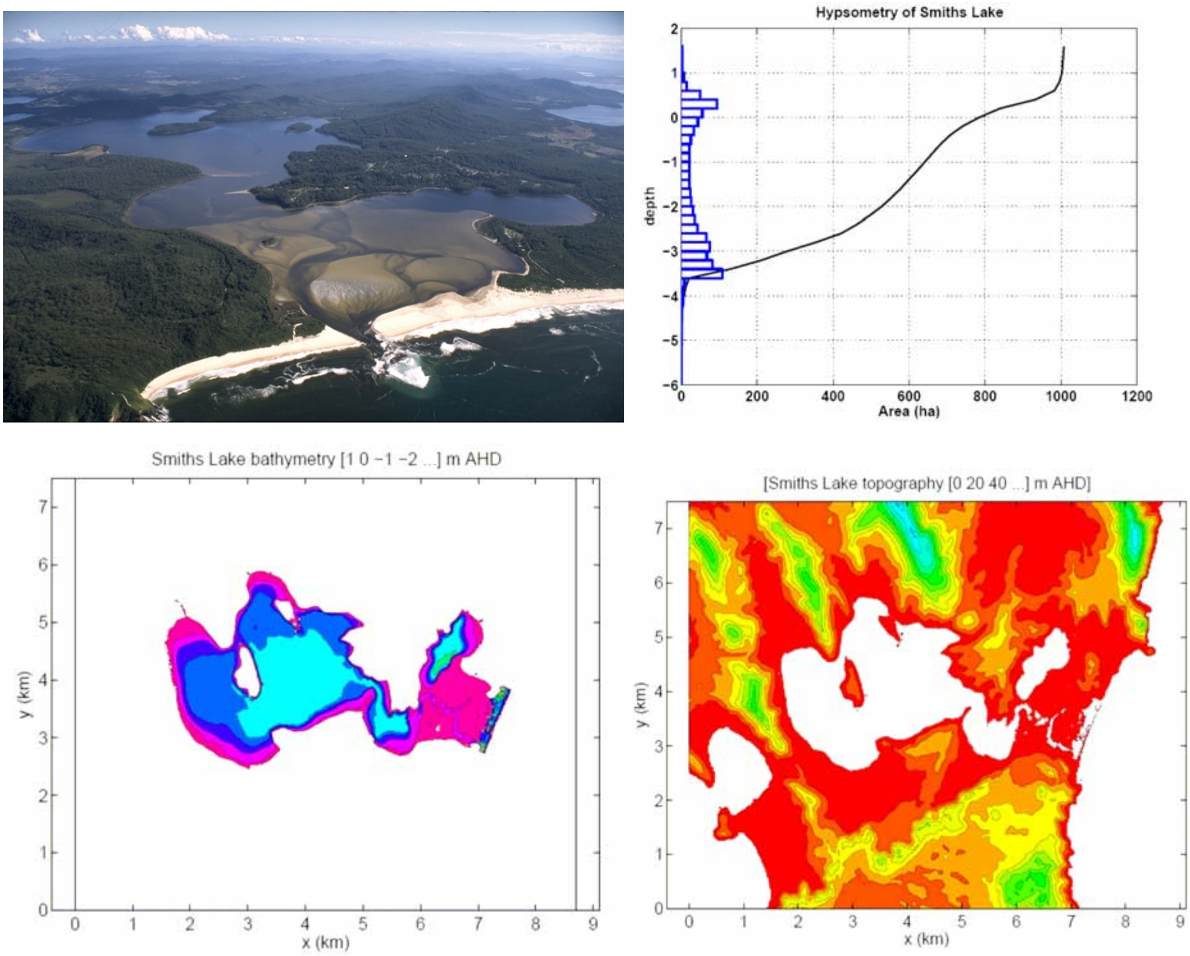


Figure 3: Example hypsometry for Smiths Lake

As only 53 out of a total of 184 estuaries have hydrosurveys sufficiently detailed to calculate volumes, exploratory analysis was conducted to determine if other physical variables, such as estuary and catchment areas, could be used to empirically predict volumes for the remaining 131 estuaries without hydrosurveys. The best correlation was found between estuary surface area and estuary volume as shown in Figure 4 (line of best fit only shown for 0.0 m AHD).

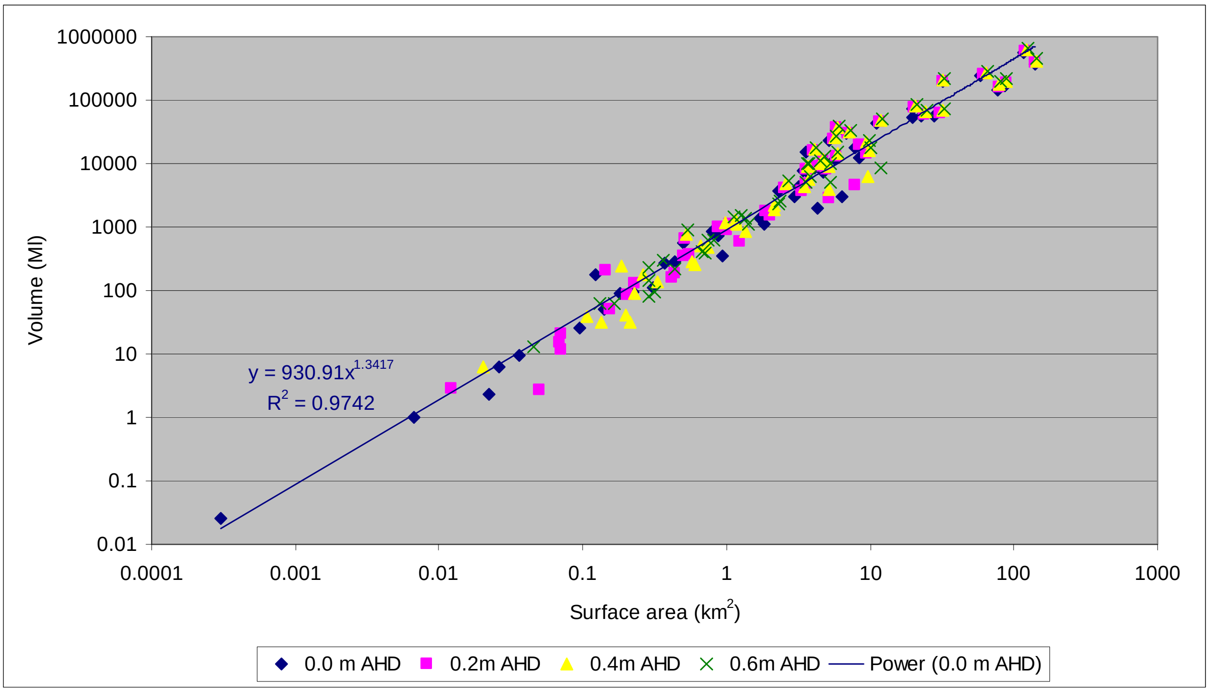


Figure 4: Comparison of estuary surface area and volume

While the correlation explains much of the variability, the logarithmic scales mask considerable scatter. Further analysis of the area-volume relationships found grouping estuaries by geomorphic type in accordance with the scheme of Roy et al. (2001) improved the correlations. This was particularly important for the large number of estuaries with relatively small surface areas. Four groups of different estuary geomorphic types were found to adequately account for variability as shown in Figure 5.

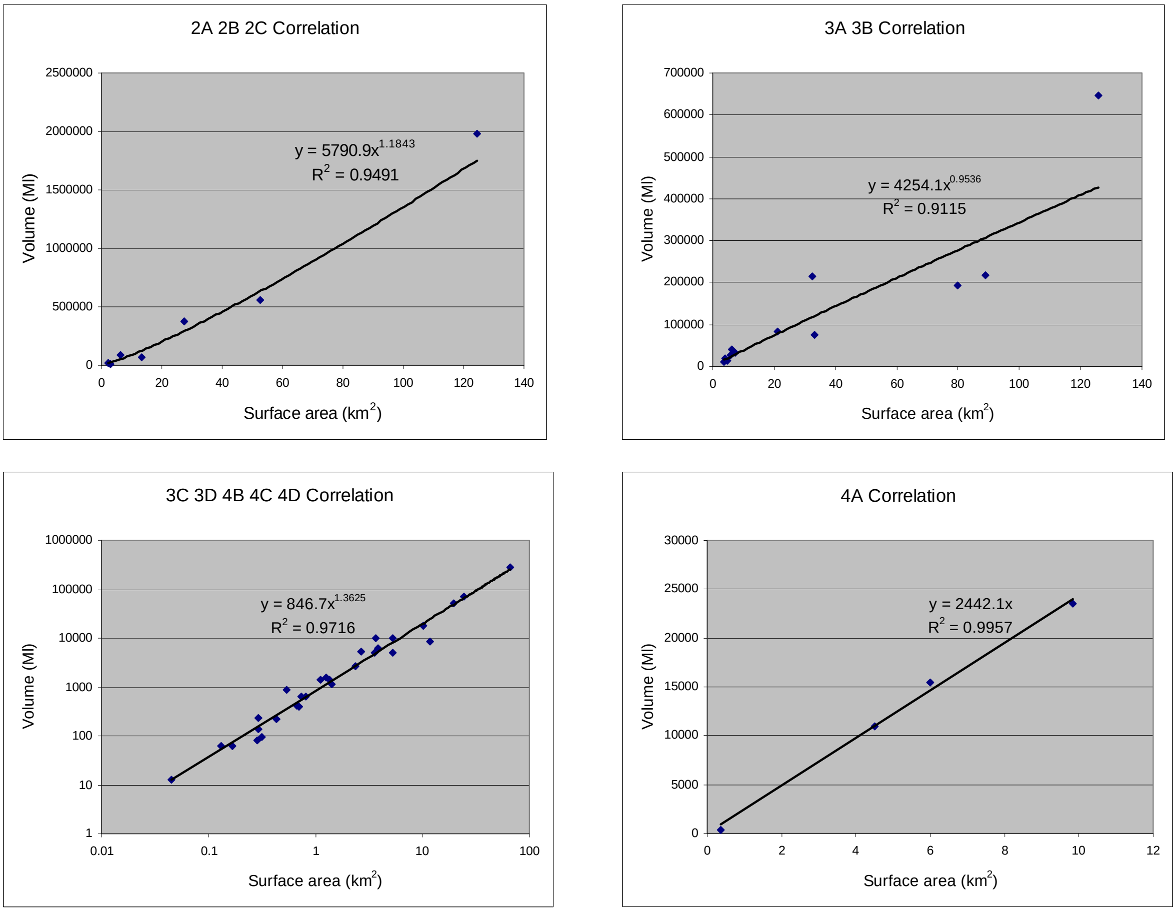


Figure 5: Correlations between estuary volume and surface area for different geomorphic types

Note: 2 = tide-dominated estuaries, 3 = wave-dominated estuaries, 4 = intermittent estuaries
A = youthful, B = intermediate, C = semi mature, D = mature

All correlations were based on areas at 0.6 m AHD for a number of reasons, including the following:

- LPI mapping of the boundaries of estuary water surfaces is generally done with aerial photographs selected with maximum inundation
- MHW Spring tides are generally around 0.6 m AHD or higher
- Coastal lagoons generally experience closure around 0.6 m AHD so this is likely to be a minimum level at which aerial photography is flown.

A comparison was made between the estuary surface areas generated using the merged DEM methods described in DECC (2009a) and those generated from the MER program using aerial photograph interpretation (API) all at 0.6 m AHD. The results shown in Figure 6 for estuaries less than 20 km^2 in area (38 estuaries or 78 per cent of 49 total) indicate that the merged DEM areas are significantly below the MER program API areas. This is to be expected for reasons including the following:

- The gathering of bathymetric data is limited to depths generally navigable by boat although some more recent surveys are being extended to top of bank. Large areas of low-lying semi-submerged banks may not have been surveyed and the merged DEMs may not have adequately captured these potentially large expanses

- Areas of mangrove and saltmarsh are generally not captured by hydrosurveys with similar implications to the above
- There could be tributaries of estuaries that for various reasons (eg limited access) may not have been included in the hydrosurvey.

Also included in Figure 6 are the MER program API areas excluding saltmarsh areas which extend down to Mean High Water level of about 0.6 m AHD. These are a closer fit to the merged DEM areas and therefore have been used to generate volumes for the 131 estuaries without hydrosurveys based on the regression relationships shown in Figure 5. Checking of the actual volumes of the 53 estuaries having hydrosurveys with the predicted volumes using the total estuary area including mangrove and saltmarsh showed a median overestimate in predicted volume of 23 per cent (inter-quartile range -5 to +70 per cent). Reducing the total area to exclude saltmarsh reduced the median in predicted volume to an underestimate of five per cent (inter-quartile range -17 to +51 per cent). The final volumes adopted were the actual volume where available; otherwise, the volume predicted using the estuary without saltmarsh area.

As the merged DEM areas are smaller than the MER program API-derived areas, the total volumes for the former are likely to be less than the actual amount. The extent to which this occurs cannot be determined without comparison between the merged DEMs and more accurate DEMs generated using topographic data at a finer resolution, eg Light Detection And Ranging (LiDAR) data which uses laser pulses to generate large amounts of information on the physical layout of terrain and landscape features.

Additional work is required to refine the volume estimates for the next round of SOC reports. A report has been prepared for OEH exploring options for storing bathymetric data and generating DEMs and other useful tools to better integrate bathymetric, topographic and LiDAR data.

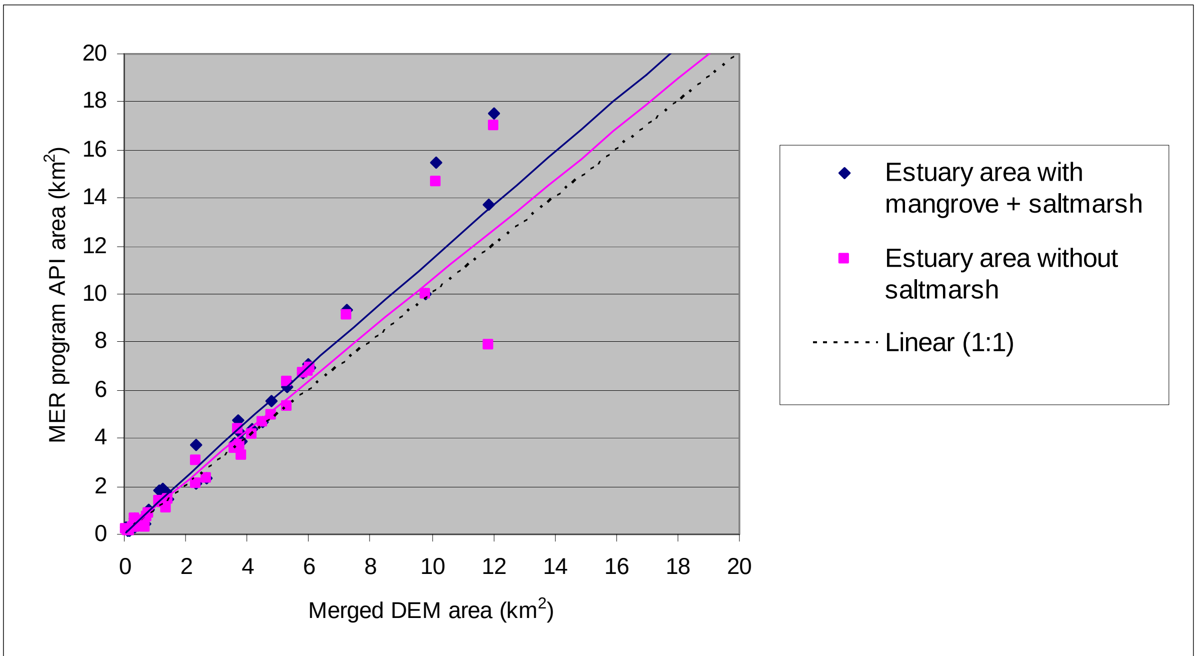


Figure 6: **Comparison of estuary areas from merged DEMs and MER program API**

4.1.2 Estuary depth

Estuary depth has been estimated by dividing the total volume at 0.6 m AHD by the total surface area of the estuary including seagrass and mangrove but excluding saltmarsh.

4.1.3 Estuary perimeter

The combined LPI estuary and DPI macrophyte polygon layer was used to generate estuary perimeters. However, the fine scale resolution of the macrophyte layer resulted in unrealistically large estimates of perimeter. The LPI estuary layer is relatively smooth in its delineation of the water boundary and was used to generate the final perimeters. This method is sufficient for the purposes of the MER program as the primary use of perimeter is for comparison of the proportion of foreshores disturbed by human activity such as foreshore structures or riparian vegetation removal. It was also used for exploratory analysis of potential scaling factors for nutrient loading.

A summary of morphometric parameters for NSW estuaries is shown in Appendix 3.

4.2 Catchment area

4.2.1 Data sources

Land-use mapping for Eastern and Central NSW commenced in April 2001 and was completed in June 2007 by OEH. Aerial photography and satellite imagery was acquired between 1999 and 2006 depending on availability and the timing of mapping. While the photography and imagery were acquired over a seven-year period, the scale of land-use change is unlikely to significantly affect the accuracy of the analysis and modelling relying on this information.

Land-use is classified using three separate schemes:

- Australian Land-Use and Management (ALUM)
- NSW Standard Classification for Attributes of Land (SCALD)
- NSW Land-Use Mapping Program (LUMAP).

The ALUM classification is the coarsest of the three schemes with 159 land-use classes as shown in Appendix 4. The NSW LUMAP has the finest resolution of land-use totalling 481 separate classes. Land-use classes with similar runoff characteristics were allocated to one of 21 hydrological groups for the purposes of 2CSalt hydrological modelling as shown in Appendix 5. This was followed by further aggregation into nine classes of forest, cleared land, urban, crops, grazing, irrigated pasture, dry forb, irrigated forb and other for the purposes of nutrient and sediment export modelling as shown in Appendix 6.

The estuary surface GIS layer which included water, seagrass, mangrove and saltmarsh was clipped to the detailed land-use layer and summary statistics derived for the nine aggregated land-use classes. Data for all nine land-uses excluding 'forest' and 'other' were summed to provide an estimate of the total area of disturbed land within each estuary catchment as shown in Appendix 7.

4.2.2 Limitations of the land-use mapping

A comparison was made between the estuary surface including macrophytes mapped under this MER program and the land-use mapping layer. A map of Cudgera Creek land-use shown in Figure 7 illustrates a number of limitations. These include the following:

- A significant mismatch exists between the lateral boundaries of the estuary under the two mapping programs
- The land-use mapping program has allocated the ALUM Code 6.3.0 River to the estuary in preference to ALUM Code 6.6.0 Estuary/coastal waters
- The southern tributary has mapped as ALUM Code 6.3.0 River in contrast to the northern tributary which has mapped as ALUM Code 1.3.3 Residual native cover
- ALUM Code 1.3.3 Residual native cover has mapped variously as estuary, seagrass, mangrove and saltmarsh
- The ALUM Code 6.6.0 has mapped to areas of mangroves at the northern end but not at the southern end.

A map of Tomaga River land-use is shown in Figure 8 illustrating the various codes under the ALUM, SCALD and LUMAP classification schemes that make up the ALUM Major Category Code 6 Water. These are the main codes that cover the MER program estuary mapping boundaries. It can be seen that:

- the MER program estuary area is covered by up to six SCALD and LUMAP codes describing various estuarine features
- there are significant differences in the area of mangrove mapped between the two programs
- the 6.5.0/k0o/56 (ALUM, SCALD, LUMAP codes respectively) Coastal marsh/estuarine swamp covers variously saltmarsh, mangrove or sometimes neither
- the 6.6.0/f5o/55 Mudflat covers variously saltmarsh, mangrove or sometimes neither
- one patch of seagrass has mapped as 6.1.0/f5a/105 Coastal lake.

The MER program estuary and macrophyte areas are included in either the 'forest' (as conservation area such as a national park) or 'other' (as river, wetland or sand) hydrological land-use classes. The exception is ports, bays and harbours which were not generally included under the NSW LUMAP.

These two figures demonstrate differences in interpretation and accuracy between the two mapping methods. The differences are minor when grouping land-uses into broad categories for hydrological modelling and sediment and nutrient export calculations.

Also shown in Appendix 7 is a comparison between the areas defined in the MER program and those extracted into the nine land-use classes for the hydrological models. There are differences of 4% or more for 30 estuaries (10% or more for 18 of those 30 estuaries), the reasons for which have been identified as:

- incorrect land-use extraction for 14 estuaries
- estuary excluded from the land-use map for nine estuaries
- land-use map was clipped along the coastline for one estuary
- incomplete land-use map for six estuaries, all of which are in the Sydney Metropolitan Area where land-use mapping is incomplete and coarse scale land-use data from the National Land and Water Resources Audit was substituted.

As these data were used for calculating the percentage of disturbed land in each estuary catchment, the cleared land pressure indicator (see Section 9.6) for these 30 estuaries may change in the next round of SOC reporting. The extent of the change will be variable with most scores either not changing at all or moving by one scoring class while a small number may change significantly. The effect on the overall pressure indices will be small as the cleared land indicator is one of eight used in the assessment. Separate land-use extractions were performed in subsequent processes for modelling catchment rainfall runoff (see Section 4.3) and calculating sediment and nutrient export loads (see Section 9.9 and Section 9.10) and are unaffected.

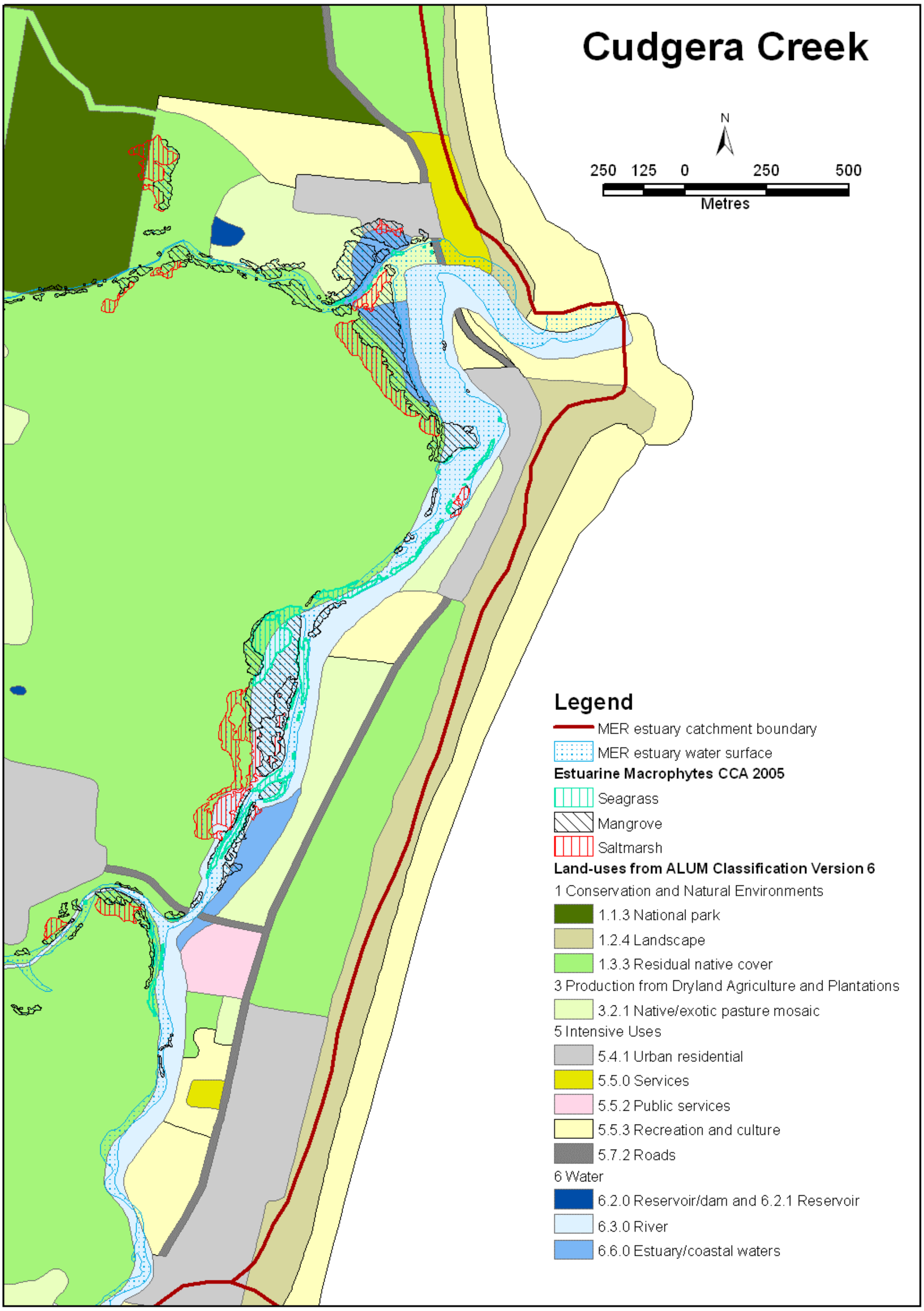


Figure 7: Land-use map for Cudgera Creek

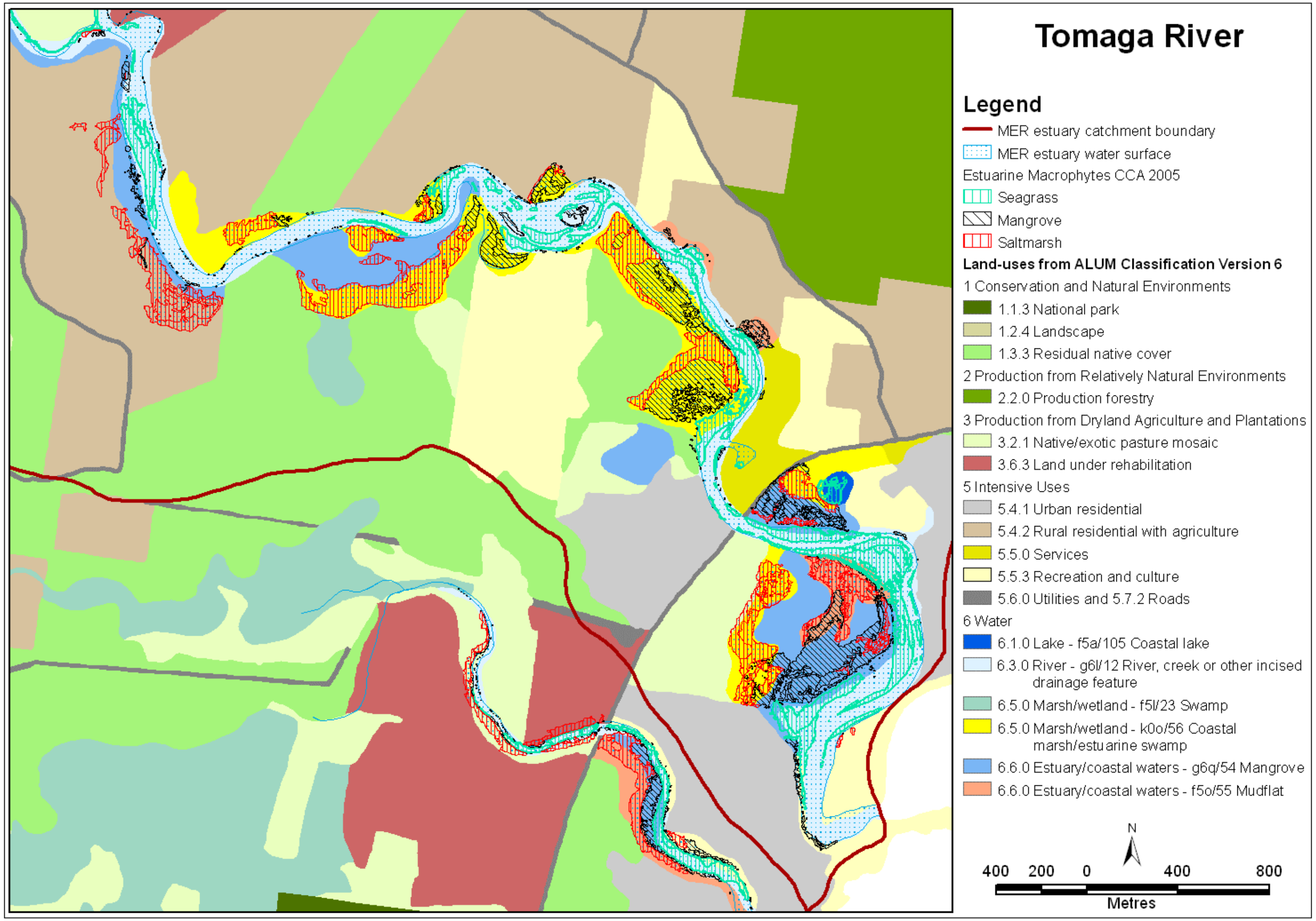


Figure 8: Land-use map for Tomaga River

4.3 Hydrology

Hydrological modelling has been undertaken as part of the NSW Government's WSP process for only a very small number of catchments on the coastline. The Integrated Quantity and Quality Model is the primary means of simulating freshwater streamflow on a daily basis which is required for setting water sharing rules. For the purposes of the Estuaries MER program, total annual inflows were required to assess the effect of freshwater flows on dilution capacity and flushing times, and to estimate the annual export of sediments and nutrients from catchments into the estuary.

The coastal stream gauging network consists of 98 gauging stations with more than five years of data, located across 34 catchments providing a limited dataset for model calibration. Of these 98 stations, 78 had data useful for calibration across 28 estuary catchments. These 28 estuary catchments were Tweed River, Brunswick River, Richmond River, Corindi River, Bellinger River, Nambucca River, Macleay River, Hastings River, Camden Haven River, Manning River, Wallis Lake, Myall River, Karuah River, Lake Illawarra, Minnamurra River, Shoalhaven River, Currambene Creek, St Georges Basin, Butlers Creek, Clyde River, Tuross River, Wallaga Lake, Bermagui River, Murrah River, Bega River, Back Lagoon, Towamba River and Merrica River.

As hydrology was required for all 184 estuary catchments, any model needed to be capable of providing regionalised parameters for use in catchments without a flow gauge. The model selected that best met the requirements and limitations was 2CSalt.

The 2CSalt model was designed to allow state agencies within Australia to model upland unregulated catchments in a consistent manner across large areas (Littleboy et al. 2009). It has been developed and extensively tested and applied with the Murray–Darling Basin but can be applied more widely. The model quantifies surface and sub-surface contributions to salt and water export and predicts the impacts of land-use change on those exports at a catchment scale. It was designed to make use of existing regional datasets such as Groundwater Flow Systems (GFSs) and topography. Outputs include monthly predictions of water and salt movement across several water pathways with a hillslope and alluvial groundwater store, leading to water and salt contributions to streams.

4.3.1 Input data

A number of datasets were required as input for the modelling:

- Land-use mapping was simplified into the 21 hydrological classes that better reflect catchment rainfall runoff response
- DEM was based on 25 m resolution but resampled to 100 m
- Climate zones reflected total rainfall and rainfall seasonality. For each of the 528 climate zones of NSW, daily weather data from 1956–2006 were extracted from the Queensland Department of Natural Resources SILO dataset. SILO is an online database developed by the Bureau of Meteorology in 1997, with about 120 years of continuous daily weather records for Australia including rainfall, temperature (minimum and maximum), radiation, evaporation and vapour pressure. The mean annual rainfall is shown in Figure 9
- Detailed soil mapping was used where available and infilled with coarser land systems mapping for other areas. After attributing each soil unit with a Greater Soil Group, soil hydraulic

properties (water content at air dry, wilting point, field capacity and saturation, and hydraulic conductivity) were obtained

- As there is no detailed GFS mapping for coastal NSW, a simple GFS map was generated from 1:250,000 geology mapping. Attributes of aquifer depth, specific yield and hydraulic conductivity were added using simple lookup tables based on geological type.

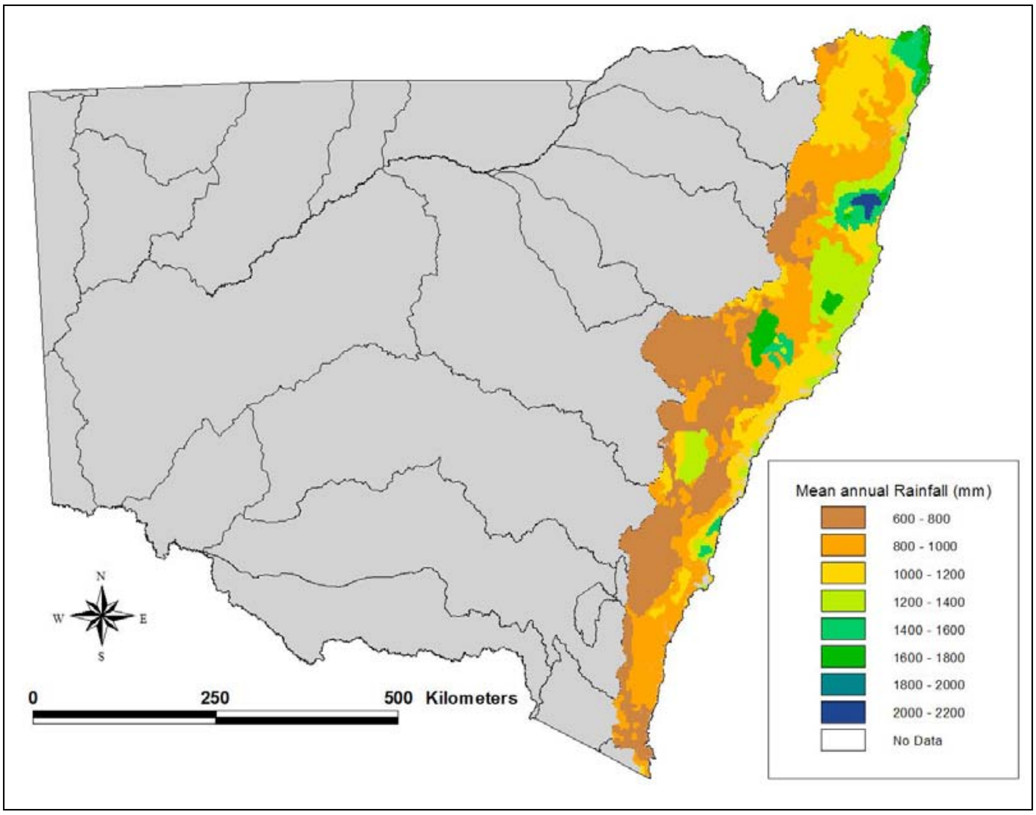


Figure 9: Mean annual rainfall in NSW coastal catchments

4.3.2 Model calibration

Rather than calibrating a model with historical streamflow data, then regionalising parameters to ungauged catchments, 2CSalt can be run with a standard set of parameters and still provide acceptable predictions of streamflow and salt loads. Flows estimated from the model can be scaled based on regionalising scale factors. The procedure was as follows:

- For each of the 78 gauging stations, the ratio between the measured and uncalibrated modelled annual flows was calculated on an average annual basis
- The 78 ratios were grouped according to the river basin the gauging station was located in. These 14 river basins were Tweed, Brunswick, Richmond, Bellinger, Macleay, Hastings, Manning, Karuah, Shoalhaven, Clyde, Tuross, Bega and Towamba River basins and the Wollongong Coast Basin
- For each river basin, the mean ratio was calculated and applied as a scaling factor to linearly adjust estimated flows.

Estimated and measured average annual streamflows for the 78 gauging stations are shown in Figure 10 for the uncalibrated model in ML (a) and mm (c) and for the uncalibrated model after application of the regionalised scaling factors in ML (b) and mm (d). Results have been given in mm as well as ML to remove the effects of catchment area when assessing model performance. After application of the linear scaling factors, 2CSalt explained 98 per cent and 78 per cent of the variation in average annual flows in ML and mm respectively. Model performance was poorer for the flow in mm, probably due to the wide range in catchment area (0.3 km^2 to 22,100 km^2).

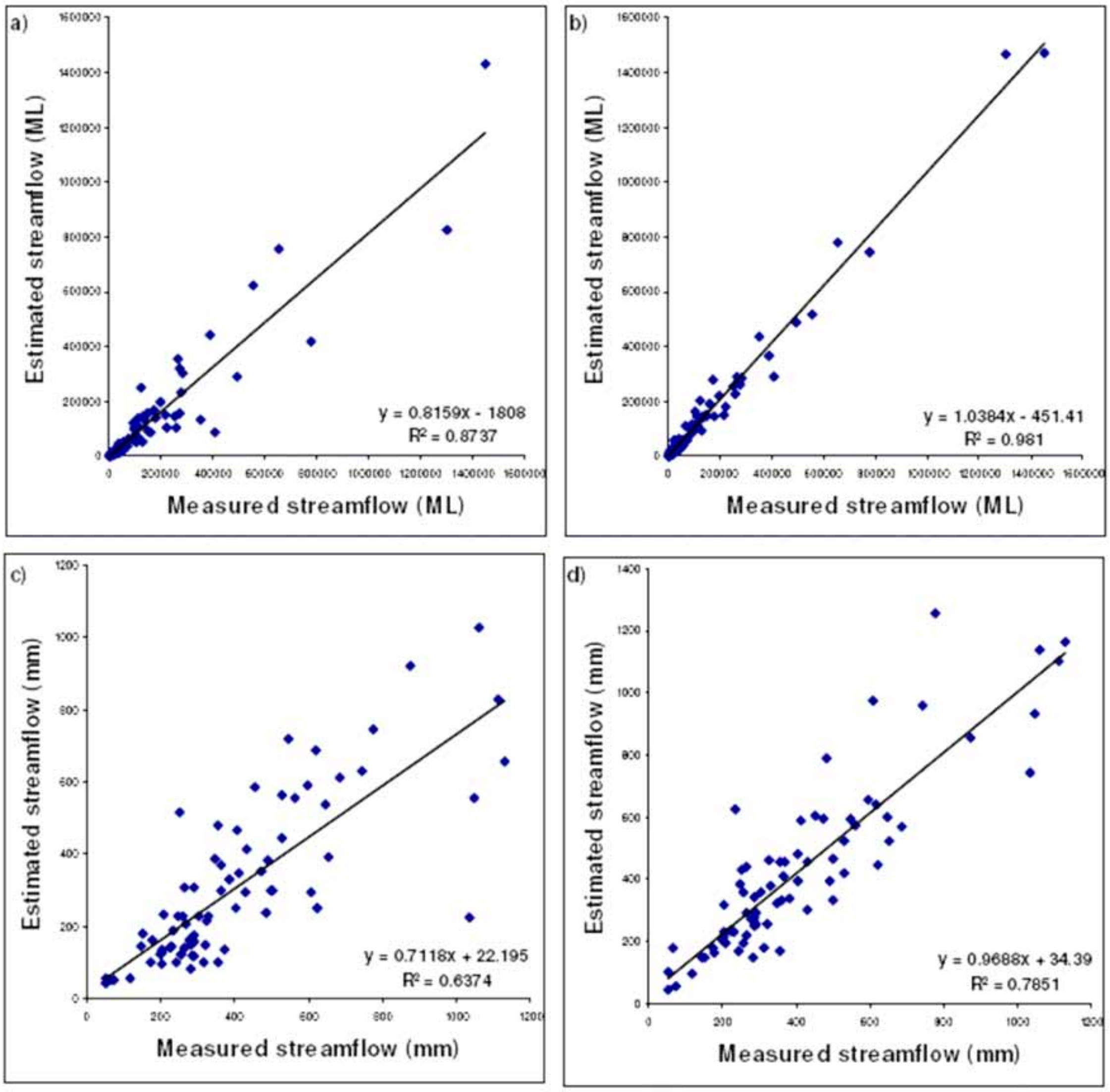


Figure 10: Comparison between mean annual measured and modelled streamflow

Notes: ML = megalitres of annual streamflow
mm = millimetres depth of annual streamflow normalised by catchment area
a) and c) = uncalibrated model
b) and d) = uncalibrated model after application of regionalised scaling factors

4.3.3 Model results

The models were run for two land-use scenarios: current land-use and a pre-European settlement undisturbed catchment. Modelling provided estimates of surface flow (high flows), base flow (low flows) and total streamflow in a monthly time series (see Appendix 8). Increases in surface flows reached 76 per cent, base flows 913 per cent and total streamflows 142 per cent with averages of

14 per cent, 97 per cent and 27 per cent respectively. More than 50 per cent increases in surface, base and total flows occurred in 16 per cent, 53 per cent and six per cent of catchments respectively.

Runoff coefficients representing the ratio of annual runoff to rainfall for pre-European undisturbed catchment conditions and current land-use are shown in Figure 11 together with annual rainfall. As would be expected the relative proportion of rainfall appearing as runoff increases as the rainfall increases and soil moisture stores become saturated. Clearing of land within catchments serves to further increase the relative proportion of rainfall appearing as runoff.

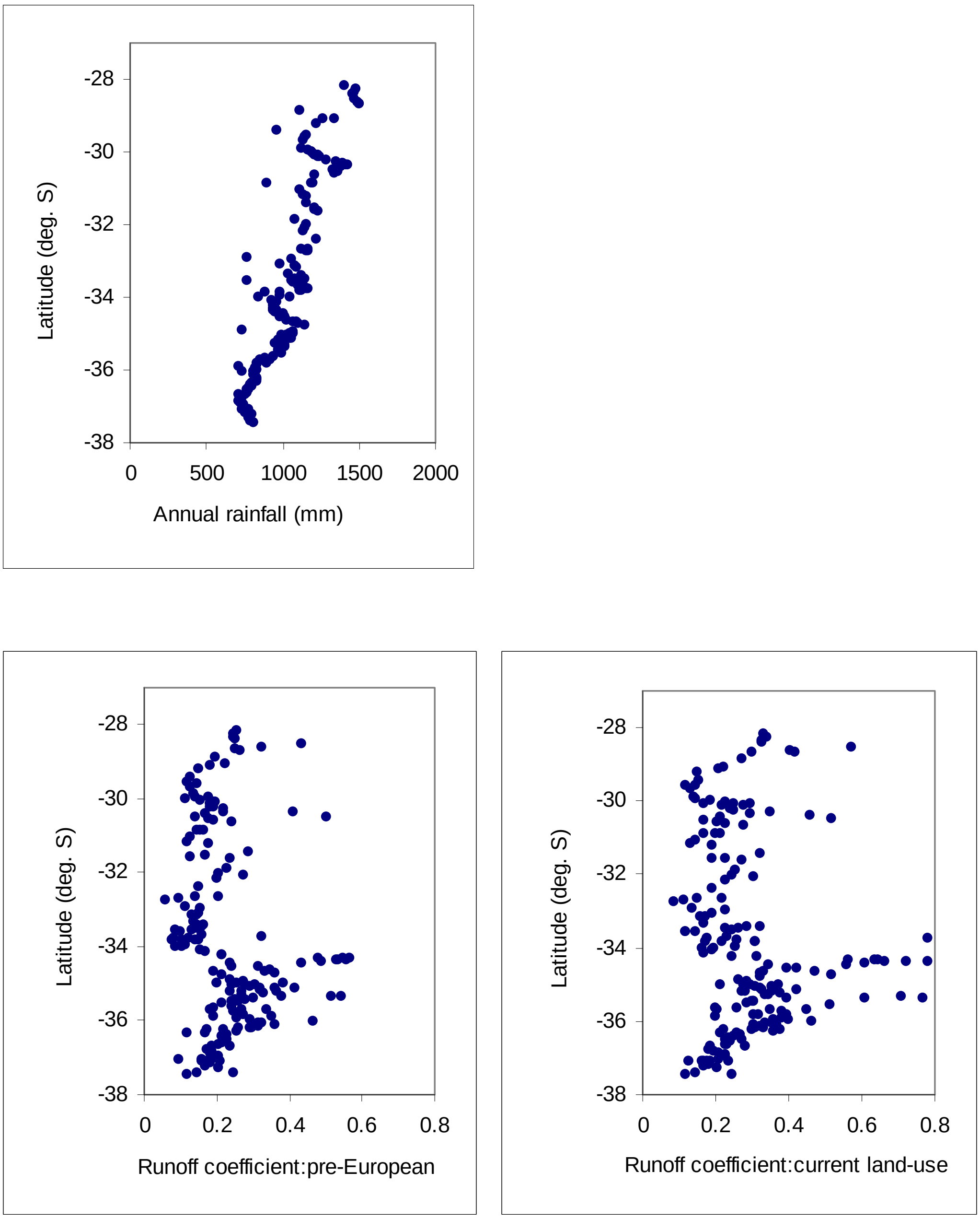


Figure 11: Rainfall and pre-European/current land-use runoff coefficients

4.3.4 Limitations and recommendations

Further work is required to assess the validity of the regionalisation procedure by the systematic removal of a subset of catchments from the process. The impacts of catchment area on the results should be further examined.

A scaling procedure using daily rainfall records could be used to break down the monthly flow estimates into a daily time series and generate flow duration curves. These could be used in:

- finer scale assessment of the influence of rainfall runoff on chlorophyll a and turbidity
- development of additional metrics of hydrological stress particularly under low flows
- generating daily water balance models to assess changes to inundation regimes and peripheral vegetation in intermittently open estuaries subjected to entrance manipulation.

The table in Appendix 8 showing catchment runoff also includes the catchment area from the DEM generated for use in the modelling process. The areas derived for the purposes of hydrological modelling were in a GIS raster format, as required by the 2CSalt model, compared with the GIS polygon format used for generating MER program areas. A comparison was made between the DEM areas and the MER program catchment areas. Some of the DEM areas were found to be larger primarily due to either the DEM capturing large areas of estuary foreshore down to 0.0 m AHD or else the DEM capturing the estuary surface area particularly in shallow systems where the water surface is elevated. The effect on total flows from each catchment is minimal.

4.4 Hydrodynamics

Algal blooms are dependent on a complicated interplay between physical, chemical and biotic controls on bloom dynamics (Pinckey et al. 2001). Factors influencing nutrient movement include tidal range and asymmetry, ocean currents, upwelling, wind, density stratification and gradients (salinity/temperature), advection, catchment hydrology, biological community composition, microbial associations, grazing, rate and magnitude of biotic cycling, water residence time (McKee et al. 2000; Pinckey et al. 2001).

A number of different terms are applied to the transport and removal of materials such as nutrients from estuaries including residence time, flushing time and turnover time (US EPA 2001). More generally these are referred to as 'water residence time'.

'Freshwater residence time' is defined as the average amount of time freshwater resides in the estuary before exiting the entrance. It can be calculated by the freshwater fraction method which gives the time required for the volume of freshwater in an estuary to be replaced by the input rate of freshwater. It requires knowledge of inflows, estuary volumes and average salinity. This is generally the most useful for analysis of eutrophication in estuaries because most nutrients are introduced with freshwater. It has been criticised for an apparent focus on freshwater at the expense of not including flushing by seawater. However tidal flushing is accounted for implicitly because the average estuarine salinity used in the calculation reflects all processes bringing seawater into the estuary. The method can only be applied to systems with significant freshwater input. Numerical models can be developed to segment complex systems and improve the spatial resolution of residence time estimates.

Where salinity data are not readily available and tidal flow is the dominant flushing mechanism, 'estuary flushing time' can be calculated using the classical tidal prism method (Dyer 1973). This requires knowledge of estuary volume and tidal prism and assumes that the system is well mixed. A modification to this method is to include an exchange efficiency coefficient applied to the tidal prism. This can be used to account for the incomplete mixing that occurs inside the estuary with each new flood tide and the potential for some of the ebb tide flow to not disperse away from the entrance if offshore wave and current energy is low. Any moderate freshwater flows will be accounted for in the tidal prism but the exchange efficiency may be lower. Guo & Lordi (2000) found the third method gave flushing times lying between times from the freshwater fraction and tidal prism methods.

'Estuary residence time' can be calculated using numerical models to determine either:

- the mean amount of time for a particle of water at any location within an estuary to leave the estuary
- the time necessary to reduce an initial pollutant concentration to 1/e (where e ~ 2.718).

For the MER program, estuary flushing time was assessed using the tidal prism method modified with an exchange efficiency coefficient. Salinity data were available for 33 of the 80 estuaries that are permanently open or are intermittent and have a tidal gauging. There was insufficient salinity data for all 80 estuaries to use the freshwater fraction method. Numerical models of estuary residence time were not feasible considering the large number of estuaries that could have potentially been modelled. The key dataset required was therefore tidal prism from which tidal flushing could be derived.

4.4.1 Tidal prism

Tidal gaugings have been conducted by OEH and former constituent agencies on 51 estuaries within NSW dating back to 1977. A compilation of all tidal gaugings was prepared by Manly Hydraulics Laboratory (MHL 2004) and was accessed for data on:

- gauging line location closest to the estuary entrance
- ebb tide tidal prism and range at gauging line
- flood tide tidal prism and range at gauging line
- Fort Denison ebb and flood tidal range.

Tidal gaugings are generally undertaken near the spring tide cycle to capture as much inundation of peripheral tidal flats as possible. For smaller systems subject to closure, gauging tends to occur during scoured rather than shoaled entrance conditions so that, again, tidal flows are maximised. Reasons for historically favouring this particular combination of oceanographic conditions relate primarily to gathering data useful for calibrating numerical models.

For the MER program, flushing times are of interest for developing classification systems and for exploratory analysis of scaling factors to be applied to nutrient loading. Field sampling of water quality for the MER program is done on a monthly basis at irregular stages of the spring-neap tidal cycle. Flushing times more representative of typical conditions are therefore required.

The tidal prism data from tidal gaugings were adjusted in a three-stage process as follows:

1. The ratio of the Fort Denison tidal range recorded on the gauging day (averaged over the ebb and flood tides) to the long-term average Fort Denison tidal range (calculated between MHW

and Mean Low Water) was used to linearly scale down the gauged tidal prism (also averaged over ebb and flood). However, tidal planes were calculated for the period 1987 to 2006 using water level records from Middle Head as the recorder has been operated continuously by MHL as part of a state-wide network.

The tidal planes relative to AHD are as follows:

- o HHWSS 1.00 m AHD
- o MHWS 0.66 m
- o MHW 0.53 m
- o MHWN 0.41 m
- o MSL 0.03 m
- o MLWN -0.33 m
- o MLW -0.47 m
- o MLWS -0.60 m
- o ISLW -0.85 m.

The mean adjustment was -24% with an inter-quartile range of -35 to -13%. Only two estuaries, Port Hacking and St Georges Basin, were corrected upwards

2. Long-term water level recorders are located in a number of estuaries. Some of those estuaries, particularly in riverine systems, have more than one recorder. Tidal plane analysis of these long-term records has been conducted by MHL (MHL 2003). Tidal planes were available in eight estuaries with tidal gaugings. For those eight, the tidal range at the downstream gauging line was interpolated and the ratio between the interpolated value and the Fort Denison corrected range applied as a linear adjustment. Where the gauging was between the entrance and the most downstream water level recorder (a further nine estuaries), the range at the recorder was adopted. Five more estuaries had tidal planes available at or near their entrances. The mean adjustment was -6 per cent with an inter-quartile range of -14 to +5 per cent. Ten estuaries were found to be shoaled (mean adjustment of +10 per cent) and 12 scoured (mean adjustment of -18 per cent)
3. For the 46 estuaries with tidal gaugings upstream of the entrance, a further addition to the tidal prism was required to include the volume between the gauging line and the entrance mouth. The estuary surface area polygons were manually examined on-screen and the entrance channel width at the gauging line determined then checked, to be generally representative of the downstream inlet channel width. The additional tidal prism was calculated as the product of the gauging line width, the distance from the entrance mouth and the average of the tidal range at the gauging line location and the ocean (which was taken as the mean Fort Denison range). The average additional volume was 18 per cent.

4.4.2 Tidal range

Tidal range can be calculated by dividing the volume of the average tidal prism by the surface area. Surface areas are available for open water (including seagrass extent), mangrove and saltmarsh. As mangroves and saltmarsh can occupy up to 69 per cent and 43 per cent respectively of the total surface area of an estuary it is important to consider which surface area best represents the average for the estuary.

Saltmarsh typically occurs between Mean High Water and Highest Astronomical Tide. As the tidal range of interest lies between Mean High Water and Mean Low Water, saltmarsh areas were excluded.

At least five mangrove species are found in NSW with the two most common being Grey Mangrove and the River Mangrove. Mangrove species occur in zones parallel to the shoreline, determined by tide levels and soil conditions. The River Mangrove occurs in the fringing zone, adjacent to open water, close to the Mean Sea Level mark. The Grey Mangrove is found behind the River Mangrove at a level just above Mean Sea Level and extends inland to a level well below Mean High Water. The Grey Mangrove occupies extensive areas of inter-tidal flats whereas the River Mangrove tends to be confined to a narrower fringing band closer to the waterbody. For the purposes of the MER program, the surface area adopted was open water (including seagrass extent) plus 50 per cent of the mangrove area in recognition of the large expanse of relatively flat inter-tidal area associated with some estuaries and their extent of colonisation by the Grey Mangrove. This reduced the mean tidal range across the 46 estuaries with tidal gaugings from 0.54 m to 0.45 m and importantly, produced tidal ranges that appeared reasonable in those estuaries with substantial mangrove and saltmarsh communities.

For the 34 permanently open estuaries without tidal gaugings, 18 were bays or drowned river valleys and were assigned a Fort Denison range of 1.01 m while the remaining 16 were rivers, lakes, lagoons or creeks and were assigned the mean range of 0.45 m.

A check was made on the internal consistency of the derived tidal range, tidal prism, estuary volume and area as follows:

- A comparison was made between the derived tidal range and the tidal range established from the tidal gauging corrected for the spring/neap tidal cycle. It would be expected that the derived tidal range over the full estuary length would be less than the tidal range at the downstream gauging site
- A comparison was also made between the derived tidal range and the ocean tidal range which could be expected to provide an upper limit to the derived tidal range
- The percentage of the tidal prism to total estuary volume was calculated and would be expected to be significantly less than 100 per cent. Systems that are relatively shallow and short would likely approach 100 per cent as they can be close to fully drained at low tide.

Two inconsistencies were observed being Mooball Creek and Sandon River where the tidal prism ratios were 135 and 91 per cent respectively. On examination of the tidal gauging records, it was evident that the high tide levels were between 0.8 and 0.9 m AHD. The gauged tidal prisms were therefore expanding into saltmarsh and other low-lying areas above 0.6 m AHD which was the level at which areas and hence ranges and prisms have been derived. As both these systems are relatively short and open to the ocean (Mooball artificially trained and Sandon naturally open) it is reasonable to assume the average tidal range as the spring/neap adjusted range at the downstream gauging location. This reduced the tidal prism ratios to 86 and 81 per cent respectively.

4.4.3 Estuary flushing time

Flushing time was calculated for all those estuaries with a tidal gauging which included a number of systems that are intermittently open. The tidal prism method, as previously described, was used adopting a typical exchange efficiency coefficient of 0.15.

For the remaining 104 intermittently open estuaries without a tidal gauging as well as those that were open for a long enough period to warrant a tidal gauging, the concept of a flushing time required different treatment. For intermittently open estuaries that are closed for long periods of time, a flushing time can be approximated by the period the estuary remains closed.

When intermittent estuaries open, water levels drop dramatically as the entrance berm is breached and the estuary is largely flushed during breaching and the ensuing tidal influence. The period until next closure occurs depends on the relative energy of tidal and freshwater flows keeping the entrance open compared with offshore wave and current energy transporting sediment alongshore infilling and ultimately closing the entrance. Based on water level records from intermittently open estuaries, complete closure generally occurs when the beach berm has rebuilt up to about 0.6 m AHD. Breaching levels can be between 2.5 m and 3.0 m AHD or higher.

The flushing time can be estimated by comparing the volume of runoff to the volume of water between the closing level of 0.6 m and the breaching level of 2.5 m AHD. This will give an upper bound to the number of times an entrance may open in a year and a corresponding lower bound to the flushing time. The actual flushing time is likely to be longer due to uncertainties associated with the following:

- A significant proportion of the runoff beyond the initial volume is required to generate a breakout is likely to flow directly to the ocean
- The volumes between 0.6 m and 2.5 m AHD are conservatively calculated as the total estuary surface area is held constant between those two levels
- Breakout levels are likely to vary between 2.5 m and >3.0 m AHD.

For those intermittently open estuaries with relatively large surface areas compared to catchment area, rainfall over a number of events is required to breach the entrance berm, which means these uncertainties are less significant. For smaller systems, relatively minor rainfall will breach the entrance berm so that the flushing times simply converge to the period between rainfall events that breach the berm.

To calculate this period, the volume of runoff and direct rainfall onto the estuary surface required to raise water levels from 0.6 m to 2.5 m AHD was determined. A rainfall record taken from 1889 to 2007 at the Milton Post Office near Ulladulla on the south coast, where small intermittently open lakes, lagoons and creeks are concentrated, was analysed for the frequency of rainfall events as shown in Figure 12. Assuming the entrances to very small systems close relatively rapidly after rainfall, the period between rainfall events sufficient to breach the berm was taken as the flushing time. This procedure was applied to all intermittently open estuaries with the lower bound to flushing times, as defined above, of less than 20 days. This duration approximates the 30 days found by DECC (2009a) as being the lower limit where rainfall event frequency begins dominating the period between openings. A total of 46 estuaries were captured by this process representing 25, 30 and 74 per cent of type 4B, 4C and 4D estuaries respectively. The average flushing time was raised from nine to 29 days which is likely to be a more realistic estimate. These estimates could be considerably improved by constructing a simple daily water balance model for each estuary.

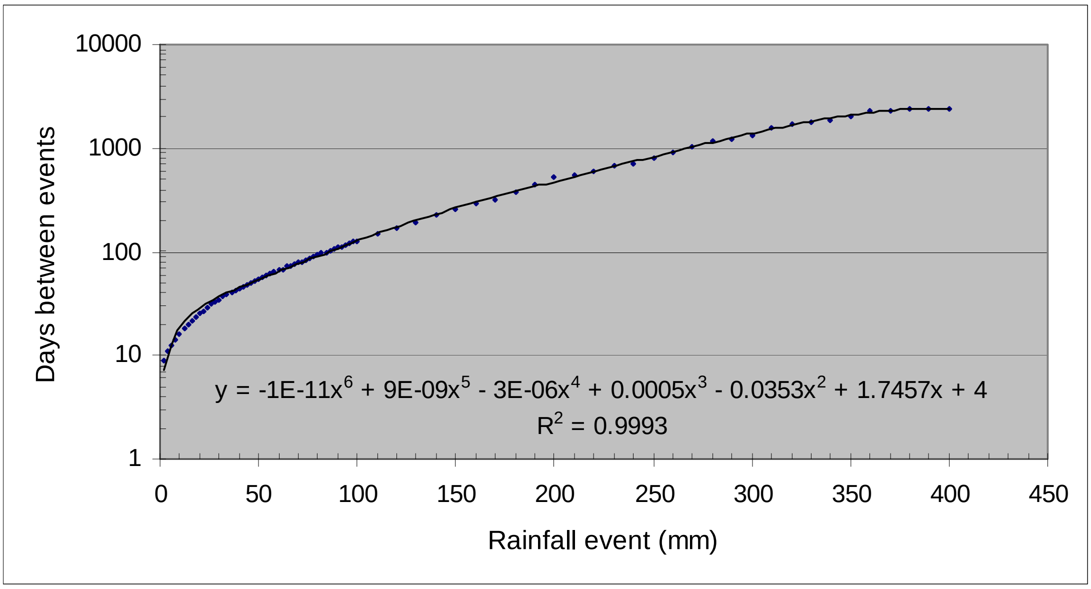


Figure 12: Rainfall event frequency at Milton Post Office

4.4.4 Freshwater flushing

As salinity data were not available for many estuaries, the freshwater residence time has not been calculated. However, there is likely to be further salinity data available from sources not accessed for the MER program that would expand the current database. The use of the freshwater fraction method is most valid in wedge-shaped, well-mixed, relatively vertical riverine estuaries with significant freshwater inputs. It may be that different methods of calculating water residence time are appropriate for different estuarine geomorphic types. This is an area that warrants investigation for the next round of SOC reports.

4.4.5 Estuary dilution

The capacity of an estuary to dilute incoming freshwater flows, and associated nutrients and suspended sediments, during a rainfall event and baseflows from ongoing seepage of groundwater flows can be measured by the relative volume of the estuary compared to catchment inflows. This is a simplistic approach as mixing is greatest at the point of entry of inflows and decreases with distance away from the inflow. In the absence of hydrodynamic models to simulate this effect, assessing relative volumes provides a first pass at dilution capacity. A dilution factor was calculated as the ratio of the estuary volume to the volume of runoff from a large rainfall event, assumed at 10 per cent of the total annual inflow. As an example, a factor of 15 would indicate that the estuary volume is 15 times larger than the runoff from a large rainfall event. Substantial dilution could be expected and therefore only a minor deterioration in water quality.

A summary of the hydrodynamic data discussed above is shown in Appendix 9.

5. Estuary classification

5.1 Purpose of classification

Estuaries are characterised by high biological production and diversity which, together with their geomorphic and hydrodynamic settings, make no two systems exactly alike. Classification is a process of grouping units such as estuaries, with similar properties that inform or simplify a management question (Kurtz et al. 2006). Classification can be used as a tool for (Engle et al. 2007):

- describing and developing an inventory of estuarine systems
- increasing understanding of differences and similarities between hundreds of semi-discrete units
- identifying and prioritising conservation efforts
- managing ecosystem resources
- guiding research.

By establishing groups with similar properties, classification avoids comparing systems inappropriately. However, clear boundaries are often difficult to define as diversity in aquatic ecosystems is part of a continuum (Hale & Butcher 2008). The aim is to minimise 'noise' through partitioning of variability and make it easier to identify signals of human disturbance as well as landscape sensitivity (US EPA 2002; Detenbeck 2000). Variability within classes is minimised, and is maximised between classes (US EPA 2001).

Attempts at aquatic ecosystem classification have relied on attributes such as geomorphology, salinity distribution, water circulation patterns, hydrology, water chemistry, biological species or communities. Burgess et al. (2004) lists 25 different methods of classifying coastal systems in the US. The common use of physical attributes such as geomorphology and hydrology for classification of aquatic ecosystems is based on the assumption that the organisation and function of biological communities is largely in response to these physical 'controlling factors' (Hale & Butcher 2008). The US EPA (2001) suggest that geomorphic classification schemes also provide insight to the circulation structure and are a first-order estimate of water residence time or flushing characteristics. While geophysical context is a fundamental determinant of variation in biological systems, it is commonly acknowledged that classification must be appropriate to the specific goals being sought (Karr 1999).

More generally, classification schemes can be characterised firstly as either geographically dependent or geographically independent (Detenbeck et al. 2000). Geographically dependent schemes have boundaries fixed in space and include ecoregions and ecological units. Geographically independent schemes can be based on physical, environmental or ecological variables or some combination thereof. They can be either structural or functional and relate to the landscape, watershed or ecosystem/community.

Hale & Butcher (2008) proposed four types of classification system:

- Unstructured, in which there are no explicit criteria for classifying different systems
- Driver, which is based on abiotic drivers of ecosystems principally geomorphology and/or hydrology

- Biological, which is based on bottom-up classifications based on species or communities
- Holistic, which is a combination of drivers, responses, abiotic and biotic components.

The choice of classification system will depend on the available data and the purpose of classification. Within the context of the MER program the primary objective was to group estuaries by their stressor response as measured by the adopted water, macrophyte and fish indicators. This is a holistic approach in which abiotic drivers are identified and the biological responses used to validate the classification. The response-based classification can then be used to:

- establish reference conditions for each class
- set trigger values for management
- broadly determine the cause of impairment
- predict changes in environmental condition as the stressors change.

By grouping estuaries into classes with similar responses to stressors, a management framework can be established for all 184 NSW estuaries and management prescriptions extrapolated across estuaries with limited monitoring or bio-physical data. Major driving processes can be identified based on conceptual models developed and tested for each type. Data available on stressors and response can be used to validate and refine the models and classification scheme.

5.2 Existing classification systems

Comprehensive reviews of existing systems for classifying estuaries in NSW can be found in a number of publications including Hale & Butcher (2008) and Barton et al. (2007). Most are based on one or more of geomorphology, salinity and hydrology. None of the systems available specifically consider grouping estuaries by their response to stressors.

Within NSW the most widely used classification scheme for estuaries is that of Roy et al. (2001) which is based on geology and geomorphology. Estuaries were classified into geomorphological group, type and evolutionary stage (Table 4 and Table 5) but not all types are represented in NSW. Although the estuarine classification system of Roy et al. (2001) is based on physical rather than biophysical attributes the scheme was seen as providing a framework to characterise estuary ecology.

Table 4: Roy et al. (2001) classification scheme

Groups	Types (and examples)
I. Bays	1. Ocean embayments (Botany Bay)
II. Tide dominated estuaries	2. Funnel-shaped macrotidal estuary (South Alligator River)
	3. Drowned valley estuary (Hawkesbury River)
	4. Tidal basin (Moreton Bay)
III. Wave dominated estuaries	5. Barrier estuary (Lake Macquarie)
	6. Barrier lagoon (The Broadwater/South Stradbroke Island)
	7. Interbarrier estuary (Tilligerry Creek)
IV. Intermittent estuaries	8. Saline coastal lagoon (Smiths Lake)
	9. Small coastal creeks (Dalhousie Creek)
	10. Evaporative lagoons (The Coorong)
V. Freshwater bodies	11. Brackish barrier lake (Myall Lakes)
	12. Perched dune lake (Lake Hiawatha)
	13. Backswamp (Everlasting Swamp, Clarence River)

Table 5: Stages of sediment infilling (Roy et al. 2001)

Infilling stage	
A	Youthful
B	Intermediate
C	Semi-mature
D	Mature

The Roy et al. (2001) scheme has been tested by Saintilan (2004) to assess the extent to which it and its associated geomorphic units predict the floral and faunal characteristics of an estuary. Saintilan (2004, p.600) found '*the classification system proposed by Roy et al. (2001) is an effective means of distinguishing between estuaries on the basis of geomorphic units and to a lesser extent their biological characteristics*'.

Another classification scheme widely adopted at the national scale is that of Heap et al. (2001) that used energy to classify the 780 estuaries and coastal waterways contained in the Australian Estuarine Database. The ratio of wave energy to tide energy at the mouth of the estuary was determined, with the amount of river energy subsequently used to distinguish systems that are characterised by river processes. Seven subclasses were derived: tide dominated estuary, tide dominated delta, wave dominated estuary, wave dominated delta, tidal flat/creeks, strandplain and others including coastal creeks, coastal lagoons, embayments, drowned river valleys and freshwater lakes.

5.3 Eutrophication indicator response classification

Burgess et al. (2004) propose that three primary factors control the stressful actions of pollutants in aquatic systems:

- The residence time of water and pollutant in the system
- The natural processing capacity of the system for the pollutant including the pathways that decompose, bind, take-up or sequester the material
- Ancillary factors that modify the form of a pollutant, the rate of processing, or the kind of action the pollutant exerts within the ecosystem.

For nutrient loading specifically, NRC (2000) proposed a number of factors important to characterising the susceptibility of estuaries to nutrient loading including:

- system dilution and water residence time or flushing rate
- ratio of nutrient load per unit area of estuary
- vertical mixing and stratification
- algal biomass, eg chlorophyll a
- wave exposure (especially relevant to seagrass potential habitat)
- depth distribution (bathymetry and hypsographic profiles)
- ratio of side embayment(s) volume to open estuary volume or other measures of embayment influence on flushing.

Many of these factors are likely to be common in characterising the susceptibility of estuaries to a wider range of catchment and waterbody stressors other than nutrients (Kurtz et al. 2006) and will drive the response of the three condition indicator groups of eutrophication, habitat and fish.

Of the factors listed in NRC (2000) driving the response of algal biomass and water clarity, those amenable to quantification and application across all 184 estuaries were dilution and water residence time. Estuaries with limited inputs and/or that dilute well and flush quickly will assimilate and/or export pollutants readily, resulting in lower pollutant concentrations. In addition, estuaries with residence times shorter than the doubling time of algal cells will inhibit formation of algal blooms.

5.3.1 Dilution and flushing analysis

Dilution and flushing times were plotted against each other for the 184 estuaries as shown in Figure 13. Estuaries are deemed intermittently or permanently open in accordance with Roy et al. (2001) as extended by OEH (see Section 5.3.3 and Table 7). The plot has been shaded green to indicate systems with high dilution capacity and short flushing times and therefore low vulnerability to the effects of nutrient pollution (Bricker et al. 1999). By contrast, systems falling within areas shading towards orange are considered highly vulnerable. Figure 14 and Figure 15 present two plots, one for the Roy et al. (2001) geomorphic types 1, 2 and 3 corresponding to ocean embayments, drowned river valleys and barrier estuaries, most of which are permanently open, and the other for type 4 which are mainly systems closed for most of the time. The different geomorphic types are overlaid within each plot using multiple colours to assist in visually detecting natural groupings. A number of observations were made:

- For dilution, there are almost six orders of magnitude difference (10^6) between the capacity of large embayments and very small creeks to dilute pollutant inputs. This confirms the high variability ascribed to estuarine dynamics generally
- For permanently open systems, flushing times are less variable, although still ranging across more than two orders of magnitude (10^2) from three to 470 days
- For large bays, dilution factors of between 10 to more than 100 imply rainfall events will only generate a minor pulse of pollutant input representing 10 per cent and one per cent respectively, of the estuary volume at 0.6 m AHD. A relatively small rise in receiving water pollutant concentrations could be expected. More than half the drowned river valleys also fall within this dilution range. From the water quality analysis of seven drowned river valleys, the coefficient of variability of chlorophyll a (standard deviation/mean) averaged 1.16 (range 0.84 to 1.46)
- Some intermittently open lakes with the type 4A classification also have large dilution capacity. Large rainfall events of 10 per cent or more, (around 150 mm) of annual runoff are unlikely to breach the entrance berm so that all inflowing pollutants will be retained and processed within the estuary
- At the other end of the spectrum, very small creeks and lagoons with dilution factors of 0.1 to 0.001 experience volumes of runoff from 10 to 1000 times larger, respectively, than their typical volumes at 0.6 m AHD. During rainfall events, the water quality of these systems will quickly reflect the pollutant concentrations of inflowing water. This is confirmed by the water quality analysis where the average coefficient of variability for 17 type 4C and 4D systems was 1.51 (range 0.69 to 4.62), or 30 per cent higher than for drowned river valleys. It is also likely that with these volumes of inflowing water, the entrance berm will be breached and a high proportion of runoff will discharge directly to the ocean
- For estuaries between these two extremes, water quality will reflect the combined influence of the initial dilution of pollutants, the speed of flushing following a rainfall event, whether an entrance opens or scours during the event, the relative size of tidal prism keeping the entrance open compared to entrance exposure to the offshore wave climate and longshore transport tending to close the entrance, and climatic variability in rainfall, runoff and evaporation.

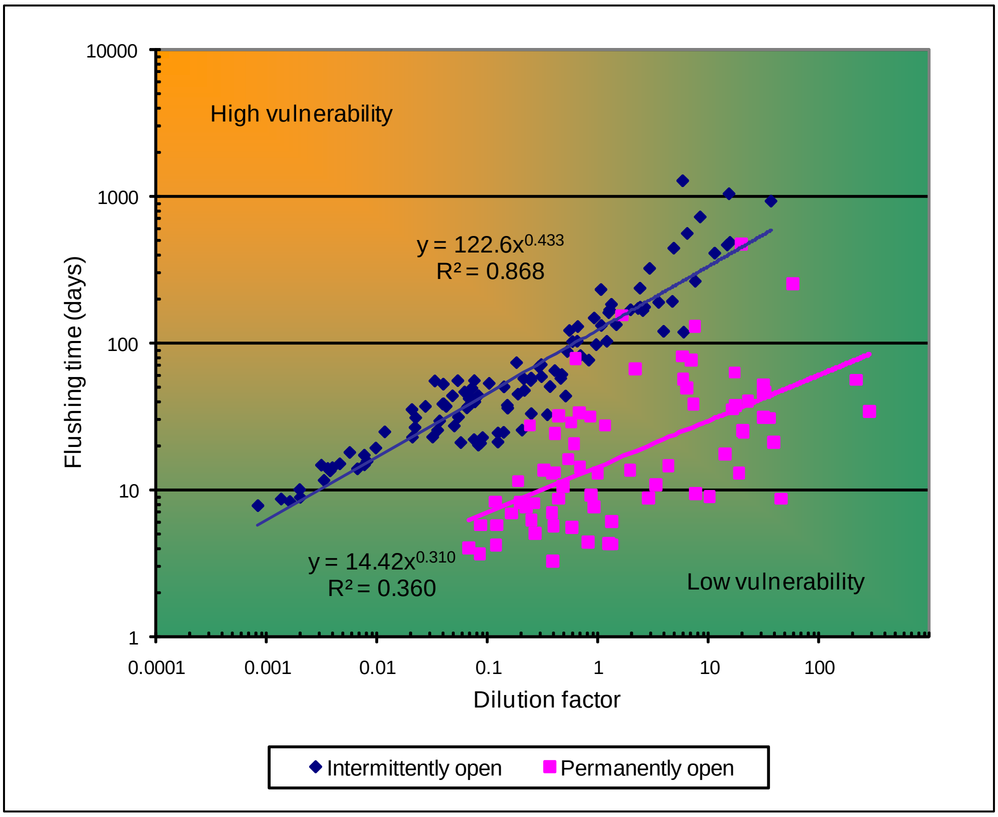


Figure 13: Dilution and flushing for intermittently and permanently open systems

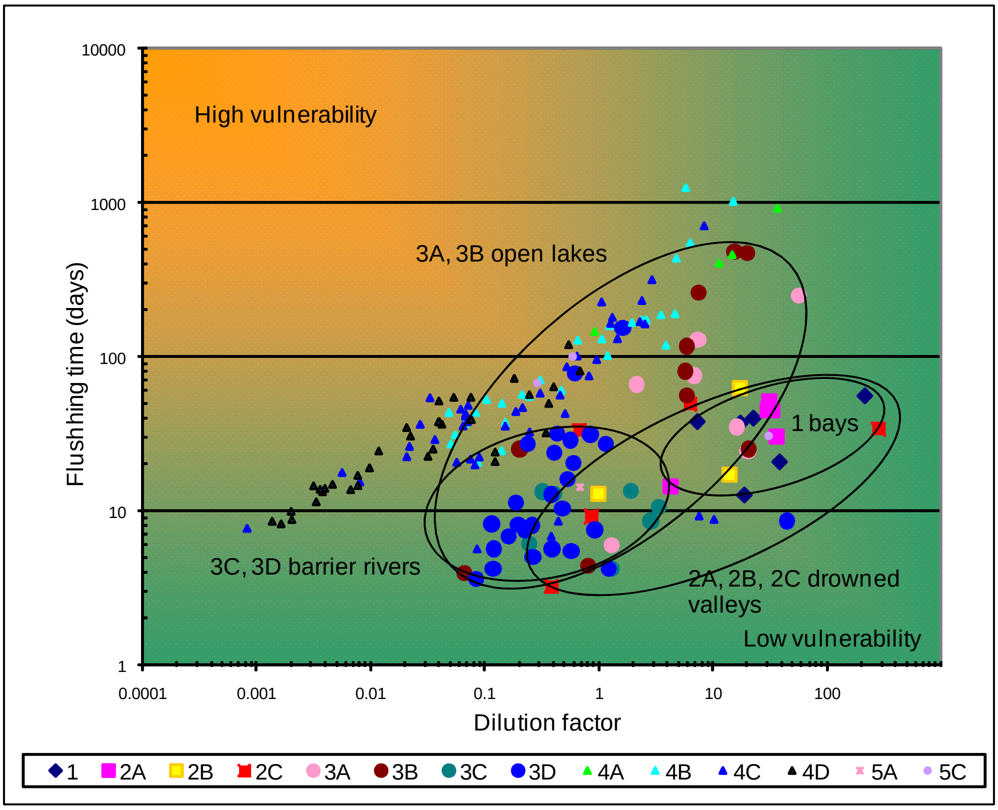


Figure 14: Dilution factor and flushing time for Roy et al. (2001) types 1, 2 and 3

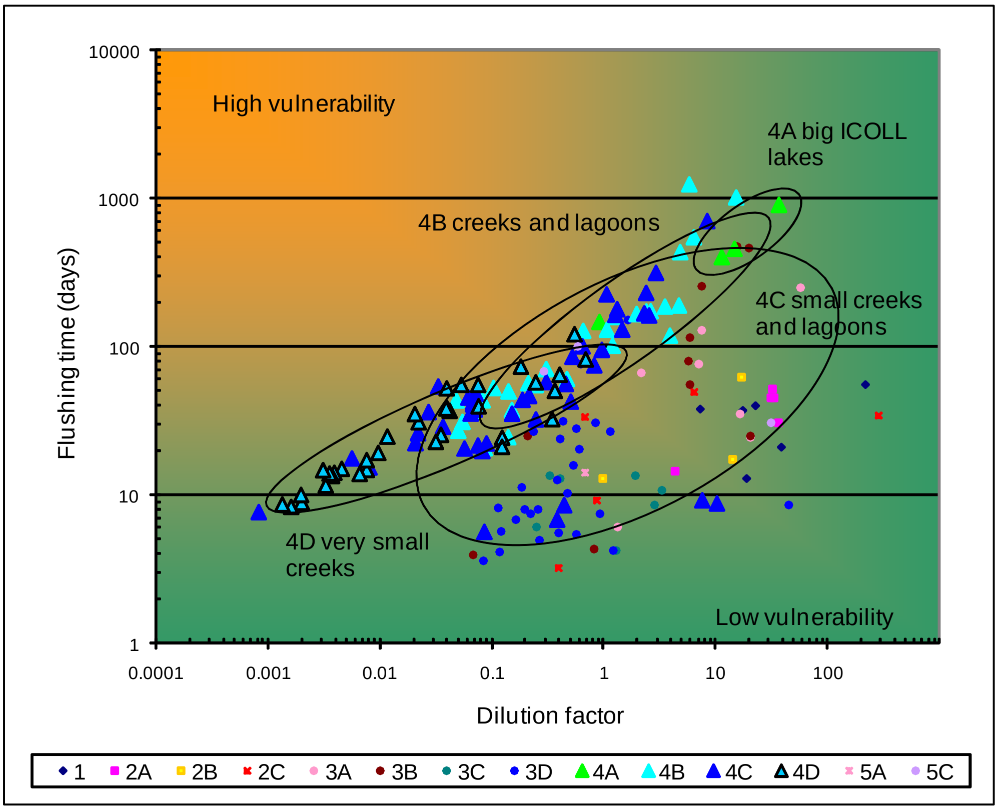


Figure 15: Dilution factor and flushing time for Roy et al. (2001) type 4

5.3.2 Conceptual models for NSW estuaries

Based on observations from the above plots and the water quality analysis, three conceptual models of estuarine response to pollutant inputs were hypothesised and tested:

1. For systems with high dilution capacity and a concomitant minor deterioration in water quality during rainfall, the significance of flushing time is reduced.

   From the plots above, a natural breakpoint in the clustering of data for each geomorphic type occurs at a dilution factor of about 3. This means for a rainfall event which produces runoff equivalent to 10 per cent of the total annual runoff, the volume of the estuary is three times larger than the 10 per cent event runoff. A 10 per cent event is relatively infrequent so that for lesser rainfall, the dilution factor would be greater than 3. Some initial deterioration in water quality would be expected with a 10% runoff event for systems with a dilution factor greater than 3 but it could be expected to be small.

   From the plots, dilution factors greater than 3 correspond to relatively long flushing times of between 10 and 1000 days. Internal processing of pollutants will dominate flushing in reducing concentrations back to ambient levels. Systems that match the criteria of dilution factor greater than 3 include examples of embayments, drowned river valleys, large permanently open and intermittently open (but mostly open) barrier estuaries, primarily lakes

2. A second clustering of data on dilution, flushing and geomorphic type occurs for those systems defined by Roy et al. (2001) as riverine estuaries or the mature form of wave-dominated estuaries (3C and 3D). These correspond to dilution factors ranging from about 0.1 to 3 and flushing times of three to 30 days.

For a dilution factor of 0.1, the volume of runoff during a 10 per cent event is ten times the volume of the estuary so that the water quality will reflect the poorer quality of inflowing water. Following the event, internal processing and flushing will reduce pollutant concentrations relatively quickly. As the dilution factor increases up to 3, the effect of rainfall events on water quality is reduced.

Due to the role of flushing in this conceptual model, only permanently open systems were included with examples being most mature barrier estuaries, including some open lakes, and some drowned river valleys

3. The third and largest group of systems are the small, intermittently open lakes, lagoons and creeks. These all have dilution factors less than 3 but range down to extremely small values of about 0.001.

   For systems with very small dilution factors, relatively minor rainfall will break open the entrance berm. Generally these systems are very small in surface area so the tidal prism will also be small and longshore sediment transport from coastal processes will rapidly close the entrance. These systems are very dynamic with highly variable water quality from the constant cycle of opening, closing, filling and subsequent breakout. Often, samples are taken for testing of water quality in these systems only well after severe weather episodes have passed.

Within these three broad classes, there are likely to be further divisions that could be made. For example, embayments and large intermittently open lakes may have similar dilution and flushing characteristics and hence water quality response but their biological assemblages may be quite different because of their hypsography, light regime, stratification and benthic processes. Similarly, the large number of intermittently open small systems will have a continuum in opening regime from breaking out with minor rainfall to remaining closed for extended periods of time.

Classification seeks to account for the effects of natural variability to make it easier to identify signals of human disturbance and predict management responses. An excessive number of classes will impede the design of cost-effective monitoring programs and add to the cost of establishing reference conditions. Too few classes will make it more difficult to detect and define the biological effects from natural variability and human activity (US EPA 2002).

The three estuary types corresponding to the three conceptual models described above have been labelled as ‘Lakes’, ‘Rivers’ and ‘Lagoons’ respectively representing the dominant geomorphic type. Within each class exist geomorphic subclasses, including the following:

- Lakes: open embayments, drowned river valleys, large permanently open and intermittently open lakes as defined by Roy et al. (2001)
- Rivers: mature barrier river estuaries also as defined by Roy et al. (2001)
- Lagoons: intermittently open lagoons and creeks which can be separated by those with dilution ratios above and equal/below 0.1 respectively.

Conceptually, the chlorophyll response of the three estuary types can be represented as shown in Figure 16. The conceptual model changes for each estuary class as the algal biomass response, expressed in terms of chlorophyll a concentration, changes with the dilution and flushing characteristics of each class. For the same rainfall, the magnitude and rate of increase in chlorophyll a is greater for lagoons, then lesser for rivers and then lower again for lakes (likewise the rate of return to ambient conditions). Within each class, longer flushing times will mean a slower decline of chlorophyll a concentrations back to ambient. The ambient chlorophyll concentration levels for lagoons and creeks approximate oceanic concentrations for the relatively short period of time following breaching when tidal exchange is maximised, but rises following entrance closure.

Rissik at al. (2009) found nutrients increased significantly in an urban coastal lagoon the day following rainfall before reverting to pre-event levels five days later. The biomass of phytoplankton grew tenfold within a week while zooplankton responded within a day with a twofold increase as they grazed the phytoplankton. The assemblage of phytoplankton and zooplankton increased dramatically after one day and again six days later, then returned to the original community within two weeks of the initial event. Growth rates of the assemblage would have been underestimated if dilution had not been accounted for. Other similar studies reviewed in Rissk et al. (2009) also linked rainfall with high phytoplankton production in temporarily open/closed systems.

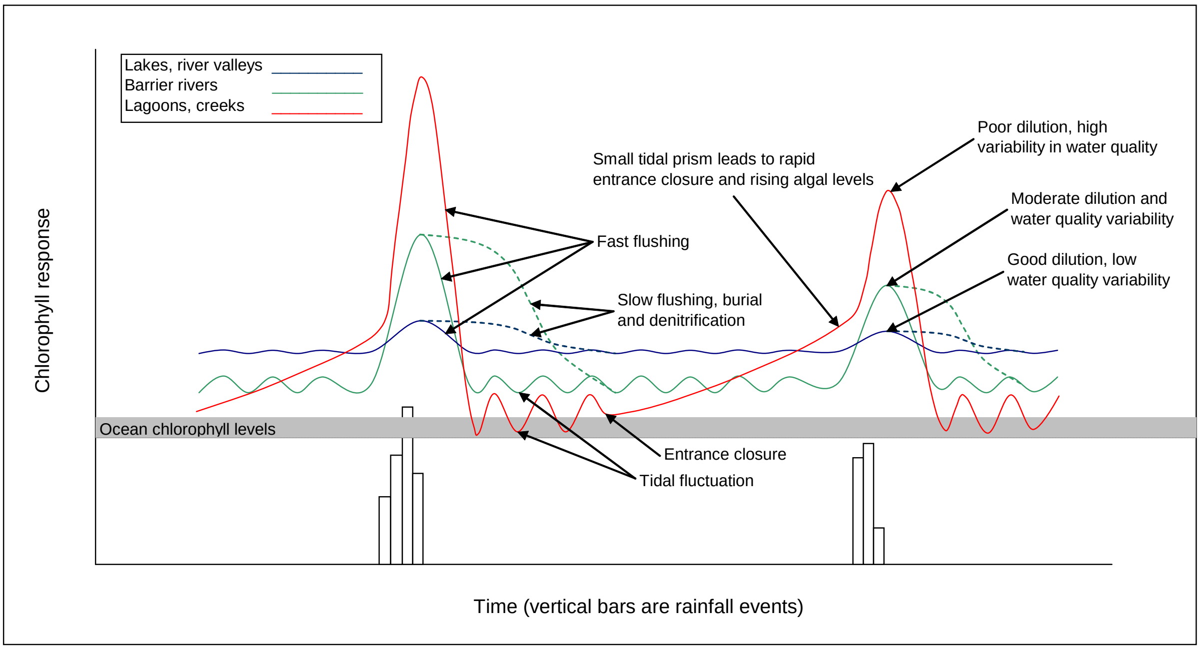


Figure 16: Conceptual model of chlorophyll response in the three generic estuary types

5.3.3 Comparison with other conceptual models

A generalised conceptual model of nutrient dynamics within an estuary is shown in Figure 17 (OZCOASTS www.ozcoasts.org.au). This model has schematised the estuary geometry for the purpose of displaying nutrient-related processes. Smaller scale effects will be present in all estuaries due to variation in depth profiles, entrance condition, salinity zonation, catchment characteristics etc. In a study of persistently high levels of phytoplankton in Berowra Creek, a tributary of the Hawkesbury–Nepean River system, Rissik et al. (2007) found a deep hole at the bloom site (>15 m) increased residence times sufficiently to exponentially increase the growth rate of algae and result in large accumulations of cells and high rates of primary production. The smallest zooplankton size classes also responded but the relationship with chlorophyll a concentrations decreased in the larger particle size classes indicating an uncoupling between chlorophyll a and larger zooplankton.

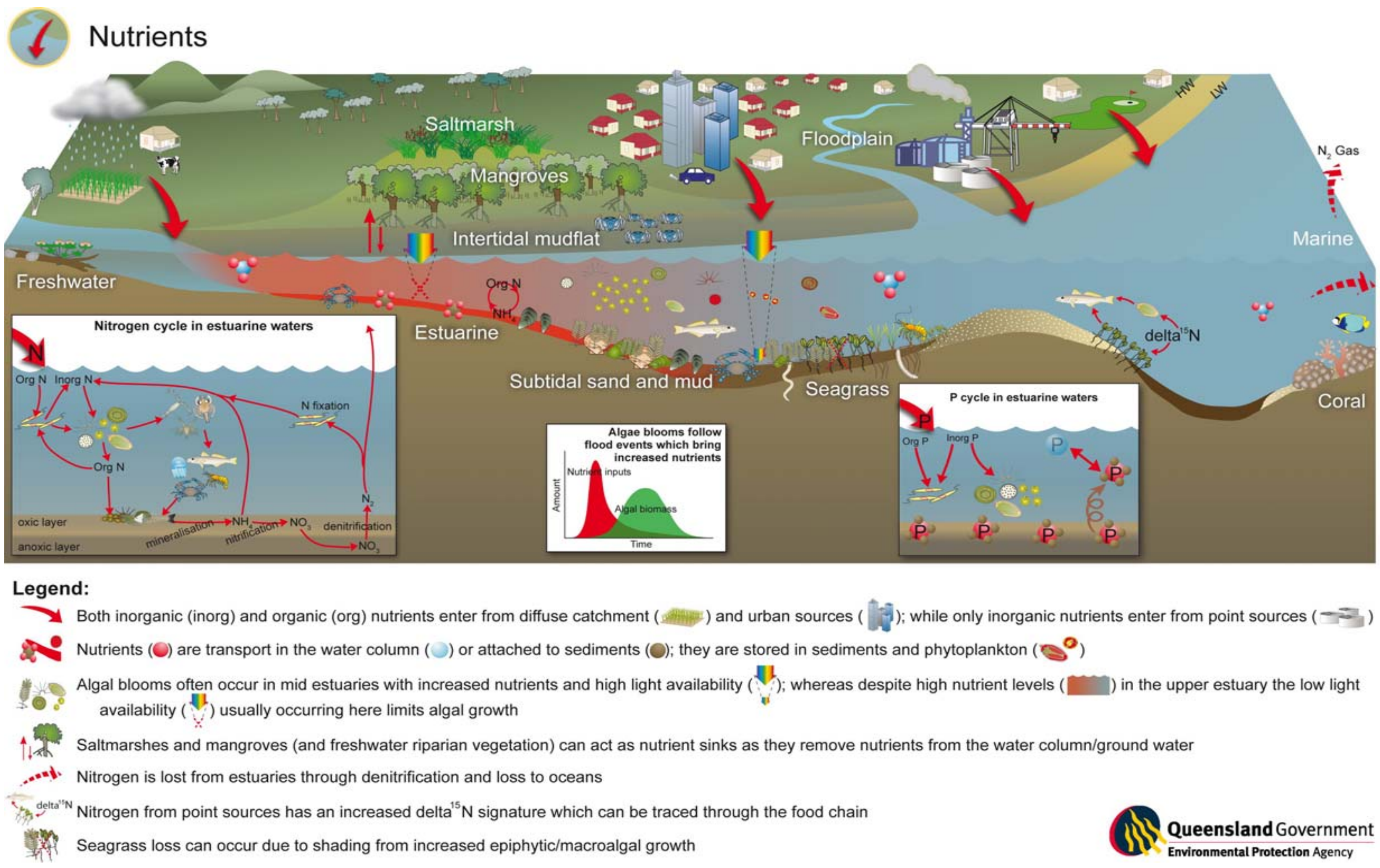


Figure 17: Conceptual model for nutrient processing within an estuary

Geosciences Australia (Heap et al. 2001) developed schematic conceptual models for each of the six subclasses of estuaries represented in NSW. These subclasses were divided into tide dominated and wave dominated:

- Tide dominated subclasses: tide dominated estuary (TDE), tide dominated delta (TDD), tidal flat/creeks (TC)
- Wave dominated subclasses: wave dominated estuary (WDE, which can include coastal lagoons [CL]), wave dominated delta (WDD) and strandplain (SP).

The main characteristics of the three chlorophyll response classes are summarised and compared to the classification systems of Roy et al. (2001) and Heap et al. (2001) in Table 6. There is some limited convergence between the three classification systems but the quantification of dilution and flushing characteristics together with entrance condition, has resulted in examples of both Roy et al. (2001) and Heap et al. (2001) being included in generally more than one of the new chlorophyll response classes.

Table 6: Comparison of classification schemes

Attribute	Classification for chlorophyll a response		
	Lake	**River**	**Lagoon**
Total no.	43	44	97
Entrance condition	Permanently open (29) Some intermittent (14)	All permanently open	All intermittent
Geomorphic types	Embayments (6) Drowned river valleys (9) Large permanently open lakes (14) Large ICOLLs with high dilution (14)	Riverine estuaries (44)	Small lakes (22) Coastal lagoons (16) Small rivers (3) Coastal creeks (56)
Roy et al. (2001) type (see note)	All 1, 2A Some 2B, 2C Most 3A, 3B One 3C and 3D Almost all 4A Some 4B, 4C	Some 2B, 2C Some 3A, 3B Almost all 3C Almost all 3D Some 4C	Some 3B, 3D Some 4A Almost all 4B, 4C All 4D
Heap et al. (2001) type	Embayments Wave dominated estuary Coastal lagoon	Wave dominated delta Wave dominated estuary Coastal lagoon Tidal creek	Wave dominated estuary Coastal lagoon

Attribute	Classification for chlorophyll a response		
	Lake	**River**	**Lagoon**
Dilution factor (ratio)	Very high: median 15 Quartiles 6–27 All ≥ 3	Low: median 0.4 Quartiles 0.2–0.9 All < 3	Very low: median 0.4 Quartiles 0.03–0.5 All < 3
Flushing time (days)	Very long: median 56 Quartiles 31–255	Moderate: median 9 Quartiles 6–17	Long: median 62 Quartiles 23–71 Highly dependent on rainfall frequency
Area (km^2)	Large: median 9 Quartiles 3–33	Moderate: median 2.2 Quartiles 1.2–14	Small: median 0.10 Quartiles 0.02–0.28

Note: (using numbering system from Roy et al. [2001]):
1 = bays, 2 = tide dominated (drowned river valleys), 3 = wave dominated (barriers), 4 = intermittent
A = youthful, B = intermediate, C = semi-mature, D = mature
ICOLLs = intermittently closed and open lakes and lagoons.

A summary of the new and existing classification systems for each estuary in NSW is shown in Table 7. The entrance condition is from Roy et al. (2001) from which the dominant condition was then assumed and reviewed. Using aerial photography, the Roy classification was extended by OEH from the 131 estuaries provided in Roy et al. (2001) to the 184 estuaries mapped as part of the Estuaries MER program. This extended classification as well as the original classification by Roy et al. (2001) should be confirmed using statistical analysis and field checking where necessary of physical and geomorphological characteristics.

