

GOSFORD CITY COUNCIL

COASTAL LAGOONS
DATA INVENTORY

PART A
SUMMARY REPORT

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SUMMARY

The Coastline Management, Lagoon Management and Coastal Planning Committee (CLP Committee) was established by Gosford City Council in December 1992 with representation from relevant Government Departments and interested sections of the community. A principal objective of the CLP Committee is to oversee the preparation of Plans of Management for the Wamberal, Terrigal, Avoca (Bulbararing) and Cockrone coastal lagoons in accordance with the Estuary Management Manual and the Floodplain Development Manual. The CLP Committee commissioned the preparation of the Data Inventory as an initial segment of the work.

Council has commissioned various studies over the past two decades. Additional research and investigation has been undertaken by government bodies, students and private organisations. With two notable exceptions, these studies have not attempted to look at all four lagoons from an overall perspective. Either, they have been directed at particular issues, usually dealing with only one of the four lagoons, or, they are generalised studies, where the lagoons are not the primary concern.

This Data Inventory is intended to assist the CLP Committee in identifying the adequacy of existing data, and the need for additional information to complete management plans for the lagoons. The study is also useful in clarifying issues of importance which the Committee will need to address in its future planning.

MAJOR ISSUES

A search of files and documents over the last twenty years has revealed a variety of concerns. Some of these have been resolved by actions taken during the period, most notably sewerage reticulation to urban areas within the catchment. However, there are three major issues which have been a consistent source of debate within the community. These are closely interrelated and encapsulate most of the other concerns which have been raised at various times. They can be summarised as :

Artificial Opening of the Lagoons

Artificial opening of lagoons to control flooding of lagoon foreshore areas and as means of improving water quality, compared to negative effects on lagoon ecology. This matter effects all lagoons.

Dredging

Dredging is perceived by some as a means of resolving various problems relating to the lagoons, including :

- Relieving flood problems,
- Improving water quality,
- Improving recreational and aesthetic quality,
- Reducing siltation,
- A potential source of sand for beach nourishment in areas of high coastal erosion.

Against these perceived benefits questions have been raised about the impacts of dredging on the lagoon ecology including effects on water quality, and aquatic flora and fauna.

To date dredging issues have mainly been confined to Terrigal Lagoon and Avoca Lake. In time it could be expected that the issue of dredging will be raised in relation to the remaining lagoons. In this respect it can be seen as an issue effecting all lagoons.

Water Quality and Catchment Management

The on going effects of urbanisation in the catchments in relation to water quality and increased siltation have been raised consistently, and are highlighted by Cheng's concern at the potential for rapid deterioration of the lagoons under certain conditions. Again this is a matter affecting all lagoons.

DATA DEFICIENCIES AND ADDITIONAL INFORMATION REQUIRED

As a result of our analysis of the Data Inventory, we have identified priority areas where additional information is needed to enable the Committee to proceed with management plans for the lagoons.

Water Quality

Water quality is an overriding issue since it has implications for all aspects of the aquatic environment. Although some of the studies provide baseline information, there has been no coordinated or consistent water quality monitoring since 1975. To be of value water quality monitoring needs to be conducted over an extended time frame. A minimum of 12 months is required to account for variations in seasons and in holiday population loadings. Monitoring should be done on a regularly basis and should also be carried out after heavy rainfall, and periods when the lagoons are opened. Testing should include:

- Faecal coliforms.
- Turbidity.
- Nitrate, Nitrite, Ammonia and Total Nitrogen.
- Total Phosphorus and orthophosphates.
- Chlorophyll 'a'
- Dissolved oxygen

The locations and procedures should be standardised to enable comparisons with Cheng (1992).

Potential acid sulphate soils have been observed by Andrews Neil in at least part of the Terrigal lagoon catchment. None of the studies have examined the impact of acid sulphate soils, which can have major impacts on receiving waters. A separate study is required to determine the extent of potential acid and actual sulphate soils in all catchments. This investigation needs to be coordinated with any total catchment management plans developed for the respective lagoons.

Sedimentation and Bathymetry

Historical analysis of sedimentation for the lagoons has not been carried out to establish the extent of lagoon infilling, if any. It may be that water levels are now generally lower and sedimentation is a perceived notion. Studies should include updated bathymetry mapping for all lagoons by detail survey.

Additionally the source of sediment material and its resource value, for both commercial use and beach nourishment needs to be determined to establish the feasibility of any dredging program. This should be determined through a detailed geotechnical assessment.

The soft anaerobic "ooze" in Cockrone Lagoon was specifically identified by Cheng and needs to be examined to determine its source, effect on water quality, aquatic fauna and flora, and any remedial action which may be required.

Lagoon Opening

The effect of artificial lagoon opening on the environmental status of the lagoons is not well understood.

Further information on the effects on benthic flora and fauna is required. This should include analysis of seagrass populations to determine :

- Whether the depletion is cyclical,
- The rate of regrowth and limiting growth factors,
- The degree of salt water intrusion and its effect on aquatic flora and fauna.

Additional information is also required to establish the effect the lagoon opening has on reducing pollution loads. This would form an integral part of the water quality monitoring program referred to above.

Catchment Management

For a total catchment management program to be effective quantitative data on nutrient and sediment loads is required. Modelling of inputs from the catchment would assist in :

More accurately targeting land use controls to improve water quality in each lagoon.
Establishing priorities for the design and placement of nutrient treatment structures.
Determining priorities for conservation zones and land acquisitions under the Coastal Open Space System.

Flora and fauna

Additional studies are required on aquatic flora and fauna. Apart from aquatic flora and fauna referred to previously under lagoon openings, there is probably sufficient information at this stage in relation to terrestrial flora and fauna and birds. Further detailed studies will be needed as Management Plans are developed to determine the impacts of specific proposals, eg, dredge stockpiles as part of any dredging EIS. Additionally, any recreation planning will need to take into account effects on flora and fauna

Recreation Potential

There is very little information available on recreational attributes or demand, yet recreational demand in its needs to be examined once the environmental constraints are more clearly identified and is also relevant to any assessment of dredging works. Any recreation study should include an assessment of water and land based resources and demands, including access requirements. 6 p245Xbro

Aesthetic values are an integral part of recreation planning, and the recreation study should include a visual/landscape analysis of the lagoon catchments.

Land Tenure

Mapping of public lands around the foreshores is required as part of planning and management process. This should identify the responsible authority, status of the land and cadastral boundaries. The plans of management can then develop appropriate land use policies as the various constraints and opportunities are determined and specific objectives set for each lagoon.

Archaeology

Apart from some areas within the Wamberal Lagoon catchment there is virtually no archaeological data. Additional archaeological information could be provided as a stand alone study, or dealt with as separate studies forming part of any specific proposals to carry out works within the catchment or the lagoons.

MANAGEMENT CONSIDERATIONS

Interim Policy Measures

There is an obvious time lag if the Committee decides to undertake the various additional studies prior to implementing detailed investigation of actions such as dredging, and changed practices to lagoon opening. In particular, the water quality monitoring can only provide useful results over a minimum period of say one year and preferably longer. Other investigations can proceed more rapidly, but ultimately water quality is a critical factor in most decisions effecting the lagoons.

There are a number of policy and management decisions which can assist in the interim, many of which have been recommended in the various studies already completed. It is beyond the scope of this report to deal with and assess the relevance of all of those recommendations, however, now the documents have been collated it may be a useful task for the committee to review past recommendations and develop an up to date set of interim actions for implementation, pending finalisation of plans of management.

Dredging

From our investigations the reasons for dredging of the lagoons appear to have varied over the years and the Committee should review its overall objectives in relation to this issue. It may be that rather than issuing a brief for an EIS for dredging, that the brief should be more in the form of a feasibility study; which includes among other things a systematic evaluation of matters relating to dredging, including real and perceived benefits. Until the additional environmental data is available this study would not be sufficient to be used as an EIS. However, it could assist in defining a policy position for each of the lagoons.

In the short term such a study may need to focus on Terrigal since this is the centre of current interest. An initial feasibility study will provide valuable input to any EIS in the event that Council chooses to obtain the necessary approvals for dredging.

Even if the Committee chooses to proceed directly with an EIS, the purpose of the dredging will have to be more clearly established.

Lagoon Opening

As a separate issue to the ongoing water quality monitoring, the Committee should investigate the feasibility of controlling the residual level of the lagoons after they have been breached. The options for this appear to be limited but because of the potential environmental impacts they need to be reviewed. For example, the options might include mechanically closing the opening with bulldozers after the flood height is reduced to an acceptable level. The investigations into the implications of lagoon opening and its ecological impacts need to be closely tied into any investigations on dredging and the outcomes of the current flood studies.

Water Quality Monitoring

Monitoring could be carried out by Council staff, subject to funding for staff and equipment, or by consultants. The benefits of Council conducting monitoring using in house resources become relevant if it is decided that longer term monitoring beyond the initial 12 months will be carried out. This may warrant closer examination by Council of the cost/benefits of upgrading its in house capacity for monitoring of other water bodies throughout the city as well as the coastal lagoons.

Flooding

The results of the current flood studies need to be incorporated into a catchment management plan. These studies also need to confirm whether dredging has any mitigating effect, since this is one of the perceived benefits of dredging.

It would also be useful if the flood investigations can verify any change in the mean water level of the lagoons since the practice of artificial lagoon opening has been commenced. This may confirm whether perceptions of the lagoons silting up are in fact a result of the water level being artificially lowered.

Coordination of activities within Council

Many recommendations have been made over the years in various studies relating to the management of the lagoons. It is not always clear from the files if and how these recommendations have been implemented. In addition there are other activities carried out by the various sections of Council which relate to the lagoons. Some of these activities relate to the collection of information, eg monitoring faecal coliforms, and some times they relate to specific works, eg installation of services, road works and capital works on foreshore reserves.

Coordination of these activities and following up implementation of recommendations will be an important role for the committee to incorporate in future management plans.

Public involvement

It is clear from the correspondence on Council's files that the welfare of lagoons is an issue of considerable importance to the community. Considerable thought and effort is required in establishing an effective public consultation program.

A public education program could inform residents of the Committee's activities and the general study program for preparation and implementation of the plans of management in order that there is an ongoing information dissemination. This would assist in obtaining informed public input when key documents such as plans of management or environmental impact statements are released for public comment.

A well established public liaison process can also be of value as various work programs are undertaken in the implementation phase eg foreshore clean ups and community tree planting days. This could possibly extend to schools and resident groups becoming involved in the monitoring process.

Issuing pamphlets on desirable practices to minimise the use of fertilisers and detergents, and control disposal of weeds and rubbish will assist in increasing public participation in management of the lagoons.

Lake care committees established to assist with management of each lagoon may also be advisable. This should not occur until the basic plans of management are developed to a stage where the committees have a clear policy frame work in which to operate. The logical point to establish such committees is probably around the time that the draft plans of management are being exhibited for public comment.

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PART B
STUDY OF THE DATA

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SCOPE OF STUDY

The data inventory is intended to:

- Source relevant studies and reports specifically concerning the lagoons and their catchments.
- Comment on the general adequacy of existing information
- Determine additional data which may be required to prepare future management plans.

METHODOLOGY

The data inventory involved a comprehensive review of reports, documents, file notes correspondence, and photographic records. The inventory deals with information which is specific to the study area. The historical time frame adopted for the purposes of Council files and archive searches was 20 years.

As the Committee's investigations proceed it is probable that further research into estuary management in other areas will be necessary. The scope of the Data Inventory has been restricted to documents and information specific to the four lagoons. However, where useful reference material outside the study area has been discovered, eg, in bibliographies, it has been included as part of Appendix 5.

Information for the inventory was derived from the following sources:

Gosford City Council

- Development and Environment Records
- Health
- Parks and Reserves
- Construction Section, Works Depot, Erina

Government Departments

- Department of Planning (Sydney, Newcastle and Regional offices)
- NSW Fisheries (Sydney and Port Stephens)
- CALM (Regional office)
- Public Works Department (Coastal and Estuaries Branch, Sydney)
- National Parks and Wildlife Service (Hawkesbury District)

Libraries

- Gosford City Library
- Department of Planning Library, Sydney
- NSW Fisheries Library, Cronulla
- National Parks and Wildlife Service, Head Office Library, Hurstville

Tertiary Education Institutions

- University of Technology, Biology Department, Sydney
- University of NSW, Geography Department, Kensington
- University of Newcastle, Geography Department, Newcastle
- Macquarie University, Earth Sciences Department, Ryde

The results of the study are provided in several parts:

Part A, a summary report dealing with the main issues and suggested areas where additional information is required.

Part B, a covering report describing the results of the investigation.

Part C, a data base of reports studies and documents.

A list of available photography
A list of available base maps
A list of miscellaneous data
A list of related bibliographies

The following documents are contained in Appendix 5 which is in separate volumes and are not bound in this report.

Copies of relevant Council Minutes
Copies of relevant Council correspondence and file notes
Copies of significant reports which are not readily available

The Data Base (Part C)

The list of reference documents is stored on a computer data base which enables searches to be carried out according to various criteria. For example by author, by topic or by lagoon catchment. The data base can be updated as more information becomes available.

Each document is categorised by a primary index under one of the following lagoon catchment descriptions:

Wamberal
Terrigal
Avoca
Cockrone
All Lagoons

Where a document relates to only one lagoon it is referenced under the relevant catchment description. Where a document covers more than one lagoon, but not all four, it is included under the All Lagoons category.

The data base provides a summary description for each document, including the location or source of the document. The description covers key aspects of the report, including conclusions and recommendations.

Academic studies and planning and policy documents are included where appropriate. Environmental Impact Statements are also included when they provide relevant information not covered by other studies.

Council Files and Council Resolutions

A detailed search of Council's minute books was not undertaken since there is no indexing system which will enable searching on a specific topic without searching every resolution over the historical period of 20 years adopted for the purposes of the inventory.

As an alternative, Council files dating back to 1973 were searched for relevant correspondence and Council resolutions. Copies of significant documents were made with the file numbers noted for future retrieval. Copies of Council resolutions relating to lagoon issues were made and are arranged chronologically.

Confidentiality

Miscellaneous file notes and correspondence provide useful historical information. In some instances this information may be sensitive or deal with confidential issues. We have not sought advice on the status of these documents under the Freedom of Information Act and draw the issue to Council's attention. At this stage we have marked the relevant files *For Internal Council Use Only*. The remainder of the information we believe to be Public Domain.

Base maps and Photography

Additional information that may be useful in the development of management plans is included as appendices. These include lists of available maps, photos and reference lists from various sources.

Related Studies

Council has commissioned flood studies for the lagoons which will be completed by the end of 1993. For this reason the data inventory does not reference flooding information.

The Coastal Management Program of Public Works is currently carrying out a similar inventory for information concerning coastal processes in the study area. Several of the source documents included in the data inventory were kindly provided by the Public Works Department, including the list of aerial photos held by the Department.

SUMMARY OF MAJOR REPORTS FOR ALL LAGOONS

There are only two documents which cover the entire study area. These two studies provide the most useful baseline data. The Gosford Lagoons Environmental Study by PA Management has become the most frequently referenced source document for other studies covering the lagoons.

Gosford Lagoons Environmental Study

P.A. Management Consultants Pty Ltd 1975

The 1975 P.A. Management Consultant's Report is the most important and complete environmental study to date as it covers all four of the coastal lagoons, was carried out over a 12 month period, which included peak holiday periods, and considered a wide range of issues. It contains scientific data for a range of issues. Mapping includes soils, geology, morphology, bathymetry, slopes, land use and vegetation.

Recommendations include; installation of reticulated sewage, restrictions on septic tank installation, diffusion of stormwater, retention of lagoon fringe vegetation and a recommendation against dredging. The report also recommended year round water sampling.

It is a comprehensive and useful document.

Ecological Assessment of Wamberal, Avoca, Cockrone and Terrigal Lagoons

A./Professor D. Cheng 1992

This report focuses on the water quality of the four lagoons. Cheng notes that the study was of short duration, and that regular ongoing monitoring is essential. Recommendations include restricting swimming to the lagoon mouths and controlling the entry of phosphorus and nitrogen into the waters to minimise the risk of eutrophication. In particular it was noted that the absence of a sizeable community of seagrass in Wamberal Lagoon was a matter of concern as it appears to have been substantially reduced since the last study of Nash. Cheng identified that the development of superhaline conditions, as a result of evaporative concentration of salt during drought conditions and the lack of interchange with the sea, may be a possible causal factor in seagrass die-off.