Table 7: Classification system for chlorophyll response

Estuary	Dilution factor	Flushing (days)	Roy type	Heap type	Entrance condition	Dominant condition	Area (km^2) Catchment	Estuary	Response classification	Subclass
Tweed River	1.158	27.3	3D	WDE	O/T	O	1054.76	21.954	River	Barrier river
Cudgen Creek	0.687	14.2	5A	WDE	O/T	O	68.61	2.095	River	Barrier river
Cudgera Creek	0.086	5.7	4C	CL	O	O	60.55	0.409	River	Barrier river
Mooball Creek	0.067	4.0	3B	CL	O/T	O	109.14	0.524	River	Barrier river
Brunswick River	0.225	7.6	3D	WDD	O/T	O	226.34	3.278	River	Barrier river
Belongil Creek	0.048	43.3	4B	CL	I	C	30.41	0.189	Lagoon	Creek
Tallow Creek	0.139	24.4	4B	CL	I	C	5.34	0.119	Lagoon	Lagoon
Broken Head Creek	0.305	70.7	4B		I	C	1.12	0.053	Lagoon	Lagoon
Richmond River	0.569	28.7	3D	WDD	O/T	O	6861.84	37.776	River	Barrier river
Salty Lagoon	0.643	101.9	4C		I	C	3.57	0.159	Lagoon	Lagoon
Evans River	1.317	6.1	3A	WDD	O/T	O	75.84	2.302	River	Barrier river
Jerusalem Creek	0.204	25.3	3B	CL	I	C	48.32	0.319	Lagoon	Lagoon
Clarence River	0.850	31.3	3D	WDE	O/T	O	22055.11	129.416	River	Barrier river
Lake Arragan	6.368	551.8	4B	CL	I	C	9.28	0.971	Lake	Lake
Cakora Lagoon	0.547	120.6	4D	CL	I	C	12.33	0.229	Lagoon	Lagoon
Sandon River	1.237	4.2	3D	WDD	O	O	131.52	2.144	River	Barrier river
Wooli Wooli River	0.923	7.6	3D	WDE	O/T	O	180.00	3.078	River	Barrier river
Station Creek	0.366	50.1	4D	WDE	I	C	21.36	0.255	Lagoon	Lagoon
Corindi River	0.481	10.4	3D	WDD	O	O	146.44	1.324	River	Barrier river
Pipe Clay Creek	0.040	52.0	4D		I	C	1.63	0.011	Lagoon	Creek
Arrawarra Creek	0.124	24.2	4D	CL	I	C	17.82	0.114	Lagoon	Lagoon
Darkum Creek	0.076	55.0	4D		I	C	6.11	0.055	Lagoon	Creek
Woolgoolga Lake	0.103	52.7	4B	WDE	I	C	21.02	0.155	Lagoon	Lagoon
Flat Top Point Creek	0.053	54.9	4D		I	C	2.57	0.022	Lagoon	Creek
Hearns Lake	0.211	56.7	4B	CL	I	C	6.60	0.102	Lagoon	Lagoon
Moonee Creek	0.326	13.4	3C	CL	O	O	41.11	0.278	River	Barrier river
Pine Brush Creek	0.012	24.6	4D		I	C	7.34	0.016	Lagoon	Creek
Coffs Creek	0.249	6.2	3C	CL	O	O	24.04	0.459	River	Barrier river
Boambee Creek	0.393	5.7	3D	WDE	O	O	48.48	0.963	River	Barrier river
Bonville Creek	0.198	8.1	3D	WDE	O	O	113.47	1.496	River	Barrier river
Bundageree Creek	0.001	7.8	4C		I	C	10.12	0.003	Lagoon	Creek
Bellinger River	0.190	11.4	3D	WDD	O/T	O	1100.32	8.019	River	Barrier river
Dalhousie Creek	0.151	35.8	4C	CL	I	C	6.26	0.068	Lagoon	Lagoon
Oyster Creek	0.123	21.0	4D	CL	I	C	16.78	0.139	Lagoon	Lagoon
Deep Creek	0.506	43.2	4C	WDE	I/(O)	C	89.80	1.084	Lagoon	Lagoon
Nambucca River	0.534	16.1	3D	WDD	O/T	O	1298.93	11.366	River	Barrier river
Macleay River	0.408	23.9	3D	WDD	O/T	O	11287.03	27.393	River	Barrier river
South West Rocks Creek	7.543	9.3	4C	CL	O/T	O	3.67	0.827	Lake	Lake
Saltwater Creek (Frederickton)	0.290	68.4	5C	WDE	I	C	11.11	0.282	Lagoon	Lagoon
Korogoro Creek	0.811	4.4	3B	CL	O	O	9.51	0.244	River	Barrier river
Killick Creek	1.957	166.9	4B	CL	I	C	7.93	0.281	Lagoon	Lagoon
Goolawah Lagoon	0.585	101.3	5C		I	C	3.95	0.127	Lagoon	Lagoon
Hastings River	0.384	12.7	3D	WDD	O/T	O	3658.57	28.092	River	Barrier river
Cathie Creek	2.912	319.1	4C	WDE	I/(O)	C	105.50	7.861	Lagoon	Lagoon
Duchess Gully	0.022	30.7	4D		I	C	10.59	0.025	Lagoon	Creek
Camden Haven River	5.747	80.6	3B	WDE	O/T	O	588.99	31.390	Lake	Lake
Manning River	0.435	31.6	3D	WDD	O/T	O	8124.50	32.268	River	Barrier river
Khappinghat Creek	0.346	32.2	4D	WDD	I	C	90.73	1.033	Lagoon	Lagoon
Black Head Lagoon	0.021	34.9	4D		I	C	1.99	0.009	Lagoon	Creek
Wallis Lake	6.996	76.0	3A	WDE	O/T	O	1196.90	92.802	Lake	Lake
Smiths Lake	36.454	915.8	4A	CL	I	C	27.97	10.011	Lake	Lake
Myall River	30.977	30.8	5C	WDE	O	O	818.74	112.525	Lake	Lake
Karuah River	0.870	9.2	2C	TDD	O	O	1448.42	14.122	River	Barrier river
Tilligerry Creek	44.658	8.6	3D	WDE	O	O	114.77	20.452	Lake	Lake
Port Stephens	31.438	52.0	2A	WDE	O	O	296.77	123.745	Lake	Drowned valley
Hunter River	0.604	20.4	3D	WDE	O/T	O	21366.95	41.830	River	Barrier river
Glenrock Lagoon	0.086	20.6	4B		I	C	7.37	0.052	Lagoon	Creek
Lake Macquarie	57.097	249.9	3A	WDE	O/T	O	604.39	113.210	Lake	Lake
Middle Camp Creek	0.027	36.7	4C		I	C	5.01	0.013	Lagoon	Creek
Moonee Beach Creek	0.003	14.6	4D		I	C	3.48	0.002	Lagoon	Creek
Tuggerah Lake	15.516	479.7	3B	WDE	I/(O)	C	714.47	80.633	Lake	Lake
Wamberal Lagoon	4.677	190.3	4B	CL	I	C	5.82	0.517	Lake	Lake
Terrigal Lagoon	0.467	60.5	4B	CL	I	C	8.94	0.282	Lagoon	Lagoon
Avoca Lake	0.916	146.7	4A	CL	I	C	10.77	0.673	Lagoon	Lagoon
Cockrone Lake	1.063	130.5	4B	CL	I	C	6.85	0.331	Lagoon	Lagoon
Brisbane Water	20.589	24.6	3A	WDE	O	O	152.55	27.216	Lake	Lake
Hawkesbury River	6.369	49.2	2C	WDE	O	O	21624.06	111.627	Lake	Drowned valley
Pittwater	285.561	33.9	2C	WDE	O	O	50.77	18.365	Lake	Drowned valley
Broken Bay	0.679	33.3	2C		O	O	12.93	17.144	River	Barrier river
Narrabeen Lagoon	3.893	119.0	4B	WDE	I/(O)	C	52.41	2.311	Lake	Lake
Dee Why Lagoon	0.033	54.7	4C	CL	I	C	4.27	0.239	Lagoon	Creek
Curl Curl Lagoon	0.214	47.2	4C	CL	I	C	4.65	0.065	Lagoon	Lagoon
Manly Lagoon	0.068	42.9	4C	CL	I	C	17.25	0.098	Lagoon	Creek
Middle Harbour Creek	30.652	45.7	2A		O	O	76.98	6.114	Lake	Drowned valley
Lane Cove River	4.330	14.4	2A		O	O	95.36	2.977	Lake	Drowned valley
Parramatta River	14.144	17.3	2B		O	O	252.36	13.736	Lake	Drowned valley
Port Jackson	32.492	45.8	2A	WDE	O	O	55.74	28.968	Lake	Drowned valley
Cooks River	0.391	3.2	2C	TC	O	O	110.57	1.199	River	Barrier river
Georges River	17.206	62.5	2B	EMB	O	O	930.91	25.754	Lake	Drowned valley
Botany Bay	22.650	39.9	1	WDE	O	O	54.87	38.789	Lake	Bay
Port Hacking	35.924	30.6	2A	WDE	O	O	165.34	11.575	Lake	Drowned valley
Wattamolla Creek	0.062	46.0	4C		I	C	8.05	0.033	Lagoon	Creek
Hargraves Creek	0.006	17.9	4C		I	C	2.02	0.003	Lagoon	Creek
Stanwell Creek	0.008	17.1	4D		I	C	7.69	0.009	Lagoon	Creek
Flanagans Creek	0.001	8.6	4D		I	C	2.02	0.002	Lagoon	Creek
Woodlands Creek	0.004	13.4	4D		I	C	2.00	0.004	Lagoon	Creek
Slacky Creek	0.003	11.5	4D		I	C	3.08	0.005	Lagoon	Creek
Bellambi Gully	0.008	14.7	4D	CL	I	C	6.46	0.017	Lagoon	Creek
Bellambi Lake	0.075	21.8	4C	CL	I	C	1.31	0.031	Lagoon	Creek
Towradgi Creek	0.021	22.7	4C	CL	I	C	8.56	0.042	Lagoon	Creek
Fairy Creek	0.035	25.3	4D	CL	I	C	20.65	0.111	Lagoon	Creek
Allans Creek	0.382	6.9	4C		O	O	50.46	1.164	River	Barrier river

Estuary	Dilution factor	Flushing (days)	Roy type	Heap type	Entrance condition	Dominant condition	Area (km^2) Catchment	Area (km^2) Estuary	Response classification	Subclass
Port Kembla	38.543	20.9	0	WDE	O	O	6.25	1.374	Lake	Bay
Lake Illawarra	7.530	260.7	3B	WDE	O/(I)	C	238.43	35.529	Lake	Lake
Elliott Lake	0.068	41.5	4C		I	C	9.97	0.080	Lagoon	Creek
Minnamurra River	0.266	5.0	3D	WDD	O	O	117.33	1.534	River	Barrier river
Spring Creek	0.072	48.8	4C		I	C	5.83	0.052	Lagoon	Creek
Munna Munnora Creek	0.004	13.9	4D		I	C	3.63	0.004	Lagoon	Creek
Werri Lagoon	0.066	36.6	4B	WDE	I	C	16.48	0.142	Lagoon	Creek
Crooked River	0.119	4.2	3D	CL	O	O	31.99	0.260	River	Barrier river
Shoalhaven River	0.625	78.2	3D	WDD	O	O	7085.83	29.836	River	Barrier river
Wollumboola Lake	4.807	437.7	4B	WDE	I	C	34.13	6.328	Lake	Lake
Currarong Creek	0.022	26.4	4C		I	C	12.33	0.034	Lagoon	Creek
Cararma Creek	10.188	8.9	4C		O	O	6.80	2.385	Lake	Lake
Wowly Gully	0.403	64.3	4D		I	C	6.02	0.162	Lagoon	Lagoon
Callala Creek	0.002	8.8	4D		I	C	19.79	0.006	Lagoon	Creek
Currambene Creek	0.442	8.6	4C	WDD	O	O	160.02	2.221	River	Barrier river
Moona Moona Creek	0.065	35.8	4C		I	C	28.57	0.140	Lagoon	Creek
Flat Rock Creek	0.010	19.1	4D		I	C	6.88	0.014	Lagoon	Creek
Captains Beach Lagoon	0.090	22.5	4C		I	C	3.14	0.046	Lagoon	Creek
Telegraph Creek	0.005	14.9	4D		I	C	4.28	0.005	Lagoon	Creek
Jervis Bay	217.031	55.5	1	EMB	O	O	32.39	122.407	Lake	Bay
St Georges Basin	19.801	470.7	3B	WDE	O	O	315.75	40.759	Lake	Lake
Swan Lake	14.651	460.5	4A	WDE	I	C	26.38	4.675	Lake	Lake
Berrara Creek	0.140	49.9	4B	CL	I	C	35.04	0.255	Lagoon	Lagoon
Nerrindillah Creek	0.037	29.2	4C	CL	I	C	17.22	0.073	Lagoon	Creek
Conjola Lake	5.855	56.1	3B	WDE	O	O	139.09	6.694	Lake	Lake
Narrawallee Inlet	0.241	27.2	3D	WDE	O(I)	O *	80.92	0.862	River	Barrier river
Mollymook Creek	0.004	14.1	4D	CL	I	C	2.72	0.006	Lagoon	Creek
Millards Creek	0.002	8.3	4D		I	C	4.50	0.005	Lagoon	Creek
Ulladulla	18.866	12.8	0	CL	O	O	0.30	0.093	Lake	Bay
Burrill Lake	7.480	130.0	3A	WDE	O(I)	O *	60.74	4.143	Lake	Lake
Tabourie Lake	0.819	75.8	4C	WDE	O(I)	C	46.14	1.449	Lagoon	Lagoon
Termeil Lake	0.957	96.6	4C	WDE	I	C	14.05	0.575	Lagoon	Lagoon
Meroo Lake	2.287	170.3	4C	WDE	I	C	19.27	1.367	Lagoon	Lagoon
Willinga Lake	0.247	57.2	4D		I	C	13.59	0.314	Lagoon	Lagoon
Butlers Creek	0.039	38.1	4D		I	C	3.06	0.027	Lagoon	Creek
Durras Lake	3.513	187.3	4B	WDE	I	C	58.38	3.599	Lake	Lake
Durras Creek	0.040	38.2	4D		I	C	5.92	0.021	Lagoon	Creek
Maloneys Creek	0.042	36.8	4D		I	C	8.17	0.028	Lagoon	Creek
Cullendulla Creek	1.630	153.6	3D	TC	I(O)	O *	15.16	1.118	River	Barrier river
Clyde River	0.991	13.0	2B	WDE	O	O	1722.91	17.028	River	Barrier river
Batemans Bay	7.272	37.9	1	WDE	O	O	28.00	34.484	Lake	Bay
Saltwater Creek (Rosedale)	0.002	10.0	4D		I	C	2.82	0.002	Lagoon	Creek
Tomaga River	0.574	5.5	3D	WDD	O	O	91.90	1.353	River	Barrier river
Candlagan Creek	0.085	3.6	3D	WDD	O	O	24.12	0.129	River	Barrier river
Bengello Creek	0.007	13.8	4D		I	C	16.32	0.011	Lagoon	Creek
Moruya River	0.261	8.1	3D	WDD	O/T	O	1423.67	5.353	River	Barrier river
Congo Creek	0.032	22.7	4D	CL	I	C	43.19	0.116	Lagoon	Creek
Meringo Creek	0.150	37.3	4B	CL	I	C	5.29	0.072	Lagoon	Lagoon
Kellys Lake	0.245	55.1	4B		I	C	2.11	0.064	Lagoon	Lagoon
Coila Lake	11.282	405.0	4A	WDE	I	C	47.64	6.773	Lake	Lake
Tuross River	0.406	13.1	3C	WDE	O	O	1813.78	14.696	River	Barrier river
Lake Brunderee	0.523	86.7	4C	CL	I	C	5.72	0.194	Lagoon	Lagoon
Lake Tarourga	1.241	159.4	4B	WDE	I	C	5.99	0.328	Lagoon	Lagoon
Lake Brou	2.528	164.7	4C	WDE	I	C	41.64	2.365	Lagoon	Lagoon
Lake Mummuga	2.394	173.6	4B	WDE	I	C	25.76	1.631	Lagoon	Lagoon
Kianga Lake	0.306	58.5	4C	CL	I	C	7.50	0.170	Lagoon	Lagoon
Wagonga Inlet	16.477	35.3	3A	WDE	O/T	O	93.28	6.914	Lake	Lake
Little Lake (Narooma)	0.651	128.3	4B		I	C	2.17	0.097	Lagoon	Lagoon
Bullengella Lake	5.794	1259.4	4B		I	C	0.59	0.149	Lake	Lake
Nangudga Lake	1.312	181.6	4C	WDE	I	C	9.47	0.596	Lagoon	Lagoon
Corunna Lake	2.617	174.1	4B	WDE	I	C	29.74	2.082	Lagoon	Lagoon
Tilba Tilba Lake	2.379	233.8	4C	WDE	I	C	17.09	1.015	Lagoon	Lagoon
Little Lake (Wallaga)	1.056	228.9	4C		I	C	2.37	0.115	Lagoon	Lagoon
Wallaga Lake	5.910	117.5	3B	WDE	O/I	C	263.84	9.145	Lake	Lake
Bermagui River	1.314	4.2	3C	WDD	O/T	O	83.46	1.989	River	Barrier river
Baragoot Lake	1.264	166.3	4C	CL	I	C	12.61	0.471	Lagoon	Lagoon
Cuttagee Lake	1.194	101.7	4B	WDE	I	C	53.12	1.236	Lagoon	Lagoon
Murrah River	0.122	5.7	3D	WDE	O	O	195.76	0.679	River	Barrier river
Bunga Lagoon	0.187	44.5	4C	WDE	I	C	11.55	0.108	Lagoon	Lagoon
Wapengo Lagoon	3.350	10.8	3C	WDE	O	O	68.50	3.166	Lake	Lake
Middle Lagoon	0.689	81.5	4D	WDE	I	C	27.32	0.506	Lagoon	Lagoon
Nelson Lagoon	2.846	8.7	3C	WDE	O	O	26.98	1.194	River	Barrier river
Bega River	0.164	6.9	3D	WDE	I/O	O *	1934.83	3.306	River	Barrier river
Wallagoot Lake	15.208	1027.1	4B	WDE	I	C	26.52	3.865	Lake	Lake
Bournda Lagoon	0.054	31.0	4B		I	C	34.50	0.079	Lagoon	Creek
Back Lagoon	0.457	56.9	4C	CL	I	C	31.35	0.359	Lagoon	Lagoon
Merimbula Lake	20.444	25.3	3B	WDE	O	O	37.90	4.989	Lake	Lake
Pambula River	1.935	13.6	3C	WDE	O	O	296.46	4.356	River	Barrier river
Curalo Lagoon	1.454	132.0	4C	WDE	I	C	28.22	0.714	Lagoon	Lagoon
Shadrachs Creek	0.008	15.5	4C		I	C	13.23	0.009	Lagoon	Creek
Nullica River	0.247	32.8	4C	WDE	I	C	54.77	0.316	Lagoon	Lagoon
Boydtown Creek	0.057	20.8	4C		I	C	3.86	0.016	Lagoon	Creek
Towamba River	0.116	8.2	3D	WDE	O	O	1026.17	1.914	River	Barrier river
Fisheries Creek	0.182	72.9	4D		I	C	6.45	0.053	Lagoon	Lagoon
Twofold Bay	17.441	37.1	1	EMB	O	O	11.01	30.730	Lake	Bay
Saltwater Creek (Eden)	0.070	38.2	4C		I	C	17.19	0.056	Lagoon	Creek
Woodburn Creek	0.082	20.0	4C		I	C	13.51	0.050	Lagoon	Creek
Wonboyn River	2.154	66.4	3A	WDE	O	O	335.44	3.689	River	Barrier river
Merrica River	0.050	27.0	4B	CL	I	C	60.54	0.123	Lagoon	Creek
Table Creek	0.082	43.4	4B		I	C	17.29	0.056	Lagoon	Creek
Nadgee River	0.076	39.4	4D		I	C	58.79	0.192	Lagoon	Creek
Nadgee Lake	8.340	714.3	4C	CL	I	C	13.70	1.204	Lake	Lake

LEGEND

Main class	Subclass		
Lake	Bay	Drowned valley	Lake
River	Barrier river		
Lagoon	Creek	Lagoon	

T = trained, I = intermittent, O = open, C = closed

O * = assumed predominantly open irrespective of Roy et al. (2001) entrance condition

Estuary area excludes saltmarsh

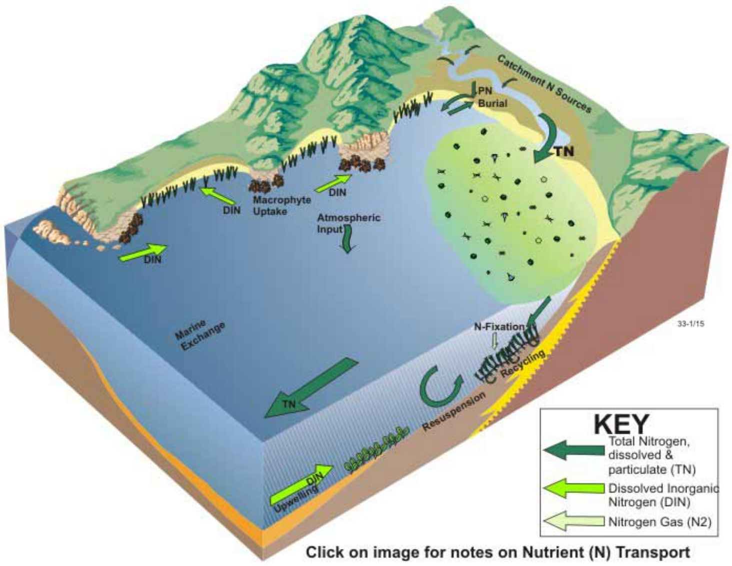
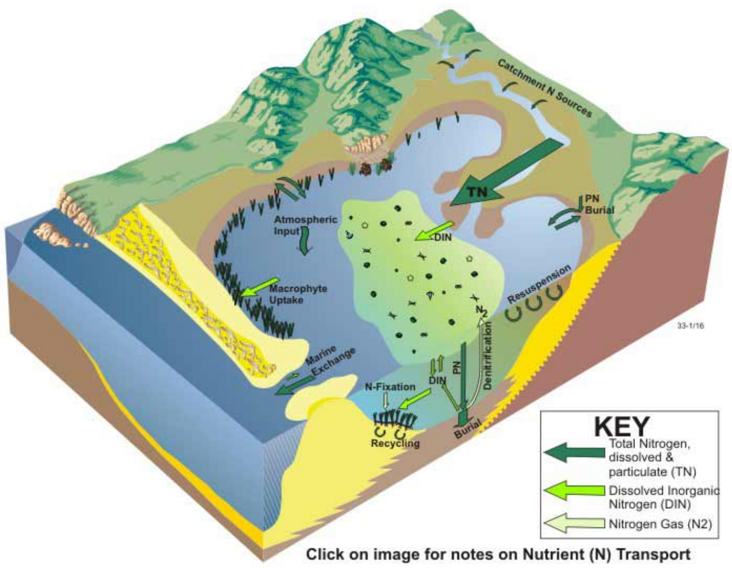
5.3.4 Validation of the conceptual models

Table 8 shows the number of Roy et al. (2001) and Heap et al. (2001) classes represented in each of the lake, river and lagoon chlorophyll response classes. Of the 130 estuaries classified by Heap et al. (2001), the main classes represented are wave dominated estuaries and coastal lagoons, followed by wave dominated deltas and embayments. Conceptual models of nutrient dynamics for each of these four classes are shown in Figure 18 (Ryan et al. 2003).

Table 8: Comparison of classification systems

Classification system		Lake	River	Lagoon
Roy	Bays 1	6		
	Drowned river valleys 2A, 2B, 2C	9	4	
	Immature barrier lake estuaries 3A, 3B	12	4	1
	Mature barrier river estuaries 3C, 3D	2	32	
	Large ICOLL lakes 4A	3		1
	Creek and lagoon ICOLLs 4B	7		21
	Small creek and lagoon ICOLLs 4C, 4D	3	3	72
Heap	Embayments	3		
	Tide dominated deltas		1	
	Tidal creeks		2	
	Wave dominated estuaries	29	16	20
	Wave dominated deltas		17	1
	Coastal lagoons	6	6	29

(shaded) Dominant geomorphic type in Roy et al. (2001) and Heap et al. (2001)

Embayments (three)  Click on image for notes on Nutrient (N) Transport	**Uptake and processing of nitrogen by phytoplankton** The catchment-derived dissolved inorganic nitrogen is transported into the embayment, where it is rapidly processed and assimilated by phytoplankton and benthic microalgae, if temperature and light levels are suitable (Elosegui et al. 1987; Nicholson et al. 1999; Longmore et al. 1999). **Large tidal prism and exchange of marine waters** A large tidal prism results in much of the dissolved and particulate nitrogen, including phytoplankton debris, being transported offshore (Bulthuis et al. 1984) and diluted by seawater.
Wave dominated estuaries (29)  Click on image for notes on Nutrient (N) Transport	**Uptake and processing of nitrogen by phytoplankton** The dissolved inorganic nitrogen is transported into the central basin of the estuary, with biological uptake by phytoplankton (Gaughan et al.1995; Webster & Ford 1998), seagrasses, benthic microalgae and macroalgae (Webster et al. 2002), and macrophytes occurring along the way, if residence times are long enough, and if temperature, turbidity, and light levels are suitable. The balance between planktonic and benthic primary productivity may depend on catchment nitrogen loads (Eyre et al. 2002). **Small export of nitrogen to the marine environment** Due to the long residence time typical of wave dominated estuaries, most catchment derived nitrogen is processed and effectively trapped by the estuary. Typically, only very small quantities of the TN load are exported to the marine environment; however, export is much larger during significant flood events (Nixon et al. 1996).

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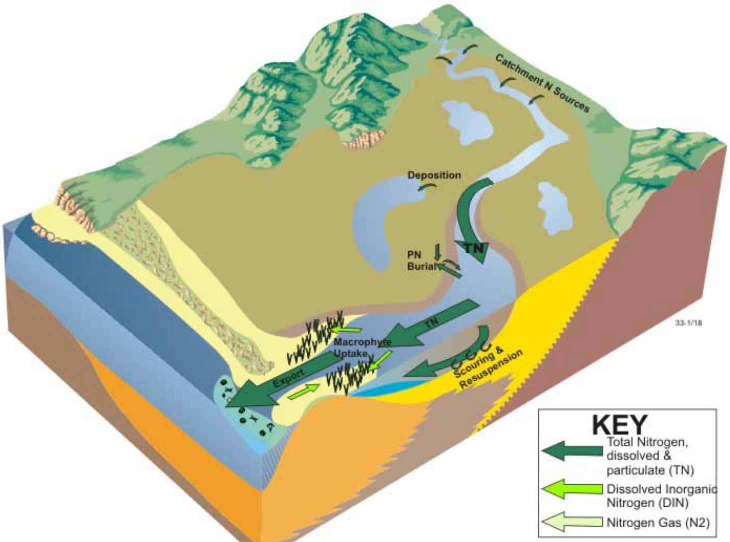
Wave dominated deltas (17)



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Uptake and processing of nitrogen by phytoplankton

Limited deposition and burial of particulate nitrogen occurs in flanking environments, due to the baffling effect of saltmarsh and/or mangrove vegetation, depending on latitude. Burial and resuspension of particulate nitrogen and dissolved inorganic nitrogen can also occur within intertidal flats. Flanking environments typically play a much smaller role in deltas in comparison to wave dominated estuaries.

Large export of nitrogen

A large proportion of the TN load is exported through the mouth of the delta into the marine environment (Eyre 2000; Nixon et al. 1996). Uptake of dissolved inorganic nitrogen by seagrasses may occur in the mouth of the delta. The nitrogen exported into the ocean is typically assimilated by marine phytoplankton.
</td>
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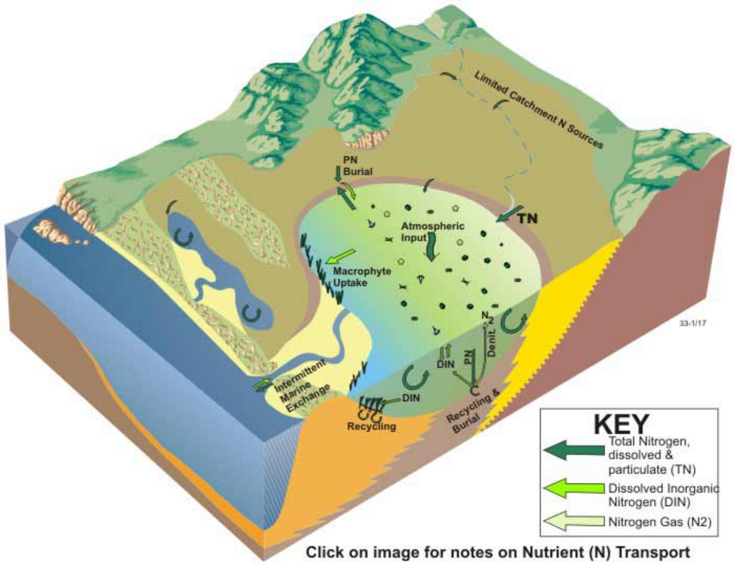
Coastal lagoons (29)  	**Uptake and processing of nitrogen by phytoplankton** Any nitrogen entering the lagoon is typically processed mostly by phytoplankton, if temperature and light levels are suitable (Gaughan et al. 1995; Webster et al. 1998). Long residence times (during barrier closure) ensure that processing of dissolved inorganic nitrogen is complete. Coastal lagoons and strand plain-associated coastal creeks that are open to the ocean can intermittently undergo dramatic changes in their physical and chemical parameters over short periods, owing to their dynamic connection to the sea (Pollard 1994; Griffiths 2001). **Limited exchange with the marine environment** Very small quantities of the TN load are exported to the marine environment only during periods of open entrance conditions. Export is more significant during flood events. Due to limited marine flushing, coastal lagoons and strandplain-associated creeks may be highly susceptible to increased nutrient input.

Figure 18: Conceptual models based on energy and geomorphology (Heap et al. 2001)

To validate the conceptual models, available data on chlorophyll a concentrations and modelled diffuse source nutrient loading were analysed for potential relationships. Chlorophyll a data were available for 82 estuaries (see Chapter 6) while nutrient loads had been modelled for all 184 estuaries (see Chapter 9). Of the 82 estuaries with data, 16 were excluded from the analysis for the following reasons:

- Tallow Creek: continual press of a large point source load from a sewage treatment works flowing into a small estuary
- Evans River, Tomaga Tiver, Candlagan Creek, Bega River and Towamba River: limited number of samples across all three river salinity zones (12, 12, 11, 12 and 6 respectively)
- Parramatta River: immediately upstream of Port Jackson with very limited oceanic influence
- Cooks River: >99 per cent of samples taken in the upper river only

- Stanwell, Flanagans, Slacky, Munna Munnora and Mollymook Creeks: very small surface areas of <0.01 km^2 making them subject to wide swings in water quality which, combined with the limited number of samples (15, 16, 16, 37 and six respectively), meant the sampling results were likely not representative of creek and lagoon systems
- Crooked River: tidal limit only 3.2 km upstream so oceanic water quality most of the time in comparison to other rivers
- Tilba Tilba and Nadgee Lakes: major algal blooms during sampling.

Medians were used for chlorophyll a, in preference to means, as the data used in the assessment originated from a number of custodians collecting samples at different frequencies, tidal stage and rainfall conditions. High variability in water quality, particularly during rainfall events, may skew results if uncorrected for climatic conditions. Separating chlorophyll a sampling results into ambient and event-based should be investigated in the future. In addition, further analysis should be conducted using chlorophyll a sampling results taken from the summer algal growth period. The 2CSalt hydrology model outputs of monthly flows would also allow finer scale temporal analysis of potential load-response relationships between nutrient loads and chlorophyll a. For each river class estuary, the average of median chlorophyll a values for each of three functional zones defined by salinity (see Section 6.1.3) was used to represent overall river chlorophyll a concentrations.

Four scaling factors for nutrient loads were assessed: estuary area (including seagrass and mangrove but excluding saltmarsh or at Mean High Water level of about 0.6 m AHD – see Section 4.1), estuary volume (at 0.6 m AHD), residence time and a Vollenweider flushing term. The residence time T_w recognises the role of flushing in reducing the effect of nutrient loading and is applied linearly to the volume loading. The Vollenweider flushing term recognises the reduced role of flushing in systems with very long residence times and the increasing role of burial in sediments and denitrification in removing nutrient loading. The Vollenweider term is expressed as $(1+T_w^{½})$ where T_w is the residence time and is applied to the denominator of the residence time loading. Accordingly, allowable loads increase with application of the Vollenweider term (Costa et al. 1999).

The four scaling factors were applied to the modelled Total Nitrogen (TN) diffuse source loading in recognition of the role of nitrogen in limiting productivity in estuarine systems (reviewed in Dettmann 2001). Of the four scaling factors, areal loading produced the best correlations as shown in Figure 19.

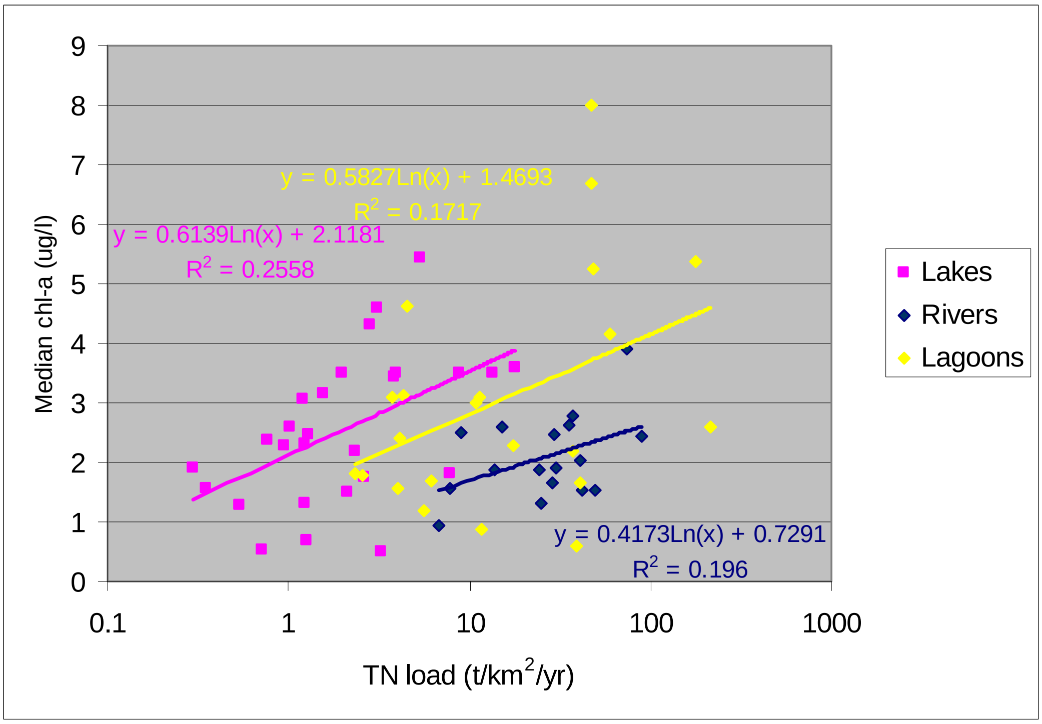


Figure 19: Comparison of nutrient areal loading and chlorophyll response

A number of observations can be made from this plot:

- Chlorophyll a concentrations generally increase with rising TN area loads although the correlations are relatively weak across all estuary types
- Rivers generally have higher areal loading than lakes, bays and drowned river valleys as their evolutionary history has been one of infilling of paleo-valleys with sediment derived from catchment erosion and hence higher areal loadings
- Rivers, lagoons and creeks have loading rates of the same order reflecting similar patterns of infilling and geomorphological development
- Chlorophyll a levels are generally lower for rivers than lakes, bays and drowned river valleys in response to high flushing rates and poorer light regimes limiting the ability of phytoplankton to develop and maintain their populations. Lakes and bays have stiller environments more conducive to light conditions suitable for phytoplankton growth and a greater role for benthic processes in recycling nutrients back to the water column
- Lakes, bays and drowned river valleys have better correlations than rivers, lagoons and creeks
- Rivers can display large variability in algal response during and immediately after rainfall but flushing restores conditions back to ambient relatively quickly which is when sampling usually occurs. However the correlation is only marginally better than for lagoons and creeks
- Lakes and bays have lower variability due to their very high dilution ratios and hence buffering capacity. The signal to noise ratio is therefore higher
- Lagoons and creeks are more problematic because of the high variability in entrance conditions, dilution capacity, flushing times and hence water quality response and ecological processes. Sampling is conducted irrespective of entrance condition which is then reflected in the high variance in chlorophyll a values evident from the statistical analysis. The correlation for

lagoons and creeks is very poor and warrants further investigation of the variables controlling water quality response

- The load-response relationships shown in Figure 19 were based on modelled diffuse source loads of TN exported from the estuary catchment. Adding the loads from licensed sewage discharge loads (see Sections 9.9 and 9.10) to the modelled diffuse source loads to give a total nutrient areal loading marginally improved the correlation for lagoons and creeks (R^2 = 0.1882) but had negligible change for lakes (R^2 = 0.2537) and rivers (R^2 = 0.1975). This factor may become more significant in water quality sampling results from the summer tourist season when discharge loads tend to rise. The relationship of summer chlorophyll a concentrations to nutrient loading should be further investigated.

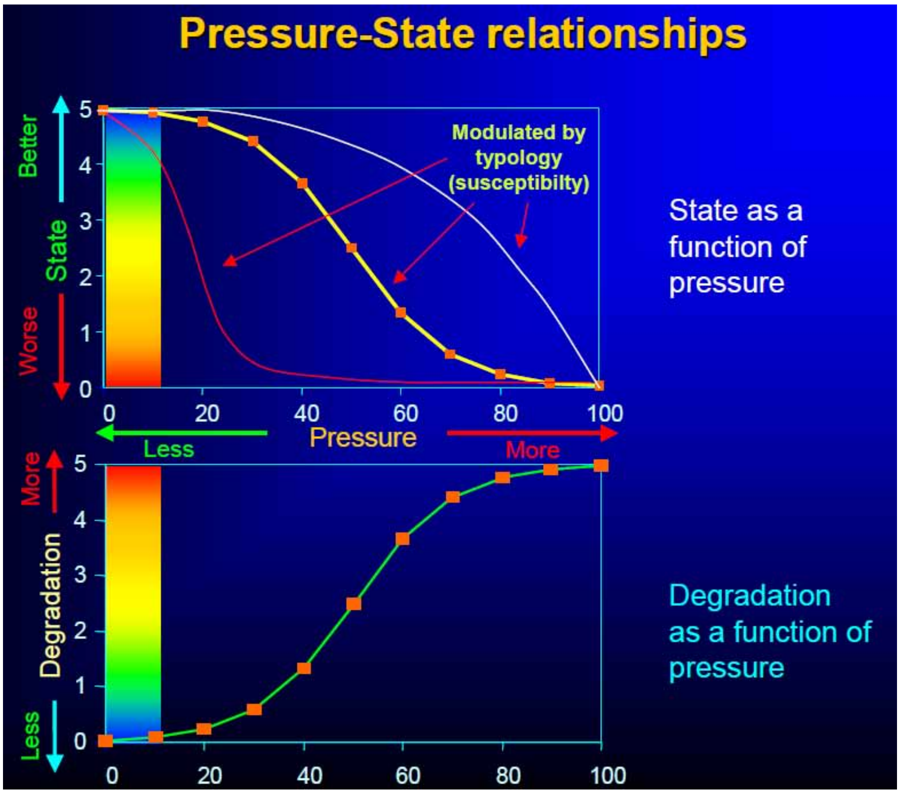
By way of comparison with the proposed classification for NSW estuaries, Scavia & Liu (2009) used a simple nutrient-driven phytoplankton model to assist classifying estuaries according to their susceptibility to nutrients. The model performed well for predicting estimates of measured chlorophyll a and for primary production, grazing and sinking losses consistent with the literature. They suggest that estuaries with a ratio of annual inflow to estuary volume (Q/V) greater than 2.0 per year are less susceptible to nutrient loads and those between 0.3 and 2.0 per year are moderately susceptible.

Allowing for the dilution factor adopted in the chlorophyll response classification system using 10 per cent of annual inflow and being the inverse of Q/V, the methodology of Scavia & Liu (2009) suggests that estuaries with a dilution factor of less than 5 are less susceptible and between 5 and 33 are moderately susceptible. The boundary value of 5 is of the same order as the dilution factor of 3 (Figure 14) separating bays, drowned river valleys and lakes which have higher median chlorophyll a values (Figure 19) from rivers and creeks which tend to have lower chlorophyll values due to higher flushing rates. Scavia & Liu (2009) intended their simple model to be a first-order screening tool for estuarine susceptibility classification. Naturally higher phytoplankton populations could suggest that such systems are closer to an ecological threshold but susceptibility is also governed by other factors not accounted for in these models including flushing and entrance condition.

The preliminary classification of NSW estuaries into lakes, rivers and lagoons for the MER program was subsequently used to stratify sampling designs, set reference conditions for each class of estuary, identify trigger values for a management response, establish scoring intervals for classes and predict which systems are at risk of degradation in the future.

5.3.5 Functional classification

The response-based or functional classification scheme proposed for NSW estuaries is very similar with conceptualisations of load-response or pressure-state models being developed by the US EPA and the National Oceanic and Atmospheric Administration. Response can be modulated or filtered by physical variables such as typology, residence time or ecoregion. Three generalised examples are shown in Figure 20 (Bricker et al. 2007; Latimer & Kelly 2003). The intent behind each model is to incorporate any factors into the classification scheme which fundamentally alter response. Biological or ecological thresholds are then sought for each class of estuary and loading limits defined by the predictive model for each class.



Source: Bricker et al. 2007

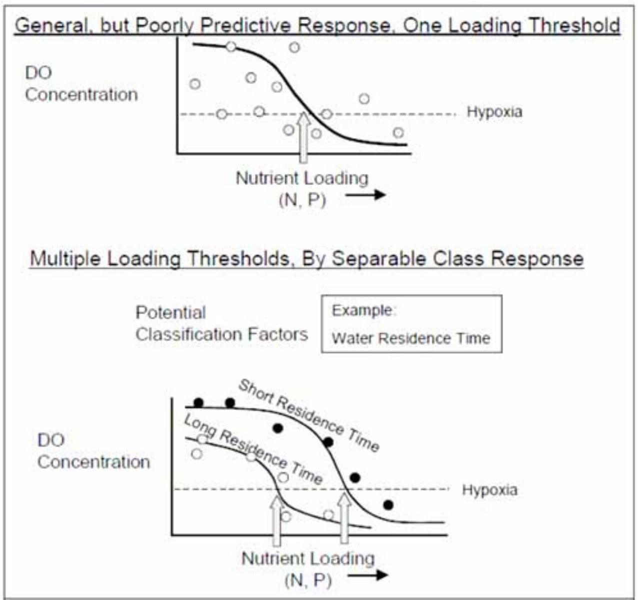


Figure 1. The goal for response classification, a theoretical example.

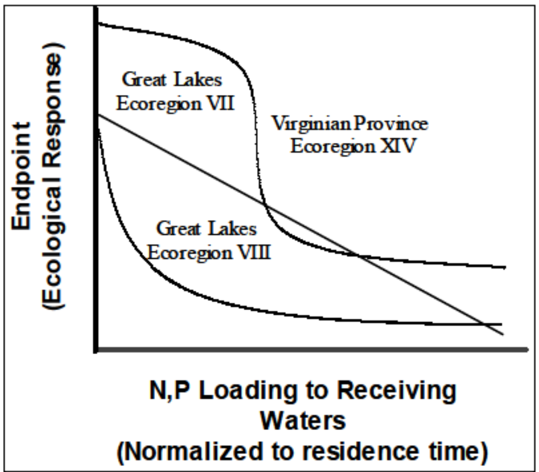


Figure 5. Generalized nutrient load-ecological response models illustrating differences in responses to nutrient loads for 3 ecoregions and 2 biogeographic provinces.

Source: Latimer & Kelly 2003

Figure 20: Generalised stressor-response models

5.4 Macrophyte classification

Heap et al. (2001) mapped geomorphic and sedimentary facies for 405 estuaries around Australia. The eight facies mapped were barrier and back barrier, central basin, fluvial bayhead delta, flood and ebb tide delta, intertidal flat, mangrove, saltflat/saltmarsh and tidal sand banks.

Cluster analysis identified two main groups in the data:

- Tide dominated Group 1 characterised by an association of saltmarsh, mangrove, tidal sand banks, intertidal flats and flood/ebb-tide delta
- Wave dominated Group 2 characterised by an association of fluvial bayhead delta, central basin and barrier/back-barrier.

There was also a close association between saltmarsh and mangrove which was not unexpected since the probability analysis had indicated they both were likely to occur in all six subclasses of estuary.

The probability analysis and the cluster analysis demonstrated that tide dominated subclasses and wave dominated subclasses each have diagnostic facies suites. The dominant facies in each subclass were as follows:

- The central basin is the dominant facies in wave dominated estuaries
- Mangroves and channels are the dominant facies in wave dominated deltas
- Intertidal flats, barrier/back barriers and channels are the dominant facies in strandplains
- Mangroves, saltmarsh and channels are the dominant facies in tide dominated estuaries
- Mangroves are the dominant facies in tide dominated deltas
- Mangroves and saltmarsh are the dominant facies in tidal creeks.

The strong association between facies and subclass was used to develop an index to assess the degree of deviation from an ideal or normal state. Heap et al. (2001) assumed that the greatest habitat integrity occurs in a system that has an idealised facies distribution. A Deviation Index was used to count or score the absence of facies that should be associated with a particular subclass and/or the presence of facies not generally associated with that subclass. A score of 0 to 2 indicated that deviations were mostly due to natural variations based on regional characteristics in the nature of facies. A deviation score of 3 showed deviations due to either natural or anthropogenic activities while >3 was flagged for further investigation into the reasons (natural or otherwise) for the high deviation score. The maximum Deviation Index score was 8, representing the total number of facies mapped and would indicate very poor habitat integrity.

A significant proportion of the Deviation Index scores for NSW estuaries were 3 or greater. However, NSW is characterised by a wave dominated coastline in contrast to the northern regions of Australia that are tide dominated as shown in Figure 21. Specifically, many of the wave dominated systems in NSW are intermittently open coastal lakes, lagoons and creeks which inhibit the growth of mangroves. The absence of mangroves was one of the main factors in driving up the Deviation Index scores for NSW. In addition, regional variability in climatic and estuary biophysical characteristics is high and is not appropriately accounted for in the six subclasses if they are to be used for assessing mangrove and saltmarsh extent.

Exploratory analysis of the key physical and environmental drivers of saltmarsh and mangrove extent and distribution, together with seagrass extent and distribution, is required using the extensive database developed for the MER program. Refinement of the Deviation Index approach based on the wave, tide and river power classification of Heap et al. (2001) may eventuate, or alternatively a response-based system of classification along similar lines to the chlorophyll response model.

For the purposes of the MER program, no *a priori* estuary classification for macrophytes was attempted. Rather, all estuaries in NSW were examined and, if any macrophytes were found, their spatial extent was mapped for comparison of the extent of change between a recent survey and one carried out over 30 years ago (West et al. 1985).

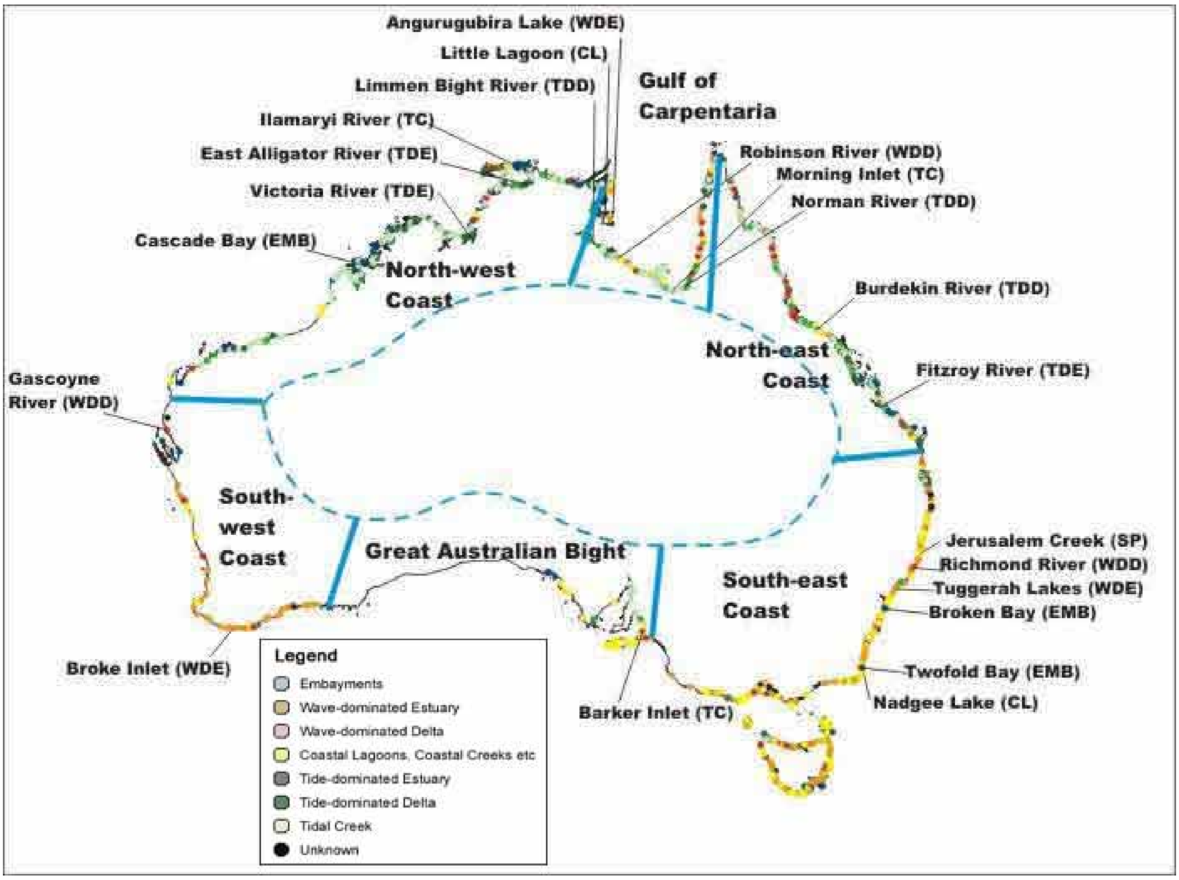


Figure 21: Geomorphic classification of Australian estuaries (Heap et al. 2001)

5.5 Fish assemblage classification

Pease (1999) used estuarine commercial fishery data and eight physical and environmental attributes to define three bioregions within NSW. The physical and environmental attributes analysed were latitude, geomorphological type, catchment area, water area, entrance depth, entrance width, average annual rainfall and seagrass area. Multivariate analysis indicated that NSW estuaries could be grouped into three latitudinal regions with the primary factor being estuary size. Most of the largest estuaries, which were typically drowned river valleys and large barrier lake estuaries, are found in the central region. Most of the smallest estuaries, mainly coastal lagoons, are located in the southern end of the coastline; many of the medium to large estuaries are in the northern area dominated by barrier rivers.

Classification by fishing method, and by richness and catch by taxa also found correlations with estuary size defined by water area. The bioregional pattern for estuarine fisheries established by Pease (1999) is consistent with the findings of other bioregional studies and was adopted for the design and assessment of estuarine fish assemblages (see Figure 22). The north bioregion aligns well with the Northern Rivers CMA region, similarly for the south bioregion and Southern Rivers CMA region. The central bioregion incorporates the other three coastal CMA regions.

In an earlier study, biological sources of variation in fisheries communities were examined in a report to the Fisheries Research Development Corporation (Cappo et al. 1998). In the studies reviewed, the distribution of estuarine faunas was found to be structured by:

- distance from the mouth
- extent of tidal intrusion
- salinity and episodic floods
- position of the halocline (salt wedge)
- depth of the channel
- position and nature of vegetated habitats

Sufficient data were not available to test these variables within NSW estuaries. However, as for macrophytes, a substantial database of physical, environmental and ecological attributes has been established through the MER program and this could be analysed to identify possible drivers of spatial patterns in estuarine fish assemblages.

Research is currently ongoing to examine the spatial scales of variability within the estuarine fish communities of large coastal lakes in NSW with a view to determining the optimum sampling strategy for future quantification of abundance patterns (C Gray pers. comm. 2009).

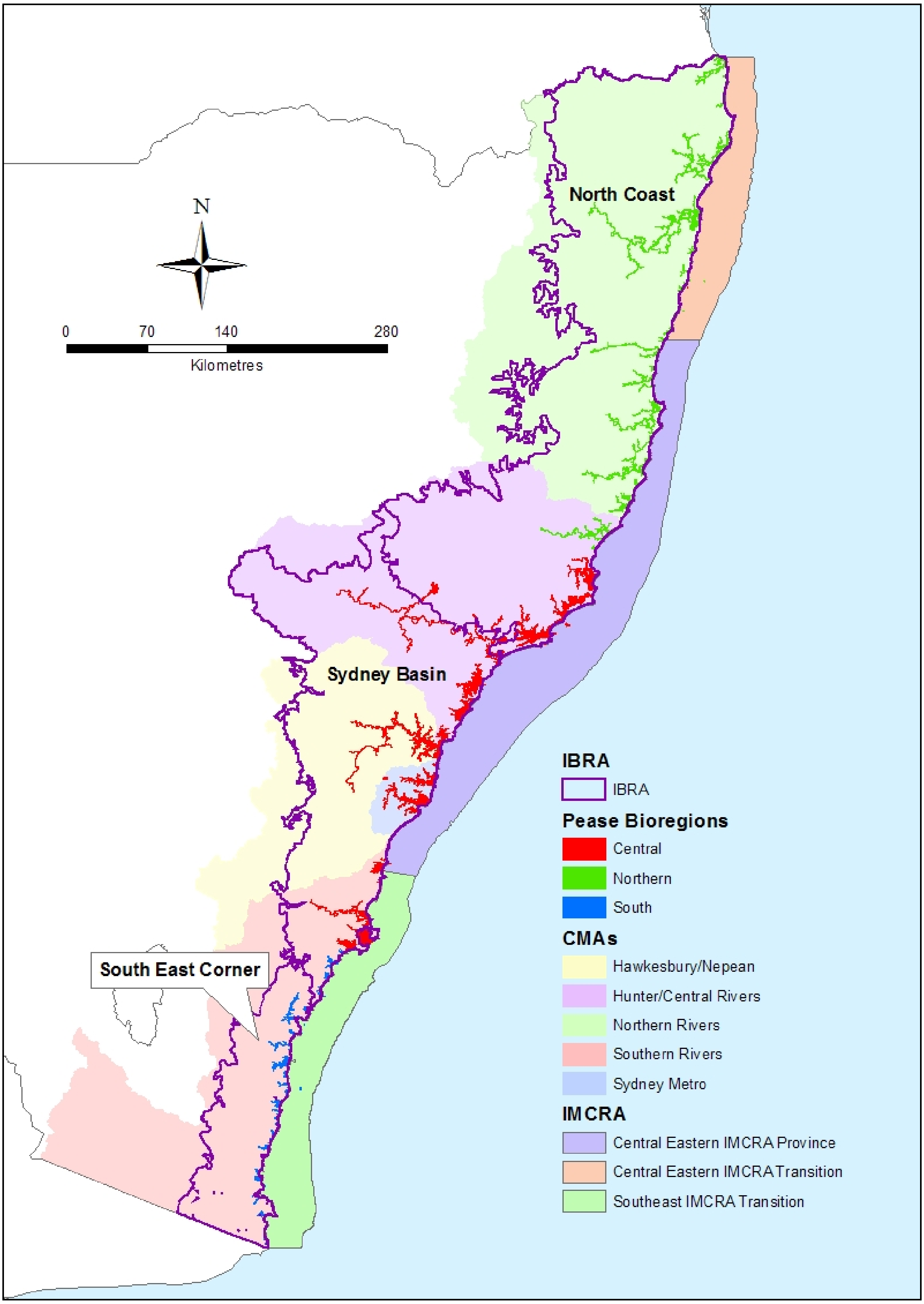


Figure 22: The bioregions used for fish sampling (after Pease 1999)

5.6 Future direction for classification

The classification systems adopted across indicator groups comprised both non-geographical and bioregionalisation approaches. Further exploratory analysis of existing databases augmented by ongoing collection of new data will potentially result in refinement of existing classification systems or development of new systems particularly for macrophytes. Statistical approaches that could be explored for classification include statistical-cluster analysis and/or a statistical-Bayesian classification and regression tree (B-CART) that simultaneously optimises estuary class membership and the fitting of variables to load-response models (Gilbert et al. 2010).

Subsequent to the release of the SOC 2010 reports, work on the chlorophyll response classification has indicated a minor change to the classification criteria may be appropriate. Examination of the types of systems captured by the river class shows that six of the seven estuaries classified by Roy et al. (2001) as 'type 3C mature barrier river estuaries' are included. The exception is the permanently open type 3C Wapengo Lagoon which could also be captured by the river class through an increase in the dilution factor from 3.0 to 3.5 that separates the lake from the river class. Wapengo Lagoon has a dilution factor of 3.35 compared with the system with the next highest dilution factor which is Durras Lake with 3.51. Figure 19 has been replotted in Figure 23 reclassifying Wapengo Lagoon as a river. The R-squared values for lakes and rivers have both increased significantly from 0.256 up to 0.325 and from 0.196 up to 0.350 respectively. Further improvements are likely as more data and analysis become available.

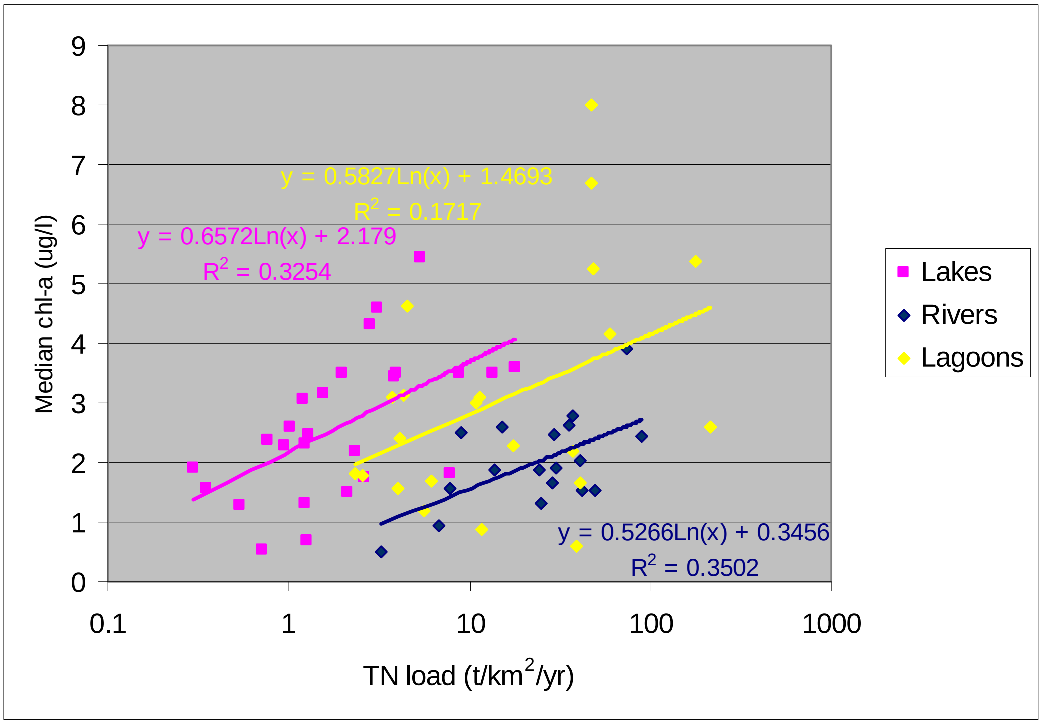


Figure 23: Load-response relationships with amended chlorophyll classification system

6. Condition data

The condition indicators proposed by the NRC are a mix of attributes of structural elements, ecological processes and community composition of estuarine ecosystems. They represent biological endpoints in preference to the drivers, pressures or stressors controlling condition.

Considerable work on indicators has been undertaken at the national level by ICAG for the Marine and Coastal Committee (MACC). ICAG engaged the Cooperative Research Centre (CRC) for Coastal Zone, Estuary and Waterway Management to develop a set of national indicators under the National Natural Resource Monitoring and Evaluation Framework (NM&EF). An indicator list was developed by the CRC (Scheltinga et al. 2004) as shown in Table 9 together with the indicators from the NRC (NRC 2005) and the Estuaries MER program.

The alignment between the indicators proposed for use and those of the NRC is relatively good. Emergent macrophytes and freshwater inflow have been dropped from the NRC measures while ephemeral macroalgae and water clarity measured as turbidity have been added. However, changes in freshwater inflow were modelled and reported as part of a suite of associated pressure indicators (see Chapter 9). The indicators initially used in the NSW Estuaries MER program are a subset of the larger suite at the national level.

Table 9: Comparison of NSW indicators with national indicators

NM&EF heading	National indicators (Scheltinga et al. 2004)	NRC indicators (NRC 2005)	NSW Estuaries MER program
Estuarine, coastal and marine habitat extent and distribution	Extent/distribution of key habitat types	Extent of mangroves, saltmarsh, seagrass and macrophytes	Extent of mangroves, saltmarsh and seagrass
	Extent/distribution of subtidal macroalgae		Ephemeral macroalgae blooms including seagrass epiphytes
Estuarine, coastal and marine habitat condition	**Biological condition**		
	Algal blooms		Ephemeral macroalgae blooms including seagrass epiphytes
	Animal disease/lesions		
	Animal kills		
	Animal or plant species abundance	Fish assemblages	Fish assemblages
	Animals killed or injured by litter (entanglement, starvation, suffocation)		

NM&EF heading	National indicators (Scheltinga et al. 2004)	NRC indicators (NRC 2005)	NSW Estuaries MER program
	Benthic microalgae biomass (in intertidal sand/mudflat communities)		
	Biomass, or number per unit area, of epiphytes (in seagrass or mangrove communities)		Ephemeral macroalgae blooms including seagrass epiphytes
	Biomass, or number per unit area, of macroalgae (in rocky shore, rocky reef or coral reef communities)		
	Chlorophyll a	Chlorophyll a	Pelagic chlorophyll a
	Coral bleaching		
	Death of marine mammals, endangered sharks and reptiles caused by boat strike, shark nets or drum lines)		
	Mass mortality events		
	Occurrence of imposex		
	Pest species (number, density, distribution)		Caulerpa taxifolia only
	Seagrass: depth range	Extent of seagrass	Extent of seagrass
	Vertebrates impacted by human activities		Three species of shorebirds are monitored by OEH under the Fox Threat Abatement Plan and could be reported
	Physical/chemical condition		
	Dissolved oxygen		Sampled concurrently with chlorophyll a
	Estuary mouth opening/closing		Level of estuary mouth artificial opening
	Nutrients		
	pH		
	Presence/extent of litter		

NM&EF heading	National indicators (Scheltinga et al. 2004)	NRC indicators (NRC 2005)	NSW Estuaries MER program
	Salinity		Sampled concurrently with chlorophyll a
	Sedimentation/erosion rates		
	Shoreline position		
	Temperature		Sampled concurrently with chlorophyll a
	Targeted pathogen counts		
	Total nutrients in the sediments WITH dissolved nutrients in the sediments		
	Total nutrients in the water column WITH dissolved nutrients in the water column		
	Toxicants in biota		
	Toxicants in the sediment		
	Turbidity/water clarity		Turbidity
	Water/current patterns		
	Water soluble toxicants in the water column		
	Water temperature		
	Other		
		Freshwater inflow	Limited existing gauges but 2CSalt hydrology models developed for all catchments
		Stress biomarkers	

6.1 *Chlorophyll a and turbidity*

6.1.1 Data sources

Data on resource condition indicators were sought from as wide a range of potential custodians as possible. Parties approached for each group of indicators are listed below:

- The former NSW Department of Environment and Climate Change, NSW Department of Water and Energy and NSW Department of Primary Industries

- All local councils along the NSW coastline including the LGAs of Tweed, Byron, Ballina, Richmond River, Clarence Valley, Bellingen, Nambucca, Kempsey, Port Macquarie-Hastings, Greater Taree, Great Lakes, Port Stephens, Newcastle, Lake Macquarie, Wyong, Gosford, Hornsby, Pittwater, Warringah, Manly, North Sydney, Lane Cove, Parramatta, Rockdale, Botany Bay, Sutherland, Wollongong, Shellharbour, Kiama, Shoalhaven, Eurobodalla and Bega Valley
- Sydney Water Corporation
- Wollongong, Newcastle and Southern Cross Universities
- Lake Illawarra Authority
- Pacific Power
- J.H. & E.S. Laxton Environmental Consultants P/L.

A questionnaire on water parameter sampling was issued to most custodians (Table 10).

Table 10: Standard information requested from custodians of water data

1.	What estuaries and waterways do you sample?
2.	How many/where are the locations within estuaries that you sample? Are there maps, GPS points available?
3.	What is the frequency of sampling? Is this consistent among estuaries?
4.	What parameters are collected at all sites?
5.	How are the data collected and where are the samples analysed?
6.	Are there any quality assurance and quality control protocols and procedures in place? (If water quality collected by lab, then it's usually just the lab's protocols).
7.	Reporting and management: a) Is the reporting State of the Environment (SOE)? b) Have you developed your own water quality index? c) Do you use ANZECC guidelines? d) Is there a management response if there are low or high values?

A summary of the sample counts is shown in Appendix 10. Most custodians forwarded their data on request while a very small number requested data licence agreements to be put in place before supplying their data. Not all custodians, particularly councils, were able to supply their data for a variety of reasons. Significant additional data are known to exist and should be accessed for the next round of SOC reporting.

Data were received from councils for 29 estuaries. There is large variability between LGAs in the number of estuaries within the LGA, the proportion of estuaries sampled, the parameters sampled, the frequency of sampling and the usefulness of the data for resource condition assessment. Of the 32 coastal councils, 21 are gathering data that can be used for assessment and reporting of estuary health.

6.1.2 Data quality

The quality control steps undertaken for each dataset are outlined as follows:

- Location of sampling point – data upstream of the upper tidal limits of estuaries were discarded
- Availability of metadata – if no metadata were available, the data were discarded
- Age of data – data older than 1950 were discarded due to uncertainty in analytical techniques
- Data entry errors – data for each estuary were individually checked for obvious errors arising during data entry eg conversions to correct units of measurements
- Outliers – data for each estuary were individually checked for obvious outliers eg negative values of temperature during the summer months, or extraordinarily high turbidity values (in the 10,000s). Where chlorophyll a values exceeded 200 µg/l, a check was made on the location of sampling. If sampling was near, for example, a sewage overflow, the data were retained in the database but were not used for the purposes of assessing estuary health. Including sample results from the plume of a specific point source would bias the assessment of ambient conditions.

Once quality controlled, the remaining data were stored in the Keeping Estuarine Values Integrated for NSW (KEVIN) water quality database based on an Excel spreadsheet and maintained by OEH. A more permanent database solution is being explored using SQL Server into which the KEVIN data may be migrated. Some data were not entered into the KEVIN database as it has not been publicly released; this included data from the University of Wollongong on Shoalhaven River, Clyde River, Moruya River, Burrill Lake, Coila Lake and Lake Illawarra and from Wollongong City Council on Stanwell, Flanagans, Slacky and Towradgi Creeks and Bellambi Lake. The data are stored separately for later inclusion in the KEVIN database but have been analysed for the purposes of this report.

The SOC reports also required an assessment of the level of confidence in each dataset. This is a significant issue for water quality data which have been acquired from a number of custodians. Criteria were developed for assessing the quality and reliability of the data and scores in a range from 1 to 3 assigned to each dataset as shown in Table 11. The data quality score for each estuary is shown in Table 12. Note for turbidity, the data quality scores were identical for each estuary as only data from the Estuaries MER program have been retained in the database. Myall River has been the subject of a Commonwealth-funded Comprehensive Coastal Initiative project and has been assigned a higher turbidity data quality score.

Table 11: Criteria for assessing reliability of water quality data

Score	1 (Poor)	2 (Fair)	3 (Good)
Analysis	Laboratory/field analysis without quality system in place.	Laboratory has internal quality system (not National Association of Testing Authorities (NATA) registered), and/or field analysis, instrument calibration is unknown.	Laboratory NATA registered or other highly developed Quality Assurance/Quality Control (QA/QC) procedures including inter-laboratory calibrations or other external processes (such as government and research agency labs), and/or field analysis on appropriately calibrated instruments.
Field sampling	Collectors with minimal experience with no training (ie, community groups), or no QA/QC documented procedures.	Suitably qualified collectors, who have some degree of professional training or are working under professional supervision, less than optimal QA/QC.	Professionally trained organisations / individuals (eg government and/or research agencies), appropriate QA/QC (eg field and transport procedures documented).
Sampling replication	One replicate only.		More than one replicate.
Spatial coverage	Not representative (eg single site on edge of waterway).	Sampling representative of limited parts of system (eg two sites in a central basin, upstream and downstream of outfall etc).	Variability assessed and accounted for in sample design, sampling representative of system (eg bays, basins and longitudinal river sections).
Temporal coverage	Inconsistent data collection and data gaps.	Consistent collection at less than optimal scale (eg quarterly) >two years, or; Consistent data collection <two years at optimal scale (eg monthly).	Variability assessed and consistent collection at optimal scale (eg monthly) for >two years.
Age of data	Data >10 years old.	Data 5–10 yrs old.	Data <five years old.
Data source	Data from three or more programs.	Data from two programs.	Data from one program.

Scoring: 15–21 = Good 8–14 = Fair 1–7 = Poor

Table 12: Data quality scores for KEVIN water quality data

Estuary (T) = estuary has turbidity data	Analysis	Field sampling	Sampling replication	spatial coverage	Temporal coverage	Age of data	Data source	Total quality score
	Quality score for chlorophyll a							
Brunswick River (T)	2	2	1	1	1	3	3	13
Belongil Creek	2	2	1	3	2	3	3	16
Tallow Creek	3	3	1	2	2	3	3	17
Evans River (T)	3	3	1	1	1	3	3	15
Sandon River (T)	3	3	1	1	1	3	3	15
Hastings River (T)	2	2	1	2	2	3	3	15
Manning River	2	2	1	2	2	3	3	15
Khappinghat Creek (T)	3	3	1	2	1	3	3	16
Wallis Lake (T)	3	3	2	3	3	3	2	19
Smiths Lake	2	3	2	3	2	3	2	17
Myall River	3	3	1	3	2	3	3	18
Karuah River (T)	3	3	1	1	1	3	3	15
Lake Macquarie	2	2	1	2	2	3	1	13
Tuggerah Lake (T)	2	2	3	3	1	3	1	15
Wamberal Lagoon (T)	3	3	1	2	1	3	3	16
Avoca Lake (T)	2	3	1	2	1	3	2	14
Hawkesbury River	2	2	1	1	1	3	3	13
Narrabeen Lagoon	2	2	2	3	2	3	2	16
Dee Why Lagoon	3	3	1	3	2	3	2	17
Curl Curl Lagoon	3	3	1	3	2	3	2	17
Manly Lagoon (T)	2	2	2	2	3	3	2	16
Parramatta River (T)	2	2	1	2	2	3	2	14
Port Jackson	2	2	2	2	2	3	3	16
Cooks River	2	2	1	1	1	3	2	12
Georges River (T)	2	2	3	3	2	3	2	17
Botany Bay	3	3	1	1	1	3	3	15
Wattamolla Creek (T)	3	3	1	3	3	3	2	18
Towradgi Creek (T)	3	3	1	1	1	3	3	15
Fairy Creek (T)	2	2	1	3	1	3	1	13
Lake Illawarra (T)	2	2	1	3	2	3	2	15
Minnamurra River (T)	2	2	1	1	3	3	2	14
Spring Creek	2	2	1	1	1	3	3	13
Munna Munnora Creek	2	2	1	1	2	3	3	14
Werri Lagoon	2	2	1	2	2	3	3	15
Crooked River	2	2	1	2	2	3	3	15
Shoalhaven River (T)	3	3	1	1	1	3	3	15
Burrill Lake (T)	3	3	1	3	1	3	3	17
Termeil Lake (T)	3	3	1	2	1	3	3	16
Durras Lake (T)	3	3	1	2	1	3	3	16
Clyde River (T)	3	3	1	1	1	3	3	15
Congo Creek (T)	3	3	1	2	1	3	3	16
Coila Lake (T)	3	3	1	2	1	3	3	16
Corunna Lake (T)	2	2	1	2	1	3	2	13
Cuttagee Lake (T)	3	3	1	2	1	3	3	16
	Quality score for turbidity							
Myall River	3	3	1	3	2	3	3	18
Other estuaries (26)	3	3	1	1	1	3	3	15

Data quality: good (green), fair (yellow), poor (orange)

6.1.3 Data analysis

Chlorophyll a and turbidity data were analysed for summary statistics on the three estuary classes of lakes, rivers and lagoons. Chlorophyll a data were available for 29 lakes, 24 rivers and 29 lagoon class estuaries and for turbidity, data were available for 18 lakes, 16 rivers and 18 lagoons.

Box plots were generated to visually display the median and inter-quartile range. The upper and lower ranges of the plots represent the 5^{th} and 95^{th} percentiles as shown in Figure 24, Figure 25 and Figure 26 for chlorophyll a for lakes, rivers and lagoons respectively. Likewise, Figure 27, Figure 28 and Figure 29 show the turbidity box plots.

For riverine estuaries, Ferguson et al. (2009 unpubl) defined three functional zones based on salinity ranges of 0 to <10, 10 to <25 and ≥25 ppt. A generalised model of ecological function in estuaries is emerging that recognises the importance of pelagic and benthic light climates as controls over biogeochemistry and ecological function of different zones along the estuarine gradient. High light (photic) sediments tend to tightly conserve or take up nutrients while sub-photic sediments tend to be a significant source of nutrients to the water column. The interaction of bathymetry, light, hydrology and salinity results in longitudinal variation in water quality and phytoplankton production. Three zones can be characterised by the relative proportion of deep channel to shoals: channelised upper reaches, wider middle reaches with sub-tidal shoals and lower reaches with extensive inter-tidal shoals. These generally correspond with the three salinity ranges although the longitudinal location of the salinity ranges will vary dynamically with rainfall events. In generating the summary statistics and box plots, data for all three functional zones have been consolidated for analysis.

For riverine estuaries, sampling can often be unevenly distributed longitudinally along the river. Medians in each of the three functional zones were also calculated and averaged to show the potential bias in results. Statistical summaries of the data underpinning Figures 24 – 29 and the river functional zone averages are shown in Appendix 11 for chlorophyll a and Appendix 12 for turbidity.

For riverine estuaries, quality control was applied to the data prior to inclusion in the analysis as follows:

- Only chlorophyll a values with an associated salinity value were included
- For Sydney Water data, where salinity was not available, the locations of sampling sites as described in the annual technical reports on Sydney Water's website were used to ascribe a low, mid or upper river category to the data. Also any data with zero as an entry were excluded
- Any data collected with salinity below 2 ppt were excluded as a further check to ensure only estuarine sites were included and to reduce the bias introduced by multiple sampling programs targeting data collection to either ambient or wet weather conditions. For the MER program sampling conducted by OEH since 2007, all upper river sampling locations are known to be located within the estuary and therefore all data irrespective of salinity have been included in the analysis.

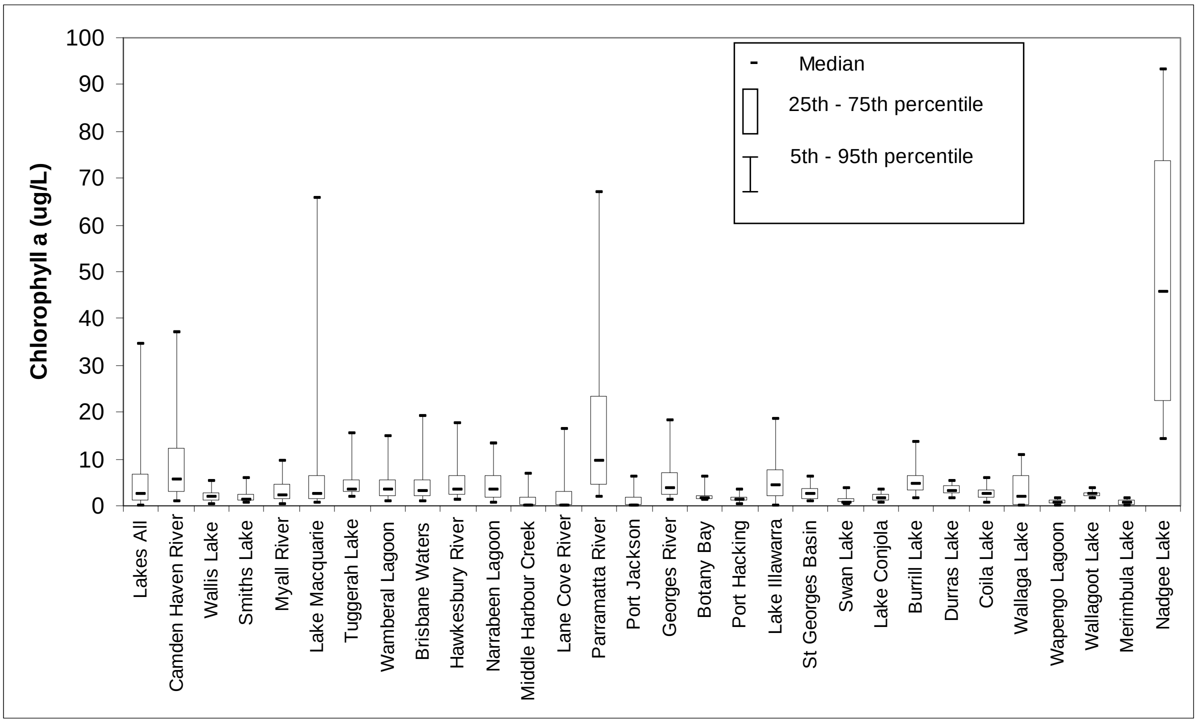


Figure 24: Box plot of chlorophyll a for lake class

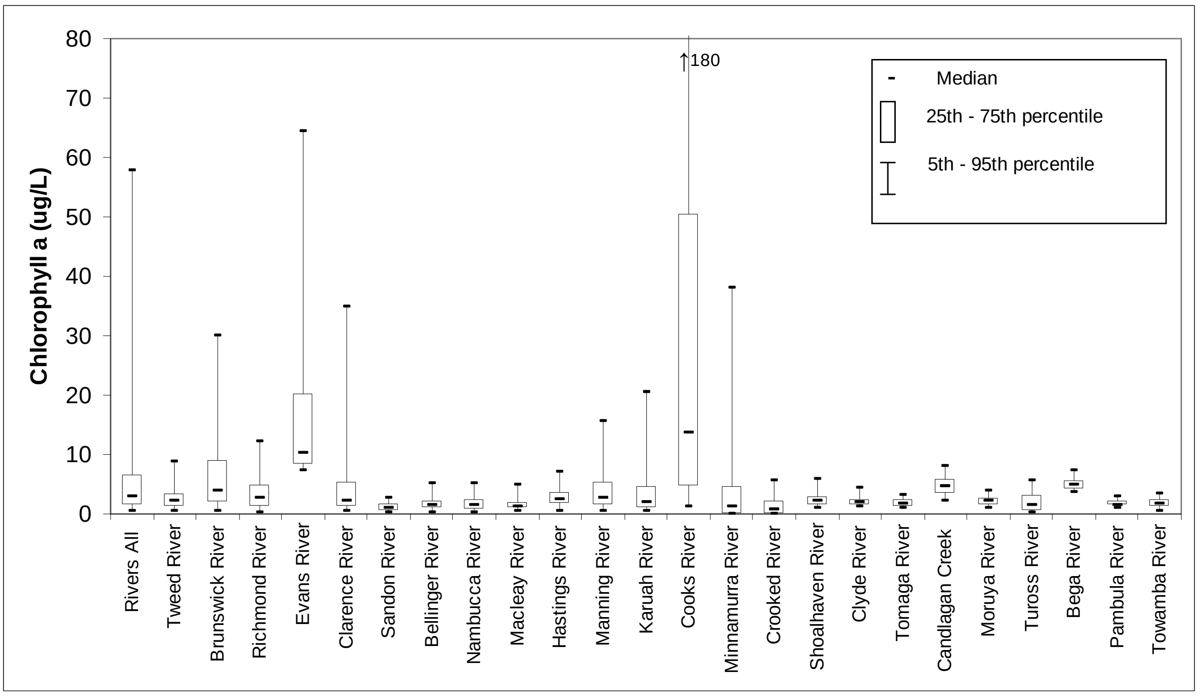


Figure 25: Box plot of chlorophyll a for river class

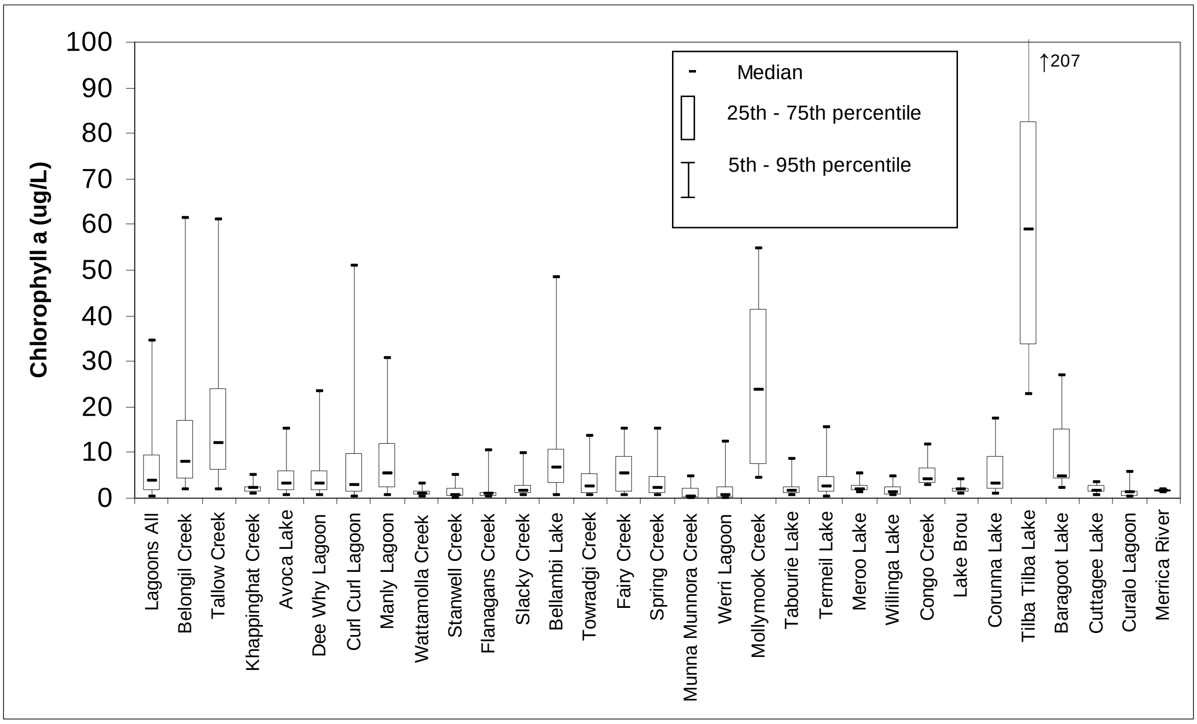


Figure 26: Box plot of chlorophyll a for lagoon class

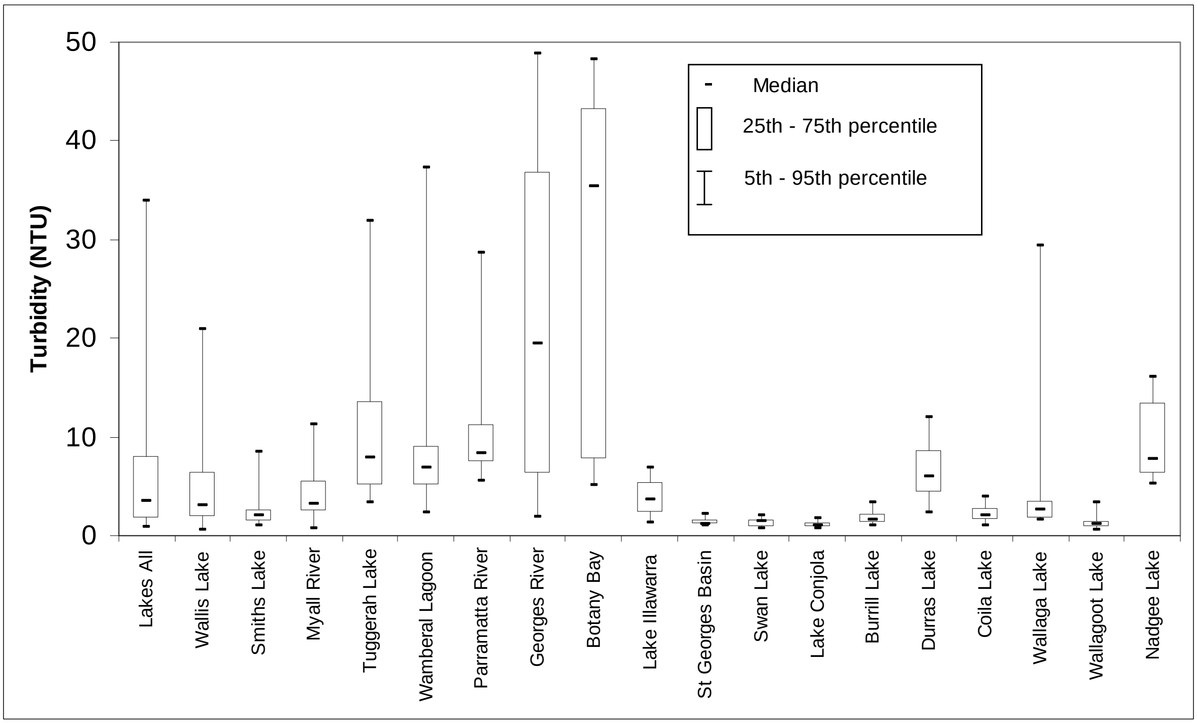


Figure 27: Box plot of turbidity for lake class

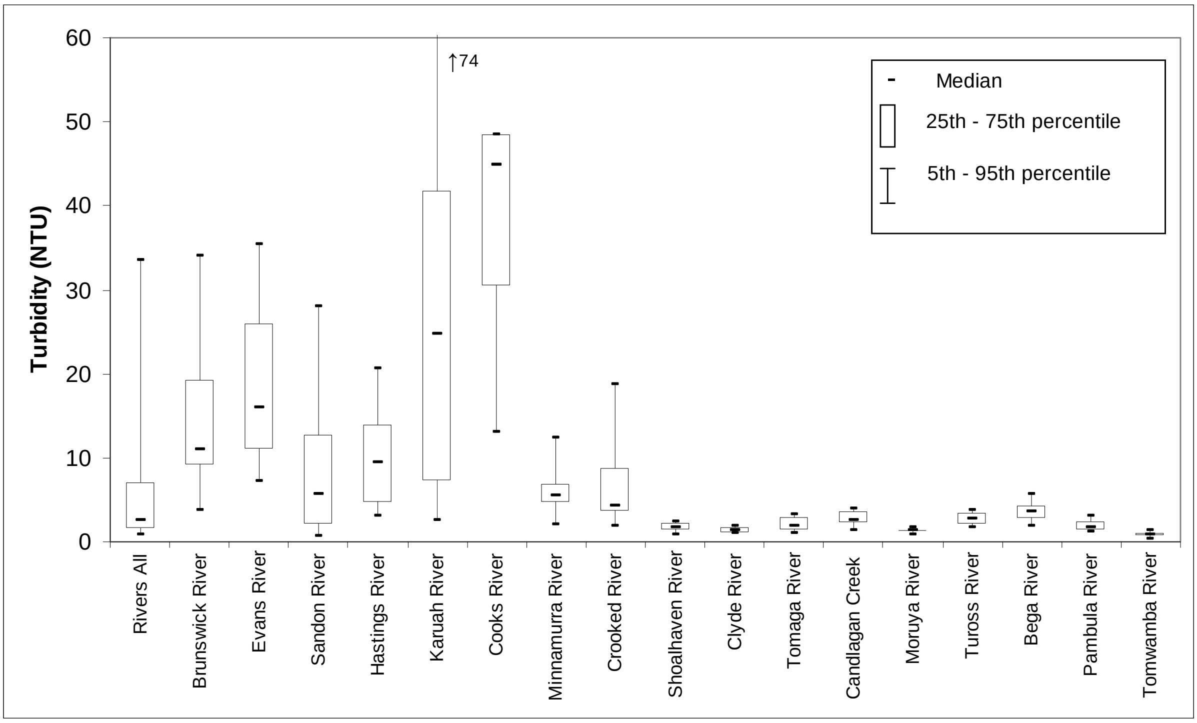


Figure 28: Box plot of turbidity for river class

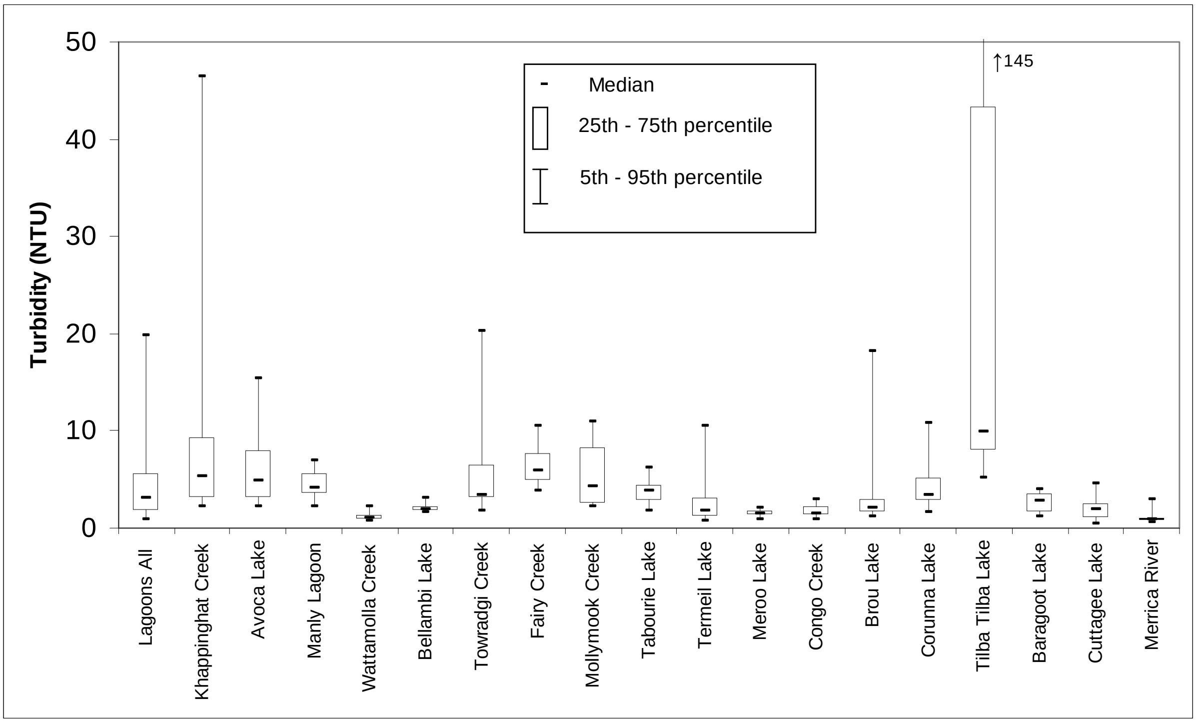


Figure 29: Box plot of turbidity for lagoon class

6.1.4 Sampling design

The design used assumes that short-term temporal variability in chlorophyll concentrations is not great and that samples from a single day are sufficient to represent a longer time period (1–2 weeks). This assumption is supported by Wellman (2008) who demonstrated that rates of phytoplankton production derived from sequential daily estimates for a fortnight were not significantly different from those derived from spatially replicated samples from a single day in that month. In addition, OEH data have indicated that pelagic chlorophyll concentrations differ between edge waters and central basin waters of coastal lakes (Scanes et al. 2007), (OEH unpubl), but not within these zones. This means that central basins can be adequately represented by a small number of replicate samples. In the sampling described below, those samples are integrated within (but not between) zones that are spatially large in comparison to the size of the estuary, thus providing greater confidence that the data do represent the entire estuary.

Power analysis can be used to assure that the sampling design has a reasonable chance of detecting a desired level of change. The sensitivity of a test will depend on the number of samples taken, the variability of the parameter being tested and the desired level of change to be detected. Variability can be estimated from available data or, if data are lacking, a subjective estimate may be necessary. The analysis should be revisited as more data become available and the sampling design refined.

The initial design, which used extracts from water samples to determine chlorophyll concentrations, was based on power analyses of two existing datasets (Scanes et al. 2007). Those datasets were monthly data (n = two replicates per site) for 18 coastal lakes, where means ranged from 15.2 to 0.6 and coefficient of variability (CV = standard deviation/mean) from 0.01 to 0.6, with an average CV of 0.17; and annual means for 10 lakes (n = 12 months; n per month = two) where means ranged from 6.3 to 0.9 and CV from 0.03 to 0.36, with an average CV of 0.21. The first dataset was composed predominantly of lake type estuaries (16 lakes, two rivers, one lagoon). It was not possible to do power analyses for each type of estuary, therefore only lakes were analysed. The second dataset was more varied with five lakes, three rivers and two lagoons. In this set, power was calculated for each type of estuary.

The analysis was based on a test of the hypothesis that the mean chlorophyll concentration for an estuary at any time was not greater than the trigger value. An acceptable level of power by convention is taken as 0.8. Power was calculated for a two-sample comparison with an effect size of a change in mean from 1.6 (current overall mean) to 3 (above trigger criteria). The standard deviation for the power analysis was estimated by taking the average CV (standard deviation/mean) for all samples (of each estuary type) within each dataset and applying that to calculate the standard deviation for each hypothesised mean. CV for dataset 1 was 0.17, and the number of samples to achieve a power of 0.8 was just 2. In dataset 2, mean CV for sites within an estuary each month was 0.4 for lakes, 0.8 for rivers and 0.7 for lagoons. This resulted in five, 14 and 12 samples (respectively) to achieve power of 0.8 for the comparison. In this dataset it would thus only be appropriate to compare annual means to triggers.

Post-hoc analyses of data from the 2008/09 summer MER sampling resulted in CVs of 0.22 for lakes, 0.16 for rivers and 0.17 for small lagoons – power to adequately test the hypothesis could thus be obtained by three samples for lakes and two samples for rivers and small lagoons. The large decrease in CV compared to dataset 2 is attributed to the move from analysis of water samples to use of a logger to record data over a large spatial area, thus avoiding small to micro-scale variability.

An appropriate sample size is, as always, a compromise between power (protection against Type II error) and desired effect size. A sampling scheme with two or three samples collected from central basin sites six times (over the summer period only) would be more than sufficient to detect ecologically significant change between summer means and would even have sufficient power to reliably detect exceedances of trigger values at each time.

6.1.5 Estuary selection

In the pilot study commenced in MER Year 1 (2007), eight estuaries were sampled in each of the three estuary functional types: lakes, rivers and lagoons. Within each estuary type, three relatively undisturbed, two moderately disturbed and three highly disturbed systems were randomly chosen for sampling.

After the data and logistical considerations from the pilot were evaluated, an estuary selection strategy utilised a mixed model, with seven fixed 'sentinel' estuaries that are sampled every year to track inter-annual variability and a minimum of 27 stratified random 'roving' estuaries sampled within a particular region each year. Using a combination of fixed and stratified random sites is based on the sampling design for macroinvertebrates and fish used by the Sustainable Rivers Audit (Davies et al. 2008), which was established after considerable evaluation of a range of possible sampling strategies.

Roving estuaries will be sampled on a three-year rolling basis, with a specific CMA region (or group of CMAs) sampled each year. The CMA region divisions are:

- Northern Rivers
- Hunter–Central Rivers, Hawkesbury–Nepean, Sydney Metropolitan
- Southern Rivers.

Roving estuaries

Estuaries within a CMA region (or CMA region group) were initially divided into disturbance classes based on the ratio of current to pre-European settlement TN loads. Systems with TN load ratio <1.5 were defined as relatively undisturbed, 1.5 to 2.5 as moderately disturbed and >2.5 as highly disturbed (see Section 9.10). Estuaries within each disturbance class were then sub-divided into three types: lakes, rivers and lagoons. At least three examples of each disturbance/type group were selected from the available systems at random. Additional systems were selected as back-ups if access was not possible.

Sentinel estuaries

One example of high and low disturbance for each estuary type was selected as fixed sentinel sites. These were all in the central part of the NSW coast (but away from Sydney) for logistical reasons. Preference was given to systems with existing datasets.

Estuaries sampled in 2007/08 and 2008/09 are shown in Table 13. Note the number of estuaries sampled in each disturbance category were not identical reflecting subsequent refinement to the classification scheme.