Cheng's report has been criticised in some quarters for its lack of management guidelines and recommendations. Cheng states that this was beyond the study brief.

Study of Wamberal, Terrigal and Avoca Lagoons - Report on Phase 1

P.A. Management Consultants, November 1973

The first phase of the P.A. Consultants study (1973) concerned only three lagoons, excluding Cockrone. It was intended to provide short term solutions to the problems of water pollution, first detected by the Health Department who found the lagoon waters had high faecal coliform bacteria levels. The main recommendations were that Council install a public sewage scheme and take measures to ensure that pump-out facilities be readily available to residents with septic holding tanks.

SUMMARY OF SPECIFIC REPORTS

WAMBERAL

Wamberal Lagoon Catchment Study

J. Gray, Gosford City Council (1987)

This report draws on the 1975 P.A. Consultant's report for base data on soils, geology, geomorphology, slopes and vegetation. Description of the natural vegetation, aquatic flora and fauna, birds, mammals, reptiles and fish populations were provided by National Parks and Wildlife Service and NSW Fisheries. Water quality tests carried out by Nash (1986) were also included.

An Ecological Investigation of Wamberal Lagoon

Sharon Nash 1986 (10 August to 15 October 1986) Final Year Environmental Biology Report

The report contains analysis of water samples taken from nine lagoon sites and seven drain sites on three occasions. It also contains results of sediment samples from seven sites.

TERRIGAL

Management Plan for Terrigal Lagoon

Energy Consultants of Australia Pty Ltd 1984

This is a management plan that contains results of water testing at 11 sites and sediment sampling from three test bores. Discusses methods of controlling the lagoon opening including mechanical gate and weir. Report is strongly in favour of dredging.

AVOCA

EIS Restoration and Improvement of Avoca Lake and Bulbararing Lagoon

F. Barry-Cotter and Associates 1983

This report outlines details of the proposal to dredge 40% of the lagoon and leave 30% of the swamplands to act as a natural filtering system to control upland contaminants. Bed sampling, wave analysis, water sampling and fauna analysis were carried out by the consultants. The study concludes there are wide fluctuations throughout the year in salinity and temperature, often with extensive weekly variations. The report also concludes there may be considerable change in faunal species composition over time.

Avoca Lake Draft Development Control Plan

P. Hughes, J. Hancock, S. Wearing 1984

This Development Plan draws on the 1975 report by P.A. Management Consultants for base data. It contains survey of benthic flora and fauna conducted over 19 sites and lists species and population numbers, and a comparison with 1975 figures. A bird survey was also included.

The Sedimentology and Water Quality of Avoca Lake

Kelvin Lambkin - Master of Science Research Thesis 1991

This is a thesis which studied the effects on water quality and lake sediments in Avoca Lake from restoration dredging. Scientific data includes a topographic profile of the lake bed, measurement of relative levels along the beachfront to examine changes in the beach profile, water sampling on five (5) occasions at eight (8) sites and core sampling of the lagoon sediment with use of Caesium-137 isotopes to trace depositional history. The study concludes that the lagoon is primarily filling with marine sand and erosion from back barrier deposits rather than catchment derived sediment.

COCKRONE

No significant reports have been found which deals exclusively with Cockrone Lagoon.

DISCUSSION OF REPORTS

There have been numerous studies undertaken on the four lagoons over the past twenty years but only a few of the studies contain scientific data from which the status of the lagoons can be measured. Such studies include P.A. Management Consultants Pty Ltd (1975), Nash (1986), Cheng (1992) and Lambkin (1991). Additionally, the studies so far undertaken are generally related to specialist fields of interest and only one study (P.A. Management Consultants Pty Ltd, 1975) contains a comprehensive investigation of a wide range of scientific fields.

A number of data gaps need to be addressed in order that future management decisions can be made. The deficiencies are discussed in more detail hereunder:

WATER AND SEDIMENT QUALITY

Water and sediment quality data over time is available in the studies by P.A. Management Consultants (1975), Nash (1986), Eardley (1986) and Cheng (1992). The studies are widely spaced in time with no continuity over a period longer than a year.

P.A. Management Consultants (1975) reported that high rainfall leads to low salinity and pH and correspondingly high readings of *E. coli* bacteria the latter being a water pollution indicator. The greater the population numbers (i.e. during summer holidays), combined with maximum run-off and temperature, the greater the coliform readings. Council records confirm this but there has been no analysis to date that scientifically links climatic information and *E. coli* readings for the lagoons.

Nash (1986) found high levels of nitrogen and phosphorus in Wamberal Lagoon, particularly after heavy rain. The latest study by Cheng (1992) has some alarming findings and it is not known whether the lagoon's management procedures are contributory factors. These findings relate to hypersaline conditions and high levels of total phosphorus under dry weather conditions. The high particulate phosphorus levels found, place the lagoon waters in the eutrophic category, although the phosphorus in this form is not directly available for plant growth. More regular monitoring is required to trace the source of phosphorus. Cheng (1992) also found that pH levels in Cockrone Lagoon were highly variable although the reason for this is unknown.

More regular monitoring of lagoon water quality and a study of its relationship to lagoon openings, rainfall and the health of aquatic fauna and flora is required. Target levels for nutrients also need to be established that will determine the performance criteria for nutrient traps in the catchment.

SEDIMENTATION

The study by P.A. Management Consultants (1975) concluded that there was limited soil erosion occurring in the catchment areas of Wamberal, Avoca and Terrigal Lagoons. Surprisingly Cockrone, the least developed of the four catchments, showed evidence of significant soil erosion. The 1975 study indicated a range of sediment types which were identified as marine and lacustrine sediments. Terrigal Lagoon was predominantly comprised of marine sand and had a relatively constant clay sediment throughout which suggested that the marine sand was not introduced by tidal activity but by slumping and reworking of the shores. Marine sands in the other lagoons were generally found at the entrance to the lagoons and were thought to have been derived from the beachfront, predominantly by wind activity.

The EIS prepared for Avoca Lake (1983) stated that siltation had reduced the lake capacity but provided no scientific basis for the conclusion, referring only to the Consultant's comment that the reed beds were more extensive than in the past. The Management Plan for Terrigal Lagoon (Energy Consultants of Australia, 1984) stated that forty years ago depths of twenty to thirty feet (6 - 10m) were reported as common although this was anecdotal evidence only. Lambkin (1991) in his study of Avoca Lake found extensive areas of sandy sediments, which he identified as being derived from marine sources and erosion from back barrier deposits.

The actual rates of sedimentation and sources of sediment in all lagoons needs to be more fully investigated. The use of Caesium-137 isotopes to trace sediment history in Avoca Lagoon may be a method that could be used for the other lagoons but additional geological data is required as well.

The studies do not show a breakdown between Pleistocene and Holocene sands. Lambkin (1991) mentions one isolated occurrence of a Holocene deposit. The differentiation between the two profiles is able to be determined by dating and investigating the fossil and mineral compositions of the sediment (Bird, 1976).

Fossil (Pleistocene) sands were possibly deposited between 12,000 and 500,000 years ago during different aeolian conditions and glacial periods (Myerscough and Carolin, 1986). These sands were deposited at a time when the sea level was up to 60 metres higher than the present level.

The Holocene sands are referred to as the later episodes of beach dune formation and are possibly not older than 6,500 years. The Holocene sands may be responsible for the current infilling of the lagoons from aeolian activity.

Pleistocene sediments were deposited before recent human influence in the catchments, and can therefore be considered to represent the state of the lagoons in "pre modern" times. These sediments are fossil sands and have different characteristics to the more recent Holocene sands. For these reasons it is considered any dredging should not intrude into the Pleistocene sediment profile, without an exhaustive examination of potential impacts. This should be a specific issue to be addressed in any Environmental Impact Assessment if dredging approval is sought.

BATHYMETRY

Bathymetry data was collected by P.A. Management Consultants (1975). Depth contours are rudimentary, levels are related to bench marks placed by the New South Wales Department of Lands and contours are shown at intervals of one (1) metre with an additional contour of 0.7 metres. According to the study, the bathymetry data was collected at a time when the lagoons were in an environmentally healthy state and where natural processes were operating which could reduce faecal coliform bacterial contamination. Bathymetry data maps are shown at a scale of 1:10000.

The Terrigal Management Plan (1984) has some contour information. Lambkin (1991) produced a topographic profile of the bed of Avoca Lake but no contours are actually presented. Lambkin (1991) notes marked changes in lagoon contours with severe undercutting of some banks and major deposition in other areas. Although the diagram in his report has been drawn to scale the information presented is too general in its present form to be of any real use. It is noted that the survey was connected to the survey mark near the Avoca Bridge and the task was carried out by using surveying equipment. It may be possible that the field notes can be resurrected and transformed into meaningful depth contours. This matter needs to be explored further.

In the case of the other lagoons there has been no subsequent bathymetry data collected. Therefore to ascertain subsequent infilling of the lagoons, if any, from a time when the lagoons were relatively healthy, new survey will be required. Depending on the accuracy of this data, cross sections may be able to be transcribed to show where and by how much infilling has occurred over 20 years (1975 - 1993) and related to the original survey of P.A. Management Consultants (1975).

Comparative analysis in parts of Terrigal and Avoca lagoons may be limited because of dredging which has been undertaken in selective areas since the 1975 survey .

DREDGING

The report by P.A. Management Consultants (1975) recommended against dredging in all lagoons as the disturbance could expose sediments, thereby creating the risk of releasing phosphates and heavy metals. It was also noted that it could cause turbidity which would affect the natural ecosystem and aesthetic qualities of the lagoons.

Cheng comments (in Council records) that dredging may offer a number of beneficial features such as increased capacity to reduce flooding, a more stable environment and increased water clarity. He notes however that these benefits must be weighed against factors such as possible disturbance to existing benthic flora and fauna and the possible release of plant nutrients from the sediments causing increased algal growth. He suggests further investigation into the possible effects of dredging and notes that a comparison between Tuggerah Lakes and the coastal lagoons is not valid.

Lambkin's (1991) assessment of the impacts of dredging on Avoca Lake is that the silt content of the lagoons may be of particular concern in dredging operations. He notes that silt is difficult to dispose of and only has specialised use demands in small quantities. Any dredging process must consider the issue of disposal and possibly the best option is to avoid removal of any sediment areas that have larger concentrations of silt. Particular attention must be paid to the design of settling ponds and the protection of fringe vegetation.

The consequences of dredging for beach nourishment directly relates to separate investigations into coastal erosion processes being undertaken by the Public Works Department.

BENTHIC FLORA AND FAUNA

P.A. Management Consultants (1975) did not map the extent of seagrass communities during their study of the lagoons. Although aerial photography was available as far back as 1954 it is doubtful whether the presence of past seagrass communities can be properly mapped where aerial photography is only available in black and white. Colour aerial photography only came into use during the 1970s and the first available maps of seagrass communities were produced between 1981 and 1984 by West, Thorogood, Walford and Williams (1985). Seagrass communities mapped by (West et. al., 1985) showed that they tended to be sparse in Terrigal and Avoca Lagoon with no seagrasses in Cockrone Lagoon in those years. Wamberal Lagoon had an extensive bed of *Ruppia sp.*, a species which is related to growing in a particular sediment type, probably silty muds.

No detailed comparative mapping of the seagrass communities is available. Benthic flora in Avoca was studied in 1982 and although no map was produced the report states that the floral species were spread widely around the lagoon, particularly *Ruppia sp.* and to lesser extent *Enteromorpha sp.*

Eardley (1986) gives an indication of the locations of the *Ruppia* beds then present in Wamberal Lagoon. Nash (1986) recorded wet and dry weights for macrophyte biomass in Wamberal and found that at that time that the lagoon was a very productive system. Nash (1986) also observed after a natural lagoon breakout occurred that attached macrophytes exposed to the air died off but that there was very rapid and extensive regeneration. The Wamberal Lagoon Catchment Study (1987) stated that *Ruppia sp.*, *Enteromorpha sp.* and *Cladophora sp.* (both algae) were dominant. Cheng (1992) notes that in 1991 the *Ruppia* beds identified by Eardley had almost disappeared and expresses a concern that hypersalinity could be a major reason for their decrease.

A survey of aquatic fauna in all lagoons was undertaken by P.A. Management Consultants (1975) over 11 months. It was sampled in a once-only study in 1982 at Avoca and Eardley (1986) and Nash (1986) also studied fauna in Wamberal. They found a range of fresh and saline species with molluscs and polychaetes common in the muddy sites. The 1982 survey showed a lower species diversity in Avoca compared with the 1975 results and the almost complete absence of crustaceans.

The 1975 study sampled fish populations, finding crustaceans only in Avoca Lake and a total of eight fish species throughout the lagoons. Avoca was very poorly represented having only one species at one of the two sample points. The only more recent information obtained by the Department of Fisheries in studies undertaken in 1986/7 has not been published. Some information was made available for the Avoca Development Control Plan and this provides a species list and assessment of abundance for fish populations in Avoca only.

A later study undertaken for the Bay River Sands Dredging Company has the results of seine nettings in Avoca which shows several fish species of commercial interest in both juvenile and adult forms in contrast with the 1975 findings.

Benthic fauna are important indicators in assessing environmental conditions of lagoons, such as sedimentation and water pollution. Without this information it may not be possible to establish whether the environmental conditions of the lagoon are changing because water quality testing results are fairly consistent over time (within a certain range) with some variations. Research into aquatic ecology and the biology of indicator species relative to environmental conditions has improved over the past twenty years (Viz. Fairweather 1993; Green 1993; Warwick 1993). More useful management conclusions are now being obtained by gathering data on benthic communities to assist in the analysis of environmental conditions.

Although the fish and crustacean populations may now be fairly unsubstantial the lagoons have in the past been very productive areas and further study may be needed to determine reasons for the decline and possible remedies if this is practical. XYZ (1828) reports at that time in Cockrone Lagoon the "fish were so abundant that a blackfellow, with a seine, can load a bullock-cart at 1 or 2 hauls and it forms a constant food for farmers." Further studies are now needed to examine the benthic and foraminiferal populations in the lagoons as an aid to monitoring environmental conditions. Aquatic flora and fauna may become exposed to dehydration and high salinity levels if water levels decrease. This appears to be the scenario now as a result of more regular lagoon openings. A study to determine exactly what is the status of aquatic flora and fauna of the coastal lagoons and how natural adaptations may help to mitigate the conditions is needed.

LAGOON OPENING

When the flood level reaches a particular level, breaching of the bar is carried out by machinery to reduce the risk of flooding to surrounding properties.

Council has recorded lagoon openings and heights of the sandbar since 1970. The relationship between rainfall and the height of the sand bar is crucial to flooding impacts, although the rate of run-off and the total volume of stormwater will also affect lagoon levels. Council records show lagoons generally naturally close within a short period of time. Records of known naturally occurring openings have been recorded by Council but may not be comprehensive. The study by Nash on Wamberal Lagoon in 1986 was carried out during the period when the lagoon opened naturally.

There is some contention over the effects of openings, as its impact on benthic flora and fauna is relatively unknown. Cheng (1992) notes that openings remain a key management tool and that further investigation is necessary to determine their long term effects. The P.A. Management Study (1975) suggests that opening of the lagoons flushes out polluted waters (as a result of heavy rainfall and associated surface run-off) and allows the inflow of saline water which in turn fosters natural predators of bacteria and greater species diversity. It has been observed that a natural opening tends to be more effective in flushing the lagoons as it occurs when the maximum amount of water is in the lagoon and is consequently more forceful.

Control of the lower water level of the lagoon when it is opened is a matter which requires further consideration since it may have an effect on the ability of aquatic flora and fauna communities to survive.

The flooding level may be reviewed as a result of the current flood studies. Further study needs to determine whether or not pollutant loads exit from the system after a lagoon opening and whether the entry of saline water into the lagoon decreases any significant *E. coli* levels or affects seagrasses and other aquatic flora and fauna. This would require several days monitoring after a flood event.