Table 13: Estuaries sampled for chlorophyll a and turbidity

2007/08			2008/09		
Estuary	**Type**	**Disturbance**	**Estuary**	**Type**	**Disturbance**
Fixed sites					
Durras Lake	Lake	L	Durras Lake	Lake	L
			Wallis Lake	Lake	M
Lake Illawarra	Lake	H	Lake Illawarra	Lake	H
Clyde River	River	L	Clyde River	River	L
Shoalhaven River	River	M	Shoalhaven River	River	M
Khappinghat Creek	Lagoon	M	Khappinghat Creek	Lagoon	M
Fairy Creek	Lagoon	H	Fairy Creek	Lagoon	H
Random sites					
Coila Lake	Lake	L	Conjola Lake	Lake	L
Tuggerah Lake	Lake	M	Durras Lake	Lake	L
Burrill Lake	Lake	M	Coila Lake	Lake	L
Wamberal Lagoon	Lake	H	Wallagoot Lake	Lake	L
Sandon River	River	L	Burrill Lake	Lake	M
Hastings River	River	M	Wallaga Lake	Lake	M
Karuah River	River	M	Merimbula Lake	Lake	M
Hawkesbury River	River	M	Pambula River	River	L
Tweed River	River	H	Moruya River	River	L
Brunswick River	River	H	Tuross River	River	L
Richmond River	River	H	Towamba River	River	L
Evans River	River	H	Tomaga River	River	M
Parramatta River	River	H	Candlagan Creek	River	M
Georges River	River	H	Bega River	River	M
Minnamurra River	River	H	Crooked River	River	H
Wattamolla Creek	Lagoon	L	Cullendulla Creek	River	H
Cuttagee Lake	Lagoon	L	Tabourie Lake	Lagoon	L
Termeil Lake	Lagoon	M	Lake Brou	Lagoon	L
Corunna Lake	Lagoon	M	Baragoot Lake	Lagoon	L
Avoca Lake	Lagoon	H	Merrica River	Lagoon	L
Manly Lagoon	Lagoon	H	Meroo Lake	Lagoon	M
Towradgi Creek	Lagoon	H	Bellambi Lake	Lagoon	H
			Mollymook Creek	Lagoon	H
			Tilba Tilba Lake	Lagoon	H

6.1.6 Sampling methods

National indicator guidelines

Indicator guidelines have been developed by the former NLWRA via national coordination committees and their associates. The NLWRA advocates that the guidelines should be used as standards for the collection, collation and storage of data in order to assist NRM service providers and community groups make observations that can be potentially be pooled and re-used at a later date. Guidelines are available for chlorophyll a and turbidity/water clarity and have been adopted as the standard with some procedural modifications to suit the MER program objectives. The detailed sampling methods are described below and have also been incorporated into the national guidelines (see Appendix 13).

Site selection within estuaries

The spatial scale of interest is the entire central basin of lakes and lagoons, and the assumed chlorophyll maximum that occurs in the mid-upper sections of river estuaries. To facilitate representative spatial coverage, estuaries were divided into zones. For creeks and lagoons, zones were assigned on charts before sampling commenced. A zone was an area 500 to 700 m diameter in which sampling takes place. Sufficient zones (up to three) were allocated to the central basin of each estuary so that the majority of the estuary is represented. This may mean small systems have only one zone. In MER Year 2 (2008), only the middle estuary was sampled in river estuaries. The middle estuary was defined as having a salinity of 8–15 ppt, but due to the short-term temporal variability in salinity, the long-term location was defined as being in the vicinity of the upper limit of mangrove trees and this is where sampling was concentrated. Two zones were placed in the river in this vicinity. This procedure for rivers will be replaced by a longitudinal transect with continuously logged data from mid to upper estuary from MER Year 3 (2009) onwards.

Sample timing

The relevant temporal scale was the annual seasonal chlorophyll maxima. This was determined from the data gathered for the MER Year 1 (2007) pilot study, which collected data over the entire NSW coast for up to 16 months, and from other data sources. In general, chlorophyll concentrations were correlated with increasing water temperature, which occurred earlier in the north and central areas. Estuaries south of Sydney showed a distinct maximum in chlorophyll between late spring (mid November) and early autumn (end March). Between Sydney and the Manning River the maximum spanned the entire spring to autumn period. North of the Manning River, the maximum tended to be from early spring until early summer, before tropical rains flush the estuaries.

Sampling windows are thus:

- Northern Rivers CMA: mid September to end December
- Hunter–Central Rivers, Hawkesbury–Nepean and Sydney Metropolitan CMAs: mid September to end March
- Southern Rivers CMA: mid November to end March.

Spacing of sampling occasions was determined by a combination of logistics and the desire to fit six sampling occasions within the defined window. Southern Rivers CMA (MER Year 2 – 2008) estuaries were sampled at intervals of approximately three weeks, with all estuaries sampled within the same week.

Variables

The MER indicators that OEH sampled were chlorophyll a and clarity (turbidity and secchi), supported by salinity data.

Traditionally, chlorophyll concentrations in samples were determined by spectroscopic or fluorometric analysis of chlorophyll filtered from water samples and extracted in acetone. For reasons of logistics and spatial representation, OEH tested the use of in-situ fluorometer probes (YSI) for chlorophyll determination in the MER program. In order to cross-calibrate, water samples for chlorophyll a analysis were also collected.

Instrument calibration

The YSI Model 6820V2-S multiprobes used for the MER sampling were fitted with a fluorometric chlorophyll probe and a turbidity probe. The chlorophyll probe is factory calibrated and a standard solution of rhodamine was used prior to every field trip, to check that the calibration remains constant over time and is consistent among probes. Prior to each trip, turbidity is calibrated to nil and 50 NTU using milli-q filtered water and formazin standard respectively. Salinity is also calibrated to known standards prior to every trip.

Field procedures

Field procedures are provided in the national indicator guidelines (Appendix 13) and have been modified for the NSW Estuaries MER program as follows.

In brief, the field procedure was to travel to the upwind boundary of each zone in the estuary. The boat was then stopped and a reading of secchi depth was made. The water quality probe, which recorded chlorophyll (fluorometric), turbidity, salinity, temperature, depth and time, was lowered into the water in a special cradle to a depth of approximately 400 mm. The probe was set to log readings every second and the boat allowed to drift for five minutes, noting the start and end times of the drift. If there was insufficient wind, the boat was rowed or paddled for five minutes. This procedure captures data for a transect through the zone and allows the calculation of an average chlorophyll a and turbidity for the zone.

During the drift, a pole sampler was used to collect 10 x 1 m integrated water samples approximately 30 seconds apart. These samples were composited into a black bucket (to reduce light reflection). The fluorometric chlorophyll in the bucket was logged for two minutes and a water sample taken from the bucket.

Field data sheets which recorded the entrance state, riparian condition, observations about macroalgae and other submerged aquatic vegetation, weather and any other relevant observations were also filled out for each estuary.

Data analysis

Using the recorded start and end times, data for the transects in each zone and the data for the bucket, were extracted from the data files stored by the YSI probe. Mean and standard error was calculated for salinity, temperature, chlorophyll a and turbidity for each zone. Estuary means were calculated for each time by taking the mean of all zones in the estuary.

Calibration of in-situ fluorometric chlorophyll a and laboratory extracted chlorophyll was done by comparing the laboratory derived chlorophyll concentration in the composite water sample collected for the purpose during routine sampling, with the mean chlorophyll concentration in the bucket indicated by the fluorometry probe prior to the laboratory sample being collected. The results showed that there was a non-linear relationship between laboratory and in-situ fluorometry chlorophyll measurements. This relationship was best represented by two linear relationships, one for low to medium chlorophyll (≤19 µg/l) and the other for high to very high chlorophyll (>19 µg/l). For in-situ fluorometry readings ≤ 19 µg/l, lab = 0.68 x in-situ (n = 242; r^2 = 0.88). For in-situ >19 µg/l, lab = 0.92 x in-situ (n = 14; r^2 = 0.98). These relationships will, however, be affected by the calibration of the in-situ probe and may not be immediately transferable to other probes. The basis of these relationships is provided in Appendix 14.

6.2 Macrophytes

Estuarine macrophytes, including seagrass, mangroves and saltmarsh, play an important ecological role in estuaries. Seagrass beds provide food and shelter for numerous species (Keough & Jenkins 1995) and seagrass beds are recognised as essential nursery grounds for many economically and recreationally valuable species of fish. Seagrass plays an important role in the function of estuaries, but is susceptible to impacts resulting from variations in sedimentation, turbidity, light, salinity and nutrient levels (eg Gillanders 2007). The degradation or loss of this habitat impacts not only on the immediate location but on estuarine biological function as a whole.

Mangroves occur in estuaries along the entire NSW coastline. They are highly productive habitats, a rich source of nutrients and organic matter, and are recognised as providing important larval habitat for many species (Connolly & Lee 2007). Their proximity to the coastal fringe has made this habitat susceptible to various impacts, primarily resulting from anthropogenic origins. Clearing, increases in sediment discharge and changes in tidal regimes have impacted on the distribution of mangroves. Coastal development is seen to be the major cause of mangrove habitat loss in many parts of the world (Connolly & Lee 2007). However, in some NSW estuaries, it is suggested that human activities have enabled the expansion of mangroves at the expense of saltmarsh (Saintilan & Williams 1999, 2000). Historic mapping of estuarine macrophytes in the Hacking River (Williams & Meehan 2004) indicates that there has been a considerable amount of in-stream expansion of mangroves (DPI unpubl) potentially as a result of increased sedimentation.

Saltmarsh generally occurs on the same types of muddy shorelines as mangrove and is typically found landward of mangroves in the high tide zone (Adam 1990). Recent studies (eg Mazumder et al. 2005a, 2005b, 2005c, 2006) have shed some light on the importance of saltmarsh in estuarine ecosystems and it is recognised as an important habitat for invertebrates and fish (Williams 2001). Saltmarsh, particularly when in close proximity to developed areas, is prone to loss or degradation. The incursion of mangroves into saltmarsh habitat is considered the cause of saltmarsh loss in many estuaries (Saintilan & Williams 1999; Wilton 2002).

All seagrass and mangrove species in NSW are protected under the *Fisheries Management Act 1994.* The guidelines identify types of activities that can be injurious to estuarine habitats and offer measures to minimise disturbance. In relation to saltmarsh, this group of plants was listed as a Threatened Ecological Community under the *NSW Threatened Species Conservation Act 1995* (NSW Scientific Committee 2004) and there is a legal imperative to protect and monitor its distribution.

In line with procedures adopted at an Australia-wide level by the NLWRA (Mount et al. 2007) and endorsed for NSW by the NRC, only the three broad macrophyte categories are used in assessing estuarine condition in this report. However, mapping done in NSW describes distribution at the species level (Creese et al. 2009). This allows a finer scale examination of any changes that may have occurred in the spatial extent of this macrophyte type.

6.2.1 Data sources

Estuarine inventory, 1985

The first comprehensive mapping of estuarine macrophytes in NSW commenced in the early 1980s, when the then NSW Fisheries began mapping the distribution of seagrass, mangrove and saltmarsh (West et al. 1985). The final inventory included a total of 133 estuaries. The methodology of this exercise involved API by the *camera lucida* technique. This system involved the use of a Bausch and Lomb Zoom Transfer Scope. The process included the tracing of macrophyte boundaries identified in the photos to 1:25,000 scale base maps. Most of the photos were of the scale 1:16 000. The area of each type of macrophyte was then determined by overlaying the mapped boundaries on 1 mm graph paper and counting the grid squares within the boundary of the defined macrophyte. All areas were reported in km^2. Further details are in Williams et al. (2003).

Current state-wide mapping, 2006

The current status of estuarine macrophytes in NSW has only recently been determined. This mapping is the result of a combination of projects including the NSW Comprehensive Coastal Assessment (CCA), Historic Mapping of Estuarine Macrophytes (HMEM) project for the Sydney Metropolitan CMA and the Seabed Mapping Project (SMP).

The CCA study focused on updating the estuarine macrophyte data in the estuaries north of Newcastle and south of Lake Illawarra (Williams et al. 2006). A key component of this study was the application of mapping protocols developed by DPI. With the exception of Georges River/Botany Bay, the estuaries from Lake Macquarie to Port Hacking were mapped in the SMP. Georges River/Botany Bay was mapped as part of the HMEM project.

Historic time series mapping

Extensive time series data are available for a small number of estuaries in NSW. This list expands as opportunities arise to map historical distributions of macrophytes at more locations or at other times.

Historic assessment includes some very recent ones in the Sydney Metropolitan CMA region (Table 14). Other published studies include Meehan 1997; Wilton 2002; Larkum & West 1990; Williams et al. 2000; Williams & Thiebaud 2007 (Table 15).

Table 14: Estuaries of the Sydney region with time series macrophyte data (DPI unpubl)

Estuary	1930s	1940s	1950s	1960s	1970s	1980s	1990s	2000s	Reference
Narrabeen Lake	-	1943	-	1964	1971	1986	-	2005*	HMEM/SMP
Dee Why Lagoon	-	1943	-	1964	1971	1986	-	2005*	HMEM/SMP
Harbord Lagoon	-	1943	-	1964	1971	1986	-	2005*	HMEM/SMP
Manly Lagoon	-	1943	-	1964	1971	1986	-	2005*	HMEM/SMP
Parramatta River/Sydney Harbour	-	1943	-	-	1978	1986	-	2000, 2003, 2005*	West et al. 2004; West & Williams 2008; HMEM; SMP
Georges River/Cooks River/Botany Bay	-	-	1951	-	1971	1986	-	2005	HMEM
Port Hacking	1930	1942	1951	1961	1975	1985	1999	2005*	Williams & Meehan (2004)/SMP

Table 15: Estuaries outside of Sydney with time series macrophyte data

	Area mapped	Date (start - finish; decadal data in between)
Seagrass	Cudgen Creek	1980–2000
	Cudgera Creek	1980–2000
	Mooball Creek	1947–2000
	Brunswick River	1980–2000
	Evans River	1990–2000
	St Georges Basin	1961–1998
	Burrill Lake	1940–1990
	Wagonga Inlet	1957–1994
	Wallaga Lake	1957–1994
	Bermagui River	1957–1998
	Merimbula Lake	1948–1993
	Pambula Lake	1948–1993
	Wonboyn River	1962–1997

	Area mapped	Date (start - finish; decadal data in between)
Saltmarsh/mangroves	Tweed River	1947–2000
	Ukerebagh Island, Tweed River	1948–1998
	Cudgen Creek	1947–2000
	Cudgera Creek	1947–2000
	Mooball Creek	1947–2000
	Brunswick River	1947–2000
	Belongil Creek	1947–2000
	Richmond River	1947–2000
	Evans River	1947–2000
	Tilligerry Ck, Port Stephens	1954–1996
	Black Neds Bay, Lake Macquarie	1950–1999
	Brisbane Waters	1954–1998
	Courangra Point, Hawkesbury River	1954–1994
	Careel Bay, Pittwater	1940–1996
	Currambene Ck and Cararma Inlet, Jervis Bay	1948–1999

6.2.2 Data quality

All mapping was carried out using the following standards:

- All mapping is derived from air photo interpretation.
- All scanned photos have an output resolution of 1 m
- Images provided in digital format are kept at their original resolution
- All images are orthorectified using
  - NSW LPI 25 m DEM
  - NSW LPI Digital Cadastral Database (DCDB)
  - NSW LPI Digital Topographic Database (DTDB)
- The rectification error is no greater than 15 m, but can be as small as 2 m
- A preliminary map of all features for each estuary is mapped via on-screen digitising of macrophyte boundaries from the orthorectified images
- All digitising is carried out at a scale of 1:1 500
- Digitising tolerances are
  - snapping tolerance 0.75 map units (metres)
  - streaming tolerance 1.5 map units (metres)

- Preliminary maps for every estuary are validated by field investigation (see Creese et al. 2009) with as many polygons and boundaries between habitat types checked as time allowed
- Preliminary maps are edited and amended where necessary based on the field validations
- All polygons are attributed to one of the three macrophyte categories. For seagrass, this is done on the basis of presence/absence – if any seagrass at all is present in a polygon it is classified as 'seagrass'. Similarly, a 'mangrove' classification is given to any polygon which contains mangroves, even if some saltmarsh plants are also present. A polygon is classified as 'saltmarsh' only if it is the only macrophyte present
- A final map is created and lodged in the NSW Estuarine Macrophytes database, a corporate geodatabase held by DPI. An example of the distribution of macrophytes in the Brunswick River is shown in Figure 30.

6.2.3 Data analysis

A comparison of the change in extent of seagrass, mangrove and saltmarsh between the two surveys appears in Appendix 15. In summary, the distribution of the two main datasets and the change between them is shown in Figure 31.

There has been a relatively small increase from 107 to 110 estuaries in which seagrass was detected, an overall increase of 23.6 km^2 to 161.4 km^2 (17.1 per cent) in seagrass extent, and no obvious patterns in change along the coastline. By contrast, there was a large increase from 61 to 86 estuaries in which mangroves were detected representing mainly smaller systems being artificially opened or trained. An overall increase of 16.3 km^2 to 126.0 km^2 (14.8 per cent) in mangrove extent was recorded with increases appearing more frequent and larger along the north coast. For saltmarsh, there was an increase from 92 to 110 estuaries in which saltmarsh was detected but this may be attributed to the higher resolution attained in the 2006 mapping. For possibly similar reasons, an overall increase of 14.1 km^2 to 72.7 km^2 (24.2 per cent) in saltmarsh extent was observed between surveys.

Figure 30: Distribution of macrophytes in Brunswick River (from Williams et al. 2006)

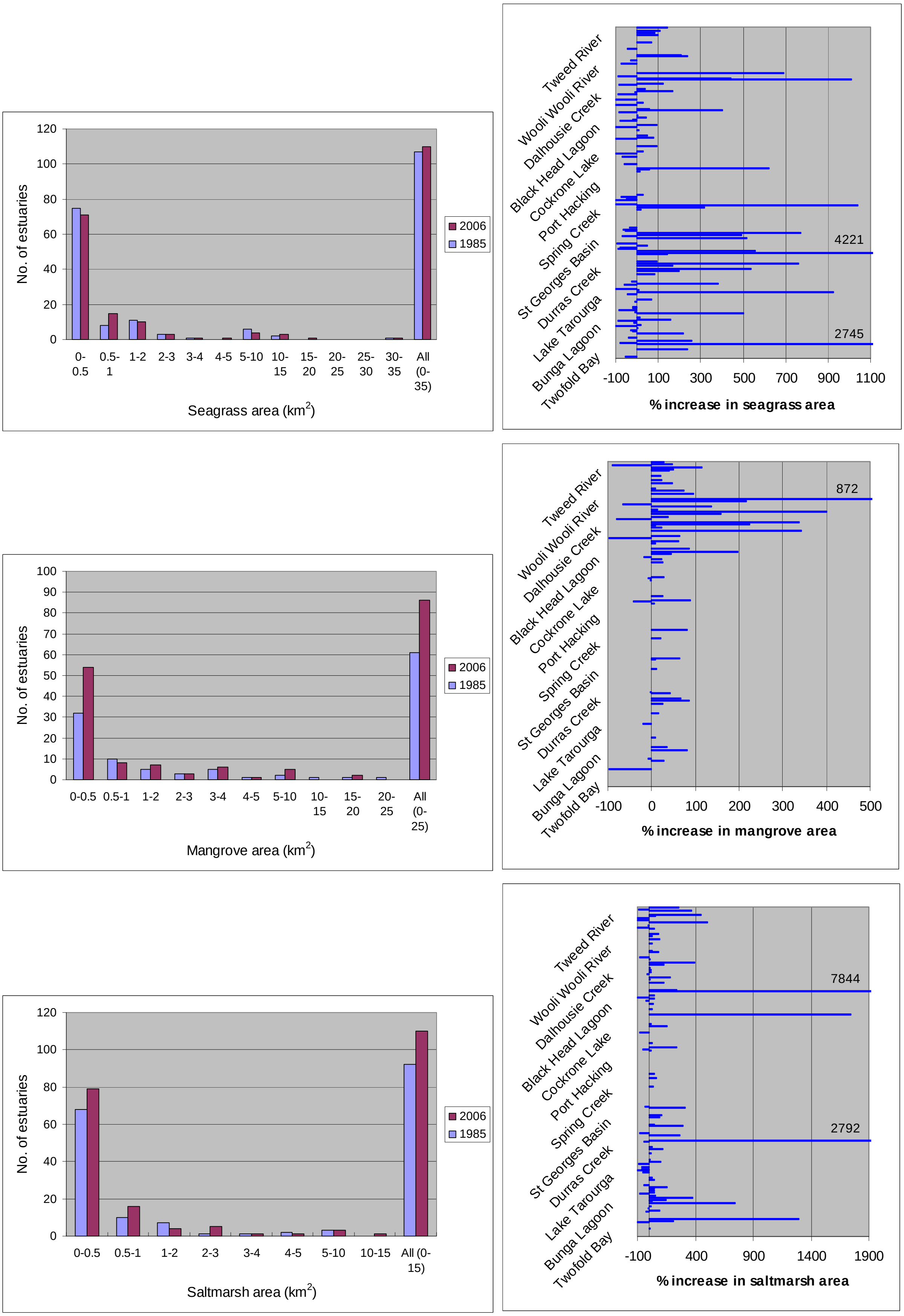


Figure 31: Data distributions of seagrass, mangrove and saltmarsh extent and change

6.3 *Fish*

6.3.1 Data availability

Past collection and analysis of data on the fish communities in NSW estuaries has been for a variety of purposes including stock assessment for commercially or recreationally important species, ecological studies of fish habitat use or biodiversity surveys. While most of this work has been done by DPI, much work has also been done by university researchers. Historically, apart from commercial fish catch data which are held by DPI in its ComCatch database, information on estuarine fish surveys is kept on Excel spreadsheets by the individual researchers. Even if this information was collated into a single database, most of it would not be suitable for use in estimating a fish condition index because that relies on having a dataset collected in a uniform way across a large number of estuaries (preferably along the entire coast) over a relatively short period of time.

In recognition of the need to more effectively ensure long-term availability of estuarine fish data however, a process was begun within DPI – Fisheries as part of the MER program to collate some of these data into a more easily searchable MS Access database known as the Estuarine Fish Ecology Database (EFED). To date, information from 17 fish biodiversity surveys done by DPI or associated groups since the late 1970s has been compiled in this system.

The data resides in the database in three main tables. The Environmental Table (13,961 records) includes information about the project, sample date and time, estuary (currently 140 estuaries), sample location (latitude, longitude, substrate, vegetation), sampling method (mostly seine net, but also beam trawl, prawn trawl, fish trawl, gill net, fyke net, dip net, crab trap, shrimp trap, poison station and diver census) and in most cases basic water quality data such as water temperature, salinity, turbidity, etc. The Catch Table (102,498 records) includes information about each fish species (572 species), number of individuals caught, total weight and length range in each sample. The Biological Table (404,953 records) includes the individual lengths of each commercially and recreationally important fish species and, in many cases also, the individual weight. The numbers of records cited above are current as at 12 August 2009.

Additional data on estuarine fish in NSW can be accessed from the Australian Museum's fish database. However, many of the data in this system come from the projects that comprise the EFED system. Also, the focus of the Australian Museum is the taxonomy and distribution of individual species rather than fish community structure. Catch data from commercial fishers who operate in estuaries also provide information on the geographical occurrence of fish species.

Information from these databases, together with information published on the website FishBase, in books and in scientific papers, is used to generate lists of fish species that might be expected to occur in NSW estuaries and to classify those species according to attributes like their geographical range or feeding mode.

6.3.2 Data used

The Estuarine Fish Community Index (EFCI) is a multi-metric index that combines four broad fish community attributes: species diversity and composition, species abundance, nursery function and trophic integrity into a single measure of estuarine condition. The index was developed for application to South African fish communities (Harrison & Whitfield 2004, 2006) and was trialled for

NSW estuaries for the SOC reports. Further details of how the data are used to generate the index and how these are then converted into scores of condition are given in Section 7.3.

In a pilot study in 2008, three estuary geomorphic types from Roy et al. (2001) (drowned river valleys, barrier estuaries and intermittently closed and open lakes and lagoons (ICOLLs) were defined within the central bioregion of the NSW coast and sampling conducted in each of these types. Sampling was done using seine nets for all three estuary types, but gillnets were also used in barrier estuaries and ICOLLs. Data from field surveys were checked and entered into EFED under the project name 'MER'. Analysis was then done to produce the indices for the SOC 2010 reports for the Hunter–Central Rivers and combined Hawkesbury–Nepean/Sydney Metropolitan regions.

No recent estuarine fish data, collected using a standard sampling protocol, are available for the northern and southern bioregions. Instead, data collected during a state-wide survey in 1999–2002 and stored in EFED under the project name 'Estuarine Biodiversity Survey' (EBS) were used for the assessment of the condition of fish assemblages in the Northern Rivers and Southern Rivers CMA regions. Fish were sampled using the same sized seine nets as used in the 2008 survey, but gill nets were not deployed. These data were analysed in the same way as for the ac l rp_j `gmregion.

6.3.3 Data quality

For both surveys, all data were entered twice by different individuals into a Microsoft Access database at the end of each sampling period. The datasets were cross-checked for errors using a series of queries, with a single edited copy of the dataset then exported into the final EFED Access database.

6.3.4 Sampling methods

For both surveys, seine netting was used in all estuaries, with a minimum of five replicate hauls done at all sites. Sites were all situated within the Central Mud Basin (CMB) of estuaries (as defined by Roy et al. 2001). For the EBS survey, sites were sampled in several different estuarine zones, but data from only the CMB sites were used in the analysis.

Samples were collected using a 12 mm stretched mesh seine net with a 20 m headline, a 2 m drop and a cod-end. This net is designed to catch only small or slow-moving fish, and therefore does not provide a measure of the total fish diversity at a site. Each replicate net haul was done during daylight hours to form a U-shape that covered approximately 100 m^2. The ends were drawn together so that the sample was collected in the cod-end. The catch was then placed into a bucket, with fish over 100 mm being quickly measured and released alive. Remaining animals were euthanased with Benzocaine (ethyl p-amino-Benzoate) then transferred to 10 per cent formalin/seawater for transportation to the laboratory for processing. All fish sampling was undertaken in accordance with a DPI (Fisheries) Animal Care and Ethic Committee permit (no. 98/10).

All fish collected were identified to the lowest practicable taxonomic level, counted and measured. The Fish Section of the Australian Museum confirmed all fish identifications from initial surveys and any fish that could not be readily given a species name were kept for later determination by them as well. Either the entire sample (MER project) or a subset of fish caught (EBS project) were measured (total length).

Central bioregion

Data used to construct the final metrics for the central bioregion were based on MER data collected in 2008. Six sites were randomly selected using a GIS procedure. First, a polygon was created for the CMB. Second, the shoreline contained within this polygon was divided into 100 m segments which were numbered consecutively. Third, a random number generator was used to select six segments from the available list. Fourth, the selection was checked to ensure that not all selected sites were clumped together in one place. Wherever possible, sites on either shoreline were included in the selection.

At each site, five seine net shots were done as described above. In addition, for barrier estuaries and ICOLLs, three multi-panelled gill nets (total length of 25 m) were set on arrival at each site, spaced at least 20 m apart. Each net was set from a boat at a 45° angle from the shore and at a depth of no more than 3 m. Each gill net was left out for at least an hour of fishing time (while seine netting was undertaken) and then retrieved. Fish caught in gill nets were processed in the same way as described above. Thus, for each estuary there were 30 seine net samples and 18 gill net samples. These data were pooled to calculate the final metrics.

Northern and southern bioregions

Data used to construct the final metrics for the northern and southern regions were based on EBS data collected between 1999 and 2002. Some estuaries were sampled more than once during this time. In contrast to central region data, the methodology (eg number of seines, season sampled) varied among estuaries. In all cases, the most recent data were used in analyses. Where data for multiple seasons were available, 'summer' data were used wherever possible. If summer data were unavailable, 'spring' or 'autumn' data (in order of choice) were used (see Table 16).

Sites were not randomly selected *a priori* as they were for the MER program fish sampling, but rather were haphazardly chosen on arrival at an estuary. The number of sites sampled varied among estuaries based on estuary size (n = 1–8), but there were always at least five replicate hauls done at a site. Unequal replication at the 'site' level was not deemed problematic as the calculated metrics are based on pooled data and the interpretation is done on relative differences only (see Section 7.3).

For the purposes of making these relative comparisons, estuaries were categorised prior to analysis (Table 16 and Table 17). For the northern region, only 'permanently open (mature) barrier estuaries' and 'predominantly closed ICOLLs' were sampled. For the southern region, 'permanently open (mature) barrier estuaries', 'predominantly open ICOLLs' and 'predominantly closed ICOLLs' were sampled.

Table 16: EBS data used in analyses for the northern bioregion

NORTHERN BIOREGION			
Estuary type	**Season**	**Year**	**Total no. seines**
Permanently open (mature) barrier estuaries			
Tweed River	Spring	1999	25
Brunswick River	Spring	1999	33
Richmond River	Summer	1999	40
Clarence River	Summer	1999	40
Sandon River	Autumn	2002	20
Wooli Wooli River	Autumn	2002	20
Boambee Creek	Summer	2002	30
Moonee Creek	Spring	2002	15
Bellinger/Kalang River	Autumn	2002	40
Nambucca River	Autumn	2000	25
Macleay River	Summer	1999	25
Korogoro Creek	Summer	2001	20
Hastings River	Summer	2000	40
Manning River	Autumn	2000	40
Predominantly closed ICOLLs			
Cudgera Creek	Summer	2002	10
Belongil Creek	Summer	2002	6
Tallow Creek	Summer	2002	5
Broken Head Creek	Summer	2002	5
Station Creek	Spring	2002	10
Corindi River	Autumn	2002	20
Pipe Clay Creek	Summer	2002	5
Arrawarra Creek	Summer	2002	5
Darkum Creek	Summer	2002	10
Woolgoolga Lake	Summer	2002	10
Hearns Lake	Summer	2002	10
Dalhousie Creek	Autumn	2002	10
Oyster Creek	Autumn	2002	15
South West Rocks Creek	Autumn	2002	15
Saltwater Creek	Autumn	2002	10
Killick Creek	Summer	2001	10
Lake Cathie	Summer	2000	25

Table 17: EBS data used in analyses for the southern bioregion

SOUTHERN BIOREGION			
Estuary type	**Season**	**Year**	**Total no. seines**
Permanently open (mature) barrier estuaries			
Shoalhaven River	Autumn	2000	40
Cullendulla Creek	Spring	2001	10
Candlagan Creek	Spring	2001	10
Moruya River	Summer	2001	25
Bega River	Spring	2001	25
Towamba River	Summer	2001	10
Predominantly closed ICOLLs			
Meroo Lake	Autumn	2001	8
Willinga Lake	Autumn	2001	5
Lake Brunderee	Spring	2001	10
Lake Brou	Summer	2001	8
Lake Mummuga (Dalmeny)	Summer	2001	8
Nangudga Lake	Autumn	2001	10
Tilba Tilba Lake	Autumn	2001	5
Baragoot Lake	Autumn	2001	8
Murrah Lagoon	Spring	2001	10
Bunga Lagoon	Spring	2001	8
Middle Lagoon	Spring	2001	5
Wallagoot Lake	Summer	2001	15
Back Lagoon	Summer	2001	5
Curalo Lagoon	Summer	2001	10
Nullica River	Summer	2001	5
Predominantly open ICOLLs			
Conjola Lake	Spring	2000	40
Narrawallee Inlet	Autumn	2001	10
Tuross Lake	Summer	2001	40
Wapengo Lagoon	Autumn	2001	10
Nelson Lagoon	Autumn	2001	10
Merimbula Lake	Summer	2000	40
Pambula River/Lake	Summer	2000	40
Wonboyn River	Summer	2001	30

7. Reference conditions and scoring classes

To assess the health or integrity of an estuary requires establishing reference or baseline conditions against which biological data can be compared. Reference conditions are necessary for each estuary class so that comparisons can be made among estuaries within that class and between classes. There are a number of different approaches to the setting of reference conditions:

- Use of historical records where available, recognising that some disturbance will have occurred, and adopting the median as the reference condition (US EPA 2001)
- Sampling of least disturbed reference sites and adopting the 75th percentile (US EPA 2001) or the 80th percentile (ANZECC 2000) as reference. It is desirable to have at least ten sites per class to sample (US EPA 2000)
- Using all available data from across the spectrum of least to highly disturbed systems and adopting a conservative percentile, eg 25th, of the data distribution as reference. This approach can be applied where too few reference sites exist (eg one or two) or where all existing sites are known to be impaired to varying degrees (US EPA 2000)
- Use of either descriptive or mechanistic models to hind-cast reference conditions. Descriptive models rely on empirical relationships (correlative or statistical models) between variables to predict what reference conditions might have been pre-development. Mechanistic models simulate the underlying processes with the same objective of predicting reference. They both rely on comprehensive datasets (Harrison & Whitfield 2004)
- Expert input using a qualified team of regional specialists to provide professional judgement on reference conditions.

Once reference conditions are established for each estuary class, those systems that are highly degraded define the other end of the spectrum of condition. Each biological metric can then be assessed by the extent of deviation from reference and threshold risk levels set between reference and highly disturbed for rating the condition. Ideally, the thresholds are based on ecological or biological effects of the metric exceeding each threshold. Examples might include the level of dissolved oxygen at which fish mortality rises or the light levels at which seagrass and other submerged aquatic vegetation is affected. Frequently this information is not available and the alternatives are to use the data distribution to divide the data into equal intervals, equal percentiles (equal areas under a frequency distribution curve) or else some multiple of deviation from reference.

Once these threshold levels have been defined and the condition scored, simple risk assessment methods may be used to combine data on pressures and modulating factors such as dilution, flushing, water clarity etc. with the condition assessment to assign priorities for management. If a predictive modelling framework is available, more detailed assessment of cause-effect may provide greater spatial resolution and certainty to the management response. Depending on the data, the scale at which responses can be framed may be specific to an issue within an estuary or at a higher level if the issue is more ubiquitous and better dealt with on a regional or state-wide basis.

7.1 *Chlorophyll a and turbidity*

7.1.1 Reference conditions

For each of the three classes of lakes, rivers and lagoons, there were 29, 24 and 29 datasets (82 in total) available for chlorophyll a and 18, 16 and 18 for turbidity (52 in total) respectively. As explained in Section 5.3.4, chlorophyll a datasets for 16 estuaries were excluded from further analysis, thus reducing the number of available chlorophyll a datasets to 27, 17 and 22 for lakes, rivers and lagoons respectively. To define those sites that were minimally impacted with respect to chlorophyll a and turbidity, the ratio of increase in TN loading (see Section 9.10) was adopted as the measure of disturbance in recognition that estuaries are generally nitrogen limited (Ryther & Dunstan 1971). Other related measures of disturbance such as the pressure indicators of cleared land or population density are not as closely linked to eutrophication effects and others such as freshwater flows or habitat disturbance even less so (Table 30). An overall pressure index describing general catchment and waterway disturbance was not considered to provide a realistic indication of which estuaries are likely to be in reference condition whereas the increase in TN loading captures the combined effects of catchment development generally.

Shown following in Figure 32 are stressor-response plots of annual TN areal load and chlorophyll a replotted from Figure 19. Coloured data points have been used for the TN load increase to show the distribution of data by the level of disturbance. The dataset from the 66 estuaries underpinning the plots is shown in Appendix 16. The dataset for river class estuaries has chlorophyll a concentrations averaged across medians for three functional zones based on salinity (see Sections 5.3.4 and 6.1.3).

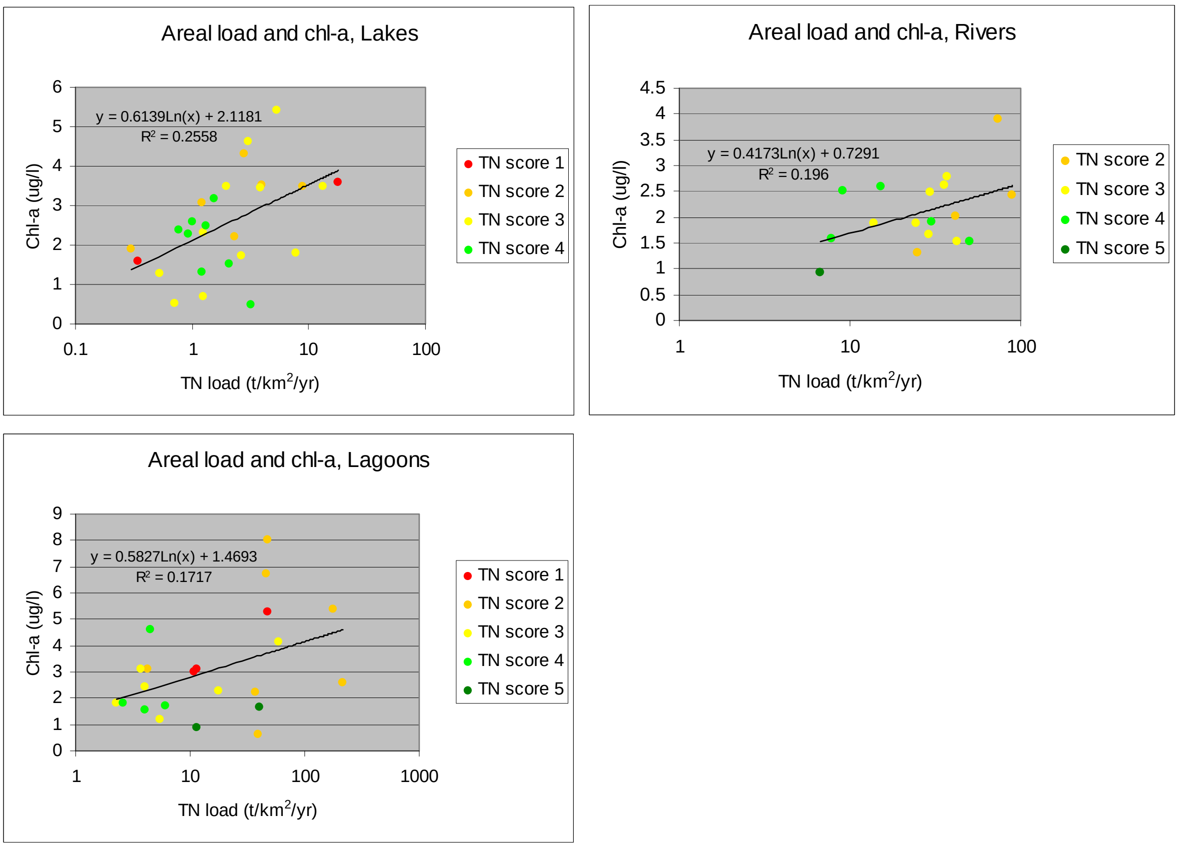


Figure 32: Median chlorophyll a concentrations by load and estuary class

There are a number of observations that can be made from these plots and the dataset in Figure 32 and Appendix 16:

- For each of the lake, river and lagoon classes, there are 0, 1 (Sandon River) and 2 (Wattamolla Creek and Merrica River) sites respectively that have the lowest TN ratio score of 5 representing relatively undisturbed conditions. This would suggest that the sole use of undisturbed sites to set reference conditions is not practical
- A significant number of moderately to highly disturbed sites, as indicated by the yellow (TN score 3) and orange (TN score 4) coloured data points respectively, have relatively low TN areal loads and chlorophyll a concentrations. This is not unexpected as they represent systems that would have higher dilution and/or flushing rates than other systems in the same estuary class
- Natural variability in catchment, geomorphic, hydrodynamic and morphometric characteristics will mean that some systems within a class have a greater capacity to withstand increased catchment nutrient loads. At the other end of the spectrum, some systems will have naturally higher chlorophyll levels and will only tolerate a relatively small increase in nutrient loads before eutrophication becomes an issue. These systems are more susceptible to human disturbance.

In view of the above, two approaches were examined:

- The definition of an undisturbed catchment was relaxed to include those estuaries with a TN increase score of 4 as well as 5. TN increase scores of 4 and 5 correspond to percentage increases in TN export from undisturbed catchment conditions to current land-use of 50 and 10% respectively (Table 40). Adopting this approach increased the number of reference estuaries from 0, 1 and 2 to 8, 6 and 6 for each of lakes, rivers and lagoons respectively (see Appendix 16).

  The 80^{th} percentile (ANZECC 2000) and 75^{th} percentile (US EPA 2001) of all data for reference estuaries in each class were then calculated. Chlorophyll a sample numbers varied between 15–552 for the eight lakes; 6–57, 4–44 and 5–25 for the 7 lower, 5 mid and 3 upper river estuaries respectively; and 5-283 for the 6 lagoons (see Table 18). For an explanation of the lower mid and upper river zonation see Section 6.1.3. The percentile calculations took all samples together which can bias the percentiles towards those estuaries with larger sample numbers. Examination of the box and whisker plots revealed that the data distributions for reference systems in each estuary class fell in about the same range. The notable exception was Port Hacking which had 552 samples out of a total of 881 (63 per cent) for all eight lake reference systems. Port Hacking sample results reflected oceanic conditions as the two sampling sites were located very near the mouth. Accordingly Port Hacking was excluded from the calculation.

  Further consideration could be given to whether other statistical methods should be used to reduce the effect of sample size, for example re-sampling randomly the minimum sample size from the other datasets (which would lose some data) or else calculating the 80^{th} percentile for each reference system and, if the distribution is normal, taking the median or mean
- The 25^{th} percentile of all data within each class was also calculated for comparison.

For the purpose of calculating trigger values, all data back to 1975 were pooled but with the same proviso used for the summary statistics for rivers (Section 6.1.3) – that data collected with salinity <

2 ppt were excluded except for MER program data. This same rule was also applied to the scoring of sampling results against the trigger values. For the lake and lagoon estuary classes all data were used irrespective of salinity. Older data were also excluded if large numbers of samples were taken on a single day in a month over only a few months.

Two lake class estuaries qualifying as being in reference condition, Nadgee Lake and Port Hacking, were excluded from the trigger value calculations. Nadgee Lake was excluded because of major algal blooms over the sampling periods. Port Hacking was excluded because 63% of all the pooled sample data for the lake class were from Port Hacking and the two sites monitored by Sydney Water were at Gunnamatta Bay and Maianbar, close to the estuary mouth, which would reflect oceanic conditions. Pooling Port Hacking samples collected only near the estuary mouth would therefore bias trigger value calculations. It should be noted that nearly all data used for trigger values and results scoring were collected in the 1990s and 2000s.

The trigger values were initially calculated incorporating new chlorophyll a and turbidity data collected in reference condition estuaries during the 2007/08 summer sampling period. Triggers were calculated for lake, low/mid/upper river and lagoon sites. Over the course of the project, additional data were collected during the 2008/09 summer which, for chlorophyll, generally increased the number of reference estuaries with data from 5 lake; 6, 5 and 3 lower, mid and upper river; and 3 lagoon sites to 7, 7, 5, 3 and 6 sites respectively. For turbidity, the corresponding increase in the number of systems was from 4 lake; 3, 4 and 2 lower, mid and upper river; and 2 lagoon sites up to 6, 7, 5, 2 and 6 sites respectively. The reference condition systems on which the trigger values are based, the sampling period and numbers of samples are shown in Table 18.

Table 18: Reference estuaries for calculation of trigger values

	Sample dates and no.			
Lake	**Years**	**Chl a**	**Years**	**Turb**
Myall River/Lake	05-09	70	05-09	36
St Georges Basin	08-09	15	08-09	15
Conjola Lake	08-09	18	08-09	18
Durras Lake	07-09	48	07-09	48
Coila Lake	06-09	68	07-09	47
Wapengo Lagoon	95-96	82	Nil	0
Wallagoot Lake	02-09	22	02-09	18

	Lower – sample dates and no.				Mid – sample dates and no.				Upper – sample dates and no.			
River	**Years**	**Chl a**	**Years**	**Turb**	**Years**	**Chl a**	**Years**	**Turb**	**Years**	**Chl a**	**Years**	**Turb**
Sandon River	97-99	57	97-99	47	97-07	44	97-07	42	98-08	10	07-08	14
Bellinger River	96	32	96	32	96	36	96	36	96	25	96	25
Clyde River	06-09	52	07-09	25	07-08	15	07-08	7	Nil	0	Nil	0
Moruya River	06-09	38	08-09	11	07-08	4	08	1	07	5	Nil	0
Tuross River	95-09	36	08-09	4	95-09	10	08-09	6	Nil	0	Nil	0
Pambula River	02-09	22	08-09	18	Nil	0	Nil	0	Nil	0	Nil	0
Towamba River	08-09	6	08-09	6	Nil	0	Nil	0	Nil	0	Nil	0

	Sample dates and no.			
Lagoon	**Years**	**Chl a**	**Years**	**Turb**
Wattamolla Creek	96-08	283	07-08	32
Tabourie Lake	08-09	12	08-09	11
Lake Brou	08-09	12	08-09	12
Baragoot Lake	08-09	12	08-09	12
Cuttagee Lake	07-08	26	07-08	22
Merrica River	09	5	08-09	5

New 80th percentile trigger values incorporating the 2008/09 data were calculated all as shown in Table 19 and Table 20 for chlorophyll a and turbidity respectively. As can be seen, the 25th percentile values taken from all sites are generally below the 80th percentile values taken from only reference condition sites. The consistent difference may reflect the more degraded nature of estuaries in the United States and the concomitant skewing of data distributions towards degraded conditions. In compliance with the recommendations of the ANZECC water quality guidelines, the 80th percentile concentrations were adopted as the trigger values for a management response.

After including the 2008/09 data, the trigger values changed marginally for chlorophyll a except for the mid river and lake sites because of the larger increase in the number of these sites from which data could be drawn. There were major changes in the turbidity triggers at nearly all sites because of the large increase in the number of estuaries with turbidity data after the 2008/09 sampling season. The trigger values calculated from inclusion of the 2008/09 data in the datasets were adopted. Following 2009/10 sampling in the northern region, triggers are likely to be recalculated on a three year cycle corresponding with completion of future rounds of resampling in the southern, central and northern regions.

In the future, if extensive data exists for an individual estuary, the guidelines recommend water quality statistical distributions be examined (eg for break-points indicating change) and ecological and/or biological effects of physical and chemical stressors. This would enable trigger values to be calculated for an individual system.

Table 19: Comparison of chlorophyll a trigger values

	Chlorophyll a (µg/l)			
	All data up to and including MER program 2007/08			Incl. 2008/09
Estuary class	80th %ile of reference	75th %ile of reference	25th %ile of all sites	80th %ile of reference
Lake	2.5	2.3	1.2	3.6
River – lower	2.1	2.0	1.3	2.3
River – mid	2.2	1.9	1.1	2.9
River – upper	3.5	3.4	2.2	3.4
Lagoon	1.9	1.7	1.5	2.0

Table 20: Comparison of turbidity trigger values

	Turbidity (NTU)			
	All data up to and including MER program 2007/08			Incl. 2008/09
Estuary class	80th %ile of reference	75th %ile of reference	25th %ile of all sites	80th %ile of reference
Lake	6.7	5.9	2.2	5.7
River – lower	1.9	1.8	1.5	5.0
River – mid	1.9	1.8	1.7	8.0
River – upper	23.9	22.4	7.0	13.7
Lagoon	2.2	1.9	1.9	3.3

7.1.2 Scoring classes

For chlorophyll a and turbidity, there are a number of alternative approaches to scoring the extent of deviation from reference condition:

- The ANZECC water quality guidelines recognise three ecosystem conditions and levels of protection:
    - Level 1: high conservation/ecological value systems
    - Level 2: slightly to moderately disturbed systems
    - Level 3: highly disturbed systems

  A level of protection is a level of quality desired by stakeholders and reference conditions may vary depending on the level of protection selected. Statistical decision criteria for detecting departure from reference vary according to the level of protection. Ideally data should be collected monthly over two years to understand ecosystem variability and set trigger values, below which there is a low risk that adverse biological effects will occur.

  For Level 1, no change beyond natural variability is recommended and where reference condition is poorly characterised, actions to increase the power of detecting change are also recommended. However no specific criteria are provided.

  For Level 2, negotiated decision criteria are recommended with a default of the 80^{th} percentile of reference condition.

  For Level 3, decision criteria may be more lenient than the previous two condition categories with a default of the 90^{th} percentile of reference.

  The guidelines recommend comparing the median of replicate samples from a test site with the low risk trigger value as the median represents the most robust descriptor. The guidelines were not specifically established to rate the extent of deviation of the median beyond trigger values and are therefore silent on this subject

- The Queensland water quality guidelines (DERM 2009) adopt the general approaches of the ANZECC guidelines but are more specific with regard to statistical decision criteria for Level 1 systems. If the 20^{th}, 50^{th} and 80^{th} percentiles of the reference site data fall within the 75 per cent confidence intervals around each of the 20^{th}, 50^{th} and 80^{th} percentiles of the test site data, then the site is taken as complying. Again though, no attempt is made to rate the extent of deviation from reference
- The Ecosystem Health Monitoring Program for South East Queensland (EHMP 2008) measures compliance with a water quality objective (WQO) in four categories
    - <0.5 x WQO (compliant: dark green)
    - 0.5 – 1.0 x WQO (compliant: light green)
    - 1.0 – 1.5 x WQO (non-compliant: orange)
    - >1.5 x WQO (non-compliant: red).

  A benefit of this method is that the extent of deviation of sample values from the water quality objective can be seen from the number of values lying in each category
- A fourth option is to compare the number of samples complying with the guideline trigger values using pre-determined statistical decision criteria. This method is not as useful in

showing how close a sample value is to meeting the guideline trigger value. A sample value may be very close to meeting the trigger value but still be classed as non-complying. However, after considering the lack of data on ecologically or biologically relevant thresholds, this was the option initially adopted for the MER program. After examining the data distribution, the scoring system used was:

- o very good: <10% exceedance of test site data above trigger
- o good: 10 – <50% exceedance
- o fair: 50 – <75% exceedance
- o poor: 75 – <90% exceedance
- o very poor: ≥90% exceedance.

Other scoring methods might include dividing scores into three equal percentiles between, say, the 5th and 95th percentiles, or else anchoring the frequency distribution by an ecologically relevant threshold then dividing scores equally amongst percentiles either side of the threshold, say in two percentiles representing condition better than the threshold and three percentiles representing worse (Wicks et al. 2011). These alternatives should be further explored for the next round of SOC reporting.

7.2 Macrophytes

7.2.1 Reference conditions

As discussed in Chapter 5, current classification systems for macrophytes and the status of research on factors controlling macrophyte distribution and extent are not sufficiently advanced to define an 'ideal mix' of seagrass, mangrove and saltmarsh in any given system. Research by DPI is leading to a better understanding of the factors controlling seagrass colonisation preferences (see West & Williams 2008 in relation to Sydney Harbour) and it is anticipated that this knowledge, together with other research findings (Ron West, University of Wollongong, pers comm.), will allow better assessment of the condition of macrophyte assemblages in the future.

Until better research is available, the approach adopted has been to report on the change in macrophyte extent based on the two major surveys covering all NSW estuaries.

7.2.2 Scoring classes

Prior to developing scoring classes, a comparison was made between the change in macrophyte extent shown by the two major surveys and the limited number of time series surveys identified in Chapter 6. The broad direction of change was confirmed by the comparison for seagrass, but there were inconsistencies for mangrove and saltmarsh.

For mangroves, comparison of the two survey periods was likely to more accurately reflect real change as operator error between surveys of this large woody vegetation type is likely to be minimal. However, interpretation of what any change means ecologically is open to challenge.

Increasing mangrove extent could be due to a number of factors including:

- recolonisation in areas previously removed which would be viewed as a positive change
- colonisation upslope into areas currently occupied by saltmarsh which might be viewed as negative considering the limited areas of saltmarsh within NSW estuaries and its listing as a Threatened Ecological Community

- marinisation (increasing salinity) of estuaries through entrance training, artificial entrance openings of lagoons, water extraction upstream and lower rainfall associated with drought and climate change which could be considered as negative.

Mangroves have an important functional role in providing structural habitat, a food source, filtering capacity and erosion protection. However, with current knowledge, it is difficult to generalise as to whether a change in mangrove extent is positive or negative for estuary health without conducting estuary specific studies. The scoring system adopted has therefore been to say that stable mangrove extent, defined as change of between -10 to +10% between the two surveys, is good. Any change outside that range has been shaded grey, indicating that change data were held but interpretation requires further investigation. The data, therefore, are considered as 'baseline only'.

More realistic assessments of condition were considered possible for the other two macrophyte categories – seagrass and saltmarsh. As the two major surveys used different methods, changes of between -10% and +10% in extent were interpreted as being within the order of accuracy of the methods. Gains or losses beyond ±10% were scored according to the following scale: very good >10% gain, (good ≤10% gain to -10% loss, fair >-10 to -40% loss, poor >-40 to -70% loss and very poor >-70 to -100% loss.

The first survey did not differentiate between all the tributaries flowing into each port, bay or harbour. To enable direct comparisons, the areas of macrophytes for Port Stephens, Hawkesbury–Nepean River, Port Jackson, Jervis Bay and Ulladulla Harbour incorporate some of the tributary areas from the second survey. For example, the areas for Tilligery Creek from the second survey, but not the Karuah River or Myall River/Lakes areas, have been incorporated into the Port Stephens areas to enable comparison with the first survey.

A rating of 'not applicable' (na) has been assigned when the areas in both surveys have been recorded as zero showing that the macrophyte has never occurred in that estuary. This is particularly relevant for estuaries that intermittently close for periods of time which is not conducive to mangrove colonisation. Some of the smaller creeks also have minimal seagrass.

7.3 Fish

Traditionally, biotic measures of ecosystem condition have often included single indicators based on species diversity, dominance or presence/absence. Indices are being developed particularly for freshwater systems that capture information from individual, population and community levels to provide a more integrated assessment of biological integrity (Harrison & Whitfield 2006). One such index is the multi-metric Estuarine Fish Community Index (EFCI) developed to describe the health of 190 South African estuaries spanning three biogeographic regions and three distinct estuary types.

The EFCI uses 14 metrics that represent four broad fish community attributes: species diversity and composition, species abundance, nursery function and trophic integrity. The rationale for each metric and an *a priori* hypothesis of direction that disturbance should drive the metric are shown in Table 21.

Table 21: Metrics used in the EFCI (from Harrison & Whitfield 2004, 2006)

EFCI metric	Rationale	Response to environmental stress
Species diversity and composition		
1. Total number of taxa	Simplest measure of diversity	Reduced
2. Rare or threatened species	Presence imparts additional conservation value	Absent
3. Exotic or introduced species	Potential threat to naturally occurring taxa	Present
4. Species composition (relative to reference assemblage)	Similarity is a measure of biological integrity	Reduced
Species abundance		
5. Species relative abundance	Captures change from many species in relatively low proportions to simple assemblages dominated by few communities	Reduced
6. Number of species that make up 90 per cent of the abundance	Dominance by fewer species	Reduced
Nursery function		
7. Number of estuarine resident taxa	Estuaries are important habitat for resident taxa	Reduced
8. Number of estuarine-dependent marine taxa	Estuaries fulfil role of nursery habitat for marine taxa as well as estuarine resident taxa	Reduced
9. Relative abundance of estuarine resident taxa	Between 9. and 10., quantitative, complementary measures of estuarine habitat quality and nursery function	Very low or very high
10. Relative abundance of estuarine-dependent marine taxa		Very low or very high
Trophic integrity		
11. Number of benthic invertebrate feeding taxa	Indirect measure of the condition of the benthic invertebrate fauna	Reduced
12. Number of piscivorous taxa	Diverse and abundant top carnivores represent the broader trophic network in estuaries	Reduced
13. Relative abundance of benthic invertebrate feeding taxa	Between 13. and 14., quantitative and complementary analysis of trophic integrity	Reduced
14. Relative abundance of piscivorous taxa		Reduced

7.3.1 Reference conditions

For South African fish assemblages, Harrison & Whitfield (2006) developed reference conditions taking into account inherent morphological differences between estuaries as well as zoogeographic differences. Three geomorphic types of small closed, moderate to large closed and predominantly open estuaries and three biographic regions of sub-tropical, warm-temperate and cool-temperate climate were adopted and separate reference conditions developed for each of the nine possible combinations of type and bioregion. This was necessary for eight of the 14 metrics used to construct the index.

Rather than making *a priori* assumptions about which systems are undegraded, the EFCI for South African estuaries uses the best values observed for each metric for a particular estuary type in a particular region to define the reference conditions. The same approach was adopted for NSW estuaries.

Metrics 1, 6, 7, 8, 11 and 12 used the mean of the upper quartile of the data distribution as the reference condition, and metrics 2 and 3 used presence and/or absence. Metrics 4 and 5 used a Bray-Curtis similarity measure to compare the species assemblage and abundance in each estuary with a reference assemblage and abundance for each estuary type and bioregion after removing all exotic and introduced taxa. For metrics 9 and 10, reference conditions were considered as those where the species numerically comprised between 25 and 75 per cent of the total abundance. Metric 13 adopted reference conditions as being benthic invertebrate feeding fishes numerically comprising ≥ a percentage which varied by estuary type and bioregion (eg 10 per cent for moderate to large closed estuaries in warm-temperature climates) of the total fish abundance. Similarly for metric 14, reference was defined as piscivores comprising ≥ a percentage (eg 1 per cent for the same estuary type and climate as 13) of the total fish abundance.

Due to the different dates and designs of sampling programs for the northern/southern bioregions (Estuary Biodiversity Survey 1999–2002) and the central bioregion (MER Sampling Program 2008) and the geographic distribution of estuary geomorphologies, the estuary types sampled varied as follows:

- Northern region – permanently open riverine barrier estuaries and predominantly closed ICOLLs
- Central bioregion – drowned river valleys, large barrier lagoons and predominantly closed ICOLLs
- Southern bioregion – permanently open riverine barrier estuaries, predominantly closed ICOLLS and predominantly open ICOLLs.

Reference conditions were therefore required for five different estuarine geomorphic types.

Drowned river valleys and large barrier lagoons in the central region are all highly modified and/or support significant commercial fishers. Therefore, reference conditions are probably less representative of 'undisturbed' environments than for the other two regions.

7.3.2 Scoring classes

Having established reference conditions for each metric, the extent of deviation from reference can be used to assign thresholds for scoring each estuary. The EFCI established thresholds such that a score of 5, 3 or 1 could be assigned to each metric as shown in Table 22.

Table 22: Metric scoring thresholds for fish assemblages

Metric	Score		
	5	**3**	**1**
Total number of taxa	≥90% of reference	<90% and ≥50%	<50%
Rare or threatened species	Present	Absent	
Exotic or introduced species		Absent	Present
Species composition (% similarity to reference)	≥80%	<80% and ≥50%	<50%
Species relative abundance (% similarity to reference)	≥60%	<60% and ≥40%	<40%
Number of species that make up 90% of abundance	≥90% of reference	<90% and ≥50%	<50%
Number of estuarine resident taxa	≥90% of reference	<90% and ≥50%	<50%
Number of estuarine-dependent marine taxa	≥90% of reference	<90% and ≥50%	<50%
Relative abundance of estuarine resident taxa	25–75%	≥10% and <25% or >75% and ≤90%	<10% or >90%
Relative abundance of estuarine-dependent marine taxa	25–75%	≥10% and <25% or >75% and ≤90%	<10% or >90%
Number of benthic invertebrate feeding taxa	≥90% of reference	<90% and ≥50%	<50%
Number of piscivorous taxa	≥90% of reference	<90% and ≥50%	<50%
Relative abundance of benthic invertebrate feeding taxa	Dependent on spread of the data	Dependent on spread of the data	Dependent on spread of the data
Relative abundance of piscivorous taxa	Dependent on spread of the data	Dependent on spread of the data	Dependent on spread of the data

The metric scoring thresholds corresponding to each of the five different estuary geomorphologies and three different bioregions are given in Table 23.

Assuming that all metrics have equal weighting, the overall index is calculated by summing all the individual metric scores. The minimum possible score is 16, the maximum is 68 and a score of 3, or moderate, for each metric yields a total index score of 42. Harrison & Whitfield (2006) adopted five scoring classes of: very good (64–68), good (46–62), moderate (40–44), poor (22–38) and very poor (16–20). After examining the data distribution for NSW fish assemblages the scoring classes adopted for the MER program were: very good (60–68), good (49–59), fair (36–48), poor (25–35) and very poor (16–24) which approximated a normal data distribution.

These biological criteria can be used to provide information to support management decisions such as establishing goals to protect or restore biological integrity, determining whether designated uses have been attained and whether they are appropriate or attainable (Harrison & Whitfield 2004).

Table 23: Metric scoring criteria for NSW estuaries

	N = Northern bioregion	Predominantly Closed ICOLLs (N, C, S)			Large Barrier Lagoons (C) / Predominantly Open ICOLLS (S)			Permanently Open Riverine Barrier Estuaries (N, S) / Drowned River Valleys (C)		
	C = Central bioregion	Score			Score			Score		
Estuarine Fish Community Index Metric	**S = Southern bioregion**	**5**	**3**	**1**	**5**	**3**	**1**	**5**	**3**	**1**
Species Diversity and Composition										
1	Total number of taxa (species richness per estuary)									
	Northern Bioregion	>25	25-15	<15				>47	47-24	<24
	Central Bioregion	>27	27-15	<15	>37	37-21	<21	>33	33-19	<19
	Southern Bioregion	>23	23-14	<14	>42	42-24	<24	>40	40-23	<23
2	Protected species (present or absent per estuary)	present	absent		present	absent		present	absent	
3	Exotic / introduced species (present or absent per estuary)		absent	present		absent	present		absent	present
4	Species composition (frequency of occurence per estuary)	≥80%	<80% and ≥50%	<50%	≥80%	<80% and ≥50%	<50%	≥80%	<80% and ≥50%	<50%
Species Abundance										
5	Relative species abundance (using mean relative (%) abundance)	≥60%	<60% and ≥40%	<40%	≥60%	<60% and ≥40%	<40%	≥60%	<60% and ≥40%	<40%
6	Most abundant species (number of species that make up 90% of abundance)									
	Northern Bioregion	>6	6-4	<4				>8	8-5	<5
	Central Bioregion	>7	7-4	<4	>13	13-8	<8	>11	11-7	<7
	Southern Bioregion	>9	9-6	<6	>15	15-9	<9	>14	14-9	<9
Nursery Function										
7	Estuarine resident taxa (number of estuarine resident taxa per estuary)									
	Northern Bioregion	>13	13-8	<8				>30	30-17	<17
	Central Bioregion	>18	18-10	<10	>23	23-13	<13	>20	20-12	<12
	Southern Bioregion	>16	16-10	<10	>28	28-16	<16	>28	28-16	<16
8	Estuarine dependent marine taxa (number of estuarine dependent marine taxa per estuary)									
	Northern Bioregion	>6	6-3	<3				>10	10-6	<6
	Central Bioregion	>7	7-4	<4	>9	9-6	<6	>9	9-6	<6
	Southern Bioregion	>6	6-4	<4	>11	11-7	<7	>10	10-6	<6
9	Abundance of estuarine residents (relative (%) abundance of estuarine resident taxa)	25%-75%	≥10% and <25% or >75% and ≤90%	<10% or >90%	25-75%	≥10% and <25% or >75% and ≤90%	<10% or >90%	25-75%	≥10% and <25% or >75% and ≤90%	<10% or >90%
10	Abundance of estuarine dependents (% abundance of estuarine-dependent marine taxa)	25%-75%	≥10% and <25% or >75% and ≤90%	<10% or >90%	25-75%	≥10% and <25% or >75% and ≤90%	<10% or >90%	25-75%	≥10% and <25% or >75% and ≤90%	<10% or >90%
Trophic Integrity										
11	Benthic feeding taxa (number of benthic invertebrate feeding taxa)									
	Northern Bioregion	>13	13-8	<8				>27	27-16	<16
	Central Bioregion	>13	13-8	<8	>22	22-13	<13	>21	21-12	<12
	Southern Bioregion	>14	14-8	<8	>26	26-15	<15	>23	23-14	<14
12	Fish eating taxa (number of piscivorous feeding taxa)									
	Northern Bioregion	>3	3-2	<2				>5	5-3	<3
	Central Bioregion	>2	2	<2	>3	3-2	<2	>2	2	<2
	Southern Bioregion	>1	1	<1	>4	4-3	<3	>4	4-3	<3
13	Abundance of benthic feeders (% abundance of benthic invertebrate feeding taxa per estuary)	≥10%	<10% and ≥5%	<5%	≥10%	<10% and ≥5%	<5%	≥10%	<10% and ≥5%	<5%
14	Abundance of fish eaters (% abundance of piscivorous taxa)	≥1%	<1% and ≥0.5%	<0.5%	≥1%	<1% and ≥0.5%	<0.5%	≥1%	<1% and ≥0.5%	<0.5%

8. Results of sampling programs

8.1 Chlorophyll a and turbidity

Data collected from sampling under the MER program during the 2007/08 and 2008/09 summer seasons were entered into the KEVIN database and the last three years of data supplied by all custodians (see Appendix 10) were used to score compliance of each estuary with the guideline trigger values described in Chapter 7. Three years was chosen as the assessment period for a number of reasons:

- It would reduce the inter-annual climatic variability in rainfall and temperature
- The sampling program is on a three-year cycle
- It is consistent with the approach of the Sustainable Rivers Audit for inland rivers and the comparable program for coastal rivers.

The actual dates used for sorting data were based on financial years from July to June to capture all summer data in each year of analysis. However for the first round of SOC reporting, data from July 2005 to June 2008 together with data from the 08/09 MER program summer sampling have been used for the analysis. In addition, all data have been analysed and reported but any assessments using data collected before July 2005 have been identified with cross-hatching over the top of the colour ramp.

8.2 Macrophytes

As trials on mapping of macrophytes using remote sensing technology are still in progress (Anstee et al. 2009), no new satellite-derived data were collected for the SOC reports. Rather, analyses of aerial photographs were used to make the comparisons for this assessment.

Two different mapping methodologies (initially *camera lucida*, followed by GIS) were used to compare the extent of macrophyte cover over the past several decades. Variations in detail, representation and minimum mapping unit between the datasets means that where small changes have occurred it is difficult to determine how much of the variation is attributed to change in habitat cover or is simply a difference in the mapping process. Nevertheless, where large changes have occurred, at the scale of hectares, there are strong implications that cover has expanded or contracted (Meehan et al. 2005). For this reason, condition scores are based on broad estimates of change between the two different surveys. It is recommended that the values used in the calculation of these comparisons only be a guide and should be used by CMAs and other NRM agencies to prioritise the selection of estuaries, for which more detailed and standardised mapping could be applied to determine the historic trends.

Analysis of historic time series data are currently available for a small number of estuaries and any future mapping of historic trends in these and other estuaries will provide a better understanding of the variations of estuarine macrophytes within the individual estuaries.

8.3 Fish

The two datasets used in this analysis (see Section 6.3) yielded the values shown in Table 24. These have been adopted as the initial scoring results for assessing the health of NSW fish assemblages. As analytical techniques improve, the values may be refined. Further, ongoing research being done by DPI on so-called 'Fishery Independent' ways of measuring the abundance of estuarine fish (Rotherham et al. 2007), (C. Gray pers. comm.) can probably be used just as effectively for fish biodiversity assessments as for more traditional assessments of harvestable fish stocks.

Table 24: Scoring classes for fish assemblages in NSW estuaries

(a) Northern Rivers region. Seine net samples from the Estuary Biodiversity Survey dataset.

Estuary	Index score	Index rating	Condition score
Tweed River	40	Fair	3
Cudgera Creek	42	Fair	3
Brunswick River	40	Fair	3
Belongil Creek	40	Fair	3
Tallow Creek	22	Very poor	1
Broken Head Creek	28	Poor	2
Richmond River	54	Good	4
Clarence River	48	Fair	3
Sandon River	40	Fair	3
Wooli Wooli River	40	Fair	3
Station Creek	38	Fair	3
Corindi River	46	Fair	3
Pipe Clay Creek	32	Poor	2
Arrawarra Creek	46	Fair	3
Darkum Creek	34	Poor	2
Woolgoolga Lake	52	Good	4
Hearns Lake	46	Fair	3
Moonee Creek	38	Fair	3
Boambee Creek	56	Good	4
Bellinger River	50	Good	4
Dalhousie Creek	46	Fair	3
Oyster Creek	36	Fair	3
Nambucca River	50	Good	4
Macleay River	48	Fair	3
South West Rocks Creek	48	Fair	3
Saltwater Creek	28	Poor	2
Korogoro Creek	42	Fair	3
Killick Creek	34	Poor	2
Hastings River	56	Good	4
Lake Innes/Lake Cathie	52	Good	4
Average score			3.00

Rating	Range
Very poor	16–24
Poor	25–35
Fair	36–48
Good	49–59
Very good	60–68

(b) Hunter–Central Rivers region. Seine net samples combined with gill net samples from the MER program dataset (except for the Manning River which is from the Estuary Biodiversity Survey dataset). Drowned river valleys (**) were not sampled with gill nets.

Estuary	Index score	Index rating	Condition score
Manning River	48	Fair	3
Khappinghat Creek **	62	Very good	5
Wallis Lake	40	Fair	3
Karuah River **	42	Fair	3
Lake Macquarie	58	Good	4
Tuggerah Lake	56	Good	4
Wamberal Lagoon	40	Fair	3
Terrigal Lagoon	42	Fair	3
Avoca Lake	38	Fair	3
Cockrone Lake	32	Poor	2
Brisbane Water	54	Good	4
Average score			3.36

Rating	Range
Very poor	16–24
Poor	25–35
Fair	36–48
Good	49–59
Very good	60–68

(c) Hawkesbury–Nepean/Sydney Metropolitan region. Seine net samples combined with gill net samples from the MER program dataset. Drowned river valleys (**) were not sampled with gill nets.

Estuary	Index score	Index rating	Condition score
Hawkesbury River **	56	Good	4
Pittwater **	50	Good	4
Dee Why Lagoon	42	Fair	3
Port Jackson **	48	Fair	3
Georges River **	46	Fair	3
Port Hacking **	58	Good	4
Average score			3.50

Rating	Range
Very poor	16–24
Poor	25–35
Fair	36–48
Good	49–59
Very good	60–68

(d) Southern Rivers region. Seine net samples from the Estuary Biodiversity Survey dataset.

Estuary	Index score	Index rating	Condition score
Lake Illawarra	52	Good	4
Shoalhaven River	48	Fair	3
St Georges Basin	48	Fair	3
Conjola Lake	62	Very good	5
Narrawallee Inlet	40	Fair	3
Meroo Lake	32	Poor	2
Willinga Lake	30	Poor	2
Cullendulla Creek	44	Fair	3
Candlagan Creek	44	Fair	3
Moruya River	66	Very good	5
Tuross River	64	Very good	5
Lake Brunderee	44	Fair	3
Lake Brou	36	Fair	3
Lake Mummuga	56	Good	4
Nangudga Lake	44	Fair	3
Tilba Tilba Lake	28	Poor	2
Baragoot Lake	34	Poor	2
Murrah River	54	Good	4
Bunga Lagoon	32	Poor	2
Wapengo Lagoon	46	Fair	3
Middle Lagoon	30	Poor	2
Nelson Lagoon	42	Fair	3
Bega River	62	Very good	5
Wallagoot Lake	36	Fair	3
Back Lagoon	38	Fair	3
Merimbula Lake	46	Fair	3
Pambula Lake	56	Good	4
Curalo Lagoon	54	Good	4
Nullica River	32	Poor	2
Towamba River	52	Good	4
Wonboyn River	58	Good	4
Average score			3.26

Rating	Range
Very poor	16–24
Poor	25–35
Fair	36–48
Good	49–59
Very good	60–68

8.4 Condition ratings for NSW estuaries

Following the methods outlined in the previous chapter, ratings were generated for the condition indicators of chlorophyll a, turbidity, macrophyte extent and fish assemblages as shown in Table 25, Table 26, Table 27 and Table 28 for each CMA region.

Table 25: Condition rating of estuaries in Northern Rivers region

ALL NR ESTUARIES

3.5 Good Condition — ? Trend Unknown

	CONDITION INDEX	INDEX TREND	ICOLL (I)	Chlorophyll a	Macroalgae	Turbidity	Seagrass	Mangrove	Saltmarsh	Fish	CONFIDENCE
ALL NSW ESTUARIES	3.6	?		3.3		3.7	3.6		4.1	3.2	M
ALL NR ESTUARIES	3.5	?		3.1			3.8		4.3	3.0	L
1. Tweed River	4.3	?									M
2. Cudgen Creek											L
3. Cudgera Creek	4.3	?									M
4. Mooball Creek											L
5. Brunswick River	3.8	?									M
6. Belongil Creek	3.0	?	I				na				M
7. Tallow Creek	1.0	?	I				na	na			L
8. Broken Head Creek	1.5	?	I				na	na			L
9. Richmond River	4.5	?									M
10. Salty Lagoon			I								
11. Evans River	3.0	?									M
12. Jerusalem Creek			I				na	na			L
13. Clarence River	3.3	?									M
14. Lake Arragan			I								
15. Cakora Lagoon			I								
16. Sandon River	4.3	?									M
17. Wooli Wooli River	4.3	?									M
18. Station Creek	4.0	?	I				na				L
19. Corindi River	3.7	?									M
20. Pipe Clay Creek			I								L
21. Arrawarra Creek	3.0	?	I								M
22. Darkum Creek	4.0	?	I								M
23. Woolgoolga Lake	4.5	?	I				na				L
24. Flat Top Point Creek			I								
25. Hearns Lake	4.0	?	I				na				L
26. Moonee Creek	4.3	?									M
27. Pine Brush Creek			I								
28. Coffs Creek											L
29. Boambee Creek	3.3	?									M
30. Bonville Creek											L
31. Bundageree Creek			I								
32. Bellinger River	4.5	?									M
33. Dalhousie Creek	3.0	?	I								M
34. Oyster Creek	4.0	?	I				na				L
35. Deep Creek			I								L
36. Nambucca River	4.5	?									M
37. Macleay River	3.8	?									M
38. South West Rocks Creek	2.3	?									M
39. Saltwater Creek (Frederickton)			I				na	na	na		L
40. Korogoro Creek	3.7	?									M
41. Killick Creek	2.7	?	I								M
42. Goolawah Lagoon			I								
43. Hastings River	4.0	?									M
44. Cathie Creek	3.3	?	I								M
45. Duchess Gully			I								
46. Camden Haven River	4.0	?									M

Indicator Score and Rating

CONDITION		TREND		CONFIDENCE	
5	Very good	↑	Improving	H	High
4	Good	↔	No change	M	Medium
3	Fair	↓	Declining	L	Low
2	Poor	?	Unknown		
1	Very poor			(blank)	no data
				(grey)	baseline only
(hatched)	data >3 years old			na	not applicable

Index Rating and Range

Very good	>4.2 – 5.0
Good	>3.4 – 4.2
Fair	>2.6 – 3.4
Poor	>1.8 – 2.6
Very poor	≤1.8

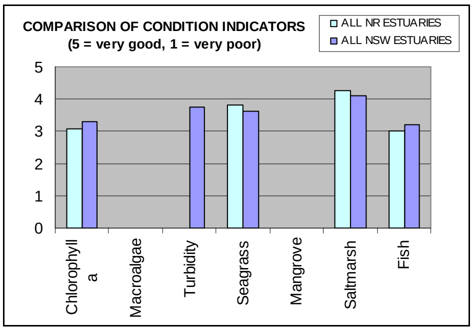


Table 26: Condition rating of estuaries in Hunter–Central Rivers region

ALL HCR ESTUARIES

3.6 Good Condition — ? Trend Unknown

	CONDITION INDEX	INDEX TREND	ICOLL (I)	Chlorophyll a	Macroalgae	Turbidity	Seagrass	Mangrove	Saltmarsh	Fish	CONFIDENCE
ALL NSW ESTUARIES	3.6	?		3.3		3.7	3.6		4.1	3.2	M
ALL HCR ESTUARIES	3.6	?		3.5		3.4	3.3		4.3	3.4	M
1. Manning River	4.0	?									M
2. Khappinghat Creek	3.4	?	I								M
3. Black Head Lagoon			I								
4. Wallis Lake	4.0	?									M
5. Smiths Lake	3.5	?	I					na			M
6. Myall River	4.0	?									M
7. Karuah River	2.8	?									M
8. Tilligerry Creek											L
9. Port Stephens											L
10. Hunter River											L
11. Glenrock Lagoon			I								
12. Lake Macquarie	4.3	?									M
13. Middle Camp Creek			I								
14. Moonee Beach Creek			I								
15. Tuggerah Lake	4.2	?	I								M
16. Wamberal Lagoon	3.0	?	I					na	na		M
17. Terrigal Lagoon	3.0	?	I						na		L
18. Avoca Lake	2.8	?	I								M
19. Cockrone Lake	2.5	?	I					na	na		L
20. Brisbane Water	4.3	?									M

Indicator Score and Rating

CONDITION	TREND	CONFIDENCE
5 Very good	↑ Improving	H High
4 Good	↔ No change	M Medium
3 Fair	↓ Declining	L Low
2 Poor	? Unknown	no data
1 Very poor		baseline only
data >3 years old		na not applicable

Index Rating and Range

Very good	>4.2 – 5.0
Good	>3.4 – 4.2
Fair	>2.6 – 3.4
Poor	>1.8 – 2.6
Very poor	≤1.8

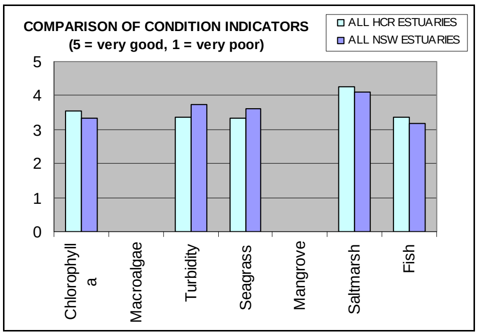


Table 27: Condition rating of estuaries in Hawkesbury–Nepean and Sydney Metropolitan regions

ALL HNSM ESTUARIES

3.2 Fair Condition

? Trend Unknown

	CONDITION INDEX	INDEX TREND	ICOLL (I)	INDICATOR: Chlorophyll a	Macroalgae	Turbidity	Seagrass	Mangrove	Saltmarsh	Fish	CONFIDENCE
ALL NSW ESTUARIES	3.6	?		3.3		3.7	3.6		4.1	3.2	M
ALL HNSM ESTUARIES	3.2	?		3.6		2.2	3.1		3.8	3.5	M
1. Hawkesbury River	4.4	?		Good			Very good	Good	Very good	Good	M
2. Pittwater	4.0	?					Good	Good	Good	Good	M
3. Broken Bay											
4. Narrabeen Lagoon	4.7	?	I	Good			Very good	baseline only	Very good		M
5. Dee Why Lagoon	2.0	?	I	Fair			Very poor	na	Very poor	Fair	M
6. Curl Curl Lagoon			I	Poor			na	na	na		L
7. Manly Lagoon	1.7	?	I	Poor		Poor	Very poor	baseline only	na		M
8. Middle Harbour Creek				Very good							L
9. Lane Cove River				Good							L
10. Parramatta River				Poor		Very poor					L
11. Port Jackson	3.8	?		Very good			Poor	baseline only	Very good	Fair	M
12. Cooks River				Poor		Very poor					L
13. Georges River	3.8	?		Good		Poor	Very good	baseline only	Very good	Fair	M
14. Botany Bay	2.8	?		Good		Poor	Fair	baseline only	Poor		M
15. Port Hacking	3.5	?		Very good			Poor	baseline only	Fair	Good	M
16. Wattamolla Creek			I	Good		Very good					L

Indicator Score and Rating

CONDITION	TREND	CONFIDENCE
5 Very good	↑ Improving	H High
4 Good	↔ No change	M Medium
3 Fair	↓ Declining	L Low
2 Poor	? Unknown	no data
1 Very poor		baseline only
data >3 years old		na not applicable

Index Rating and Range

Very good	>4.2 – 5.0
Good	>3.4 – 4.2
Fair	>2.6 – 3.4
Poor	>1.8 – 2.6
Very poor	≤1.8

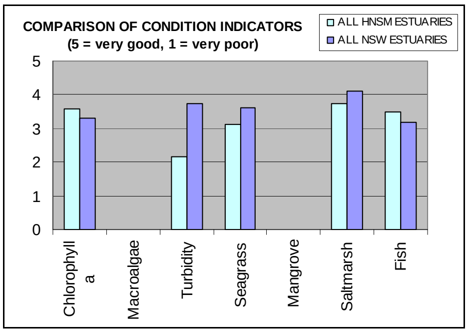


Table 28: Condition rating of estuaries in Southern Rivers region

ALL SR ESTUARIES

3.7 Good Condition

? Trend Unknown

	CONDITION INDEX	INDEX TREND	ICOLL (I)	Chlorophyll a	Macroalgae	Turbidity	Seagrass	Mangrove	Saltmarsh	Fish	CONFIDENCE
ALL NSW ESTUARIES	3.6	?		3.3		3.7	3.6		4.1	3.2	M
ALL SR ESTUARIES	3.7	?		3.3		4.1	3.6		4.1	3.3	M
1. Hargraves Creek			I								
2. Stanwell Creek			I								L
3. Flanagans Creek			I								L
4. Woodlands Creek			I								
5. Slacky Creek			I								L
6. Bellambi Gully			I								
7. Bellambi Lake			I								L
8. Towradgi Creek	2.3	?	I						na		M
9. Fairy Creek			I								L
10. Allans Creek											
11. Port Kembla							na	na	na		
12. Lake Illawarra	4.4	?	I								M
13. Elliott Lake			I								L
14. Minnamurra River	4.0	?									M
15. Spring Creek	2.0	?	I					na	na		L
16. Munna Munnora Creek			I								L
17. Werri Lagoon	2.5	?	I						na		L
18. Crooked River	4.5	?									M
19. Shoalhaven River	4.4	?									M
20. Wollumboola Lake			I					na	na		L
21. Currarong Creek			I								
22. Cararma Creek											L
23. Wowly Gully			I								
24. Callala Creek			I								
25. Currambene Creek											L
26. Moona Moona Creek			I								
27. Flat Rock Creek			I								
28. Captains Beach Lagoon			I								
29. Telegraph Creek			I								
30. Jervis Bay											L
31. St Georges Basin	4.0	?									M
32. Swan Lake	4.0	?	I					na	na		L
33. Berrara Creek			I					na			L
34. Nerrindillah Creek			I					na	na		L
35. Conjola Lake	4.4	?									M
36. Narrawallee Inlet	4.3	?	I								M
37. Mollymook Creek			I								L
38. Millards Creek			I								
39. Ulladulla											L
40. Burrill Lake	3.8	?	I					na			M
41. Tabourie Lake	3.3	?	I					na			M
42. Termeil Lake	2.7	?	I					na	na		L
43. Meroo Lake	4.0	?	I					na	na		M
44. Willinga Lake	3.7	?	I					na	na		L
45. Butlers Creek			I					na			L
46. Durras Lake	4.0	?	I					na			M
47. Durras Creek			I								

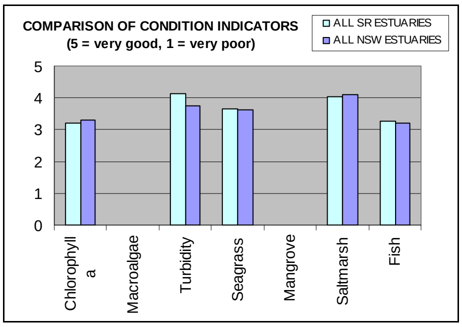
Indicator Score and Rating

CONDITION		TREND		CONFIDENCE	
5	Very good	↑	Improving	H	High
4	Good	↔	No change	M	Medium
3	Fair	↓	Declining	L	Low
2	Poor	?	Unknown		
1	Very poor				

data >3 years old; no data; baseline only; na not applicable

Index Rating and Range

Very good	>4.2 – 5.0
Good	>3.4 – 4.2
Fair	>2.6 – 3.4
Poor	>1.8 – 2.6
Very poor	≤1.8



48. Maloneys Creek			I								
49. Cullendulla Creek	4.3	?	I								M
50. Clyde River	4.0	?									M
51. Batemans Bay									na		L
52. Saltwater Creek (Rosedale)			I								
53. Tomaga River	4.8	?									M
54. Candlagan Creek	3.8	?									M
55. Bengello Creek			I								
56. Moruya River	4.8	?									M
57. Congo Creek	4.0	?	I					na			M
58. Meringo Creek			I				na	na			L
59. Kellys Lake			I								
60. Coila Lake	4.0	?	I					na			M
61. Tuross River	4.2	?									M
62. Lake Brunderee	2.0	?	I					na			L
63. Lake Tarourga			I								
64. Lake Brou	2.8	?	I					na			M
65. Lake Mummuga	3.7	?	I								M
66. Kianga Lake			I					na			L
67. Wagonga Inlet											L
68. Little Lake (Narooma)			I								
69. Bullengella Lake			I								
70. Nangudga Lake	4.3	?	I					na			L
71. Corunna Lake	3.5	?	I					na			M
72. Tilba Tilba Lake	2.8	?	I					na			M
73. Little Lake (Wallaga)			I								
74. Wallaga Lake	2.5	?	I					na			M
75. Bermagui River											L
76. Baragoot Lake	2.6	?	I					na			M
77. Cuttagee Lake	4.0	?	I					na			M
78. Murrah River	4.7	?									M
79. Bunga Lagoon	2.7	?	I					na			L
80. Wapengo Lagoon	4.5	?									M
81. Middle Lagoon	4.0	?	I					na			L
82. Nelson Lagoon	3.0	?									M
83. Bega River	3.6	?	I					na			M
84. Wallagoot Lake	4.6	?	I					na			M
85. Bournda Lagoon			I					na			L
86. Back Lagoon	4.0	?	I					na			L
87. Merimbula Lake	3.3	?									M
88. Pambula River	4.0	?									M
89. Curalo Lagoon	4.0	?	I					na			M
90. Shadrachs Creek			I								
91. Nullica River	3.0	?	I								M
92. Boydtown Creek			I								
93. Towamba River	4.6	?									M
94. Fisheries Creek			I					na			L
95. Twofold Bay								na			L
96. Saltwater Creek (Eden)			I								
97. Woodburn Creek			I								
98. Wonboyn River	4.3	?									M
99. Merrica River			I				na	na	na		L
100. Table Creek			I								
101. Nadgee River			I					na			L
102. Nadgee Lake	2.8	?	I					na			M

9. Pressure data

9.1 Sources of pressure data

Catchment action plans (CAPs) from the Northern Rivers, Hunter–Central Rivers and Southern Rivers CMAs all contained information on the main pressures affecting the health of their catchments. These pressures have been extracted from the CAPs in the form they were expressed and grouped up into themes (Appendix 18). The other two CAPs from the Hawkesbury–Nepean and Sydney Metropolitan CMAs did not identify pressures in a form suitable for a summary. While there is significant overlap of pressures between CMAs there are also differences which may reflect local priorities or expertise.

A second source of potential pressures on estuaries can be found in the work of the CRC for Coastal Zone, Estuary and Waterway Management. In the Users' Guide to Estuarine, Coastal and Marine Indicators for Regional NRM Monitoring (Scheltinga et al. 2004), the CRC have identified 13 main stressors as being physical, chemical and biological components of the environment that, when changed by human or other activities, can result in degradation of natural resources. Ecosystem condition (physical-chemical and biological) and habitat extent indicators have been identified for each stressor together with potential causes of change to the stressor and potential symptoms of a changed stressor. Finally the CRC compiled a list of direct and indirect indicators of pressures potentially impacting each stressor. A summary has been prepared showing stressor, direct and indirect pressure indicators, ecosystem condition and habitat extent indicators (Appendix 19). A preliminary assessment of the feasibility of collating these pressure data on the basis of estuaries theme team familiarity with available datasets is shown as green (feasible) or brown (more difficult) shading.

The table in Appendix 19 was reworked to only include condition indicators proposed to be monitored under the MER strategy together with their corresponding stressors and pressures and is shown in Table 29 with feasibility shading. Note that freshwater flow regime has been included as a stressor even though it was not associated with a specific condition indicator in Scheltinga et al. (2004). Changing environmental flows into estuaries has multiple effects on salinity and turbidity regimes, sedimentation patterns, entrance condition, algal response, aquatic vegetation distribution and the estuarine food web generally.

9.2 Criteria for selecting estuary pressures

Criteria relevant to the selection of which pressure data, identified through the CAPs and the Coastal CRC tables, were feasible to collect include:

- data availability along all the NSW coastline
- time required to collate available data
- ability to gap-fill pressures using empirical relationships
- ability to model pressure (if no monitored data available)
- strength of known link to resource condition in the literature
- readily available reference condition.

Table 30 lists those pressures and stressors best satisfying most of the selection criteria, and includes the rationale or pathway for how the pressure or stressor impacts resource condition. The pressure/stressor indicators have been categorised by catchment, riparian, foreshore or waterway use and climate change. These are the datasets for which collation and/or modelling were initiated.

Table 29: Stressors and pressures for each condition indicator

Condition indicator	Stressor		Pressure	
	Type	Change	Direct	Indirect
Pelagic chlorophyll a Macroalgae over seagrass beds Epiphytes on seagrass leaves	Nutrients (changed)	Nutrient load Water column concentrations Bioavailability	Total diffuse source nutrient load (monitored or modelled)	Catchment land-use Amount of fertiliser applied per unit area (including urban) % of farming area using best management practice % of length of stream with healthy riparian zone % of urban area under stormwater management plan % of area under aquaculture
			Total point source nutrient load (monitored or modelled)	% of sewage treatment plants with tertiary treatment Volume/number of sewage overflow events
	Hydrodynamics (changed)	Tidal exchange Water currents Wave patterns	Change in tidal exchange rates/residence time Change in tidal compartment	
Secchi disk depth, turbidity, seagrass depth range	Aquatic sediments (changed)	Sediment load Distribution/movement patterns Settlement/resuspension rates Grain size of suspended or settled sediments	Total diffuse sediment load (monitored or modelled)	Catchment land-use % of farming area using best management practice % of length of stream with healthy riparian zone % of length of streams in grazing area fenced
			Total point source sediment load (monitored or modelled)	
			Volume of sediment moved / extracted	

Condition indicator	Stressor		Pressure	
	Type	Change	Direct	Indirect
Seagrass, saltmarsh, mangrove extent/distribution	Habitat removal / disturbance	Removal, loss or disturbance of large areas of habitat	% of estuary / coas t/ marine area modified	% of aquatic area under mining lease Number of boating/shipping visits Number of registered boats in region % of estuary/coast/marine area designated for future modification Coastal population size Recreational usage (eg number of facilities on coast [boat ramps, parks, etc.), % estuary, coast and marine systems accessible, tourism (visitation rates, etc.]) % of area under aquaculture
Fish assemblages	Biota removal / disturbance	Removal, loss or disturbance of individual organisms of a specific species	Commercial seafood catch Recreational seafood catch Bait catch Area disturbed by bait fishing Area disturbed by trawling Area disturbed by boat anchor damage Fisheries by-catch	Number of registered boats in region Length of shark nets/drum line present Recreational usage (eg number of facilities on coast [boat ramps, parts, etc.], % estuary, coast and marine systems accessible, tourism [visitation rates, marina berths, etc.]) Coastal population size Number of trawlers and dredges using area Number of commercial fishing licences Number of licensed collectors (of aquarium fish, shells, etc.) Number of impoundments without fish ladders

Condition indicator	Stressor		Pressure	
	Type	Change	Direct	Indirect
No specific indicator(s)	Freshwater flow regime (changed)	Changes to pattern/amount of catchment waters entering estuarine and coastal systems	Change in median freshwater input (volume) Base freshwater input compared to total estuary volume Number of times freshwater flow greater than estuary volume Change in seasonality of freshwater input	% of median annual flow impounded/extracted

LEGEND — Data feasible to collate (green) — Data more difficult to collate (orange)

Table 30: Estuary pressures and stressors with data likely to be available state-wide

Pressure indicator	Rationale	Strength of link to condition indicator [1]							Reference condition for pressure	Data source	Used (Y/N) [2]
		Chlorophyll a	Turbidity	Macroalgae	Seagrass	Mangrove	Saltmarsh	Fish			
Catchment use											
Catchment population	Component of urban stormwater, sewage overflows, contributes to general degradation	✓	✓	✓	×	×	×	×	Increase from zero baseline	ABS 2001 census plus OEH proportioning of Census Collection Districts	Yes
Land-use	Increase in sediment, nutrient and organic loads	✓✓	✓✓	✓✓	✓✓	✓	✓	✓	Increase from zero baseline	OEH mapping 2000–07	Yes
Catchment runoff	Increase in streambank erosion and frequency of erosive events, change in flushing time	✓	✓	✓	✓	×	×	×	Increase from pre-1750	OEH catchment hydrology models (2CSalt)	Yes
Soil erosion potential	Potential reduction in estuary water clarity	×	✓✓	×	✓	×	×	×	Increase from pre-1750	OEH soil erosion hazard models and, Future results from MER Soils Theme	No
Sediment loads	Reduction in estuary water clarity	×	✓✓	×	✓	✓	×	×	Increase from pre-1750	OEH export models linked to 2CSalt	Yes
Reticulation vs unsewered septics	Contributes to nutrient and organic loads	✓	✓	✓	✓	×	×	×	Increase from zero baseline	OEH records and forward plans	No
Licenced STP discharges	Contributes to nutrient, suspended solid and organic loads	✓	✓	✓	✓	×	×	×	Increase from zero baseline	OEH licence records	Yes
Nutrient loads	Increase in algal growth, reduction in water clarity	✓✓	×	✓✓	✓	×	×	✓	Increase from pre-1750	OEH export models linked to 2CSalt	Yes

Pressure indicator	Rationale	Strength of link to condition indicator [1]							Reference condition for pressure	Data source	Used (Y/N) [2]
		Chlorophyll a	Turbidity	Macroalgae	Seagrass	Mangrove	Saltmarsh	Fish			
Riparian use (freshwater streams and estuary shoreline)											
Riparian vegetation extent	Indicative of water quality filtering capacity	✓	✓	✓	✓	×	×	×	Increase from zero baseline	OEH SLATS mapping, SPOT5 imagery and, Future results from MER Rivers Theme	No
Riverine geomorphic condition	Bed and bank stability and erosion	×	✓✓	×	✓	×	×	×	River Styles reference reaches	River Styles assessments, OEH river reference reach database and, Future results from MER Rivers Theme	No
Water extraction	Reduction in freshwater inputs especially during low flows	✓	✓	✓	✓	×	×	×	Increase from zero baseline	NOW licence records	Yes
Riverine macroinvertebrate communities	Indicative of freshwater stream pollution potential and input	✓	✓	✓	✓	×	×	×	Observed / expected SIGNAL2 score	OEH macroinvertebrate records and, Future results from MER Rivers Theme	No

Pressure indicator	Rationale	Strength of link to condition indicator [1]							Reference condition for pressure	Data source	Used (Y/N) [2]
		Chlorophyll a	**Turbidity**	**Macroalgae**	**Seagrass**	**Mangrove**	**Saltmarsh**	**Fish**			
Foreshore use (intertidal and adjacent shallow water)											
Foreshore structures – reclamation, walls, groynes, jetties, oyster depuration sites	Removal of foreshore habitat	✗	✗	✗	✓✓	✓✓	✓✓	✗	Increase from zero baseline	Crown Lands licence records	Yes
Moorings – piles, marinas	Shading and/or disturbance of seagrass beds	✗	✗	✗	✓	✗	✗	✗	Increase from zero baseline	Crown Lands licence records	No
Aquaculture	Shading and/or disturbance of seagrass beds	✗	✗	✗	✓	✗	✗	✗	Increase from zero baseline	DPI Fisheries lease records	Yes
Waterway use											
Entrance works	Training walls increase tidal range, flushing, marinisation (salinity)	✓✓	✓✓	✓✓	✗	✗	✗	✓	Increase from zero baseline	OEH Estuaries database	Yes
Artificial entrance opening	Reduces inundation frequency and duration of peripheral aquatic vegetation, increases marinisation (salinity)	✓✓	✓✓	✓✓	✓	✓	✓	✓	Increase from natural frequency	Council records, aerial photos, OEH water level recorders	Yes
Dredging	Generates fine sediment plumes, removes aquatic habitat	✗	✓✓	✗	✓	✗	✗	✓	Increase from zero baseline	Crown Lands licence records	No
Wild harvest fisheries	Reduces commercially important fish and prawn species	✗	✗	✗	✗	✗	✗	✓✓	Increase from zero baseline	DPI Fisheries licence records	Yes
Invasive species	Competition for native species	✗	✗	✗	✓✓	✗	✗	✗	Increase from zero baseline	DPI Fisheries records	No

Pressure indicator	Rationale	Strength of link to condition indicator [1]							Reference condition for pressure	Data source	Used (Y/N) [2]
		Chlorophyll a	Turbidity	Macroalgae	Seagrass	Mangrove	Saltmarsh	Fish			
Climate change											
Sea level rise	Raises inundation levels of peripheral aquatic vegetation, changes light regimes and submerged aquatic vegetation distribution	×	×	×	✓	✓✓	✓✓	×	Change from earliest record	OEH ocean water level recorders	No
Rainfall change	Changes estuary hydrology, pollutant export and flushing rates	✓	✓	✓	✓	×	×	×	Change from earliest record	BoM/OEH rainfall stations	No
Air temperature change	Changes water temperature, biological productivity, bio-geochemistry, species composition	✓	×	✓	×	×	×	×	Change from earliest record	BoM temperature gauges	No

Notes:

1: The column on strength of link indicates the extent to which current literature supports a cause-effect relationship between pressure and condition. This table needs to be supported by conceptual models with references to relevant papers and reports. The scoring system of ticks and crosses is intended to show:

- ✓✓ strong link with good potential for development of empirical stressor-response model of pressure and condition
- ✓ known link but relationship unlikely to be significant or capable of modelling
- × very indirect link with no modelling potential.