HEALTH ISSUES FOR HUMAN USE

As a result of the P.A. Management (1975) consultant's recommendations Council voted to establish regular water monitoring in 1976, provide reticulated sewerage to the areas, and limit installation of septic tanks near waterways. The provision of reticulated sewerage to a majority of residences would have had considerable impact on the water quality of the lagoons, reducing the threat of bacterial contamination. The Terrigal Management Plan (Energy Consultants of Australia, 1984) stated that anecdotal evidence indicated many Terrigal residences were still unconnected to the sewer in 1984. High *E. coli* readings were detected in this study and once again regular monitoring was recommended. The study by Cheng (1992) did not test *E. coli* levels. Council records show that there are still odd occasions when *E. coli* levels exceed the recommended standard.

Despite a Council resolution regular water monitoring was not undertaken and readings for faecal and total coliform at selected locations in the lagoons has only occurred during the swimming season since 1989 (pers. comm. Robin Benson). In addition the Council's Kincumber Treatment Works samples sites near pump stations periodically.

Further investigation is required to assess how many residences still rely on septic tank disposal. A thorough assessment of the impact of reticulated sewerage on water quality in the lagoons should be made which would also identify the future threats of bacterial contamination of the lagoons.

CATCHMENT MANAGEMENT

Catchment management involves a range of issues including soils, vegetation, land use and tenure and planning regulations. Pollutant loads on the lagoon system from the catchment can now be measured and modelled to give an idea of what can be expected to happen in the future. If development proceeds too much further the lagoons may deteriorate to a condition where their health cannot be retrieved. This may be particularly important with respect to Avoca Lagoon where all stations measured had high levels of total phosphorus on one occasion during dry weather. Particulate forms of phosphorus may be related to catchment runoff and soil disturbance as development proceeds in the catchment.

The amount of soil disturbance and therefore runoff is also relative to the intensity of development in the catchment. Thus, the catchment of the lagoons may be able to only tolerate a certain level of development because resources are not available to put in place the required controls to reduce pollutant loads even under normal weather conditions. The high readings of particulate forms of phosphorus that Cheng (1992) noted should be investigated to determine if the source is the catchment. This fact is not able to be substantiated without further investigation and monitoring at the drainage outlets.

Council engaged in a program of constructing silt traps and nutrient filters in wetlands adjacent to Terrigal, Wamberal and Cockrone Lagoons in 1987. A full assessment of the value of these filters is required with recordings of nutrients entering the traps and exiting into the drainage systems.

ACID SULPHATE SOILS

None of the studies to date deal with the issue of acid sulphate soils. From field observations by Andrews, Neil potential acid sulphate soils exist in part of the Terrigal Lagoon catchment and could well occur in other catchments. These soils have the potential to seriously affect the aquatic environment by:

- Contributing to acidity and salinity in non - marine waters.
- Causing the dissolution of clay minerals and release of aluminium to waters.
- Permitting iron to remain in solution which is toxic to aquatic life.
- Lowering pH levels in water bodies.

The procedures for dealing with acid sulphate soils are outlined in Department of Planning Circular No F11, and need to be addressed as part of the completion of the database of information for the lagoons. This is a potentially important consideration for management of the water bodies within the lagoons, and the surrounding catchments.

SOIL MAPPING

Soil mapping was carried out by Bell and Lee (1976) for all four lagoons as part of the P.A. Management (1975) study. Detailed study was undertaken for Terrigal Lagoon, however, Bell notes that since soils, slope and drainage systems are reasonably similar throughout the area, that the range of conditions expected in the catchments of Avoca, Wamberal and Cockrone would also be comparable. The exception may be the large, relatively flat area to the north of Wamberal Lagoon which he notes is probably an area of high runoff but slow drainage. Bell and Lee (1976) calculates that increased residential development will increase run-off volumes from impervious surfaces and that more efficient surface drainage is likely to shorten the time lags between rainfall and resulting flood peaks.

A Reconnaissance Soil Capability Study for Avoca (Soil Conservation Service of New South Wales, 1987) provides a more detailed soil sample analysis for the entire catchment while additional surveys for Terrigal and Wamberal study only parcels of land within the catchment areas. Draft maps for protected lands within the catchments have been prepared by the Department of Soil Conservation for the lagoon areas that designate areas where controls on land clearing apply. Detailed land capability studies and maps are required for Wamberal, Terrigal and Cockrone in particular.

ENVIRONMENTAL PLANNING

Since the establishment of SEPP 14 wetland boundaries many planning decisions have been made by Council. Two sites, one on Terrigal Drive and another on Tramway Road, North Avoca in SEPP 14 wetland areas were approved for residential development with certain conditions attached. Council's Draft Wetlands Management Report (1992) lists particular sites for acquisition. It is unclear on the maps provided exactly what areas are in private holdings. Two sites at Cockrone and one in Avoca have been recommended for acquisition by Council. However, there are very few areas of significant vegetation in Terrigal that are not already under Council's administration. Two significant Melaleuca Swamp forests to the west of the Entrance Road at Wamberal are noted but not assessed for acquisition.

The Wetland Management Study states that past experience has shown that SEPP 14 and SEPP 19 do not adequately protect wetlands within privately owned properties. Future plans of management should ensure adequate protection for these lands in particular.

Land tenure maps are also needed for all the lagoons describing what lands are under public ownership to determine what public land is still available for management and its capacity for recreation and conservation purposes.

TERRESTRIAL FAUNA AND FLORA

Fauna and flora surveys for all lagoons are generally fairly minimal, particularly for Cockrone Lagoon which is in part due to the difficulty of observation through the dense perimeter vegetation.

The importance of fringe wetlands vegetation as a natural filtering system has been recognised in various studies, particularly by P.A. Consultants (1975), the Wamberal Lagoon Catchment Study (Cheng, 1992) and most recently in the Draft Wetlands Management Study (Gosford City Council, 1993) for the Brisbane Waters Area, however effective legislation and management techniques to conserve the areas are required. The extent of fringing lagoon vegetation needs to be mapped at a sufficient scale for detailed planning.

The study by P.A. Management (1975) mapped vegetation in the catchment identifying shoreline wetlands, banksia scrub, teatree scrub and swamp forest with grassy open forest around the foreshores. Later studies for Wamberal (Gray, 1987) and Avoca (Hughes, Hancock and Wearing, 1984) have zoning and vegetation maps based on the P.A. Management (1975) report but with slightly more detail. Comparison between zoning and vegetation maps highlights areas of recent vegetation under threat from development, however the studies do not single out particular lots that are to be acquired or protected.

Detailed remnant native vegetation mapping is required with an assessment of its current conditions and the threats of degradation. The Draft Wetland Management Study for the Brisbane Waters Area Study (Gosford City Council, 1992) has recent maps for wetland vegetation and targets particular sites for future acquisition and inclusion in SEPP 14 boundaries. The study is very general however and only covers wetlands. A similar process is required for remaining vegetation in the catchment areas with similar criteria for assessment which would take into consideration information from the soil capability studies.

The significant Tree Committee identified Swamp Mahogany *Eucalyptus robusta* as a species of special conservation significance, in the Gosford area and recommended inclusion in Schedule 1 of the Council's Tree Preservation Order. The species was once common around the foreshores and along the creek system draining into the coastal lagoons. It is an important species as it is the only consistent winter flowering Eucalypt (with the exception of *E. maculata* which flowers about once in five years). The species therefore provides a valuable food source for nectivorous faunal populations in the area. Only small remnants remain, in particular behind Avoca Lake, and conservation of this pocket would be a priority in a future plan of management for the area. Also revegetation schemes for areas now cleared of Swamp Mahogany should be encouraged. Other significant trees and pockets of vegetation are listed by the Significant Trees Committee for Avoca, Macmasters Beach, Terrigal and Wamberal and these would also need to be part of the vegetation mapping for the areas.

ARCHAEOLOGY

Very limited information is available for archaeological sites in the study area. No important European sites have been identified however further research may be required in this area. Aboriginal sites have also not been well documented, possibly many sites have been destroyed or perhaps they were not abundant. A section in the EIS by Travers Morgan contains a list for several sites that were obtained from a search of the Aboriginal Site Register in National Parks and Wildlife Service Head Office. These listed locations of middens and campsites at Terrigal and Wamberal. Several sites were also known to exist around the shore of Avoca Lake.

The Consultant's report in the EIS states that the area could be expected to have a relatively high prehistoric occupation potential due to the wide variety of food resources however the evidence of occupation may not be well preserved or it may be conserved beneath parkland. The estuarine shorelines are likely to have shell middens.

Archaeological surveys are required for those parts of catchment which have not already been covered in existing plans of management (e.g. Wamberal) or environmental impact statements for specific sites. These surveys will need to cover the lagoon beds if dredging is proposed.

RECREATION

Many studies refer to the importance of the lagoons for recreational use. Some assessment of recreational needs has been done in the Wamberal Lagoon DCP for areas under the control of the National Parks and Wildlife Service. The Avoca Lake DCP also makes some reference to recreation. However there is very little documentation on the recreational attributes of the lagoons, and no comprehensive plan to manage recreational use. Issues such as accessibility, linkages, active and passive zones, use of water bodies, visual sensitivity and support infrastructure such as parking areas, amenities buildings picnic areas, walking trails and interpretive facilities have generally not been considered.

REFERENCES

- Barry-Cotter F. and Associates (1983) Environmental Impact Statement. Restoration and Improvement of Avoca Lake and Bulbararing Lagoon prepared for Gosford City Council.
- Bird E.C.F. (1976) Coasts - An Introduction to Systematic Geomorphology Australian National University Press - Canberra.
- Cheng D. (1992) Ecological Assessment of Wamberal, Avoca, Cockrone and Terrigal Lagoons. University of Technology, Sydney.
- Eardly K. (1986) Wamberal Lagoon 1986 Project Report for Bachelor of Science, University of Technology, Sydney.
- Energy Consultants, Australia Pty Ltd (1984) Management Plan for Terrigal Lagoon prepared for Gosford City Council.
- Fairweather P.G. (1993) Links between Ecology and Ecophilosophy, Ethics and the Requirements of Environmental Management. *Aust. J. Ecol. Vol 18(1)*.
- Gray J. (1987) Wamberal Lagoon Catchment Study. Gosford City Council.
- Green R.H. (1993) Application of Repeated Measures design in Environmental Impact and Monitoring Studies. *Aust. J. Ecol. Vol 18(1)*.
- Hughes P., Hancock J. and Wearing S. (1984) Avoca Lake Development Control Plan prepared for Gosford City Council.
- Lambkin K. (1991) The Sedimentology and Water Quality of Avoca Lake - Master of Science Research Thesis. University of Newcastle.
- Myerscough P.J. and Carolin R.C. (1986) The Vegetation of the Eurunderee Sand Mass, Headlands and Previous Islands in the Myall Lakes Area, New South Wales. *Cunninghamia 1(4) pp 399 - 466*.
- Nash S. (1986) An Ecological Investigation of Wamberal Lagoon (10 August to 15 October 1986). Final year Environmental Biology Report. University of Technology, Sydney.
- P.A. Management Consultants Pty Ltd (1973) Study of Wamberal, Terrigal and Avoca Lagoons - Report on Phase 1 prepared for Gosford City Council.
- P.A. Management Consultants Pty Ltd (1975) Gosford Lagoons Environmental Study prepared for Gosford City Council.

REFERENCES

- Soil Conservation Service
Thomas D.K. and Chapman G. (1987) Reconnaissance Urban and Rural Capability Survey/Avoca Lake Catchment Area
- Warwick R.M. (1993) Environmental Impact Studies on Marine Communities - Pragmatic Considerations
Aust. J. Ecol. Vol 18(1)
- West R.J., Thorogood C.A,
Walford T.R. and Williams R.J An Estuarine Inventory for New South Wales, Australia, Fisheries Bulletin No 2. Department of Agriculture, New South Wales.
- XYZ (alias William John Dumaresq) (1828) Rambles in New South Wales in the New Monthly Magazine and Literature Journal Volume 22, p220.

**APPENDIX 1
PHOTOGRAPHS**

Gosford City Council Photographic Collection
General Collection - negatives

No.	Date	Name	Locality	Subject
00/86	20/11/86	S. Clark	Wamberal Beach	Beach erosion
1/87	Sept 87	Short/Nordsvan	Wamberal	Erosion
2/87	Oct 87	Gray	Wamberal	Lagoon study
3/87	Oct 87	Gray	Avoca	Avoca Lake
5/88	Feb 88	Short/De Fina	Pt 93 (12206) Malinya Ave	Proposed Wetland Subdivision
6/88	Feb 88	Short/De Fina	Wamberal	Drainage to lagoon/2m signs
32/87	March 89	Nordsvan	Wamberal	Beach erosion
39/89	28/4/89	Short/Davies	Wamberal ridge	Court case appeal
65/89	Oct 89	Short/Taylor	Kincumber/Avoca	Illegal signs/Illegal clearing
79/89	1/12/89	Short/Price	Wamberal/Terrigal/Avoca/ Cockrone	Aerial photos
80/89	1/12/89	Short/Price	Wamberal/Terrigal/Avoca/ Cockrone	Aerial photos
30/90	6/4/90	Short	Maps & diagrams	Coastal Open Space System
40/91	22/4/91	Jones	Brush Rd, Wamberal	Wetland study

Negative Prints

Date	Subject
1970	Terrigal Bridge Construction

Slides

Coastal Erosion Presentation

Date	Subject
July 1991	Aerial Terrigal and Wamberal
14 May 1991	Aerial PWD duplicates. Wamberal opening

Gosford City Council Aerial Photographs

Date	Type	Scale (approx)	Subject
1954	BW	1:16000	All coastal lagoons
1957	BW	1:16000	All coastal lagoons
1964	BW	1:6336	All coastal lagoons
1983	Colour	1:16000	All coastal lagoons
1986	Colour	1:16000	All coastal lagoons
1988	Colour	1:16000	All coastal lagoons
1991/2	Colour	1:16000	All coastal lagoons

Ray Clark - Erina Depot

Provided information on artificial lake openings (instigated by Council) 1970 - 1993.

Early records are patchy with only dates of openings recorded however later records (1977 onwards) contain heights of lake above flood level and height above sand dunes at time of opening, weather conditions, days that lagoon remained open and comments.

The Depot office also has a chart that Ray prepared that plots the relationship between rainfall and water levels in order to determine evaporative rate.

Some climatic data also available that was collected at the Terrigal/Wamberal Country Club and the Avoca Bowling Club for a period.

Records of Sandbar RLs and Lake RLs for 1989 - 1991 for all lagoons available. Recordings were made at first weekly, then monthly but later became more irregular.

Photos in album include:

Date	Subject
25 June 1950	Terrigal flooding
June 1974	Storm damage Avoca, Terrigal, Wamberal
1978	Terrigal storm debris, lake opening and scouring, Wamberal loss of houses and erosion sequences
1980	Terrigal/Wamberal
1982	Wamberal, Cockrone, Terrigal especially showing sand moved from beach
9 July 1983	Copacabana
1983	Avoca sewer works
22 December 1983	Avoca
26 May 1983	North Avoca flooding and Wamberal
9 May 1983	North Avoca
July 1984	Terrigal
24 January 1986	North Avoca
1986	Beaches, Avoca, North Avoca, Copacabana and Wamberal
5 August 1986	Terrigal, Copacabana and Avoca Lagoons
17 January 1988	Terrigal closing lagoon for school holidays
16 March 1990	Terrigal

APPENDIX 2
MAPS

Gosford City Council

- Cadastral maps at 1:2000 (showing boundaries, roads for all areas)

- Enlargements from the 1964 series aerial photos at 1:4000

Terrigal	5004
Terrigal/Avoca	5110
Copacabana	5035
Cockrone	5033
Wamberal	5100

- Orthomaps at 1:4000 (contours overlaid onto aerial photographic information)

231231 Wamberal - older maps
245246 Terrigal - older maps
258259 Avoca
270271 Cockrone
270280 Cockrone

- There is an overlay taken from the cadastral map that plots information for all lagoons and catchments on the one sheet (has boundaries and lot subdivisions)

Scale 1:8000 done in 1989/90
also 1:8000 Terrigal, Wamberal and most Avoca 1986 Cadastral

APPENDIX 3 COMMENTS

Peter Stitt

Did basic research for 2 locals who wanted to dredge Cockrone Lagoon. Very preliminary report as base data was not available such as detailed soil sampling. Notes on procedure for establishing viability of dredging operations, what sort of plant acceptable, where it would be positioned and what sort of base data is needed to do the report.

John Laxton

Did study on temperature, salinity, water levels and turbidity from 15 February 1980 to 31 May 1980 for Wamberal, Terrigal, Avoca, Cockrone and Cockle Creek. Just notes and does not know exactly where they are.