2: Some of the pressures not currently reported on will be incorporated into future SOC reports as data become available.

9.3 Ports, bays and harbours

For the five pressure indicators of cleared land, population, sediment input, nutrient input and freshwater flow, the contributions from each tributary catchment together with the catchment draining directly to the port, bay or harbour were summed and reported. This is a more meaningful way of reporting the total pressure acting on the port, bay or harbour.

9.4 Pressure indicator correlation

A correlation analysis of the pressure variables was generated to assess whether metrics were too closely related to act as single metrics. As might be expected Total Suspended Solids (TSS), Total Nitrogen (TN) and Total Phosphorus (TP) all had correlation coefficients greater than 0.85 as shown in Table 31 and are potentially redundant (Morris et al. 2007). All of the other pressure variables had coefficients less than 0.85. TN was chosen to represent nutrient input but TSS has been retained for the purposes of this initial assessment. Further investigation will be undertaken on methods for separating pressures, as defined by human activity, from environmental stressors such as changes to nutrient and sediment inputs, freshwater and tidal flows.

Table 31: Correlation matrix for pressure variables

	Marked correlations (in red) are significant at p < .05000										
Pressure variable	% cleared land	Population / km²	% surface flows extracted	% structures perimeter	% estuary under aquaculture	Entrance opening level m AHD	No. of entrance training walls	Annual fish catch / km²	% TSS increase	% TP increase	% TN increase	Freshwater flow / volume
% cleared land	1.000											
Population / km²	***0.533***	1.000										
% surface flows extracted	0.114	0.022	1.000									
% structures perimeter	-0.102	-0.037	***0.284***	1.000								
% estuary under aquaculture	***-0.149***	-0.121	0.088	0.090	1.000							
Entrance opening level m AHD	-0.136	***-0.154***	0.055	***-0.035***	0.133	1.000						
No. of entrance training walls	***0.148***	-0.082	0.095	0.108	***0.182***	0.142	1.000					
Annual fish catch / km²	0.015	-0.124	***0.198***	0.135	0.039	-0.083	***0.252***	1.000				
% TSS increase	0.144	0.011	0.106	-0.076	-0.080	0.073	-0.034	-0.087	1.000			
% TP increase	***0.212***	0.112	0.012	-0.118	-0.125	0.079	***-0.055***	-0.131	***0.697***	1.000		
% TN increase	***0.158***	0.038	0.061	-0.104	-0.112	0.092	-0.055	-0.121	***0.906***	***0.924***	1.000	
Freshwater flow / volume	0.046	0.028	-0.057	-0.105	-0.101	0.109	-0.113	-0.125	***0.303***	***0.822***	***0.656***	1.000

9.5 Indicator scoring classes

In common with the condition indicators, there are a number of similar approaches to developing scoring classes. If the relationships between pressures, stressors and ecological response were well understood, thresholds at which pressures triggered unacceptable biological or ecological effects would be available. This is not the case and simple statistical decision rules were developed based on whether the pressure data were normally distributed or skewed. Equal intervals were generally applied to normally distributed data and equal percentiles to data skewed to one end of the distribution.

9.6 Cleared land

9.6.1 Data sources

The land-use areas aggregated for calculating the amount of cleared land in each estuary catchment are discussed in Section 4.2.2 and are shown in Appendix 7. The area of cleared land within each estuary catchment was normalised by comparing it to the total area of the catchment and calculating a percentage cleared. Because of the method used to aggregate land-uses for the 2CSalt modelling, the catchment area includes the estuary and macrophyte areas except for the nine ports, bays and harbours.

9.6.2 Interpretation

Land cleared for agricultural, residential and industrial development is a major pressure in many NSW coastal catchments and is known to result in increased inputs of eroded sediments, nutrients and organic material to the estuary.

The data distribution using the two options of equal percentiles and equal intervals is shown in Table 32. Using the equal percentile data bands, minimal catchment disturbance was assumed to occur for cleared land <7.5 per cent.

Table 32: Data distribution for cleared land

Pressure score	Equal percentiles (% cleared)		Equal intervals (% cleared)	
	Data band	No. of estuaries	Data band	No. of estuaries
5	0 – <7.5	37	0 – <20	71
4	7.5 – <21.7	37	20 – <40	41
3	21.7 – <39.1	36	40 – <60	24
2	39.1 – <68.5	37	60 – <80	29
1	68.5 – 100	37	80 – 100	19

9.7 Population density

9.7.1 Data sources

Census data were obtained from the Australian Bureau of Statistics for 1996, 2001 and 2006. The finest spatial scale at which data were available is Census Collection District (CCD) which is the standard geographic unit of collection and captures between 150 and 250 dwellings per CCD. At each census, Collection Districts may be redesigned to accommodate growth in population or to conform to other administrative data. To enable comparison between each census, non-populated areas were removed from each CCD by extracting National Park and State Forest areas. Where a CCD intersected with an estuary catchment boundary, the population in the remaining area of the CCD was proportioned by how much of the CCD fell inside and outside the catchment boundary.

The 2006 population in each estuary catchment was normalised by comparing it to the total area of the catchment and calculating a population density.

9.7.2 Interpretation

The population density of people residing in an estuary catchment is a general measure of pressure placed on an estuary. Effects can include increased pollution loads in stormwater and sewage overflows, disturbance of riparian and foreshore vegetation, litter and general degradation of the environment.

The data distribution using the two options of equal percentiles and equal intervals is shown in Table 33. Using the equal percentile data bands, minimal catchment disturbance was assumed to occur for population density <1.5 head/km^2.

Table 33: Data distribution for population density

Pressure Score	Equal percentiles (head/km²)		Equal intervals (head/km²)	
	Data band	No. of estuaries	Data band	No. of estuaries
5	0 – <1.5	37	0 – <684	161
4	1.5 – <9.0	37	684 – <1367	12
3	9.0 – <40.7	36	1367 – <2051	5
2	40.7 – <264.1	37	2051 – <2735	4
1	264.1 – 3419	37	2735 – 3419	2

9.7.3 Trend

The total population across all estuary catchments in each of the three census years was:

- for 1996: 4,864,849 persons or 38.3 persons/km^2 (representing 80.6 per cent of the total population of NSW)
- for 2001: 5,183,414 persons or 40.8 persons/km^2 (81.3 per cent of NSW)
- for 2006: 5,366,126 persons or 42.2 persons/km^2 (82.1 per cent of NSW).

The increase between each census was 6.5 per cent and 3.8 per cent relative to the 1996 census for a total increase of 10.3 per cent over the ten-year period. The increase in total NSW population from the 1996 census of 6,038,631 persons was 5.5 per cent and 2.8 per cent for a total increase of 8.3 per cent over the ten-year period. A population shift to coastal catchments is evident with the increase in the proportion of population across NSW living in coastal catchments increasing from 80.6 per cent to 82.1 per cent between 1996 and 2006. A breakdown in the population increase by catchment area (Figure 33) indicates higher variability in population for smaller catchments with even some reductions recorded. This reduction may be real or an artifact of the method used to proportion population in CCDs intersecting with catchment boundaries.

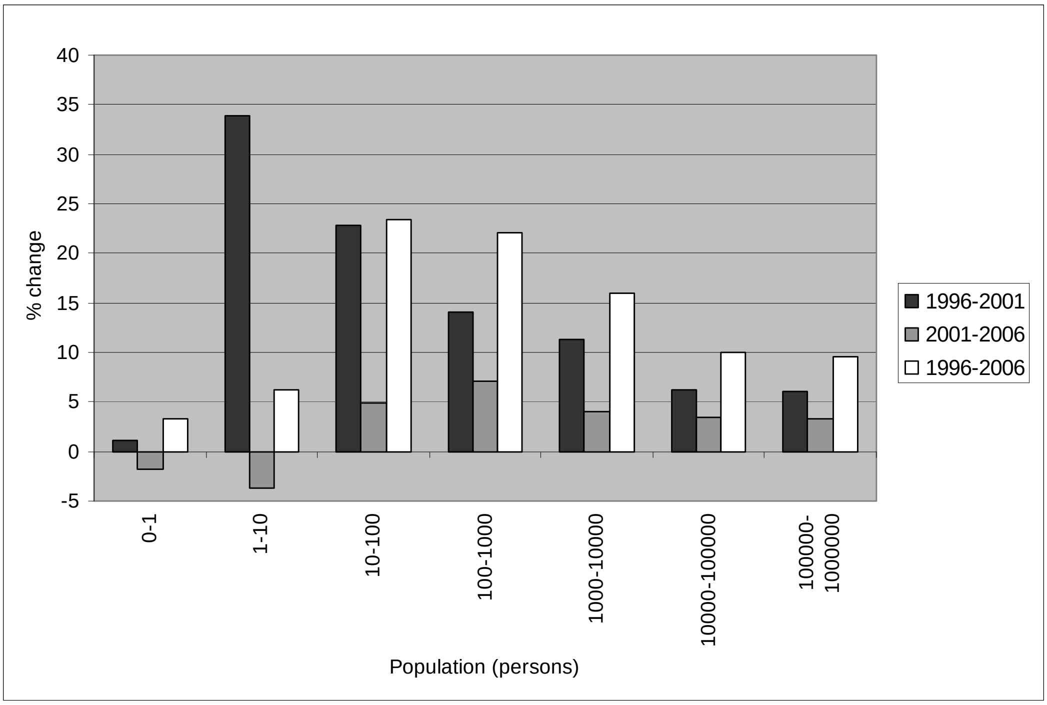


Figure 33: Population change in estuary catchments

9.8 Freshwater flow

9.8.1 Data sources

Data were collected for two variables: change in freshwater inflows from catchment clearing and the quantity of licenced water extraction.

There are 78 flow gauging stations operating and maintained by the NSW Office of Water in the freshwater streams draining 37 estuary catchments. The 2CSalt model was developed to provide water and salt inputs to regulated river models (Stenson et al. 2005) and has been extensively tested and applied within the Murray–Darling Basin. It can quantify surface and subsurface flows of water and salt and is able to predict the impacts of land-use change at a catchment scale. The model was applied to all 184 estuary catchments and calibrated using data from the 78 flow gauges (Littleboy et al. 2009). The output from the model is a monthly time series of water and salt generation to streams. Base flows, surface flows and groundwater flows are provided. Further disaggregation of flows into daily time series for generating flow duration curves is not possible.

Indicators of flow and pollutant export (sediments and nutrients) can not be normalised in the same manner as new pressures that did not exist prior to European settlement, such as land clearing or population. Flow and sediment and nutrient inputs can be assessed on the basis of the size of change between pre-European conditions and current day land-use. For flows, components of the flow regime that are significant to estuary function should be identified and quantified through hydrological modelling at suitable spatial and temporal scales.

For the Sustainable Rivers Audit of freshwater streams, indicators reported include changes in high-flow events, low-flow and zero-flow events, flow variability, seasonality and gross volume both as a mean and a median annual discharge (Davies et al. 2008).

For estuaries, the WSP process adopted two measures (Harris et al. 2008):

- The ratio of peak daily demand compared to low flows, defined as the 80th percentile, of the critical month
- The sensitivity of the estuary to changes in freshwater flows which was defined as a function of catchment and estuary area. Small intermittent systems were the most sensitive.

Both these measures are focused specifically on managing extraction of water by users during periods of low flow rather than stress arising from changes to all components of the flow regime. Also, flow duration curves are not available for all estuary catchment streams.

As a gross measure of impact on estuary water balance, the indicator adopted was the percentage increase in mean annual flow (MAF) above the pre-European settlement MAF. Future modelling and assessment may uncover additional metrics to better represent ecologically significant changes to flow regimes.

For water extraction licences, data on annual entitlements for streams draining to an estuary were extracted from the Licencing Administration System database administered by the the NSW Office of Water. The annual entitlements for all streams in an estuary catchment were summed and normalised by comparison with the mean annual flows summed for all streams in the estuary catchment.

9.8.2 Interpretation

Freshwater flow into estuaries affects salinity levels, flushing time, aquatic plant distributions, migration and spawning of aquatic animals, frequency of estuary mouth openings and fish catches. These characteristics are all modified by catchment clearing which increases the frequency and intensity of rainfall runoff causing a change to the quantity and timing of ecologically significant freshwater inflows to the estuary, catchment and river bed/bank erosion and polluted runoff. Extraction of water can have similar effects to changes in catchment hydrology but particularly during periods of low flow when extraction as a proportion of flow is greatest.

The data distribution for increases to pre-European settlement freshwater flows using the two options of equal percentiles and equal intervals is shown in Table 34. Using the equal interval data bands, minimal change to catchment streams was assumed to occur for freshwater flow increases of <3.9 per cent of MAF.

Table 34: Data distribution for freshwater flow increases

Pressure score	Equal percentiles (% of MAF)		Equal intervals (% of MAF)	
	Data band	No. of estuaries	Data band	No. of estuaries
5	-2.8 – <3.9	37	-2.8 – <29	125
4	3.9 – <11.9	37	29 – <58	35
3	11.9 – <21.9	36	58 – <87	12
2	21.9 – <44.3	37	87 – <116	6
1	44.3 – 142.2	37	116 – 142	6

The data distribution for water extraction using the two options of equal percentiles and equal intervals is shown in Table 35. Using the equal interval data bands, minimal change to catchment streams was assumed to occur for water extraction <6.3 per cent of mean annual flow.

Table 35: Data distribution for water extraction

Pressure score	Equal percentiles (% of MAF)		Equal intervals (% of MAF)	
	Data band	No. of estuaries	Data band	No. of estuaries
5	0 – <0.2	19	0 – <6.3	173
4	0.2 – <0.8	19	6.3 – <12.7	4
3	0.8 – <1.6	19	12.7 – <19.0	2
2	1.6 – <3.7	19	19.0 – <25.4	3
1	3.7 – 31.7	20	25.4 – 31.7	2

9.9 Sediment input

9.9.1 Data sources

Literature reviews were undertaken to establish typical event mean concentrations of TSS exported from the primary land-uses within coastal catchments.

To estimate both sediment and nutrient exports from each catchment, the freshwater surface flows generated for eight of the nine hydrological land-use classes from the 2CSalt modelling were multiplied by measured (median) sediment and nutrient concentration data obtained from the published scientific literature or from past OEH monitoring projects. The 'other' land-use class was excluded from the calculations as it represented 'river', 'sand' or 'wetland'. This multiplication produced annual sediment and nutrient load exports for each catchment.

Concentration data are expressed as event mean concentration (EMC), which is equivalent to the mean concentration of sediments or nutrients in runoff from a rain event. A search of the literature (publications available between the 1990s and June 2008) for local EMC data produced a total of only 25 relevant publications, which are listed separately at the end of the References section. The results demonstrate not only the paucity of EMC data in Australia but also the large variation in EMCs for various land-use types. To account for the limited and large variation in the EMC data, bootstrap techniques (Monte Carlo random sampling of the original data to produce a new data set [Baginska et al. 2003]) were used to derive EMC median, means and confidence intervals for each land-use type as shown in Table 36. Median values were adopted.

Table 36: Typical EMCs for TSS in catchment runoff

Land-use	EMC for TSS (mg/L)			
	Median	Mean	95% confidence interval	
Crops	200			
Dryforb	2972			
Forest	13.5	13.5	11.0	16.0

Land-use	EMC for TSS (mg/L)			
	Median	Mean	95% confidence interval	
Grazing	18.0	18.3	12.0	25.0
Irrigated pasture	2972			
Urban	63.3	67.3	5.3	129
Unsealed roads	900	1169	710	2625

A second source of sediment input is point source discharges from sewage treatment plants (STPs) directly into estuaries or their catchments. Discharges from STPs and from sewage overflow points are licensed by OEH and details stored on the Integrated Statutory Environmental Management System database. Data are available on actual, weighted, agreed and assessable load defined as follows (DECC 2009b):

- Assessable load is the lowest of the actual, weighted or agreed load and is used to calculate fees
- Actual load of a pollutant is the annual mass in kilograms released into the environment from the potential emission sources
- Weighted load of a pollutant is the actual load adjusted in recognition of practices that reduce environmental harm without reducing the actual pollutant loads
- Agreed load is a load that will be achieved through future improvements as part of a Load Reduction Agreement.

Loads were available for discharges to enclosed waters (waters other than estuarine or open coastal), estuarine waters (tidal and a mean range greater than 800 mm) and open coastal waters (Pacific Ocean) as defined in DECC (2008).

Assessable loads are also available from the OEH public register on licences, applications and notices issued under Section 308 of the *Protection of the Environment Operations Act 1997* [www.environment.nsw.gov.au/prpoeo/licences.htm].

The discharge locations were supplied as text-based descriptions which were manually converted into latitude and longitude coordinates with the assistance of regional licensing officers where required. The final coordinates were plotted as a spatial layer to visually confirm that the discharge points were located in a catchment stream or the tidal waterway of an estuary.

At the time of accessing the database, data were available generally for the years 2001 to 2007. Data from the latest year of records were used to quantify STP point source loads discharging into estuaries. These loads were summed with the diffuse source loads to give the total annual TSS load.

9.9.2 Interpretation

Sediment inputs are generated by soil erosion in catchments disturbed by human activity as well as riverbank and shoreline erosion. Coarse sediment settles out along river beds, floodplains and at tributary mouths while finer suspended sediment fills bays and central basins and reduces water clarity. The flows from the 2CSalt hydrology models were combined with the EMCs of TSS and summed with the sewage discharge loads to estimate the percentage increase in the quantity of

TSS exported on an annual basis for current land-use compared to an undisturbed catchment condition.

The data distribution using the two options of equal percentiles and equal intervals is shown in Table 37. A third more subjective assessment was made using expert opinion on breakpoints in the relationship between percentage increase in TSS and turbidity scores. These may provide ecologically relevant thresholds which will need testing when further data and analysis become available. Using the subjective assessment data bands, minimal change to catchment streams was assumed to occur for sediment inputs showing <10 per cent increase above natural.

Table 37: Data distribution for sediment exports

	Equal percentiles (% increase)		Equal intervals (% increase)		Subjective assessment (% increase)	
Pressure score	**Data band**	**No. of estuaries**	**Data band**	**No. of estuaries**	**Data band**	**No. of estuaries**
5	-5.5 – <15.6	37	-5.5 – <2120	174	-5.5 – <10	31
4	15.6 – <75.3	37	2120 – <4240	5	10 – <40	23
3	75.3 – <185	36	4240 – <6360	1	40 – <80	23
2	185 – <497	37	6360 – <8479	2	80 – <600	79
1	497 – 10594	37	8479 – 10594	2	600 – 10594	28

9.10 Nutrient input

9.10.1 Data sources

As for sediment inputs, literature reviews were undertaken to establish typical EMCs of TN and TP exported from the primary land-uses within coastal catchments. The median concentrations adopted for TN and TP are shown in Table 38 and Table 39 respectively.

Table 38: Typical EMCs for TN in catchment runoff

	EMC for TN (mg/L)			
Land-use	**Median**	**Mean**	**95% confidence interval**	
Crops	2.39			
Dryforb	31.9			
Forest	0.65	0.66	0.59	0.71
Grazing	1.58	1.58	1.39	1.8
Irrigated pasture	10.45	10.64	5.2	14.6
Urban	2.05	1.9	1.0	2.32
Unsealed roads	12.17			

Table 39: Typical EMCs for TP in catchment runoff

Land-use	EMC for TP (mg/L)			
	Median	Mean	95% confidence interval	
Crops	0.32			
Dryforb	1.81			
Forest	0.04	0.04	0.03	0.04
Grazing	0.21	0.21	0.16	0.27
Irrigated pasture	4.5	4.53	3.6	4.9
Urban	0.38	0.37	0.25	0.47
Unsealed roads	1.1			

A process identical to that used for generating sediment discharge data from sewage treatment plants was used to quantify annual STP nutrient discharge loads.

9.10.2 Interpretation

Nutrient inputs are also associated with catchment disturbance as well as fertiliser application, effluent discharges and urban stormwater. Excess nutrients can lead to blooms of microscopic algae (phytoplankton), increased growth of epiphytic algae, loss of submerged vegetation and the growth of macroalgae leading to changes in habitats and the structure and function of estuarine food webs. As for sediment inputs, the flows from the 2CSalt hydrology models were combined with the event mean concentrations of TN and TP and summed with the sewage discharge loads to estimate the percentage increase in the quantity of nutrients exported on an annual basis for current land-use compared to an undisturbed catchment condition. However, as algal growth in estuaries is generally limited by the supply of nitrogen although this can vary between systems, only the TN increase has been used as a pressure.

The data distribution for TN using the two options of equal percentiles and equal intervals is shown in Table 40. As for sediment inputs, a third more subjective assessment was made using expert opinion on breakpoints in the relationship between percentage increase in TN and chlorophyll a scores. These may also provide ecologically relevant thresholds which will need to be tested. Using the subjective assessment data bands, minimal change to catchment streams was assumed to occur for TN inputs showing <10 per cent increase above natural.

Table 40: Data distribution for nutrient exports

Pressure score	Equal percentiles (% increase)		Equal intervals (% increase)		Subjective assessment (% increase)	
	Data band	No. of estuaries	Data band	No. of estuaries	Data band	No. of estuaries
5	-14.8 – <20.7	37	-14.8 – <479	172	-14.8 – <10.0	26
4	20.7 – <67.6	37	479 – <959	7	10.0 – <50	33
3	67.6 – <140	36	959 – <1438	1	50 – <150	57
2	140 – <242	37	1438 – <1917	2	150 – <400	52
1	242 – 2382	37	1917 – 2382	2	400 – 2382	16

9.11 Disturbed habitat

9.11.1 Data sources

There were a number of variables with data available that were considered for inclusion as metrics in this indicator:

- Foreshore structures – licences are issued by the Crown Lands Division of the Department of Primary Industries for any foreshore structures on Crown Land above and below the Mean High Mark around estuaries. NSW Maritime administers licences in Sydney Harbour, Newcastle Harbour, Botany Bay and Port Kembla. The licences are identified in a GIS layer as either a point, line or area feature. Depending on the type of foreshore structure, typical realistic estimates were adopted of the area and length occupied by each of the point, line and area features as shown in Table 41.

Table 41: Foreshore structure dimensions

Structure type		Average structure dimension		
Code	Description	Width (m)	Length (m)	Area (m^2)
ACC	Access structure	1	10	10
BDG	Miscellaneous building	3	3	9
BTH	Berth	3	10	30
CHL	Channel or canal	2	25	50
CML	Commercial building	10	10	100
CMY	Community building	8	8	64
JTY	Jetty	1.5	10	15
LND	Land reclamation	6	1.5	9
PLN	Pipe or power line	0.1	10	1
PLS	Piles	2	2	4
PLT	Platform	3	3	9

Structure type		Average structure dimension		
PMP	Pump or bowser	1	1	1
RMP	Ramp	3	3	9
SPL	Swimming pool or enclosure	3	8	24
SPT	Sporting/recreation structure	5	5	25
STR	Storage structure	3	3	9
SWL	Seawall	10	1	10
SWY	Slipway	3	5	15
USG	Underground storage	1	1	1
UTL	Utility structure	3	3	9
WHF	Wharf/marina/dock	5	20	100

The foreshore structure length estimates were used to calculate a metric based on the proportion of estuary perimeter occupied by foreshore structures

- Aquaculture leases – leases and permits are issued by DPI for aquaculture such as oyster and mussel farming. Recognised Aquaculture Sites (RAS) where a lease is or has been in place were spatially mapped by DPI over the period 1996 to 2000. The area of aquaculture was normalised by comparison with the total estuary surface area
- Barriers to tidal flow – an inventory was prepared by DPI on impediments to tidal flow in estuarine fish habitats (Williams et al. 1996). The length of tributary isolated from tidal influence and hence significance of each impediment was not estimated so this metric was not used. However, the tidal limit mapping (DNR 2006) indicates when the tidal limit is a weir so assessments could potentially be made in the future
- Areas of *Caulerpa Taxifolia* infestation – selected estuaries have been mapped by DPI where *C. taxifolia* has been sighted and reported. There is no comprehensive survey available of the potential for *C. taxifolia* presence in all estuaries across NSW. The *C. taxifolia* area was normalised by comparison with the open water including seagrass area (excluding mangrove and saltmarsh) of each estuary
- Estuary area open to commercial or recreational fishing – closure of part or all of the waterway area of an estuary is regulated by DPI and is available as a spatial layer. The estuary area open to recreational and commercial fishing can be normalised by the total estuary surface area
- Riparian vegetation extent – mapping of the presence or absence of woody and non-woody vegetation in a 30 m buffer either side of catchment streams, of third order and above, and around the estuary foreshores has been completed by the NSW Office of Water (Garlapati et al. 2010). The binary layer is based on a 25 m grid size corresponding to the Landsat imagery pixel size used in the SLATS methodology to generate the NSW Interim Native Vegetation Extent dataset.

  Additional analysis was carried out using a nominal buffer width of 100 m around the estuary as this width was viewed as more representative of the functions of the foreshore zone. These include filtering overland flow and improving water quality; protection against bank erosion from wind, currents or boat wakes and providing a food source and habitat for estuarine-dependent fauna including mammals, reptiles and birds. In addition, a 100 m wide buffer improves the accuracy of the assessment using a 25 m pixel size. Buffering commenced from the outermost extent of the estuary perimeter so that the buffers surrounding any mangrove and saltmarsh communities were also captured.

The results of this work were inconclusive. While there was a weak negative correlation between the extent of woody vegetation and percentage of cleared land in the catchment, the variability in woody vegetation extent for relatively pristine catchments was high (from 100 per cent to less than 70 per cent). Part of this may be attributed to the presence of heath and other low non-woody vegetation. However, if the woody vegetation extent was to be further partitioned to native and non-native the extent of native woody vegetation may be even lower than 70 per cent. Garlapati et al. (2010) created a secondary product called the Hybrid Riparian Native Vegetation Extent dataset which consists of 10 different vegetation classes. It was derived from interim foliage projective cover (FPC) and includes 'native non-woody', 'native woody', 'non-native non-woody', 'non-native woody' classes. Further investigation is required to optimise the use of these data for a riparian vegetation extent layer in the estuaries theme. The feasibility of using existing land-use mapping should also be examined.

The presence or absence of vegetation will be normalised by the total area contained within the 100 m buffer and the percentage of riparian vegetation removed adopted as the metric. Other metrics could be investigated for use such as continuity along the water-edge, connectivity and degree of fragmentation.

9.11.2 Interpretation

Disturbed habitat can arise from removal of foreshore vegetation, placement of foreshore structures such as reclamation walls, jetties, moorings etc., aquaculture leases particularly over seagrass beds, barriers such as weirs in the upper reaches of tidal tributaries, presence of the invasive seaweed *Caulerpa taxifolia,* and trawling for fish, prawns and molluscs. Collectively these activities have a range of impacts on the foreshore, inter-tidal zones and estuary bed that can change the structure and condition of aquatic habitats.

Currently data on only the presence of foreshore structures and aquaculture leases have been used. However, these two disturbances are not ubiquitous to all estuaries as aquaculture is restricted to estuaries continuously open to the ocean, and they both tend to occur in larger systems. When the data become available, a more reliable measure of habitat disturbance across all estuaries will be riparian vegetation presence/absence which will need to be weighted higher than other metrics. To some extent it also captures foreshore structures for which clearing of the riparian buffer often occurs.

The data distribution for foreshore structures using the two options of equal percentiles and equal intervals is shown in Table 42. Using the equal interval data bands, minimal change to aquatic habitats was assumed to occur for foreshore structures occupying <4.1 per cent of the estuary perimeter.

Table 42: Data distribution for foreshore structures

Pressure score	Equal percentiles (% of perimeter)		Equal intervals (% of perimeter)	
	Data band	**No. of estuaries**	**Data band**	**No. of estuaries**
5	0.008 – <0.2	18	0.008 – <4.1	68
4	0.2 – <0.8	17	4.1 – <8.2	13
3	0.8 – <1.5	17	8.2 – <12.3	0
2	1.5 – <4.2	17	12.3 – <16.4	2
1	4.2 – 20.5	18	16.4 – 20.5	4

The data distribution for foreshore structures using the two options of equal percentiles and equal intervals is shown in Table 43. Using the equal interval data bands, minimal change to aquatic habitats was assumed to occur for aquaculture leases occupying <4.9% of the total estuary area.

Table 43: Data distribution for aquaculture leases

Pressure score	Equal percentiles (% of area)		Equal intervals (% of area)	
	Data band	**No. of estuaries**	**Data band**	**No. of estuaries**
5	0.1 – <0.6	10	0.1 – <4.9	27
4	0.6 – <2.8	9	4.9 – <9.9	11
3	2.8 – <5.1	9	9.9 – <14.8	3
2	5.1 – <8.3	9	14.8 – <19.8	1
1	8.3 – 24.8	9	19.8 – 24.8	4

To give an overall score for the disturbed habitat indicator, the scores for both metrics were summed and averaged with rounding up to the next highest integer (lower pressure) where required.

9.12 Tidal flow

9.12.1 Data sources

Data were collected for two variables: the presence of one or more breakwaters or training walls at the entrance of permanently open estuaries and the level at which intermittently open estuaries were manually opened. Aerial photography was used to detect whether an entrance was trained and whether the rock protection occurred on both sides. For artificially opened entrances, coastal councils and OEH regional offices were contacted for existing records and/or personal knowledge of the level at which the entrance was opened.

9.12.2 Interpretation

Tidal flow can be affected by breakwaters or training walls built to keep estuary entrances open and the artificial opening of lagoon entrances for flood mitigation, water quality, fish and prawn recruitment and other purposes. Both result in an increase in salinity levels, tidal ranges and flushing which can alter water quality and the distribution and composition of aquatic vegetation and animal species. Entrance training can also increase the erosion of inlet channels altering sediment processes and feeding back into even larger tidal ranges. Artificial opening at levels below natural can also lower frequency of inundation of peripheral vegetation such as saltmarsh and other macrophytes such as reeds.

A score of 5 was assigned to estuaries without training walls (149 estuaries), 3 for one wall (22 estuaries) and 1 for two walls (13 estuaries).

Artificial opening of estuaries was found to be occurring at levels of between 0.9 m and 3.4 m AHD. The data distribution for entrance opening using the two options of equal percentiles and equal intervals is shown in Table 44. Using the equal interval data bands, minimal change to aquatic habitats was assumed to occur for foreshore structures occupying <1.4 per cent of the estuary perimeter.

Table 44: Data distribution for entrance opening level

Pressure score	Equal percentiles (m AHD)		Equal intervals (m AHD)	
	Data band	No. of estuaries	Data band	No. of estuaries
5	<1.4	7	<1.4	7
4	1.4 – <1.5	7	1.4 – <1.9	18
3	1.5 – <1.8	6	1.9 – <2.4	6
2	1.8 – <2.0	8	2.4 – <2.9	3
1	2.0 – 3.4	7	2.9 – 3.4	1

As training and entrance opening are generally mutually exclusive (only occurs in three NSW estuaries), the overall score for the tidal flow indicator is whichever of the two metrics is applicable to an estuary. For the other three, the scores are averaged and rounded down to the next integer (higher pressure) where required.

9.13 Fishing

9.13.1 Data sources

Data on recreational fishing catches are available for very few estuaries. Annual commercial finfish and shellfish catch data are available from DPI for all estuaries open to the commercial fishing industry.

The annual fish catch was normalised by comparison with the total surface area of the estuary.

9.13.2 Interpretation

Fishing by recreational and commercial fishers removes finfish and shellfish from the estuarine ecosystem. Disturbance of habitats by boats, gear and people can also be associated with these activities.

The data distribution using the two options of equal percentiles and equal intervals is shown in Table 45. Using the equal interval data bands, minimal estuary disturbance was assumed to occur for fish catch <2.0 tonnes/km^2/year.

Table 45: Data distribution for fish catches

Pressure score	Equal percentiles (t/km²/yr)		Equal intervals (t/km²/yr)	
	Data band	No. of estuaries	Data band	No. of estuaries
5	0 – <0.3	12	0 – <2.0	25
4	0.3 – <1.2	9	2.0 – <3.9	12
3	1.2 – <3.3	11	3.9 – <5.9	11
2	3.3 – <5.2	13	5.9 – <7.8	5
1	5.2 – 9.8	12	7.8 – 9.8	4

9.14 Climate change

For coastal ecosystems such as estuaries, sea level rise; changes in water temperature; alteration to freshwater inflows and subsequent delivery of nutrients and sediments; changes to circulation patterns, water quality and salinity regimes may result in fundamental shifts in ecosystem structure and functioning. The potential major physical and ecosystem impacts of climate change on coastal areas are summarised in Table 46. While some of this knowledge is available at a national scale, site-specific regional impacts have not been quantified to date. Climate change impacts have therefore not been included in the current SOC reports but it is anticipated some of these data will be available for the next round of reporting.

Table 46: Potential impacts of climate change

Potential physical and ecosystem effects	Potential secondary effects
Sea level rise	
Increased coastal erosion Increased inundation of coastal wetlands, floodplains, estuaries and low lying areas Landward displacement of shorelines, estuaries, wetlands and salt marshes Intrusion of saltwater into estuaries and groundwater systems Increased risk to coastal housing and infrastructure.	Infrastructure and economic activities Changes to property boundaries Loss of habitat values Changes in habitat distribution and land-use Changes to tidal ranges and circulation patterns Changes to sediment transport and deposition Changes to drainage patterns.
Increase in water and air temperature	
Latitudinal shifts in species distribution and abundance Changes in primary productivity Changes to hypoxia conditions (low DO) Changes to biogeochemical processes Changes to evaporation rates and water balances.	Impacts on tourism and economic activity Changes to risk of disease and parasitism Joint effects of increased temperature, CO_2 and acidification Impacts on aquaculture and commercial fishing.
Altered rainfall and runoff	
Implications for flooding and erosion	Changes to coastal habitats.

Potential physical and ecosystem effects	Potential secondary effects
Changes to sedimentation and erosion rates Changes in sediment and nutrient loads Change to salinity regimes, residence times, stratification, circulation patterns, water balances and water quality.	
Altered wave climate	
Altered erosion and accretion Altered beach alignment Increased wave power.	Changes to intertidal and rock foreshore ecosystems Loss of sandy habitats.
Altered frequency and severity of extreme weather events	
Increased waves and storm surges Altered cyclone zones Further damage to coastal infrastructure and ecosystems Increased flooding.	Implication for flooding and erosion Implication for disaster relief.

9.15 Distribution of estuary pressures

A summary of all the raw pressure data for NSW estuaries together with the normalised pressure data are given in Appendix 20 and Appendix 21 respectively. The distribution of estuaries within each pressure scoring class is shown in Figure 34.

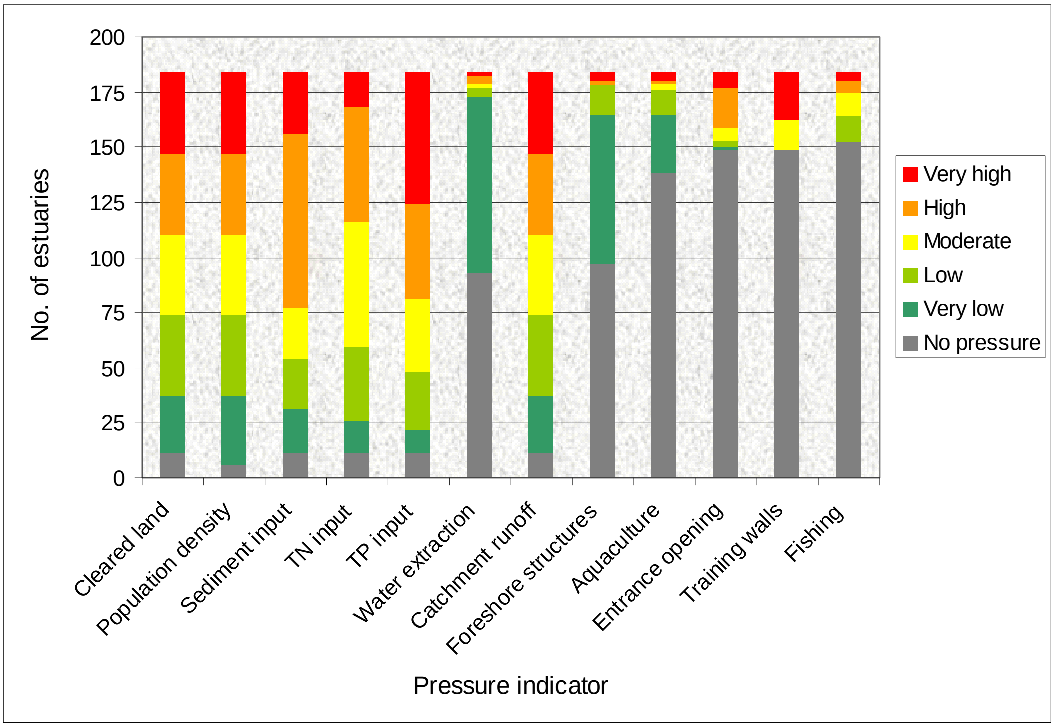


Figure 34: Distribution of estuaries within pressure scoring classes

9.16 Summary of condition and pressure scoring criteria

Shown in Table 47 following are the metrics and scoring classes for all condition and pressure indicators developed as part of the MER program and used in SOC reports.

9.17 Comparison of scoring classes

A compilation of pressure scoring classes developed by other organisations was undertaken from the following sources:

- A NSW Index of Estuary Condition was developed as a trial for the former Department of Land and Water Conservation (SKM 1999)
- A guide on the use of indicators for assessing estuarine health was prepared by the former Department of Infrastructure, Planning and Natural Resources (Laegdsgaard 2003)
- An integrated estuary assessment framework was prepared by the former CRC for Coastal Zone, Estuary & Waterway Management (Moss et al. 2006)
- A Stream and Estuary Assessment Program (SEAP) was prepared by the Queensland EPA (Scheltinga & Moss 2008).

A summary of the various pressure scoring classes is included in Appendix 22.

9.18 Estuary pressure ratings for NSW estuaries

Using the methods described in this chapter, ratings were generated for each of the pressure indicators as shown in Table 48, Table 49, Table 50 and Table 51 for all estuaries in each CMA region.

Table 47: Summary of condition and pressure metrics and scoring classes

Condition indicator	Area	Estuary type	Metric	Min	Max	Trigger value		Scoring intervals	Very good (5)	Good (4)	Fair (3)	Poor (2)	Very poor (1)
Chlorophyll a	Sampling sites or estuary	Lake	% compliance with trigger value (µg/l)	0.0	32.8	80th %ile of reference	3.6	Expert opinion	≥90	75–<90	50–<75	10–<50	<10
		Lagoon		0.0	29.7		2.0						
		Low river		0.0	8.4		2.3						
		Mid river					2.9						
		Up river					3.4						
Turbidity	Sampling sites or estuary	Lake	% compliance with trigger value (NTU)	0.5	17.0	80th %ile of reference	5.7	Expert opinion	≥90	75–<90	50–<75	10–<50	<10
		Lagoon		0.5	36.1		3.3						
		Low river		0.3	90.0		5.0						
		Mid river					8.0						
		Up river					13.7						
Seagrass	Estuary	All	Extent change	100% loss	4221% gain	Significant loss	-10%	Expert opinion	>10%	+/-10%	>-10 to -40%	>-40 to -70%	>-70%
Mangrove	Estuary	All	Extent change	98% loss	872% gain	Significant gain or loss	±10%	Expert opinion	na	±10%	na	na	na
Saltmarsh	Estuary	All	Extent change	100% loss	7844% gain	Significant loss	-10%	Expert opinion	>10%	+/-10%	>-10 to -40%	>-40 to -70%	>-70%
Fish assemblages	Estuary	River Lagoon ICOLL	Index of 14 metrics	16	68	na	na	Equal intervals of normal distribution	60–68	49–59	36–48	25–35	16–24
All condition indicators	CMA or NSW	All	Average score	1	5	na	na	Equal intervals 1–5	>4.2	>3.4–4.2	>2.6–3.4	>1.8–2.6	≤1.8

Pressure indicator	Area	Estuary type	Metric	Min	Max	Trigger value		Scoring intervals	Very low (5)	Low (4)	Moderate (3)	High (2)	Very high (1)
Cleared land	Catchment	All	% cleared	0	100.0	na	na	Equal percentiles	<7.5	7.5–<21.7	21.7–<39.1	39.1–<68.5	≥68.5
Population	Catchment	All	Head/km^2	0	3419	na	na	Equal percentiles	<1.5	1.5–<9	9–<41	41–<264	≥264
Sediments	Catchment	All	% increase from natural	-6	10594	na	na	Expert opinion	<10	10–<40	40–<80	80–<600	≥600
Nutrients - TN	Catchment	All	% increase from natural	-15	2382	na	na	Expert opinion	<10	10–<50	50–<150	150–<400	≥400
Freshwater flow	Catchment	All				na	na						
- water extraction			% annual flow	0	31.7			Equal intervals	<6.3	6.3–<12.7	12.7–<19.0	19.0–<25.4	≥25.4
- catchment runoff			% increase	-2.8	142			Equal percentiles	<3.9	3.9–<11.9	11.9–<21.9	21.9–<44.3	≥44.3
Disturbed habitat	Estuary	All				na	na						
- structures			% of perimeter	0.0	20.5			Equal intervals	<4.1	4.1–<8.2	8.2–<12.3	12.3–<16.4	≥16.4
- aquaculture			% of area	0.0	24.8			Equal intervals	<4.9	4.9–<9.9	9.9–<14.8	14.8–<19.8	≥19.8
Tidal flow	Estuary	All				na	na						
- entrance opening			Level m AHD	0.9	3.4			Equal intervals	≥2.9	2.4–<2.9	1.9–<2.4	1.4–<1.9	<1.4
- training walls			Number off	0	2				na	na	1: one side	na	2: both sides
Fishing	Estuary	All	Annual t/km^2	0	9.8	na	na	Equal intervals	<2.0	2.0–<3.9	3.9–<5.9	5.9–<7.8	≥7.8
All pressure indicators	CMA or NSW	All	Average score	1	5	na	na	Equal intervals 1–5	>4.2	>3.4–4.2	>2.6–3.4	>1.8–2.6	≤1.8

Note: minimum and maximum values are the median for all estuaries in a class and are provided as a single value for the full length of river class estuaries.

Table 48: Pressure rating of estuaries in Northern Rivers region

ALL NR ESTUARIES

3.5 Low Pressure

? Trend Unknown

	PRESSURE INDEX	INDEX TREND	ICOLL (I)	Cleared land	Population	Sediment input	Nutrient input	Freshwater flow	Disturbed habitat	Tidal flow	Fishing	CONFIDENCE
ALL NSW ESTUARIES	3.6	?		3.0	3.0	2.7	3.0	4.1	4.8	3.9	4.6	H
ALL NR ESTUARIES	3.5	?		2.8	2.8	2.2	2.7	4.1	4.9	3.5	4.6	H
1. Tweed River	2.3	?										H
2. Cudgen Creek	2.5	?										H
3. Cudgera Creek	3.3	?										H
4. Mooball Creek	2.9	?										H
5. Brunswick River	2.6	?										H
6. Belongil Creek	2.9	?	I									H
7. Tallow Creek	2.8	?	I									H
8. Broken Head Creek	3.3	?	I									H
9. Richmond River	2.5	?										H
10. Salty Lagoon	5.0	?	I									H
11. Evans River	3.1	?										H
12. Jerusalem Creek	5.0	?	I									H
13. Clarence River	3.0	?										H
14. Lake Arragan	5.0	?	I									H
15. Cakora Lagoon	4.9	?	I									H
16. Sandon River	4.5	?										H
17. Wooli Wooli River	4.4	?										H
18. Station Creek	5.0	?	I									H
19. Corindi River	3.9	?										H
20. Pipe Clay Creek	3.1	?	I									H
21. Arrawarra Creek	3.5	?	I									H
22. Darkum Creek	2.9	?	I									H
23. Woolgoolga Lake	2.8	?	I									H
24. Flat Top Point Creek	2.8	?	I									H
25. Hearns Lake	3.1	?	I									H
26. Moonee Creek	3.4	?										H
27. Pine Brush Creek	2.9	?	I									H
28. Coffs Creek	2.5	?										H
29. Boambee Creek	3.1	?										H
30. Bonville Creek	3.6	?										H
31. Bundageree Creek	3.9	?	I									H
32. Bellinger River	4.1	?										H
33. Dalhousie Creek	3.8	?	I									H
34. Oyster Creek	3.8	?	I									H
35. Deep Creek	3.4	?	I									H
36. Nambucca River	3.0	?										H
37. Macleay River	3.4	?										H
38. South West Rocks Creek	3.3	?										H
39. Saltwater Creek (Frederickton)	3.3	?	I									H
40. Korogoro Creek	3.9	?										H
41. Killick Creek	3.6	?	I									H
42. Goolawah Lagoon	4.9	?	I									H
43. Hastings River	3.3	?										H
44. Cathie Creek	3.0	?	I									H
45. Duchess Gully	3.3	?	I									H
46. Camden Haven River	3.0	?										H

Indicator Score and Rating

PRESSURE		TREND		CONFIDENCE	
5	Very low	↓	Declining	H	High
4	Low	↔	No change	M	Medium
3	Moderate	↑	Increasing	L	Low
2	High	?	Unknown		
1	Very high				

Index Rating and Range

Very low	>4.2 – 5.0
Low	>3.4 – 4.2
Moderate	>2.6 – 3.4
High	>1.8 – 2.6
Very high	≤1.8

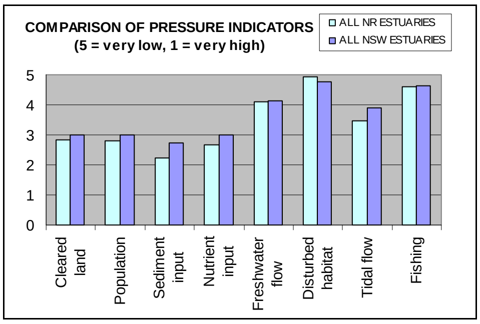


Table 49: Pressure rating of estuaries in Hunter–Central Rivers region

ALL HCR ESTUARIES

3.3 Moderate Pressure

? Trend Unknown

	PRESSURE INDEX	INDEX TREND	ICOLL (I)	Cleared land	Population	Sediment input	Nutrient input	Freshwater flow	Disturbed habitat	Tidal flow	Fishing	CONFIDENCE
ALL NSW ESTUARIES	3.6	?		3.0	3.0	2.7	3.0	4.1	4.8	3.9	4.6	H
ALL HCR ESTUARIES	3.3	?		2.7	2.6	2.4	2.7	3.9	4.9	3.7	4.2	H
1. Manning River	3.4	?										H
2. Khappinghat Creek	3.9	?	I									H
3. Black Head Lagoon	3.4	?	I									H
4. Wallis Lake	3.0	?										H
5. Smiths Lake	3.3	?	I									H
6. Myall River	4.4	?										H
7. Karuah River	4.1	?										H
8. Tilligerry Creek	3.3	?										H
9. Port Stephens	3.9	?										H
10. Hunter River	2.5	?										H
11. Glenrock Lagoon	3.5	?	I									H
12. Lake Macquarie	2.6	?										H
13. Middle Camp Creek	4.3	?	I									H
14. Moonee Beach Creek	3.8	?	I									H
15. Tuggerah Lake	3.1	?	I									H
16. Wamberal Lagoon	2.8	?	I									H
17. Terrigal Lagoon	2.5	?	I									H
18. Avoca Lake	2.9	?	I									H
19. Cockrone Lake	3.4	?	I									H
20. Brisbane Water	3.1	?										H

Indicator Score and Rating

PRESSURE		TREND		CONFIDENCE	
5	Very low	↓	Declining	H	High
4	Low	↔	No change	M	Medium
3	Moderate	↑	Increasing	L	Low
2	High	?	Unknown		
1	Very high				

Index Rating and Range

Very low	>4.2 – 5.0
Low	>3.4 – 4.2
Moderate	>2.6 – 3.4
High	>1.8 – 2.6
Very high	≤1.8

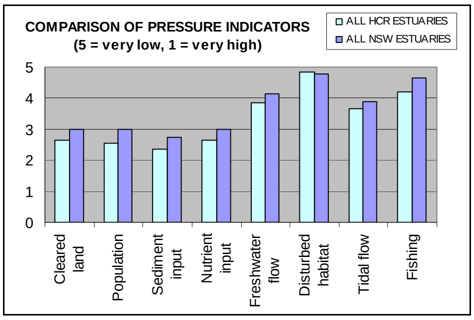


Table 50: Pressure rating of estuaries in Hawkesbury–Nepean and Sydney Metropolitan regions

ALL HNSM ESTUARIES

3.0 Moderate Pressure — **?** Trend Unknown

	PRESSURE INDEX	INDEX TREND	ICOLL (I)	Cleared land	Population	Sediment input	Nutrient input	Freshwater flow	Disturbed habitat	Tidal flow	Fishing	CONFIDENCE
ALL NSW ESTUARIES	3.6	?		3.0	3.0	2.7	3.0	4.1	4.8	3.9	4.6	H
ALL HNSM ESTUARIES	3.0	?		2.2	1.4	1.7	2.2	3.3	4.4	4.3	4.8	H
1. Hawkesbury River	3.5	?										H
2. Pittwater	3.0	?										H
3. Broken Bay	3.6	?										H
4. Narrabeen Lagoon	3.0	?	I									H
5. Dee Why Lagoon	2.4	?	I									H
6. Curl Curl Lagoon	2.5	?	I									H
7. Manly Lagoon	2.4	?	I									H
8. Middle Harbour Creek	3.1	?										H
9. Lane Cove River	3.0	?										H
10. Parramatta River	2.9	?										H
11. Port Jackson	2.9	?										H
12. Cooks River	2.8	?										H
13. Georges River	2.6	?										H
14. Botany Bay	2.8	?										H
15. Port Hacking	3.3	?										H
16. Wattamolla Creek	5.0	?	I									H

Indicator Score and Rating

PRESSURE		TREND		CONFIDENCE	
5	Very low	↓	Declining	H	High
4	Low	↔	No change	M	Medium
3	Moderate	↑	Increasing	L	Low
2	High	?	Unknown		
1	Very high				

Index Rating and Range

Very low	>4.2 – 5.0
Low	>3.4 – 4.2
Moderate	>2.6 – 3.4
High	>1.8 – 2.6
Very high	≤1.8

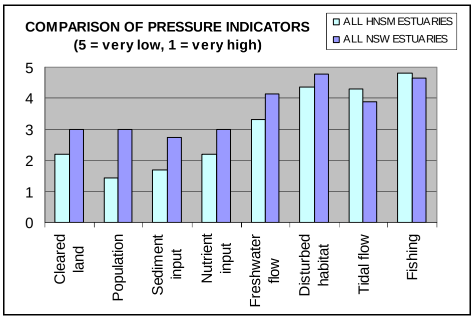


Table 51: Pressure rating of estuaries in Southern Rivers region

ALL SR ESTUARIES

3.9 Low Pressure

? Trend Unknown

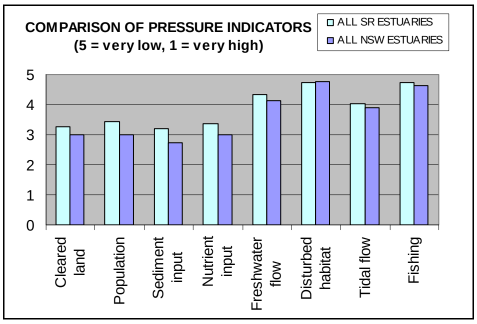
	PRESSURE INDEX	INDEX TREND	ICOLL (I)	Cleared land	Population	Sediment input	Nutrient input	Freshwater flow	Disturbed habitat	Tidal flow	Fishing	CONFIDENCE
ALL NSW ESTUARIES	3.6	?		3.0	3.0	2.7	3.0	4.1	4.8	3.9	4.6	H
ALL SR ESTUARIES	3.9	?		3.3	3.4	3.2	3.4	4.3	4.7	4.0	4.7	H
1. Hargraves Creek	3.3	?	I									H
2. Stanwell Creek	3.6	?	I									H
3. Flanagans Creek	3.4	?	I									H
4. Woodlands Creek	3.4	?	I									H
5. Slacky Creek	3.3	?	I									H
6. Bellambi Gully	2.8	?	I									H
7. Bellambi Lake	3.0	?	I									H
8. Towradgi Creek	2.9	?	I									H
9. Fairy Creek	2.8	?	I									H
10. Allans Creek	2.6	?										H
11. Port Kembla	2.9	?										H
12. Lake Illawarra	2.5	?	I									H
13. Elliott Lake	2.5	?	I									H
14. Minnamurra River	3.4	?										H
15. Spring Creek	3.4	?	I									H
16. Munna Munnora Creek	3.1	?	I									H
17. Werri Lagoon	2.9	?	I									H
18. Crooked River	2.8	?										H
19. Shoalhaven River	3.3	?										H
20. Wollumboola Lake	4.4	?	I									H
21. Currarong Creek	4.1	?	I									H
22. Cararma Creek	5.0	?										H
23. Wowly Gully	3.9	?	I									H
24. Callala Creek	3.9	?	I									H
25. Currambene Creek	3.6	?										H
26. Moona Moona Creek	3.6	?	I									H
27. Flat Rock Creek	4.9	?	I									H
28. Captains Beach Lagoon	5.0	?	I									H
29. Telegraph Creek	5.0	?	I									H
30. Jervis Bay	3.9	?										H
31. St Georges Basin	4.1	?										H
32. Swan Lake	3.6	?	I									H
33. Berrara Creek	4.9	?	I									H
34. Nerrindillah Creek	4.9	?	I									H
35. Conjola Lake	4.6	?										H
36. Narrawallee Inlet	3.9	?	I									H
37. Mollymook Creek	3.1	?	I									H
38. Millards Creek	3.0	?	I									H
39. Ulladulla	3.0	?										H
40. Burrill Lake	3.3	?	I									H
41. Tabourie Lake	3.9	?	I									H
42. Termeil Lake	4.0	?	I									H
43. Meroo Lake	4.0	?	I									H
44. Willinga Lake	3.9	?	I									H
45. Butlers Creek	3.5	?	I									H
46. Durras Lake	4.0	?	I									H
47. Durras Creek	4.5	?	I									H

Indicator Score and Rating

PRESSURE		TREND		CONFIDENCE	
5	Very low	↓	Declining	H	High
4	Low	↔	No change	M	Medium
3	Moderate	↑	Increasing	L	Low
2	High	?	Unknown		
1	Very high				

Index Rating and Range

Very low	>4.2 – 5.0
Low	>3.4 – 4.2
Moderate	>2.6 – 3.4
High	>1.8 – 2.6
Very high	≤1.8



48.	Maloneys Creek	4.0	?	I	H
49.	Cullendulla Creek	3.3	?	I	H
50.	Clyde River	4.5	?		H
51.	Batemans Bay	4.6	?		H
52.	Saltwater Creek (Rosedale)	3.3	?	I	H
53.	Tomaga River	4.0	?		H
54.	Candlagan Creek	3.9	?		H
55.	Bengello Creek	4.3	?	I	H
56.	Moruya River	3.6	?		H
57.	Congo Creek	2.9	?	I	H
58.	Meringo Creek	3.8	?	I	H
59.	Kellys Lake	3.8	?	I	H
60.	Coila Lake	3.4	?	I	H
61.	Tuross River	4.3	?		H
62.	Lake Brunderee	4.8	?	I	H
63.	Lake Tarourga	5.0	?	I	H
64.	Lake Brou	4.5	?	I	H
65.	Lake Mummuga	4.0	?	I	H
66.	Kianga Lake	3.5	?	I	H
67.	Wagonga Inlet	3.8	?		H
68.	Little Lake (Narooma)	3.4	?	I	H
69.	Bullengella Lake	3.8	?	I	H
70.	Nangudga Lake	3.1	?	I	H
71.	Corunna Lake	3.4	?	I	H
72.	Tilba Tilba Lake	3.5	?	I	H
73.	Little Lake (Wallaga)	3.4	?	I	H
74.	Wallaga Lake	2.9	?	I	H
75.	Bermagui River	3.1	?		H
76.	Baragoot Lake	4.5	?	I	H
77.	Cuttagee Lake	4.5	?	I	H
78.	Murrah River	4.1	?		H
79.	Bunga Lagoon	4.6	?	I	H
80.	Wapengo Lagoon	4.5	?		H
81.	Middle Lagoon	3.9	?	I	H
82.	Nelson Lagoon	4.5	?		H
83.	Bega River	3.5	?	I	H
84.	Wallagoot Lake	4.4	?	I	H
85.	Bournda Lagoon	4.6	?	I	H
86.	Back Lagoon	3.3	?	I	H
87.	Merimbula Lake	3.0	?		H
88.	Pambula River	4.3	?		H
89.	Curalo Lagoon	3.6	?	I	H
90.	Shadrachs Creek	5.0	?	I	H
91.	Nullica River	4.9	?	I	H
92.	Boydtown Creek	4.3	?	I	H
93.	Towamba River	4.5	?		H
94.	Fisheries Creek	5.0	?	I	H
95.	Twofold Bay	4.5	?		H
96.	Saltwater Creek (Eden)	5.0	?	I	H
97.	Woodburn Creek	5.0	?	I	H
98.	Wonboyn River	4.9	?		H
99.	Merrica River	5.0	?	I	H
100.	Table Creek	5.0	?	I	H
101.	Nadgee River	5.0	?	I	H
102.	Nadgee Lake	5.0	?	I	H

10. Condition and pressure indices

10.1 Developing an index

The monitoring program designed to report on estuary condition has focused on three key assemblages of plants and animals: algae (phytoplankton and macroalgae), vascular plants and fish in preference to other assemblages such as amphibians, birds, macroinvertebrates, and periphyton (organisms attached to submerged surfaces). Taken together the three assemblages represent important and valued aspects of an estuarine ecosystem's function (phytoplankton biomass), structure (aquatic habitat extent) and composition (fish and macrophyte species) and the science behind sampling and interpretation of these indicators is more advanced than for the other assemblages. As assemblages sometimes differ in their response to environmental stressors, having more than one assemblage provides sensitivity to a wider range of stressors and increases the power and confidence of the assessment (Karr 1999). Ideally, measures of condition include individuals, populations, communities, ecosystems and landscapes. Monitoring such biological endpoints integrates the effects of all forms of degradation caused by human actions and of associated environmental stressors such as changed water quality and habitat destruction (Harrison & Whitfield 2006).

Accordingly, the goal of an index of condition is to integrate a number of measures to provide a more balanced and complete assessment of ecosystem health. The index needs to include biological attributes that respond reliably to human activities, are minimally affected by natural variability, are cost-effective to measure and can be expressed as metrics able to be combined into an index. A process for developing an index would consist of:

- identifying estuarine flora and fauna
- developing biological metrics from species richness and composition, tolerance and intolerance to disturbances, trophic composition and population characteristics
- collecting data on human disturbance
- analysing redundancy between disturbance metrics
- testing biological response across the gradient of disturbance
- selecting the best performing metrics
- scoring metrics against a reference condition
- normalising between metrics and amongst estuary classes
- weighting metrics into an index responsive to disturbance.

10.2 Index of estuary condition

In recognition of the lack of clear causal relationships between biotic indicators and stressors resulting from human activity and, sometimes, the paucity of cost-effective data, developers of condition indices have often adopted the approach of including a range of abiotic measures that are known from studies to influence condition. Indices therefore become a mixture of condition and surrogate measures using physico-chemical condition, pressures, stressors and even impacts. Examples are:

- Victorian Index of Estuary Condition: hydrology, physical form, water quality, sediment, flora, fauna (Arundel at al. 2009)
- Victorian Index of Stream Condition: hydrology, physical form, water quality, streamside zone, aquatic biota (www.vicwaterdata.net/vicwaterdata/data_warehouse_content.aspx?option=5)
- National Framework for the Assessment of River and Wetland Health (FARWH): catchment disturbance, hydrological disturbance, water quality and soils, physical form, fringing zone, aquatic biota (NWC 2007)
- South African Estuarine Health Index: water quality, biology, aesthetics (Cooper et al. 1994).

For the purposes of this assessment, the FARWH definitions of 'integration' and 'aggregation' of indicators and indices have been adopted (NWC 2007). Integration denotes assembling different indicators or indices at a given scale into a combined index at the same scale while aggregation refers to assembling indicators or indices up to a larger spatial scale. The initial approach adopted for NSW has been to integrate the condition indicators based on biological assemblages into a single condition index with certain rules applied and the pressure and stressor indicators into a single pressure index. The rules applied to the condition index were as follows:

- Individual estuary condition:
    - o The indicators were grouped into the three main types being eutrophication (chlorophyll a, macroalgae and turbidity), habitat (seagrass, mangrove and saltmarsh) and fish. An integration rule was set that at least one indicator from a minimum of two indicator groups must be populated, for example at least one eutrophication and habitat or fish indicator
    - o Provided more than one indicator type was populated, the scores from all indicators were summed with equal weighting and averaged to give an overall estuary score
- Regional estuary condition: in recognition of the patchiness of some of the condition indicator datasets, an aggregation rule was set that for the Northern Rivers, Hunter–Central Rivers, Hawkesbury–Nepean and Sydney Metropolitan regions, the regional score would only be calculated if there were more than five estuaries in that region with individual estuary scores. For the Southern Rivers region, the minimum number of estuaries was set at 10 due to the relatively high total number of 102 estuaries
- State-wide estuary condition: similar to the regional aggregation, the minimum number of estuaries before a state-wide score is calculated was set at 20, about 10 per cent of the total number of estuaries.

Condition index scores and ratings were able to be calculated for 101 of the 184 estuaries using the above integration and aggregation rules and are shown in the individual regional SOC reports in Chapter 8 and summarised in Figure 35.

There are a number of improvements that could be made to the condition index:

- Investigate combining indicators into a eutrophication index and a habitat index similar to the concept of the fish index which includes 14 metrics
- Conduct multivariate statistical analysis to complement the current visual graphical assessment of stressor-response relationships and explore combinations of condition indicators and sub-indices that respond to gradients of disturbance

- Compare the current assessment with the expert approach to index development being trialled by CSIRO on behalf of the Estuary MER program
- To reduce the fish index variability, sites should be sampled twice before being assessed (Seegert 2000).

10.3 Index of estuary pressure

As there was limited redundancy between pressure and stressor indicators, the initial approach to integration and aggregation has been to equally weight indicators and calculate an average score. There has been some limited integration of metrics within individual indicators as described in earlier chapters but the value of further integration into sub-indices may result from statistical analysis.

Other datasets also gathered but not used in the current assessment are:

- percentage of catchment area with non-reticulated sewerage systems (eg septics)
- extent of recreational and commercial fish closures or, conversely, available for fishing
- extent of marine protected areas or, conversely, subject to activities banned in marine protected areas
- estuarine Beachwatch and Harbourwatch compliance data on bacterial contamination
- riparian vegetation extent (completed subsequent to the SOC 2010 reports).

Further analysis of these data could yield additional metrics suitable for incorporation in the pressure index, particularly riparian vegetation extent and other riparian metrics related to connectivity.

Both marine protected area extent and Beachwatch compliance data (from ocean beaches) have been reported under the Marine MER program to complement relatively sparse biological datasets on marine condition.

Pressure index scores and ratings were able to be calculated for all 184 estuaries and are shown in the individual regional SOC reports in Chapter 9 and summarised in Figure 36.

10.4 Confidence levels

A system was developed and applied for rating confidence in the data on water quality. Seven criteria were defined and applied to the available data. Ideally, confidence would be reported for each indicator and perhaps an integrated score given for each estuary. However, in view of the number of data gaps in the condition report, it was decided to initially rate the confidence on the number of indicators for which data were available. When data were available for all seven condition indicators the confidence was rated 'high', four to six indicators 'medium' and three or less 'low'. In the future when more of the data gaps have been filled, it is proposed that the alternative system be used based on the confidence ratings for each individual indicator.

For the pressure indicators most of the data confidence is rated high except for the sediment and nutrient loads which are rated medium. As data are available for all indicators across all estuaries, a confidence level has been assigned on the basis of how many indicators have high, medium or low confidence. All indicators have the same datasets available, six of which are rated as high and two as medium confidence; therefore an overall rating of high has been assigned to all estuaries. This is the type of rating system that will be applied to the condition indicators in future.

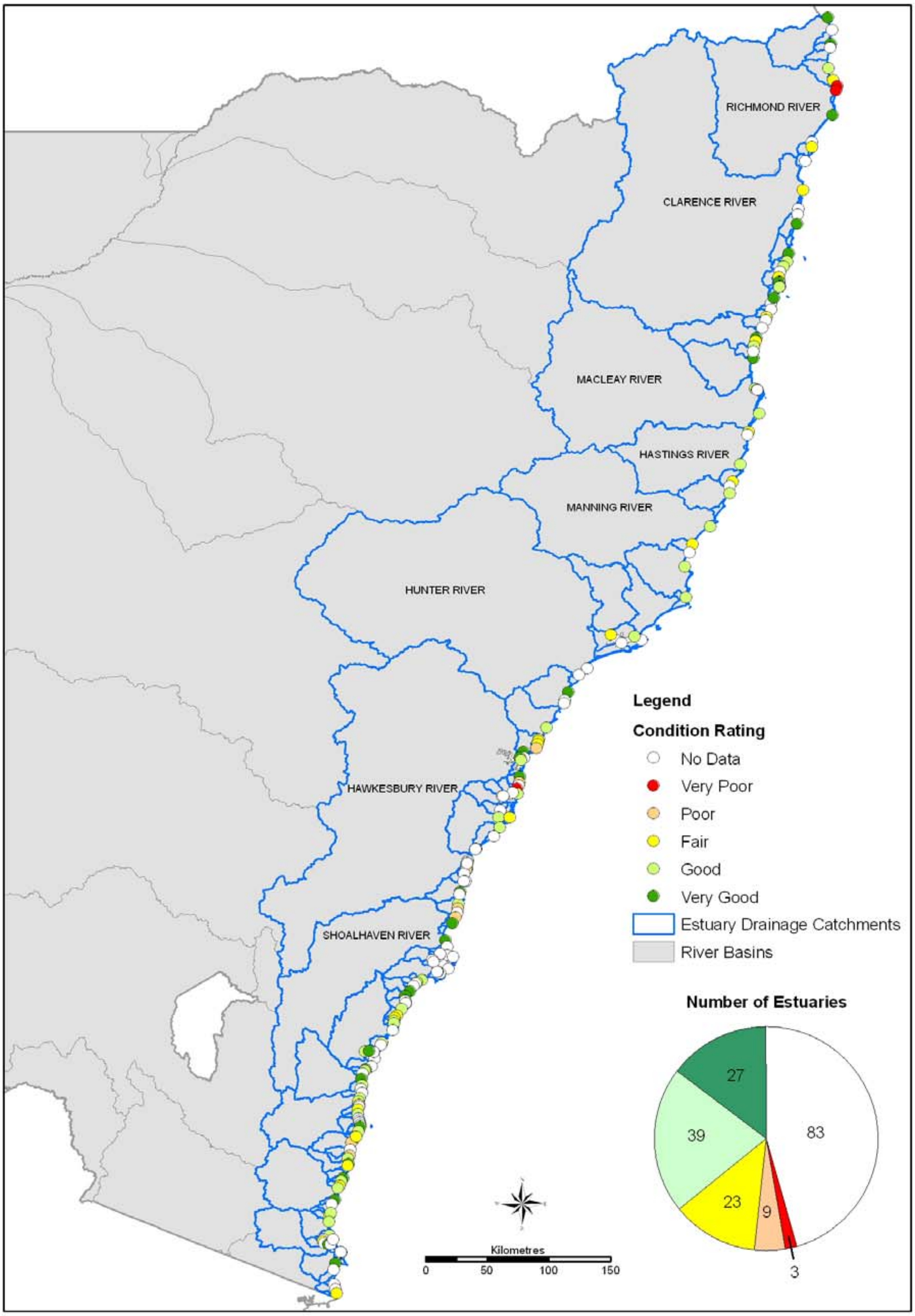


Figure 35: Condition ratings for NSW estuaries

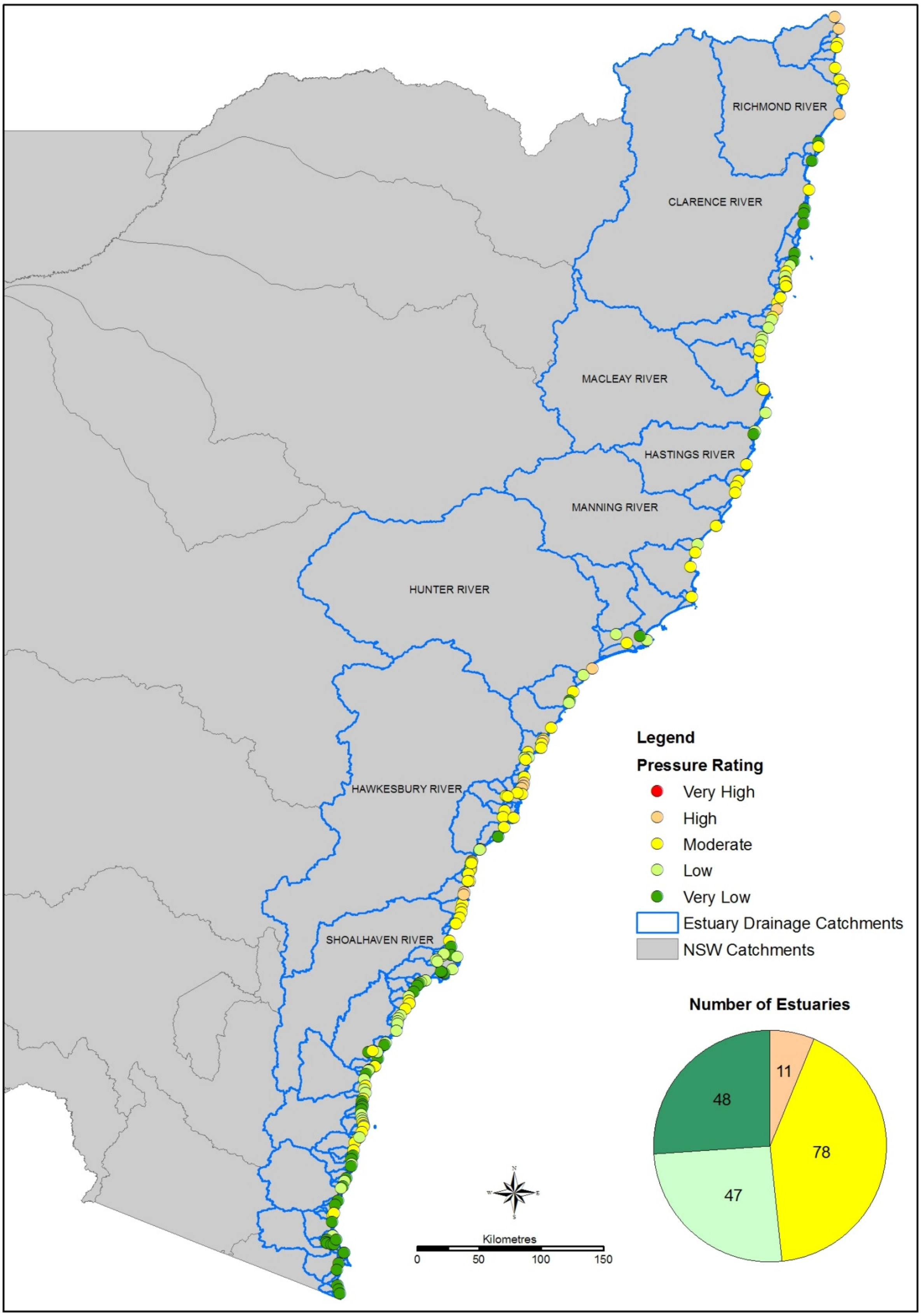


Figure 36: Pressure ratings for NSW estuaries

11. Data management

All data have been collected in accordance with standard methods and protocols detailed in Chapter 6 and Appendix 13 of this report.

Spatial datasets are held within corporate GIS systems of the two main natural resource agencies, OEH and DPI. Geo-referenced data such as water quality and fish data as well as pressure data are held in a mix of formats including geodatabases, Access databases and Excel spreadsheets. OEH is responsible for managing its data in accordance with the Natural Resource and Environment Information Management Framework and bringing datasets up to that standard.

A central element of the Framework is metadata which has been prepared for all datasets. Those metadata that are not already publicly available will be made available through the NSW Spatial Data Catalogue managed by LPI on behalf of the NSW Government. The Catalogue is located at www.sdi.nsw.gov.au.

Where required, licences will need to be negotiated with other data custodians such as local councils so that data can be accessed on an ongoing basis, analysed and publicly presented through the SOC reports. An SOC page has been developed on the OEH website for accessing SOC reports which is located at www.environment.nsw.gov.au/soc/stateofthecatchmentsreport.htm. Current development of the website will allow users to search for indicators, access metadata, download datasets and to display and compare condition and pressure assessments for different estuaries online. Links will be created to the national OzCoasts website located at www.ozcoasts.gov.au and to the OEH estuaries web page located at www.environment.nsw.gov.au/estuaries.

A summary of the availability of different data types for all 184 estuaries is shown in Figure 37.

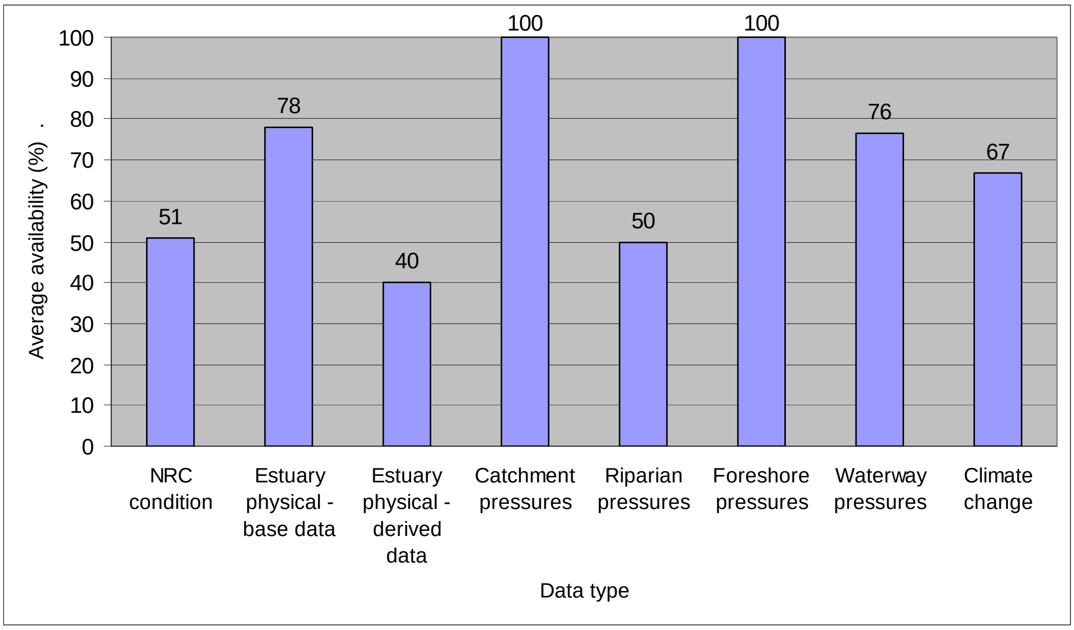


Figure 37: Comparison of data availability by data type

In Table 52, data underpinning the SOC reports are listed together with the quantity of missing data, current location of data, custodians and whether the data are held in a corporate system readily available for access or are stored on a local server. Of the 44 datasets listed, 21 are or will be located in corporate systems with ready access; the other 23 are currently managed at a local level. A directory structure for scientific, including MER, data has been established within OEH to centralise and corporately manage all datasets for SOC reporting. OEH estuary datasets for the SOC 2010 reports are being migrated into the new directory structure.

Table 52: Data availability and management

Attribute	Parameter	Missing values		Database	Custodian	Corporate or local
		Frequency	Percent			
Condition data	Chlorophyll a	100	54%	KEVIN	OEH	Local
	Macroalgae	184	100%	EMERP	OEH	Local
	Turbidity	131	71%	KEVIN	OEH	Local
	Seagrass extent	38	21%	NSW EM	DPI	Corporate
	Mangrove extent	37	20%	NSW EM	DPI	Corporate
	Saltmarsh extent	37	20%	NSW EM	DPI	Corporate
	Fish assemblages	107	58%	EFED	DPI	Corporate
Physical base data	Coordinates	0	0%	EDB	OEH	Corporate
	Geomorphology	0	0%	EMERP	OEH	Local
	Entrance condition	0	0%	EMERP	OEH	Local
	Rainfall	0	0%	SILO	DERM	Corporate
	Evaporation	0	0%	SILO	DERM	Corporate
	Estuary area	0	0%	EDB	OEH	Corporate
	Bathymetry	131	71%	EMERP	OEH	Local
	Tidal prism	29	16%	EMERP	OEH	Local
	Tidal planes	54	29%	Report	OEH	Local
	Tidal limits	37	20%	EDB	OEH	Corporate
	Catchment area	0	0%	EDB	OEH	Corporate
	Catchment above tidal limit	184	100%	EDB	OEH	Corporate
	Salinity (time series)	96	52%	MHL/Councils	MHL	Corporate
Physical derived data	Estuary volume	132	72%	EMERP	OEH	Local
	Catchment runoff	0	0%	EMERP	OEH	Local
	Dilution	132	72%	EMERP	OEH	Local
	Freshwater replacement time	184	100%	EMERP	OEH	Local
	Exchange efficiency	184	100%	EMERP	OEH	Local
	Tidal flushing	29	16%	EMERP	OEH	Local
Catchment pressure	Population	0	0%	EDB	OEH	Corporate
	Land use	0	0%	EDB	OEH	Corporate
	Runoff change	0	0%	EMERP	OEH	Local
	Sediment load	0	0%	EMERP	OEH	Local
	Non-reticulated sewerage area	0	0%	EMERP	OEH	Local
	Sewerage discharges	0	0%	ISEMS	OEH	Corporate
	Nutrient load	0	0%	EMERP	OEH	Local
Riparian pressure	Vegetation extent	184	100%	EDB	OEH	Corporate
	Water extraction	0	0%	LAS	OEH	Corporate
Foreshore pressure	Structures	0	0%	DTDB	LPI	Corporate
	Aquaculture	0	0%	DTDB	DPI	Corporate
Waterway pressure	Entrance works	0	0%	EMERP	OEH	Local
	Entrance opening	0	0%	EMERP	OEH	Local
	Harvesting	0	0%	ComCatch	DPI	Corporate
	Invasive species	174	95%	Caulerpa GIS	DPI	Corporate
Climate change	Sea level rise	0	0%	EMERP	OEH	Local
	Rainfall change	0	0%	EMERP	OEH	Local
	Runoff change	184	100%	EMERP	OEH	Local

Notes on databases:
ComCatch: Commercial fish catch statistics database
DTDB: Digital Topographic DataBase
EDB: Enterprise Database of spatial information
EFED: Estuarine Fish Ecology Database
EMERP: Estuaries MER program spatial files and spreadsheets
ISEMS: Integrated Statutory Environmental Management System
KEVIN: Keeping Estuarine Values Integrated for NSW water quality database
LAS: Licencing Administration System database
MHL: Manly Hydraulics Laboratory database
NSW EM: NSW Estuarine Macrophytes database
SILO: Meteorological database

Notes on custodians:
OEH: Office of Environment and Heritage
DPI: Department of Primary Industries
MHL: Manly Hydraulics Laboratory
LPI: Land and Property Information
DERM: Queensland Department of Environment and Resource Management

12. Recommendations for improvement

Within the timeframe and resources available to the Estuaries MER program, the best available data and analysis have been incorporated into the SOC reports. This represents three years of effort in collating and interpreting data through a number of pilot studies. While many data gaps were able to be filled, the process identified further data that would be valuable in extending the current analysis and interpretation. The data and analyses considered to be of most value are listed in the sections following.

Estuary definition

1. Finish surveys of the few remaining estuaries without tidal and mangrove limits
2. Compare and reconcile estuary water surface boundary from current mapping with photogrammetry associated with hydrosurveys
3. Develop better DEMs using bathymetric and topographic data and validate with merged water and macrophyte layers. Generate more accurate hypsometry for use in calculating estuary areas at various water levels
4. Use the recently completed digitising of estuary catchments into separate areas above and below the tidal limits to explore potential relationships between catchment pressures and stressors originating below the tidal limits and estuary health.

Catchment hydrology

5. Assess the validity of the regionalisation procedure for the 2CSalt models by systematically removing subsets of catchments
6. Examine the effect of catchment area on the modelling results
7. Refine and correct the catchment land-use areas for the 2CSalt rainfall runoff models and the sediment and nutrient export calculations including the Sydney Metropolitan Area where detailed land-use mapping was not available
8. Use daily rainfall records to interpolate catchment runoff and generate daily time series to assess:
   a) the influence of rainfall runoff on variability in chlorophyll a and turbidity levels
   b) additional metrics of hydrological stress, particularly under low flows, and including those developed for the WSP process
   c) the effect of artificially opening lakes and lagoons at lower than natural breakout levels which can impact inundation regimes for peripheral vegetation, light levels for submerged aquatic vegetation and effectiveness of entrance scour and hence the period of opening and tidal flushing

   The Queensland Department of Environment and Resource Management are modelling daily nutrient and pesticide loads using the WaterCAST software developed by the eWater CRC. Comparisons of methods and results should be considered
9. Use the models to assess the effect of climate change on catchment hydrology and the downstream impacts on estuarine ecosystems. The 2CSalt models developed for the coastal catchments are in the process of being re-run by OEH for related climate change projects.

Flushing time

10. Develop simple daily water balance models for intermittently open estuaries and calibrate with water level records available from the hydrometric network managed by OEH. Natural opening levels could be estimated using the work of Sheedy (1996). This will improve the estimates of flushing time particularly for smaller systems that open with minor rainfall. The models will benefit greatly from more accurate hypsometry flowing from improved DEMs of merged bathymetric and topographic data
11. Collate all available salinity data from custodians and:
    a) calculate freshwater replacement time as a lower bound to water residence time
    b) examine exchange efficiencies using:
        i. time series of rainfall runoff and estuary salinity together with tidal prism to calculate flushing rate (Officer & Kester 1991)
        ii. data on post-flood recovery rate of salinity
        iii. DEMs to explore the role of entrance morphology in tidal flushing, for example, entrance inlet channel volume relative to tidal prism
        iv. hydrodynamic models developed for a number of estuaries available from past projects, the results from which could be used in this assessment
12. Examine whether different methods of calculating water residence time should be applied to different estuary types.

Estuary classification

13. Investigate expanding the three class classification scheme of lake, river and lagoon into five classes of bay/drowned valley, lake, river, lagoon and creek to better represent ecological processes and reduce response variability within classes. This will require more detailed analysis of chlorophyll a data to validate relationships between nutrient load and response. Data analysis should separate ambient conditions from rainfall events, summer from annual chlorophyll a concentrations, diffuse from point source nutrient loads and the influence of entrance condition and river zonation. 2CSalt monthly flow outputs should be used to generate monthly nutrient loads to allow more detailed temporal analysis. Statistical approaches to classification such as cluster analysis and a statistical-Bayesian classification and regression tree (B-CART) should be explored
14. Use the effective loading concept developed by OEH for the Coastal Eutrophication Risk Assessment Tool (CERAT) to investigate whether load-response relationships can be improved within classes
15. Conduct exploratory analysis of data on physical and environmental drivers and their influence on the distribution and extent of seagrass, mangrove and saltmarsh and on the composition of fish assemblages. Factors to be analysed should include nutrient and sediment loads, soil types, regolith stability, water clarity, chlorophyll a, salinity, hypsometry, geomorphology and entrance condition
16. Confirm the geomorphological classification of Roy et al. (2001) and as extended by OEH for all 184 estuaries using statistical analysis and field checking where necessary.

Condition data

17. Contact those local councils that hold, but were unable to supply, water quality data for the SOC 2010 reports and gain access to the data. Also update data on water quality from all councils
18. Using all available data, the power analysis for the sampling designs should be revisited to refine the level of change required for changes to be significant
19. As turbidity is highly variable, protocols for field sampling need to be tightly defined and the role of water clarity in eutrophication processes further explored
20. Ongoing development of a suitable methodology for gathering data on macroalgae abundance is required
21. Mapping of macrophytes using remote sensing techniques is still at the development stage but should continue to be supported so that time series data can be acquired and analysed for trends through time
22. Further assessment of change between the two major surveys of macrophytes needs to be undertaken. Detailed time series mapping available for a limited number of estuaries should be used to determine a minimum patch size that was not mapped in the West et al. (1985) survey. Confidence in the change estimates may increase if the results from the detailed time series and the change data can be aligned
23. Initiate new time series mapping of macrophytes in a small number of estuaries to validate change estimates. Include estuaries in reference condition to partition natural variability from disturbance due to human activity
24. Additional historical data on fish assemblages from a number of projects are held by DPI. These data could be used for for analysis and refinement of reference conditions, threshold scoring criteria and sampling designs.

Reference conditions and scoring classes

25. Further explore measures of catchment disturbance, in addition to the increase in TN load, to improve stressor-response relationships
26. Investigate statistical methods for removing the biasing effect of sample size in calculating the trigger value of the 80th percentile of chlorophyll a and turbidity sampling in reference condition estuaries
27. Conduct multivariate statistical analysis of multiple stress gradients and biological responses to complement the current visual graphical assessment of stressor-response relationships. Investigate the potential for ecologically or biologically relevant thresholds to better define estuary health and how scoring of health might be linked to the thresholds.

Pressure indicators

28. Further investigate the use of riparian vegetation extent mapping and land-use mapping to create a metric representing the pressure of clearing vegetation in riparian zones along catchment streams and estuary foreshores
29. Incorporate data on riparian vegetation extent, and condition if available, along catchment streams and estuary foreshores into the disturbed habitat indicator and weight accordingly.

Investigate utility of other disturbed habitat indicators for which data are available such as barriers to tidal flow, Caulerpa taxifolia infestation and estuary area open to commercial or recreational fishing

30. Explore different ways of portraying and analysing catchment pressure data using various distance weighting measures to improve stressor-response relationships, for example:
    a) Pressure originating above and below the tidal limits
    b) Reducing the pressure with distance upstream of the tidal limit
    c) Reducing the pressure with distance from the fluvial stream system
    d) Reducing the pressure using a combination of distance from the fluvial stream system and decreasing stream order. Sub-catchments draining to first and second order streams have the least influence on pressure while those draining directly to the estuary have the most influence
31. Historical data on commercial fish catch are available from DPI and could be analysed for trends through time
32. Likewise, historical data on sewage treatment plant and overflow discharges could be analysed for trends but would not be expected to have a significant effect on total loads
33. In addition to the 2CSalt modelling of the effects of climate change on rainfall runoff patterns, investigate quantifying impacts of climate change into indicators suitable for SOC reporting
34. Assess whether the effects of climate change are evident in existing bio-physical data.

Index of estuary condition

35. Investigate combining indicators into a eutrophication index and a habitat index similar to the concept of the fish index which includes 14 metrics
36. Explore combinations of condition indicators and sub-indices that respond to gradients of disturbance
37. Compare the current assessment with the expert approach to index development being trialled by CSIRO on behalf of the Estuary MER program
38. To reduce the fish index variability, sites should be sampled twice before being assessed (Seegert 2000).

Index of estuary pressure

39. Other datasets also gathered but not used in the current assessment are:
    - percentage of catchment area without reticulated sewerage
    - extent of recreational and commercial fish closures or, conversely, available for fishing
    - extent of marine protected areas or, conversely, subject to activities banned in marine protected areas
    - estuarine Beachwatch and Harbourwatch compliance data on bacterial contamination
    - riparian vegetation extent (completed subsequent to the SOC 2010 reports)

Further analysis of these data could yield additional metrics suitable for incorporation in the pressure index, particularly riparian vegetation extent and other riparian metrics related to connectivity and fragmentation.

Data management

40. Bring all estuary datasets created to support the SOC reports into corporate data systems

41. Make data accessible through the OEH and DPI websites and improve the functionality of data manipulation through further development of those sites including the application of Google Earth where appropriate.

Integration across themes

42. Other themes within the wider MER program are collating data and generating metrics that may be useful as pressures to the estuary theme, and conversely the estuary theme is generating metrics that may be useful to other themes (eg marine). These should be investigated in detail but might include measures of river health, soil condition particularly erosion and changes in native vegetation cover through time.

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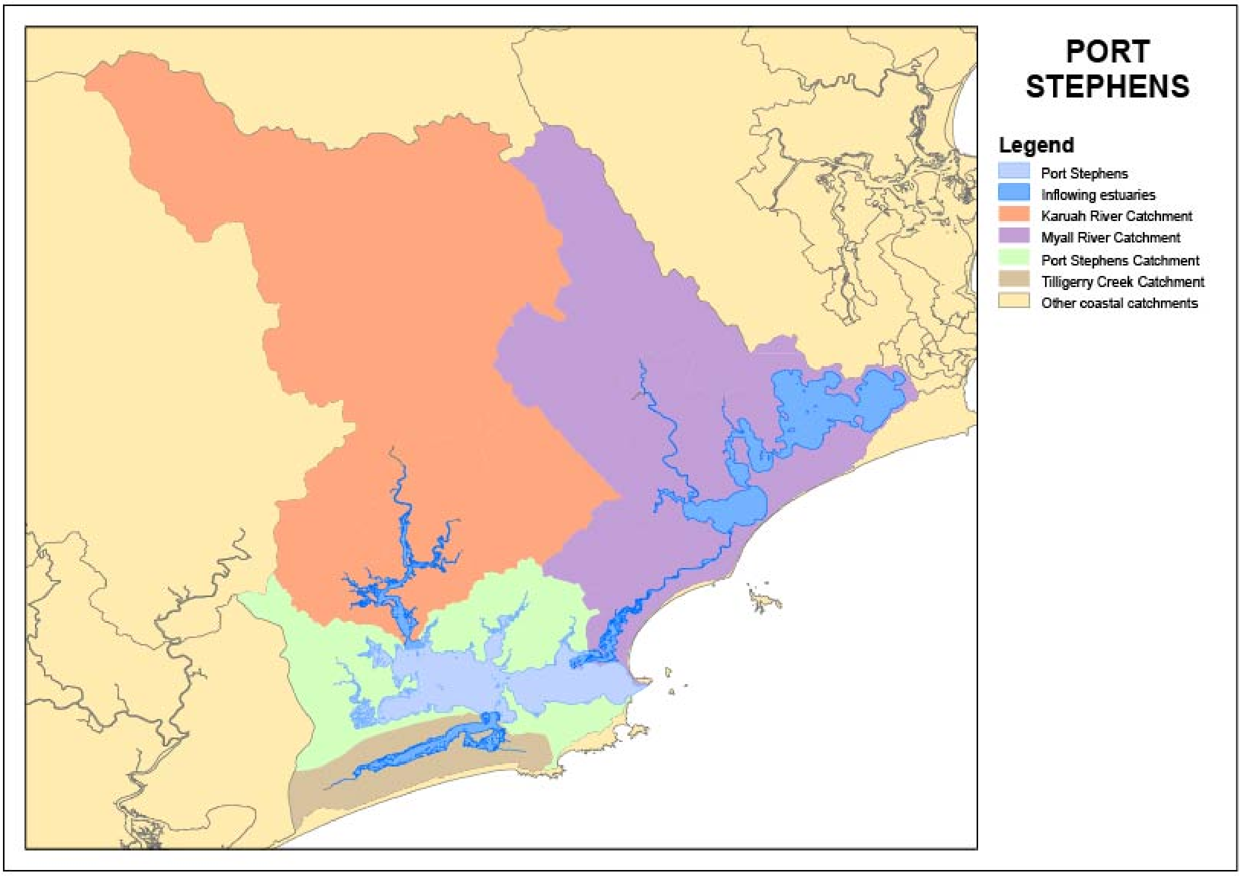
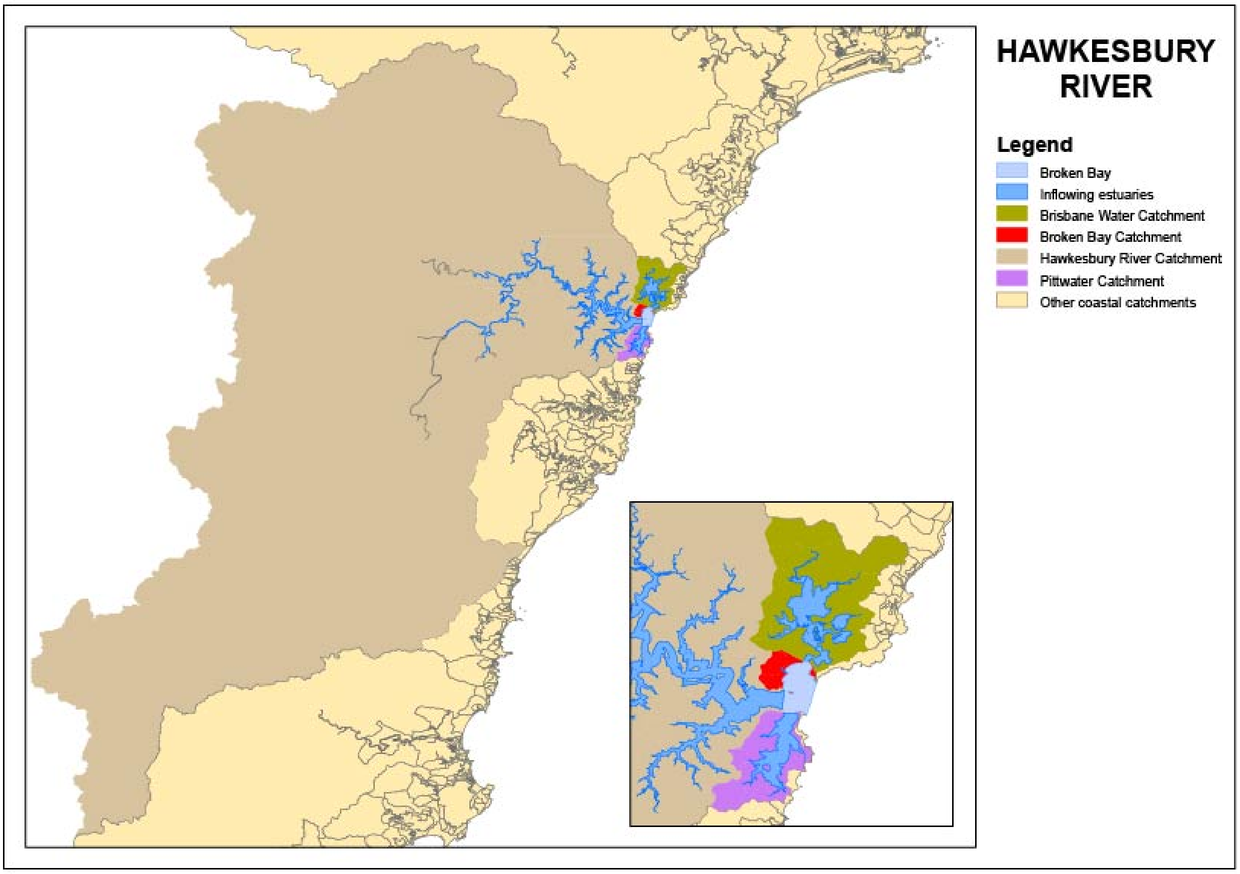
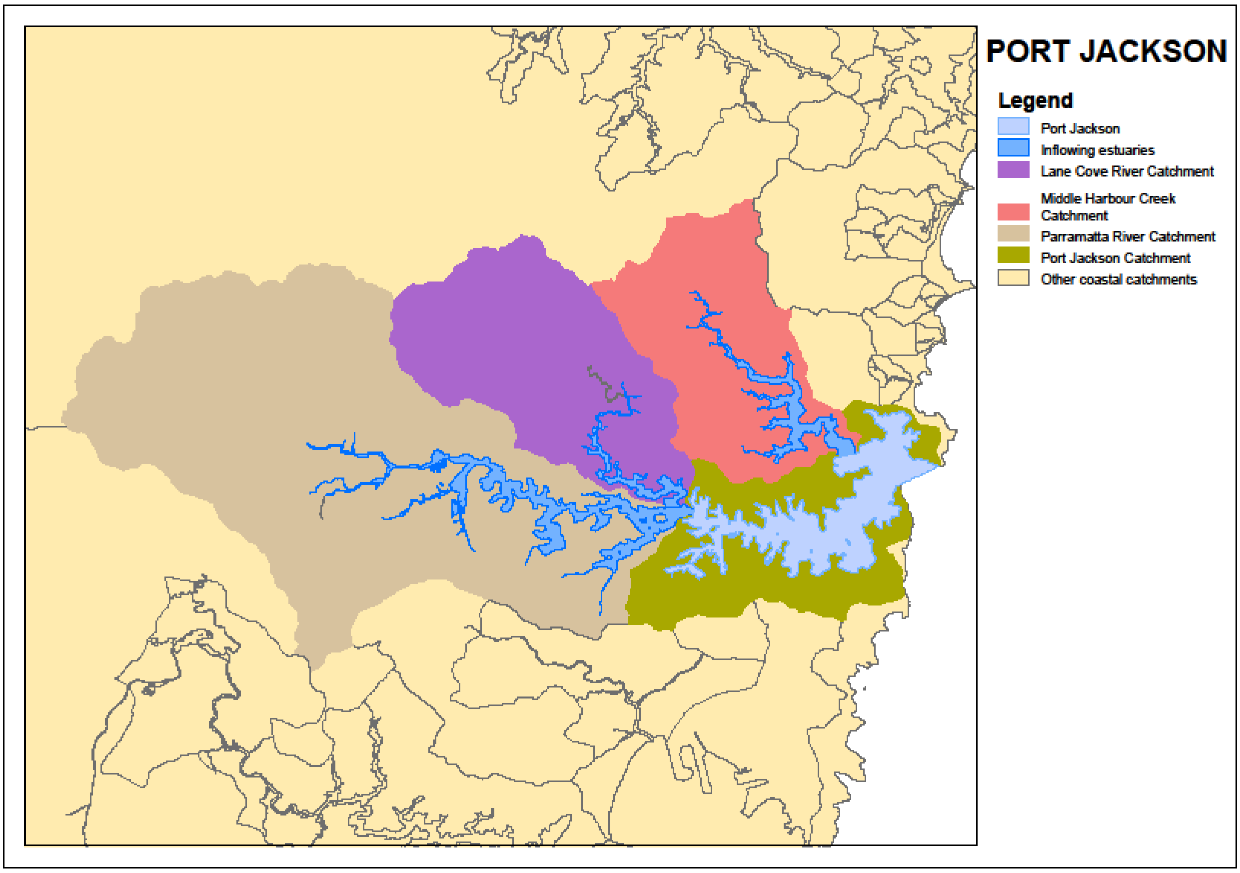
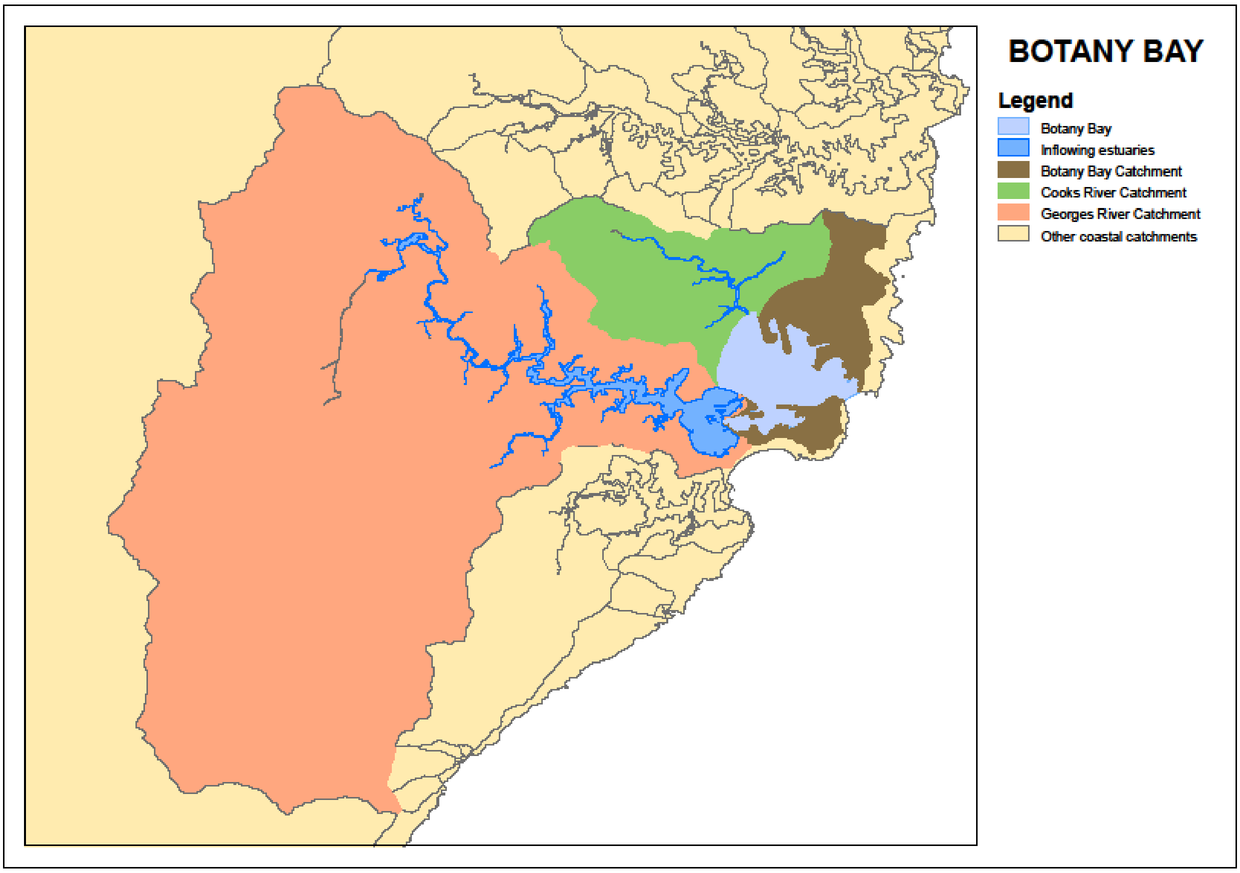
Appendix 1

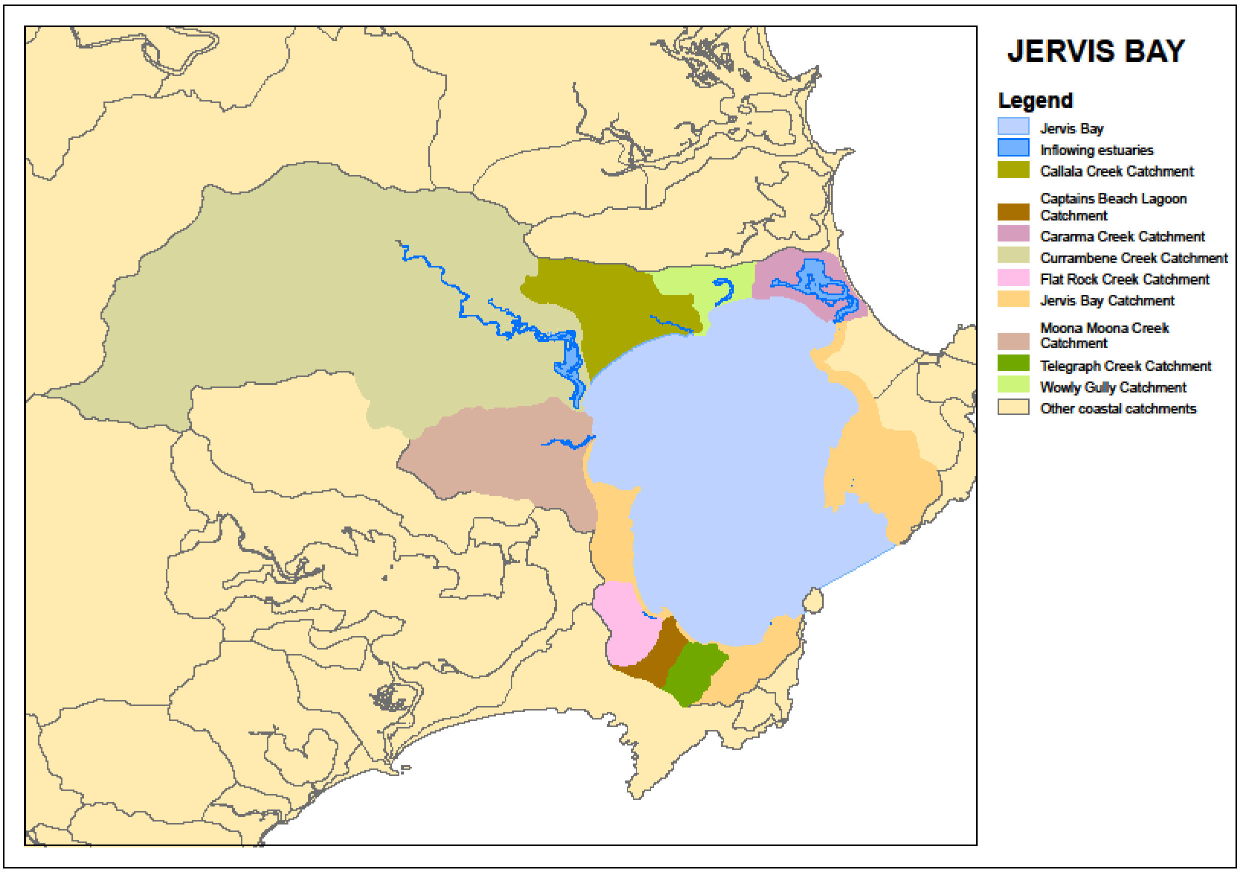
Catchments of ports, bays and harbours

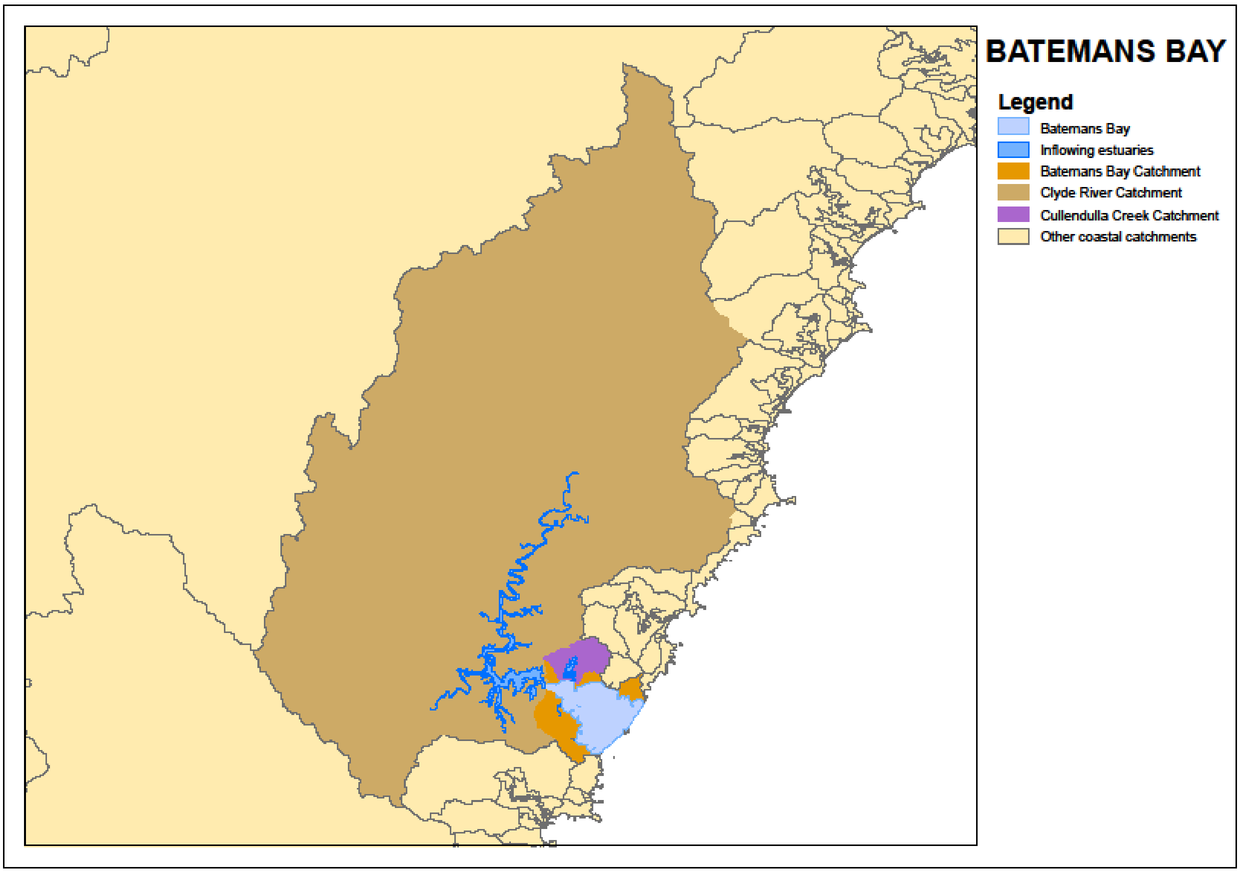


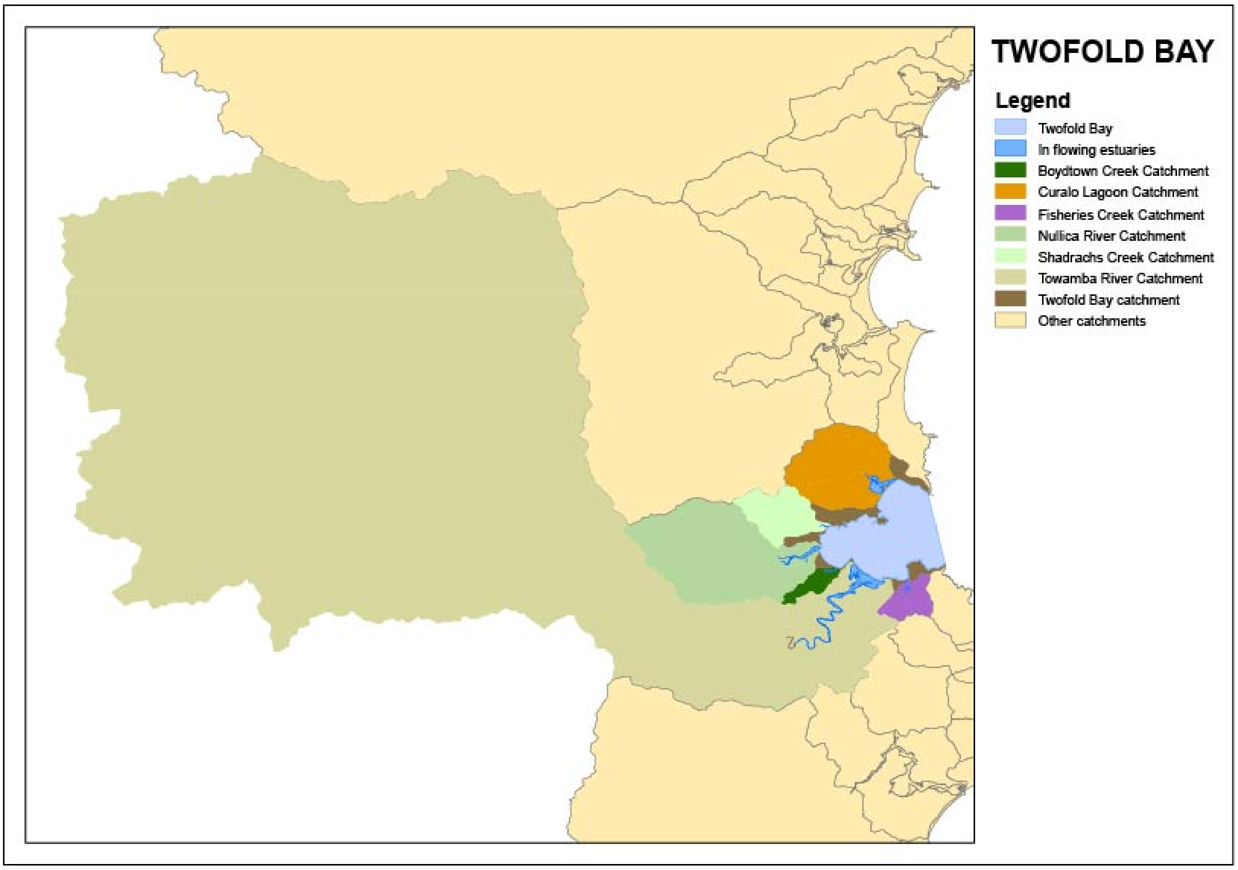



PORT JACKSON
Legend
Port Jackson
Inflowing estuaries
Lane Cove River Catchment
Middle Harbour Creek Catchment
Parramatta River Catchment
Port Jackson Catchment
Other coastal catchments

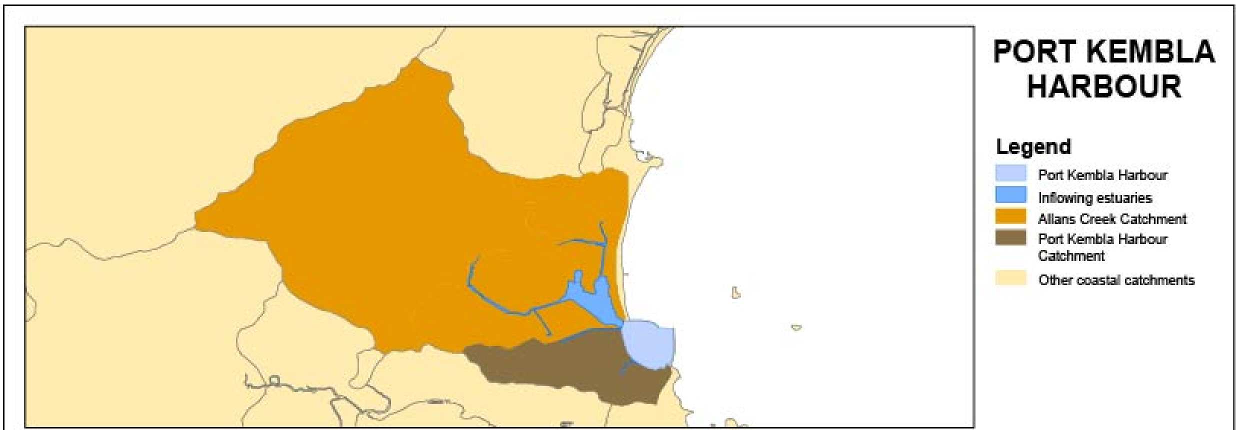

BOTANY BAY
Legend
Botany Bay
Inflowing estuaries
Botany Bay Catchment
Cooks River Catchment
Georges River Catchment
Other coastal catchments


JERVIS BAY
Legend
Jervis Bay
Inflowing estuaries
Callala Creek Catchment
Captains Beach Lagoon Catchment
Cararma Creek Catchment
Currambene Creek Catchment
Flat Rock Creek Catchment
Jervis Bay Catchment
Moona Moona Creek Catchment
Telegraph Creek Catchment
Wowly Gully Catchment
Other coastal catchments

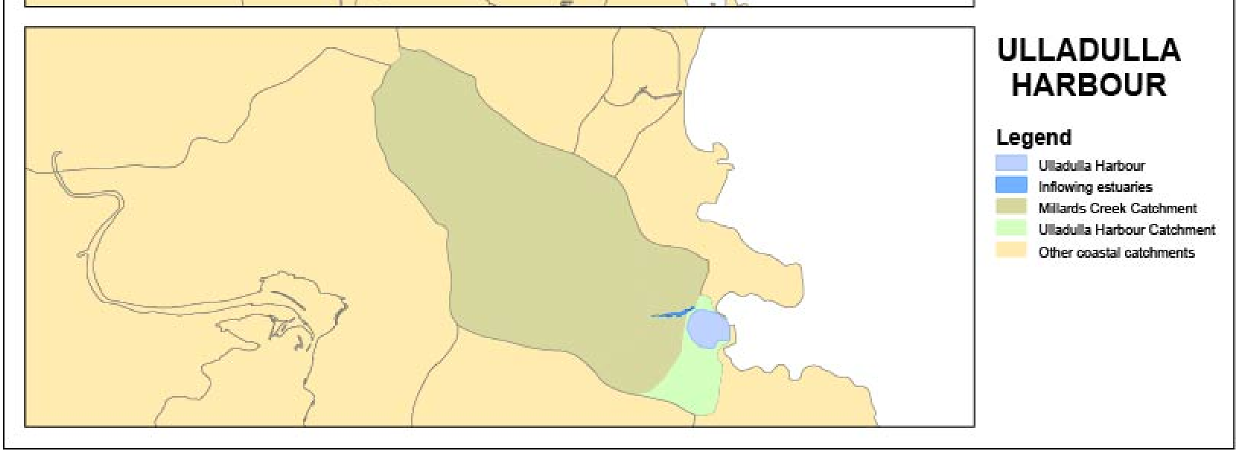

BATEMANS BAY
Legend
Batemans Bay
Inflowing estuaries
Batemans Bay Catchment
Clyde River Catchment
Cullendulla Creek Catchment
Other coastal catchments



TWOFOLD BAY
Legend
Twofold Bay
In flowing estuaries
Boydtown Creek Catchment
Curalo Lagoon Catchment
Fisheries Creek Catchment
Nullica River Catchment
Shadrachs Creek Catchment
Towamba River Catchment
Twofold Bay catchment
Other catchments



PORT KEMBLA HARBOUR
Legend
Port Kembla Harbour
Inflowing estuaries
Allans Creek Catchment
Port Kembla Harbour Catchment
Other coastal catchments



ULLADULLA HARBOUR
Legend
Ulladulla Harbour
Inflowing estuaries
Millards Creek Catchment
Ulladulla Harbour Catchment
Other coastal catchments

Appendix 2

Hydrographic surveys

Includes all data captured up to January 2009

Estuary	Date	PDF	Sheets	XYZ file reference
Tweed River and Terranora Broadwater	August 1995	10232	16	Tweed.xyz, Terranora.xyz – digital for lower estuary (NP)
Cudgen Lake and Creek	Feb 1993 May 1993	9533 9616	2 10	Cudgen.xyz (NP)
Mooball and Cudgera Creeks	Sept 2007			Fieldwork complete. Plan preparation nearing completion.
Brunswick River	Feb 1997 2007	53061	2	Brunswick.xyz – digital lower estuary only. Paper cross sections Complete.
Belongil Creek	July 1994	10042	5	Belongil.xyz
Lake Ainsworth	Feb 1996	10395	1	Ainsworth.xyz
Richmond River	2004/2005	55281	62	55281.xyz
Shaws Bay	July 1999	53755	1	ShawsBay.xyz
Evans River	June 1997 March 2006	53139 55326	2 7	Evans.xyz – lower estuary only 55326.xyz
Clarence Entrance	March 2004	54732	2	Entrance.xyz, Channel.xyz – lower entrance area only
Wooli Wooli River	Feb 2003	54762	13	Wooli.xyz
Corindi River	March 2004	55072	4	Corindi_2004.xyz
Arrawarra Creek	August 2005	55165	1	55165.xyz
Darkum Creek	March 2004	55067	1	Darkum_2004.xyz
Woolgoolga Lake	March 2004	55066	1	Woolgoolga_2004.xyz
Hearns Lake	August 2005	55081	1	Hearns_2005.xyz
Moonee Creek	Dec 2002	54555	6	Moonee.xyz
Coffs Creek	Oct 1997		6	Digital data available (NP)
Bellinger / Kalang Rivers	1984/85 2008		49	No digital data, paper copies only Majority of fieldwork completed
Boambee Creek	March 2006	55770	5	Boambee.xyz
Deep Creek	May 2002	54362	8	DeepCreek.xyz
Nambucca River	1989/90 2008/09		40	No digital data, paper copies only Approx 50% of fieldwork complete
Macleay River	April 2003	54969	39	Macleay.xyz
Saltwater Creek	July 2001	54317	5	Saltwater.xyz
Korogoro Creek	Nov 2005	55208	3	55208.xyz
Killick Creek	July 2001	54316	4	Killick.xyz
Hastings River	Oct 2000	54218	49	Hastings.xyz, Hastingsposdepths.xyz
Lake Innes / Lake Cathie	Dec 1991 April 1992	9320 9332	3 7	Cathie.xyz (NP)
Camden Haven	1979		12	No digital data, paper copies only (NP)
Manning Estuary	1999	53872	44	Manning.xyz
Wallis Lake	Nov 1998	53665	61	Wallis.xyz
Smiths Lake	Nov 1995 August 1996	52552 52572	7 1	Smiths.xyz
Myall Lake	August 2002	54797	44	Myall.xyz – excludes upper Myall River
Lake Macquarie / Swansea Channel	April 1996	53077	9	LakeMacquarie.xyz – covers inlet channel only
Black Neds Bay	Sept 2006		1	Blackneds.xyz
Tuggerah Lakes	Sept 1975		28	No digital data paper copy only (NP)
Wamberal Lagoon	Dec 2003	55083	1	Wamberal.xyz
Avoca Lake and Bulbararing Lagoon	Dec 1995	53498	7	Avoca.xyz
Brisbane Water	Feb 1993	51018	6	Brisbane.xyz
Brisbane Water – Fagans Bay	Feb 2004	54763	1	Brisbane 2004.xyz
Brisbane Water – Woy Woy Bay & inlet	Feb 2004	54774	1	Brisbane 2004.xyz
Hawkesbury River / Broken Bay	1988 June 1989	8493 8678	12 12	Hawkesbury.xyz – majority of river covered by paper cross sections (NP)
Sandbrook Inlet	May 2006	55382	2	55382.xyz
Berowra Creek	Sept 1995	52647	12	Berowra.xyz
Narrabeen Lakes	Feb 2005	54936	7	Narrabeen.xyz

Estuary	Date	PDF	Sheets	XYZ file reference
Cooks River	May 1989 April 1989	8710 8599	13 11	Cooks.xyz (NP)
Georges River	1976–1997	53496	33	Sections 52 – 159 – survey10.xyz (NP) Sections 1–51 not available in digital format.
Port Hacking	May 2003	54639	15	PtHacking.xyz – Lower estuary only
Hewitts Creek	March 2005	55234	1	55234.xyz
Towradgi Creek	March 2005	55211	1	55211.xyz
Fairy Creek	Feb 2005	55232	1	55232.xyz
Lake Illawarra	Jan 1999 2008	53525	2	Illawarra.xyz – Inlet channel only. Paper copy for lake basin Fieldwork nearing completion. Photogrammetric base plan done
Elliot Lake	Dec 2002	54603	3	ElliotLake.xyz
Minnamurra River	July 1992	9486 9487	1 6	Not Available (NP) Not Available
Werri Lagoon	Feb 2003	54583	2	Werri_Lagoon.xyz
Crooked River	Nov 2000	54169	7	Crooked.xyz
Shoalhaven / Crookhaven Estuary	April 1989 2005/2006	8641	6 28	Shoalhaven.xyz
Berrys Canal	May 1992	10128	3	No xyz, pdf only
Lake Wollumboola	Nov 1991	9290	4	Wollumboola.xyz
Currarong Creek and offshore	Oct 1996	53095	5	Currarong.xyz
Sussex Inlet	Feb 1992	10055	5	Sussex.xyz, (NP)
St Georges Basin	Feb 1992		5	Pdf only
Swan Lake	June 2000	54042	5	Swanlake.xyz
Lake Conjola	Jan 1993	9538	19	Conjola.xyz Photogrammetric base plan done
Narrawallee Creek	August 1993	9787	7	Narrawallee.xyz (NP)
Burrill Lake	April 1990 March 2001	8879 54330	6 7	Burrill_1990.xyz Burrill_2001.xyz
Tabourie Lake	Jan 1993	9554	13	Tabourie.xyz (NP)
Termeil Lake	August 2004	55078	1	Termeil.xyz
Meroo Lake	August 2004	55079	3	Meroo.xyz
Willinga Lake	August 2002	54421	1	Willinga.xyz
Durras Lake	June 2004	55023	6	Durras_Lake.xyz
Clyde River	Dec 1998	53592	14	Clyde.xyz
Batemans Bay	Dec 1995	53614	9	Batemans_1995.xyz
Tomaga River	Feb 1997	53500	11	Tomaga.xyz, Tomaga_offshore.xyz
Moruya River	April 2000	53981	18	Moruya.xyz
Coila Lake and Creek and Tuross Lake and tributaries	April 1994 April 1994	52578 10064	17 15	Coila.xyz, Tuross.xyz, Sections.xyz
Kianga Lake and Inlet	August 2002	54541	1	Kianga.xyz
Wagonga Inlet	May 1997	53175	7	Wagonga.xyz
Nangudga Lake and Inlet	August 2002	54550	1	Nangudga.xyz
Wallaga Lake	Dec 1993	9792	11	Wallaga.xyz
Bermagui Boat Harbour	July 2002	54569 54570	6	Bermagui_BH.xyz
Bermagui River	Dec 1990 Dec 1990	9091 9147	11 3	Bermagui_River.xyz (NP) Not Available
Bega River	Sept 2002	54625	11	Bega_2002.xyz
Back Lagoon	Aug 2003	55075	1	Back_Lagoon.xyz
Merimbula Lake	Aug 2003	55076	13	Merimbula_Pambula.xyz
Pambula Lake	Aug 2003	55076	13	Merimbula_Pambula.xyz
Curalo Lagoon	Nov 1996	53425	1	Curalo.xyz
Wonboyn River and Lake	Oct 1997	53499	14	Wonboyn.xyz
				Bathymetry has been gridded

Note: NP = No Photogrammetric base plan available

Appendix 3

Estuary morphometric parameters

	Area (km^2)						Estuary	Average	Peri-	Upper limit (km)	
Estuary	Seagrass	Mangrove	Saltmarsh	Open water	Total estuary	Tot. estuary - saltmarsh	volume (Ml)	depth (m)	meter (km)	Tidal	Mang-rove
Tweed River	0.806	3.982	0.763	17.16	22.72	21.95	56955	2.59	246.4	42.0	32.5
Cudgen Creek	0.009	0.139	0.052	1.95	2.15	2.10	2371	1.13	22.7	13.7	11.3
Cudgera Creek	0.034	0.148	0.074	0.23	0.48	0.41	250	0.61	14.0	5.8	3.4
Mooball Creek	0.024	0.114	0.008	0.39	0.53	0.52	351	0.67	13.2	10.6	10.1
Brunswick River	0.036	1.233	0.310	2.01	3.59	3.28	4268	1.30	79.2	14.0	12.6
Belongil Creek	0.000	0.070	0.083	0.12	0.27	0.19	88	0.46	6.2	3.5	3.2
Tallow Creek	0.000	0.000	0.000	0.12	0.12	0.12	47	0.39	4.2	2.8	1.6
Broken Head Creek	0.000	0.000	0.000	0.05	0.05	0.05	15	0.29	1.7		
Richmond River	0.320	6.026	0.599	31.43	38.38	37.78	119314	3.16	678.2	114.1	44.9
Salty Lagoon	ns	ns	ns	0.16	0.16	0.16	69	0.43	5.9	2.1	0.9
Evans River	0.006	0.409	0.358	1.89	2.66	2.30	2637	1.15	46.8	15.4	15.0
Jerusalem Creek	0.000	0.000	0.000	0.32	0.32	0.32	179	0.56	11.2	5.0	1.5
Clarence River	0.826	7.653	2.901	120.94	132.32	129.42	283001	2.19	841.4	109.5	53.0
Lake Arragan	ns	ns	ns	0.97	0.97	0.97	814	0.84	11.8		
Cakora Lagoon	0.000	0.005	0.129	0.22	0.36	0.23	114	0.50	11.1	2.1	1.4
Sandon River	0.086	0.574	0.477	1.48	2.62	2.14	2393	1.12	50.1	14.7	13.5
Wooli Wooli River	0.094	0.860	0.669	2.12	3.75	3.08	2611	0.85	63.1	17.0	16.7
Station Creek	0.000	0.000	0.004	0.25	0.26	0.25	132	0.52	13.1	6.4	1.7
Corindi River	0.024	0.371	0.572	0.93	1.90	1.32	1557	1.18	34.2	12.3	10.2
Pipe Clay Creek	ns	ns	ns	0.01	0.01	0.01	1.7	0.16	1.1	0.9	0.6
Arrawarra Creek	0.001	0.010	0.010	0.10	0.12	0.11	44	0.39	6.3	2.4	2.3
Darkum Creek	0.013	0.010	0.000	0.03	0.06	0.06	16	0.30	2.9	2.6	2.4
Woolgoolga Lake	0.000	0.006	0.000	0.15	0.16	0.16	67	0.43	4.5	2.7	2.0
Flat Top Point Creek	ns	ns	ns	0.02	0.02	0.02	4.7	0.21	2.1		1.4
Hearns Lake	0.000	0.003	0.045	0.10	0.15	0.10	38	0.37	4.6	2.0	1.9
Moonee Creek	0.032	0.085	0.132	0.16	0.41	0.28	414	1.49	10.1	7.3	7.6
Pine Brush Creek	ns	ns	ns	0.02	0.02	0.02	2.9	0.19	0.8	1.0	
Coffs Creek	0.002	0.192	0.002	0.26	0.46	0.46	293	0.64	11.6	6.8	5.5
Boambee Creek	0.060	0.331	0.029	0.57	0.99	0.96	805	0.84	24.7	7.1	6.9
Bonville Creek	0.089	0.137	0.159	1.27	1.66	1.50	1466	0.98	37.2	10.4	9.2
Bundageree Creek	ns	ns	ns	0.00	0.00	0.00	0.25	0.10	0.3	3.6	
Bellinger River	0.133	1.172	0.143	6.71	8.16	8.02	14442	1.80	145.0	26.1	18.9
Dalhousie Creek	0.002	0.007	0.007	0.06	0.08	0.07	22	0.32	4.6	2.3	2.1
Oyster Creek	0.000	0.000	0.003	0.14	0.14	0.14	58	0.41	9.2	2.7	2.5
Deep Creek	0.010	0.035	0.639	1.04	1.72	1.08	1387	1.28	26.5	9.3	4.7
Nambucca River	0.605	1.455	1.277	9.31	12.64	11.37	23227	2.04	214.8	30.7	24.5
Macleay River	0.957	5.710	4.247	20.73	31.64	27.39	70235	2.56	363.4	56.7	21.9
South West Rocks Creek	0.002	0.648	0.112	0.18	0.94	0.83	654	0.79	7.2	3.1	2.7
Saltwater Creek (Frederickton)	0.000	0.000	0.000	0.28	0.28	0.28	83	0.29	9.1	4.3	4.3
Korogoro Creek	0.000	0.058	0.040	0.19	0.28	0.24	124	0.51	12.5	6.4	5.4
Killick Creek	0.000	0.045	0.009	0.24	0.29	0.28	236	0.84	9.6	2.9	2.7
Goolawah Lagoon	ns	ns	ns	0.13	0.13	0.13	51	0.40	4.7		
Hastings River	1.458	3.437	1.867	23.20	29.96	28.09	52686	1.88	433.3	35.8	24.8
Cathie Creek	0.000	0.000	5.887	7.86	13.75	7.86	8379	1.07	32.3	8.9	3.1
Duchess Gully	ns	ns	ns	0.02	0.02	0.02	5.4	0.22	3.4	1.6	
Camden Haven River	10.250	1.408	0.768	19.73	32.16	31.39	113802	3.63	164.7	25.9	20.9
Manning River	1.654	3.905	2.447	26.71	34.72	32.27	96259	2.98	395.4	53.9	37.8
Khappinghat Creek	0.003	0.000	0.159	1.03	1.19	1.03	885	0.86	33.2	9.3	
Black Head Lagoon	0.000	0.000	0.000	0.01	0.01	0.01	1.4	0.15	0.8		
Wallis Lake	31.897	1.471	5.900	59.43	98.70	92.80	217951	2.35	403.5	32.1	32.1
Smiths Lake	2.960	0.000	0.000	7.05	10.01	10.01	23552	2.35	29.0	5.9	
Myall River	2.173	3.028	2.670	107.32	115.20	112.53	448258	3.98	297.4	61.5	32.9
Karuah River	0.066	5.070	3.756	8.99	17.88	14.12	31221	2.21	153.0	47.7	46.2
Tilligerry Creek	1.797	6.255	4.142	8.26	20.45	20.45	51714	2.53	71.8	35.9	33.0
Port Stephens	12.594	12.788	6.490	102.50	134.38	123.75	1741516	14.07	251.4		
Hunter River	0.000	19.217	5.204	22.61	47.03	41.83	137089	3.28	389.6	63.5	33.2
Glenrock Lagoon	ns	ns	ns	0.05	0.05	0.05	15	0.29	2.2	1.0	0.5
Lake Macquarie	14.633	1.249	0.887	97.33	114.10	113.21	646274	5.71	320.9	24.0	24.0
Middle Camp Creek	ns	ns	ns	0.01	0.01	0.01	2.3	0.18	2.2		
Moonee Beach Creek	ns	ns	ns	0.00	0.00	0.00	0.21	0.09	0.4	0.5	7.1
Tuggerah Lake	17.318	0.001	0.129	63.31	80.76	80.63	193231	2.40	138.1	19.5	4.8
Wamberal Lagoon	0.436	0.000	0.000	0.08	0.52	0.52	880	1.70	6.3	2.9	
Terrigal Lagoon	0.000	0.001	0.000	0.28	0.28	0.28	151	0.54	5.4	2.5	1.8
Avoca Lake	ns	ns	ns	0.67	0.67	0.67	293	0.44	10.8	2.2	
Cockrone Lake	0.289	0.000	0.000	0.04	0.33	0.33	187	0.57	4.2	2.0	
Brisbane Water	5.582	2.078	1.124	19.56	28.34	27.22	84199	3.09	126.5	21.2	20.7
Hawkesbury River	0.915	9.833	2.878	100.88	114.50	111.63	1541412	13.81	808.7	138.5	68.0
Pittwater	1.855	0.175	0.027	16.33	18.39	18.36	181836	9.90	56.2	11.3	10.8
Broken Bay	0.036	0.000	0.000	17.11	17.14	17.14	167615	9.78	21.9		
Narrabeen Lagoon	0.617	0.000	0.008	1.69	2.32	2.31	5252	2.27	21.7	6.5	3.5
Dee Why Lagoon	0.000	0.000	0.063	0.24	0.30	0.24	13	0.05	3.7	1.4	
Curl Curl Lagoon	0.000	0.000	0.000	0.07	0.07	0.07	21	0.31	1.7	1.2	
Manly Lagoon	0.001	0.000	0.000	0.10	0.10	0.10	36	0.36	5.6	2.8	
Middle Harbour Creek	0.058	0.142	0.000	5.91	6.11	6.11	81900	13.40	49.1	16.8	16.3
Lane Cove River	0.015	0.359	0.000	2.60	2.98	2.98	12600	4.23	33.6	23.3	23.3

Estuary	Area (km^2)						Estuary volume (Ml)	Average depth (m)	Peri-meter (km)	Upper limit (km)	
	Seagrass	Mangrove	Saltmarsh	Open water	Total estuary	Tot. estuary - saltmarsh				Tidal	Mang-rove
Parramatta River	0.105	1.346	0.095	12.19	13.74	13.74	69700	5.07	111.8	30.3	30.2
Port Jackson	0.340	0.000	0.000	28.72	29.06	28.97	376400	12.99	100.5		
Cooks River	0.000	0.108	0.003	1.09	1.20	1.20	1084	0.90	37.6	21.9	20.7
Georges River	1.934	3.825	0.840	20.00	26.59	25.75	271394	10.54	221.3	49.3	47.9
Botany Bay	5.358	2.296	0.762	31.14	39.55	38.79	440816	11.36	59.0		
Port Hacking	1.002	0.299	0.128	10.27	11.70	11.57	105262	9.09	74.3	14.1	13.3
Wattamolla Creek	ns	ns	ns	0.03	0.03	0.03	8.2	0.25	1.6	1.1	
Hargraves Creek	ns	ns	ns	0.00	0.00	0.00	0.34	0.11	0.4	0.3	
Stanwell Creek	ns	ns	ns	0.01	0.01	0.01	1.3	0.15	0.6	0.4	
Flanagans Creek	ns	ns	ns	0.00	0.00	0.00	0.16	0.09	0.3		
Woodlands Creek	ns	ns	ns	0.00	0.00	0.00	0.40	0.11	0.4	0.2	
Slacky Creek	ns	ns	ns	0.00	0.00	0.00	0.61	0.12	0.7	0.6	
Bellambi Gully	ns	ns	ns	0.02	0.02	0.02	3.4	0.19	1.5	1.0	0.2
Bellambi Lake	ns	ns	ns	0.03	0.03	0.03	7.3	0.24	1.5	0.7	0.7
Towradgi Creek	0.000	0.000	0.000	0.04	0.04	0.04	11	0.27	3.2	1.9	1.4
Fairy Creek	ns	ns	ns	0.11	0.11	0.11	42	0.38	7.5	2.6	1.5
Allans Creek	0.000	0.021	0.008	1.14	1.17	1.16	1042	0.89	16.0		
Port Kembla	0.000	0.000	0.000	1.37	1.37	1.37	8439	6.14	7.8		
Lake Illawarra	7.966	0.000	0.302	27.56	35.83	35.53	74275	2.09	88.5	11.5	8.2
Elliott Lake	0.007	0.005	0.001	0.07	0.08	0.08	27	0.34	4.1	2.0	1.7
Minnamurra River	0.117	0.879	0.327	0.54	1.86	1.53	1517	0.99	16.8	9.6	7.8
Spring Creek	0.000	0.000	0.000	0.05	0.05	0.05	15	0.29	2.6	1.0	
Munna Munnora Creek	ns	ns	ns	0.00	0.00	0.00	0.46	0.11	0.5	0.5	
Werri Lagoon	0.001	0.000	0.000	0.14	0.14	0.14	62	0.44	8.1	2.1	0.8
Crooked River	0.046	0.008	0.017	0.21	0.28	0.26	141	0.54	7.3	3.1	2.7
Shoalhaven River	4.239	4.180	2.058	21.42	31.89	29.84	86509	2.90	271.9	50.2	22.4
Wollumboola Lake	1.340	0.000	0.000	4.99	6.33	6.33	4979	0.79	25.7		
Currarong Creek	ns	ns	ns	0.03	0.03	0.03	8.6	0.25	3.4	1.7	1.6
Cararma Creek	0.264	0.993	1.089	0.04	2.39	2.39	2767	1.16	12.9	17.3	17.0
Wowly Gully	0.000	0.000	0.094	0.07	0.16	0.16	71	0.44	3.2	15.3	15.0
Callala Creek	0.000	0.000	0.000	0.01	0.01	0.01	0.88	0.14	0.4	15.1	14.9
Currambene Creek	0.251	0.943	0.266	0.76	2.22	2.22	2511	1.13	38.2	29.6	29.0
Moona Moona Creek	0.033	0.055	0.000	0.05	0.14	0.14	58	0.42	4.7	14.3	14.2
Flat Rock Creek	0.000	0.000	0.006	0.01	0.01	0.01	2.5	0.18	1.0	8.2	8.2
Captains Beach Lagoon	0.000	0.000	0.000	0.05	0.05	0.05	13	0.28	2.4		
Telegraph Creek	0.000	0.000	0.000	0.01	0.01	0.01	0.67	0.13	0.6	6.9	
Jervis Bay	5.534	0.062	0.028	118.27	123.89	122.41	1977656	16.16	62.4		
St Georges Basin	3.170	0.276	0.149	37.31	40.91	40.76	215079	5.28	124.7	21.9	14.7
Swan Lake	0.261	0.000	0.000	4.41	4.68	4.68	10998	2.35	16.2		
Berrara Creek	0.052	0.000	0.005	0.20	0.26	0.26	132	0.52	8.0	3.8	
Nerrindillah Creek	0.030	0.000	0.000	0.04	0.07	0.07	24	0.33	2.9		
Conjola Lake	0.166	0.001	0.027	6.53	6.72	6.69	26799	4.00	58.2	12.2	8.5
Narrawallee Inlet	0.087	0.416	0.176	0.36	1.04	0.86	636	0.74	17.1	7.1	5.9
Mollymook Creek	0.000	0.000	0.001	0.01	0.01	0.01	0.77	0.13	0.9	0.8	0.3
Millards Creek	0.001	0.001	0.001	0.00	0.00	0.00	0.57	0.12	0.3	0.7	0.5
Ulladulla	0.000	0.000	0.000	0.09	0.09	0.09	350	3.74	1.2		
Burrill Lake	0.764	0.000	0.237	3.38	4.38	4.14	17653	4.26	34.9	10.0	5.6
Tabourie Lake	0.219	0.000	0.040	1.23	1.49	1.45	1124	0.78	22.4	6.6	
Termeil Lake	0.006	0.000	0.000	0.57	0.57	0.57	398	0.69	10.3	4.3	
Meroo Lake	0.755	0.000	0.000	0.61	1.37	1.37	1297	0.95	15.9		
Willinga Lake	0.173	0.000	0.000	0.14	0.31	0.31	95	0.30	7.4	3.3	
Butlers Creek	0.007	0.000	0.001	0.02	0.03	0.03	6.1	0.23	1.8	1.0	
Durras Lake	0.496	0.000	0.171	3.10	3.77	3.60	5051	1.40	37.9	9.3	
Durras Creek	ns	ns	ns	0.02	0.02	0.02	4.4	0.21	2.0	1.1	
Maloneys Creek	0.000	0.000	0.000	0.03	0.03	0.03	6.4	0.23	2.1		
Cullendulla Creek	0.125	0.881	0.174	0.11	1.29	1.12	986	0.88	9.0	4.1	4.2
Clyde River	0.793	3.310	0.521	12.92	17.55	17.03	50737	2.98	187.9	43.7	33.6
Batemans Bay	0.189	0.004	0.000	34.29	34.48	34.48	383484	11.12	44.1	2.5	2.4
Saltwater Creek (Rosedale)	ns	ns	ns	0.00	0.00	0.00	0.20	0.09	0.3	0.2	
Tomaga River	0.293	0.351	0.458	0.71	1.81	1.35	1411	1.04	29.0	11.5	9.8
Candlagan Creek	0.048	0.039	0.070	0.04	0.20	0.13	52	0.40	5.5	3.4	2.7
Bengello Creek	0.000	0.000	0.000	0.01	0.01	0.01	1.8	0.16	1.1		
Moruya River	1.197	0.474	0.790	3.68	6.14	5.35	10168	1.90	77.7	20.8	
Congo Creek	0.002	0.000	0.011	0.11	0.13	0.12	45	0.39	9.1	4.8	0.2
Meringo Creek	0.000	0.000	0.012	0.07	0.08	0.07	24	0.33	4.4		
Kellys Lake	0.000	0.000	0.000	0.06	0.06	0.06	20	0.31	2.4	1.1	
Coila Lake	1.367	0.000	0.343	5.41	7.12	6.77	15442	2.28	24.1	7.8	
Tuross River	2.176	0.664	0.802	11.86	15.50	14.70	18208	1.24	161.8	25.0	7.5
Lake Brunderee	0.026	0.000	0.017	0.17	0.21	0.19	90	0.47	4.9		
Lake Tarourga	0.000	0.000	0.000	0.33	0.33	0.33	185	0.57	3.9		
Lake Brou	0.000	0.000	0.088	2.37	2.45	2.37	2736	1.16	15.1	4.6	
Lake Mummuga	0.325	0.013	0.022	1.29	1.65	1.63	1649	1.01	17.0	3.6	
Kianga Lake	0.113	0.000	0.000	0.06	0.17	0.17	63	0.37	3.3		
Wagonga Inlet	0.809	0.197	0.023	5.91	6.94	6.91	39101	5.66	53.3	11.5	10.5
Little Lake (Narooma)	0.000	0.000	0.000	0.10	0.10	0.10	35	0.36	3.0	2.0	1.7
Bullengella Lake	0.000	0.000	0.000	0.15	0.15	0.15	63	0.42	2.3		
Nangudga Lake	0.202	0.000	0.146	0.39	0.74	0.60	389	0.65	9.9	3.4	3.3
Corunna Lake	0.161	0.000	0.049	1.92	2.13	2.08	2300	1.10	24.6	4.3	
Tilba Tilba Lake	0.095	0.000	0.156	0.92	1.17	1.02	865	0.85	9.4	3.6	
Little Lake (Wallaga)	0.000	0.000	0.017	0.12	0.13	0.12	45	0.39	2.5	1.0	

	Area (km^2)						Estuary	Average	Peri-	Upper limit (km)	
Estuary	**Seagrass**	**Mangrove**	**Saltmarsh**	**Open water**	**Total estuary**	**Tot. estuary - saltmarsh**	**volume (Ml)**	**depth (m)**	**meter (km)**	**Tidal**	**Mang-rove**
Wallaga Lake	1.085	0.000	0.162	8.06	9.31	9.14	33512	3.66	78.3	11.1	
Bermagui River	0.271	0.473	0.168	1.24	2.16	1.99	2160	1.09	33.4	10.4	7.4
Baragoot Lake	0.006	0.000	0.079	0.47	0.55	0.47	304	0.64	7.8		
Cuttagee Lake	0.385	0.000	0.113	0.85	1.35	1.24	1130	0.91	22.3	3.7	
Murrah River	0.097	0.017	0.161	0.57	0.84	0.68	500	0.74	17.1	4.9	1.8
Bunga Lagoon	0.000	0.000	0.030	0.11	0.14	0.11	41	0.38	3.4		
Wapengo Lagoon	0.418	0.555	0.506	2.19	3.67	3.17	4070	1.29	19.2	7.6	7.2
Middle Lagoon	0.211	0.000	0.052	0.30	0.56	0.51	335	0.66	8.9		
Nelson Lagoon	0.010	0.491	0.155	0.69	1.35	1.19	1078	0.90	11.8	3.4	3.0
Bega River	0.261	0.000	0.533	3.05	3.84	3.31	6371	1.93	62.3	14.6	0.6
Wallagoot Lake	0.774	0.000	0.118	3.09	3.98	3.87	5342	1.38	15.6		
Bournda Lagoon	0.000	0.000	0.005	0.08	0.08	0.08	27	0.34	4.0		
Back Lagoon	0.215	0.000	0.022	0.14	0.38	0.36	216	0.60	7.7	2.9	
Merimbula Lake	1.638	0.349	0.591	3.00	5.58	4.99	12924	2.59	19.4	6.8	6.5
Pambula River	0.706	0.580	0.366	3.07	4.72	4.36	9774	2.24	34.6	9.8	8.2
Curalo Lagoon	0.185	0.000	0.090	0.53	0.80	0.71	638	0.89	8.1	2.4	
Shadrachs Creek	ns	ns	ns	0.01	0.01	0.01	1.3	0.15	0.7	0.6	
Nullica River	0.012	0.008	0.018	0.30	0.33	0.32	176	0.56	7.7	3.0	2.1
Boydtown Creek	ns	ns	ns	0.02	0.02	0.02	3.1	0.19	2.0	1.0	
Towamba River	0.097	0.017	0.125	1.80	2.04	1.91	2050	1.07	37.4	12.3	3.8
Fisheries Creek	0.006	0.000	0.035	0.05	0.09	0.05	16	0.29	2.9	2.7	
Twofold Bay	0.740	0.000	0.000	29.99	30.73	30.73	334559	10.89	39.0		
Saltwater Creek (Eden)	ns	ns	ns	0.06	0.06	0.06	17	0.30	3.2	1.7	
Woodburn Creek	ns	ns	ns	0.05	0.05	0.05	14	0.29	4.6	2.4	
Wonboyn River	0.806	0.000	0.518	2.88	4.21	3.69	9809	2.66	33.9	11.4	5.2
Merrica River	0.000	0.000	0.000	0.12	0.12	0.12	48	0.40	3.7	2.0	
Table Creek	0.000	0.000	0.001	0.06	0.06	0.06	17	0.30	3.2	1.1	
Nadgee River	0.000	0.000	0.082	0.19	0.27	0.19	90	0.47	7.2	3.7	
Nadgee Lake	0.032	0.000	0.001	1.17	1.20	1.20	1090	0.91	5.8		
Total	**161.378**	**126.042**	**72.717**	**1431.09**	**1791.23**	**1718.51**			**10121.3**		

Estuary area, volume, depth and perimeter are measured at 0.6 m AHD

ns = **n**ot **s**urveyed.

Appendix 4

Australian land-use and management classification version 6

1 Conservation and Natural Environments

1.1.0 Nature conservation
- 1.1.1 Strict nature reserves
- 1.1.2 Wilderness area
- 1.1.3 National park
- 1.1.4 Natural feature protection
- 1.1.5 Habitat/species management area
- 1.1.6 Protected landscape
- 1.1.7 Other conserved area

1.2.0 Managed resource protection
- 1.2.1 Biodiversity
- 1.2.2 Surface water supply
- 1.2.3 Groundwater
- 1.2.4 Landscape
- 1.2.5 Traditional indigenous uses

1.3.0 Other minimal use
- 1.3.1 Defence
- 1.3.2 Stock route
- 1.3.3 Residual native cover
- 1.3.4 Rehabilitation

2 Production from Relatively Natural Environments

2.1.0 Grazing natural vegetation

2.2.0 Production forestry
- 2.2.1 Wood production
- 2.2.2 Other forest production

3 Production from Dryland Agriculture and Plantations

3.1.0 Plantation forestry
- 3.1.1 Hardwood production
- 3.1.2 Softwood production
- 3.1.3 Other forest production
- 3.1.4 Environmental

3.2.0 Grazing modified pastures
- 3.2.1 Native/exotic pasture mosaic
- 3.2.2 Woody fodder plants
- 3.2.3 Pasture legumes
- 3.2.4 Pasture legume/grass mixtures
- 3.2.5 Sown grasses

3.3.0 Cropping
- 3.3.1 Cereals
- 3.3.2 Beverage & spice crops
- 3.3.3 Hay & silage
- 3.3.4 Oil seeds
- 3.3.5 Sugar
- 3.3.6 Cotton
- 3.3.7 Tobacco
- 3.3.8 Legumes

3.4.0 Perennial horticulture
- 3.4.1 Tree fruits
- 3.4.2 Oleaginous fruits
- 3.4.3 Tree nuts
- 3.4.4 Vine fruits
- 3.4.5 Shrub nuts fruits & berries
- 3.4.6 Flowers & bulbs
- 3.4.7 Vegetables & herbs

3.5.0 Seasonal horticulture
- 3.5.1 Fruits
- 3.5.2 Nuts
- 3.5.3 Flowers & bulbs
- 3.5.4 Vegetables & herbs

3.6.0 Land in transition
- 3.6.1 Degraded land
- 3.6.2 Abandoned land
- 3.6.3 Land under rehabilitation
- 3.6.4 No defined use

4 Production from Irrigated Agriculture and Plantations

4.1.0 Irrigated plantation forestry
- 4.1.1 Irrigated hardwood production
- 4.1.2 Irrigated softwood production
- 4.1.3 Irrigated other forest production
- 4.1.4 Irrigated environmental

4.2.0 Irrigated modified pastures
- 4.2.1 Irrigated woody fodder plants
- 4.2.2 Irrigated pasture legumes
- 4.2.3 Irrigated legume/grass mixtures
- 4.2.4 Irrigated sown grasses

4.3.0 Irrigated cropping
- 4.3.1 Irrigated cereals
- 4.3.2 Irrigated beverage & spice crops
- 4.3.3 Irrigated hay & silage
- 4.3.4 Irrigated oil seeds
- 4.3.5 Irrigated sugar
- 4.3.6 Irrigated cotton
- 4.3.7 Irrigated tobacco
- 4.3.8 Irrigated legumes

4.4.0 Irrigated perennial horticulture
- 4.4.1 Irrigated tree fruits
- 4.4.2 Irrigated oleaginous fruits
- 4.4.3 Irrigated tree nuts
- 4.4.4 Irrigated vine fruits
- 4.4.5 Irrigated shrub nuts fruits & berries
- 4.4.6 Irrigated flowers & bulbs
- 4.4.7 Irrigated vegetables & herbs

4.5.0 Irrigated seasonal horticulture
- 4.5.1 Irrigated fruits
- 4.5.2 Irrigated nuts
- 4.5.3 Irrigated flowers & bulbs
- 4.5.4 Irrigated vegetables & herbs

4.6.0 Irrigated land in transition
- 4.6.1 Degraded irrigated land
- 4.6.2 Abandoned irrigated land
- 4.6.3 Irrigated land under rehabilitation
- 4.6.4 No defined use (irrigation)

5 Intensive Uses

5.1.0 Intensive horticulture
- 5.1.1 Shadehouses
- 5.1.2 Glasshouses
- 5.1.3 Glasshouses (hydroponic)

5.2.0 Intensive animal production
- 5.2.1 Dairy
- 5.2.2 Cattle
- 5.2.3 Sheep
- 5.2.4 Poultry
- 5.2.5 Pigs
- 5.2.6 Aquaculture

5.3.0 Manufacturing and industrial

5.4.0 Residential
- 5.4.1 Urban residential
- 5.4.2 Rural residential
- 5.4.3 Rural living

5.5.0 Services
- 5.5.1 Commercial services
- 5.5.2 Public services
- 5.5.3 Recreation and culture
- 5.5.4 Defence facilities
- 5.5.5 Research facilities

5.6.0 Utilities
- 5.6.1 Electricity generation/transmission
- 5.6.2 Gas treatment, storage and transmission

5.7.0 Transport and communication
- 5.7.1 Airports/aerodromes
- 5.7.2 Roads
- 5.7.3 Railways
- 5.7.4 Ports and water transport
- 5.7.5 Navigation and communication

5.8.0 Mining
- 5.8.1 Mines
- 5.8.2 Quarries
- 5.8.3 Tailings

5.9.0 Waste treatment and disposal
- 5.9.1 Stormwater
- 5.9.2 Landfill
- 5.9.3 Solid garbage
- 5.9.4 Incinerators
- 5.9.5 Sewage

6 Water

6.1.0 Lake
- 6.1.1 Lake - conservation
- 6.1.2 Lake - production
- 6.1.3 Lake - intensive use

6.2.0 Reservoir/dam
- 6.2.1 Reservoir
- 6.2.2 Water storage - intensive use/farm dams
- 6.2.3 Evaporation basin
- 6.2.4 Effluent pond

6.3.0 River
- 6.3.1 River - conservation
- 6.3.2 River - production
- 6.3.3 River - intensive use

6.4.0 Channel/aqueduct
- 6.4.1 Supply channel/aqueduct
- 6.4.2 Drainage channel/aqueduct

6.5.0 Marsh/wetland
- 6.5.1 Marsh/wetland - conservation
- 6.5.2 Marsh/wetland - production
- 6.5.3 Marsh/wetland - intensive use

6.6.0 Estuary/coastal waters
- 6.6.1 Estuary/coastal waters - conservation
- 6.6.2 Estuary/coastal waters - production
- 6.6.3 Estuary/coastal waters - intensive use

The ALUM Classification is based on a scheme developed by Baxter and Russell (1994). It has been refined collaboratively by partners in the Western Australia Department of Agriculture; New South Wales Department of Natural Resources; Northern Territory Department of Lands, Planning and Environment; South Australia Department of Water, Land and Biodiversity Conservation; Queensland Department of Natural Resources and Mines; Tasmanian Department of Primary Industries, Water and Environment; the Victorian Department of Primary Industries; the National Land and Water Resources Audit; the Murray-Darling Basin Commission; the Australian Government Bureau of Rural Sciences and Department of Agriculture, Fisheries and Forestry.

Appendix 5

Land-use classes for 2CSalt hydrology models

Hydro group	ALUM version 6 major category	ALUM V6 code	ALUM V6 detailed description	SCALD code	LUMAP code	Detailed land-use class: version 23
Cleared	Other minimal use	1.3.0		j9m	109	Cliff/rock outcrop
		1.3.4	Rehabilitation	j..	119	Constructed grass waterway for water disposal. Part of a soil erosion control system carrying run-off from graded banks
				f5j	125	Salt treatment or salt demonstration site (discharge and recharge sites)
					125E	Salt treatment or salt demonstration site (discharge and recharge sites) - exotic species
	Production forestry	2.2.0		nsg	109A	Cliff/rock outcrop
	Production from dryland agriculture and plantations	3.6.1	Degraded land	e4h	221	Abandoned gypsum mine
					43	Derelict mining land
					43A	Derelict mining land within a State Forest
		3.6.3	Land under rehabilitation	e4f	49	Restored mining lands
	Intensive animal production	5.2.0		d3.	26	Intensive animal production
					26a	Intensive animal production - alpaca
					26e	Intensive animal production - emu
					26g	Intensive animal production - goat
					26h	Intensive animal production - horse
				d3f	26o	Intensive animal production - ostriches
					26r	Intensive animal production - deer
		5.2.2	Cattle	d3c	26b	Intensive animal production - beef feedlot
		5.2.3	Sheep	d3.	26s	Intensive animal production - sheep
	Services	5.5.0		h7.	179	Levee bank for urban area
		5.5.1	Commercial services	h7a	135	Saleyard
		5.5.3	Recreation and culture	i8.	166	Illegal recreation
	Mining	5.8.1	Mines	e4.	209	Gypsum mine and associated processing
				e4a	44	Mine site
					44A	Mine site within a State Forest
		5.8.2	Quarries		7	Quarry
					7A	Quarry - within a State Forest
		5.8.3	Tailings	e4b41	133	Stock pile of mined material, located remotely from mine site. Often situated next to railway lines or at ports
				e4b	78	Fly ash dam/spoil dump
					78A	Fly ash dam/spoil dump within a State Forest
	Waste treatment and disposal	5.9.0		j9.	193	Disposal site for horticultural waste
				j9i	237	Waste dump from sawmill site
		5.9.2	Landfill	h7g	33	Landfill (garbage)
					33A	Landfill (garbage) within a State Forest
	River	6.3.0		f5c	63	River navigation structure
				j9f	71	Flood or irrigation structure
Conservation	Nature conservation	1.1.3	National park	nsg	MP	Marine park
					NP	National park
					NR	Nature reserve
		1.1.7	Other conserved area	j9o	157	Cultural heritage site - aboriginal or european
					169	Protected area managed for conservation of specific natural features.
	Managed resource protection	1.2.0		h7.	210	Land vested with an aboriginal land council
		1.2.2	Surface water supply	j9r	148	SCA unused land
	Other minimal use	1.3.2	Stock route	j9c	117F	Wide road reserve or TSR, heavily timbered but with some grazing
					117TS	Wide road reserve or TSR, with some grazing - with a woody vegetation cover of woodland
		1.3.3	Remnant native cover	j..	167	Crown reserve
				i8.	191	Riparian strip in urban and other developed areas but with minimal use
				g6t	67	Native woody shrub
		1.3.4	Rehabilitation	nsg	143	Regeneration area in reference to Section 47 notice under the NVC Act
					145	Lands fenced and treated for land degradation problems
				g6l	146	Land fenced for riparian management
				j9o	199	Regeneration reserve (in semi arid or arid area)
	Production forestry	2.2.0		nsg	83A	Degraded land (salt site, eroded area) within a State Forest
					SF	State forest
	Production from dryland agriculture and plantations	3.6.4	No defined use	…	97	No identified use
	Services	5.5.3	Recreation and culture	nsg	SRA	State recreation area
	Transport and communication	5.7.2	Roads	j9c	19A	Road or road reserve within a State Forest
					19TI	Road or road reserve - with a woody vegetation cover of isolated trees
					19TV	Road or road reserve - with a woody vegetation cover of open woodland
Cropping	Cropping	3.3.0		a0a	1	Cropping - continuous or rotation
				a0g	186	Cropping within controlled flood system; prohibition on the construction of barriers to the movement of water
					187	Cropping within bed of an ephemeral lake; lake is regulated
					188	Cropping within bed of an ephemeral lake; lake is not regulated or above regulation level
				a0a	1A	Cropping - continuous or rotation within a State Forest
					1Q	Cropping - with a fixed irrigation system not used at the time of mapping

Hydro group	ALUM version 6 major category	ALUM V6 code	ALUM V6 detailed description	SCALD code	LUMAP code	Detailed land-use class: version 23
					1Q(1)	Cropping - with a fixed irrigation system not used at the time of mapping; irrigation practice - laser levelled with no apparent tail water reticulation and no on-farm storage of tail water
					1Q(2)	Cropping - with a fixed irrigation system not used at the time of mapping; irrigation practice - contour irrigation
					1Q(3)	Cropping - with a fixed irrigation system not used at the time of mapping; irrigation practice - laser levelled with tail water reticulation and on-farm storage of tail water
					1Q(4)	Cropping - with a fixed irrigation system not used at the time of mapping; irrigation practice - centre pivot
					1Q(5)	Cropping - with a fixed irrigation system not used at the time of mapping; irrigation practice - travel irrigator
					1Q(6)	Cropping - with a fixed irrigation system not used at the time of mapping; irrigation practice - drip irrigation
					1Q(7)	Cropping - with a fixed irrigation system not used at the time of mapping; irrigation practice - sub-surface irrigation
					1Q(8)	Cropping - with a fixed irrigation system not used at the time of mapping; irrigation practice - sprinkler irrigation
					1TI	Cropping - continuous or rotation - with a woody vegetation cover of isolated trees
					1TS	Cropping - continuous or rotation - with a woody vegetation cover of woodland
					1TV	Cropping - continuous or rotation - with a woody vegetation cover of open woodland
				a0g	232	Cropping within an ephemeral wetland (does not include cropping within an ephemeral lake - see classes 186 & 187)
					232TS	Cropping within an ephemeral wetland - with a woody vegetation cover of woodland
		3.3.3	Hay & silage	a0d	84	Fodder crop
		3.3.5	Sugar	a0f	161	Sugar cane
		3.3.8	Legumes	a0a	140	Cropping of legumes for seed - chickpeas, lupins, vetches, field beans
	Channel/aqueduct	6.4.0		f5.	121	Drainage depression in cropping paddock
					121R	Drainage depression in cropping paddock - with more than 30% of ground area having regeneration of native tree species
DryForb	Perennial horticulture	3.4.0		b1e	174	Bamboo plantation (for food)
		3.4.2	Oleaginous fruits	b..	154	Jojoba planting
		3.4.6	Flowers & bulbs	b1.	172	Scented oil production (eg lavender)
		3.4.7	Vegetables & herbs	b1c	203	Perennial horticulture - eg asparagus
	Seasonal horticulture	3.5.0		b1f	37	Seed production including clover seed
		3.5.3	Flowers & bulbs	b1c	116	Cut flowers & herbs
		3.5.4	Vegetables & herbs		39	Vegetables
	Irrigated modified pastures	4.2.0		a0e	88	Turf farming
	Irrigated seasonal horticulture	4.5.3	Irrigated flowers & bulbs	b1.	89	Bulb production for flower trade
Grazing	Managed resource protection	1.2.2	Surface water supply	j9q	58	Foreshores land to State Water dam
					58R	Foreshores land to State Water dam - with more than 30% of ground area having regeneration of native tree species
					58SD	Foreshores land to State Water dam - with a woody vegetation cover of closed shrubland
					58SM	Foreshores land to State Water dam - with a woody vegetation cover of shrubland
					58TM	Foreshores land to State Water dam - with a woody vegetation cover of open forest
					58TS	Foreshores land to State Water dam - with a woody vegetation cover of woodland
	Other minimal use	1.3.0		c2a	231	Areas of dense standing dead trees with the ground cover consisting of volunteer species such as bracken, blady grass and tea tree.
		1.3.2	Stock route	j9c	117	Wide road reserve or TSR, with some grazing
		1.3.4	Rehabilitation	e4.	82	Grassland within mining lease
					82L	Grassland within mining lease with previous evidence of cultivation
					82R	Grassland within mining lease - with more than 30% of ground area having regeneration of native tree species
					82TM	Grassland within mining lease - with a woody vegetation cover of open forest
					82TS	Grassland within mining lease - with a woody vegetation cover of woodland
					82TV	Grassland within mining lease - with a woody vegetation cover of open woodland
	Grazing natural vegetation	2.1.0		c2a	168	Grazing of native vegetation. Grazing of domestic stock on essentially unmodified native vegetation
					168L	Grazing of native vegetation. Grazing of domestic stock on essentially unmodified native vegetation, with previous evidence of cultivation
					168MS	Grazing of native vegetation. Grazing of domestic stock on essentially unmodified native vegetation - with a woody vegetation cover of mallee woodland

Hydro group	ALUM version 6 major category	ALUM V6 code	ALUM V6 detailed description	SCALD code	LUMAP code	Detailed land-use class: version 23
					168R	Grazing of native vegetation. Grazing of domestic stock on essentially unmodified native vegetation - with more than 30% of ground area having regeneration of native tree species
					168SR	Grazing of native vegetation. Grazing of domestic stock on essentially unmodified native vegetation - with more than 30% of ground area having native shrub regeneration
					168TS	Grazing of native vegetation. Grazing of domestic stock on essentially unmodified native vegetation - with a woody vegetation cover of woodland
					170	Grazing - Residual strips (block or linear feature) of native grassland within cultivated paddock. Strips contain scattered to isolated trees only.
					170R	Grazing - Residual strips (block or linear feature) of native grassland within cultivated paddock. Strips contain scattered to isolated trees only - with more than 30% of ground area having native shrub regeneration.
					170TM	Grazing - Residual strips (block or linear feature) of native grassland within cultivated paddock - with a woody vegetation cover of open forest
					170TS	Grazing - Residual strips (block or linear feature) of native grassland within cultivated paddock - with a woody vegetation cover of woodland
					182	Grazing within bed of an ephemeral lake or watercourse; lake or watercourse are not regulated or above regulation level
					183	Rangeland grazing
					183R	Rangeland grazing - with more than 30% of ground area having regeneration of native tree species
					183SR	Rangeland grazing - with more than 30% of ground area having native shrub regeneration
					184	Grazing within controlled flood system; prohibition on the construction of barriers to the movement of water
					189	Grazing within bed of an ephemeral lake; lake is regulated
					201	Low intensity grazing (of native pastures) and low intensity forestry combined
					202	Grazing within controlled flood management systems
					213	Grazing of areas on the western floodplains with heavy clays and subject to prolonged wetness after floods
					217	Grazing pastures within the Macquarie Marshes landscape
					217R	Grazing pastures within the Macquarie Marshes landscape - with more than 30% of ground area having regeneration of native tree species
					218	Grazing of areas on the western floodplains with heavy clays and subject to prolonged wetness after floods; area covered with dense trees
					220	Grazing within bed of an ephemeral lake or watercourse; lake or watercourse are not regulated or above regulation level with a dense shrub or tree cover
					233	Grazing within an ephemeral wetland (does not include cropping within an ephemeral lake - see classes 182 & 189)
					233R	Grazing within an ephemeral wetland - with more than 30% of ground area having regeneration of native tree species
					233TD	Grazing within an ephemeral wetland - with a woody vegetation cover of closed forest
					233TM	Grazing within an ephemeral wetland - with a woody vegetation cover of open forest
					233TS	Grazing within an ephemeral wetland - with a woody vegetation cover of woodland
	Production forestry	2.2.0		nsg	101A	Secondary grassland in forested areas within a State Forest
					45A	Airstrip (local/farmer, grass or bare surface, not sealed)
					47A	Energy corridor within a State Forest
					4A	Volunteer, naturalised, native or improved pastures within a State Forest
					4RA	Volunteer, naturalised, native or improved pastures - with more than 30% of ground area having regeneration of native tree species and within a State Forest
					4SRA	Volunteer, naturalised, native or improved pastures - with more than 30% of ground area having native shrub regeneration and within a State Forest
					5A	Sown, improved perennial pastures within a State Forest
	Production from dryland agriculture and plantations	3.0.0		c2a	137	Firebreak
	Grazing modified pastures	3.2.0			175	Grazing of riparian land
				c2f	205	Grazing land - previously mined for gemstones
				c2b	211	Grazing of areas with water ponding treatments
				g9j	215	Regeneration within sites cleared under a 'window-pane' pattern
				c2b	242	Grazing of areas with chequer-board treatment for scald reclamation
		3.2.1	Native/exotic pasture mosaic		101	Secondary grassland in forested areas
					117G	Wide road reserve or TSR, currently used for intensive grazing

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				c2.	144	Agro forestry
					144E	Agro forestry - exotic species
				c2b	4	Volunteer, naturalised, native or improved pastures
					4L	Volunteer, naturalised, native or improved pastures, with previous evidence of cultivation
					4Q	Volunteer, naturalised, native or improved pastures - with fixed irrigation system not used at the time of mapping
					4Q(1)	Volunteer, naturalised, native or improved pastures - with fixed irrigation system not used at the time of mapping; irrigation practice - laser levelled with no apparent tail water reticulation and no on-farm storage of tail water
					4Q(2)	Volunteer, naturalised, native or improved pastures - with fixed irrigation system not used at the time of mapping; irrigation practice - contour irrigation
					4Q(3)	Volunteer, naturalised, native or improved pastures - with fixed irrigation system not used at the time of mapping; irrigation practice - laser levelled with tail water reticulation and on-farm storage of tail water
					4Q(4)	Volunteer, naturalised, native or improved pastures - with fixed irrigation system not used at the time of mapping; irrigation practice - centre pivot
					4Q(5)	Volunteer, naturalised, native or improved pastures - with fixed irrigation system not used at the time of mapping; irrigation practice - travel irrigator
					4R	Volunteer, naturalised, native or improved pastures - with more than 30% of ground area having regeneration of native tree species
					4RTI	Volunteer, naturalised, native or improved pastures - with more than 30% of ground area having regeneration of native tree species and a woody vegetation cover of isolated trees
					4RTS	Volunteer, naturalised, native or improved pastures - with more than 30% of ground area having regeneration of native tree species and a woody vegetation cover of woodland
					4RTV	Volunteer, naturalised, native or improved pastures - with more than 30% of ground area having regeneration of native tree species and a woody vegetation cover of open woodland
					4SD	Volunteer, naturalised or improved pastures - with a woody vegetation cover of closed shrubland
					4SM	Volunteer, naturalised or improved pastures - with a woody vegetation cover of shrubland
					4SR	Volunteer, naturalised, native or improved pastures - with more than 30% of ground area having native shrub regeneration
					4SS	Volunteer, naturalised or improved pastures - with a woody vegetation cover of open shrubland
					4SV	Volunteer, naturalised or improved pastures - with a woody vegetation cover of sparse shrubland
					4TD	Volunteer, naturalised or improved pastures - with a woody vegetation cover of closed forest
					4TI	Volunteer, naturalised or improved pastures - with a woody vegetation cover of isolated trees
					4TM	Volunteer, naturalised or improved pastures - with a woody vegetation cover of open forest
					4TS	Volunteer, naturalised or improved pastures - with a woody vegetation cover of woodland
					4TV	Volunteer, naturalised or improved pastures - with a woody vegetation cover of open woodland
					4W	Volunteer, naturalised, native or improved pastures - with more than 30% of ground area having exotic weeds
					4WTI	Volunteer, naturalised, native or improved pastures - with more than 30% of ground area having exotic weeds and a woody vegetation cover of isolated trees
					4WTS	Volunteer, naturalised, native or improved pastures - with more than 30% of ground area having exotic weeds and a woody vegetation cover of woodland
					4WTV	Volunteer, naturalised, native or improved pastures - with more than 30% of ground area having exotic weeds and a woody vegetation cover of open woodland
				c2c	5	Sown, improved perennial pastures
					5Q	Sown, improved pastures - with fixed irrigation system not used at the time of mapping
					5Q(1)	Sown, improved pastures - with fixed irrigation system not used at the time of mapping; irrigation practice - laser levelled with no apparent tail water reticulation and no on-farm storage of tail water
					5Q(2)	Sown, improved pastures - with fixed irrigation system not used at the time of mapping; irrigation practice - contour irrigation
					5Q(3)	Sown, improved pastures - with fixed irrigation system not used at the time of mapping; irrigation practice - laser levelled with tail water reticulation and on-farm storage of tail water

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					5Q(4)	Sown, improved pastures - with fixed irrigation system not used at the time of mapping; irrigation practice - centre pivot
					5Q(5)	Sown, improved pastures - with fixed irrigation system not used at the time of mapping; irrigation practice - travel irrigator
					5R	Sown, improved pastures - with more than 30% of ground area having regeneration of native tree species
					5TI	Sown, improved perennial pastures - with a woody vegetation cover of isolated trees
					5TM	Sown, improved perennial pastures - with a woody vegetation cover of open forest
					5TS	Sown, improved perennial pastures - with a woody vegetation cover of woodland
					5TV	Sown, improved perennial pastures - with a woody vegetation cover of open woodland
					5W	Sown, improved perennial pastures - with more than 30% of ground area having exotic weeds
				g6m	68	Recently cleared land (cleared of forest vegetation as yet not covered by crop or pasture)
					68R	Recently cleared land (cleared of forest vegetation as yet not covered by crop or pasture) - with more than 30% of ground area having regeneration of native tree species
				c2a	184L	Grazing within controlled flood system; prohibition on the construction of barriers to the movement of water; evidence of previous cultivation
					189L	Grazing within bed of an ephemeral lake; lake is regulated; evidence of previous cultivation
		3.2.2	Woody fodder plants	c2g	164	Saltbush plantings (for grazing purposes and not as part of a salinity control program)
	Cropping	3.3.3	Hay & silage	a0d	84Q	Fodder crop - with a fixed irrigation system not used at the time of mapping
	Production from dryland agriculture and plantations	3.6.1	Degraded land	c2b	204	Grazing of salt affected land
				c2i^^d	48W	Lantana, blackberry and other exotic weed infested grazing land
				…	83	Degraded land (salt site, eroded area)
					83TV	Degraded land (salt site, eroded area) - with a woody vegetation cover of open woodland
		3.6.3	Land under rehabilitation	e4f	49A	Restored mining lands within a State Forest
		3.6.4	No defined use	j9f	134	Flood refuge (constructed features located within flood prone areas)
	Intensive uses	5.0.0		d3.	141	Rural Quarantine Site (animals, crops, horticulture & pastures)
				h7.	236	Levee for flood protection around house and farm infrastructure
	Residential	5.4.2	Rural residential	h7e	151	Hobby farm (as distinct from rural residential. Small, single blocks no longer used for rural purposes
	Services	5.5.3	Recreation and culture	i8b	130	Rural recreation. Blocks are isolated and not associated with an urban area
	Utilities	5.6.0		c2b	113	Land controlled by Macquarie Generation (Hunter Valley), currently unused or lightly grazed
					113R	Land controlled by Macquarie Generation (Hunter Valley), currently unused or lightly grazed - with more than 30% of ground area having regeneration of native tree species
					113TM	Land controlled by Macquarie Generation (Hunter Valley), currently unused or lightly grazed - with a woody vegetation cover of open forest
					113TS	Land controlled by Macquarie Generation (Hunter Valley), currently unused or lightly grazed - with a woody vegetation cover of woodland
				j9a	47	Energy corridor
	Transport and communication	5.7.0		j9j	45	Airstrip (local/farmer, grass or bare surface, not sealed)
	Channel/aqueduct	6.4.0		f5.	181	Bore drain (not longer used)
				j9f	185	Waterway associated with controlled flooding/opportunistic cropping systems
Irrforb10	Irrigated perennial horticulture	4.4.0		b1e	174I	Bamboo plantation (for food) - irrigated
		4.4.2	Irrigated oleaginous fruits	b..	154I	Jojoba planting - irrigated
		4.4.7	Irrigated vegetables & herbs	b1c	203I	Perennial horticulture - eg asparagus - irrigated
	Irrigated seasonal horticulture	4.5.4			39I	Vegetables - irrigated
					39I(1)	Vegetables - irrigated: irrigation practice - laser levelled with no apparent tail water reticulation and no on-farm storage of tail water
					39I(4)	Vegetables - irrigated; irrigation practice - centre pivot
					39I(8)	Vegetables - irrigated; irrigation practice; irrigation practice - sprinkler irrigation
					39I(9)	Vegetables - irrigated; irrigation practice - furrow irrigation
Irrforb15	Irrigated modified pastures	4.2.0		a0e	88I	Turf farming - irrigated
Irrforb5	Irrigated perennial horticulture	4.4.6	Irrigated flowers & bulbs	b1.	172I	Scented oil production (eg lavender) - irrigated
	Irrigated seasonal horticulture	4.5.3		b1c	116I	Cut flowers & herbs - irrigated
					116I(5)	Cut flowers & herbs - irrigated: irrigation practice - travel irrigator

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Irrig10	Irrigated cropping	4.3.0		a0c	1I(3)	Cropping - continuous or rotation - irrigated; irrigation practice - laser levelled with tail water reticulation and on-farm storage of tail water
					1I(4)	Cropping - continuous or rotation - irrigated; irrigation practice - centre pivot
					1I(5)	Cropping - continuous or rotation - irrigated; irrigation practice - travel irrigator
		4.3.5	Irrigated sugar	a0f	161I	Sugar cane - irrigated
Irrig15	Services	5.5.3	Recreation and culture	i8c	222	Golf courses, greens and fairways with internal housing allotments
	Waste treatment and disposal	5.9.5	Sewage	c2f08	29I	Areas irrigated with effluent from sewage disposal ponds
Irrig20	Cropping	3.3.6	Cotton	a0a	129	Cotton
	Irrigated cropping	4.3.1	Irrigated cereals	a0c	40	Rice
					40I	Irrigated rice
					40I(2)	Irrigated rice; irrigation practice - contour irrigation
		4.3.6	Irrigated cotton	aoc	129I	Cotton - irrigated
					129I(1)	Cotton - irrigated; irrigation practice - laser levelled with no apparent tail water reticulation and no on-farm storage of tail water
					129I(3)	Cotton - irrigated; irrigation practice - laser levelled with tail water reticulation and on-farm storage of tail water
					129I(5)	Cotton - irrigated; irrigation practice - travel irrigator
Irrig5	Production from dryland agriculture and plantations	3.0.0		c2b	111	Grassland areas (eg mown/slashed grass areas) within vineyards
	Grazing modified pastures	3.2.2	Woody fodder plants	c2g	164Q	Saltbush plantings (for grazing purposes and not as part of a salinity control program) - with a fixed irrigation system not used at the time of mapping
	Irrigated modified pastures	4.2.0		c2f	6	Irrigated pastures
					6(1)	Irrigated pastures; irrigation practice - laser levelled with no apparent tail water reticulation and no on-farm storage of tail water
					6(2)	Irrigated pastures; irrigation practice - contour irrigation
					6(3)	Irrigated pastures; irrigation practice - laser levelled with tail water reticulation and on-farm storage of tail water
					6(4)	Irrigated pastures; irrigation practice - centre pivot
					6(5)	Irrigated pastures; irrigation practice - travel irrigator
					6(8)	Irrigated pastures; irrigation practice - sprinkler irrigation
	Grazing modified pastures	4.2.1	Irrigated woody fodder plants	c2g	164I(1)	Saltbush plantings (for grazing purposes and not as part of a salinity control program): irrigation practice - laser levelled with no apparent tail water reticulation and no on-farm storage of tail water
					164I(3)	Saltbush plantings (for grazing purposes and not as part of a salinity control program); irrigation practice - laser levelled with tail water reticulation and on-farm storage of tail water
	Irrigated cropping	4.3.0		a0c	1I	Cropping - continuous or rotation - irrigated
					1I(1)	Cropping - continuous or rotation - irrigated; irrigation practice - laser levelled with no apparent tail water reticulation and no on-farm storage of tail water
					1I(2)	Cropping - continuous or rotation - irrigated; irrigation practice - contour irrigation
					1I(6)	Cropping - continuous or rotation - irrigated; irrigation practice - drip irrigation
					1I(7)	Cropping - continuous or rotation - irrigated; irrigation practice - sub-surface irrigation
					1I(8)	Cropping - continuous or rotation - irrigated; irrigation practice - sprinkler irrigation
		4.3.3	Irrigated hay & silage	a0d	84I	Fodder crop - irrigated
					84I(1)	Fodder crop - irrigated: irrigation practice - laser levelled with no apparent tail water reticulation and no on-farm storage of tail water
		4.3.8	Irrigated legumes	a0c	140I	Cropping of legumes for seed - chickpeas, lupins, vetches, field beans - irrigated
					140I(3)	Cropping of legumes for seed - chickpeas, lupins, vetches, field beans - irrigated; irrigation practice - laser levelled with tail water reticulation and on-farm storage of tail water
	Intensive animal production	5.2.0		d3.	90	Horse stud and/or horse breeding facilities
	Waste treatment and disposal	5.9.0		f5i	62	Irrigation from abattoir and other industry
Irrig6	Production from dryland agriculture and plantations	3.0.0		c2b	111TS	Grassland areas (eg mown/slashed grass areas) within vineyards - with a woody vegetation cover of woodland
IrrTree10	Irrigated cropping	4.3.2	Irrigated beverage & spice crops	b1e (17 or 18)	173I	Tea and Coffee plantation - irrigated
	Irrigated perennial horticulture	4.4.0		b1i	126I	Truffle production - irrigated
				b1e (20)	176I	Tea Tree Plantation
		4.4.1	Irrigated tree fruits	b1a11	102I	Banana plantation - irrigated
				b1a	2I	Orchard - tree fruits - irrigated
					2I(9)	Orchard - tree fruits - irrigated; irrigation practice - furrow irrigation
		4.4.3	Irrigated tree nuts	b1a14	104I	Pecan, macadamia and other nuts - irrigated
IrrTree5		4.4.1	Irrigated tree fruits	b1a	2I(6)	Orchard - tree fruits - irrigated; irrigation practice - drip irrigation
		4.4.2	Irrigated oleaginous fruits		38I	Olives - irrigated
					38I(6)	Olives - irrigated; irrigation practice - drip irrigation

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					38I(9)	Olives - irrigated; irrigation practice - furrow irrigation
		4.4.3	Irrigated tree nuts	b1a14	104I(6)	Pecan, macadamia and other nuts - irrigated; irrigation practice - drip irrigation
		4.4.4	Irrigated vine fruits	b1b	3I	Vineyard - grape and other vine fruits - irrigated
					3I(6)	Vineyard - grape and other vine fruits - irrigated; irrigation practice - drip irrigation
					3I(9)	Vineyard - grape and other vine fruits - irrigated; irrigation practice - furrow irrigation
River	Grazing natural vegetation	2.1.0		c2a	216	Flood runners in western NSW. (Vegetation is indicative of a more prolonged period of inundation or wetness.)
					216R	Flood runners in western NSW - with more than 30% of ground area having regeneration of native tree species
					216TS	Flood runners in western NSW - with a woody vegetation cover of woodland
	Production forestry	2.2.0		nsg	8A	Farm dam within a State Forest
	Intensive animal production	5.2.6	Aquaculture	d3e	34	Aquaculture - fish, prawn, yabby or beach worm farm
	Services	5.5.0		f5c	150	Training facility for marine pilots
	Transport and communication	5.7.4	Ports and water transport	f5d	100	Marina
				f5.	196	Mooring or jetty for house boat
					197	Boat ramp
	Waste treatment and disposal	5.9.5	Sewage	j9k	29	Sewage disposal ponds
	Lake	6.1.0		f5a	105	Coastal lake
				f5.	76	Lagoon or inland lake
					76TD	Lagoon or inland lake - with a woody vegetation cover of closed forest
					76TM	Lagoon or inland lake - with a woody vegetation cover of open forest
					76TS	Lagoon or inland lake - with a woody vegetation cover of woodland
		6.1.1	Lake - conservation		86	Inland salt lake
	Reservoir or dam	6.2.0		f5g	132	Irrigation dam
					132(Q)	Irrigation dam - not used at the time of mapping
					132Y	Irrigation dam - under construction or constructed between the date of the satellite imagery and the date of the aerial photography
					8	Farm dam
				f5.	85	Temporary water storage area (eg rice farming - opportunistic storage of water in natural depressions
		6.2.1	Water storage and treatment	f5g	123	Ancillary (saddle) wall to reservoir
					46	Reservoir
					46A	Reservoir within a State Forest
					80	Water supply pressure reservoir including water filtration plant
		6.2.3	Evaporation basin	f5i	207	Disposal dam, depression or lake bed for irrigation tail water
				f5j	91	Evaporation basin
		6.2.4	Effluent pond	f5i	124	Effluent ponds from intensive animal industries
	River	6.3.0		g6l	108	River and riparian vegetation where the river channel is filled by more than 50% of phragmites or cumbungi
					12	River, creek or other incised drainage feature; includes cowals in western NSW
					12A	River, creek or other incised drainage feature within a State Forest; includes cowals in western NSW
					12SD	River, creek or other incised drainage feature; includes cowals in western NSW - with a woody vegetation cover of closed shrubland
					12SM	River, creek or other incised drainage feature; includes cowals in western NSW - with a woody vegetation cover of shrubland
					12TI	River, creek or other incised drainage feature; includes cowals in western NSW - with a woody vegetation cover of isolated trees
					12TM	River, creek or other incised drainage feature; includes cowals in western NSW - with a woody vegetation cover of open forest
					12TS	River, creek or other incised drainage feature; includes cowals in western NSW - with a woody vegetation cover of woodland
					12TV	River, creek or other incised drainage feature; includes cowals in western NSW - with a woody vegetation cover of open woodland
				c2ew	131	Flood chute (flood runners that are filled with water during and after floods) and designated floodway in irrigation districts, localities
				f5.	219	River diversion work (inland, not coastal)
				f5p	51	River training work
		6.3.3	River - intensive use	f5c	107	Canal (canal estate, navigation canal)
	Channel/aqueduct	6.4.0		f5.	180	Bore drain (active)
		6.4.1	Supply channel/aqueduct	j9q	128	Water supply channel (non irrigation system eg Sydney water supply)
				j9f	136	Irrigation supply channel
					136Y	Irrigation supply channel - under construction or constructed between the date of the satellite imagery and the date of the aerial photography

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		6.4.2	Drainage channel/aqueduct	f5h	57	Drainage channel (from irrigation system or a channel draining a swamp; base of channel is lined)
					79	Drainage or water supply channel - base of channel is not lined
	Estuary/coastal waters	6.6.0		k0o	106	Estuarine waters
		6.6.2	Estuary/coastal waters - production	k..	158	Submerged oyster leases
Sand	Managed resource protection	1.2.4	Landscape	f5.	99	Foreshore protection - vegetated fore dune (coastal feature)
	Other minimal use	1.3.4	Rehabilitation	e4f	95	Restored sand mining area
	Services	5.5.3	Recreation and culture	f5n	64	Beach
	Estuary/coastal waters	6.6.0			96	Sand spit/estuarine sand island
Scrub	Nature conservation	1.1.7	Other conserved area	i8.	198	Crown reserve with public access
				j9o	27	Private conservation agreement
	Managed resource protection	1.2.2	Surface water supply	j9r	59	Foreshores or reserved land to water supply dam (Sydney Water, Hunter Water, SMHEA or Public Works Dam)
	Other minimal use	1.3.3	Remnant native cover	g6z	13	Native forest - filter strips in softwood plantation
					13A	Native forest - filter strips in softwood plantation and within a State Forest
					13W	Native forest - filter strips in softwood plantation with heavy weed infestation (mostly blackberry)
				g6n	66	Recently burnt areas (woody vegetation)
				g6a	9	Native forest
		1.3.4	Rehabilitation	g6j	11SR	Native woody species - regeneration comprising shrub or understorey species
					11TV	Native forest - regeneration - with a woody vegetation cover of open woodland
				g6t	162	Dense shrub growth - limited to nil grazing capacity
				e4.	214	Woodlands within mining lease
	Grazing natural vegetation	2.1.0		c2a	168TM	Grazing of native vegetation. Grazing of domestic stock on essentially unmodified native vegetation - with a woody vegetation cover of open forest
	Production forestry	2.2.0		nsg	41A	Hardwood plantation within a State Forest
		2.2.1	Wood production	g6b	10	Native forest - logged
					10A	Native forest - logged and within a State Forest
				g6j	11A	Native forest - regeneration and within a State Forest
				g6a	9A	Native forest and within a State Forest
	Plantation forestry	3.1.0		g6x	15	Softwood plantation - nursery
		3.1.1	Hardwood production	g6g	177	Rainforest plantation
					41	Hardwood plantation
		3.1.2	Softwood production	g6e	14	Softwood plantation
					142	Pine planting interspersed amongst eucalypt/shrub forest and/or areas with poor to nil establishment
					14A	Softwood plantation and within a State Forest
					206	Pine plantation - previously used for mining or quarrying activity
				g6p	52	Poplar plantation
		3.1.4	Environmental	g6c	24	Windbreak or tree corridor
					24R	Windbreak or tree corridor - with more than 30% of ground area having regeneration of native tree species
					24TS	Windbreak or tree corridor - with a woody vegetation cover of woodland
					24TV	Windbreak or tree corridor - with a woody vegetation cover of open woodland
				g6d	25	Tree lot
				g6c	25E	Tree lot - exotic species
				g6d	25N	Tree lot - native species
					25Q(1)	Tree lot - with a fixed irrigation system not used at the time of mapping; irrigation practice - laser levelled with no apparent tail water reticulation and no on-farm storage of tail water
					25TV	Tree lot - with a woody vegetation cover of open woodland
	Grazing modified pastures	3.2.1	Native/exotic pasture mosaic	g6k	70	Woodland (unmodified native vegetation)
	Production from dryland agriculture and plantations	3.6.1	Degraded land	g6i	110	Forest dominated by camphor laurel
		3.6.3	Land under rehabilitation	g6j	11	Native forest - regeneration
	Irrigated plantation forestry	4.1.0		g6x	15I	Softwood plantation - nursery - irrigated
		4.1.1	Irrigated hardwood production	g6g	41I	Hardwood plantation - irrigated
		4.1.2	Irrigated softwood production	g6w	14I	Softwood plantation - irrigated
		4.1.4	Irrigated environmental	g6d	25I	Tree lot - irrigated
					25I(1)	Tree lot - irrigated; irrigation practice - laser levelled with no apparent tail water reticulation and no on-farm storage of tail water
					25I(3)	Tree lot - irrigated; irrigation practice - laser levelled with tail water reticulation and on-farm storage of tail water
	Residential	5.4.3	Rural living	h7e	152	Small to medium forested or wilderness blocks with isolated residential buildings. (Rural residential but the forested or wilderness feature of the block is worth noting.)
	Services	5.5.4	Defence facilities	j9l	32	Defence facility
	River	6.3.0		g6i	30	Riparian vegetation - exotic species (principally willow)
Treehort	Plantation forestry	3.1.3	Other forest production	g6o	178	Lemon Myrtle plantation