Liz Kirkby

Has personal records of over 200 plant species on her property, North Avoca (Tabletop Road). Area important in catchment area. Also has very old photographs of Terrigal and Avoca areas.

Fisheries - David Pollard

Have done studies 1986/7 but these are not in available form. Data has not been separated into individual lagoons but some was provided for Wamberal and was included in 87 catchment study.

Ron West - Authority on seagrasses.

Soil Conservation Service

Can build on slopes greater than 20% with recent building techniques (e.g. pole houses) therefore earlier soil studies now considered somewhat out of date.

APPENDIX 4
ISSUES IDENTIFIED BY COMMITTEE

A number of issues were identified by the CLP Committee (Minutes 1 March 1993). These are currently being reviewed by a sub-committee. The list defines the range of issues to be addressed in the plans of management process.

The issues identified by the CLP Committee and some additional issues resulting from the inventory research are listed below:

1. Council Services
 - o Sewerage
 - o Drainage/stormwater
 - o Flood mitigation/flood management strategy
 - o Artificial lagoon openings
2. Planning
 - o Urban development/zoning
 - o Tourist and rural development
 - o Land management
 - o Appropriate infrastructure
 - o Beach and foreshore use and development
3. Impacts/Influences
 - o Population densities
 - o Tourist development
 - o Offshore mining/exploration
 - o Dredging
4. Environment Issues
 - o Nutrient control/eutrophication
 - o Sediment control composition
 - o Benthic organisms
 - o Acid sulphate soils
 - o Water quality - salinity
 - o Anaerobic muds in Cockrone
 - o Monitoring ecological health lagoons
 - o Identification/management littoral rainforests and wetland habitats
 - o Headlands/catchment protection
 - o Flora and fauna surveys catchments
 - o Wildlife habitats
 - o Introduced plant and animal species
5. Coastal and Lagoon Processes
 - o Beach wave erosion
 - o Coastal dune erosion
 - o Coastal hazard protection
 - o Offshore reefs and rock outcrops
 - o Historical water depth lagoons
 - o Effect of lagoon openings

6. Recreation

- o Of waterways - jet skis, surfers, windsurfers, swimming
- o Of foreshores - Bikes, walkers, Parks/Golf courses, etc.

7. Heritage Values

- o National Parks and Wildlife Service
- o Aboriginal cultural heritage
- o Historic sites
- o Visual landscape qualities

8. Community

- o Expectations coastal development and lagoon management
- o Public participation
- o Public education/awareness

GOSFORD CITY COUNCIL

COASTAL LAGOONS
DATA INVENTORY

PART C
THE DATA INVENTORY

ANDREWS.NEIL
ARCHITECTS.PLANNERS.LANDSCAPE CONSULTANTS

MAY 1993

Reference Number: 39
Title: Gosford/Wyong Rural Lands Study
Author: New South Wales Planning and Environment Commission
Year: 1975
Source:
Catchment: All Lagoons
Primary Subject Matter:
Secondary Subject Matter:

Description:

Study complements the Gosford/Wyong Structure Plan (1975) and deals with the rural setting for existing and planned urban areas. Study suggests policies for the protection and future development of rural areas within the region with the aims of conserving the natural and semi-natural environment wherever possible and preserving the livelihood of full-time farming.

Reference Number: 52
Title: Gosford Lake Macquarie
Author:
Year:
Source: Department of Conservation and Land Management ISBN 0730591662
Catchment: All Lagoons
Primary Subject Matter:
Secondary Subject Matter:

Description:

Provides 1:100000 scale maps covering all four lagoons and catchments. Mapping was prepared on 1:25000 base maps and is quite suitable for catchment analysis. The accompanying report provides technical details on soil landscapes for the catchments including among other things limitations to development and erosion hazard.

Gosford City Council - Coastal Lagoons Data Research

29 April 1993

Reference Number: 21
Title: Gosford - Wyong Tourist Recreation Study Stage II
Author: Prepared for NSW Planning & Environment Commission
Year: 1978
Source: Gosford City Library (G338.479194/42 Liew)
Catchment: All Lagoons

Primary Subject Matter:

Secondary Subject Matter:

Description:

Study aimed to examine existing supply and demand for tourist/recreation facilities in Gosford - Wyong. Contains results of extensive resident and visitor questionnaire.

Reference Number: 20
Title: Gosford City Council Coastal Open Space System
Author: Gosford City Council
Year: 1984
Source: Gosford City Library (333 784 Gosf)
Catchment: All Lagoons

Primary Subject Matter:

Secondary Subject Matter:

Description:

Proposal for continuous open space system serving as wildlife corridors and recreation areas to be retained by Gosford City Council. In particular two large areas around Avoca Lake and Cockrone Lagoon are listed as essential acquisitions.

Gosford City Council - Coastal Lagoons Data Research

29 April 1993

Reference Number: 31
Title: Gosford City Coastline Review
Author: Nielsen Lord Associates & Geomarine Pty Ltd
Year: 1988
Source: PWD NSW Coastal Branch
Catchment: All Lagoons

Primary Subject Matter:

Secondary Subject Matter:

Description:

Notes prepared to assist Council in developing and implementing coastal management practices. Includes summary of various experiences and applications in other local government areas. Summarises some relevant Council resolutions.

Reference Number: 19
Title: Draft Coastline Development Manual
Author: New South Wales Government
Year: 1989
Source: Gosford City Library (LS 333 9171 Coas)
Catchment: All Lagoons

Primary Subject Matter:

Secondary Subject Matter:

Description:

Discusses need for an integrated planning approach to coastline development, the Coastline Hazard Policy, role of local Councils and State Government and other interested/relevant bodies, management options such as development controls and structural measures such as seawalls. Appendix A contains a general description of coastal processes including water levels and wave actions. Appendix B has a section on coastal entrance hazards such as breakthrough of rivers at coastal entrances.

Reference Number: 18
Title: Wamberal - Terrigal Manual for Coastal Developments
Author: Gosford City Council in conjunction with Geomarine Pty Ltd
Year: 1989
Source: Gosford City Library
Catchment: All Lagoons
Primary Subject Matter:

Secondary Subject Matter:

Description:

Wamberal and Terrigal - Manual provides information to assist with Building and Development Applications for land fronting the coast at Terrigal and Wamberal. Four sections: Hazard definition; Coastal Management Issues; Data Directory and Examples of DA and BAs. Precinct 3 is Terrigal Lagoon. Precinct 5 is Wamberal Lagoon. Provides figures for short and long term erosion from storms, depth of scour, wave run-up and minimum floor levels for lagoon flooding.

Reference Number: 34
Title: Wamberal Beach and Avoca Beach Coastal Engineering Advice
Author: A.F. Nielsen PWD Civil Engineering Division
Year: 1985
Source: PWD NSW Coastal Branch
Catchment: All Lagoons

Primary Subject Matter:

Secondary Subject Matter:

Description:

Wamberal and Terrigal - Report prepared by the Public Works Department (Coastal Branch) to advise Council Coastal Committee on coastal engineering matters. Outlines the coastal processes operating at Avoca and Wamberal Beaches, describing the nature and extent of the coastal engineering hazards. Provides advice on beach processes, oceanographic factors, long term trends in sand transportation and the extent of coastal hazard. Includes information on the nearshore wave climates of the beaches which was obtained from a wave analysis done by Lawson and Treloar Pty Ltd. Presents the range of physical options available to mitigate the problems.

Reference Number: 35

Title: Recommended Beach Management Strategies Wamberal - Terrigal Beach

Author: Beach Protection Association

Year: Undated

Source: PWD NSW Coastal Branch

Catchment: All Lagoons

Primary Subject Matter:

Secondary Subject Matter:

Description:

Wamberal and Terrigal - A submission to Council from the association of property owners of beach front land between Terrigal and Wamberal Lakes and adjacent properties which could be affected by beach erosion. Contains general recommendations on sand stabilisation/dune formation works and acquisition of land for public recreation. Contains comments by Slater Jessop and Armstrong (Consulting Engineers). Was part of the public submissions to Council.

Reference Number: 5

Title: Coastal Wetlands of New South Wales. A Survey and Report Prepared for the Coastal Council of NSW 1985.