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	Cropping	3.3.2	Beverage & spice crops	b1e (17 or 18)	173	Tea and Coffee plantation
	Perennial horticulture	3.4.0		b1.	120	Eucalyptus oil plantation
				b1i	126	Truffle production
				b1e (20)	176	Tea Tree Plantation - irrigated
				b1g	35	Eucalypts and other Australian native species for cut flower arrangements
				g6o	69	Native shrub plantation (eg tea tree)
		3.4.1	Tree fruits	b1a11	102	Banana plantation
				b1a	2	Orchard - tree fruits
		3.4.2	Oleaginous fruits		38	Olives
		3.4.3	Tree nuts	b1a14	104	Pecan, macadamia and other nuts
		3.4.4	Vine fruits	b1b	3	Vineyard - grape and other vine fruits
	Production from dryland agriculture and plantations	3.6.2	Abandoned land	b1.	87	Abandoned orchard and vine lands; trees/vines not maintained and may be dying; regrowth of native shrubs and trees is occurring
	Irrigated perennial horticulture	4.4.0			120I	Eucalyptus oil plantation - irrigated
				b1g	35I	Eucalypts and other Australian native species for cut flower arrangements - irrigated
Urban	Production forestry	2.2.0		nsg	16A	Industrial/commercial within a State Forest
					31A	Urban recreation within a State Forest
					92A	Government and private facilities - gaol, training centre, school, religious institutions & training centres, religious retreats within a State Forest
	Perennial horticulture	3.4.4	Vine fruits	b1c	118	Vineyards with residential facilities scattered amongst plantings (hobby, retreat or tourist feature)
	Irrigated perennial horticulture	4.4.4	Irrigated vine fruits		118I	Vineyards with residential facilities scattered amongst plantings (hobby, retreat or tourist feature) - irrigated
	Intensive uses	5.0.0		h7.	139	Farm Infrastructure - house, machinery & storage sheds and garden areas
					200	Irrigation farm infrastructure; miscellaneous lands within farms including access roads, bund walls, buildings and services
	Intensive horticulture	5.1.0		b1d	42	Nursery
					42I	Nursery - irrigated
		5.1.1	Shade houses	b1.	81	Shade house or glass house (includes hydroponic use)
	Intensive animal production	5.2.0		d..	159	Dog kennel, dog run for greyhounds
				d3.	224	Abandoned poultry shed
		5.2.1	Dairy	d3a	26d	Intensive animal production -dairy shed
		5.2.4	Poultry	d3b	26c	Intensive animal production - poultry
		5.2.5	Pigs	d3a	26p	Intensive animal production - piggery
	Manufacturing and industrial	5.3.0		h7.	147	Abandoned urban or industrial area and site is locked up e.g. Glen Alice
				h7a	165	Sawmill
				a1.	234	Storage site for agricultural chemicals and products (eg fertiliser dumps, cotton bunkers and temporary grain storages)
					235	Agricultural industry in a rural location eg cotton gin (See also class 53.)
				b1h	53	Building associated with horticultural industry (winery, packing shed)
				h7a	60	Abattoir
	Residential	5.4.0		h..	160	Area recently under development for urban, commercial and/or industrial uses - infrastructure in place but no building activity
				h7d	94	Caravan park or mobile home village
		5.4.1	Urban residential	h7b	17	Residential
					17TM	- with a woody vegetation cover of open forest
					17TS	Residential - with a woody vegetation cover of woodland
				h7.	208	Aboriginal settlement
				h7b	223	Internal housing allotments within golf course complexes
		5.4.2	Rural residential	h7e	115	Rural residential within vineyard
				h7c	171	Alternate life style community under multiple occupancy
				h7e	18	Rural residential
					18R	Rural residential - with more than 30% of ground area having regeneration of native tree species
					18TI	Rural residential - with a woody vegetation cover of isolated trees
		5.4.3	Rural living		18TM	Rural residential - with a woody vegetation cover of open forest
					18TS	Rural residential - with a woody vegetation cover of woodland
	Services	5.5.0		i8d	149	Resort style private land use
				h7a	16	Industrial/commercial
				j9g	50	Cemetery
		5.5.2	Public services	h7.	77	University or other tertiary institution
					92	Government and private facilities - gaol, training centre, school, religious institutions & training centres, religious retreats
		5.5.3	Recreation and culture	i8c	155	Surf club and/or coastal car parking facilities
					31	Urban recreation
					31I	Urban recreation - irrigated
					31TS	Urban recreation - with a woody vegetation cover of woodland
				i8d	75	Tourist development

Hydro group	ALUM version 6 major category	ALUM V6 code	ALUM V6 detailed description	SCALD code	LUMAP code	Detailed land-use class: version 23
				nsg	94A	Caravan park or mobile home village within a State Forest
		5.5.5	Research facilities	h7.	61	Research facility
	Utilities	5.6.0		f5.	190	Pump site, urban or irrigation supply
		5.6.1	Electricity generation/transmission	j..	112	Electricity generation (power station and associated stockpiles, hydro-electric plants
				c2b90	127	Green power site (eg wind turbines)
				j..	153	Disused power station
				j9.	93	Electricity substation
		5.6.2	Gas treatment, storage and transmission	j..	163	Gas supply facility
	Transport and communication	5.7.0		j9b	192	Roadside rest area
		5.7.1	Airports/aerodromes	j9n	156	Glider field for recreational activities
				j9j	36	Aerodrome/airport
		5.7.2	Roads	j9c	19	Road or road reserve
		5.7.3	Railways	j9d	20	Railway
					20V	Railway - track no longer used
		5.7.5	Navigation and communication	j9h	103	Communications facility
					72	Trig station or beacon
	Mining	5.8.0		e..	114	Conveyor Belt
		5.8.1	Mines	e4d	212	Mining infrastructure - buildings, sheds, conveyor belts, tanks and general plant associated with mining operations
	Waste treatment and disposal	5.9.5	Sewage	f5.	195	Pump out site for house boat effluent
	Reservoir or dam	6.2.3	Evaporation basin	j9.	194	Salt interception pump site
	Estuary/coastal waters	6.6.3	Estuary/coastal waters - intensive use	d3e	98	Oyster spoil & sheds, but not submerged leases
Wetland	Grazing natural vegetation	2.1.0		c2a	241	Swampy landscape in western drainage system
	Production forestry	2.2.0		nsg	54A	Mangrove within a State Forest
					55A	Mudflat within a State Forest
	Reservoir or dam	6.2.0		f5.	122	Constructed wetland for conservation or water improvement
	River	6.3.0		c2a	138	Prior stream
					138TM	Prior stream - with a woody vegetation cover of open forest
					138TS	Prior stream - with a woody vegetation cover of woodland
				f5m	65	River gravel deposit
	Marsh/wetland	6.5.0		k0a	21	Floodplain swamp - back swamp
				k0b	22	Floodplain swamp - billabong
				f5l	23	Swamp
					23R	Swamp - with more than 30% of ground area having regeneration of native tree species
					23TD	Swamp - with a woody vegetation cover of closed forest
					23TM	Swamp - with a woody vegetation cover of open forest
					23TS	Swamp - with a woody vegetation cover of woodland
				k0o	56	Coastal marsh/estuarine swamp
				k0j	73	Dunal swamp
				k0b	74	Floodplain swamp
					74TM	Floodplain swamp - with a woody vegetation cover of open forest
					74TS	Floodplain swamp - with a woody vegetation cover of woodland
	Estuary/coastal waters	6.6.0		g6q	54	Mangrove
				f5o	55	Mudflat

Appendix 6

Land-use classes for pollutant export models

Pollutant land-use class	Hydrological land-use class
Forest	Conservation
	Scrub
Cleared land	Cleared
Urban	Urban
Crops	Cropping
Grazing	Grazing
Irrigated pasture	Irrig5
	Irrig10
Dry forb	Dryforb
	Treehort
Irrigated forb	Irrigforb5
	Irrigforb10
	Irrigtree5
	Irrigtree 10
Other	River
	Sand
	Wetland
Not used	Irrforb15
	Irrig6
	Irrig15
	Irrig20

Appendix 7

Current catchment land-uses

	Land-use (ha)														
		Disturbed													
Estuary	Undisturbed forest	Cleared	Urban	Crops	Grazing	Irrigated pasture	Dry forb	Irrigated forb	Other	Total disturbed	% disturbed	Total area (ha): A	Total area (ha) from Table 1: B	Ratio A/B	Reason for difference
Tweed River	45678	206	12287	7179	36141	715	1846	195	1806	58569	55.2	106053	107748	0.98	
Cudgen Creek	2052	58	879	227	2641	3	436	494	121	4738	68.6	6911	7076	0.98	
Cudgera Creek	2473	26	721	604	1860	0	332	9	70	3552	58.3	6095	6103	1.00	
Mooball Creek	3433	9	1181	1294	3831	44	717	18	453	7094	64.6	10980	10968	1.00	
Brunswick River	6562	24	4770	676	9906	22	709	10	192	16117	70.5	22871	22993	0.99	
Belongil Creek	1212	8	661	0	1082	0	0	0	97	1751	57.2	3060	3068	1.00	
Tallow Creek	152	5	306	0	52	0	0	0	18	363	68.1	533	546	0.98	
Broken Head Creek	0	0	1	0	0	0	0	0	0	1	100.0	1	117	0.01	Incorrect land-use extraction
Richmond River	286174	631	35457	26829	302121	4244	16870	1730	14910	387882	56.3	688966	690022	1.00	
Salty Lagoon	367	0	0	0	0	0	0	0	0	0	0.0	367	373	0.98	
Evans River	5773	23	556	97	926	0	0	0	295	1602	20.9	7670	7850	0.98	
Jerusalem Creek	4463	0	0	0	114	0	0	0	262	114	2.4	4839	4864	0.99	
Clarence River	1305310	1748	21821	20342	814999	538	1848	1326	42668	862622	39.0	2210600	2218742	1.00	
Lake Arragan	945	0	0	0	0	0	0	0	0	0	0.0	945	1025	0.92	Estuary excluded from map
Cakora Lagoon	1004	0	17	0	11	0	0	0	31	28	2.6	1063	1269	0.84	Incorrect land-use extraction
Sandon River	13053	0	7	0	94	0	0	0	43	101	0.8	13197	13414	0.98	
Wooli Wooli River	17580	0	121	0	106	0	3	0	365	230	1.3	18175	18374	0.99	
Station Creek	2093	0	0	0	5	0	0	0	0	5	0.2	2098	2162	0.97	
Corindi River	11493	36	184	0	2449	0	122	27	276	2818	19.3	14587	14834	0.98	
Pipe Clay Creek	25	0	76	0	4	0	0	0	8	80	70.8	113	164	0.69	Incorrect land-use extraction
Arrawarra Creek	1407	0	149	0	80	0	35	0	98	264	14.9	1769	1795	0.99	
Darkum Creek	149	0	108	0	222	0	134	0	1	464	75.6	614	617	1.00	
Woolgoolga Lake	1232	0	392	0	222	0	231	3	14	848	40.5	2094	2118	0.99	
Flat Top Point Creek	10	0	78	0	21	0	65	5	58	169	71.3	237	259	0.91	Estuary excluded from map
Hearns Lake	160	7	49	0	122	0	259	0	61	437	66.4	658	675	0.98	
Moonee Creek	2445	0	670	0	752	0	175	0	40	1597	39.1	4082	4152	0.98	
Pine Brush Creek	227	0	92	0	87	0	324	0	3	503	68.6	733	735	1.00	
Coffs Creek	381	10	1136	0	255	0	583	0	45	1984	82.3	2410	2450	0.98	
Boambee Creek	1531	39	1451	0	891	0	642	0	305	3023	62.2	4859	4948	0.98	
Bonville Creek	6839	7	1115	0	3004	0	234	0	167	4360	38.4	11366	11513	0.99	
Bundageree Creek	783	0	166	0	42	0	0	0	7	208	20.8	998	1013	0.99	
Bellinger River	93393	7	1425	35	13572	4	160	3	1498	15206	13.8	110097	110849	0.99	
Dalhousie Creek	454	0	57	0	46	0	14	40	10	157	25.3	621	633	0.98	
Oyster Creek	1175	0	101	0	380	0	24	0	20	505	29.7	1700	1692	1.00	
Deep Creek	5246	2	221	0	2941	0	415	5	313	3584	39.2	9143	9153	1.00	
Nambucca River	83073	41	1810	4	41617	109	517	30	3917	44128	33.7	131118	131157	1.00	
Macleay River	475612	501	23471	3658	604676	24	515	500	22143	633345	56.0	1131100	1131867	1.00	
South West Rocks Creek	222	4	116	0	6	0	0	0	114	126	27.3	462	461	1.00	
Saltwater Creek (Frederickton)	560	8	377	0	69	0	21	0	101	475	41.8	1136	1140	1.00	
Korogoro Creek	851	4	79	0	7	0	0	0	44	90	9.1	985	979	1.01	
Killick Creek	457	0	95	0	157	0	0	0	111	252	30.7	820	822	1.00	
Goolawah Lagoon	134	0	16	0	13	0	0	0	241	29	7.2	404	408	0.99	
Hastings River	248146	226	9035	347	100250	34	1444	113	8824	111449	30.3	368419	368853	1.00	
Cathie Creek	8390	0	1895	0	1560	0	8	0	51	3463	29.1	11904	11925	1.00	
Duchess Gully	414	0	291	0	263	0	14	0	70	568	54.0	1052	1062	0.99	

	Land-use (ha)														
		Disturbed													
Estuary	Undisturbed forest	Cleared	Urban	Crops	Grazing	Irrigated pasture	Dry forb	Irrigated forb	Other	Total disturbed	% disturbed	Total area (ha): A	Total area (ha) from Table 1: B	Ratio A/B	Reason for difference
Camden Haven River	42716	57	2526	216	13398	0	116	1	2993	16314	26.3	62023	62115	1.00	
Manning River	458277	644	12018	2330	327327	0	50	0	13898	342369	42.0	814544	815922	1.00	
Khappinghat Creek	6381	3	1267	0	1301	0	3	0	109	2574	28.4	9064	9192	0.99	
Black Head Lagoon	7	0	56	0	23	0	0	0	0	79	91.9	86	200	0.43	Incorrect land-use extraction
Wallis Lake	57790	208	7836	174	50031	0	25	0	13247	58274	45.1	129311	129561	1.00	
Smiths Lake	1948	6	737	0	94	0	0	0	1008	837	22.1	3793	3798	1.00	
Myall River	71760	9	3367	7	14056	0	0	0	4033	17439	18.7	93232	93393	1.00	
Karuah River	92195	44	2470	30	47912	0	0	0	3674	50456	34.5	146325	146630	1.00	
Tilligerry Creek	6295	213	1659	0	2114	0	125	0	3096	4111	30.4	13502	13522	1.00	
Port Stephens	20551	105	4450	0	3845	0	0	0	14063	8400	19.5	43014	43114	1.00	
Hunter River	790376	21825	55968	39970	1176048	3151	616	7924	36078	1305502	61.2	2131956	2141399	1.00	
Glenrock Lagoon	0	0	0	0	0	0	0	0	0	0	0.0	0	742	0.00	Incorrect land-use extraction
Lake Macquarie	34914	1728	11967	0	10493	22	134	0	1478	24344	40.1	60736	71848	0.85	Estuary excluded from map
Middle Camp Creek	423	0	48	0	22	0	0	0	7	70	14.0	500	503	1.00	
Moonee Beach Creek	284	59	6	0	0	0	0	0	1	65	18.6	350	348	1.00	
Tuggerah Lake	46372	312	9791	0	12540	119	800	0	1353	23562	33.1	71287	79523	0.90	Estuary excluded from map
Wamberal Lagoon	141	0	424	0	11	0	0	0	6	435	74.7	582	634	0.92	Estuary excluded from map
Terrigal Lagoon	67	0	695	0	103	0	2	0	17	800	90.5	884	922	0.96	Estuary excluded from map
Avoca Lake	407	7	382	0	239	0	8	0	37	636	58.9	1080	1144	0.94	Estuary excluded from map
Cockrone Lake	406	0	187	0	77	0	0	0	14	264	38.6	684	718	0.95	Estuary excluded from map
Brisbane Water	6920	92	7100	0	760	0	32	0	413	7984	52.1	15317	18089	0.85	Estuary excluded from map
Hawkesbury River	1542787	9697	42847	1209	533656	6622	158	1997	24691	596186	27.6	2163664	2173856	1.00	
Pittwater	3442	79	587	0	0	0	0	0	0	666	16.2	4108	6916	0.59	Incomplete land-use map
Broken Bay	823	65	308	0	0	0	0	0	0	373	31.2	1196	1293	0.92	Incomplete land-use map
Narrabeen Lagoon	3886	73	1446	0	0	0	0	0	0	1519	28.1	5405	5473	0.99	
Dee Why Lagoon	28	20	884	0	0	0	0	0	0	904	97.0	932	457	2.04	Incorrect land-use extraction
Curl Curl Lagoon	0	0	202	0	0	0	0	0	0	202	100.0	202	472	0.43	Incorrect land-use extraction
Manly Lagoon	319	39	892	0	0	0	0	0	0	931	74.5	1250	1734	0.72	Incorrect land-use extraction
Middle Harbour Creek	2167	0	5376	0	121	0	0	0	363	5497	68.5	8027	8309	0.97	
Lane Cove River	2225	0	7076	0	265	0	0	0	240	7341	74.9	9806	9833	1.00	
Parramatta River	2601	153	22706	0	0	0	0	0	1098	22859	86.1	26558	26610	1.00	
Port Jackson	614	212	4165	0	0	0	0	0	364	4377	81.7	5355	5574	0.96	Incomplete land-use map
Cooks River	662	311	9786	0	67	0	0	0	0	10164	93.9	10826	11177	0.97	
Georges River	36950	20133	30276	0	5367	7	13	112	1893	55908	59.0	94751	95750	0.99	
Botany Bay	1926	433	2634	0	9	0	0	0	0	3076	61.5	5002	5793	0.86	Incomplete land-use map
Port Hacking	13105	209	2442	0	169	2	0	4	4	2826	17.7	15935	16577	0.96	Incomplete land-use map
Wattamolla Creek	577	0	0	0	0	0	0	0	0	0	0.0	577	808	0.71	Incomplete land-use map
Hargraves Creek	120	1	74	0	0	0	0	0	1	75	38.3	196	202	0.97	
Stanwell Creek	650	11	60	0	29	0	0	0	13	100	13.1	763	769	0.99	
Flanagans Creek	123	5	70	0	0	0	0	0	1	75	37.7	199	202	0.98	
Woodlands Creek	99	3	65	0	33	0	0	0	0	101	50.5	200	201	1.00	
Slacky Creek	147	3	138	0	20	0	0	0	3	161	51.8	311	308	1.01	
Bellambi Gully	80	62	408	0	93	0	0	0	2	563	87.3	645	647	1.00	
Bellambi Lake	0	0	124	0	0	0	0	0	9	124	93.2	133	134	1.00	
Towradgi Creek	277	15	550	0	12	0	0	0	3	577	67.3	857	860	1.00	
Fairy Creek	515	20	1483	0	58	0	0	0	3	1561	75.1	2079	2076	1.00	
Allans Creek	1274	96	2980	0	767	0	0	0	29	3843	74.7	5146	5163	1.00	
Port Kembla	28	27	543	0	84	0	0	0	2	654	95.6	684	625	1.09	Incorrect land-use extraction
Lake Illawarra	7240	402	5966	0	9707	144	3	12	3884	16234	59.3	27358	27427	1.00	
Elliott Lake	84	0	706	0	182	0	0	0	29	888	88.7	1001	1005	1.00	

	Land-use (ha)														
		Disturbed													
Estuary	Undisturbed forest	Cleared	Urban	Crops	Grazing	Irrigated pasture	Dry forb	Irrigated forb	Other	Total disturbed	% disturbed	Total area (ha): A	Total area (ha) from Table 1: B	Ratio A/B	Reason for difference
Minnamurra River	3812	143	881	0	6732	32	8	14	273	7810	65.7	11895	11919	1.00	
Spring Creek	16	6	96	0	458	0	0	0	7	560	96.1	583	588	0.99	
Munna Munnora Creek	47	0	70	0	244	0	0	0	3	314	86.3	364	363	1.00	
Werri Lagoon	371	0	97	0	1168	0	5	0	19	1270	76.5	1660	1663	1.00	
Crooked River	382	22	252	0	2461	0	0	29	71	2764	85.9	3217	3227	1.00	
Shoalhaven River	436317	990	30495	355	227379	308	408	259	12755	260194	36.7	709266	711772	1.00	
Wollumboola Lake	3069	3	129	0	165	0	0	0	675	297	7.3	4041	4046	1.00	
Currarong Creek	1173	0	47	0	3	0	0	0	12	50	4.0	1235	1237	1.00	
Cararma Creek	828	1	8	0	17	0	0	0	54	26	2.9	908	919	0.99	
Wowly Gully	436	0	97	0	3	0	0	0	83	100	16.2	619	619	1.00	
Callala Creek	1499	0	279	0	0	0	0	0	196	279	14.1	1974	1979	1.00	
Currambene Creek	10182	51	1955	0	3341	6	2	15	644	5370	33.2	16196	16224	1.00	
Moona Moona Creek	2023	1	492	0	221	0	0	0	129	714	24.9	2866	2871	1.00	
Flat Rock Creek	689	0	1	0	0	0	0	0	0	1	0.1	690	689	1.00	
Captains Beach Lagoon	315	0	0	0	0	0	0	0	0	0	0.0	315	319	0.99	
Telegraph Creek	431	0	0	0	0	0	0	0	0	0	0.0	431	429	1.01	
Jervis Bay	2847	20	259	0	2	0	0	0	92	281	8.7	3220	3248	0.99	
St Georges Basin	25935	37	2958	0	2230	0	0	15	4419	5240	14.7	35594	35666	1.00	
Swan Lake	2209	9	365	0	15	0	0	0	497	389	12.6	3095	3106	1.00	
Berrara Creek	3434	3	32	0	25	0	0	0	32	60	1.7	3526	3530	1.00	
Nerrindillah Creek	1612	0	8	0	103	0	0	0	7	111	6.4	1730	1729	1.00	
Conjola Lake	12371	3	283	0	1107	0	2	2	787	1397	9.6	14555	14581	1.00	
Narrawallee Inlet	4495	3	134	10	3364	0	3	7	171	3521	43.0	8187	8196	1.00	
Mollymook Creek	66	0	156	0	45	0	0	0	5	201	73.9	272	272	1.00	
Millards Creek	70	0	324	0	56	0	0	0	2	380	84.1	452	451	1.00	
Ulladulla	0	0	26	0	0	0	0	0	1	26	96.3	27	30	0.91	Incorrect land-use extraction
Burrill Lake	2776	20	503	2	2670	0	0	1	531	3196	49.1	6503	6512	1.00	
Tabourie Lake	3827	3	109	0	621	0	0	0	193	733	15.4	4753	4763	1.00	
Termeil Lake	953	3	14	0	432	0	0	0	55	449	30.8	1457	1462	1.00	
Meroo Lake	1437	0	50	0	443	0	6	2	117	501	24.4	2055	2064	1.00	
Willinga Lake	1005	0	35	0	266	0	0	0	83	301	21.7	1389	1390	1.00	
Butlers Creek	112	0	190	0	0	0	0	0	6	190	61.7	308	309	1.00	
Durras Lake	5437	2	379	0	5	0	0	0	379	386	6.2	6202	6215	1.00	
Durras Creek	510	0	22	0	40	0	0	0	22	62	10.4	594	594	1.00	
Maloneys Creek	747	2	69	0	0	0	0	0	3	71	8.6	821	820	1.00	
Cullendulla Creek	893	0	604	0	37	0	0	0	104	641	39.1	1638	1645	1.00	
Clyde River	164586	6	1004	0	5911	0	0	2	2244	6923	4.0	173753	174046	1.00	
Batemans Bay	1580	17	1062	0	24	0	0	0	90	1103	39.8	2773	2801	0.99	
Saltwater Creek (Rosedale)	89	0	58	0	137	0	2	0	0	197	68.9	286	282	1.01	
Tomaga River	7455	22	1175	0	419	0	7	0	282	1623	17.3	9360	9371	1.00	
Candlagan Creek	1838	25	178	0	216	0	0	0	173	419	17.2	2430	2431	1.00	
Bengello Creek	335	0	11	0	6	0	0	0	1	17	4.8	353	1633	0.22	Land-use map clipped
Moruya River	122508	61	2848	2	15314	0	0	146	1908	18371	12.9	142787	142982	1.00	
Congo Creek	1052	7	466	0	2629	0	0	0	169	3102	71.8	4323	4332	1.00	
Meringo Creek	280	0	102	0	152	0	0	0	2	254	47.4	536	538	1.00	
Kellys Lake	34	0	94	0	84	0	0	0	1	178	83.6	213	218	0.98	
Coila Lake	3448	0	325	0	917	0	0	0	775	1242	22.7	5465	5476	1.00	
Tuross River	155947	155	1664	20	21840	84	48	18	2983	23829	13.0	182759	182928	1.00	
Lake Brunderee	552	0	8	0	21	0	0	0	12	29	4.9	593	593	1.00	
Lake Tarourga	584	0	2	0	3	0	0	0	39	5	0.8	628	631	0.99	

	Land-use (ha)														
		Disturbed													
Estuary	Undisturbed forest	Cleared	Urban	Crops	Grazing	Irrigated pasture	Dry forb	Irrigated forb	Other	Total disturbed	% disturbed	Total area (ha): A	Total area (ha) from Table 1: B	Ratio A/B	Reason for difference
Lake Brou	4018	1	15	0	319	0	0	0	53	335	7.6	4406	4409	1.00	
Lake Mummuga	2604	0	129	0	7	0	0	0	0	136	5.0	2740	2741	1.00	
Kianga Lake	566	4	128	0	49	0	0	0	24	181	23.5	771	767	1.01	
Wagonga Inlet	8336	0	583	0	366	0	0	0	733	949	9.5	10018	10022	1.00	
Little Lake (Narooma)	50	0	93	0	11	0	0	0	0	104	67.5	154	227	0.68	Incorrect land-use extraction
Bullengella Lake	15	0	0	0	38	0	0	0	18	38	53.5	71	74	0.96	Incorrect land-use extraction
Nangudga Lake	166	0	398	0	354	0	0	0	100	752	73.9	1018	1021	1.00	
Corunna Lake	1538	1	733	0	707	0	2	6	207	1449	45.4	3194	3187	1.00	
Tilba Tilba Lake	326	1	98	0	1224	0	0	1	178	1324	72.4	1828	1827	1.00	
Little Lake (Wallaga)	24	0	5	0	156	0	0	0	18	161	79.3	203	251	0.81	Incorrect land-use extraction
Wallaga Lake	15787	6	824	0	9322	6	8	48	1296	10214	37.4	27297	27314	1.00	
Bermagui River	5710	19	540	0	2014	0	1	0	283	2574	30.0	8567	8562	1.00	
Baragoot Lake	1009	0	124	0	114	0	0	0	65	238	18.1	1312	1316	1.00	
Cuttagee Lake	5034	0	156	0	102	0	1	0	152	259	4.8	5445	5447	1.00	
Murrah River	12685	6	986	0	5635	0	7	0	336	6634	33.8	19655	19660	1.00	
Bunga Lagoon	1003	0	11	0	126	0	0	9	17	146	12.5	1166	1168	1.00	
Wapengo Lagoon	5684	1	17	0	1149	0	0	0	362	1167	16.2	7213	7218	1.00	
Middle Lagoon	1829	0	25	0	868	0	3	0	71	896	32.0	2796	2788	1.00	
Nelson Lagoon	2639	0	17	0	42	0	0	0	131	59	2.1	2829	2833	1.00	
Bega River	109276	22	3245	13	78058	27	15	16	3337	81396	42.0	194009	193867	1.00	
Wallagoot Lake	2190	0	49	0	390	0	0	0	425	439	14.4	3054	3050	1.00	
Bournda Lagoon	3133	2	80	0	217	0	0	0	22	299	8.7	3454	3458	1.00	
Back Lagoon	2675	10	241	0	179	0	0	2	76	432	13.6	3183	3174	1.00	
Merimbula Lake	1862	0	747	0	1091	0	0	2	599	1840	42.8	4301	4348	0.99	
Pambula River	24328	31	830	0	4446	0	6	2	504	5315	17.6	30147	30118	1.00	
Curalo Lagoon	2337	9	313	0	136	0	0	0	112	458	15.8	2907	2903	1.00	
Shadrachs Creek	1270	0	7	0	47	0	0	0	2	54	4.1	1326	1324	1.00	
Nullica River	5212	5	7	0	248	0	0	0	47	260	4.7	5519	5511	1.00	
Boydtown Creek	273	0	12	0	95	0	0	0	10	107	27.4	390	387	1.01	
Towamba River	87820	2	555	0	13506	0	1	21	1084	14085	13.7	102989	102821	1.00	
Fisheries Creek	630	0	1	0	16	0	0	0	7	17	2.6	654	654	1.00	
Twofold Bay	507	7	122	0	77	0	0	0	35	206	27.5	748	1101	0.68	Incorrect land-use extraction
Saltwater Creek (Eden)	1721	0	0	0	0	0	0	0	0	0	0.0	1721	1724	1.00	
Woodburn Creek	1355	0	0	0	0	0	0	0	0	0	0.0	1355	1356	1.00	
Wonboyn River	33198	0	140	0	335	0	0	0	374	475	1.4	34047	33964	1.00	
Merrica River	6087	0	0	0	0	0	0	0	0	0	0.0	6087	6066	1.00	
Table Creek	1740	0	0	0	0	0	0	0	0	0	0.0	1740	1735	1.00	
Nadgee River	5914	0	0	0	0	0	0	0	0	0	0.0	5914	5907	1.00	
Nadgee Lake	1492	0	0	0	0	0	0	0	0	0	0.0	1492	1490	1.00	
Total	**7258769**	**62753**	**452835**	**105630**	**4581400**	**16267**	**31317**	**15175**	**269812**	**5265377**		**12793958**	**12866053**	**0.99**	

Estuary draining to a port, bay or harbour (shaded: Curalo Lagoon to Twofold Bay)

Appendix 8

Catchment hydrology (1975-2007)

Estuary	Area from DEM clip (ha)	Annual rainfall (mm)	Annual evapo-ration (mm)	Pre-clearing catchment condition				Current land-use conditions				% increase in flow		
				Annual surface flow (Ml)	Annual base flow (Ml)	Total annual flow (Ml)	Runoff coeff't	Annual surface flow (Ml)	Annual base flow (Ml)	Total annual flow (Ml)	Runoff coeff't	Surf-ace flow	Base flow	Total flow
Tweed River	105777	1403	1538	268058	111800	379858	0.26	307266	184464	491730	0.33	14.6	65.0	29.5
Cudgen Creek	6879	1476	1649	19323	5727	25050	0.25	23119	11381	34500	0.34	19.6	98.7	37.7
Cudgera Creek	6076	1473	1631	16053	6048	22102	0.25	18444	10730	29174	0.33	14.9	77.4	32.0
Mooball Creek	10930	1464	1629	29418	10782	40200	0.25	34468	17763	52231	0.33	17.2	64.8	29.9
Brunswick River	22801	1466	1586	122525	21304	143829	0.43	141069	48934	190003	0.57	15.1	129.7	32.1
Belongil Creek	3055	1494	1650	10611	4037	14648	0.32	12069	6235	18304	0.40	13.7	54.4	25.0
Tallow Creek	539	1500	1630	1437	564	2001	0.25	2022	1325	3347	0.41	40.7	135.1	67.3
Broken Head Creek	74	1500	1611	305	142	447	0.40	325	177	502	0.45	6.4	24.9	12.3
Richmond River	685490	1113	1606	1276151	241096	1517247	0.20	1479477	618504	2097981	0.28	15.9	156.5	38.3
Salty Lagoon	367	1339	1672	481	591	1071	0.22	481	591	1071	0.22	0.0	0.0	0.0
Evans River	7653	1260	1640	10475	7033	17508	0.18	12015	8006	20021	0.21	14.7	13.8	14.4
Jerusalem Creek	4870	1217	1636	5268	3568	8836	0.15	5310	3452	8762	0.15	0.8	-3.3	-0.8
Clarence River	2212365	963	1412	1936833	778370	2715202	0.13	2138886	1190766	3329652	0.16	10.4	53.0	22.6
Lake Arragan	947	1159	1583	740	537	1277	0.12	741	537	1278	0.12	0.2	0.0	0.1
Cakora Lagoon	1263	1151	1561	1508	552	2060	0.14	1525	549	2074	0.14	1.2	-0.6	0.7
Sandon River	13192	1133	1583	14883	4207	19090	0.13	15136	4214	19351	0.13	1.7	0.2	1.4
Wooli Wooli River	18135	1124	1569	23336	4527	27863	0.14	23631	4643	28274	0.14	1.3	2.6	1.5
Station Creek	2110	1165	1577	2860	689	3549	0.14	2907	690	3597	0.15	1.7	0.1	1.4
Corindi River	14580	1189	1553	25570	5106	30676	0.18	26589	5800	32389	0.19	4.0	13.6	5.6
Pipe Clay Creek	164	1193	1625	176	47	223	0.11	250	190	439	0.22	41.7	304.7	97.0
Arrawarra Creek	1773	1200	1605	2523	763	3287	0.15	2684	869	3552	0.17	6.4	13.8	8.1
Darkum Creek	613	1211	1580	1054	397	1452	0.20	1284	896	2180	0.29	21.8	125.5	50.2
Woolgoolga Lake	2103	1233	1544	3886	1077	4963	0.19	4482	2032	6514	0.25	15.3	88.7	31.2
Flat Top Point Creek	255	1232	1548	421	165	586	0.19	500	372	872	0.28	18.8	125.0	48.8
Hearns Lake	675	1243	1553	1114	383	1496	0.18	1226	566	1792	0.21	10.1	48.0	19.8
Moonee Creek	4077	1289	1530	6480	3112	9593	0.18	7361	5361	12722	0.24	13.6	72.3	32.6
Pine Brush Creek	735	1353	1472	1415	490	1905	0.19	1637	861	2498	0.25	15.7	75.5	31.1
Coffs Creek	2402	1391	1530	5269	2142	7411	0.22	6901	4858	11760	0.35	31.0	126.8	58.7
Boambee Creek	4872	1425	1533	11149	4137	15286	0.22	13461	7034	20494	0.30	20.7	70.0	34.1
Bonville Creek	11365	1421	1507	39162	27043	66205	0.41	42320	31710	74030	0.46	8.1	17.3	11.8
Bundageree Creek	1004	1384	1606	1836	559	2395	0.17	2048	925	2973	0.21	11.5	65.4	24.1
Bellinger River	110104	1335	1394	438111	299414	737525	0.50	446835	314955	761791	0.52	2.0	5.2	3.3
Dalhousie Creek	622	1363	1576	1000	223	1223	0.14	1102	346	1448	0.17	10.2	55.6	18.4
Oyster Creek	1676	1363	1551	2958	1108	4066	0.18	3179	1485	4665	0.20	7.5	34.0	14.7
Deep Creek	8986	1342	1555	18202	5054	23255	0.19	19490	7915	27405	0.23	7.1	56.6	17.8
Nambucca River	130266	1215	1482	271138	108195	379333	0.24	286007	148697	434704	0.27	5.5	37.4	14.6
Macleay River	1129897	903	1297	924229	551731	1475960	0.14	998044	723854	1721899	0.17	8.0	31.2	16.7
South West Rocks Creek	455	1191	1604	487	196	683	0.13	575	292	867	0.16	18.1	49.1	27.0
Saltwater Creek (Frederickton)	1130	1198	1582	1498	677	2175	0.16	1788	1079	2867	0.21	19.4	59.3	31.8
Korogoro Creek	958	1116	1557	1217	140	1358	0.13	1337	188	1525	0.14	9.9	34.0	12.4
Killick Creek	796	1140	1486	961	112	1074	0.12	1067	138	1205	0.13	11.0	22.5	12.2
Goolawah Lagoon	396	1156	1515	516	305	821	0.18	581	290	872	0.19	12.6	-4.8	6.2
Hastings River	366637	1155	1381	760166	464998	1225164	0.29	817062	554614	1371676	0.32	7.5	19.3	12.0
Cathie Creek	11922	1209	1468	18025	3829	21854	0.15	21245	7531	28776	0.20	17.9	96.7	31.7
Duchess Gully	1059	1214	1428	1443	231	1674	0.13	1887	545	2432	0.19	30.8	136.0	45.3
Camden Haven River	59127	1230	1436	128603	43674	172277	0.24	140404	57609	198013	0.27	9.2	31.9	14.9
Manning River	817177	1078	1355	1045553	961872	2007425	0.23	1117487	1096467	2213954	0.25	6.9	14.0	10.3
Khappinghat Creek	9178	1157	1460	15073	6753	21826	0.21	16862	8741	25604	0.24	11.9	29.5	17.3
Black Head Lagoon	196	1151	1462	563	67	630	0.28	409	284	693	0.31	-27.4	324.9	10.0
Wallis Lake	121852	1139	1445	182897	90542	273439	0.20	198179	113346	311525	0.22	8.4	25.2	13.9
Smiths Lake	2618	1220	1441	3125	1994	5120	0.16	3661	2799	6461	0.20	17.2	40.4	26.2
Myall River	82036	1172	1451	96006	38606	134612	0.14	100365	44344	144708	0.15	4.5	14.9	7.5
Karuah River	147978	1127	1450	214025	121650	335674	0.20	222005	136869	358874	0.22	3.7	12.5	6.9
Tilligerry Creek	13040	1165	1509	7236	819	8055	0.05	9114	2466	11580	0.08	26.0	201.3	43.8
Port Stephens	32307	1158	1499	28250	4921	33172	0.09	30443	8353	38796	0.10	7.8	69.7	17.0
Hunter River	2138152	770	1486	1136070	755307	1891377	0.11	1250654	1019018	2269672	0.14	10.1	34.9	20.0
Glenrock Lagoon	738	1057	1510	975	243	1218	0.16	1121	641	1762	0.23	15.0	164.0	44.7
Lake Macquarie	60844	988	1516	78147	11721	89868	0.15	89290	23899	113188	0.19	14.3	103.9	25.9
Middle Camp Creek	502	1078	1502	610	176	786	0.15	658	193	851	0.16	7.9	9.1	8.2
Moonee Beach Creek	350	1094	1501	388	114	502	0.13	440	225	664	0.17	13.2	96.9	32.2
Tuggerah Lake	71468	1032	1467	84781	17248	102029	0.14	93122	31417	124539	0.17	9.8	82.2	22.1
Wamberal Lagoon	582	1124	1453	938	133	1070	0.16	1260	622	1882	0.29	34.4	369.0	75.8
Terrigal Lagoon	894	1120	1464	1154	290	1444	0.14	1741	1497	3238	0.32	50.9	416.0	124.3
Avoca Lake	1077	1130	1500	1481	455	1936	0.16	1902	1297	3199	0.26	28.4	185.1	65.3
Cockrone Lake	685	1141	1503	917	278	1195	0.15	1121	641	1762	0.23	22.2	130.6	47.4
Brisbane Water	15349	1082	1476	18563	5521	24083	0.14	24398	16496	40894	0.25	31.4	198.8	69.8
Hawkesbury River	2162800	764	1318	1393276	785390	2178666	0.13	1468289	951792	2420081	0.15	5.4	21.2	11.1
Pittwater	5402	1073	1467	3804	1692	5496	0.09	4170	2197	6368	0.11	9.6	29.9	15.9
Broken Bay	1425	1062	1501	869	331	1201	0.08	1053	586	1639	0.11	21.1	76.9	36.5
Narrabeen Lagoon	5455	1108	1431	6181	3232	9413	0.16	7430	6061	13491	0.22	20.2	87.5	43.3
Dee Why Lagoon	929	1146	1451	1108	471	1579	0.15	1851	1974	3825	0.36	67.0	319.3	142.2
Curl Curl Lagoon	368	1151	1453	253	178	431	0.10	413	543	956	0.23	63.1	205.3	121.8
Manly Lagoon	1353	1164	1466	1656	785	2441	0.15	2571	2653	5225	0.33	55.3	238.0	114.0
Middle Harbour Creek	8219	1116	1467	7905	5164	13068	0.14	12013	14707	26720	0.29	52.0	184.8	104.5
Lane Cove River	1400	988	1480	9951	3410	13361	0.97	15191	13908	29099	2.10	52.7	307.9	117.8
Parramatta River	26549	887	1510	21109	2907	24016	0.10	34288	14991	49278	0.21	62.4	415.6	105.2
Port Jackson	6317	1125	1505	3088	1817	4904	0.07	5249	5497	10746	0.15	70.0	202.6	119.1
Cooks River	11131	981	1498	10423	2032	12455	0.11	18290	9471	27760	0.25	75.5	366.1	122.9
Georges River	94610	1047	1468	68684	17698	86382	0.09	95285	62450	157735	0.16	38.7	252.9	82.6
Botany Bay	5898	848	1505	4027	781	4807	0.10	6298	2824	9122	0.18	56.4	261.9	89.8
Port Hacking	16967	930	1435	13330	10619	23950	0.15	14787	14514	29301	0.19	10.9	36.7	22.3
Wattamolla Creek	811	968	1440	508	813	1322	0.17	508	813	1322	0.17	0.0	0.0	0.0
Hargraves Creek	200	943	1375	256	153	408	0.22	315	281	597	0.32	23.3	84.1	46.1
Stanwell Creek	766	939	1341	869	686	1556	0.22	920	839	1759	0.24	5.8	22.3	13.1
Flanagans Creek	200	946	1336	718	361	1079	0.57	757	461	1218	0.64	5.5	27.8	12.9
Woodlands Creek	202	937	1341	588	310	898	0.47	639	416	1055	0.56	8.7	34.0	17.4
Slacky Creek	303	937	1341	1096	483	1579	0.56	1184	679	1864	0.66	8.0	40.7	18.0
Bellambi Gully	642	942	1354	2305	910	3215	0.53	2587	1808	4395	0.73	12.2	98.7	36.7
Bellambi Lake	131	958	1388	599	71	670	0.53	651	325	976	0.78	8.7	356.4	45.6
Towradgi Creek	859	946	1361	3943	570	4513	0.56	4159	1206	5365	0.66	5.5	111.7	18.9
Fairy Creek	2072	955	1374	8499	1114	9613	0.49	9297	2753	12050	0.61	9.4	147.2	25.4
Allans Creek	5080	969	1394	16729	4589	21318	0.43	18726	8532	27258	0.55	11.9	85.9	27.9

			Annual	Pre-clearing catchment condition				Current land-use conditions				% increase in flow		
Estuary	Area from DEM clip (ha)	Annual rainfall (mm)	evapo-ration (mm)	Annual surface flow (Ml)	Annual base flow (Ml)	Total annual flow (Ml)	Runoff coeff't	Annual surface flow (Ml)	Annual base flow (Ml)	Total annual flow (Ml)	Runoff coeff't	Surf-ace flow	Base flow	Total flow
Port Kembla	596	1010	1473	1218	287	1505	0.25	1494	696	2189	0.36	22.6	142.4	45.5
Lake Illawarra	23806	980	1394	58836	14965	73801	0.32	67611	31032	98643	0.42	14.9	107.4	33.7
Elliott Lake	1000	1022	1461	2353	114	2466	0.24	3418	615	4033	0.39	45.3	440.7	63.5
Minnamurra River	11842	1029	1303	32637	9075	41712	0.34	37041	19921	56962	0.47	13.5	119.5	36.6
Spring Creek	583	1072	1361	1262	825	2088	0.33	1262	825	2088	0.33	0.0	0.0	0.0
Munna Munnora Creek	364	1089	1347	688	72	760	0.19	840	442	1282	0.32	22.1	511.1	68.7
Werri Lagoon	1646	1106	1352	5216	1339	6556	0.36	6128	3313	9441	0.52	17.5	147.3	44.0
Crooked River	3187	1150	1444	7113	724	7837	0.21	9249	2604	11853	0.32	30.0	259.8	51.2
Shoalhaven River	709369	739	1216	871397	367352	1238749	0.24	924726	458451	1383177	0.26	6.1	24.8	11.7
Wollumboola Lake	3417	1067	1455	7759	2249	10008	0.27	8020	2337	10358	0.28	3.4	3.9	3.5
Currarong Creek	1235	1074	1460	2978	740	3719	0.28	3163	755	3917	0.30	6.2	2.0	5.3
Cararma Creek	900	1069	1466	1157	1639	2796	0.29	1156	1560	2716	0.28	-0.1	-4.8	-2.8
Wowly Gully	611	1056	1460	1066	572	1637	0.25	1152	607	1759	0.27	8.1	6.2	7.5
Callala Creek	1991	1045	1459	2931	1239	4169	0.20	3287	1086	4373	0.21	12.1	-12.3	4.9
Currambene Creek	16133	997	1414	43160	5419	48579	0.30	47259	9594	56853	0.35	9.5	77.0	17.0
Moona Moona Creek	2864	1026	1450	6481	632	7112	0.24	7308	1696	9004	0.31	12.8	168.4	26.6
Flat Rock Creek	684	1047	1426	1613	979	2592	0.36	1684	939	2623	0.37	4.4	-4.1	1.2
Captains Beach Lagoon	314	1051	1433	926	452	1378	0.42	975	428	1403	0.43	5.3	-5.3	1.8
Telegraph Creek	419	1054	1433	950	493	1444	0.33	999	470	1469	0.33	5.1	-4.8	1.8
Jervis Bay	3804	1051	1452	7087	2878	9964	0.25	7682	3241	10923	0.27	8.4	12.6	9.6
St Georges Basin	31662	968	1367	82624	15329	97952	0.32	88404	20214	108618	0.35	7.0	31.9	10.9
Swan Lake	2687	1006	1437	5662	644	6306	0.23	6097	1410	7506	0.28	7.7	119.0	19.0
Berrara Creek	3496	985	1411	8297	1032	9330	0.27	8336	1064	9400	0.27	0.5	3.1	0.8
Nerrindillah Creek	1720	1001	1432	4768	1539	6306	0.37	4880	1621	6501	0.38	2.4	5.4	3.1
Conjola Lake	13990	951	1295	33890	9940	43830	0.33	34721	11052	45773	0.34	2.5	11.2	4.4
Narrawallee Inlet	8157	974	1299	18632	2723	21355	0.27	20281	6164	26445	0.33	8.8	126.4	23.8
Mollymook Creek	272	1021	1406	1046	462	1508	0.54	1265	706	1971	0.71	21.0	52.7	30.7
Millards Creek	451	1016	1415	1649	721	2370	0.52	2131	1376	3507	0.77	29.2	90.7	48.0
Ulladulla	31	1018	1423	76	39	115	0.36	105	80	185	0.59	38.5	106.5	61.4
Burrill Lake	6100	983	1347	15508	2442	17950	0.30	17429	6172	23601	0.39	12.4	152.7	31.5
Tabourie Lake	4620	974	1353	10948	1586	12533	0.28	11581	2134	13715	0.30	5.8	34.6	9.4
Termeil Lake	1410	972	1339	3077	380	3458	0.25	3321	836	4157	0.30	7.9	119.7	20.2
Meroo Lake	1974	974	1362	4335	570	4905	0.26	4653	1018	5670	0.29	7.3	78.6	15.6
Willinga Lake	1359	988	1385	2840	435	3275	0.24	3106	724	3830	0.29	9.4	66.4	16.9
Butlers Creek	306	992	1367	446	214	660	0.22	725	833	1557	0.51	62.5	288.8	136.0
Durras Lake	5856	944	1371	11587	1724	13311	0.24	12117	2260	14377	0.26	4.6	31.1	8.0
Durras Creek	592	939	1384	883	177	1060	0.19	900	208	1108	0.20	1.9	17.3	4.5
Maloneys Creek	815	918	1382	1094	271	1365	0.18	1194	332	1527	0.20	9.2	22.4	11.8
Cullendulla Creek	1638	891	1376	3047	613	3660	0.25	3862	2188	6050	0.41	26.7	257.1	65.3
Clyde River	172502	851	1264	380367	116585	496953	0.34	385807	126007	511814	0.35	1.4	8.1	3.0
Batemans Bay	3010	891	1368	5212	979	6191	0.23	6576	2933	9510	0.35	26.2	199.5	53.6
Saltwater Creek (Rosedale)	282	893	1339	555	95	650	0.26	679	312	991	0.39	22.5	227.8	52.6
Tomaga River	9261	836	1308	17830	3168	20998	0.27	19586	5006	24591	0.32	9.8	58.0	17.1
Candlagan Creek	2423	834	1310	4394	950	5345	0.26	4705	1400	6106	0.30	7.1	47.4	14.2
Bengello Creek	1636	837	1331	2113	484	2596	0.19	2157	580	2737	0.20	2.1	20.0	5.4
Moruya River	142412	717	1215	279715	80352	360067	0.35	291405	98131	389537	0.38	4.2	22.1	8.2
Congo Creek	4322	821	1329	7755	1397	9152	0.26	8642	5505	14146	0.40	11.4	294.1	54.6
Meringo Creek	530	833	1337	1223	74	1297	0.29	1295	279	1574	0.36	5.9	277.7	21.3
Kellys Lake	212	834	1341	355	465	820	0.46	355	465	820	0.46	0.0	0.0	0.0
Coila Lake	4799	806	1322	11532	945	12476	0.32	12032	1654	13687	0.35	4.3	75.2	9.7
Tuross River	181364	732	1177	348451	72142	420593	0.32	359790	88265	448055	0.34	3.3	22.3	6.5
Lake Brunderee	598	820	1336	1576	115	1691	0.34	1617	110	1727	0.35	2.6	-4.6	2.1
Lake Tarourga	599	820	1332	1346	134	1479	0.30	1365	129	1493	0.30	1.4	-3.8	1.0
Lake Brou	4108	808	1313	9544	977	10521	0.32	9642	1181	10823	0.33	1.0	20.9	2.9
Lake Mummuga	2579	818	1290	6277	404	6682	0.32	6432	455	6887	0.33	2.5	12.6	3.1
Kianga Lake	752	826	1286	1487	140	1627	0.26	1671	373	2044	0.33	12.4	166.1	25.6
Wagonga Inlet	9337	817	1272	20818	1645	22462	0.29	21727	2004	23731	0.31	4.4	21.9	5.6
Little Lake (Narooma)	217	835	1318	421	122	542	0.30	421	122	542	0.30	0.0	0.0	0.0
Bullengella Lake	59	837	1326	86	0	86	0.17	104	5	109	0.22	20.7	0.0	26.8
Nangudga Lake	951	830	1306	1666	62	1728	0.22	2340	624	2964	0.38	40.4	913.2	71.5
Corunna Lake	2981	827	1257	5965	293	6258	0.25	7288	1498	8785	0.36	22.2	410.4	40.4
Tilba Tilba Lake	1724	827	1252	2100	278	2378	0.17	2436	1198	3634	0.25	16.0	330.7	52.8
Little Lake (Wallaga)	234	826	1300	169	63	232	0.12	194	229	423	0.22	14.7	263.7	82.5
Wallaga Lake	26401	795	1280	42982	4707	47688	0.23	46080	10622	56702	0.27	7.2	125.7	18.9
Bermagui River	8368	791	1276	13006	1096	14102	0.21	13957	2480	16437	0.25	7.3	126.2	16.6
Baragoot Lake	1269	800	1298	2071	136	2207	0.22	2168	236	2403	0.24	4.7	72.9	8.9
Cuttagee Lake	5324	781	1280	8567	694	9260	0.22	8727	741	9468	0.23	1.9	6.8	2.2
Murrah River	19588	768	1257	30698	3896	34594	0.23	32739	8360	41099	0.27	6.6	114.6	18.8
Bunga Lagoon	1157	779	1287	1917	147	2063	0.23	2009	173	2182	0.24	4.8	18.1	5.8
Wapengo Lagoon	6928	773	1275	10508	864	11371	0.21	10825	1323	12148	0.23	3.0	53.1	6.8
Middle Lagoon	2738	766	1251	4002	270	4272	0.20	4217	645	4862	0.23	5.4	139.0	13.8
Nelson Lagoon	2722	756	1258	3539	248	3787	0.18	3542	245	3787	0.18	0.1	-1.2	0.0
Bega River	193535	711	1153	268256	59967	328223	0.24	283873	104236	388109	0.28	5.8	73.8	18.2
Wallagoot Lake	2659	731	1219	3182	203	3386	0.17	3257	256	3513	0.18	2.3	25.8	3.8
Bournda Lagoon	3450	729	1215	4423	316	4738	0.19	4475	450	4925	0.20	1.2	42.4	3.9
Back Lagoon	3139	718	1201	3970	299	4269	0.19	4195	529	4724	0.21	5.7	76.9	10.7
Merimbula Lake	3755	729	1223	4795	264	5059	0.18	5378	944	6322	0.23	12.1	257.7	25.0
Pambula River	29772	749	1183	40150	5569	45719	0.21	41661	8859	50520	0.23	3.8	59.1	10.5
Curalo Lagoon	2831	750	1237	3681	274	3955	0.19	3872	513	4385	0.21	5.2	87.3	10.9
Shadrachs Creek	1323	765	1232	1481	159	1640	0.16	1504	166	1670	0.16	1.6	4.3	1.8
Nullica River	5480	776	1199	6141	743	6884	0.16	6219	902	7121	0.17	1.3	21.4	3.4
Boydtown Creek	387	761	1243	460	29	489	0.17	491	57	548	0.19	6.7	98.3	12.1
Towamba River	102711	732	1120	123603	35231	158834	0.21	128333	47861	176194	0.23	3.8	35.8	10.9
Fisheries Creek	650	751	1281	806	44	850	0.17	810	46	856	0.18	0.5	5.8	0.7
Twofold Bay	1109	746	1275	718	83	802	0.10	813	231	1044	0.13	13.2	176.9	30.2
Saltwater Creek (Eden)	1712	755	1234	2199	187	2386	0.18	2199	187	2386	0.18	0.0	0.0	0.0
Woodburn Creek	1351	759	1220	1615	129	1744	0.17	1615	129	1744	0.17	0.0	0.0	0.0
Wonboyn River	33618	797	1223	41501	3769	45270	0.17	41647	3894	45542	0.17	0.4	3.3	0.6
Merrica River	6057	779	1147	7411	2326	9737	0.21	7411	2326	9737	0.21	0.0	0.0	0.0
Table Creek	1729	790	1157	1629	390	2018	0.15	1629	390	2018	0.15	0.0	0.0	0.0
Nadgee River	5888	808	1157	8294	3453	11747	0.25	8294	3453	11747	0.25	0.0	0.0	0.0
Nadgee Lake	1370	808	1199	1187	120	1307	0.12	1187	120	1307	0.12	0.0	0.0	0.0
Total				**13928386**	**6452524**	**20380910**		**15142349**	**8765714**	**23908062**				

Note negative values for some changes in flow were caused by spatially averaging surface runoff for every combination of soil type and land-use which introduced rounding errors. Negative values mainly occurred in some baseflows, which are usually much smaller than surface flows, and one total flow.

Appendix 9

Hydrodynamic attributes for mostly open estuaries

	Tidal gauging data					Spring/neap adjustment			Inlet shoaling adjustment				Entrance adjustment				Tidal range	Tidal prism		Flushing				Dilution
Estuary	Date of tidal gauging	Tidal prism on flood (m^3x10^6)	Tidal prism on ebb (m^3x10^6)	Fort Denison range (m)	Mean gauging range (m)	Range adjusted for spring tide (m)	Spring/ neap during gauging	% change to tidal range	Distance entrance to gauging line (km)	Distance entrance to water level station (km)	Entrance condition at time of gauging	% shoaled or scoured	Adopted tidal range at gauging line (m)	Assumed entrance width (m)	Tidal prism in entrance (Ml)	% of entrance tidal prism	Mean or default tidal range including 50% mangrove (m)	Actual or predicted tidal prism from range x area (Ml)	% tidal prism to estuary volume at 0.6m AHD	Tidal flushing time (days)	No. of times ICOLL breakout volume flushed per year	ICOLL breakout volume flushing time (days)	Total flushing time (days)	Dilution factor for 10% annual runoff
Tweed River	17/02/1988	13.49	6.91	1.59	1.285	0.817	spring	-36	1.200		shoaled	6	0.870	239	269	4	0.36	7175	13	27.3			27.3	1.158
Cudgen Creek	14/10/1993	0.8	0.79	1.49	1.245	0.842	spring	-32	0.500				0.842	80	37	7	0.28	575	24	14.2			14.2	0.687
Cudgera Creek																	0.45	151	60	5.7			5.7	0.086
Mooball Creek	14/10/1993	0.63	0.55	1.49	0.960	0.649	spring	-32	0.860				0.649	106	76	19	0.65	303	86	4.0			4.0	0.067
Brunswick River	11/10/1994	2.27	2.51	1.17	1.230	1.060	spring	-14	0.580		scoured	-9	0.972	89	51	3	0.73	1940	45	7.6			7.6	0.225
Belongil Creek																					35.5	10.3	43.3	0.048
Tallow Creek																					14.9	24.4	24.4	0.139
Broken Head Creek																					5.2	70.7	70.7	0.305
Richmond River	3/11/1994	21.9	25	1.64	1.545	0.950	spring	-39	0.870		scoured	-3	0.919	422	353	3	0.41	14302	12	28.7			28.7	0.569
Salty Lagoon																					3.6	101.9	101.9	0.643
Evans River	6/02/1980	2.38	2.47	1.83	1.625	0.895	spring	-45	0.365	1.100	shoaled	8	0.975	109	39	3	0.71	1494	57	6.1			6.1	1.317
Jerusalem Creek																					14.4	25.3	25.3	0.204
Clarence River	24/10/1996	39.72	41.34	1.35	1.240	0.926	spring	-25	0.450	0.500	shoaled	2	0.944	393	173	1	0.25	31028	11	31.3			31.3	0.850
Lake Arragan																					0.7	551.8	551.8	6.368
Cakora Lagoon																					3.0	120.6	120.6	0.547
Sandon River	9/07/1980	2.94	3.25	1.45	1.500	1.043	spring	-30	0.500				1.043	50	26	1	1.04	1936	81	4.2			4.2	1.237
Wooli Wooli River	20/02/2003	1.57	1.69	1.56	1.460	0.946	spring	-35	1.300		scoured	-13	0.838	208	249	27	0.45	1185	45	7.6			7.6	0.923
Station Creek																					7.3	50.1	50.1	0.366
Corindi River																	0.45	512	33	10.4			10.4	0.481
Pipe Clay Creek																					21.7	16.8	52.0	0.040
Arrawarra Creek																					15.1	24.2	24.2	0.124
Darkum Creek																					20.5	17.8	55.0	0.076
Woolgoolga Lake																					22.1	16.5	52.7	0.103
Flat Top Point Creek																					20.9	17.5	54.9	0.053
Hearns Lake																					6.4	56.7	56.7	0.211
Moonee Creek																	0.45	106	26	13.4			13.4	0.326
Pine Brush Creek																					84.5	4.3	24.6	0.012
Coffs Creek																	0.45	163	56	6.2			6.2	0.249
Boambee Creek	5/05/2005	0.56	0.52	1.45	0.890	0.621	spring	-30	0.710				0.621	193	112	30	0.61	488	61	5.7			5.7	0.393
Bonville Creek	21/08/1997	0.74	0.75	1.46	0.495	0.342	spring	-31	1.330				0.342	118	106	21	0.43	620	42	8.1			8.1	0.198
Bundageree Creek																					614.6	0.6	7.8	0.001
Bellinger River	19/09/2001	5.49	6.27	1.56	1.210	0.784	spring	-35	1.300				0.784	475	553	15	0.59	4365	30	11.4			11.4	0.190
Dalhousie Creek																					10.2	35.8	35.8	0.151
Oyster Creek																					17.4	21.0	21.0	0.123
Deep Creek	26/04/2002	0.22	0.28	1.70	0.265	0.158	spring	-41	0.600				0.158	126	44	30	0.18	193	14	24.7	8.5	43.2	43.2	0.506
Nambucca River	27/09/1999	5.24	3.96	1.15	0.660	0.579	spring	-12	4.700		scoured	-15	0.503	411	1460	42	0.47	4966	21	16.1			16.1	0.534
Macleay River	21/02/1979	16.48	16.65	1.70	1.385	0.824	spring	-41	0.500	2.800	shoaled	1	0.836	209	96	1	0.41	10095	14	23.9			23.9	0.408
South West Rocks Creek	23/11/1977	0.31	0.19	1.05	1.035	0.994	spring	-4	0.050				0.994	24	1	0	0.48	241	37	9.3			9.3	7.543
Saltwater Creek (Frederickton)																					5.3	68.4	68.4	0.290
Korogoro Creek																	0.45	97	78	4.4			4.4	0.811
Killick Creek																					2.2	166.9	166.9	1.957
Goolawah Lagoon																					3.6	101.3	101.3	0.585
Hastings River	24/10/1999	21.31	19.47	1.15	1.250	1.100	spring	-12	0.550		scoured	-27	0.864	256	132	1	0.54	14220	27	12.7			12.7	0.384
Cathie Creek	22/04/1982	0.22	0.35	1.33	0.290	0.220	spring	-24	0.500				0.220	181	56	26	0.03	272	3	106.0	1.1	319.1	319.1	2.912
Duchess Gully																					52.3	7.0	30.7	0.022
Camden Haven River	18/09/1997	7.56	7.75	1.71	1.255	0.742	spring	-41	1.000	1.400	shoaled	5	0.779	115	103	2	0.16	4854	4	80.6			80.6	5.747
Manning River	3/11/1998	14.83	10.08	1.51	1.180	0.788	spring	-33	6.500		scoured	-33	0.593	809	4208	67	0.35	10463	11	31.6			31.6	0.435
Khappinghat Creek																					11.3	32.2	32.2	0.346
Black Head Lagoon																					39.6	9.2	34.9	0.021
Wallis Lake	28/03/1998	13.8	16.6	1.68	1.375	0.827	spring	-40	0.350	0.800	shoaled	7	0.887	137	46	0	0.11	9851	5	76.0			76.0	6.996
Smiths Lake																					0.4	915.8	915.8	36.454
Myall River																	0.45	49955	11	30.8			30.8	30.977

Estuary	Date of tidal gauging	Tidal prism on flood (m^3x10^6)	Tidal prism on ebb (m^3x10^6)	Fort Denison range (m)	Mean gauging range (m)	Range adjusted for spring tide (m)	Spring/ neap during gauging	% change to tidal range	Distance entrance to gauging line (km)	Distance entrance to water level station (km)	Entrance condition at time of gauging	% shoaled or scoured	Adopted tidal range at gauging line (m)	Assumed entrance width (m)	Tidal prism in entrance (Ml)	% of entrance tidal prism	Mean or default tidal range including 50% mangrove (m)	Actual or predicted tidal prism from range x area (Ml)	% tidal prism to estuary volume at 0.6m AHD	Tidal flushing time (days)	No. of times ICOLL breakout volume flushed per year	ICOLL breakout volume flushing time (days)	Total flushing time (days)	Dilution factor for 10% annual runoff
	Tidal gauging data					Spring/neap adjustment			Inlet shoaling adjustment				Entrance adjustment				Tidal range	Tidal prism		Flushing				Dilution
Karuah River	29/09/1993	12.6	14.65	1.06	1.295	1.231	spring	-5	0.000	0.000	scoured	-9	1.125				1.01	11680	37	9.2			9.2	0.870
Tilligerry Creek																	1.01	20616	40	8.6			8.6	44.658
Port Stephens	30/09/1993	165	150	1.10	1.170	1.072	spring	-8	0.000				1.072				1.01	115137	7	52.0			52.0	31.438
Hunter River	9/10/1995	29.2	26.8	1.37	1.415	1.045	spring	-26	3.500	6.300	shoaled	1	1.058	588	2124	10	0.72	23060	17	20.4			20.4	0.604
Glenrock Lagoon																					17.7	20.6	20.6	0.086
Lake Macquarie	16/04/1996	11.18	10.89	1.32	1.170	0.897	spring	-23	0.500				0.897	902	430	5	0.08	8888	1	249.9			249.9	57.097
Middle Camp Creek																					34.0	10.7	36.7	0.027
Moonee Beach Creek																					156.2	2.3	14.6	0.003
Tuggerah Lake	16/12/1993	2.59	2.59	1.39	1.370	0.993	spring	-27	1.000				0.993	348	349	19	0.03	2227	1	298.2	0.8	479.7	479.7	15.516
Wamberal Lagoon																					1.9	190.3	190.3	4.677
Terrigal Lagoon																					6.0	60.5	60.5	0.467
Avoca Lake																					2.5	146.7	146.7	0.916
Cockrone Lake																					2.8	130.5	130.5	1.063
Brisbane Water	3/05/1989	25.8	21.3	1.43	1.340	0.948	spring	-29	0.000				0.948				0.45	11780	14	24.6			24.6	20.589
Hawkesbury River	6/04/1993	191	199	1.58	1.630	1.040	spring	-36	0.000				1.040				1.01	107564	7	49.2			49.2	6.369
Pittwater																	1.01	18423	10	33.9			33.9	285.561
Broken Bay																	1.01	17281	10	33.3			33.3	0.679
Narrabeen Lagoon	11/09/1980	0.28	0.5	1.15	0.165	0.145	spring	-12	1.500				0.145	237	205	60	0.24	546	10	33.0	3.1	119.0	119.0	3.893
Dee Why Lagoon																					6.7	54.7	54.7	0.033
Curl Curl Lagoon																					7.7	47.2	47.2	0.214
Manly Lagoon																					28.2	13.0	42.9	0.068
Middle Harbour Creek																	1.01	6163	8	45.7			45.7	30.652
Lane Cove River																	1.01	3001	24	14.4			14.4	4.330
Parramatta River																	1.01	13846	20	17.3			17.3	14.144
Port Jackson	19/03/1992	83.22	81.43	1.56	1.595	1.034	spring	-35	0.000	0.000	scoured	-3	1.008				1.01	28269	8	45.8			45.8	32.492
Cooks River																	1.01	1154	106	3.2			3.2	0.391
Georges River	14/08/1991	19.32	16.66	1.22	1.280	1.058	spring	-17	0.100				1.058	474	49	0	0.63	14913	5	62.5			62.5	17.206
Botany Bay																	1.01	37943	9	39.9			39.9	22.650
Port Hacking	15/03/1978	5.53	6.98	0.65	0.635	0.985	neap	55	2.250				0.985	941	2109	22	1.03	11809	11	30.6			30.6	35.924
Wattamolla Creek																					20.9	17.4	46.0	0.062
Hargraves Creek																					98.3	3.7	17.9	0.006
Stanwell Creek																					104.9	3.5	17.1	0.008
Flanagans Creek																					339.5	1.1	8.6	0.001
Woodlands Creek																					154.5	2.4	13.4	0.004
Slacky Creek																					197.4	1.8	11.5	0.003
Bellambi Gully																					133.6	2.7	14.7	0.008
Bellambi Lake																					16.7	21.8	21.8	0.075
Towradgi Creek																					67.7	5.4	22.7	0.021
Fairy Creek																					57.1	6.4	25.3	0.035
Allans Creek																	0.45	519	50	6.9			6.9	0.382
Port Kembla																	1.01	1385	16	20.9			20.9	38.543
Lake Illawarra	29/03/1994	0.34	0.54	1.64	0.040	0.025	spring	-38	1.000				0.025	400	207	76	0.02	746	1	342.1	1.4	260.7	260.7	7.530
Elliott Lake																					26.1	14.0	41.5	0.068
Minnamurra River	21/02/1992	1.28	1.2	1.40	1.385	1.001	spring	-28	0.700				1.001	207	145	16	0.95	1041	69	5.0			5.0	0.266
Spring Creek																					21.2	17.2	48.8	0.072
Munna Munnora Creek																					168.9	2.2	13.9	0.004
Werri Lagoon																					35.1	10.4	36.6	0.066
Crooked River																	0.45	115	82	4.2			4.2	0.119
Shoalhaven River	19/04/1989	3.6	4.1	1.07	0.885	0.838	spring	-5	0.400				0.838	429	158	4	0.14	3802	4	78.2			78.2	0.625
Wollumboola Lake																					0.8	437.7	437.7	4.807
Currarong Creek																					59.9	6.1	26.4	0.022
Cararma Creek																	0.45	1073	39	8.9			8.9	10.188
Wowly Gully																					5.7	64.3	64.3	0.403
Callala Creek																					355.9	1.0	8.8	0.002
Currambene Creek																	0.45	999	40	8.6			8.6	0.442
Moona Moona Creek																					33.8	10.8	35.8	0.065
Flat Rock Creek																					98.0	3.7	19.1	0.010

	Tidal gauging data					Spring/neap adjustment			Inlet shoaling adjustment				Entrance adjustment				Tidal range	Tidal prism		Flushing				Dilution
Estuary	Date of tidal gauging	Tidal prism on flood (m^3x10^6)	Tidal prism on ebb (m^3x10^6)	Fort Denison range (m)	Mean gauging range (m)	Range adjusted for spring tide (m)	Spring/ neap during gauging	% change to tidal range	Distance entrance to gauging line (km)	Distance entrance to water level station (km)	Entrance condition at time of gauging	% shoaled or scoured	Adopted tidal range at gauging line (m)	Assumed entrance width (m)	Tidal prism in entrance (Ml)	% of entrance tidal prism	Mean or default tidal range including 50% mangrove (m)	Actual or predicted tidal prism from range x area (Ml)	% tidal prism to estuary volume at 0.6m AHD	Tidal flushing time (days)	No. of times ICOLL breakout volume flushed per year	ICOLL breakout volume flushing time (days)	Total flushing time (days)	Dilution factor for 10% annual runoff
Captains Beach Lagoon																					16.2	22.5	22.5	0.090
Telegraph Creek																					145.5	2.5	14.9	0.005
Jervis Bay																	1.01	122352	6	55.5			55.5	217.031
St Georges Basin	30/05/1978	1.3	1.26	0.90	0.580	0.650	neap	12	0.600				0.650	275	137	10	0.04	1570	1	470.7			470.7	19.801
Swan Lake																					0.8	460.5	460.5	14.651
Berrara Creek																					19.0	19.3	49.9	0.140
Nerrindillah Creek																					47.0	7.8	29.2	0.037
Conjola Lake	30/10/1992	1.47	1.75	1.16	0.655	0.569	spring	-13	0.600				0.569	511	242	17	0.25	1641	6	56.1			56.1	5.855
Narrawallee Inlet	30/09/1993	0.32	0.38	1.10	0.935	0.857	spring	-8	0.800		scoured	-11	0.769	357	254	88	0.83	541	85	4.0	13.4	27.2	27.2	0.241
Mollymook Creek																					155.2	2.4	14.1	0.004
Millards Creek																					393.8	0.9	8.3	0.002
Ulladulla																	1.01	94	27	12.8			12.8	18.866
Burrill Lake	13/03/2001	0.39	0.3	1.23	0.515	0.422	spring	-18	1.000		scoured	-20	0.352	202	137	58	0.09	373	2	162.7	2.8	130.0	130.0	7.480
Tabourie Lake	17/09/1992	0.21	0.25	1.08	0.435	0.408	spring	-6	0.750		scoured	-59	0.256	85	40	30	0.12	176	16	22.0	4.8	75.8	75.8	0.819
Termeil Lake																					3.8	96.6	96.6	0.957
Meroo Lake																					2.1	170.3	170.3	2.287
Willinga Lake																					6.4	57.2	57.2	0.247
Butlers Creek																					29.3	12.5	38.1	0.039
Durras Lake																					1.9	187.3	187.3	3.513
Durras Creek																					27.6	13.2	38.2	0.040
Maloneys Creek																					28.9	12.7	36.8	0.042
Cullendulla Creek																	1.01	683	69	5.0	2.4	153.6	153.6	1.630
Clyde River	26/09/1996	18.74	20.36	1.50	1.360	0.914	spring	-33	1.000				0.914	281	270	2	0.87	13408	26	13.0			13.0	0.991
Batemans Bay																	1.01	34758	9	37.9			37.9	7.272
Saltwater Creek (Rosedale)																					242.3	1.5	10.0	0.002
Tomaga River	16/09/1996	0.96	0.96	1.12	0.880	0.792	spring	-10	0.175				0.792	107	17	2	0.75	881	62	5.5			5.5	0.574
Candlagan Creek																	0.45	49	95	3.6			3.6	0.085
Bengello Creek																					131.1	2.8	13.8	0.007
Moruya River	5/04/2000	4.88	4.8	1.44	1.215	0.851	spring	-30	0.825	3.800	shoaled	5	0.892	990	776	22	0.85	4329	43	8.1			8.1	0.261
Congo Creek																					58.6	6.2	22.7	0.032
Meringo Creek																					9.8	37.3	37.3	0.150
Kellys Lake																					6.6	55.1	55.1	0.245
Coila Lake																					0.9	405.0	405.0	11.282
Tuross River	1/02/1994	5.49	4.89	1.33	0.625	0.475	spring	-24	1.300				0.475	866	835	21	0.33	4783	26	13.1			13.1	0.406
Lake Brunderee																					4.2	86.7	86.7	0.523
Lake Tarourga																					2.3	159.4	159.4	1.241
Lake Brou																					2.2	164.7	164.7	2.528
Lake Mummuga																					2.1	173.6	173.6	2.394
Kianga Lake																					6.2	58.5	58.5	0.306
Wagonga Inlet	3/12/1986	6.34	6.64	1.73	1.365	0.795	spring	-42	0.380				0.795	84	29	1	0.56	3810	10	35.3			35.3	16.477
Little Lake (Narooma)																					2.8	128.3	128.3	0.651
Bullengella Lake																					0.3	1259.4	1259.4	5.794
Nangudga Lake																					2.0	181.6	181.6	1.312
Corunna Lake																					2.1	174.1	174.1	2.617
Tilba Tilba Lake																					1.6	233.8	233.8	2.379
Little Lake (Wallaga)																					1.6	228.9	228.9	1.056
Wallaga Lake	29/03/1995	0.4	0.38	1.33	0.040	0.030	spring	-24	1.500		shoaled	54	0.066	102	82	13	0.08	726	2	158.7	3.1	117.5	117.5	5.910
Bermagui River	7/11/1990	2.5	2.5	1.46	1.425	0.987	spring	-31	0.150				0.987	139	21	1	1.00	1753	81	4.2			4.2	1.314
Baragoot Lake																					2.2	166.3	166.3	1.264
Cuttagee Lake																					3.6	101.7	101.7	1.194
Murrah River																	0.45	302	60	5.7			5.7	0.122
Bunga Lagoon																					8.2	44.5	44.5	0.187
Wapengo Lagoon																	0.45	1300	32	10.8			10.8	3.350
Middle Lagoon																					4.5	81.5	81.5	0.689
Nelson Lagoon																	0.45	427	40	8.7			8.7	2.846
Bega River	30/11/2005	0.87	1.4	1.24	0.285	0.233	spring	-18	0.600				0.233	331	123	13	0.32	1050	16	20.9	53.1	6.9	6.9	0.164
Wallagoot Lake																					0.4	1027.1	1027.1	15.208

	Tidal gauging data					Spring/neap adjustment			Inlet shoaling adjustment				Entrance adjustment				Tidal range	Tidal prism		Flushing				Dilution
Estuary	Date of tidal gauging	Tidal prism on flood (m^3x10^6)	Tidal prism on ebb (m^3x10^6)	Fort Denison range (m)	Mean gauging range (m)	Range adjusted for spring tide (m)	Spring/ neap during gauging	% change to tidal range	Distance entrance to gauging line (km)	Distance entrance to water level station (km)	Entrance condition at time of gauging	% shoaled or scoured	Adopted tidal range at gauging line (m)	Assumed entrance width (m)	Tidal prism in entrance (Ml)	% of entrance tidal prism	Mean or default tidal range including 50% mangrove (m)	Actual or predicted tidal prism from range x area (Ml)	% tidal prism to estuary volume at 0.6m AHD	Tidal flushing time (days)	No. of times ICOLL breakout volume flushed per year	ICOLL breakout volume flushing time (days)	Total flushing time (days)	Dilution factor for 10% annual runoff
Bournda Lagoon																					30.8	11.8	31.0	0.054
Back Lagoon																					6.4	56.9	56.9	0.457
Merimbula Lake	4/04/1978	3.27	1.86	1.30	0.865	0.671	spring	-22	1.800		scoured	-19	0.565	55	77	5	0.36	1752	14	25.3			25.3	20.444
Pambula River	4/10/1979	2.51	3.41	1.47	1.035	0.712	spring	-31	1.200		shoaled	8	0.775	239	256	12	0.61	2473	25	13.6			13.6	1.935
Curalo Lagoon																					2.8	132.0	132.0	1.454
Shadrachs Creek																					99.4	3.7	15.5	0.008
Nullica River																					11.1	32.8	32.8	0.247
Boydtown Creek																					17.5	20.8	20.8	0.057
Towamba River																	0.45	857	42	8.2			8.2	0.116
Fisheries Creek																					5.0	72.9	72.9	0.182
Twofold Bay																	1.01	30976	9	37.1			37.1	17.441
Saltwater Creek (Eden)																					22.2	16.4	38.2	0.070
Woodburn Creek																					18.2	20.0	20.0	0.082
Wonboyn River	15/10/1997	0.62	0.56	1.56	0.150	0.097	spring	-35	1.150				0.097	199	127	33	0.14	508	5	66.4			66.4	2.154
Merrica River																					41.8	8.7	27.0	0.050
Table Creek																					18.7	19.5	43.4	0.082
Nadgee River																					22.5	16.2	39.4	0.076
Nadgee Lake																					0.5	714.3	714.3	8.340

Note for tidal range:

1. Entries in green are for estuaries where the tidal range was adjusted down to allow for high spring ranges at the time of gauging.
2. Entries in red are default values of tidal range for ungauged estuaries.

Appendix 10

Sample counts of water quality monitoring data

			Custo-	No. of	Sample count																			
Estuary	**Start**	**End**	**dians**	**samples**	**Salinity**	**Temp.**	**DO % sat.**	**DO mg/l**	**pH**	**Secchi**	**Turbidity**	**Chl a**	**TSS**	**TN**	**TP**	**NH4**	**NO3**	**NO2**	**Nox**	**DIN**	**DIP**	**DON**	**DOP**	**Si**
Tweed River	1970	2006	C, N, U	3768	2096	3453	2658	2689	2194	2535	1538	327	2731	2452	2915	45	2384	1	248	110	122	0	0	110
Brunswick River	1971	2008	C, N, U	1419	891	1007	248	888	241	89	852	1062	661	838	892	626	602	0	153	119	452	14	14	119
Belongil Creek	2002	2006	C	456	0	0	0	0	0	0	0	433	0	0	0	0	0	0	0	0	0	0	0	0
Tallow Creek	2002	2006	C	384	0	0	0	0	0	0	0	365	0	0	0	0	0	0	0	0	0	0	0	0
Richmond River	1971	2007	C, N, U	2486	541	1112	520	598	1019	241	743	1344	412	1192	1350	799	37	0	428	452	134	0	0	110
Evans River	2007	2008	N	14	14	14	14	14	12	7	12	12	0	14	14	14	0	0	14	14	14	14	14	14
Clarence River	1913	2004	N, U	6001	639	5783	702	4520	4591	312	3717	888	646	960	1638	683	236	0	327	583	195	0	0	110
Cakora Lagoon	2002	2003	N	27	0	27	0	0	26	0	26	0	0	0	0	0	0	0	0	0	0	0	0	0
Sandon River	1997	2008	N, U	137	136	121	48	121	117	101	109	112	52	109	109	109	88	93	106	109	109	109	109	16
Bellinger River	1971	2003	U	680	112	560	112	249	457	73	502	112	111	112	343	0	4	0	109	112	178	0	0	112
Deep Creek	2002	2002	N	4	4	4	4	4	4	0	0	4	4	4	4	4	0	0	4	4	4	4	4	0
Nambucca River	1971	2007	C, U	623	111	440	109	111	328	75	405	172	109	111	229	0	3	0	0	111	111	0	0	111
Macleay River	1970	2003	U	2114	109	1937	109	206	1424	73	1276	101	151	112	445	92	126	0	70	109	149	0	0	109
Hastings River	1970	2008	C, N, U	2178	1210	2045	1210	1301	1842	636	1847	670	1193	1212	1431	1100	20	0	1190	129	1228	1100	17	129
Camden Haven River	1971	1995	C, N	683	456	678	456	456	154	220	564	456	455	457	457	456	2	0	456	456	456	456	0	0
Manning River	1970	2007	W, U	7420	3422	5839	2032	3521	3100	1340	3569	1345	1385	359	2838	1451	1710	1410	725	111	183	0	0	110
Khappinghat Creek	1994	2009	N	42	42	39	32	35	31	26	42	42	0	32	36	32	0	0	36	32	32	32	32	32
Wallis Lake	1972	2009	N	1056	217	716	202	212	565	110	709	242	29	839	852	268	12	10	604	39	264	264	264	260
Smiths Lake	2002	2007	N, U	573	252	252	6	186	4	17	126	528	4	45	45	547	0	0	547	506	546	45	45	41
Myall River	1976	2006	N	438	56	204	37	41	271	30	322	70	4	344	349	67	2	2	199	0	53	53	53	53
Karuah River	2007	2008	N	18	18	18	18	18	14	15	16	16	0	16	16	18	0	0	18	18	18	18	17	18
Lake Macquarie	1972	2007	C, N	9830	8261	8362	8262	6488	8530	3334	3120	3569	3328	5766	6700	6003	87	2	6569	4	6495	5672	24	340
Tuggerah Lake	1972	2009	C, N	984	282	794	32	280	753	221	848	42	8	292	516	45	75	7	357	35	36	35	271	32
Wamberal Lagoon	2007	2009	N	30	28	28	28	28	24	7	18	30	0	30	30	30	0	0	30	30	30	30	30	30
Avoca Lake	2007	2008	C, N	129	125	125	125	125	121	7	129	129	96	129	129	129	0	0	129	33	129	129	33	33
Brisbane Water	1992	2005	C, U	704	563	563	548	548	563	105	553	507	507	513	513	507	0	0	513	0	507	507	0	0
Hawkesbury River	1968	2007	C, W	6660	358	4939	2754	2495	3898	179	2189	2421	765	2670	2789	2807	381	0	2627	0	2052	358	0	0
Narrabeen Lagoon	1995	2007	N, W, U	1308	28	902	899	685	619	0	24	598	4	674	674	698	0	0	698	28	698	4	4	24
Dee Why Lagoon	1994	2007	C, W	1799	1161	1590	1588	1482	1459	0	1161	1445	1161	1496	1496	1496	0	0	1496	0	1496	0	0	0
Curl Curl Lagoon	1994	2007	C, W	1788	1158	1559	1555	1457	1447	0	1158	1442	1158	1493	1493	1493	0	0	1493	0	1493	0	0	0
Manly Lagoon	1994	2008	C, N, W	2703	1447	2134	2129	1941	1948	9	1451	2019	1419	2120	2121	2120	0	0	2120	32	2120	32	32	32
Middle Harbour Creek	1995	2007	W	1928	0	1393	1928	1928	1928	0	0	1922	0	980	980	980	0	0	980	0	0	0	0	0
Lane Cove River	1995	2007	W	646	0	466	646	646	646	0	0	644	0	327	327	327	0	0	327	0	0	0	0	0
Parramatta River	1979	2008	C, N	4625	4178	4310	4178	4178	4302	735	2557	4291	4274	4291	4291	4289	0	0	4291	16	4291	4291	12	16
Port Jackson	1995	2007	C, W	7674	110	5480	5448	4169	3710	0	111	3416	116	4018	4021	4018	0	0	4018	0	4015	110	0	0
Cooks River	1995	2007	N, W	1652	4	1084	1072	790	789	4	6	841	7	992	992	992	0	0	992	10	944	10	0	3
Georges River	1978	2007	N, W	3120	71	2034	1799	1395	1558	60	451	1210	87	1414	1642	1594	237	0	1414	118	1408	118	0	40
Botany Bay	2007	2007	N	23	13	13	13	13	7	13	13	20	14	23	23	23	0	0	23	23	23	23	23	0
Port Hacking	1995	2007	W	1247	0	911	911	694	613	0	0	556	0	657	657	657	0	0	657	0	657	0	0	0
Wattamolla Lagoon	1996	2008	N, W	621	33	394	389	314	266	0	32	285	0	333	333	333	0	0	333	35	333	35	35	32
Stanwell Creek	2007	2008	C	16	16	15	0	0	0	0	16	16	0	16	16	11	0	0	16	0	0	0	16	0
Flanagans Creek	2002	2008	C	81	78	78	52	62	62	0	17	17	8	43	77	74	60	0	17	0	0	0	17	0
Slacky Creek	2007	2008	C	17	17	16	0	0	0	0	17	17	0	17	17	10	0	0	17	0	0	0	17	0
Bellambi Lagoon	2002	2009	C, N	72	71	69	26	31	31	0	41	39	8	46	64	55	29	0	34	0	0	0	34	0
Towradgi Lagoon	2002	2008	C, N, U	166	150	147	58	102	94	1	116	123	8	130	149	138	29	0	122	35	71	35	81	32
Fairy Creek	2002	2009	C, N, U	111	106	107	58	97	89	12	74	78	8	82	96	98	29	0	66	33	66	33	28	32
Lake Illawarra	1976	2009	N, U, LIA	790	208	271	197	170	254	85	369	263	4	223	324	482	1	0	482	107	484	37	46	219
Minnamurra River	1976	2008	C, N	133	98	127	94	94	121	2	119	89	0	101	102	16	0	0	16	16	16	15	13	16
Spring Creek	2003	2007	C	43	41	39	39	39	41	0	41	33	0	43	43	0	0	0	0	0	0	0	0	0

			Custo-	No. of	Sample count																			
Estuary	**Start**	**End**	**dians**	**samples**	**Salinity**	**Temp.**	**DO % sat.**	**DO mg/l**	**pH**	**Secchi**	**Turbidity**	**Chl a**	**TSS**	**TN**	**TP**	**NH4**	**NO3**	**NO2**	**Nox**	**DIN**	**DIP**	**DON**	**DOP**	**Si**
Munna Munnora Creek	2003	2007	C	43	40	40	38	38	40	0	40	38	0	43	43	0	0	0	0	0	0	0	0	0
Werri Lagoon	2003	2007	C	85	82	82	78	78	82	0	81	73	0	85	85	0	0	0	0	0	0	0	0	0
Crooked River	2003	2009	C, N	97	97	97	78	78	97	11	97	84	0	85	85	0	0	0	0	0	0	0	0	0
Shoalhaven River	1908	2008	N, U	794	16	610	16	112	559	13	649	20	3	25	295	169	111	1	21	21	21	21	16	21
St Georges Basin	2002	2009	N, O	79	19	43	28	5	4	19	29	19	14	4	4	44	0	0	24	4	4	4	4	20
Swan Lake	2002	2009	N, U	118	63	62	52	100	52	48	60	70	52	52	100	97	48	0	52	52	85	4	52	0
Conjola Lake	2002	2009	N	23	23	23	4	4	4	15	18	22	4	4	4	4	0	0	4	4	4	4	4	0
Mollymook Creek	2008	2009	N	6	6	6	0	0	0	1	6	6	0	0	0	0	0	0	0	0	0	0	0	0
Burrill Lake	2001	2009	N, U	103	103	103	85	60	76	19	97	103	4	44	44	68	0	0	68	64	64	40	61	60
Tabourie Lake	2008	2009	N	12	10	12	0	0	0	1	11	12	0	0	0	0	0	0	0	0	0	0	0	0
Termeil Lake	2007	2009	N	42	41	42	29	28	29	1	42	42	0	29	29	29	0	0	29	29	29	29	29	29
Meroo Lake	2008	2009	N	12	10	11	0	0	0	0	12	12	0	0	0	0	0	0	0	0	0	0	0	0
Willinga Lake	2003	2003	U	75	36	36	36	72	36	36	36	39	36	36	72	70	36	0	36	36	55	0	36	1
Durras Lake	1998	2009	N, U	546	112	112	108	108	112	19	112	64	4	187	188	524	0	0	523	64	520	40	38	222
Clyde River	1970	2008	N, U	738	16	577	16	16	259	11	20	378	0	20	159	20	0	0	20	20	20	20	17	20
Tomaga River	2008	2009	N	12	12	12	0	0	12	12	12	12	0	0	0	0	0	0	0	0	0	0	0	0
Candlagan Creek	2008	2009	N	11	11	11	0	0	11	11	11	11	0	0	0	0	0	0	0	0	0	0	0	0
Moruya River	2006	2009	N, U	47	41	47	35	0	35	1	47	47	0	0	0	0	35	0	0	0	0	0	35	0
Congo Creek	2007	2008	N	30	27	27	27	27	27	2	30	30	0	30	30	30	0	0	30	30	30	30	30	30
Coila Lake	1995	2009	N, U	162	104	107	92	71	92	53	106	163	0	72	72	71	21	0	72	36	72	36	57	32
Tuross River	1968	2009	N	1491	48	1261	36	36	1043	48	527	102	4	38	199	36	23	0	36	0	36	0	0	0
Lake Brou	2008	2009	N	12	12	12	0	0	12	12	12	12	0	0	0	0	0	0	0	0	0	0	0	0
Nangudga Lake	2000	2002	U	38	38	38	38	38	38	38	31	0	0	0	0	0	0	0	0	0	0	0	0	0
Corunna Lake	1995	2008	N, U	232	212	212	212	212	212	203	183	50	0	32	32	32	0	0	32	32	32	32	30	32
Tilba Tilba Lake	2008	2009	N	12	10	12	0	0	0	4	12	10	0	0	0	0	0	0	0	0	0	0	0	0
Wallaga Lake	1968	2009	N	576	58	526	248	255	487	49	283	79	25	41	207	60	220	1	55	4	40	4	4	3
Baragoot Lake	1990	2009	N	14	12	12	0	0	14	12	14	12	0	0	0	0	2	1	0	0	0	0	0	0
Cuttagee Lake	2007	2008	N	26	25	25	25	25	25	2	22	26	0	26	25	26	0	0	26	26	24	26	17	26
Wapengo Lagoon	1995	2002	N	94	40	40	40	40	40	15	36	90	4	40	40	40	0	0	40	4	40	4	4	0
Bega River	2008	2009	N	12	12	12	0	0	12	12	12	12	0	0	0	0	0	0	0	0	0	0	0	3
Wallagoot Lake	1984	2009	N	23	22	22	4	4	5	10	20	22	4	4	4	4	1	0	4	4	4	4	4	0
Merimbula Lake	1978	2002	N	48	4	25	25	25	29	0	5	43	25	4	4	25	3	0	17	4	4	4	4	0
Pambula River	1968	2009	N	367	22	299	25	25	262	18	83	61	25	24	5	25	0	0	20	4	4	4	4	0
Curalo Lagoon	1969	1995	N	19	0	0	0	0	1	0	1	18	0	0	0	0	1	1	0	0	0	0	0	0
Towamba River	2008	2009	N	6	6	6	0	0	6	6	6	6	0	0	0	0	0	0	0	0	0	0	0	0
Merrica River	1984	2009	N	63	0	58	0	0	56	0	8	5	0	0	0	0	0	0	0	0	0	0	0	0
Nadgee Lake	2009	2009	N	6	6	0	0	0	0	3	6	6	0	0	0	0	0	0	0	0	0	0	0	0

C = Council N = NSW agency (OEH or NSW Office of Water) U = University LIA = Lake Illawarra Authority W = Water Authority O = OzCoasts

Note the datasets listed are from custodians who responded to the initial request for data. Significant additional data are known to be held, particularly by Councils, and were not able to be accessed for a variety of reasons.

Appendix 11

Summary statistics for chlorophyll a

Chlorophyll a summary statistics for lake class

Estuary	Valid N	Median	25th %ile	75th %ile	20th %ile	80th %ile	5th %ile	95th %ile	Mean	Std Dev	CV	Std Err	Minimum	Maximum
Lakes All (averages)	16700	4.3	2.3	7.7	1.9	8.8	1.3	17.5	6.3	7.7	1.2	0.82	0.00	801.3
Reference Lakes (pooled)	323	1.8	0.9	3.2	0.7	3.6	0.3	5.9	2.4	2.6	1.1	0.15	0.10	32.8
Camden Haven River	456	5.4	2.9	12.4	2.5	14.8	1.0	37.1	10.4	13.7	1.3	0.64	0.10	110.6
Wallis Lake	242	1.7	1.0	2.9	0.9	3.1	0.3	5.3	2.4	4.2	1.8	0.27	0.10	60.0
Smiths Lake	522	1.3	0.8	2.4	0.7	2.7	0.5	6.0	2.5	4.5	1.8	0.20	0.26	38.9
Myall River	70	2.3	1.2	4.6	1.0	4.7	0.4	9.6	3.6	4.6	1.3	0.55	0.23	32.8
Lake Macquarie	3536	2.3	1.2	6.5	1.1	9.2	0.5	65.8	13.0	42.8	3.3	0.72	0.00	801.3
Tuggerah Lake	42	3.5	2.7	5.7	2.4	6.7	1.9	15.4	5.3	4.5	0.8	0.69	1.15	19.7
Wamberal Lagoon	30	3.5	1.9	5.5	1.5	6.0	1.0	14.8	4.9	5.0	1.0	0.92	0.71	23.0
Brisbane Waters	507	3.1	1.9	5.6	1.7	7.3	0.9	19.3	6.3	19.1	3.0	0.85	0.17	384.8
Hawkesbury River	1523	3.5	2.1	6.6	1.9	7.8	1.2	17.5	5.6	6.3	1.1	0.16	0.00	75.1
Narrabeen Lagoon	594	3.5	1.6	6.6	1.4	7.4	0.5	13.4	4.8	4.6	1.0	0.19	0.10	30.0
Middle Harbour Creek	824	2.2	1.3	3.8	1.2	4.4	0.6	9.8	3.3	3.9	1.2	0.14	0.10	36.2
Lane Cove River	274	3.5	1.8	7.3	1.6	8.9	0.5	23.2	6.4	8.3	1.3	0.50	0.20	65.6
Parramatta River	4287	9.7	4.3	23.5	3.8	28.2	2.0	67.1	19.0	27.0	1.4	0.41	0.11	431.3
Port Jackson	1099	1.9	1.3	3.6	1.2	4.0	0.5	8.7	3.2	4.8	1.5	0.15	0.10	75.0
Georges River	1202	3.6	2.1	7.1	1.9	8.5	1.1	18.1	6.0	7.0	1.2	0.20	0.10	56.0
Botany Bay	20	1.6	1.3	2.3	1.3	2.3	1.2	6.1	2.2	1.7	0.8	0.39	0.79	7.9
Port Hacking	552	1.3	0.9	1.8	0.8	1.9	0.4	3.4	1.5	1.3	0.8	0.05	0.10	11.0
Lake Illawarra	263	4.3	2.0	7.6	1.6	9.1	0.1	18.5	6.1	6.2	1.0	0.38	0.05	38.1
St Georges Basin	19	2.6	1.3	3.7	1.1	4.2	1.0	6.0	2.8	1.8	0.6	0.41	0.98	6.2
Swan Lake	69	0.5	0.5	1.4	0.5	1.4	0.4	3.7	1.2	1.4	1.2	0.17	0.23	8.7
Lake Conjola	22	1.5	0.9	2.6	0.9	2.8	0.8	3.3	1.8	0.9	0.5	0.20	0.63	3.5
Burrill Lake	106	4.6	3.2	6.4	2.8	6.9	1.7	13.6	6.1	6.7	1.1	0.65	1.00	55.3
Durras Lake	49	3.2	2.5	4.4	2.4	4.5	1.7	5.1	3.4	1.2	0.4	0.17	0.71	6.2
Coila Lake	160	2.5	1.6	3.3	1.3	3.6	0.5	6.0	2.7	1.8	0.6	0.14	0.10	9.6
Wallaga Lake	79	1.8	0.0	6.4	0.0	7.9	0.0	10.7	3.6	3.9	1.1	0.44	0.00	15.9
Wapengo Lagoon	82	0.5	0.3	1.1	0.3	1.2	0.2	1.8	0.8	0.8	1.0	0.08	0.10	5.8
Wallagoot Lake	22	2.4	1.8	2.9	1.8	3.0	1.4	3.6	2.4	0.8	0.3	0.16	1.26	4.0
Merimbula Lake	43	0.7	0.0	1.1	0.0	1.1	0.0	1.5	0.7	1.0	1.4	0.15	0.00	5.1
Nadgee Lake	6	45.6	22.3	73.6	14.8	82.8	14.3	93.1	49.9	34.1	0.7	13.91	14.11	96.5

Chlorophyll a summary statistics for lagoon class

Estuary	Valid N	Median	25th %ile	75th %ile	20th %ile	80th %ile	5th %ile	95th %ile	Mean	Std Dev	CV	Std Err	Minimum	Maximum
Lagoons All (averages)	6691	5.7	2.9	10.1	2.6	12.1	1.7	25.8	9.1	12.1	1.3	1.92	0.00	1246.5
Reference Lagoons (pooled)	350	1.1	0.6	1.8	0.5	2.0	0.2	4.5	1.7	2.7	1.6	0.14	0.03	29.7
Belongil Creek	331	8.0	4.0	17.0	4.0	21.0	2.0	61.5	20.8	60.4	2.9	3.32	1.00	780.0
Tallow Creek	337	12.0	6.0	24.0	5.0	27.0	2.0	61.2	20.0	27.8	1.4	1.51	2.00	240.0
Khappinghat Creek	42	2.3	1.3	2.7	1.2	2.8	1.0	5.1	2.4	1.4	0.6	0.22	0.24	8.3
Avoca Lake	129	3.1	1.6	6.0	1.3	6.8	0.7	15.2	4.8	6.9	1.5	0.61	0.33	67.9
Dee Why Lagoon	1444	3.1	1.6	6.1	1.4	7.3	0.6	23.6	7.8	36.1	4.6	0.95	0.00	1246.5
Curl Curl Lagoon	1437	3.0	1.4	9.8	1.1	12.8	0.3	51.0	10.8	23.0	2.1	0.61	0.04	376.8
Manly Lagoon	2019	5.3	2.2	12.2	1.8	14.6	0.7	30.6	9.4	12.1	1.3	0.27	0.00	160.0
Wattamolla Creek	283	0.9	0.5	1.6	0.4	1.8	0.2	3.1	1.2	1.3	1.1	0.08	0.03	10.0
Stanwell Creek	15	0.7	0.2	2.1	0.1	2.5	0.1	5.0	1.6	2.1	1.3	0.53	0.10	7.4
Flanagans Creek	16	0.9	0.4	1.3	0.4	1.4	0.3	10.4	2.1	3.5	1.7	0.88	0.30	12.0
Slacky Creek	16	1.6	1.1	2.8	1.0	2.9	0.8	9.9	2.7	3.1	1.2	0.78	0.30	11.4
Bellambi Lake	38	6.7	3.2	10.7	2.5	13.7	0.7	48.5	12.5	17.1	1.4	2.77	0.60	81.0
Towradgi Creek	122	2.6	1.1	5.2	0.5	6.0	0.5	13.6	4.2	4.8	1.1	0.44	0.40	31.2
Fairy Creek	77	5.4	1.4	9.3	1.2	10.4	0.5	15.3	6.3	6.2	1.0	0.71	0.42	34.5
Spring Creek	20	2.2	1.0	4.9	1.0	5.9	0.5	15.1	3.9	4.7	1.2	1.05	0.20	17.4
Munna Munnora Creek	37	0.2	0.1	2.2	0.1	2.2	0.1	4.8	1.3	1.7	1.3	0.28	0.05	6.1
Werri Lagoon	73	0.6	0.1	2.5	0.1	3.1	0.1	12.4	2.8	5.2	1.9	0.61	0.05	30.0
Mollymook Creek	6	23.7	7.2	41.3	5.3	43.6	4.4	54.6	26.4	22.4	0.8	9.14	4.11	58.3
Tabourie Lake	12	1.6	1.1	2.4	0.9	2.5	0.7	8.7	2.7	3.2	1.2	0.91	0.68	11.4
Termeil Lake	42	2.4	1.3	4.6	1.1	6.1	0.3	15.4	5.7	12.1	2.1	1.86	0.17	76.8
Meroo Lake	12	1.8	1.6	2.9	1.4	3.1	1.2	5.3	2.5	1.5	0.6	0.44	1.10	6.2
Willinga Lake	39	1.2	0.5	2.5	0.5	2.7	0.5	4.7	1.8	1.7	0.9	0.27	0.50	7.7
Congo Creek	29	4.2	3.2	6.6	2.9	6.8	2.8	11.7	6.1	6.4	1.0	1.20	2.71	37.2
Lake Brou	12	1.8	1.2	2.1	1.1	2.3	0.9	4.0	2.0	1.1	0.6	0.32	0.66	4.5
Corunna Lake	50	3.1	1.8	9.0	1.7	13.1	0.9	17.3	6.2	5.9	1.0	0.84	0.40	22.4
Tilba Tilba Lake	10	59.0	33.5	82.6	30.8	106.8	22.7	206.7	80.9	69.6	0.9	22.02	22.50	209.9
Baragoot Lake	12	4.6	4.2	15.3	3.3	16.1	2.3	27.0	10.0	9.3	0.9	2.70	1.87	29.7
Cuttagee Lake	26	1.7	1.1	2.8	1.0	3.1	0.6	3.5	1.9	1.0	0.5	0.20	0.40	4.0
Merrica River	5	1.7	1.6	1.7	1.5	1.7	1.1	1.8	1.6	0.3	0.2	0.15	1.00	1.9

Chlorophyll a summary statistics for river class

Estuary	Valid N	Median	25th %ile	75th %ile	20th %ile	80th %ile	5th %ile	95th %ile	Mean	Std Dev	CV	Std Err	Minimum	Maximum
Rivers All (averages)	4192	3.0	1.8	6.4	1.6	7.9	1.0	20.0	6.0	8.7	1.1	0.88	0.01	866.2
Reference Rivers (pooled)	393	1.5	0.9	2.2	0.7	2.4	0.3	4.2	1.8	1.3	0.7	0.06	0.02	8.4
Reference UPPER	40	1.7	0.9	3.1	0.8	3.4	0.2	5.9	2.3	2.1	0.9	0.33	0.09	8.4
Reference MID	109	1.5	0.7	2.3	0.6	2.9	0.3	5.2	1.8	1.4	0.8	0.14	0.02	6.8
Reference LOWER	243	1.5	1.0	2.1	0.9	2.3	0.4	3.6	1.6	1.0	0.6	0.06	0.10	5.2
Tweed River	180	2.1	1.1	3.4	0.9	4.3	0.4	8.9	3.0	3.2	1.1	0.24	0.06	23.0
Brunswick River	574	4.0	2.0	9.0	1.7	12.0	0.6	30.0	9.2	16.9	1.8	0.71	0.11	178.0
Richmond River	122	2.7	1.3	5.0	1.1	5.9	0.3	12.2	4.6	7.6	1.6	0.69	0.20	59.0
Evans River	12	10.3	8.3	20.2	7.8	22.0	7.3	64.3	21.1	28.2	1.3	8.14	6.96	107.9
Clarence River	168	2.1	1.1	5.5	1.0	9.0	0.5	35.0	7.0	11.7	1.7	0.90	0.15	65.0
Sandon River	111	1.0	0.5	1.8	0.4	1.9	0.3	2.7	1.2	0.8	0.7	0.08	0.09	4.2
Bellinger River	93	1.4	0.9	2.1	0.7	2.2	0.3	5.2	1.8	1.6	0.9	0.16	0.02	8.4
Nambucca River	92	1.6	0.8	2.4	0.8	2.9	0.2	5.1	1.9	1.5	0.8	0.16	0.02	7.8
Macleay River	84	1.3	0.9	1.9	0.8	2.2	0.4	4.8	1.8	1.4	0.8	0.16	0.14	7.2
Hastings River	644	2.5	1.6	3.7	1.4	4.0	0.6	7.0	3.0	2.2	0.7	0.09	0.09	20.4
Manning River	829	2.6	1.4	5.4	1.2	6.3	0.5	15.6	4.7	7.0	1.5	0.24	0.01	122.0
Karuah River	16	1.9	1.0	4.7	0.9	7.1	0.4	20.4	4.8	6.7	1.4	1.66	0.39	20.4
Cooks River	829	13.6	4.7	50.6	3.5	68.5	1.1	180.0	47.1	89.0	1.9	3.09	0.10	866.2
Minnamurra River	74	1.2	0.1	4.6	0.1	6.4	0.1	38.1	6.8	15.9	2.3	1.85	0.01	103.6
Crooked River	80	0.7	0.1	2.2	0.1	2.6	0.1	5.6	1.7	3.3	1.9	0.37	0.01	25.0
Shoalhaven River	61	2.2	1.5	3.0	1.4	3.2	0.9	5.9	2.7	2.0	0.7	0.25	0.51	12.8
Clyde River	67	1.9	1.5	2.5	1.5	2.7	1.2	4.5	2.2	1.1	0.5	0.13	0.99	6.4
Tomaga River	12	1.6	1.2	2.5	1.2	2.8	1.0	3.1	1.9	0.8	0.4	0.24	0.94	3.2
Candlagan Creek	11	4.6	3.5	5.8	3.0	6.4	2.1	8.0	4.8	2.1	0.4	0.63	1.45	8.8
Moruya River	47	2.1	1.4	2.7	1.3	2.9	1.0	3.9	2.2	1.0	0.5	0.14	0.72	4.9
Tuross River	46	1.4	0.6	3.1	0.5	3.4	0.2	5.6	2.0	1.8	0.9	0.26	0.10	6.8
Bega River	12	4.9	4.2	5.7	4.1	5.8	3.6	7.4	5.1	1.4	0.3	0.41	3.59	8.8
Pambula River	22	1.6	1.4	2.2	1.2	2.3	1.0	2.9	1.8	0.6	0.3	0.13	0.89	3.0
Towamba River	6	1.7	1.1	2.5	1.0	2.7	0.5	3.3	1.8	1.1	0.6	0.47	0.39	3.6

Summary statistics for river zones

Estuary	Median				Mean			
	Lower	Mid	Upper	Average	Lower	Mid	Upper	Average
Tweed River	1.1	2.8	2.1	2.0	1.3	3.4	3.4	2.7
Brunswick River	4.0	2.0	5.7	3.9	5.2	4.7	10.7	6.9
Richmond River	1.4	2.0	3.8	2.4	1.7	3.0	6.9	3.9
Evans River	8.1	12.4	16.2	12.2	8.1	13.4	30.6	17.3
Clarence River	1.0	1.5	5.0	2.5	1.0	1.5	10.8	4.4
Sandon River	1.5	1.0	0.3	0.9	1.4	1.1	0.4	1.0
Bellinger River	1.0	1.3	2.3	1.5	1.1	1.5	3.2	1.9
Nambucca River	0.9	1.6	2.4	1.7	1.0	1.9	3.1	2.0
Macleay River	0.9	1.5	2.1	1.5	1.1	1.7	2.9	1.9
Hastings River	2.5	2.8	2.6	2.6	2.7	3.5	3.0	3.1
Manning River	2.9	2.5	3.0	2.8	3.5	4.2	5.7	4.5
Karuah River		2.3	1.5	1.9		2.3	5.1	3.7
Cooks River	2.0	0.8	13.9	5.6	4.2	0.8	47.3	17.4
Minnamurra River	0.2	1.3	2.5	1.3	3.2	8.7	9.4	7.1
Crooked River	0.9	0.1	1.2	0.7	1.9	0.2	2.3	1.5
Shoalhaven River	2.1	2.5	1.0	1.9	2.1	3.2	1.2	2.2
Clyde River	1.7	3.3		2.5	1.9	3.4		2.6
Tomaga River	1.6			1.6	1.9			1.9
Candlagan Creek	4.6	4.7		4.7	4.8	4.7		4.7
Moruya River	2.1	2.4	1.2	1.9	2.2	2.4	1.5	2.0
Tuross River	1.1	4.1		2.6	1.5	3.8		2.7
Bega River	4.9			4.9	5.1			5.1
Pambula River	1.6			1.6	1.8			1.8
Towamba River	1.7			1.7	1.8			1.8

Appendix 12

Summary statistics for turbidity

Turbidity summary statistics for lake class

Estuary	Valid N	Median	25th %ile	75th %ile	20th %ile	80th %ile	5th %ile	95th %ile	Mean	Std Dev	CV	Std Err	Minimum	Maximum
Lakes All (averages)	650	6.4	3.3	9.5	2.9	10.4	2.0	17.6	7.4	6.0	0.7	1.2	0.30	72.9
Reference Lakes (pooled)	182	2.6	1.3	4.7	1.2	5.7	0.8	10.6	3.6	3.3	0.9	0.2	0.5	17.0
Wallis Lake	123	3.0	1.9	6.5	1.5	7.0	0.5	20.9	5.6	6.7	1.2	0.6	0.3	32.6
Smiths Lake	31	2.1	1.5	2.7	1.4	3.1	1.1	8.5	2.8	2.4	0.9	0.4	1.0	10.0
Myall River	36	3.3	2.5	5.6	2.4	8.4	0.7	11.3	4.6	3.8	0.8	0.6	0.6	15.9
Tuggerah Lake	71	7.9	5.1	13.7	4.6	15.0	3.4	31.8	11.1	9.9	0.9	1.2	2.0	59.7
Wamberal Lagoon	18	6.9	5.1	9.1	4.8	10.8	2.3	37.3	12.1	16.6	1.4	3.9	2.3	72.9
Parramatta River	16	8.4	7.5	11.3	6.6	11.9	5.6	28.7	10.9	7.3	0.7	1.8	5.1	29.0
Georges River	76	19.5	6.3	36.8	4.6	39.3	1.9	48.9	22.3	17.8	0.8	2.0	0.9	68.5
Botany Bay	13	35.4	7.8	43.3	6.5	45.3	5.1	48.2	28.9	17.4	0.6	4.8	4.8	48.5
Lake Illawarra	35	3.6	2.3	5.5	2.1	5.9	1.3	6.9	4.4	4.2	1.0	0.7	0.6	26.4
St Georges Basin	15	1.2	1.1	1.6	1.1	1.7	1.0	2.2	1.4	0.5	0.3	0.1	0.9	2.7
Swan Lake	11	1.4	1.0	1.6	0.9	1.6	0.8	2.0	1.3	0.5	0.4	0.1	0.7	2.4
Lake Conjola	18	1.0	0.8	1.3	0.8	1.3	0.7	1.8	1.1	0.4	0.3	0.1	0.7	2.2
Burrill Lake	50	1.7	1.3	2.1	1.2	2.4	1.0	3.4	1.8	0.8	0.4	0.1	0.8	4.0
Durras Lake	48	6.1	4.4	8.6	3.8	9.3	2.3	12.0	6.7	3.3	0.5	0.5	1.8	17.0
Coila Lake	47	2.1	1.6	2.8	1.5	3.0	1.0	3.9	2.3	1.3	0.5	0.2	0.5	8.5
Wallaga Lake	18	2.6	1.8	3.6	1.8	3.6	1.6	29.3	5.5	8.7	1.6	2.1	1.5	29.4
Wallagoot Lake	18	1.2	0.8	1.5	0.7	1.5	0.6	3.4	1.4	1.0	0.7	0.2	0.6	3.5
Nadgee Lake	6	7.8	6.2	13.4	5.7	15.3	5.3	16.1	9.7	4.9	0.5	2.0	5.2	16.4

Turbidity summary statistics for lagoon class

Estuary	Valid N	Median	25th %ile	75th %ile	20th %ile	80th %ile	5th %ile	95th %ile	Mean	Std Dev	CV	Std Err	Minimum	Maximum
Lagoons All (averages)	413	3.4	2.5	6.6	2.4	8.3	1.8	17.9	6.2	7.0	0.8	1.7	0.47	205.0
Reference Lagoons (pooled)	94	1.7	1.0	2.8	0.9	3.3	0.7	4.5	2.4	3.8	1.6	0.4	0.5	36.1
Khappinghat Creek	42	5.3	3.1	9.3	3.0	21.5	2.3	46.4	11.9	15.3	1.3	2.4	1.1	63.2
Avoca Lake	33	4.8	3.1	8.0	2.9	8.8	2.2	15.4	6.3	4.8	0.8	0.8	2.1	23.3
Manly Lagoon	32	4.2	3.6	5.7	3.2	5.8	2.2	7.0	4.5	1.5	0.3	0.3	1.7	7.7
Wattamolla Creek	32	1.1	0.8	1.4	0.8	1.7	0.7	2.2	1.2	0.5	0.4	0.1	0.5	2.4
Bellambi Lake	6	1.9	1.8	2.2	1.8	2.3	1.6	3.1	2.2	0.6	0.3	0.3	1.6	3.4
Towradgi Creek	32	3.4	3.1	6.6	3.0	7.3	1.8	20.2	6.0	6.1	1.0	1.1	1.6	26.1
Fairy Creek	41	6.0	4.9	7.8	4.8	8.3	3.9	10.5	6.6	2.6	0.4	0.4	2.6	16.2
Mollymook Creek	6	4.3	2.6	8.3	2.5	9.1	2.2	11.0	5.7	4.0	0.7	1.6	4.1	58.3
Tabourie Lake	11	3.9	2.8	4.5	2.7	4.5	1.8	6.2	3.8	1.6	0.4	0.5	0.7	11.4
Termeil Lake	42	1.8	1.2	3.1	1.1	4.9	0.7	10.5	4.4	8.3	1.9	1.3	0.5	50.0
Meroo Lake	12	1.5	1.3	1.8	1.3	1.8	0.9	2.1	1.5	0.4	0.3	0.1	0.9	2.4
Congo Creek	29	1.5	1.3	2.2	1.2	2.3	0.9	2.9	1.9	1.5	0.8	0.3	0.8	9.2
Lake Brou	12	2.1	1.6	2.9	1.6	3.1	1.2	18.2	4.9	9.8	2.0	2.8	0.9	36.1
Corunna Lake	32	3.4	2.8	5.1	2.7	8.9	1.6	10.8	5.7	7.1	1.2	1.2	1.4	40.9
Tilba Tilba Lake	12	9.9	7.9	43.3	7.2	50.8	5.2	144.7	39.0	58.9	1.5	17.0	5.1	205.0
Baragoot Lake	12	2.8	1.6	3.6	1.4	3.6	1.2	4.1	2.6	1.1	0.4	0.3	1.1	4.2
Cuttagee Lake	22	1.9	1.0	2.6	0.9	3.6	0.5	4.6	2.2	1.4	0.6	0.3	0.5	5.0
Merrica River	5	0.9	0.9	0.9	0.8	1.4	0.6	3.0	1.4	1.2	0.9	0.5	0.6	3.5

Turbidity summary statistics for river class

Estuary	Valid N	Median	25th %ile	75th %ile	20th %ile	80th %ile	5th %ile	95th %ile	Mean	Std Dev	CV	Std Err	Minimum	Maximum
Rivers All (averages)	241	5.9	3.5	9.5	3.3	10.8	2.0	15.7	7.2	5.1	0.5	1.4	0.30	89.2
Reference Rivers (pooled)	275	4.0	1.7	7.5	1.4	8.2	1.0	18.0	5.9	7.8	1.3	0.5	0.3	90.0
Reference UPPER	39	10.0	5.8	13.0	5.1	13.7	1.9	26.8	11.5	8.8	0.8	1.4	1.0	40.9
Reference MID	92	4.5	2.0	7.0	1.8	8.0	1.0	16.0	2.3	4.8	2.1	0.5	0.7	23.0
Reference LOWER	143	3.0	1.4	5.0	1.2	5.0	1.0	13.0	4.5	2.1	0.5	0.2	0.3	90.0
Brunswick River	14	11.0	9.2	19.2	8.9	21.2	3.8	34.0	14.5	9.8	0.7	2.6	3.6	35.5
Evans River	12	16.0	10.9	25.9	10.8	31.8	7.2	35.4	18.9	10.9	0.6	3.1	6.2	37.1
Sandon River	15	5.7	2.1	12.8	1.4	13.3	0.7	28.0	9.4	10.8	1.1	2.8	0.7	40.9
Hastings River	18	9.4	4.7	13.9	4.2	15.1	3.2	20.6	10.2	6.2	0.6	1.5	2.7	22.7
Karuah River	16	24.8	7.2	41.8	6.4	51.6	2.6	74.1	29.4	26.5	0.9	6.6	2.2	89.2
Minnamurra River	14	5.4	4.7	6.8	4.6	7.0	2.1	12.4	6.4	4.7	0.7	1.2	1.7	21.5
Crooked River	11	4.3	3.5	8.7	3.4	10.2	1.9	18.8	7.3	6.8	0.9	2.0	1.7	25.1
Shoalhaven River	26	1.8	1.3	2.2	1.2	2.2	0.9	2.4	1.7	0.5	0.3	0.1	0.9	2.6
Clyde River	32	1.5	1.1	1.7	1.1	1.7	0.9	1.9	1.4	0.4	0.3	0.1	0.7	2.3
Tomaga River	12	1.9	1.4	2.9	1.3	2.9	1.0	3.3	2.1	0.9	0.4	0.2	0.8	3.6
Candlagan Creek	11	2.6	2.3	3.5	2.1	3.6	1.4	4.0	2.8	0.9	0.3	0.3	1.0	4.1
Moruya River	12	1.4	1.2	1.5	1.1	1.5	0.9	1.7	1.3	0.3	0.2	0.1	0.9	1.8
Tuross River	12	2.7	2.0	3.4	2.0	3.4	1.8	3.8	2.7	0.8	0.3	0.2	1.7	3.8
Bega River	12	3.7	2.8	4.2	2.5	4.3	1.8	5.7	3.6	1.3	0.4	0.4	1.7	6.0
Pambula River	18	1.8	1.4	2.5	1.4	2.6	1.2	3.1	2.0	0.7	0.3	0.2	1.0	3.3
Towamba River	6	0.9	0.8	1.1	0.7	1.1	0.4	1.4	0.9	0.4	0.4	0.2	0.3	1.5

Summary statistics for river zones

Estuary	Median				Mean			
	Lower	Mid	Upper	Average	Lower	Mid	Upper	Average
Brunswick River	3.8	9.3	13.4	8.8	3.8	9.3	18.6	10.5
Evans River	9.3	12.3	28.6	16.7	9.3	12.3	26.5	16.0
Sandon River		1.0	10.8	5.9		1.3	13.4	7.4
Hastings River		3.4	10.9	7.2		3.6	12.8	8.2
Karuah River		2.5	34.3	18.4		2.5	33.2	17.8
Minnamurra River	1.7	2.4	5.7	3.2	1.7	2.4	7.1	3.7
Crooked River	4.3			4.3	7.3			7.3
Shoalhaven River	2.2	1.7		2.0	2.2	1.7		2.0
Clyde River	1.3	1.7		1.5	1.3	1.7		1.5
Tomaga River	1.9			1.9	2.1			2.1
Candlagan Creek	2.9	2.3		2.6	2.9	2.3		2.6
Moruya River	1.4	1.3		1.4	1.3	1.3		1.3
Tuross River	3.5	2.2		2.9	3.5	2.4		3.0
Bega River	3.7			3.7	3.6			3.6
Pambula River	1.8			1.8	2.0			2.0
Towamba River	0.9			0.9	0.9			0.9

Appendix 13

Data collection protocols

The field protocols used are based on those developed for the indicators adopted under the National Land and Water Resources Audit. Those protocols have then been adapted to the needs and designs of the Estuary MER program sampling. This Appendix provides the text from relevant sections of the national indicator protocol along with pointers to the Sections amended, followed by the amended procedures used in the MER program. Department names, website addresses, guideline versions and references in the NLWRA protocol have been updated to reflect their status at September 2011.

Water clarity

National Protocol: www.lwa.gov.au/files/products/national-land-and-water-resources-audit/pn21553/pn21553.pdf.

Matter for target:

Estuarine, coastal and marine habitat integrity.

Indicator heading:

Estuarine, coastal and marine habitat condition.

Indicator name:

Water clarity.

This document presents the recommended monitoring guidelines for collecting, collating and reporting information on water clarity for national, state/territory and regional application.

1. Definition

This indicator documents the water clarity of estuarine, coastal or marine waters.

AIM: To determine annual median turbidity levels and Secchi depth in estuarine or coastal waters and compare with local guidelines.

INDICATOR 1: Turbidity of a waterbody.

INDICATOR 2: Secchi depth of a waterbody.

2. Rationale

Turbidity is a measure of water clarity or murkiness. It is an optical property that expresses the degree to which light is scattered and absorbed by molecules and particles. Turbidity results from soluble coloured organic compounds and suspended particulate matter in the water column. Suspended particulate matter may include clay and silt (e.g. suspended [inorganic] sediment), and [organic] detritus and organisms" (OzCoast and OzEstuaries, www.ozcoasts.gov.au/indicators/turbidity.jsp).

"Measurements of turbidity are very useful when the extent of transmission of light through water is the information sought, as in the case of estimation of the light available to photosynthetic organisms. Another strong point in favour of turbidity is that field measurement is straightforward and can be performed rapidly by monitoring teams. Turbidity is a measurement included in Waterwatch programs nationally. Because of the simplicity of the technique and its widespread use, large volumes of turbidity data are becoming available for national evaluation and interpretation. The turbidity of Australian coastal waters is an important issue in relation to benthic productivity, since many highly valued seagrass and algal bed communities have evolved in, and depend on, conditions of high light penetration (low turbidity)" (Ward *et al.* 1998).

Increased turbidity reduces the amount of light available for photosynthesis which may decrease the phytoplankton biomass and therefore result in increased dissolved nutrients in the water column.

“Turbidity caused by suspended sediment can smother benthic organisms and habitats, and cause mechanical and abrasive impairment to the gills of fish and crustaceans (ANZECC/ARMCANZ, 2000b). Suspended sediment also transports contaminants (particulate nutrients, metals and other potential toxicants) (ANZECC/ARMCANZ 2000b), promotes the growth of pathogens and waterborne diseases, makes marine pests difficult to detect (Neil 2002) and can lead to dissolved oxygen depletion in the water column if it is caused by particulate organic matter. Overall, unnaturally high turbidity levels can lead to a reduction in the production and diversity of species.” (OzCoast and OzEstuaries, www.ozcoasts.gov.au/indicators/turbidity.jsp).

For further information on turbidity and fine sediment loads including a detailed explanation of what turbidity is, what causes turbidity, the significance of turbidity, coastal systems susceptible to turbidity, the impacts of fine sediment loads on coastal waterways and the biophysical parameters that may indicate that a waterway is receiving excess sediment loads, see the OzCoast and OzEstuaries website (www.ozcoasts.gov.au/indicators/turbidity.jsp).

Secchi depth is a measure of water clarity, and is measured in-situ using a Secchi disc, as described in Australian Standard AS 3550.7-1993.

3. Monitoring methodology

Several different methods are available for measuring water clarity, ie from boats, shore or remote sensing. The methods used will depend on factors such as location and resources available but should be consistent with national/state guidelines.

The methodology below is currently the best identified for the majority of people. Local experts as well as the laboratory being used to perform the analysis should be consulted before conducting any monitoring program, particularly with regard to aspects of the quality control and quality assurance of data collected.

3.1 Monitoring locations (see MER Amendment)

Turbidity and Secchi depth measurements should be taken from the mid estuary and, where possible, from the upper and lower reaches of an estuary. In estuaries where little or no monitoring has been done before, initial samples should ideally be taken along the length of the estuary at intervals of 10% of the total length (but not closer than every 3 km). This will allow the ‘worst’ areas to be identified and continually monitored in the future. Areas near sediment point source inputs should also be monitored. A similar logic should be used to select sites within coastal waters.

3.2 Monitoring frequency required (see MER Amendment)

The direct monitoring of turbidity and Secchi depth needs to be conducted on a monthly basis on the falling tide. Turbidity can be monitored continuously or during/after specific events. Generally, turbidity measurements are most useful when continuously monitored using moored, continuously recording sensors.

A profile of turbidity through different depths should be monitored to examine any stratification effects (ie lack of mixing).

3.3 Data measurement method

Use of the Secchi disc for water clarity measurements

The Secchi disc value is used as a semi-quantitative visual index of depth of light penetration into a waterbody. The black and white disc is lowered into the water column and the distance below the water surface where the black/white interface disappears is the Secchi disc depth.

Equipment required:

- 300 mm diameter plastic disc painted with quadrants alternating in flat black and flat white waterproof paints
- A length of non-stretch rope (eg surveyor's Kinlon poly-chain) with measurement graduations
- 3 kg weight.

Site procedures from boat:

1. Prepare field recording sheets.
2. Locate the site using a Global Positioning System.
3. Remove sunglasses or tinted eyewear.
4. Lower the weighted Secchi disc into the water on the sunny side of the boat and ensure the disc lowers vertically into the water column.
5. Record the depth at which the black/white interface disappears as D1. This depth is measured from the top of the disc to the water surface. Measurement precision is half the distance between graduations on the rope or line.
6. Raise the disc slowly and record the depth at which the black/white interface becomes visible as D2.
7. The average of these two depths is the limit of visibility of the Secchi depth.
8. Record on the field recording sheet.

Important notes:

- Environment
    - o Light environment: shade can either enhance or limit the perception of the
    - o black/white quadrants. For consistency both spatially and temporally, Secchi disc
    - o depth is taken away from shade.
    - o Angle of the sun: observations should be taken between two hours after sunrise and
    - o two hours before sunset.
    - o Water surface consistency: the consistency of the water surface, which can be
    - o affected by wind chop, ground swell, surface slicks and floating matter, can affect the
    - o perception of the black/white interface. The conditions of the day must be recorded at
    - o each site.

- Observer
    - o Eyesight: the perception of the black/white interface is affected by the visual acuity of the observer. All observations should be made with corrected vision.
    - o Sunglasses: darkened or tinted glasses can affect the perception of the black/white interface and must be removed before observation.
    - o Observer accuracy: perception of the black/white interface is subjective and varies between observers.

Calibration of tether:

The Secchi disc tether is checked for graduation accuracy annually using a measuring tape.

Calibration of disc:

The black quadrants of the disc are repainted annually.

Use of a turbidity probe for water clarity measurements

A light beam is shone through a water sample and the light scattered off the particles present is measured by a photodiode at 90 degrees to the light source.

Equipment required:

Turbidity probe mounted in a sonde, an instrument designed to be lowered through the water column. Alternatively, obtain water from the specified depths and use a field turbidity meter.

Procedures (middle of estuary, from boat):

1. Prepare field recording sheets.
2. Calibrate probe prior to sampling.

Site procedures: (see MER Amendment)

3. Locate the site using a Global Positioning System.
4. While in a slow forward motion, cut the engine to prevent fouling.
5. Turn the meter on and place the sonde in the water.
6. Allow the probes to stabilise for a minimum of 90 seconds for the initial site reading.
7. Record information 0.2 m below the surface (to reduce the impact of surface slicks) on the field recording sheet.
8. Save the data in the hand-held data logger.
9. Repeat at 2 m intervals until the bottom is reached allowing a minimum of 30 seconds for the probes to stabilise at each depth. After 30 seconds, proof stability is attained by readings remaining constant for 10 seconds. If values fluctuate, continue measuring in 10 second increments until stability occurs.
10. Between sites, fill the PVC tube holding the sonde with water from the previous site to maintain probe stability.

Shore-based procedures: (not used for MER)

1. Prepare field recording sheets.
2. Calibrate probe prior to sampling.

Site procedures:

3. Locate the site using a Global Positioning System.
4. Rinse a clean 20 L plastic bucket three times and fill with sample water.
5. Place the sonde in the bucket and allow to stabilise.
6. Before taking measurements, ensure the water sample is well mixed by continuously stirring the bucket with the sonde.
7. Record information on the field recording sheet.
8. Save the data in the hand-held data logger.
9. Between sites, fill the PVC sonde holding tube with water from the previous site to maintain probe stability.

Calibration of a turbidity probe (before going out into the field): (see MER Amendment)

The turbidity probe must be calibrated weekly.

1. Remove the sensor guard and check the turbidity sensor for damage. Pay particular attention to the wiper. If the cloth for the wiper is damaged, replace the wiper.
2. Prepare and label six calibration cups with formazin turbidity standards as follows (these standards are chosen based on the range of turbidity of the water sampled):
   - 0 NTU rinse
   - 0 NTU standard
   - 400 NTU rinse

- o 400 NTU standard
- o 800 NTU rinse
- o 800 NTU standard.

3. Turn the meter on and choose the 3-point calibration from the turbidity calibration menu (some probes only use a 2-point calibration method, 0 NTU and another 'higher' standard).
4. Rinse the turbidity sensor with distilled water and then dry and immerse the sensor in the 0 NTU rinse.
5. Dry again and place the sensor in the 0 NTU standard.
6. Engage the turbidity wiper and after it has stopped calibrate the first point. Record the pre-calibration value for the first point in the turbidity section of the Individual Sensor Calibration History Documentation.
7. Rinse the sensor with distilled water and repeat steps 1–6 using the 400 NTU and 800 NTU standards taking care to invert each standard to re-suspend the formazin in solution. Do not shake as air bubbles affect the sensor's accuracy.

Post calibration: go into run mode for meter and test the accuracy of the calibration. To do this:

1. Rinse the turbidity sensor with distilled water and then dry and immerse the sensor in the 0 NTU rinse.
2. Dry again and place the sensor in the 0 NTU standard.
3. Engage the turbidity wiper and after it has stopped, record the post-calibration value in the turbidity section of the Individual Sensor Calibration History Documentation.
4. Repeat steps 1 and 2 with the 400 NTU Standard and 800 NTU standard

The post calibration values should lie within the following acceptance limits:

- 0 NTU = +/- 0.1 NTU
- 200 NTU = +/- 10 NTU
- 800 NTU = +/- 40 NTU.

If the sensor is reading outside these limits, it must be recalibrated. If the sensor cannot be calibrated to read within these limits, it must be replaced/serviced. If only the lower standard (0 NTU) is outside the limit, a one-point calibration can be completed to bring the reading within the prescribed limits. If this fails, the sensor must be replaced/serviced.

3.4 Data collation / calculation method (see MER Technical Report)

Data for a specific site should be collated over the study period and the median value calculated and compared against the relevant guidelines.

3.5 Data storage and management

Data should be stored by state/territory agencies and by the collectors (if different) of the data. If possible, the public should have access to the data (and report summaries) through a website hosted by state/territory government.

3.6 Data analysis and interpretation (see MER Technical Report)

When examining 'ambient' turbidity and Secchi depth, data from at least one year should be used in the analysis. Median turbidity and Secchi depth values should be compared with the relevant water quality guidelines. 'National' default trigger values have been listed in the 'Water Quality Guidelines' for coastal waterways in different geographic regions (ANZECC/ARMCANZ 2000a); these trigger values are superseded in Queensland by the 'Queensland Water Quality Guidelines' (DERM 2009b). Local guidelines (which supersede both national and state/territory ones) may be available for some estuaries.

Excerpts from the guidelines for State of the Environment reporting (Ward et al. 1998):

> Turbidity is an operationally determined parameter that is related to the 'murkiness' of water. Depending on the instrument used, it is quantified by light either scattered from, or absorbed by, suspended particles and colloidal material, with perhaps minor contributions also from coloured dissolved organic matter (e.g. humic substances). Reasons for measuring turbidity differ slightly from those for other water quality indicators. Although increases in turbidity are often related to deterioration in water quality, it does not follow that the severity of the contamination can be assessed. For example, severe clouding of water by clay minerals and humic substances from soil disturbance may be unsightly, but not toxic to fish or other aquatic creatures. However, a lesser loading of metal-rich particles from mine tailings discharge, or high-clarity waters loaded with aluminium arising from run-off from acid sulphate soils, can devastate biota.
>
> High turbidity values are the data of interest, and change in waters from low to high values. A problem encountered is one shared with other water quality indicators – the need for national baseline data that make it possible to distinguish values and patterns that depart from the norm and may indicate environmental problems or anomalies.
>
> Shifts in long-term patterns (in space and time) of turbidity in estuarine and coastal waters are of concern given the unique values of Australia's seagrass beds and algal assemblages, but these can only be determined by evaluation against a baseline of data. In general terms, a tendency to increasing turbidity, for longer periods or over greater areas, would usually be considered detrimental.

High turbidity levels can be the result of tidal current resuspending sediments, inputs from catchment/shoreline erosion, dredging, dissolved organic matter and/or algal blooms. Further information on the interpretation of turbidity data can be found at the OzCoast and OzEstuaries website (www.ozcoasts.gov.au/indicators/turbidity.jsp).

The Department of Sustainaibility, Environment, Water, Population and Communities (Australian Government) provides water quality targets online for turbidity (www.environment.gov.au/water/publications/quality/targets-online/index.php).

3.7 Reliability, validity and quality assurance

Quality assurance and control measures are important to minimise avoidable errors in the data and thus give more confidence in the data collected and conclusions made. Individuals collecting the data must have had adequate training in sample collection. Instrument calibration and/or laboratory quality assurance should be regularly examined and recorded.

3.8 Metadata

Metadata documentation should be completed for all datasets (see Appendix A). The metadata statement should be consistent with current ANZLIC standards, which now comply with ISO 19115.

See the following web site for the Metadata Profile:
www.osdm.gov.au/ANZLIC_MetadataProfile_v1-1.pdf?ID=303.

For the Metadata Guidelines see:
www.osdm.gov.au/ANZLIC_MetadataProfileGuidelines_v1-0.pdf?ID=397.

8. Further information

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DERM 2009a, *Monitoring and sampling manual 2009,* Version 2, ISBN 978-0-9806986-1-9, Department of Environment and Resource Management, Brisbane, 228 pp. www.derm.qld.gov.au/environmental_management/water/pdf/monitoring-man-2009-v2.pdf.

DERM 2009b, *Queensland water quality guidelines,* Version 2, ISBN 978-0-9806986-0-2, Department of Environment and Resource Management, Brisbane, 167 pp. www.derm.qld.gov.au/environmental_management/water/pdf/wq-guidelines2010.pdf.

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OzCoasts. 2007. Web site. www.ozcoasts.gov.au/index.jsp.

Ward, T., Butler, E. and Hill, B. 1998, *Environmental indicators for national state of the environment reporting – Estuaries and the sea*. Australia: State of the Environment (Environmental Indicator Reports). 81 pp. Department of the Environment; Canberra. www.environment.gov.au/soe/publications/indicators/pubs/estuaries.pdf.

Waterwatch Australia Steering Committee. 2002, *Waterwatch Australia National Technical Manual. Module 4 – physical and chemical parameters*. Environment Australia, Canberra. www.waterwatch.org.au/publications/module4/pubs/module4.pdf.

9. Glossary

Baseline data – Information collected to form a reference set for comparison of a second set of data collected at a later time; used to interpret changes over time usually after some condition has changed.

Benthic – On the bed or bottom of a body of water or in the bottom sediments.

Biomass – The total weight of all living organisms in a biological community or of a particular species/group.

In-situ – Latin term for ‘in the original place’.

Spatial – Pertaining to space or distance.

Temporal – Pertaining to time.

Appendix A: Metadata statement

Monitoring program	The name of the monitoring program
Custodian of data/Contact	The business name and address/contact details of the custodial organisation or responsible party
Summary of program	A brief narrative summary of the program
Geographic extent	The ordinary name(s) of the locations where the data was collected (ie study area)
Indicators monitored	List of all indicators monitored
Method of data collection	Summary of the methods used to collect the data
Past/future sampling	Description of when sampling started, how often it occurred, when it will finish
Quality assurance	Description of the quality control/assurance procedures used
Data access	1) Location: Where and how the data is stored. If it can be accessed 2) Format in which dataset is stored and available remotely (ie from a website) 3) Any restriction or legal prerequisites that may apply to access and use the data
Other comments	Any other comments
Information source(s)	Where information on the program can be found (eg reports, literature, websites)
Date metadata created	Date when the metadata record was created

MER AMENDMENTS

3.1 Monitoring locations

The spatial scale of interest is the entire central basin of lakes and lagoons, and the assumed chlorophyll maximum that occurs in the mid-upper sections of river estuaries. To facilitate representative spatial coverage, estuaries were divided into zones. For creeks and lagoons, zones were assigned on charts before sampling commenced. A zone was an area 500 to 700 m diameter in which sampling takes place. Sufficient zones (up to three) were allocated to the central basin of each estuary so that the majority of the estuary is represented. This may mean small systems have only one zone. In MER Year 2 (2008), only the middle estuary was sampled in river estuaries. The middle estuary was defined as having a salinity of 8 – 15 ppt, but due to the short-term temporal variability in salinity, the long-term location was defined as being in the vicinity of the upper limit of mangrove trees and this is where sampling was concentrated. Two zones were placed in the river in this vicinity. This procedure for rivers will be replaced by a longitudinal transect with continuously logged data from mid to upper estuary from MER Year 3 (2009) onwards.

3.2 Monitoring frequency required

Sampling windows across NSW are:

- NR CMA: mid September to end December
- HCR, HN and SM CMA: mid September to end March
- SR CMA: mid November to end March.

Spacing of sampling occasions was determined by a combination of logistics and the desire to fit six sampling occasions within the defined window. Southern Rivers CMA (MER Year 2 – 2008) estuaries were sampled at intervals of approximately three weeks, with all estuaries sampled within the same week.

Variables

The MER indicators that OEH sampled were chlorophyll and clarity (turbidity and secchi), supported by salinity data.

3.3 Data measurement method

Site Procedures

Field data sheets which recorded the entrance state, riparian condition, observations about macroalgae and other submerged aquatic vegetation, weather and any other relevant observations were also filled out for each estuary.

Travel to the upwind boundary of each zone in the estuary. Record secchi depth by lowering until not visible and noting depth, then lower some more and raise until visible, noting depth when visible. Secchi depth is the average of these two. The water quality probe, which recorded chlorophyll (fluorometric), turbidity, salinity, temperature, depth and time, is then fixed in the water at a depth of approximately 400 mm using a special cradle attached to the boat's gunwhale. Record the time at which the transect commences. The probe was set to log readings every second and the boat allowed to drift for five minutes. At the end of the transect, note the time that the transect ended. If there is insufficient wind, the boat was rowed or paddled for five minutes. This procedure captures data for a transect through the zone and allows the calculation of an average (or median) turbidity for the zone.

At the end of the transect, repeat secchi measurement and then slowly lower the sonde to the bottom, recording a profile of turbidity through the water column.

Note: OEH secchi disc is made from steel or thick aluminium to eliminate the need for a separate weight and is tethered using a fibreglass measuring tape to improve accuracy of measurement of depth.

Instrument Calibration

The YSI Model 6820V2-S multiprobes used for the MER sampling were fitted with a fluorometric chlorophyll probe and a turbidity probe. Prior to each trip, turbidity is calibrated to nil and 50 ntu using milli-q filtered water and formazin standard respectively. Salinity is also calibrated to a seawater standard prior to every trip.

Data Analysis

Using the recorded start and end times, data for the transects in each zone were extracted from the data files stored by the YSI probe. Mean and SE was calculated for salinity, temperature and turbidity for each zone. Estuary means were calculated for each time by taking the mean of all zones in the estuary.

Chlorophyll a

National protocol: www.lwa.gov.au/files/products/national-land-and-water-resources-audit/pn21537/pn21537.pdf.

Matter for target:

Estuarine, coastal and marine habitat integrity.

Indicator heading:

Estuarine, coastal and marine habitat condition.

Indicator name:

Surface water chlorophyll a concentrations.

This document presents the recommended monitoring guidelines for collecting, collating and reporting information on surface water chlorophyll a concentrations for national, state/territory and regional application.

1. Definition

Chlorophyll a is the main green photosynthetic pigment found in all plants including phytoplanktonic algae. The concentration of chlorophyll a in estuarine, coastal or marine waters (water column) is used as an indicator of photosynthetic plankton biomass.

AIM: To determine annual median concentrations of chlorophyll a in major functional areas of estuarine or coastal waters and compare with local guidelines.

2. Rationale

The concentration of the photosynthetic green pigment chlorophyll a in estuarine, coastal or marine waters is a proven indicator of the abundance and biomass of microscopic plants (phytoplankton) such as unicellular algae and cyanobacteria. Phytoplankton are the direct or indirect source of food for most marine animals. Chlorophyll data are useful over a range of spatial scales from small coastal waters (estuaries, embayments and coastal lagoons) up to shelf seas. It can be used to estimate primary production but there is not necessarily a rigorous or coherent relation between biomass and primary productivity.

Chlorophyll a concentration is a commonly used measure of water quality (as a surrogate of nutrient availability) with low levels suggesting good condition. However, high levels are not necessarily bad; it is the long-term persistence of high levels that is a problem. The annual median chlorophyll a concentration is therefore used as an indicator in State of the Environment reporting (Ward *et al*., 1998). Chlorophyll a was used as one determinant of ecosystem integrity in the National Estuary Assessment (stage 2: modified estuaries) completed for the National Land and Water Resources Audit (NLWRA, 2002).

The main cause of excessive algae growth appears to be increased nutrient inputs (indicating eutrophication). Declines in the abundance of filter-feeders (eg oysters and mussels), decreased turbidity (ie increased levels of light penetration), increased water temperature and decreases in flushing rates (eg. altered hydrodynamics and freshwater flow regimes) also contribute to algae growth.

For a detailed explanation of influences on chlorophyll a levels, the significance of these levels and which waterways are susceptible to elevated levels see the OzCoast and OzEstuaries website (www.ozcoasts.gov.au/indicators/chlorophyll_a.jsp).

3. Monitoring methodology

Chlorophyll a concentrations (expressed as micrograms per litre, µg/L) are determined through direct (water sample) measurement methods.

Several different methods are available for collecting samples and measuring chlorophyll a levels. For example, water samples can be collected from boats or from shore, or water colour can be detected from space by satellites. The method(s) used will depend on factors such as location and resources available; however, methods used should be consistent with these guidelines.

The methodology below is based on field sampling by boat as it currently is the most effective and best identified for the majority of people. Local experts and the laboratory carrying out the analyses should be consulted before conducting any monitoring program, particularly with regard to aspects of the monitoring methodology, the quality control and quality assurance of data collected.

3.1 Monitoring locations (see MER Amendment)

Samples should be taken from sites within the mid estuary and, where possible, from the upper and lower reaches of an estuary. Samples should be taken as close to mid-stream as possible. In estuaries where little or no monitoring has been done before, the initial samples should ideally be taken along the length of the estuary at intervals of 10% of the total length (but not closer than every 3 km). Adequate spatial coverage should also be used to select sites within coastal waters.

3.2 Monitoring frequency required (see MER Amendment)

Chlorophyll concentrations need to be monitored on a monthly basis. In estuaries with a tidal range of approximately 2 m or more, sampling should be done on the falling tide at approximately half tidal height to reduce the influence of ‘cleaner’ marine waters. In estuaries with little or no tidal movement or marine areas, sampling can be done at any stage of the tidal cycle. Sampling should occur for at least one year.

3.3 Data measurement method (see MER Amendment)

The chlorophyll sample collected must not be directly touched by hand and all equipment must be kept free of contaminants, particularly acids, as this may result in chlorophyll degradation.

Equipment required:

- Boat
- Sampling cylinder (graduated 500 mL high-density polyethylene plastic cylinder)
- Sample filtration system (vacuum flask/side arm flask) connected to a hand-operated vacuum pump. A 47 mm diameter filtering manifold funnel is used to hold the sample water while filtering)
- Chlorophyll filter sample holding tubes (labelled high-density polyethylene 15 mL screw-top tubes graduated with 5 and 10 mL levels marked. Magnesium carbonate (0.01g) is added to these tubes before collecting samples
- Filters (1.2 µm glass fibre/coarse ‘filter paper’)
- Aluminium foil
- Ice box filled with crushed ice to keep samples chilled until they can be frozen.

Site procedures:

1. Chlorophyll a samples are collected when advised on the in situ field measurement sheets.
2. Locate the site using a Global Positioning System (GPS).
3. If safe to do so, cut the engine to prevent fouling and contamination of the sample.
4. Rinse the filter funnel in the water and make sure rinsing water is poured out.
5. Place a filter paper on the support screen of the filtering apparatus and screw the funnel to the screen.
6. Clear any floating matter or surface scum using the underside of the sample cylinder.
7. Invert the cylinder and place it under the water to approximately 20 cm depth. Turn the right way up and fill.
8. Vigorously swirl the water around the cylinder and discard. Repeat three times and retain the final sample for filtering.
9. Quickly discard water from the top of the cylinder to the first graduated mark so that the total volume filtered can be measured.
10. Pour some of the water into the filter funnel, being careful not to spill any.
11. Pump the hand vacuum pump to start suction. Do not allow the vacuum to exceed 40 kPa.
12. Maintain vacuum until the volume of water being drawn through has decreased to a dribble. This will be evident with increased vacuum pressure yielding constant and then decreasing flow as the filter paper becomes blocked. The volume of sample collected and filtered is not critical as long as a filter containing solid material is obtained for laboratory analysis, however, **the exact volume of water filtered needs to be recorded** for the laboratory to calculate concentrations. Discard the filtered water.
13. When an appropriate amount of water is passed through, remove the funnel from the filter apparatus.
14. Record the time of sampling and the volume filtered.
15. Gently fold the filter paper in half and remove it from the support screen ensuring fingers do not come in contact with the direct sampling area.
16. Gently place the filter paper on a piece of blotting paper to remove excess water.
17. Fold the filter paper in half again, place it in the relevant labelled 15 mL holding tube containing magnesium carbonate (0.01g) and replace the lid tightly.
18. Cover the tube completely with aluminium foil to block out light from the sample.
19. Place the tube in a clip-sealed plastic bag, place in the ice box and cover with crushed ice.
20. Samples should be frozen as soon as possible. They can be kept frozen for up to one month before being analysed.
21. Samples should be transported on ice to a laboratory for analysis. The amount of chlorophyll a collected on the filter paper is determined from laboratory analysis using a spectrophotometer and the original sample concentration (µg/L) of chlorophyll a then calculated.

3.4 Data collation / calculation method (see MER Technical Report)

Data for a specific site should be collated over the study period and the median value calculated and compared against the relevant guidelines.

3.5 Data storage and management (see MER Technical report)

Data should be stored by state/territory agencies and by the collectors (if different) of the data. If possible, the public should have access to the data (and report summaries) through a website hosted by state/territory government.

3.6 Data analysis and interpretation (see MER Technical Report)

Data from at least one year should be used in the data analysis.

There can be significant spatial and temporal variation in phytoplankton concentrations. Spatial differences are often observed along the length of a waterway, whereas temporal differences are observed as some phytoplankton move up and down through the water column in a day/night cycle.

Low chlorophyll a levels suggest good water condition. However, high levels are not necessarily bad as increased phytoplankton growth tends to support larger heterotroph (eg. fish) populations. It is the long-term persistence of elevated levels that is a problem. Excessive growth often leads to poor water quality, noxious odours, oxygen depletion, human health problems and fish kills. It may also be linked to harmful (toxic) algal blooms.

Poor water quality associated with high chlorophyll concentrations needs to be distinguished from the natural variation observed with the seasons, with latitude, and those associated with hydrodynamic features (eg. upwelling). However, there is very little information to make this distinction (Ward *et al.* 1998).

Observed increases in the concentrations of chlorophyll in individual waterbodies may be related to increased nutrient concentrations, decreased flow/changed hydrodynamics (increased residence times) and/or decreased turbidity (increased light penetration) (ie the increasing eutrophication status). It is therefore important to try and correlate a change in chlorophyll concentration to nutrients, hydrodynamics and/or water clarity changes to determine if changes are natural or due to human impacts.

'National' default trigger values for chlorophyll a concentrations have been listed in the 'Water Quality Guidelines' for coastal waterways in different geographic regions (ANZECC/ARMCANZ 2000a); these trigger values are superseded in Queensland by the 'Queensland Water Quality Guidelines' (DERM 2009b). Local guidelines (which supersede both national and state/territory ones) may be available for some estuaries.

3.7 Reliability, validity and quality assurance

Quality assurance and control measures are important to minimise avoidable errors in the data and give more confidence in the data collected and conclusions made. Individuals collecting the data must have had adequate training in sample collection. Multiple samples and blanks should be taken occasionally as part of the QA/QC process. Instrument calibration and/or laboratory quality assurance should be regularly examined and recorded.

3.8 Metadata

Metadata documentation should be completed for all datasets (see Appendix A). The metadata statement should be consistent with current ANZLIC standards, which now comply with ISO 19115.

See the following web site for the Metadata Profile:
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8. Further information

ANZECC/ARMCANZ. 2000a, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality.* www.mincos.gov.au/publications/australian_and_new_zealand_guidelines_for_fresh_and_marine_water_quality.

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Waterwatch manuals: See www.waterwatch.org.au/.

Waterwatch Queensland, 2003. *Community Estuarine Monitoring Manual.* The State of Queensland (Department of Natural Resources and Mines).

9. Glossary

Algal bloom – A heavy growth of algae in and on a body of water.

Biomass – The total weight of all living organisms in a biological community or of a particular species/group.

Cyanobacteria – Blue-green bacteria, sometimes (incorrectly) called blue-green algae.

Embayment – A large indentation of a shoreline, bigger than a cove but smaller than a gulf.

Eutrophication – The process of enrichment of water with organic matter and the subsequent depletion of dissolved oxygen. A natural process that can be caused/enhanced by an increase in nutrient loads or decreased flushing rates resulting from human activity

In-situ – Latin term for 'in the original place'.

Noxious – Harmful to physical health.

Photosynthesis – The process by which green plants convert water and carbon dioxide into food (carbohydrates) using the energy of the sun.

Phytoplankton – Microscopic floating plants, mainly algae, that live suspended in bodies of water.

Primary production – Production of food by photosynthetic organisms at the bottom of the food chain.

Spatial – Pertaining to space or distance.

Temporal – Pertaining to time.

Unicellular –Consisting of only one cell, eg single celled organisms such as bacteria.

Appendix A: Metadata statement

Monitoring program	The name of the monitoring program
Custodian of data/Contact	The business name and address/contact details of the custodial organisation or responsible party
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MER AMENDMENTS

3.1 Monitoring locations

The spatial scale of interest is the entire central basin of lakes and lagoons, and the assumed chlorophyll maximum that occurs in the mid-upper sections of river estuaries. To facilitate representative spatial coverage, estuaries were divided into zones. For creeks and lagoons, zones were assigned on charts before sampling commenced. A zone was an area 500 to 700 m diameter in which sampling takes place. Sufficient zones (up to three) were allocated to the central basin of each estuary so that the majority of the estuary is represented. This may mean small systems have only one zone. In MER Year 2 (2008), only the middle estuary was sampled in river estuaries. The middle estuary was defined as having a salinity of 8 – 15 ppt, but due to the short-term temporal variability in salinity, the long-term location was defined as being in the vicinity of the upper limit of mangrove trees and this is where sampling was concentrated. Two zones were placed in the river in this vicinity. This procedure for rivers will be replaced by a longitudinal transect with continuously logged data from mid to upper estuary from MER Year 3 (2009) onwards.

3.2 Monitoring frequency required

Sampling windows across NSW are:

- NR CMA: mid September to end December
- HCR, HN and SM CMA: mid September to end March
- SR CMA: mid November to end March.

Spacing of sampling occasions was determined by a combination of logistics and the desire to fit six sampling occasions within the defined window. Southern Rivers CMA (MER Year 2 – 2008) estuaries were sampled at intervals of approximately three weeks, with all estuaries sampled within the same week.

Variables

The MER indicators that OEH sampled were chlorophyll and clarity (turbidity and secchi), supported by salinity data.

3.3 Data measurement method

Site Procedures

Field data sheets which recorded the entrance state, riparian condition, observations about macroalgae and other submerged aquatic vegetation, weather and any other relevant observations were also filled out for each estuary.

Travel to the upwind boundary of each zone in the estuary. Record secchi depth by lowering until not visible and noting depth, then lower some more and raise until visible, noting depth when visible. Secchi depth is the average of these two. The water quality probe, which recorded chlorophyll (fluorometric), turbidity, salinity, temperature, depth and time, is then fixed in the water at a depth of approximately 400 mm using a special cradle attached to the boat's gunwhale. Record the time at which the transect commences. The probe was set to log readings every second and the boat allowed to drift for five minutes. At the end of the transect, note the time that the transect ended. If there is insufficient wind, the boat was rowed or paddled for five minutes. This procedure captures data for a transect through the zone and allows the calculation of an average (or median) chlorophyll for the zone.

At the end of the transect, repeat secchi measurement and then slowly lower the sonde to the bottom, recording a profile of chlorophyll through the water column.

To allow calibration of chlorophyll as measured by the fluorometry probe and extracted chlorophyll an additional water sample was collected. To do this, a pole sampler was used during the drift to collect 10 x 1 m integrated water samples approximately 30 seconds apart. These samples were composited into a black bucket (to reduce light reflection). The fluorometric chlorophyll in the bucket was logged for two minutes and a 110 ml water sample taken directly from the bucket.

The water sample is kept cool and in the dark until the end of the day when it was filtered.

Samples are filtered by passing an exactly measured volume of sample (e.g. entire contents of 110 ml bottle) through the filter under vacuum. When all water has been extracted, remove vacuum pressure and funnel. Carefully fold filter into quarters with filtrate on the inside. Seal in a vial and wrap vial in foil. If freezer is available, freeze vial and keep frozen until analysis. It is essential that vial remains frozen, if continuous freezing is not available or is uncertain, it is better to keep vial cold (on ice).

Instrument Calibration

The YSI Model 6820V2-S multiprobes used for the MER sampling were fitted with a fluorometric chlorophyll probe and a turbidity probe. The chlorophyll probe is factory calibrated and a standard solution of rhodamine was used prior to every field trip to check that the calibration remains constant over time and is consistent among probes. Salinity is also calibrated to a known seawater standard prior to every trip.

Data Analysis

Using the recorded start and end times, data for the transects in each zone and the data for the bucket, were extracted from the data files stored by the YSI probe. Mean and SE was calculated for salinity, temperature, and chlorophyll for each zone. Estuary means were calculated for each time by taking the mean of all zones in the estuary.

Calibration of insitu fluorometric chlorophyll and laboratory extracted chlorophyll was done by comparing the laboratory derived chlorophyll concentration in the composite water sample collected for the purpose during routine sampling, with the mean chlorophyll concentration in the bucket indicated by the fluorometry probe prior to the laboratory sample being collected. The results showed that there was a non-linear relationship between laboratory and in-situ fluorometry chlorophyll measurements. This relationship was best represented by two linear relationships, one for low to medium chlorophyll (≤19 µg/l) and the other for high to very high chlorophyll (>19 µg/l). For in-situ fluorometry readings ≤19 µg/l, lab = 0.68 x in-situ (n = 242; r^2 = 0.88). For in-situ >19 µg/l, lab = 0.92 x in-situ (n = 14; r^2 = 0.98). These relationships will, however, be affected by the calibration of the in-situ probe and may not be immediately transferable to other probes. The basis of these relationships is provided in Appendix 14.

Appendix 14

Comparison of laboratory extracted and fluorometric chlorophyll concentrations

Linear and non-linear regression techniques were used to examine the relationship between laboratory extracted and fluorometric chlorophyll determinations on the same samples. Analyses were done in the NCSS statistical package, and included boot-strap techniques to test the robustness of the relationships.

Initial inspection of the data indicated that the majority of the data had a fluorometric concentration of <19 µg/l, with a fewer very large values. When all data were analysed together, the linear fit was strong, but the mass of data <19 µg/l were contributing very little. In order to remove this bias, data were split into 2 groups, ≤19 µg/l and >19 µg/l.

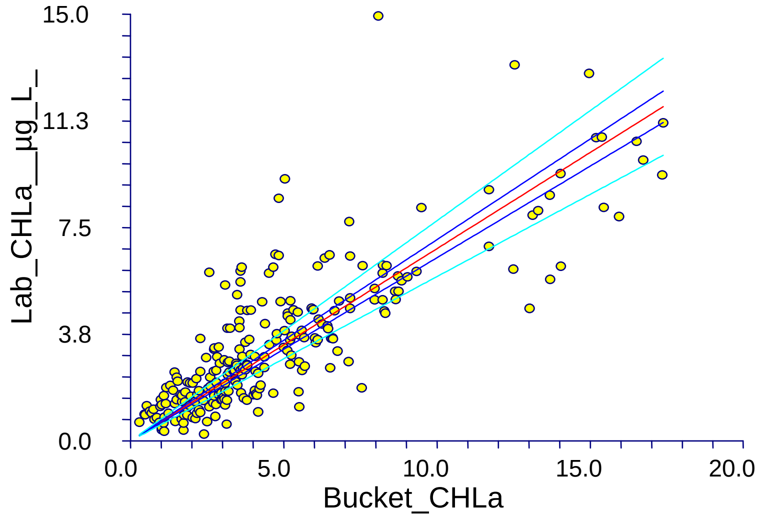
It was initially hypothesised that “true-colour” of the water may be a confounding factor in the comparison, because it is well known that colour will induce a fluorometric signal in the absence of chlorophyll. Despite this, when colour was included in a multiple regression, it’s contribution to the regression was not significant ($p > 0.05$) and so it was not included in further analyses.

The results of regressions between laboratory and in-situ chlorophyll are shown below.

1. CHLOROPHYLL ≤19 µg/l

Linear regression
Filter bucket_chla<19 and Lab_CHLa__µg_L_<19
Y = Lab_CHLa__µg_L_ X = in-situ (bucket)_CHLa

Lab_CHLa__µg_L_ vs Bucket_CHLa



Run Summary Section

Parameter	Value	Parameter	Value
Dependent Variable	Lab_CHLa__µg_L_	Rows Processed	256
Independent Variable	Bucket_CHLa	Rows Used in Estimation	242
Frequency Variable	None	Rows with X Missing	0
Weight Variable	None	Rows with Freq Missing	0
Intercept	0.0000	Rows Prediction Only	0
Slope	0.6754	Sum of Frequencies	242
R-Squared	0.8786	Sum of Weights	242.0000
Correlation	0.9373	Coefficient of Variation	0.4338
Mean Square Error	2.264892	Square Root of MSE	1.504956

Descriptive Statistics Section

Parameter	Dependent	Independent
Variable	Lab_CHLa__µg_L_	Bucket_CHLa
Count	242	242
Mean	3.4696	4.7895
Standard Deviation	4.3101	5.9818
Minimum	0.2400	0.2900
Maximum	14.9400	17.3900

Regression Estimation Section

Parameter	Intercept B(0)	Slope B(1)
Regression Coefficients	0.0000	0.6754
Lower 95% Confidence Limit		0.6435
Upper 95% Confidence Limit		0.7072
Standard Error		0.0162
Standardized Coefficient	0.0000	0.9373
T Value		41.7606
Prob Level (T Test)		0.0000
Prob Level (Randomization Test N =1000)		0.0010
Reject H0 (Alpha = 0.0500)		Yes
Regression of Y on X	0.0000	0.6754

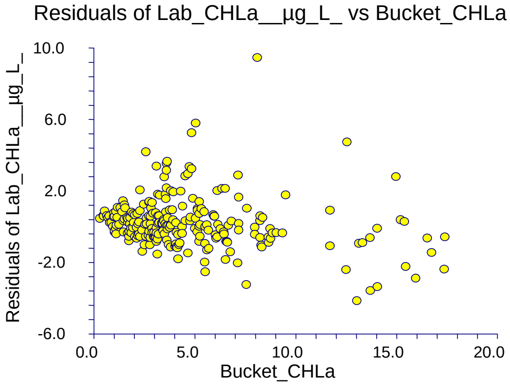
Estimated Model

0.67538041752488*Bucket_CHLa

Bootstrap Section

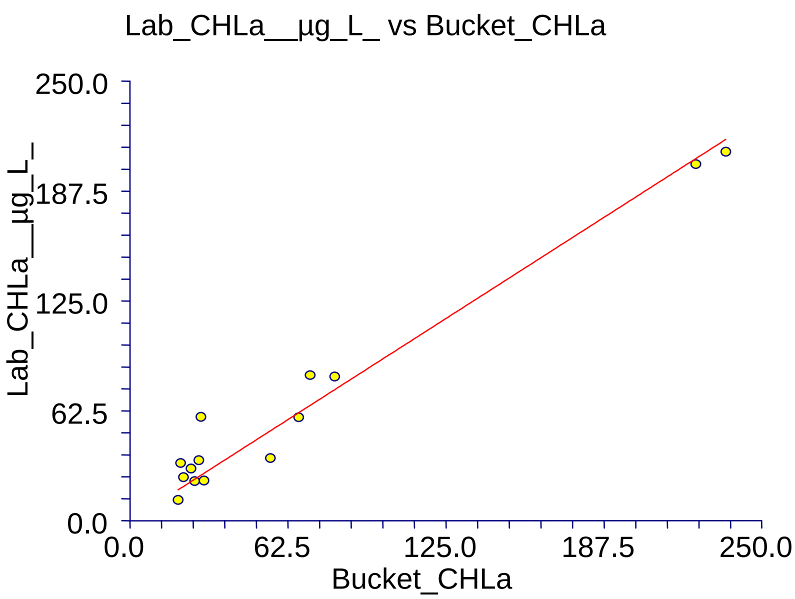
------------ Estimation Results------------		------------ Bootstrap Confidence Limits----------------		
Parameter	**Estimate**	**Conf. Level**	**Lower**	**Upper**
Slope				
Original Value	0.6754	0.9000	0.6391	0.7074
Bootstrap Mean	0.6759	0.9500	0.6318	0.7135
Bias (BM - OV)	0.0005	0.9900	0.6169	0.7255
Bias Corrected	0.6749			
Standard Error	0.0207			
R-Squared				
Original Value	0.8786	0.9000	0.8465	0.9101
Bootstrap Mean	0.8804	0.9500	0.8419	0.9172
Bias (BM - OV)	0.0018	0.9900	0.8350	0.9331
Bias Corrected	0.8768			
Standard Error	0.0193			
Standard Error of Estimate				
Original Value	1.5050	0.9000	1.2612	1.7537
Bootstrap Mean	1.4881	0.9500	1.2006	1.7918
Bias (BM - OV)	-0.0169	0.9900	1.0958	1.8734
Bias Corrected	1.5218			
Standard Error	0.1498			
Orthogonal Slope				
Original Value	0.7055	0.9000	0.6615	0.7441
Bootstrap Mean	0.7059	0.9500	0.6515	0.7515
Bias (BM - OV)	0.0004	0.9900	0.6324	0.7635
Bias Corrected	0.7051			
Standard Error	0.0253			

Residual Plots Section



2. CHLOROPHYLL >19 µg/l

Linear Regression
Filter Bucket_CHLa > 19
Y = Lab_CHLa__µg_L_ X = Bucket_CHLa



Run Summary Section

Parameter	**Value**	**Parameter**	**Value**
Dependent Variable	Lab_CHLa__µg_L_	Rows Processed	256
Independent Variable	Bucket_CHLa	Rows Used in Estimation	14
Frequency Variable	None	Rows with X Missing	0
Weight Variable	None	Rows with Freq Missing	0
Intercept	0.0000	Rows Prediction Only	0
Slope	0.9194	Sum of Frequencies	14
R-Squared	0.9804	Sum of Weights	14.0000
Correlation	0.9902	Coefficient of Variation	0.1997
Mean Square Error	168.5134	Square Root of MSE	12.98127

Descriptive Statistics Section

Parameter	**Dependent**	**Independent**
Variable	Lab_CHLa__µg_L_	Bucket_CHLa
Count	14	14
Mean	65.0086	66.3900
Standard Deviation	89.4265	96.3057
Minimum	11.8300	19.0700
Maximum	209.9100	235.8300

Regression Estimation Section

Parameter	**Intercept B(0)**	**Slope B(1)**
Regression Coefficients	0.0000	0.9194
Lower 95% Confidence Limit		0.8416
Upper 95% Confidence Limit		0.9973
Standard Error		0.0360
Standardized Coefficient	0.0000	0.9902
T Value		25.5224
Prob Level (T Test)		0.0000
Reject H0 (Alpha = 0.0500)		Yes
Power (Alpha = 0.0500)		1.0000

Estimated Model

.919439649809071*Bucket_CHLa

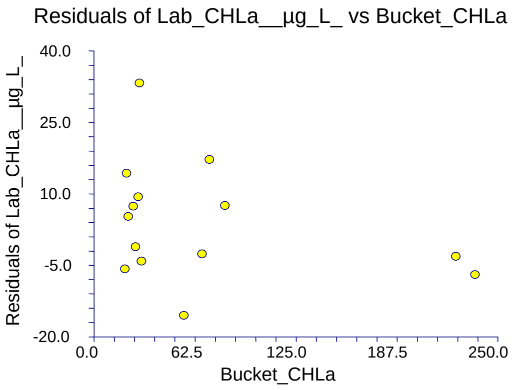
Bootstrap Section

------------ Estimation Results------------		**| ------------ Bootstrap Confidence Limits----------------**		
Parameter	**Estimate**	**| Conf. Level**	**Lower**	**Upper**
Slope				
Original Value	0.9194	| 0.9000	0.7995	0.9435
Bootstrap Mean	0.9344	| 0.9500	0.7477	0.9474
Bias (BM - OV)	0.0149	| 0.9900	0.6633	0.9630
Bias Corrected	0.9045			
Standard Error	0.0481			
Correlation				
Original Value	0.0000	| 0.9000	-0.9974	-0.9609
Bootstrap Mean	0.9864	| 0.9500	-0.9980	-0.9496
Bias (BM - OV)	0.9864	| 0.9900	-0.9987	-0.9221
Bias Corrected	-0.9864			
Standard Error	0.0129			
R-Squared				
Original Value	0.9804	| 0.9000	0.9660	1.0000
Bootstrap Mean	0.9731	| 0.9500	0.9648	1.0000
Bias (BM - OV)	-0.0074	| 0.9900	0.9634	1.0000
Bias Corrected	0.9878			
Standard Error	0.0250			
Standard Error of Estimate				
Original Value	12.9813	| 0.9000	8.3929	18.5044
Bootstrap Mean	12.3697	| 0.9500	7.6155	19.0271
Bias (BM - OV)	-0.6115	| 0.9900	5.8260	20.2298
Bias Corrected	13.5928			
Standard Error	3.0594			
Orthogonal Slope				
Original Value	0.9279	| 0.9000	0.7759	0.9558

Bootstrap Mean	0.9478 | 0.9500	0.7188	0.9600
Bias (BM - OV)	0.0200 | 0.9900	0.5991	0.9725
Bias Corrected	0.9079		
Standard Error	0.0610		

Sampling Method = Observation, Confidence Limit Type = Reflection, Number of Samples = 3000.

Residual Plots Section



Appendix 15

Seagrass, mangrove and saltmarsh areas

	Area – West et al. 1985 (m^2)			Area – Williams et al. 2006 (m^2)			Change %		
Estuary	**Seagrass**	**Mangrove**	**Saltmarsh**	**Seagrass**	**Mangrove**	**Saltmarsh**	**Seagrass**	**Mangrove**	**Saltmarsh**
Tweed River	331000	3091000	213000	806296	3982356	762540	144	29	258
Cudgen Creek	0	94000	561000	8898	138927	52146	na	48	-91
Cudgera Creek	16000	1380000	16000	33849	147656	74312	112	-89	364
Mooball Creek	13000	53000	0	24169	114381	7982	86	116	na
Brunswick River	18000	816000	56000	35833	1232821	310143	99	51	454
Belongil Creek	0	50000	54000	0	69750	83235	na	40	54
Tallow Creek	0	0	3000	0	0	0	na	na	-100
Broken Head Creek	0	0	36000	0	0	0	na	na	-100
Richmond River	189000	4949000	99000	320050	6025504	599383	69	22	505
Salty Lagoon	ns	ns	ns	ns	ns	ns	ns	ns	ns
Evans River	0	330000	375000	6344	408668	357594	na	24	-5
Jerusalem Creek	0	0	21000	0	0	0	na	na	-100
Clarence River	1540000	5208000	1954000	826195	7652740	2901312	-46	47	48
Lake Arragan	ns	ns	ns	ns	ns	ns	ns	ns	ns
Cakora Lagoon	ns	ns	ns	42	4561	128565	na	na	na
Sandon River	28000	533000	258000	85901	574307	477427	207	8	85
Wooli Wooli River	28000	493000	531000	94225	860129	668569	237	74	26
Station Creek	0	0	0	0	435	3965	na	na	na
Corindi River	33000	189000	293000	23680	371416	572380	-28	97	95
Pipe Clay Creek	ns	ns	ns	ns	ns	ns	ns	ns	ns
Arrawarra Creek	3000	0	8000	776	10171	9957	-74	na	24
Darkum Creek	0	1000	0	12955	9716	417	na	872	na
Woolgoolga Lake	0	2000	0	0	6343	180	na	217	na
Flat Top Point Creek	ns	ns	ns	ns	ns	ns	ns	ns	ns
Hearns Lake	0	8000	36000	0	2618	45023	na	-67	25
Moonee Creek	4000	36000	73000	31596	85496	131679	690	137	80
Pine Brush Creek	ns	ns	ns	ns	ns	ns	ns	ns	ns
Coffs Creek	18000	167000	0	2178	191680	1795	-88	15	na
Boambee Creek	11000	66000	158000	59900	330585	29444	445	401	-81
Bonville Creek	8000	53000	148000	88727	137016	159401	1009	159	8
Bundageree Creek	ns	ns	ns	ns	ns	ns	ns	ns	ns
Bellinger River	59000	847000	29000	132813	1171670	143445	125	38	395
Dalhousie Creek	12000	34000	3000	1629	6571	6878	-86	-81	129
Oyster Creek	0	0	0	0	217	2991	na	na	na
Deep Creek	7000	8000	604000	9608	35091	638670	37	339	6
Nambucca River	224000	449000	1034000	605399	1454650	1276702	170	224	23
Macleay River	1097000	5201000	3652000	957421	5710319	4247391	-13	10	16
South West Rocks Creek	24000	528000	141000	2169	647819	112016	-91	23	-21
Saltwater Creek (Frederickton)	0	0	0	0	0	0	na	na	na
Korogoro Creek	0	13000	14000	383	57697	39775	na	344	184
Killick Creek	11000	0	8000	102	45196	9150	-99	na	14
Goolawah Lagoon	ns	ns	ns	ns	ns	ns	ns	ns	ns
Hastings River	1141000	2078000	804000	1457532	3437018	1866684	28	65	132
Cathie Creek	7000	1000	5972000	0	32	5886867	-100	-97	-1
Duchess Gully	ns	ns	ns	ns	ns	ns	ns	ns	ns
Camden Haven River	6336000	873000	780000	10249788	1408023	767556	62	61	-2
Manning River	329000	3582000	721000	1654310	3905153	2447013	403	9	239
Khappinghat Creek	19000	0	2000	3281	70	158886	-83	na	7844
Black Head Lagoon	ns	ns	ns	0	279	0	na	na	na
Wallis Lake	30786000	786000	4005000	31896878	1470832	5900187	4	87	47
Smiths Lake	2080000	0	3000	2959901	0	0	42	na	-100
Myall River	2815000	1021000	1784000	2173230	3027972	2670020	-23	197	50
Karuah River	380000	3479000	4828000	66433	5069826	3756016	-83	46	-22
Tilligerry Creek									
Port Stephens	7453000	23260000	7719000	14390806	19043533	10631930	93	-18	38
Hunter River	153000	15481000	5049000	0	19217371	5204314	-100	24	3
Glenrock Lagoon	ns	ns	ns	ns	ns	ns	ns	ns	ns
Lake Macquarie	13391000	998000	705000	14633220	1249240	887411	9	25	26
Middle Camp Creek	ns	ns	ns	ns	ns	ns	ns	ns	ns
Moonee Beach Creek	ns	ns	ns	ns	ns	ns	ns	ns	ns
Tuggerah Lake	11619000	0	7000	17317511	802	129188	49	na	1746
Wamberal Lagoon	245000	0	0	435964	0	0	78	na	na
Terrigal Lagoon	46000	0	0	0	1303	0	-100	na	na
Avoca Lake	161000	0	0	ns	ns	ns	na	na	na
Cockrone Lake	0	0	0	288967	0	0	na	na	na
Brisbane Water	5490000	1635000	918000	5581700	2077977	1123910	2	27	22
Hawkesbury River	470000	10654000	1126000	914856	9832681	2877526	95	-8	156

	Area – West et al. 1985 (m^2)			Area – Williams et al. 2006 (m^2)			Change %		
Estuary	**Seagrass**	**Mangrove**	**Saltmarsh**	**Seagrass**	**Mangrove**	**Saltmarsh**	**Seagrass**	**Mangrove**	**Saltmarsh**
Pittwater	1934000	180000	26000	1891526	174793	26847	-2	-3	3
Broken Bay	ns	ns	ns	0	0	0	na	na	na
Narrabeen Lagoon	468000	0	0	616753	73	7906	32	na	na
Dee Why Lagoon	34000	0	440000	0	0	63405	-100	na	-86
Curl Curl Lagoon	0	0	0	0	0	0	na	na	na
Manly Lagoon	4000	0	0	1196	176	0	-70	na	na
Middle Harbour Creek									
Lane Cove River									
Parramatta River									
Port Jackson	1286000	1475000	73000	518608	1846987	94897	-60	25	30
Cooks River	ns	ns	ns	0	108241	2651	na	na	na
Georges River	268000	2038000	247000	1933594	3824546	839558	621	88	240
Botany Bay	3403000	3996000	1601000	5358454	2295572	761668	57	-43	-52
Port Hacking	869000	280000	106000	1002388	299180	128326	15	7	21
Wattamolla Creek	ns	ns	ns	ns	ns	ns	ns	ns	ns
Hargraves Creek	ns	ns	ns	ns	ns	ns	ns	ns	ns
Stanwell Creek	ns	ns	ns	ns	ns	ns	ns	ns	ns
Flanagans Creek	ns	ns	ns	ns	ns	ns	ns	ns	ns
Woodlands Creek	ns	ns	ns	ns	ns	ns	ns	ns	ns
Slacky Creek	ns	ns	ns	ns	ns	ns	ns	ns	ns
Bellambi Gully	ns	ns	ns	ns	ns	ns	ns	ns	ns
Bellambi Lake	ns	ns	ns	ns	ns	ns	ns	ns	ns
Towradgi Creek	36000	0	0	0	291	0	-100	na	na
Fairy Creek	ns	ns	ns	ns	ns	ns	ns	ns	ns
Allans Creek	ns	ns	ns	0	20549	7563	na	na	na
Port Kembla	0	0	0	0	0	0	na	na	na
Lake Illawarra	6116000	0	203000	7965998	57	302433	30	na	49
Elliott Lake	28000	0	0	7072	5136	661	-75	na	na
Minnamurra River	232000	484000	197000	116919	878742	326510	-50	82	66
Spring Creek	3000	0	0	0	0	0	-100	na	na
Munna Munnora Creek	ns	ns	ns	ns	ns	ns	ns	ns	ns
Werri Lagoon	117000	0	0	775	10	0	-99	na	na
Crooked River	4000	0	0	45618	8145	17442	1040	na	na
Shoalhaven River	1018000	3476000	1542000	4239366	4179888	2057804	316	20	33
Wollumboola Lake	1145000	0	0	1340071	0	0	17	na	na
Currarong Creek	ns	ns	ns	ns	ns	ns	ns	ns	ns
Cararma Creek									
Wowly Gully									
Callala Creek									
Currambene Creek									
Moona Moona Creek									
Flat Rock Creek									
Captains Beach Lagoon									
Telegraph Creek									
Jervis Bay	9061000	1250000	2330000	6082037	2053394	1483421	-33	64	-36
St Georges Basin	8538000	252000	36000	3170393	275761	149322	-63	9	315
Swan Lake	587000	0	0	261291	0	0	-55	na	na
Berrara Creek	6000	0	0	52266	0	5128	771	na	na
Nerrindillah Creek	5000	0	0	29593	0	0	492	na	na
Conjola Lake	527000	0	13000	166010	714	27075	-68	na	108
Narrawallee Inlet	14000	378000	91000	86505	416161	175548	518	10	93
Mollymook Creek	ns	ns	ns	24	0	797	na	na	na
Millards Creek	ns	ns	ns	ns	ns	ns	ns	ns	ns
Ulladulla	10000	0	0	628	1100	1446	-94	na	na
Burrill Lake	508000	0	157000	764311	0	236834	50	na	51
Tabourie Lake	1199000	0	10000	219062	0	39511	-82	na	295
Termeil Lake	70000	0	0	5823	0	0	-92	na	na
Meroo Lake	115000	0	0	754513	0	0	556	na	na
Willinga Lake	4000	0	0	172838	0	0	4221	na	na
Butlers Creek	3000	0	6000	7295	0	1182	143	na	-80
Durras Lake	509000	0	46000	495812	0	170619	-3	na	271
Durras Creek	ns	ns	ns	ns	ns	ns	ns	ns	ns
Maloneys Creek	ns	ns	ns	0	0	0	na	na	na
Cullendulla Creek	64000	916000	6000	125360	881264	173516	96	-4	2792
Clyde River	92000	2318000	1017000	792769	3309973	521043	762	43	-49
Batemans Bay	71000	0	0	189375	4344	0	167	na	na
Saltwater Creek (Rosedale)	ns	ns	ns	ns	ns	ns	ns	ns	ns
Tomaga River	46000	210000	351000	292731	350955	458274	536	67	31
Candlagan Creek	16000	21000	31000	47632	39364	69562	198	87	124

	Area – West et al. 1985 (m²)			Area – Williams et al. 2006 (m²)			Change %		
Estuary	**Seagrass**	**Mangrove**	**Saltmarsh**	**Seagrass**	**Mangrove**	**Saltmarsh**	**Seagrass**	**Mangrove**	**Saltmarsh**
Bengello Creek	ns	ns	ns	0	0	0	na	na	na
Moruya River	644000	380000	674000	1197096	473893	789552	86	25	17
Congo Creek	0	0	0	2240	0	11187	na	na	na
Meringo Creek	0	0	0	0	0	11572	na	na	na
Kellys Lake	ns	ns	ns	0	0	0	na	na	na
Coila Lake	1862000	0	317000	1367246	0	342675	-27	na	8
Tuross River	452000	566000	401000	2175728	663830	801659	381	17	100
Lake Brunderee	64000	0	246000	25656	0	16863	-60	na	-93
Lake Tarourga	ns	ns	ns	0	0	0	na	na	na
Lake Brou	78000	0	250000	0	0	88243	-100	na	-65
Lake Mummuga	294000	0	55000	325367	13379	21511	11	na	-61
Kianga Lake	11000	0	33000	112804	0	0	925	na	-100
Wagonga Inlet	1484000	249000	56000	809085	197145	23295	-45	-21	-58
Little Lake (Narooma)	ns	ns	ns	0	0	0	na	na	na
Bullengella Lake	ns	ns	ns	0	0	0	na	na	na
Nangudga Lake	120000	0	115000	201933	0	146448	68	na	27
Corunna Lake	179000	0	33000	161255	0	49243	-10	na	49
Tilba Tilba Lake	0	0	0	94977	0	156362	na	na	na
Little Lake (Wallaga)	ns	ns	ns	0	0	16649	na	na	na
Wallaga Lake	1343000	0	295000	1085268	0	161640	-19	na	-45
Bermagui River	338000	434000	66000	271066	473147	167667	-20	9	154
Baragoot Lake	49000	0	53000	6148	0	78956	-87	na	49
Cuttagee Lake	430000	0	76000	384785	0	112547	-11	na	48
Murrah River	16000	0	109000	96772	16990	161150	505	na	48
Bunga Lagoon	0	0	180000	177	0	29876	na	na	-83
Wapengo Lagoon	360000	409000	319000	417748	555116	505925	16	36	59
Middle Lagoon	81000	0	11000	210739	0	52178	160	na	374
Nelson Lagoon	114000	271000	63000	10050	490610	155448	-91	81	147
Bega River	301000	0	411000	261152	0	533033	-13	na	30
Wallagoot Lake	647000	0	14000	774321	0	117630	20	na	740
Bournda Lagoon	43000	0	0	261	0	4622	-99	na	na
Back Lagoon	204000	0	18000	215350	0	22052	6	na	23
Merimbula Lake	2297000	377000	629000	1638211	349144	591391	-29	-7	-6
Pambula River	868000	449000	188000	705673	580050	365549	-19	29	94
Curalo Lagoon	58000	0	116000	184735	0	89574	219	na	-23
Shadrachs Creek	ns	ns	ns	ns	ns	ns	ns	ns	ns
Nullica River	20000	0	0	11504	7596	18240	-42	na	na
Boydtown Creek	ns	ns	ns	ns	ns	ns	ns	ns	ns
Towamba River	27000	900000	9000	96833	16863	125219	259	-98	1291
Fisheries Creek	33000	0	11000	5764	0	34588	-83	na	214
Twofold Bay	26000	0	8000	739741	0	0	2745	na	-100
Saltwater Creek (Eden)	ns	ns	ns	ns	ns	ns	ns	ns	ns
Woodburn Creek	ns	ns	ns	ns	ns	ns	ns	ns	ns
Wonboyn River	237000	0	483000	806180	223	517538	240	na	7
Merrica River	0	0	0	0	0	0	na	na	na
Table Creek	ns	ns	ns	0	0	929	na	na	na
Nadgee River	0	0	0	36	0	82084	na	na	na
Nadgee Lake	75000	0	0	32302	0	959	-57	na	na

= the area for that estuary has been combined into one value for a port, bay or harbour

ns = estuary was **n**ot **s**urveyed

na = **n**ot **a**pplicable as there is only one survey for the estuary

na = **n**ot **a**pplicable as one or both surveys recorded nil area

Appendix 16

Total Nitrogen load and chlorophyll a dataset

Estuary	Classification	Entrance condition	Areal load TN ($t/km^2/yr$)	Chl a (annual median µg/l)	TN increase score
Georges River	Lake	O	17.90	3.60	1
Botany Bay	Lake	O	0.35	1.58	1
Wamberal Lagoon	Lake	I	3.95	3.50	2
Brisbane Water	Lake	O	1.20	3.07	2
Middle Harbour Creek	Lake	O	2.34	2.20	2
Lane Cove River	Lake	O	8.82	3.50	2
Port Jackson	Lake	O	0.30	1.90	2
Lake Illawarra	Lake	O/(I)	2.80	4.30	2
Camden Haven River	Lake	O/T	5.31	5.42	3
Wallis Lake	Lake	O/T	2.64	1.74	3
Smiths Lake	Lake	I	0.53	1.29	3
Lake Macquarie	Lake	O/T	1.24	2.32	3
Tuggerah Lake	Lake	I/(O)	1.97	3.49	3
Hawkesbury River	Lake	O	13.42	3.50	3
Narrabeen Lagoon	Lake	I/(O)	3.83	3.45	3
Swan Lake	Lake	I	0.72	0.53	3
Burrill Lake	Lake	O(I)	3.06	4.61	3
Wallaga Lake	Lake	O/I	7.76	1.80	3
Merimbula Lake	Lake	O	1.26	0.70	3
Myall River	Lake	O	0.94	2.27	4
Port Hacking	Lake	O	1.22	1.30	4
St Georges Basin	Lake	O	1.02	2.58	4
Conjola Lake	Lake	O	2.11	1.50	4
Durras Lake	Lake	I	1.55	3.17	4
Coila Lake	Lake	I	1.30	2.48	4
Wapengo Lagoon	Lake	O	3.24	0.50	4
Wallagoot Lake	Lake	I	0.77	2.37	4
Tweed River	River	O/T	41.28	2.02	2
Brunswick River	River	O/T	74.07	3.90	2
Richmond River	River	O/T	89.85	2.42	2
Minnamurra River	River	O	24.76	1.32	2
Clarence River	River	O/T	29.64	2.48	3
Nambucca River	River	O/T	28.94	1.66	3
Macleay River	River	O/T	42.11	1.52	3
Hastings River	River	O/T	35.82	2.62	3
Manning River	River	O/T	36.99	2.79	3
Karuah River	River	O	13.77	1.89	3
Shoalhaven River	River	O	24.31	1.87	3
Bellinger River	River	O/T	50.02	1.54	4
Clyde River	River	O	9.01	2.51	4
Moruya River	River	O/T	29.98	1.91	4
Tuross River	River	O	15.22	2.59	4
Pambula River	River	O	7.84	1.57	4
Sandon River	River	O	6.71	0.92	5
Dee Why Lagoon	Lagoon	I	11.48	3.11	1
Curl Curl Lagoon	Lagoon	I	10.80	3.00	1
Manly Lagoon	Lagoon	I	47.84	5.25	1
Belongil Creek	Lagoon	I	47.43	8.00	2
Avoca Lake	Lagoon	I	4.28	3.12	2
Bellambi Lake	Lagoon	I	46.90	6.70	2
Towradgi Creek	Lagoon	I	215.38	2.60	2
Fairy Creek	Lagoon	I	176.05	5.36	2
Spring Creek	Lagoon	I	37.00	2.20	2
Werri Lagoon	Lagoon	I	39.37	0.60	2
Khappinghat Creek	Lagoon	I	17.55	2.29	3
Termeil Lake	Lagoon	I	4.08	2.42	3
Meroo Lake	Lagoon	I	2.31	1.82	3
Willinga Lake	Lagoon	I	5.54	1.20	3
Congo Creek	Lagoon	I	59.93	4.15	3
Corunna Lake	Lagoon	I	3.72	3.10	3
Tabourie Lake	Lagoon	O(I)	3.99	1.57	4
Lake Brou	Lagoon	I	2.59	1.79	4
Baragoot Lake	Lagoon	I	4.52	4.63	4
Cuttagee Lake	Lagoon	I	6.10	1.69	4
Wattamolla Creek	Lagoon	I	11.56	0.88	5
Merrica River	Lagoon	I	40.93	1.65	5

Appendix 17

Metric scores for Estuarine Fish Community Index

	Metric no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14			
Estuary	**Metric**	**Species richness**	**Protected species**	**Introduced species**	**Species occurrence**	**Relative species abundance**	**Most abundant species**	**Estuarine resident taxa**	**Estuarine dependent marine taxa**	**Abundance of estuarine residents**	**Abundance of estuarine dependents**	**Benthic feeding taxa**	**Fish eating taxa**	**Abundance of benthic feeders**	**Abundance of fish eaters**	**Estuarine Fish Community Index score**	**Index rating**	**Index score**
Tweed River		3	3	3	3	5	3	3	3	1	1	3	3	5	1	40	Fair	3
Cudgen Creek																		
Cudgera Creek		3	3	3	3	3	3	5	3	1	1	5	3	5	1	42	Fair	3
Mooball Creek																		
Brunswick River		3	3	3	3	5	1	3	3	3	3	3	3	3	1	40	Fair	3
Belongil Creek		1	3	3	1	3	3	1	3	5	5	1	1	5	5	40	Fair	3
Tallow Creek		1	3	3	1	1	1	1	1	1	1	1	1	1	5	22	Very poor	1
Broken Head Creek		1	3	3	1	1	1	1	1	3	5	1	1	1	5	28	Poor	2
Richmond River		3	5	3	5	5	5	3	5	5	3	3	3	5	1	54	Good	4
Salty Lagoon																		
Evans River																		
Jerusalem Creek																		
Clarence River		3	5	3	5	5	3	3	5	1	1	3	3	5	3	48	Fair	3
Lake Arragan																		
Cakora Lagoon																		
Sandon River		3	5	3	3	5	1	3	3	1	1	3	3	5	1	40	Fair	3
Wooli Wooli River		3	5	3	3	5	1	3	3	1	1	3	3	5	1	40	Fair	3
Station Creek		1	3	3	1	1	3	1	1	5	5	1	3	5	5	38	Fair	3
Corindi River		5	5	3	3	3	1	5	5	1	1	5	5	3	1	46	Fair	3
Pipe Clay Creek		1	3	1	1	1	3	1	1	5	1	1	3	5	5	32	Poor	2
Arrawarra Creek		3	3	3	3	5	3	3	3	3	3	3	1	5	5	46	Fair	3
Darkum Creek		3	3	3	3	3	1	3	1	1	1	3	1	3	5	34	Poor	2
Woolgoolga Lake		3	3	3	3	3	5	3	5	5	5	1	3	5	5	52	Good	4
Flat Top Point Creek																		
Hearns Lake		3	3	3	3	3	5	3	3	3	1	3	3	5	5	46	Fair	3
Moonee Creek		1	3	3	3	5	3	1	3	1	1	1	3	5	5	38	Fair	3
Pine Brush Creek																		
Coffs Creek																		
Boambee Creek		3	5	3	5	3	5	3	3	5	5	3	3	5	5	56	Good	4
Bonville Creek																		
Bundageree Creek																		
Bellinger River		5	5	3	5	5	1	5	5	1	1	5	5	3	1	50	Good	4
Dalhousie Creek		3	3	3	3	1	3	3	1	5	5	1	5	5	5	46	Fair	3
Oyster Creek		1	3	3	3	3	3	1	1	3	1	3	1	5	5	36	Fair	3
Deep Creek																		
Nambucca River		3	5	3	5	5	3	3	3	3	1	3	3	5	5	50	Good	4
Macleay River		3	3	3	5	5	3	3	5	3	3	3	3	5	1	48	Fair	3
South West Rocks Creek		3	3	3	3	3	3	5	5	3	3	5	3	5	1	48	Fair	3
Saltwater Creek (Frederickton)		1	3	3	1	1	1	1	1	3	3	1	1	5	3	28	Poor	2
Korogoro Creek		1	3	3	3	5	5	1	3	5	5	1	1	5	1	42	Fair	3
Killick Creek		1	3	3	1	3	1	1	3	3	3	1	1	5	5	34	Poor	2
Goolawah Lagoon																		
Hastings River		5	5	3	5	5	3	5	5	3	3	5	3	5	1	56	Good	4
Cathie Creek		5	5	1	5	1	5	5	5	3	1	5	1	5	5	52	Good	4
Duchess Gully																		
Camden Haven River																		
Manning River		3	5	3	5	5	3	5	3	1	1	3	3	5	3	48	Fair	3
Khappinghat Creek		5	3	3	5	3	5	5	5	3	5	5	5	5	5	62	Very good	5
Black Head Lagoon																		
Wallis Lake		3	5	3	3	3	3	3	3	1	1	3	3	5	1	40	Fair	3
Smiths Lake																		
Myall River																		
Karuah River		3	5	3	3	3	5	5	3	1	1	3	1	5	1	42	Fair	3
Tilligerry Creek																		

Estuary	Metric	Species richness	Protected species	Introduced species	Species occurrence	Relative species abundance	Most abundant species	Estuarine resident taxa	Estuarine dependent marine taxa	Abundance of estuarine residents	Abundance of estuarine dependents	Benthic feeding taxa	Fish eating taxa	Abundance of benthic feeders	Abundance of fish eaters	Estuarine Fish Community Index score	Index rating	Index score
	Metric no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14			
Port Stephens																		
Hunter River																		
Glenrock Lagoon																		
Lake Macquarie		5	5	3	5	3	5	5	5	3	3	5	3	5	3	58	Good	4
Middle Camp Creek																		
Moonee Beach Creek																		
Tuggerah Lake		3	5	3	5	3	5	5	5	3	3	3	3	5	5	56	Good	4
Wamberal Lagoon		3	3	3	3	1	1	3	3	1	3	1	5	5	5	40	Fair	3
Terrigal Lagoon		3	3	1	5	3	3	3	3	3	1	3	3	3	5	42	Fair	3
Avoca Lake		3	3	1	3	3	3	3	3	3	1	3	1	3	5	38	Fair	3
Cockrone Lake		1	3	1	3	1	1	1	3	3	3	1	1	5	5	32	Poor	2
Brisbane Water		5	3	3	5	5	3	5	5	3	3	5	3	5	1	54	Good	4
Hawkesbury River		5	5	3	3	3	5	5	3	3	3	5	3	5	5	56	Good	4
Pittwater		3	5	3	5	5	5	5	3	3	3	3	1	5	1	50	Good	4
Broken Bay																		
Narrabeen Lagoon																		
Dee Why Lagoon		3	3	3	3	1	3	3	3	5	5	3	1	5	1	42	Fair	3
Curl Curl Lagoon																		
Manly Lagoon																		
Middle Harbour Creek																		
Lane Cove River																		
Parramatta River																		
Port Jackson		3	5	3	5	3	3	3	5	3	3	3	1	5	3	48	Fair	3
Cooks River																		
Georges River		3	5	3	3	3	3	3	3	5	5	3	1	5	1	46	Fair	3
Botany Bay																		
Port acking H		5	5	3	3	3	3	5	5	5	5	5	5	5	1	58	Good	4
Wattamolla Creek																		
Hargraves Creek																		
Stanwell Creek																		
Flanagans Creek																		
Woodlands Creek																		
Slacky Creek																		
Bellambi Gully																		
Bellambi Lake																		
Towradgi Creek																		
Fairy Creek																		
Allans Creek																		
Port Kembla																		
Lake Illawarra		3	5	3	3	3	3	3	5	3	3	3	5	5	5	52	Good	4
Elliott Lake																		
Minnamurra River																		
Spring Creek																		
Munna Munnora Creek																		
Werri Lagoon																		
Crooked River																		
Shoalhaven River		5	5	3	5	3	1	5	3	1	1	5	3	5	3	48	Fair	3
Wollumboola Lake																		
Currarong Creek																		
Cararma Creek																		
Wowly Gully																		
Callala Creek																		
Currambene Creek																		
Moona Moona Creek																		
Flat Rock Creek																		
Captains Beach Lagoon																		
Telegraph Creek																		
Jervis Bay																		
St Georges Basin		3	5	3	3	5	3	3	3	5	5	3	1	5	1	48	Fair	3

Estuary	Metric	Species richness	Protected species	Introduced species	Species occurrence	Relative species abundance	Most abundant species	Estuarine resident taxa	Estuarine dependent marine taxa	Abundance of estuarine residents	Abundance of estuarine dependents	Benthic feeding taxa	Fish eating taxa	Abundance of benthic feeders	Abundance of fish eaters	Estuarine Fish Community Index score	Index rating	Index score
	Metric no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14			
Swan Lake																		
Berrara Creek																		
Nerrindillah Creek																		
Conjola Lake		5	5	3	5	3	5	5	5	5	5	5	3	5	3	62	Very good	5
Narrawallee Inlet		3	3	3	3	3	1	3	1	5	5	3	1	5	1	40	Fair	3
Mollymook Creek																		
Millards Creek																		
Ulladulla																		
Burrill Lake																		
Tabourie Lake																		
Termeil Lake																		
Meroo Lake		1	3	3	1	3	1	1	1	5	1	1	3	3	5	32	Poor	2
Willinga Lake		1	3	3	1	1	1	1	3	1	1	1	3	5	5	30	Poor	2
Butlers Creek																		
Durras Lake																		
Durras Creek																		
Maloneys Creek																		
Cullendulla Creek		1	5	3	3	3	3	1	3	5	5	3	1	5	3	44	Fair	3
Clyde River																		
Batemans Bay																		
Saltwater Creek (Rosedale)																		
Tomaga River																		
Candlagan Creek		1	3	3	3	5	3	1	1	5	5	3	1	5	5	44	Fair	3
Bengello Creek																		
Moruya River		5	5	3	5	5	5	5	5	5	5	5	3	5	5	66	Very good	5
Congo Creek																		
Meringo Creek																		
Kellys Lake																		
Coila Lake																		
Tuross River		5	5	3	5	3	3	5	5	5	5	5	5	5	5	64	Very good	5
Lake Brunderee		3	3	1	3	3	3	1	5	3	3	3	3	5	5	44	Fair	3
Lake Tarourga																		
Lake Brou		1	3	3	3	3	1	1	1	5	1	1	3	5	5	36	Fair	3
Lake Mummuga		5	5	3	5	1	5	5	5	3	1	5	5	5	3	56	Good	4
Kianga Lake																		
Wagonga Inlet																		
Little Lake (Narooma)																		
Bullengella Lake																		
Nangudga Lake		3	5	3	3	3	1	1	1	3	5	3	3	5	5	44	Fair	3
Corunna Lake																		
Tilba Tilba Lake		1	3	3	1	3	1	1	1	5	1	1	1	5	1	28	Poor	2
Little Lake (Wallaga)																		
Wallaga Lake																		
Bermagui River																		
Baragoot Lake		1	5	3	1	1	1	1	1	5	1	1	3	5	5	34	Poor	2
Cuttagee Lake																		
Murrah River		5	5	3	3	1	5	5	5	3	3	5	3	5	3	54	Good	4
Bunga Lagoon		1	3	3	1	3	1	1	1	5	3	3	1	5	1	32	Poor	2
Wapengo Lagoon		3	5	3	3	3	3	3	3	5	5	3	1	5	1	46	Fair	3
Middle Lagoon		1	3	3	1	1	1	1	1	5	5	1	1	5	1	30	Poor	2
Nelson Lagoon		3	5	3	3	3	1	3	3	5	5	1	1	5	1	42	Fair	3
Bega River		5	5	3	5	3	5	3	5	5	5	3	5	5	5	62	Very good	5
Wallagoot Lake		1	5	3	3	3	1	3	1	5	1	3	1	5	1	36	Fair	3
Bournda Lagoon																		
Back Lagoon		1	3	3	3	3	1	1	3	5	1	1	3	5	5	38	Fair	3
Merimbula Lake		5	5	3	3	1	3	5	3	3	1	5	3	5	1	46	Fair	3
Pambula River		5	5	3	5	3	3	3	3	5	3	5	5	5	3	56	Good	4
Curalo Lagoon		5	3	3	3	3	5	3	5	5	1	3	5	5	5	54	Good	4
Shadrachs Creek																		

	Metric no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14			
Estuary	Metric	Species richness	Protected species	Introduced species	Species occurrence	Relative species abundance	Most abundant species	Estuarine resident taxa	Estuarine dependent marine taxa	Abundance of estuarine residents	Abundance of estuarine dependents	Benthic feeding taxa	Fish eating taxa	Abundance of benthic feeders	Abundance of fish eaters	Estuarine Fish Community Index score	Index rating	Index score
Nullica River		1	3	3	1	1	1	1	3	3	3	1	3	5	3	32	Poor	2
Boydtown Creek																		
Towamba River		3	5	3	5	5	3	3	3	3	3	3	3	5	5	52	Good	4
Fisheries Creek																		
Twofold Bay																		
Saltwater Creek (Eden)																		
Woodburn Creek																		
Wonboyn River		3	5	3	5	3	5	3	5	5	5	3	3	5	5	58	Good	4
Merrica River																		
Table Creek																		
Nadgee River																		
Nadgee Lake																		

Appendix 18

Estuary pressures identified in catchment action plans

Theme / CMA	Northern Rivers	Hunter–Central Rivers	Southern Rivers
Water flows	Changed hydrological regimes, mechanical opening of ICOLLs	Changed flow regimes from freshwater extraction, impervious surfaces, floodplain disconnection, entrance manipulation	Entrance management
Water quality	Pollution, stormwater runoff	Pollution particularly stormwater	Nutrient and sediment input from agriculture, industry, new development roads, acid sulfate soils
		Release of treated sewage effluent	
		Sewage from holding tanks	
Sedimentation	Dredging impacts on species, habitats and ecosystems	Dredging	Dredging
Aquatic habitats	Boating, boat moorings, construction of jetties, pontoons and boat ramps causing foreshore erosion, pollution, habitat degradation and loss	Seagrass impacts from jetties, moorings, marinas and ports	
	Mangrove expansion into seagrass and saltmarsh habitats	Saltmarsh, seagrass decline, mangrove increase	
	Estuarine weeds, vertebrate pests eg. fox, dogs, cats impact on waders and shore birds	Weeds and pests from ballast water, etc	Invasive pests
	Uncontrolled pedestrian and recreational vehicle access causing damage to inter-tidal zone species and foreshore erosion		Uncontrolled multiple access points over sensitive vegetation eg saltmarsh
Wetlands		Wetland degradation from altered water regimes, construction of canals, levee banks, floodgates, drainage lines, water extraction, infilling for development, construction of weirs and dams, uncontrolled stock access, vegetation clearing, nutrient enrichment	
		Flood mitigation: floodgates, levee banks	
Foreshores		Loss of foreshore vegetation	Riparian vegetation removal
			Vegetation clearing for views
			Rubbish
	Reclamation for development or in response to bank erosion		
		Bank erosion from boat wakes	
Natural hazards	Climate change and sea level rise	Climate change	
	Natural hazards from storms and rain causing erosion, loss of vegetation/habitat, reduced amenity, flooding, infrastructure damage/loss, some impacts worsened by seawalls, breakwaters and groynes		
Estuary use	Growing resource-based and NRM tourism		
		Boating	Divers/water-based tourism

Theme / CMA	Northern Rivers	Hunter–Central Rivers	Southern Rivers
Fishing and harvesting	Unsustainable commercial and recreational fishing practices causing habitat degradation, pollution, impacts on both target and incidental species	Commercial and recreational fishing	Commercial and recreational fishing
			Illegal harvesting/hunting
Catchment development	Population growth – increased urban, industrial and ribbon development, poor planning, inappropriate zoning, over-clearing of public land for asset protection zones, habitat fragmentation and loss, increased weeds and pests	Urban development	
	Cumulative impacts of all pressures		
Community capacity	Low levels of community awareness and understanding of coastal, estuary and marine environments and processes		
	Poor understanding and use of appropriate education programs		

Appendix 19

Potential pressure indicators for each stressor

Stressor	Direct indicators	Indirect indicators	Ecosystem condition indicators		Habitat extent indicators
			Physical-chemical	Biological	
Aquatic sediments (changed) Change to load, distribution/ movement patterns, settlement/resuspension rates, grain size of suspended or settled sediments	Total diffuse sediment load entering the estuary/coastal/marine system (monitored or modelled) Total point source sediment load entering the estuary/coastal/marine system (monitored or modelled) Volume of sediment moved/extracted	Catchment land-use (protected/natural/ minimal use, livestock grazing, cropping, horticulture, urban) % of farming area using best management practice % of length of stream with healthy riparian zone % of length of streams in grazing area fenced Volume of sediment moved/extracted	Turbidity/water clarity OR Sedimentation/erosion rates	Animal or plant species abundance (*loss of light-dependent biota, loss of sessile biota)*	Extent/distribution of intertidal mudflats *(see indicator 'extent/ distribution of key habitat types')* OR Extent/distribution of beach and dunes *(see indicator 'extent/ distribution of key habitat types')* OR Seagrass depth range
Bacteria/pathogens Bacteria, viruses, protozoans or fungi which cause disease	Total diffuse bacterial load entering the estuary/coastal/marine system (monitored or modelled) Total point source bacterial load entering the estuary/coastal/marine system (monitored or modelled)	Number of sewage overflow events % of sewage effluent disinfected % of urban area % of catchment under intensive livestock % of intensive livestock area using best management practice	None recommended	Targeted pathogen counts	None recommended
Biota (plant or animal) removal/disturbance Removal, loss or disturbance of individual organisms of a specific species, not areas of habitat	Commercial seafood catch Recreational seafood catch Bait catch Area disturbed by bait fishing Area disturbed by trawling Area disturbed by boat anchor damage Fisheries by-catch	Number of registered boats in region Length of shark nets/drum line present Recreational usage (eg number of facilities on coast (boat ramps, parts, etc.). % estuary, coast and marine systems accessible, tourism (visitation rates, number of marina berths, etc.)) Coastal population size Number of trawlers and dredges using area Number of commercial fishing licences Number of licensed collectors (of aquarium fish, shells, etc.) Number of impoundments without fish ladders	None recommended	Animal or plant species abundance OR Death of marine mammals, endangered sharks and reptiles caused by boat strike, shark nets or drum lines	None recommended

Stressor	Direct indicators	Indirect indicators	Ecosystem condition indicators		Habitat extent indicators
			Physical-chemical	Biological	
Excess freshwater as a pollutant (hypersaline) Localised or point source discharge of freshwater (not diffuse catchment runoff)	Total point source freshwater load entering the estuary/coastal/marine system (monitored or modelled)		Salinity	None recommended	None recommended
Excess salt as a pollutant (hypersaline) Localised or point source discharge of salt or salty water	Total point source salt load entering the estuary/coastal/marine system (monitored or modelled)	Number of desalinisation plants % of area under saltworks	Salinity	None recommended	None recommended
Freshwater flow regime (changed) Changes to pattern/amount of catchment waters entering estuarine and coastal systems	Change in median freshwater input (volume) Base freshwater input compared to total estuary volume Number of times freshwater flow greater than estuary volume Change in seasonality of freshwater input	% of median annual flow impounded/extracted	Salinity OR Estuary mouth opening/closing	None recommended	None recommended
Habitat removal/ disturbance Removal, loss or disturbance of large areas of habitat, such as those listed in the 'Key habitats' indicator profile	% of estuary/coast/marine area modified	% of aquatic area under mining lease Number of boating/shipping visits Number of registered boats in region % of estuary/coast/marine area designated for future modification Coastal population size Recreational usage (eg number of facilities on coast (boat ramps, parks, etc.), % estuary, coast and marine systems accessible, tourism (visitation rates, etc.)) % of area under aquaculture	None recommended	Animal or plant species abundance *(species dependent on the habitat removed/disturbed)*	Extent/distribution of key habitat types

Stressor	Direct indicators	Indirect indicators	Ecosystem condition indicators		Habitat extent indicators
			Physical-chemical	Biological	
Hydrodynamics (changed) Changes to local patterns of waves, currents or tidal exchange	Change in tidal compartment Change in tidal exchange rates/residence time Change in tidal velocity	Presence of entrance modifications Presence of canals, piers, other estuary modifications Presence of barrages Areal extent of channel dredging	Estuary mouth opening/closing OR Salinity OR Water-current patterns	Algal blooms OR Chlorophyll a OR *For seagrass and mangroves:* Biomass, or number per unit area, of epiphytes or *For intertidal sand/mudflat:* Benthic microalgae biomass or *For rocky shores, rocky reef and coral reef:* Biomass, or number per unit area, of macroalgae	None recommended
Litter Human made rubbish/ debris	Quantity and type of litter entering estuary (monitored or remodelled)	Coastal population size Number of registered boats in region Recreational usage (eg. number of facilities on coast (boat ramps, parks, etc.) % estuary, coast and marine systems accessible, tourism (visitation rates, etc.))	Presence/extent of litter	Animals killed or injured by litter (*entanglement, starvation, suffocation)*	None recommended
Nutrients (changed) Change to load, bioavailability, concentrations of nutrients	Total diffuse nutrient load entering the estuary/coastal/marine system (monitored or modelled) Total point source nutrient load entering the estuary/coastal/marine system (monitored or modelled)	Catchment land-use (protected/natural/animal use, livestock, grazing, cropping, horticulture, urban) Amount of fertiliser applied per unit area (including urban) % of farming area using best management practice % of length of stream with healthy riparian zone % of sewage treatment plants with tertiary treatment Volume/number of sewage overflow events % of urban area under stormwater management plan % of area under aquaculture	Total nutrients in the water column WITH dissolved nutrients in the water column OR Total nutrients in the sediments WITH dissolved nutrients in the sediments	Algal blooms OR Chlorophyll a OR *For seagrass and mangroves:* Biomass, or number per unit area, of epiphytes or *For intertidal sand/mudflat:* Benthic microalgae biomass or *For rocky shores, rocky reef and coral reef:* Biomass, or number per unit area, of macroalgae	Extent/distribution of subtidal macroalgae

Stressor	Direct indicators	Indirect indicators	Ecosystem condition indicators		Habitat extent indicators
			Physical-chemical	Biological	
Organic matter (changed) Organic matter is carbon based material derived from plants or animals (eg decaying plant matter or animal wastes). It can be in either dissolved or particulate forms	Total diffuse organic matter load entering the estuary/coastal/marine system (monitored or modelled) Total point source organic matter load entering the estuary/coastal/marine system (monitored or modelled)	Catchment land-use (protected/natural/ animal use, livestock, grazing, cropping, horticulture, urban) % of each level of sewage treatment Number and volume of licensed discharges Volume/number of sewage overflow events % of catchment area under intensive livestock (eg feed lots) % of intensive livestock area using best management practice % of area under aquaculture	Dissolved oxygen	Animal kills	None recommended
Pest (plant, animal) species An invasive organism that is detrimental to an ecosystem	Number of new pest species entering the estuary/coastal/marine system Extent and number of pest species present in the estuary/coastal/marine system Rate of spread of pest species through the estuary/coastal/marine system	Presence of pest species in adjacent areas Number of international and/or domestic shipping/boating visits to region Presence of aquaculture facilities using species non-native to the region Presence of port/harbour/marina (domestic and international)	None recommended	Pest species *(number, density, distribution)*	None recommended
pH (water changed) Acidity or alkalinity of water	Volume of run-off from acid affected areas (modelled) Volume and pH differential of discharge/runoff	Areal extent of disturbed acid sulphate soils (% of land <5m AHD cleared/modified) Number of industrial licensed discharges	pH	Animal kills OR Animal disease/lesions	None recommended
Toxicants Loads, concentrations or bioavailability of pesticides, herbicides, organics, oils, hydrocarbons, metals, metalloids, organometallics, radiation, other toxic chemicals and contaminants	Total diffuse toxicant load entering the estuary/coastal/marine system (monitored or modelled) Total point source toxicant load entering the estuary/coastal/marine system (monitored or modelled)	Quantity of pesticide/herbicide sold or applied per unit area (rural and urban) Area of catchment treated by pesticide/herbicide (rural and urban) Number of cars per unit urban area (hydrocarbons) % of urban area % of catchment area under mining lease % of mines using best management practice Number of industrial licensed discharges Number of boat visitations Number of berths at ports/harbours/marinas Number of slipways using best management practice	Water soluble toxicants in the water column OR Toxicants in the sediment OR Toxicants in biota	Animal kills OR Occurrence of imposex	None recommended

Stressor	Direct indicators	Indirect indicators	Ecosystem condition indicators		Habitat extent indicators
			Physical-chemical	Biological	
Water temperature (changed) Local and surface water (sea, estuary) temperature	Volume and temperature differential of discharge	Annual average air temperature Number of industries (eg power stations) which discharge hot/cold water Number and volume of dam discharges of cold water	Water temperature	Coral bleaching	None recommended

LEGEND: Data feasible to collate (green); Data more difficult to collate (orange)

Appendix 20

Raw pressure data

	Population			Total Suspended Solids Load			Total Phosphorus Load			Total Nitrogen Load								
Estuary	**1996**	**2001**	**2006**	**Diffuse pre-clear (t/yr)**	**Diffuse current (t/yr)**	**STP (t/yr)**	**Diffuse pre-clear (t/yr)**	**Diffuse current (t/yr)**	**STP (t/yr)**	**Diffuse pre-clear (t/yr)**	**Diffuse current (t/yr)**	**STP (t/yr)**	**Areal load (t/yr/km²)**	**Extraction (Ml/yr)**	**Structures (km)**	**Aqua-culture (km²)**	**Opening levels (m AHD)**	**Fish catch (t/yr/km²)**
Tweed River	55072	61648	64158	5537.6	52273.8	29.3	16.41	101.58	12.6	266.62	937.76	21.9	43.71	32843	2.47	0.28	na	6.46
Cudgen Creek	3539	3872	4327	391.4	12479.8	0	1.16	12.66	0	18.85	166.01	0	79.24	717	0.02	0	na	0
Cudgera Creek	1715	1853	2530	334.5	6147.4	0	0.99	7.35	0	16.11	89.77	0	219.67	279	0	0	na	0
Mooball Creek	3130	3747	3961	616.9	8678.9	0	1.83	14.15	0	29.70	138.82	0	264.79	917	0	0	na	0
Brunswick River	11214	11832	12226	1340.4	13298.6	7.3	3.97	29.22	0.2	64.54	265.75	5.6	82.79	2296	0.30	0.09	na	0
Belongil Creek	4646	5507	3805	119.3	271.8	7.2	0.35	1.65	0.4	5.74	12.93	3.8	88.14	0	0	0	1.11	0
Tallow Creek	2336	3129	3198	13.1	84.3	0	0.04	0.41	0	0.63	2.58	0	21.66	0	0	0	1.80	0
Broken Head Creek	362	348	284	4.0	21.4	0	0.01	0.05	0	0.19	0.48	0	9.07	0	0	0	na	0
Richmond River	102164	102481	105296	16235.9	227541.1	65.8	48.11	370.01	3.8	781.73	3448.23	13.9	91.65	94499	42.33	0.21	na	7.27
Salty Lagoon	0	0	0	7.6	7.6	0	0.02	0.02	0	0.36	0.36	0	2.29	0	0	0	na	0
Evans River	1393	1485	1277	162.9	343.5	12.3	0.48	1.26	3.0	7.84	12.90	13.9	11.65	0	3.38	0	na	0
Jerusalem Creek	12	13	13	125.5	127.7	0	0.37	0.38	0	6.04	6.34	0	19.85	0	0.14	0	na	0
Clarence River	50545	51301	52825	43161.8	97339.6	11.4	127.89	399.27	3.1	2078.16	3921.36	9.9	30.38	76254	10.56	0.18	na	7.20
Lake Arragan	0	0	0	21.4	21.5	0	0.06	0.06	0	1.03	1.03	0	1.06	0	0	0	na	0
Cakora Lagoon	97	94	83	36.8	38.4	0	0.11	0.11	0	1.77	1.83	0	8.00	0	0.29	0	na	0
Sandon River	5	33	6	359.2	365.3	0	1.06	0.97	0	17.29	17.59	0	8.20	0	0	0.07	na	0.11
Wooli Wooli River	280	294	248	558.2	598.5	0	1.65	1.77	0	26.87	28.37	0	9.22	0	0	0.18	na	0
Station Creek	0	0	1	75.9	77.2	0	0.22	0.21	0	3.66	3.73	0	14.63	0	0	0	na	0
Corindi River	574	609	637	512.7	1217.1	0	1.52	2.79	0	24.68	37.67	0	28.44	96	0	0	na	0.00
Pipe Clay Creek	299	304	353	3.4	13.0	0	0.01	0.07	0	0.16	0.43	0	40.55	0	0	0	na	0
Arrawarra Creek	670	931	664	48.2	311.4	0	0.14	0.47	0	2.32	5.80	0	50.92	45	0.04	0	1.49	0
Darkum Creek	498	516	611	16.6	939.4	0	0.05	0.80	0	0.80	11.46	0	206.57	88	0	0	na	0
Woolgoolga Lake	2355	2367	2705	65.2	1705.9	0	0.19	1.68	0	3.14	22.51	0	144.92	206	0.06	0	1.63	0
Flat Top Point Creek	685	768	821	5.3	424.8	0	0.02	0.35	0	0.26	4.99	0	227.00	5	0.00	0	na	0
Hearns Lake	643	682	623	16.3	1682.8	0	0.05	1.14	0	0.79	18.83	0	184.34	181	0.01	0	na	0
Moonee Creek	1745	2050	2752	106.6	1397.2	0	0.32	1.86	0	5.13	22.06	0	79.32	127	0	0	na	0.02
Pine Brush Creek	542	824	751	22.6	2417.8	0	0.07	1.64	0	1.09	27.02	0	1733.62	229	0	0	na	0
Coffs Creek	17478	18229	18593	83.9	6273.3	0	0.25	5.41	0	4.04	74.82	0	163.14	384	0.20	0	na	0.31
Boambee Creek	8873	9669	10325	173.0	6890.3	0	0.51	6.71	0	8.33	87.83	0	91.19	584	0.06	0	na	0.40
Bonville Creek	9900	9837	10840	543.9	2732.8	0	1.61	6.86	0	26.19	67.79	0	45.30	825	0.00	0	na	0.01
Bundageree Creek	151	153	147	32.4	62.8	0	0.10	0.29	0	1.56	2.58	0	1013.75	0	0	0	na	0
Bellinger River	7689	7808	8000	6409.2	10616.4	2.6	18.99	30.75	0.1	308.59	408.26	1.3	51.07	2910	2.16	0.24	na	0
Dalhousie Creek	15	17	19	13.7	89.0	0	0.04	0.15	0	0.66	1.74	0	25.39	0	0	0	na	0
Oyster Creek	237	261	315	51.5	193.8	0	0.15	0.45	0	2.48	5.09	0	36.62	0	0	0	na	0
Deep Creek	1295	1410	1582	294.0	2477.6	24.8	0.87	3.31	9.8	14.16	43.82	17.1	56.22	793	0.30	0	na	0
Nambucca River	11720	11756	11891	4151.3	13792.9	9.4	12.30	38.04	0.2	199.88	365.88	3.9	32.53	4155	2.02	0.65	na	8.13
Macleay River	48308	47251	47160	16644.8	27315.2	12.3	49.32	130.00	3.7	801.42	1332.50	8.2	48.94	20999	3.74	0.95	na	4.17
South West Rocks Creek	1194	1448	1406	7.8	29.7	0	0.02	0.15	0	0.38	0.98	0	1.18	0	0.32	0	na	0
Saltwater Creek (Frederickton)	1430	1679	1715	24.3	175.1	0	0.07	0.51	0	1.17	3.97	0	14.05	0	0	0	na	0
Korogoro Creek	288	284	263	20.8	41.5	0	0.06	0.15	0	1.00	1.53	0	6.28	0	0	0	na	0
Killick Creek	935	917	839	17.2	31.6	0	0.05	0.19	0	0.83	1.58	0	5.65	0	0	0	na	0
Goolawah Lagoon	8	8	8	8.8	8.3	0	0.03	0.04	0	0.42	0.36	0	2.83	0	0	0	na	0
Hastings River	36975	38884	39762	12447.1	26860.5	31.6	36.88	105.41	5.6	599.31	1073.15	15.0	38.73	31269	6.85	1.25	na	0
Cathie Creek	5319	7546	9187	273.6	656.9	0	0.81	3.57	0	13.17	27.08	0	3.45	0	1.37	0	1.56	3.76
Duchess Gully	630	1511	1968	21.5	113.8	0	0.06	0.46	0	1.03	3.41	0	138.88	3	0	0	na	0
Camden Haven River	7694	8399	8889	1857.3	5295.4	0	5.50	16.05	0	89.43	170.74	0	5.44	6527	0.65	0.94	na	5.09
Manning River	38597	38787	39610	15436.5	21756.8	5.1	45.74	136.99	4.7	743.24	1284.10	5.0	39.95	77609	3.93	2.89	na	7.34
Khappinghat Creek	663	757	1383	229.8	469.2	0	0.68	2.60	0	11.07	20.92	0	20.25	48	0	0	na	0
Black Head Lagoon	350	410	721	9.1	15.9	0	0.03	0.13	0	0.44	0.83	0	90.08	0	0	0	2.50	0

	Population			Total Suspended Solids Load			Total Phosphorus Load			Total Nitrogen Load								
Estuary	1996	2001	2006	Diffuse pre-clear (t/yr)	Diffuse current (t/yr)	STP (t/yr)	Diffuse pre-clear (t/yr)	Diffuse current (t/yr)	STP (t/yr)	Diffuse pre-clear (t/yr)	Diffuse current (t/yr)	STP (t/yr)	Areal load (t/yr/km^2)	Extraction (Ml/yr)	Structures (km)	Aqua-culture (km^2)	Opening levels (m AHD)	Fish catch (t/yr/km^2)
Wallis Lake	19634	21592	23140	2698.1	4653.7	15.0	7.99	31.61	4.5	129.91	260.79	18.3	3.01	2027	2.64	3.81	na	5.34
Smiths Lake	918	1008	964	50.7	146.4	0	0.15	0.74	0	2.44	5.35	0	0.53	0	0.76	0	1.99	5.06
Myall River	3097	3711	3728	1585.2	2054.3	2.4	4.70	10.41	0.7	76.33	108.62	3.6	1.00	477	0.35	0.28	na	3.27
Karuah River	2634	2989	2889	3289.4	4306.7	0	9.75	24.88	0	158.38	246.09	0	17.43	3608	0.73	1.20	na	3.27
Tilligerry Creek	5636	6884	6320	108.0	953.3	4.0	0.32	2.20	2.9	5.20	19.81	3.7	1.15	0	0.78	1.65	na	3.27
Port Stephens	18039	22174	23825	527.2	1184.2	0	1.56	5.10	0	25.38	45.20	0	0.37	0	0.29	8.79	na	3.27
Hunter River	302799	311298	328383	23889.1	96636.5	49.2	70.78	337.76	12.6	1150.22	3007.22	34.8	72.72	489885	18.65	0.22	na	5.86
Glenrock Lagoon	8054	7414	7670	17.0	73.2	0	0.05	0.42	0	0.82	2.46	0	47.13	0	0	0	na	0
Lake Macquarie	136012	144238	150876	1196.7	4823.4	0.4	3.55	16.34	0.3	57.62	141.51	0.5	1.25	2597	40.03	0	na	0
Middle Camp Creek	134	146	116	11.2	16.2	0	0.03	0.06	0	0.54	0.72	0	54.48	0	0	0	na	0
Moonee Beach Creek	4	3	2	6.7	109.6	0	0.02	0.14	0	0.32	1.70	0	757.74	0	0	0	na	0
Tuggerah Lake	102750	117062	125099	1382.3	7245.8	0	4.10	16.80	0	66.55	159.49	0	1.98	29962	0.85	0	na	4.12
Wamberal Lagoon	4096	4502	4521	12.6	60.4	0	0.04	0.34	0	0.61	2.04	0	3.95	0	0	0	2.40	0
Terrigal Lagoon	8219	9145	9987	14.2	85.8	0	0.04	0.52	0	0.68	2.97	0	10.50	9	0.01	0	1.20	0
Avoca Lake	6245	7031	6495	21.1	81.5	0	0.06	0.40	0	1.02	2.88	0	4.28	0	0	0	2.10	0
Cockrone Lake	1408	1651	1736	15.7	37.0	0	0.05	0.19	0	0.75	1.53	0	4.64	25	0	0	2.50	0
Brisbane Water	92774	98305	100969	245.2	962.1	0	0.73	5.32	0	11.81	34.08	0	1.25	120	3.39	1.73	na	0
Hawkesbury River	778298	858402	908032	19089.0	57397.3	12.7	56.56	162.09	2.1	919.10	1536.11	25.5	13.99	768222	28.32	4.23	na	1.99
Pittwater	25076	25737	26450	57.4	158.7	0	0.17	0.49	0	2.76	4.84	0	0.26	122	10.42	0	na	1.99
Broken Bay	9552	10176	10458	13.7	75.0	0	0.04	0.18	0	0.66	1.73	0	0.10	0	0.00	0	na	1.99
Narrabeen Lagoon	40947	42948	45575	79.6	309.2	0	0.24	1.06	0	3.83	8.87	0	3.84	431	1.75	0	1.42	0
Dee Why Lagoon	23632	24777	26711	12.4	125.6	0	0.04	0.59	0	0.60	3.47	0	14.53	0	0.02	0	1.76	0
Curl Curl Lagoon	7656	7728	8054	2.8	21.7	0	0.01	0.13	0	0.14	0.70	0	10.80	0	0	0	2.04	0
Manly Lagoon	26258	27280	28319	18.9	182.5	0	0.06	0.73	0	0.91	4.68	0	47.84	256	0.03	0	1.52	0
Middle Harbour Creek	125952	131401	137257	77.1	423.5	0	0.23	2.40	0	3.71	14.29	0	2.34	97	0.36	0	na	1.25
Lane Cove River	177459	184835	185959	131.2	780.4	0	0.39	4.54	0	6.32	26.24	0	8.82	316	0.05	0	na	1.25
Parramatta River	588316	620831	652176	250.5	1939.5	0	0.74	10.50	0	12.06	59.96	0	4.36	722	0.16	0	na	1.25
Port Jackson	257555	290837	287619	31.4	325.0	0	0.09	1.43	0	1.51	8.71	0	0.30	0	0.31	0	na	1.25
Cooks River	366260	378001	390599	110.3	1274.6	0	0.33	5.46	0	5.31	33.27	0	27.75	171	0.04	0	na	0
Georges River	786595	838137	851544	1018.5	31027.6	0	3.02	47.43	0	49.04	475.98	0	18.48	34748	10.85	2.16	na	0
Botany Bay	107416	111048	110990	46.0	652.8	0	0.14	1.92	0	2.21	13.80	0	0.36	266	2.48	0.51	na	0
Port Hacking	61911	64938	66939	202.8	397.2	0	0.60	1.25	0	9.77	14.32	0	1.24	140	12.61	0	na	0.20
Wattamolla Creek	0	0	0	7.9	7.9	0	0.02	0.02	0	0.38	0.38	0	11.56	0	0	0	na	0
Hargraves Creek	936	1245	937	4.5	29.7	0	0.01	0.10	0	0.21	0.73	0	228.58	0	0	0	na	0
Stanwell Creek	484	534	520	14.4	41.1	0	0.04	0.10	0	0.69	1.17	0	132.47	263	0	0	na	0
Flanagans Creek	1583	1636	1627	10.6	59.6	0	0.03	0.21	0	0.51	1.49	0	787.07	0	0	0	na	0
Woodlands Creek	836	869	902	9.1	28.2	0	0.03	0.14	0	0.44	1.02	0	285.00	0	0	0	na	0
Slacky Creek	1899	1997	2019	16.6	72.8	0	0.05	0.34	0	0.80	2.23	0	448.15	0	0	0	na	0
Bellambi Gully	7212	7606	8128	37.8	360.0	0	0.11	1.16	0	1.82	8.14	0	470.71	26	0	0	na	0
Bellambi Lake	2757	2796	2739	8.7	44.3	0	0.03	0.26	0	0.42	1.44	0	46.90	0	0	0	na	0
Towradgi Creek	11448	11625	11660	61.8	307.0	0	0.18	1.45	0	2.98	8.98	0	215.38	140	0	0	1.60	0
Fairy Creek	30264	30507	30372	128.2	629.3	0	0.38	3.31	0	6.17	19.55	0	176.05	0	0	0	1.40	0
Allans Creek	39328	44523	41506	251.2	1304.7	0	0.74	6.17	0	12.10	39.46	0	33.89	0	0	0	na	0
Port Kembla	3747	no data	3370	19.2	144.5	0	0.06	0.64	0	0.93	3.97	0	2.89	0	0	0	na	0
Lake Illawarra	80364	83688	85640	654.2	3922.4	0	1.94	12.91	0	31.50	100.46	0	2.83	1638	0.16	0	0.88	5.73
Elliott Lake	13103	14569	15864	20.0	115.6	0	0.06	0.71	0	0.96	4.07	0	50.56	0	0	0	na	0
Minnamurra River	5080	4953	5067	371.4	2342.1	0	1.10	7.35	0	17.88	46.07	0	30.04	938	0.14	0	na	0.68
Spring Creek	1012	1093	1241	14.9	38.2	0	0.04	0.27	0	0.72	1.91	0	37.00	0	0	0	na	0
Munna Munnora Creek	772	778	777	8.7	21.1	0	0.03	0.18	0	0.42	1.23	0	308.44	0	0	0	na	0
Werri Lagoon	962	1321	1316	45.9	94.7	0	0.14	0.70	0	2.21	5.58	0	39.37	0	0	0	1.71	0
Crooked River	1410	1559	1635	64.0	175.8	0.6	0.19	1.32	0.0	3.08	9.83	0.3	38.79	20	0	0	1.50	0
Shoalhaven River	41413	44537	46607	9428.8	16858.2	23.6	27.94	80.52	9.5	453.98	775.22	12.4	26.40	355487	55.18	1.85	3.44	4.71
Wollumboola Lake	1064	1100	1039	62.9	78.6	0	0.19	0.29	0	3.03	3.66	0	0.58	0	0	0	2.75	1.09
Currarong Creek	266	243	228	20.3	24.4	0	0.06	0.08	0	0.98	1.12	0	32.61	0	0.20	0	na	0
Cararma Creek	4	2	2	8.4	8.8	0	0.02	0.03	0	0.40	0.43	0	0.18	0	0	0	na	0
Wowly Gully	511	777	1001	8.5	15.7	0	0.03	0.07	0	0.41	0.63	0	3.87	0	0	0	na	0

Estuary	Population 1996	Population 2001	Population 2006	Total Suspended Solids Load: Diffuse pre-clear (t/yr)	Total Suspended Solids Load: Diffuse current (t/yr)	Total Suspended Solids Load: STP (t/yr)	Total Phosphorus Load: Diffuse pre-clear (t/yr)	Total Phosphorus Load: Diffuse current (t/yr)	Total Phosphorus Load: STP (t/yr)	Total Nitrogen Load: Diffuse pre-clear (t/yr)	Total Nitrogen Load: Diffuse current (t/yr)	Total Nitrogen Load: STP (t/yr)	Areal load ($t/yr/km^2$)	Extraction (Ml/yr)	Structures (km)	Aqua-culture (km^2)	Opening levels (m AHD)	Fish catch ($t/yr/km^2$)
Callala Creek	1142	1413	1437	26.9	50.8	0	0.08	0.21	0	1.30	1.99	0	307.49	0	0	0	na	0
Currambene Creek	1572	1446	1527	346.0	572.7	0	1.03	3.15	0	16.66	28.25	0	12.72	96	0.28	0.01	na	0
Moona Moona Creek	1013	979	1005	49.1	99.4	0	0.15	0.52	0	2.36	4.29	0	30.60	0	0	0.01	na	0
Flat Rock Creek	7	13	8	14.2	15.6	0	0.04	0.04	0	0.68	0.73	0	52.18	0	0	0	na	0
Captains Beach Lagoon	0	0	0	6.4	6.8	0	0.02	0.02	0	0.31	0.33	0	7.17	0	0	0	na	0
Telegraph Creek	0	0	0	8.6	9.0	0	0.03	0.02	0	0.41	0.43	0	81.69	0	0	0	na	0
Jervis Bay	1820	2146	1854	50.4	100.8	0	0.15	0.30	0	2.42	3.49	0	0.03	0	0.17	0.08	na	0.00
St Georges Basin	11351	13487	14652	615.7	872.7	0	1.82	3.90	0	29.64	41.54	0	1.02	148	1.72	0	na	0
Swan Lake	436	459	497	45.3	88.3	0	0.13	0.35	0	2.18	3.36	0	0.72	3	0	0	2.03	0
Berrara Creek	106	112	120	64.0	70.2	0	0.19	0.20	0	3.08	3.25	0	12.73	0	0	0	na	0
Nerrindillah Creek	21	26	25	32.6	35.4	0	0.10	0.14	0	1.57	1.84	0	25.32	0	0.04	0	na	0
Conjola Lake	1039	1090	1248	245.4	268.9	0.1	0.73	1.07	0.1	11.82	14.16	0.1	2.13	60	1.39	0.07	na	0
Narrawallee Inlet	1025	1289	1307	164.0	224.1	0	0.49	1.87	0	7.90	15.85	0	18.39	218	0.37	0.03	na	0
Mollymook Creek	715	909	1103	7.0	28.3	0	0.02	0.17	0	0.34	1.05	0	178.20	113	0	0	na	0
Millards Creek	2604	3157	3643	10.8	54.6	0	0.03	0.33	0	0.52	1.90	0	404.58	0	0	0	na	0
Ulladulla	180	no data	158	0.6	3.6	0	0.00	0.02	0	0.03	0.12	0	1.24	0	0	0	na	0
Burrill Lake	1942	2003	2245	127.5	219.3	0	0.38	1.69	0	6.14	13.41	0	3.24	77	0.32	0.01	1.10	0
Tabourie Lake	432	502	546	86.8	109.7	0	0.26	0.54	0	4.18	5.94	0	4.10	0	0.03	0	1.22	0
Termeil Lake	24	28	31	27.7	40.7	0	0.08	0.25	0	1.34	2.34	0	4.08	0	0.01	0	na	0.53
Meroo Lake	23	29	31	38.4	66.8	0	0.11	0.31	0	1.85	3.15	0	2.31	4	0.00	0	na	0
Willinga Lake	90	121	133	23.4	31.0	0	0.07	0.17	0	1.13	1.74	0	5.54	0	0	0	1.56	0
Butlers Creek	14	18	17	2.8	17.3	0	0.01	0.10	0	0.14	0.58	0	21.68	0	0	0	na	0
Durras Lake	71	74	68	96.6	136.7	0	0.29	0.50	0	4.65	5.83	0	1.62	0	0	0	1.83	4.78
Durras Creek	54	53	48	8.0	9.6	0	0.02	0.04	0	0.38	0.46	0	21.65	0	0	0	na	0
Maloneys Creek	262	335	516	12.2	22.8	0	0.04	0.08	0	0.59	0.86	0	30.86	0	0	0	na	0
Cullendulla Creek	469	571	941	23.6	84.6	0	0.07	0.47	0	1.14	3.05	0	2.73	7	0	0.07	na	0
Clyde River	1274	1374	1316	2979.6	3159.1	0	8.83	10.58	0	143.46	158.12	0	9.29	2666	2.07	2.22	na	0.30
Batemans Bay	8220	8912	9627	41.3	160.8	0	0.12	0.79	0	1.99	5.32	0	0.15	0	0.09	0	na	0
Saltwater Creek (Rosedale)	69	90	101	5.2	11.8	0	0.02	0.10	0	0.25	0.69	0	321.12	13	0	0	na	0
Tomaga River	1135	1224	1181	144.9	258.9	0	0.43	1.20	0	6.98	11.03	0	8.15	47	0.55	0.05	na	0
Candlagan Creek	399	403	441	35.7	115.6	0	0.11	0.34	0	1.72	3.39	0	26.30	2	0	0	na	0
Bengello Creek	50	60	73	23.9	127.9	0	0.07	0.22	0	1.15	2.67	0	243.36	0	0	0	na	0
Moruya River	3694	3707	3682	2729.9	5016.6	3.5	8.09	14.40	0.9	131.44	184.17	0.9	34.58	5403	2.12	0.13	na	2.55
Congo Creek	247	306	314	64.5	135.1	0	0.19	1.01	0	3.11	7.60	0	65.72	167	0.65	0	na	8.37
Meringo Creek	32	39	45	12.1	24.1	0	0.04	0.15	0	0.58	1.16	0	15.99	0	0	0	na	0.16
Kellys Lake	12	15	25	3.7	9.7	0	0.01	0.06	0	0.18	0.42	0	6.59	0	0	0	na	0
Coila Lake	816	954	1094	135.3	183.8	0	0.40	0.90	0	6.51	9.28	0	1.37	8	0.00	0	1.81	9.75
Tuross River	912	974	1005	3850.2	5166.7	0	11.41	20.02	0	185.38	235.85	0	16.05	8072	0.91	1.24	1.80	0
Lake Brunderee	39	36	37	19.3	21.2	0	0.06	0.07	0	0.93	1.04	0	5.37	0	0	0	na	0
Lake Tarourga	5	5	5	17.3	18.4	0	0.05	0.05	0	0.83	0.88	0	2.67	0	0	0	na	0
Lake Brou	22	23	28	119.1	128.4	0	0.35	0.42	0	5.74	6.35	0	2.68	0	0	0	na	4.94
Lake Mummuga	719	788	798	74.5	86.5	0	0.22	0.28	0	3.59	3.97	0	2.44	5	0	0	1.19	0
Kianga Lake	318	323	388	16.7	40.9	0	0.05	0.17	0	0.80	1.46	0	8.58	0	0.17	0	na	1.13
Wagonga Inlet	1416	1404	1252	247.3	335.6	0	0.73	1.29	0	11.91	15.02	0	2.17	101	0.79	0.91	na	0.00
Little Lake (Narooma)	860	930	832	5.2	18.2	0	0.02	0.11	0	0.25	0.63	0	6.51	21	0.04	0	na	0
Bullengella Lake	6	8	8	1.4	2.1	0	0.00	0.02	0	0.07	0.16	0	1.11	0	0	0	na	0
Nangudga Lake	93	113	168	18.3	77.9	0	0.05	0.51	0	0.88	3.21	0	5.38	0	0	0	na	2.96
Corunna Lake	192	228	223	68.5	186.6	0	0.20	1.10	0	3.30	7.92	0	3.80	17	0	0	1.92	3.00
Tilba Tilba Lake	98	99	98	31.8	53.3	0	0.09	0.50	0	1.53	3.85	0	3.80	134	0	0	na	0.79
Little Lake (Wallaga)	17	17	17	2.8	6.8	0	0.01	0.05	0	0.14	0.38	0	3.33	0	0	0	na	0
Wallaga Lake	1252	1294	1396	662.1	2664.1	0	1.96	6.73	0	31.88	72.22	0	7.90	1126	0.98	0.05	1.26	8.58
Bermagui River	903	979	1081	217.3	618.6	0	0.64	2.19	0	10.46	20.73	0	10.43	825	0.06	0.38	na	0
Baragoot Lake	12	14	16	36.2	55.2	0	0.11	0.25	0	1.74	2.49	0	5.28	0	0	0	na	0.89
Cuttagee Lake	15	16	19	154.4	175.5	0	0.46	0.57	0	7.44	8.22	0	6.65	20	0	0	na	4.93
Murrah River	286	306	304	475.2	647.7	0	1.41	3.80	0	22.88	36.61	0	53.91	1867	0	0.00	na	0.90
Bunga Lagoon	13	16	16	34.4	39.5	0	0.10	0.16	0	1.65	2.05	0	18.98	0	0	0	na	0

	Population			Total Suspended Solids Load			Total Phosphorus Load			Total Nitrogen Load								
Estuary	**1996**	**2001**	**2006**	**Diffuse pre-clear (t/yr)**	**Diffuse current (t/yr)**	**STP (t/yr)**	**Diffuse pre-clear (t/yr)**	**Diffuse current (t/yr)**	**STP (t/yr)**	**Diffuse pre-clear (t/yr)**	**Diffuse current (t/yr)**	**STP (t/yr)**	**Areal load ($t/yr/km^2$)**	**Extraction (Ml/yr)**	**Structures (km)**	**Aqua-culture (km^2)**	**Opening levels (m AHD)**	**Fish catch ($t/yr/km^2$)**
Wapengo Lagoon	60	75	80	193.3	210.4	0	0.57	0.97	0	9.31	11.91	0	3.76	126	0.14	0.78	na	0.97
Middle Lagoon	28	34	34	70.8	102.7	0	0.21	0.51	0	3.41	5.33	0	10.53	1	0.20	0	na	5.19
Nelson Lagoon	5	6	7	75.0	77.3	0	0.22	0.23	0	3.61	3.73	0	3.12	0	0	0.29	na	0
Bega River	8189	8431	8824	3573.6	6139.3	3.4	10.59	32.37	1.6	172.06	302.24	3.2	92.37	45389	1.82	0.04	1.82	0
Wallagoot Lake	77	91	113	49.5	58.8	0	0.15	0.26	0	2.38	3.06	0	0.79	4	0.33	0	na	2.20
Bournda Lagoon	38	45	80	69.1	85.0	0	0.20	0.29	0	3.33	3.90	0	49.30	76	0.10	0	na	0
Back Lagoon	1669	1875	1673	60.6	103.9	0	0.18	0.37	0	2.92	4.13	0	11.50	101	1.59	0	1.40	0
Merimbula Lake	2563	2833	2168	69.0	148.3	0	0.20	0.93	0	3.32	7.02	0	1.41	9	1.29	1.38	na	0.11
Pambula River	1528	1605	1749	591.0	692.9	0	1.75	3.13	0	28.46	37.04	0	8.50	790	1.41	1.00	na	0
Curalo Lagoon	2005	1836	1769	55.2	97.1	0	0.16	0.40	0	2.66	3.91	0	5.48	0	0.34	0	1.50	0.08
Shadrachs Creek	7	8	8	24.3	25.6	0	0.07	0.08	0	1.17	1.27	0	143.38	0	0	0	na	0
Nullica River	3	3	3	98.0	110.9	0	0.29	0.33	0	4.72	5.19	0	16.42	0	0	0	na	0
Boydtown Creek	1	1	1	7.1	9.3	0	0.02	0.05	0	0.34	0.52	0	31.71	0	0	0	na	0
Towamba River	377	440	379	1841.6	2045.4	0	5.46	8.65	0	88.67	110.43	0	57.70	1349	5.97	0.01	na	0
Fisheries Creek	0	0	0	12.8	13.1	0	0.04	0.04	0	0.62	0.64	0	12.09	0	0	0	na	0
Twofold Bay	1109	1160	1141	12.0	35.8	0	0.04	0.13	0	0.58	1.15	0	0.04	53	0.17	0.18	na	0
Saltwater Creek (Eden)	0	0	0	34.8	34.8	0	0.09	0.09	0	1.68	1.68	0	29.78	0	0	0	na	0
Woodburn Creek	0	0	0	25.8	25.8	0	0.07	0.07	0	1.24	1.24	0	24.80	0	0	0	na	0
Wonboyn River	73	64	9	633.8	638.3	0	1.88	1.78	0	30.51	31.09	0	8.43	14	0.21	0.54	na	0
Merrica River	0	0	0	104.2	104.2	0	0.31	0.28	0	5.01	5.01	0	40.93	0	0	0	na	0
Table Creek	0	0	0	27.3	27.3	0	0.07	0.07	0	1.31	1.31	0	23.59	0	0	0	na	0
Nadgee River	0	0	0	240.4	240.4	0	0.64	0.64	0	11.58	11.58	0	60.18	0	0	0	na	0
Nadgee Lake	0	0	0	22.2	22.2	0	0.06	0.06	0	1.07	1.07	0	0.89	0	0	0	na	0

Appendix 21

Normalised pressure data

Estuary	% cleared land	Population /km^2	% increase in annual TSS	% increase in annual TP	% increase in annual TN	% increase in annual flow	% surface flows extracted	% structures perimeter	% estuary under aquaculture	Annual fish catch t/km^2
Tweed River	55.23	58.45	844.52	596.04	259.92	29.45	6.68	1.00	1.23	6.46
Cudgen Creek	68.56	56.44	3088.44	991.73	780.88	37.72	2.08	0.07	0	
Cudgera Creek	58.28	30.60	1737.54	641.32	457.29	32.00	0.96	0	0	
Mooball Creek	64.61	34.33	1306.80	673.88	367.34	29.93	1.76	0	0	
Brunswick River	70.47	52.27	892.68	641.74	320.47	32.10	1.21	0.38	2.58	
Belongil Creek	57.22	181.11	133.91	467.08	190.51	24.96	0	0	0	
Tallow Creek	68.11	586.06	542.51	957.14	308.33	67.27	0	0	0	
Broken Head Creek	100.00	310.63	438.66	319.91	149.45	12.29	0	0	0	
Richmond River	56.30	14.93	1301.87	677.08	342.88	38.28	4.50	6.24	0.54	7.27
Salty Lagoon	0	0.01	0.01	0	0.01	0.01	0	0	0	
Evans River	20.89	19.58	118.45	781.03	241.91	14.35	0	7.22	0	
Jerusalem Creek	2.36	0.27	1.78	3.47	4.95	-0.84	0	1.21	0	
Clarence River	39.02	2.33	125.55	214.60	89.17	22.63	2.29	1.25	0.14	7.20
Lake Arragan	0	0.04	0.17	0	0.17	0.10	0	0	0	
Cakora Lagoon	2.63	7.64	4.32	2.35	3.31	0.68	0	2.63	0	
Sandon River	0.77	0.25	1.70	0	1.70	1.37	0	0	2.76	0.11
Wooli Wooli River	1.27	1.64	7.23	7.26	5.57	1.48	0	0	4.76	
Station Creek	0.24	0.02	1.74	0	2.01	1.36	0	0	0	
Corindi River	19.32	4.16	137.40	83.50	52.61	5.59	0.29	0	0	0.00
Pipe Clay Creek	70.80	186.71	279.59	637.33	162.12	97.00	0	0	0	
Arrawarra Creek	14.92	52.27	545.40	227.02	149.80	8.09	1.27	0.62	0	
Darkum Creek	75.57	84.47	5550.58	1531.30	1331.38	50.15	4.04	0	0	
Woolgoolga Lake	40.50	112.59	2515.28	771.32	616.82	31.25	3.16	1.35	0	
Flat Top Point Creek	71.31	298.71	7910.39	2155.44	1854.31	48.80	0.57	0.14	0	
Hearns Lake	66.41	103.31	10212.35	2262.70	2296.70	19.79	10.07	0.26	0	
Moonee Creek	39.12	49.86	1210.75	489.13	329.86	32.62	1.00	0	0	0.02
Pine Brush Creek	68.62	112.29	10593.78	2349.80	2381.70	31.11	9.17	0	0	
Coffs Creek	82.32	758.33	7373.43	2073.29	1751.22	58.69	3.26	1.72	0	0.31
Boambee Creek	62.21	199.44	3881.93	1208.54	954.21	34.07	2.85	0.24	0	0.40
Bonville Creek	38.36	86.69	402.42	325.59	158.84	11.82	1.11	0.01	0	0.01
Bundageree Creek	20.84	15.15	93.54	206.11	65.30	24.12	0	0	0	
Bellinger River	13.81	7.10	65.68	62.32	32.72	3.29	0.38	1.49	2.91	
Dalhousie Creek	25.28	2.75	549.47	265.72	163.03	18.43	0	0	0	
Oyster Creek	29.71	15.55	276.16	197.18	105.22	14.71	0	0	0	
Deep Creek	39.20	15.70	751.04	1401.29	330.34	17.84	2.89	1.15	0	
Nambucca River	33.66	9.05	232.48	211.05	84.99	14.60	0.96	0.94	5.13	8.13
Macleay River	55.99	4.19	64.18	171.13	67.29	16.66	1.22	1.03	3.00	4.17
South West Rocks Creek	27.27	394.10	280.54	537.20	160.59	27.00	0	4.45	0	
Saltwater Creek (Frederickton)	41.81	151.12	619.54	603.08	238.44	31.84	0	0	0	
Korogoro Creek	9.14	29.89	99.76	146.54	53.00	12.37	0	0	0	
Killick Creek	30.73	115.61	83.34	276.94	90.90	12.17	0	0	0	
Goolawah Lagoon	7.18	2.13	0	59.24	0	6.16	0	0	0	
Hastings River	30.25	10.63	116.05	201.02	81.56	11.96	2.28	1.58	4.19	
Cathie Creek	29.09	71.53	140.06	340.69	105.58	31.67	0	4.24	0	3.76
Duchess Gully	53.99	142.70	429.69	617.04	229.17	45.34	0.12	0	0	
Camden Haven River	26.30	14.26	185.12	191.61	90.93	14.94	3.30	0.39	2.91	5.09
Manning River	42.03	4.77	40.98	209.77	73.44	10.29	3.51	0.99	8.33	7.34
Khappinghat Creek	28.40	8.35	104.16	281.29	89.06	17.31	0.19	0	0	
Black Head Lagoon	91.86	206.46	75.12	371.13	90.33	9.97	0	0	0	
Wallis Lake	45.06	18.04	73.04	351.85	114.83	13.93	0.65	0.65	3.86	5.34
Smiths Lake	22.07	36.05	188.73	395.73	119.24	26.19	0	2.63	0	5.06
Myall River	18.70	4.53	29.74	137.47	47.02	7.50	0.33	0.12	0.24	3.27
Karuah River	34.48	2.06	30.93	155.26	55.38	6.91	1.01	0.48	6.74	3.27
Tilligerry Creek	30.45	59.98	786.13	1480.98	352.40	43.77	0	1.09	8.04	3.27
Port Stephens	19.53	13.35	54.36	182.93	60.97	8.30	0.74	0.12	6.54	3.27
Hunter River	61.23	14.57	304.73	394.94	164.47	20.00	21.58	4.79	0.48	5.86
Glenrock Lagoon	0	1005.69	330.66	731.37	200.13	44.70	0	0	0	
Lake Macquarie	40.08	238.65	303.10	368.00	146.55	25.95	2.29	12.47	0	
Middle Camp Creek	14.00	29.08	44.44	95.25	33.10	8.15	0	0	0	
Moonee Beach Creek	18.57	0.96	1540.43	629.24	427.32	32.20	0	0	0	
Tuggerah Lake	33.05	163.84	424.19	310.12	139.63	22.06	24.06	0.61	0	4.12
Wamberal Lagoon	74.74	773.10	378.23	813.76	236.05	75.83	0	0	0	
Terrigal Lagoon	90.50	1022.75	504.33	1131.40	333.89	124.27	0.28	0.09	0	
Avoca Lake	58.89	653.06	286.28	546.07	183.80	65.26	0	0	0	
Cockrone Lake	38.60	240.99	136.25	314.12	103.13	47.45	1.42	0	0	
Brisbane Water	52.13	644.42	292.37	632.13	188.62	69.80	0.29	2.68	6.10	
Hawkesbury River	27.55	39.70	200.75	190.33	69.90	11.08	31.74	3.50	3.69	1.99
Pittwater	16.21	506.96	176.65	189.29	75.16	15.86	1.92	18.53	0	1.99
Broken Bay	31.19	45.45	202.01	196.02	71.48	11.75	0	0.01	0	1.99
Narrabeen Lagoon	28.10	819.39	288.35	350.68	131.45	43.32	3.19	8.04	0	
Dee Why Lagoon	97.00	5800.27	912.75	1510.44	480.88	142.21	0	0.46	0	
Curl Curl Lagoon	100.00	1661.83	664.29	1429.33	414.48	121.81	0	0	0	
Manly Lagoon	74.48	1581.80	863.78	1205.60	412.79	114.03	4.90	0.49	0	
Middle Harbour Creek	68.48	1706.94	448.97	951.87	284.71	104.46	0.36	0.73	0	1.25
Lane Cove River	74.86	1938.34	494.62	1066.47	315.28	117.79	1.08	0.14	0	1.25
Parramatta River	86.07	2460.07	674.12	1314.71	397.02	105.19	1.47	0.14	0	1.25
Port Jackson	81.74	2555.76	607.42	1199.39	362.55	109.29	0.98	0.31	0	1.25
Cooks River	93.89	3418.59	1055.86	1572.44	526.63	122.89	0.62	0.11	0	
Georges River	59.01	900.35	2946.30	1471.56	870.58	82.60	22.03	4.90	8.12	
Botany Bay	61.50	1210.55	2705.25	1474.68	824.73	87.78	18.08	4.21	1.30	
Port Hacking	17.73	392.76	95.83	107.32	46.58	22.34	0.48	16.99	0	0.20
Wattamolla Creek	0	0	0	0	0	0	0	0	0	
Hargraves Creek	38.27	616.45	565.96	653.60	239.60	46.08	0	0	0	
Stanwell Creek	13.11	69.47	186.33	139.79	68.87	13.06	14.95	0	0	
Flanagans Creek	37.69	809.98	464.56	559.23	192.28	12.93	0	0	0	
Woodlands Creek	50.50	434.29	209.80	414.96	133.42	17.44	0	0	0	
Slacky Creek	51.77	648.76	337.47	588.06	177.73	18.02	0	0	0	
Bellambi Gully	87.29	1177.75	851.46	935.89	347.10	36.68	0.59	0	0	
Bellambi Lake	93.23	2141.26	407.16	914.83	241.40	45.61	0	0	0	
Towradgi Creek	67.33	1357.52	396.58	693.71	201.79	18.89	2.61	0	0	
Fairy Creek	75.08	1477.41	390.81	770.92	216.63	25.35	0	0	0	
Allans Creek	74.68	882.32	419.39	728.64	226.23	27.87	0	0	0	

Estuary	% cleared land	Population /km^2	% increase in annual TSS	% increase in annual TP	% increase in annual TN	% increase in annual flow	% surface flows extracted	% structures perimeter	% estuary under aquaculture	Annual fish catch t/km^2
Port Kembla	95.61	0	650.59	1027.97	328.65	45.47	0	0	0	
Lake Illawarra	59.34	350.99	499.60	566.29	218.97	33.66	1.66	0.18	0	5.73
Elliott Lake	88.71	1461.98	479.53	1101.34	323.55	63.52	0	0	0	
Minnamurra River	65.66	42.22	530.57	567.89	157.61	36.56	1.65	0.81	0	0.68
Spring Creek	96.05	187.41	156.58	508.59	167.39	0	0	0	0	
Munna Munnora Creek	86.26	214.32	143.00	589.53	195.13	68.65	0	0	0	
Werri Lagoon	76.51	80.13	106.19	411.72	152.17	44.01	0	0	0	
Crooked River	85.92	48.74	175.30	612.17	227.59	51.24	0.17	0	0	
Shoalhaven River	36.68	6.29	79.05	222.08	73.50	11.66	25.70	20.29	5.79	4.71
Wollumboola Lake	7.35	32.24	24.88	54.88	20.87	3.50	0	0	0	1.09
Currarong Creek	4.05	19.69	20.42	29.90	14.96	5.35	0	5.75	0	
Cararma Creek	2.86	0.25	4.81	15.57	7.01	-2.85	0	0	0	
Wowly Gully	16.16	129.04	85.43	178.61	53.93	7.46	0	0	0	
Callala Creek	14.13	71.40	88.61	157.02	53.30	4.88	0	0	0	
Currambene Creek	33.16	9.03	65.51	207.71	69.56	17.03	0.17	0.74	0.27	
Moona Moona Creek	24.91	34.27	102.41	255.68	81.50	26.60	0	0	9.38	
Flat Rock Creek	0.14	1.88	9.54	6.03	7.33	1.17	0	0	0	
Captains Beach Lagoon	0	0	5.30	0	5.30	1.83	0	0	0	
Telegraph Creek	0	0	5.13	0	5.13	1.75	0	0	0	
Jervis Bay	8.73	25.29	69.65	184.23	62.55	14.37	0.11	0.27	0.06	0.00
St Georges Basin	14.72	42.71	41.74	113.91	40.13	10.89	0.14	1.38	0	
Swan Lake	12.57	17.41	95.05	164.26	53.87	19.04	0.04	0	0	
Berrara Creek	1.70	3.21	9.60	5.76	5.34	0.75	0	0	0	
Nerrindillah Creek	6.42	1.49	8.64	40.64	17.56	3.10	0	1.38	0	
Conjola Lake	9.60	7.84	9.62	65.09	20.54	4.43	0.13	2.39	1.06	
Narrawallee Inlet	43.01	15.93	36.60	283.98	100.65	23.83	0.82	2.18	2.43	
Mollymook Creek	73.90	334.74	303.73	730.62	210.40	30.71	5.73	0	0	
Millards Creek	84.07	701.03	404.72	925.20	264.12	47.95	0	0	0	
Ulladulla	96.30	0	548.87	1198.39	336.79	61.40	0	0	0	
Burrill Lake	49.15	32.98	71.94	347.54	118.44	31.48	0.33	0.91	0.29	
Tabourie Lake	15.42	10.88	26.38	111.41	42.18	9.43	0	0.11	0	
Termeil Lake	30.82	2.00	46.72	198.66	75.53	20.22	0	0.06	0	0.53
Meroo Lake	24.38	1.52	74.26	175.59	70.70	15.60	0.07	0.02	0	
Willinga Lake	21.67	8.88	32.22	143.28	54.12	16.94	0	0	0	
Butlers Creek	61.69	6.01	508.84	1073.30	323.20	135.95	0	0	0	
Durras Lake	6.22	1.26	41.50	73.60	25.31	8.01	0	0	0	4.78
Durras Creek	10.44	8.95	20.56	53.87	19.33	4.45	0	0	0	
Maloneys Creek	8.65	41.01	87.65	127.23	46.49	11.83	0	0	0	
Cullendulla Creek	39.13	37.69	257.87	564.55	168.27	65.30	0.12	0	5.77	
Clyde River	3.98	0.80	6.02	19.79	10.22	2.99	0.52	1.10	12.63	0.30
Batemans Bay	39.78	6.15	11.83	31.11	13.58	4.06	0.51	0.20	0	
Saltwater Creek (Rosedale)	68.88	32.09	124.34	514.20	173.78	52.56	1.31	0	0	
Tomaga River	17.34	13.32	78.61	180.58	58.06	17.11	0.19	1.91	2.98	
Candlagan Creek	17.24	16.71	223.98	224.51	97.48	14.24	0.02	0	0	
Bengello Creek	4.82	3.66	435.79	209.24	132.49	5.43	0	0	0	
Moruya River	12.87	2.60	83.89	88.87	40.81	8.18	1.39	2.72	2.17	2.55
Congo Creek	71.76	7.08	109.38	427.34	144.60	54.57	1.18	7.11	0	8.37
Meringo Creek	47.39	7.44	99.21	321.40	98.35	21.34	0	0	0	0.16
Kellys Lake	83.57	6.95	164.31	497.95	139.93	0	0	0	0	
Coila Lake	22.73	20.03	35.91	124.49	42.43	9.70	0.06	0.01	0	9.75
Tuross River	13.04	0.54	34.19	75.53	27.23	6.53	1.80	0.56	8.00	
Lake Brunderee	4.89	6.26	9.76	24.01	11.95	2.10	0	0	0	
Lake Tarourga	0.80	0.81	6.22	5.15	5.19	0.95	0	0	0	
Lake Brou	7.60	0.56	7.76	19.25	10.66	2.87	0	0	0	4.94
Lake Mummuga	4.96	30.58	16.08	24.58	10.78	3.08	0.07	0	0	
Kianga Lake	23.48	43.09	144.94	234.48	81.36	25.64	0	5.17	0	1.13
Wagonga Inlet	9.47	15.05	35.73	76.28	26.18	5.65	0.43	1.49	13.12	0.00
Little Lake (Narooma)	67.53	428.12	248.01	578.59	151.15	0	3.87	1.23	0	
Bullengella Lake	53.52	13.48	48.31	384.67	142.31	26.78	0	0	0	
Nangudga Lake	73.87	11.97	325.60	849.93	264.16	71.54	0	0	0	2.96
Corunna Lake	45.37	7.65	172.60	441.80	140.28	40.38	0.19	0	0	3.00
Tilba Tilba Lake	72.43	5.81	67.72	433.94	151.90	52.83	3.69	0	0	0.79
Little Lake (Wallaga)	79.31	7.17	142.64	489.43	183.89	82.55	0	0	0	
Wallaga Lake	37.42	4.91	302.37	243.04	126.55	18.90	1.99	1.25	0.55	8.58
Bermagui River	30.05	11.73	184.65	239.88	98.14	16.56	5.02	0.18	17.75	
Baragoot Lake	18.14	1.08	52.53	129.58	42.82	8.87	0	0	0	0.89
Cuttagee Lake	4.76	0.31	13.63	24.04	10.55	2.25	0.21	0	0	4.93
Murrah River	33.75	1.56	36.30	170.09	60.01	18.80	4.54	0	0.55	0.90
Bunga Lagoon	12.52	1.37	14.82	56.83	24.10	5.77	0	0	0	
Wapengo Lagoon	16.18	1.10	8.84	69.47	27.98	6.83	1.04	0.76	21.17	0.97
Middle Lagoon	32.05	1.26	45.03	141.04	56.32	13.81	0.02	2.29	0	5.19
Nelson Lagoon	2.09	0.22	3.05	1.58	3.28	0.00	0	0	21.31	
Bega River	41.95	4.36	71.89	220.97	77.50	18.25	11.69	2.92	1.03	
Wallagoot Lake	14.37	3.45	18.81	76.79	28.59	3.75	0.11	2.08	0	2.20
Bournda Lagoon	8.66	1.31	23.03	41.24	17.23	3.93	1.54	2.52	0	
Back Lagoon	13.57	59.80	71.31	108.39	41.47	10.66	2.14	20.53	0	
Merimbula Lake	42.78	74.75	114.89	353.89	111.27	24.95	0.14	6.65	24.78	0.11
Pambula River	17.63	5.42	17.23	78.81	30.15	10.50	1.56	4.08	21.17	
Curalo Lagoon	15.76	65.04	75.98	142.67	47.26	10.88	0	4.13	0	0.08
Shadrachs Creek	4.07	0.57	5.54	13.52	8.29	1.82	0	0	0	
Nullica River	4.71	0.06	13.19	13.99	9.94	3.44	0	0	0	
Boydtown Creek	27.44	0.27	31.14	143.90	52.18	12.13	0	0	0	
Towamba River	13.68	0.43	11.06	58.52	24.53	10.93	0.77	15.95	0.51	
Fisheries Creek	2.60	0.04	1.97	2.19	4.18	0.75	0	0	0	
Twofold Bay	27.54	3.01	13.96	59.29	24.66	10.59	0.73	0.43	0.59	
Saltwater Creek (Eden)	0	0	0	0	0	0	0	0	0	
Woodburn Creek	0	0	0	0	0	0	0	0	0	
Wonboyn River	1.40	0.19	0.71	0	1.88	0.60	0.03	0.61	12.79	
Merrica River	0	0	0	0	0	0	0	0	0	
Table Creek	0	0	0	0	0	0	0	0	0	
Nadgee River	0	0	0	0	0	0	0	0	0	
Nadgee Lake	0	0	0	0	0	0	0	0	0	

Appendix 22

Comparison of scoring classes for pressures

PRESSURE INDICATOR	Estuary index of stream condition (SKM 1999)		Estuarine indicator guide (Laegdsgaard 2003)		CRC integrated estuary assessment frame -work (Moss et al. 2006)		Qld stream and estuary assessment program (SEAP) (Scheltinga & Moss 2008)	
	Rating	**Score**	**Response**	**Trigger Level**	**Scoring Category[3]**	**Indicator Value**	**Condition Score**	**Indicator Value**
Catchment land-use					1	< 30% cleared	1	All catchments classed as 'Conservation and natural environments' (ALUM1)
					2	30 – 49%	2	≤ 10% cleared
					3	50 – 65%	3	10 – 35%
					4	66 – 80%	4	35 – 65%
					5	>80%	5	> 65%
Catchment population					1	< 2 (1000 people/km^2 of catchment)	1	≤5 people/km^2 in a 20 km buffer of the waterway
					2	2 – 10	2	>5 but ≤15
					3	11 – 25	3	>15 but ≤200
					4	26 – 50	4	>200 but ≤2000
					5	> 50	5	>2000
Riparian vegetation clearance							1	< 5% of river length with no riparian vegetation within a 50m buffer
							2	5 – 10%
							3	10 – 20%
							4	20 – 50%
							5	> 50%
Shoreline alienation	4	Access totally unimpeded			1	< 5% of shoreline developed		
	3	Access to > 95% of shoreline	Initial	< 25% of foreshore with structures	2	< 50% developed for agriculture, < 5% urban		
	2	> 90%	Moderate	25 – 50%	3	> 50% agriculture or 5 – 20% urban		
	1	> 75%	Pressing	50 – 75%	4	21 – 50% urban		
	0	< 75%	Urgent	> 75%	5	> 50% urban		
Freshwater impoundments					1	No impoundments		
					2	Total impoundment volume < 20% median annual flow		
					3	20 – 50%		
					4	51 – 10%		
					5	> 100%		

PRESSURE INDICATOR	Estuary index of stream condition (SKM 1999)		Estuarine indicator guide (Laegdsgaard 2003)		CRC integrated estuary assessment frame -work (Moss et al. 2006)		Qld stream and estuary assessment program (SEAP) (Scheltinga & Moss 2008)	
	Rating	Score	Response	Trigger Level	Scoring Category[3]	Indicator Value	Condition Score	Indicator Value
Entrance openings			Initial	15 – 25% of openings are artificial				
			Moderate	25 – 50%				
			Pressing	50 – 90%				
			Urgent	90 – 100%				
Total Nitrogen load					1	0 – 5.5 kg/ha/yr		
					2	5.6 – 11		
					3	11.1 – 16.5		
					4	16.6 – 22		
					5	> 22		
Total Phosphorus load					1	0 – 0.6 kg/ha/yr		
					2	0.7 – 1.1		
					3	1.2 – 1.65		
					4	1.66 – 2.2		
					5	> 2.2		
Fine sediment load					1	< 5 kg fine sediment/year/ m^3 estuary volume	1	< 5 kg fine sediment/year/m^2 estuary and no dredging
					2		2	< 5 kg/year/m^2 estuary and dredging present
					3	5 – 10 kg/year/m^3	3	5 – 10 kg/year/m^2 and no dredging
					4		4	5 – 10 kg/year/m^2 and dredging present
					5	> 10 kg/year/m^3	5	> 10 kg/year/m^2
Point source discharges							1	No point sources
							2	
							3	1 point source
							4	
							5	> 1 point source
Boating use							1	Limited/none
							2	Recreational vessels only
							3	Recreational and commercial vessels
							4	Marina/permanent mooring facilities
							5	International port facilities

Appendix 23

Data availability for NSW estuaries

LEGEND	✓	Data available	✓	Data modelled	?	Data estimated	×	Data being acquired	×	Data unavailable	na	Not applicable

	Condition data							Estuary physical data																			Pressure/stressor data																	
	NRC indicators							Base data													Derived data						Catchment							Ripar'n		F'shore		Waterway				Climate		
Estuary	Chlorophyll	Macroalgae	Turbidity	Seagrass	Mangrove	Saltmarsh	Fish	Coordinates	Geomorphology	Entrance condition	Rainfall	Evaporation	Surface area	Bathymetry	Tidal prism	Tidal planes	Tidal limits	Catchment area	Catchment above tidal limit	Salinity (time series)	Estuary volume	Catchment runoff	Dilution	Freshwater replacement time	Exchange efficiency	Tidal flushing	Population	Land-use	Runoff change	Sediment load	Sewerage	STP discharges	Nutrient load	Vegetation extent	Water extraction	Structures	Aquaculture	Entrance works	Entrance opening	Harvesting	Invasive species	Sea level rise	Rainfall change	Runoff change
Tweed River	✓	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	×	✓	?	✓	?	×	×	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Cudgen Creek	×	×	×	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	×	✓	✓	✓	✓	×	×	✓	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Cudgera Creek	×	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	?	×	✓	✓	×	✓	?	✓	?	×	×	?	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Mooball Creek	×	×	×	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	×	✓	×	✓	✓	×	✓	?	✓	?	×	×	✓	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Brunswick River	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	×	✓	?	✓	?	×	×	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Belongil Creek	✓	×	×	na	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	✓	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Tallow Creek	✓	×	×	na	na	✓	✓	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	✓	?	✓	?	×	×	na	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Broken Head Creek	×	×	×	na	na	✓	✓	✓	✓	✓	✓	✓	✓	×	na	na	×	✓	×	×	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Richmond River	✓	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	×	✓	?	✓	?	×	×	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Salty Lagoon	×	×	×	×	×	×	×	✓	✓	✓	✓	✓	✓	×	na	na		✓	×	×	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Evans River	✓	×	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	×	×	?	✓	?	×	×	✓	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Jerusalem Creek	×	×	×	na	na	✓	×	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	×	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Clarence River	✓	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	×	×	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Lake Arragan	×	×	×	×	×	×	×	✓	✓	✓	✓	✓	✓	×	na	na	×	✓	×	×	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Cakora Lagoon	×	×	×	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	×	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Sandon River	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	×	✓	✓	×	×	?	✓	?	×	×	✓	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Wooli Wooli River	×	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×	✓	✓	✓	×	×	✓	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Station Creek	×	×	×	na	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	×	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Corindi River	×	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	?	×	✓	✓	×	×	✓	✓	✓	×	×	?	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Pipe Clay Creek	×	×	×	na	×	×		✓	✓	✓	✓	✓	✓	×	na	na		✓	×	×	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Arrawarra Creek	×	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	✓	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Darkum Creek	×	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	✓	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Woolgoolga Lake	×	×	×	na	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	✓	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Flat Top Point Creek	×	×	×	×	×	×	×	✓	✓	✓	✓	✓	✓	×	na	na	×	✓	×	×	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Hearns Lake	×	×	×	na	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	✓	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Moonee Creek	×	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	?	×	✓	✓	×	✓	✓	✓	✓	×	×	?	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Pine Brush Creek	×	×	×	×	×	×	×	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	×	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Coffs Creek	×	×	×	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	×	?	×	✓	✓	×	✓	?	✓	?	×	×	?	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Boambee Creek	×	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	×	✓	✓	×	✓	?	✓	?	×	×	✓	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Bonville Creek	×	×	×	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	×	✓	×	✓	✓	×	✓	?	✓	?	×	×	✓	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Bundageree Creek	×	×	×	×	×	×	×	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	×	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Bellinger River	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	×	✓	✓	×	✓	?	✓	?	×	×	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Dalhousie Creek	×	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	×	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Oyster Creek	×	×	×	na	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	×	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Deep Creek	×	×	×	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	na	✓	✓	×	✓	✓	✓	✓	×	×	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Nambucca River	✓	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	×	✓	?	✓	?	×	×	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Macleay River	✓	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	×	×	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×

Estuary	Condition data							Estuary physical data																			Pressure/stressor data																	
	NRC indicators							Base data													Derived data						Catchment							Ripar'n		F'shore		Waterway				Climate		
	Chlorophyll	Macroalgae	Turbidity	Seagrass	Mangrove	Saltmarsh	Fish	Coordinates	Geomorphology	Entrance condition	Rainfall	Evaporation	Surface area	Bathymetry	Tidal prism	Tidal planes	Tidal limits	Catchment area	Catchment above tidal limit	Salinity (time series)	Estuary volume	Catchment runoff	Dilution	Freshwater replacement time	Exchange efficiency	Tidal flushing	Population	Land-use	Runoff change	Sediment load	Sewerage	STP discharges	Nutrient load	Vegetation extent	Water extraction	Structures	Aquaculture	Entrance works	Entrance opening	Harvesting	Invasive species	Sea level rise	Rainfall change	Runoff change
South West Rocks Creek	×	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	×	✓	✓	×	×	?	✓	?	×	×	✓	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Saltwater Creek (Frederickton)	×	×	×	na	na	na	✓	✓	✓	✓	✓	✓	✓	✓	na	na	✓	✓	×	×	✓	✓	✓	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Korogoro Creek	×	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	?	×	✓	✓	×	×	?	✓	?	×	×	?	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Killick Creek	×	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	na	na	✓	✓	×	×	✓	✓	✓	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Goolawah Lagoon	×	×	×	×	×	×	×	✓	✓	✓	✓	✓	✓	×	na	na	×	✓	×	×	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Hastings River	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	×	×	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Cathie Creek	×	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	na	✓	✓	×	✓	✓	✓	✓	×	×	✓	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Duchess Gully	×	×	×	×	×	×	×	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	✓	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Camden Haven River	✓	×	×	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	×	✓	?	✓	?	×	×	✓	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Manning River	✓	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	×	✓	?	✓	?	×	×	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Khappinghat Creek	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	×	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Black Head Lagoon	×	×	×	na	✓	✓	×	✓	✓	✓	✓	✓	✓	×	na	na	×	✓	×	×	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Wallis Lake	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	×	×	✓	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Smiths Lake	✓	×	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	✓	na	na	✓	✓	×	✓	✓	✓	✓	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Myall River	✓	×	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	?	×	✓	✓	×	✓	✓	✓	✓	×	×	?	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Karuah River	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	×	×	?	✓	?	×	×	✓	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Tilligerry Creek	×	×	×	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	×	?	×	✓	✓	×	×	?	✓	?	×	×	?	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Port Stephens	×	×	×	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	×	✓	×	×	✓	×	×	?	✓	?	×	×	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Hunter River	×	×	×	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	×	×	?	✓	?	×	×	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Glenrock Lagoon	×	×	×	×	×	×	×	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	×	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Lake Macquarie	✓	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	×	✓	?	✓	?	×	×	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	×
Middle Camp Creek	×	×	×	×	×	×	×	✓	✓	✓	✓	✓	✓	×	na	na	×	✓	×	×	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Moonee Beach Creek	×	×	×	×	×	×	×	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	×	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Tuggerah Lake	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	na	✓	✓	×	×	✓	✓	✓	×	×	✓	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Wamberal Lagoon	✓	×	✓	✓	na	na	✓	✓	✓	✓	✓	✓	✓	✓	na	na	✓	✓	×	✓	✓	✓	✓	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Terrigal Lagoon	×	×	×	✓	✓	na	✓	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	✓	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Avoca Lake	✓	×	✓	×	×	×	✓	✓	✓	✓	✓	✓	✓	✓	na	na	✓	✓	×	✓	✓	✓	✓	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Cockrone Lake	×	×	×	✓	na	na	✓	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	✓	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Brisbane Water	✓	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	×	✓	✓	✓	✓	×	×	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	×
Hawkesbury River	✓	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	×	✓	✓	×	✓	?	✓	?	×	×	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	×
Pittwater	×	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	?	×	✓	✓	×	×	?	✓	?	×	×	?	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Broken Bay	×	×	×	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	×	?	×	×	✓	×	×	?	✓	?	×	×	?	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Narrabeen Lagoon	✓	×	×	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	na	✓	✓	×	✓	✓	✓	✓	×	×	✓	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Dee Why Lagoon	✓	×	×	✓	na	✓	✓	✓	✓	✓	✓	✓	✓	✓	na	na	✓	✓	×	✓	✓	✓	✓	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Curl Curl Lagoon	✓	×	×	×	×	×	×	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	✓	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Manly Lagoon	✓	×	✓	✓	✓	na	×	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	✓	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Middle Harbour Creek	✓	×	×	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	?	×	✓	✓	×	×	✓	✓	✓	×	×	?	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Lane Cove River	✓	×	×	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	?	×	✓	✓	×	✓	✓	✓	✓	×	×	?	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Parramatta River	✓	×	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	?	×	✓	✓	×	✓	✓	✓	✓	×	×	?	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Port Jackson	✓	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	×	✓	✓	✓	✓	×	×	✓	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	×
Cooks River	✓	×	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	×	?	×	✓	✓	×	✓	?	✓	?	×	×	?	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Georges River	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	×	✓	✓	×	✓	?	✓	?	×	×	✓	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Botany Bay	✓	×	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	×	?	×	×	✓	×	×	?	✓	?	×	×	?	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	×
Port Hacking	✓	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	×	✓	✓	×	✓	?	✓	?	×	×	✓	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	×

Estuary	Condition data							Estuary physical data												
	NRC indicators							Base data												
	Chlorophyll	Macroalgae	Turbidity	Seagrass	Mangrove	Saltmarsh	Fish	Coordinates	Geomorphology	Entrance condition	Rainfall	Evaporation	Surface area	Bathymetry	Tidal prism	Tidal planes	Tidal limits	Catchment area	Catchment above tidal limit	Salinity (time series)
Wattamolla Creek	✓	×	✓	×	×	×	×	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	✓
Hargraves Creek	×	×	×	×	×	×	×	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	×
Stanwell Creek	✓	×	×	×	×	×	×	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	×
Flanagans Creek	✓	×	×	×	×	×	×	✓	✓	✓	✓	✓	✓	×	na	na	×	✓	×	×
Woodlands Creek	×	×	×	×	×	×	×	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	×
Slacky Creek	✓	×	×	×	×	×	×	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	×
Bellambi Gully	×	×	×	×	×	×	×	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	×
Bellambi Lake	✓	×	✓	×	×	×	×	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	✓
Towradgi Creek	✓	×	✓	×	✓	×	×	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	×
Fairy Creek	✓	×	✓	×	×	×	×	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	✓
Allans Creek	×	×	×	×	✓	✓	×	✓	✓	✓	✓	✓	✓	×	?	×	×	✓	×	×
Port Kembla	×	×	×	×	×	×	×	✓	✓	✓	✓	✓	✓	×	?	×	×	✓	×	×
Lake Illawarra	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	×	✓
Elliott Lake	×	×	×	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	×
Minnamurra River	✓	×	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	×	✓	×	✓	✓	×	✓
Spring Creek	✓	×	×	✓	na	na	×	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	×
Munna Munnora Creek	✓	×	×	×	×	×	×	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	×
Werri Lagoon	✓	×	×	✓	✓	na	×	✓	✓	✓	✓	✓	✓	✓	na	na	✓	✓	×	✓
Crooked River	✓	×	×	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	?	×	✓	✓	×	✓
Shoalhaven River	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	×	✓	✓	×	✓
Wollumboola Lake	×	×	×	✓	na	na	×	✓	✓	✓	✓	✓	✓	✓	na	na	×	✓	×	✓
Currarong Creek	×	×	×	×	×	×	×	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	✓
Cararma Creek	×	×	×	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	×	?	×	✓	✓	×	×
Wowly Gully	×	×	×	×	×	✓	×	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	×
Callala Creek	×	×	×	×	×	×	×	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	×
Currambene Creek	×	×	×	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	×	?	×	✓	✓	×	×
Moona Moona Creek	×	×	×	✓	✓	×	×	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	×
Flat Rock Creek	×	×	×	×	×	✓	×	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	×
Captains Beach Lagoon	×	×	×	×	✓	×	×	✓	✓	✓	✓	✓	✓	×	na	na	×	✓	×	×
Telegraph Creek	×	×	×	×	×	×	×	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	×
Jervis Bay	×	×	×	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	?	×	×	✓	×	✓
St Georges Basin	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	×	✓
Swan Lake	✓	×	✓	✓	na	na	×	✓	✓	✓	✓	✓	✓	✓	na	na	×	✓	×	✓
Berrara Creek	×	×	×	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	✓
Nerrindillah Creek	×	×	×	✓	na	na	×	✓	✓	✓	✓	✓	✓	×	na	na	×	✓	×	×
Conjola Lake	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	×	✓
Narrawallee Inlet	×	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓
Mollymook Creek	✓	×	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	×
Millards Creek	×	×	×	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	✓
Ulladulla	×	×	×	×	×	×	×	✓	✓	✓	✓	✓	✓	×	?	×	×	✓	×	×
Burrill Lake	✓	×	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓
Tabourie Lake	✓	×	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓
Termeil Lake	✓	×	✓	✓	na	na	×	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	✓
Meroo Lake	✓	×	✓	✓	na	na	✓	✓	✓	✓	✓	✓	✓	×	na	na	×	✓	×	✓

Estuary	Estuary physical data						Pressure/stressor data																	
	Derived data						Catchment							Ripar'n		F'shore		Waterway				Climate		
	Estuary volume	Catchment runoff	Dilution	Freshwater replacement time	Exchange efficiency	Tidal flushing	Population	Land-use	Runoff change	Sediment load	Sewerage	STP discharges	Nutrient load	Vegetation extent	Water extraction	Structures	Aquaculture	Entrance works	Entrance opening	Harvesting	Invasive species	Sea level rise	Rainfall change	Runoff change
Wattamolla Creek	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Hargraves Creek	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Stanwell Creek	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Flanagans Creek	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Woodlands Creek	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Slacky Creek	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Bellambi Gully	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Bellambi Lake	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Towradgi Creek	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Fairy Creek	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Allans Creek	?	✓	?	×	×	?	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Port Kembla	?	✓	?	×	×	?	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Lake Illawarra	✓	✓	✓	×	×	✓	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Elliott Lake	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Minnamurra River	?	✓	?	×	×	✓	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Spring Creek	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Munna Munnora Creek	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Werri Lagoon	✓	✓	✓	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Crooked River	✓	✓	✓	×	×	?	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Shoalhaven River	?	✓	?	×	×	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Wollumboola Lake	✓	✓	✓	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Currarong Creek	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Cararma Creek	?	✓	?	×	×	?	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Wowly Gully	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Callala Creek	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Currambene Creek	?	✓	?	×	×	?	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Moona Moona Creek	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Flat Rock Creek	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Captains Beach Lagoon	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Telegraph Creek	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Jervis Bay	✓	✓	✓	×	×	?	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
St Georges Basin	✓	✓	✓	×	×	✓	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	×
Swan Lake	✓	✓	✓	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Berrara Creek	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Nerrindillah Creek	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Conjola Lake	✓	✓	✓	×	×	✓	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	×
Narrawallee Inlet	✓	✓	✓	×	×	✓	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	×
Mollymook Creek	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Millards Creek	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Ulladulla	?	✓	?	×	×	?	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Burrill Lake	✓	✓	✓	×	×	✓	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	×
Tabourie Lake	✓	✓	✓	×	×	✓	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Termeil Lake	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Meroo Lake	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×

Estuary	Condition data							Estuary physical data																			Pressure/stressor data																	
	NRC indicators							Base data													Derived data						Catchment							Ripar'n		F'shore		Waterway				Climate		
Estuary	Chlorophyll	Macroalgae	Turbidity	Seagrass	Mangrove	Saltmarsh	Fish	Coordinates	Geomorphology	Entrance condition	Rainfall	Evaporation	Surface area	Bathymetry	Tidal prism	Tidal planes	Tidal limits	Catchment area	Catchment above tidal limit	Salinity (time series)	Estuary volume	Catchment runoff	Dilution	Freshwater replacement time	Exchange efficiency	Tidal flushing	Population	Land-use	Runoff change	Sediment load	Sewerage	STP discharges	Nutrient load	Vegetation extent	Water extraction	Structures	Aquaculture	Entrance works	Entrance opening	Harvesting	Invasive species	Sea level rise	Rainfall change	Runoff change
Willinga Lake	✓	×	×	✓	na	na	✓	✓	✓	✓	✓	✓	✓	✓	na	na	✓	✓	×	✓	✓	✓	✓	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Butlers Creek	×	×	×	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	na	na	×	✓	×	×	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Durras Lake	✓	×	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	✓	na	na	✓	✓	×	✓	✓	✓	✓	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Durras Creek	×	×	×	×	×	×	×	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	×	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Maloneys Creek	×	×	×	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	×	na	na	×	✓	×	×	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Cullendulla Creek	×	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	?	×	✓	✓	×	×	?	✓	?	×	×	?	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Clyde River	✓	×	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	×	✓	✓	✓	✓	×	×	✓	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Batemans Bay	×	×	×	✓	✓	na	×	✓	✓	✓	✓	✓	✓	×	?	×	✓	✓	×	×	?	✓	?	×	×	?	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Saltwater Creek (Rosedale)	×	×	×	×	×	×	×	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	✓	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Tomaga River	✓	×	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	×	✓	✓	✓	✓	×	×	✓	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Candlagan Creek	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	?	×	✓	✓	×	×	?	✓	?	×	×	?	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Bengello Creek	×	×	×	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	×	na	na	×	✓	×	×	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Moruya River	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	×	×	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Congo Creek	✓	×	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	×	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Meringo Creek	×	×	×	na	na	✓	×	✓	✓	✓	✓	✓	✓	×	na	na	×	✓	×	×	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Kellys Lake	×	×	×	✓	×	✓	×	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	×	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Coila Lake	✓	×	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	✓	na	na	✓	✓	×	✓	✓	✓	✓	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Tuross River	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	×	✓	✓	✓	✓	×	×	✓	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Lake Brunderee	×	×	×	✓	na	✓	✓	✓	✓	✓	✓	✓	✓	×	na	na	×	✓	×	×	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Lake Tarourga	×	×	×	na	na	na	×	✓	✓	✓	✓	✓	✓	×	na	na	×	✓	×	×	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Lake Brou	✓	×	✓	✓	na	✓	✓	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	×	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Lake Mummuga	×	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	×	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Kianga Lake	×	×	×	✓	na	✓	×	✓	✓	✓	✓	✓	✓	✓	na	na	×	✓	×	×	✓	✓	✓	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Wagonga Inlet	×	×	×	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	×	✓	✓	✓	✓	×	×	✓	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Little Lake (Narooma)	×	×	×	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	×	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Bullengella Lake	×	×	×	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	×	na	na	×	✓	×	×	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Nangudga Lake	×	×	×	✓	na	✓	✓	✓	✓	✓	✓	✓	✓	✓	na	na	✓	✓	×	✓	✓	✓	✓	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Corunna Lake	✓	×	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	✓	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Tilba Tilba Lake	✓	×	✓	✓	na	✓	✓	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	×	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Little Lake (Wallaga)	×	×	×	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	×	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Wallaga Lake	✓	×	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	×	×	✓	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Bermagui River	×	×	×	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	×	✓	×	✓	✓	×	×	?	✓	?	×	×	✓	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Baragoot Lake	✓	×	✓	✓	na	✓	✓	✓	✓	✓	✓	✓	✓	×	na	na	×	✓	×	✓	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Cuttagee Lake	✓	×	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	×	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Murrah River	×	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	?	×	✓	✓	×	×	?	✓	?	×	×	?	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Bunga Lagoon	×	×	×	✓	na	✓	✓	✓	✓	✓	✓	✓	✓	×	na	na	×	✓	×	×	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Wapengo Lagoon	✓	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	?	×	✓	✓	×	✓	?	✓	?	×	×	?	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Middle Lagoon	×	×	×	✓	na	✓	✓	✓	✓	✓	✓	✓	✓	×	na	na	×	✓	×	×	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Nelson Lagoon	✓	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	?	×	✓	✓	×	✓	?	✓	?	×	×	?	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Bega River	✓	×	✓	✓	na	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	×	✓	✓	✓	✓	×	×	✓	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Wallagoot Lake	✓	×	✓	✓	na	✓	✓	✓	✓	✓	✓	✓	✓	×	na	na	×	✓	×	×	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Bournda Lagoon	×	×	×	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	na	na	×	✓	×	×	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Back Lagoon	×	×	×	✓	na	✓	✓	✓	✓	✓	✓	✓	✓	✓	na	na	✓	✓	×	✓	✓	✓	✓	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Merimbula Lake	✓	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	×	×	✓	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×

Estuary	Condition data							Estuary physical data												
	NRC indicators							Base data												
	Chlorophyll	Macroalgae	Turbidity	Seagrass	Mangrove	Saltmarsh	Fish	Coordinates	Geomorphology	Entrance condition	Rainfall	Evaporation	Surface area	Bathymetry	Tidal prism	Tidal planes	Tidal limits	Catchment area	Catchment above tidal limit	Salinity (time series)
Pambula River	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓
Curalo Lagoon	✓	×	×	✓	na	✓	✓	✓	✓	✓	✓	✓	✓	✓	na	na	✓	✓	×	✓
Shadrachs Creek	×	×	×	×	×	×	×	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	×
Nullica River	×	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	×
Boydtown Creek	×	×	×	×	×	×	×	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	×
Towamba River	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	?	×	✓	✓	×	×
Fisheries Creek	×	×	×	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	×
Twofold Bay	×	×	×	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	?	×	×	✓	×	×
Saltwater Creek (Eden)	×	×	×	×	×	×	×	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	×
Woodburn Creek	×	×	×	×	×	×	×	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	×
Wonboyn River	×	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	×	✓
Merrica River	✓	×	✓	na	na	na	×	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	×
Table Creek	×	×	×	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	×
Nadgee River	×	×	×	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	na	na	✓	✓	×	×
Nadgee Lake	✓	×	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	na	na	×	✓	×	×

Estuary	Estuary physical data						Pressure/stressor data																	
	Derived data						Catchment							Ripar'n		F'shore		Waterway				Climate		
	Estuary volume	Catchment runoff	Dilution	Freshwater replacement time	Exchange efficiency	Tidal flushing	Population	Land-use	Runoff change	Sediment load	Sewerage	STP discharges	Nutrient load	Vegetation extent	Water extraction	Structures	Aquaculture	Entrance works	Entrance opening	Harvesting	Invasive species	Sea level rise	Rainfall change	Runoff change
Pambula River	✓	✓	✓	×	×	✓	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Curalo Lagoon	✓	✓	✓	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Shadrachs Creek	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Nullica River	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Boydtown Creek	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Towamba River	?	✓	?	×	×	?	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Fisheries Creek	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Twofold Bay	?	✓	?	×	×	?	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Saltwater Creek (Eden)	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Woodburn Creek	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Wonboyn River	✓	✓	✓	×	×	✓	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Merrica River	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Table Creek	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Nadgee River	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×
Nadgee Lake	?	✓	?	×	×	na	✓	✓	✓	✓	✓	na	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	×

Note: Estuaries sampled during 08/09 are included to show all currently available data. Some intermittently open estuaries have had a tidal gauging during an extended opening period but 'na' is shown for tidal prism.

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