Author: P. Adam, N. Urwin, P. Weiner, I. Sim

Year: 1985

Source: Government Printer, Coastal Council, Department of Planning

Catchment: All Lagoons

Primary Subject Matter:

Secondary Subject Matter:

Description:

Identifies all SEPP 14 wetland areas in NSW. Contains general information on the value of wetlands, including their role in the provision of habitat for birds and fish. Also provides description of wetland definitions. Highlights difficulty in making comparative assessment of site values. Contains review of existing data (including comprehensive list of references). General discussion of plant and fauna in NSW wetland communities.

Map numbers list wetland areas:

Wamberal 907,909;
Terrigal 908, 910;
Avoca 911, 912, 913;
Cockrone 914, 915.

Reference Number: 22

Title: Gosford City Council Beach Management Strategies Part 1 - Wamberal/Terrigal Beach and Avoca Beach

Author: Report of the Coastal Committee Working Party

Year: 1985

Source: Gosford City Library (LS333.917 15099442 Gosf.)

Catchment: All Lagoons

Primary Subject Matter:

Secondary Subject Matter:

Description:

Wamberal, Terrigal and Avoca - Report attempts to address the problem of coastal erosion by analysing beach processes, planning and legislation and management constraints and considerations. Reviews options and proposes particular beach management strategies. Contains history of dune erosion and damage to beach homes, substantial data on dune erosion mapping (1965 - 1978) prepared by PWD. Plans of subsurface materials along beach and at lagoon openings, also cadastral mapping. Appendix F is a position statement of the Coastal Lagoons by M.G. Alsop 1984.

Reference Number: 27

Title: Gosford Lagoons Environmental Study

Author: P.A. Management Consultants Pty Ltd

Year: 1975

Source: DEP Library E 574.5 PAM (a)

Catchment: All Lagoons

Primary Subject Matter:

Secondary Subject Matter:

Description:

The major environmental study carried out for Gosford City Council for the four lagoons. Report was Phase 2 in 3 phase programme and contained a comprehensive management plan (3rd phase was the implementation of the plan). Report found that water quality of lagoons is controlled by a complex inter-relationship between the aquatic ecosystem, climate and terrestrial systems of the catchment areas. Main sources of pollution identified were septic tank effluent (draining through groundwater), surface run-off from overflowing septic systems, and from other sources such as animal faeces/grease, etc. The three factors most related to the pollution indication (E. coli) were rainfall, salinity and pH. High rainfall led to increased E. coli while salinity and pH dropped, disturbing the balanced ecosystem and the combination of factors resulted in bacterial pollution.

The study was carried out over a 12 month period, tests included:

- Water sampling at 12 sites each week (pH, temperature, dissolved oxygen, salinity, E. coli and turbidity).
- Sampling at same 12 sites each month for suspended solids, heavy metals, nutrients and marine fauna (bimonthly).
- Analysis of sediment type and chemical composition at 36 sites.
- Measurement of bottom contours.
- Continuous tidal recordings.
- Geological mapping.

An analysis of changes in land use and vegetation (1954 - 1974) was carried out. Useful maps of geology, geomorphology, slopes, an extensive soil survey and vegetation. Analysis of Terrigal lagoon system included rainfall and evaporation.

The Management Plan is divided into 3 sections: Water, Land and Social Issues. Generally report recommends installation of reticulated sewerage and that Council not approve septic tank installation with absorption trenches within 100 metres of lagoon or water courses. Dredging was not recommended as it causes muddiness and risk of release of very small amounts of phosphate and heavy metals. The report also recommended that Council diffuse water from drains through swampland wherever possible and that drains should not be cut through swampland to lagoons but should discharge into vegetation fringe. Recommended that Council should completely prohibit removal of any swamp or lagoon fringe vegetation. Also contains recommendation for all year round water sampling. Land management recommendations that land with slope in excess of 20% should not be used for purposes that disturb soil or vegetation, that DAs for dwellings in lagoon catchments include review of environmental factors and that existing natural vegetation be retained in catchment area for recreational use.

Reference Number: 38
Title: Gosford/Wyong Structure Plan
Author: New South Wales Planning and Environment Commission
Year: 1975
Source:
Catchment: All Lagoons
Primary Subject Matter:
Secondary Subject Matter:
Description:

The structure plan outlines proposals for future development of the Gosford/Wyong area in order to accommodate planned population growth. Follows on from Gosford/Wyong Urban Strategy Report (1973) and was endorsed by steering committee comprised of Council and State Planning Authority representatives.

Reference Number: 40
Title: An Environmental Inventory of Estuaries and Coastal Lagoons in NSW
Author: Dr. F. C. Bell and A.R. Edwards
Year: 1980
Source: Total Environment Centre
Catchment: All Lagoons
Primary Subject Matter:
Secondary Subject Matter:
Description:

An inventory intended to provide a rapid overview and preliminary data for environmental scientists, conservationists and others concerned with maintaining the natural heritage values of NSW coastal lagoons and estuaries. It identifies 137 of these and identifies the few that are still in a relatively natural condition. Was the first stage in a 3 phase project by the Total Environment Centre. Bibliography references are keyed to the four lagoon sites. States that all lagoons are rarely open to the sea and that water problems have occurred due to septic tank effluent. Has mean annual rainfall and runoff and rates degree of disturbance in water and catchment.

Reference Number: 41
Title: Estuary Management Manual
Author: New South Wales Government
Year: 1992
Source: Public Works Department
Catchment: All Lagoons

Primary Subject Matter:

Secondary Subject Matter:

Description:

Manual produced to assist community in implementation of Government's Estuary Management Policy in accordance with existing legislation. Prepared under direction of steering committee comprising representatives of various organisations such as PWD, Department of Planning, CALM, EPA and NSW Fisheries. Contains a step by step approach to Estuary Management, discussed various Government Departments roles and spheres of authority. Also gives information on Government financial assistance for estuary management. Appendices deal with wide range of estuary management issues.

Reference Number: 42
Title: Geological Contribution to Environmental Management of Coastal Lagoons at Gosford, New South Wales (Australia)
Author: Albani, A.D., Brown G.A. University of New South Wales and Australian Marine Resources Pty Ltd Australia
Year: 1976
Source: Bulletin of the International Association of Engineering Geology No 14 p89-104, Kre
Catchment: All Lagoons

Primary Subject Matter:

Secondary Subject Matter:

Description:

The study summarises information published in P.A. Consultant's report (1975) and in particular the results of tests for water level changes, lagoon sediments and Benthonic foraminifera (protozoa). Concludes that the water levels in the lagoons vary on a daily basis however no tidal effect was detected. Sediment sampling showed limited soil erosion in the catchment areas of Wamberal and Avoca-Bulbararing Lagoons. Terrigal sediment was dominated by marine population, the report suggests that this was introduced not by tidal activity but partly through removal by wind from the dunes on the eastern shore and partly by slumping and reworking of the shores. The northern stream flowing into Cockrone Lagoon appeared to carry a considerable amount of sediment which suggested intensive soil erosion. Other testing sites suggested that the whole of the Cockrone catchment area was affected by erosion even though it was the least developed of the four catchments.

Sampling of benthonic foraminifera did not show extensive water pollution however author notes that such a delicate balance may be quickly modified with disastrous consequences. Concludes that septic tank control is needed, that dredging or any other development or activity that disturbs the sediment should not be permitted, and that existing natural vegetation in catchments should be acquired by Council and retained and revegetated where necessary.

Reference Number: 15
Title: A Wetland Management Study Draft Brisbane Waters Area
Author: Gosford City Council
Year: 1990
Source: Gosford City Council
Catchment: All Lagoons

Primary Subject Matter:

Secondary Subject Matter:

Description:

A comprehensive but general wetland study which aims to establish criteria for wetlands acquisition and/or dedication. The report contains basic vegetative mapping at scale 1:16000 for wetlands around all four lagoons, brief fauna and flora descriptions, relevant zoning and protection clauses and management recommendations. Tables are included for various wetland sites rating the impacts of land use factors and forms of degradation as well as conservation values. These are used to establish a priority in terms of proposed future land acquisitions by Council.

Reference Number: 14

Title: Ecological Assessment of Wamberal, Avoca, Cockrone and Terrigal Lagoons

Author: A/Professor D. Cheng, Ph.D.

Year: 1992

Source: University of Technology, Sydney

Catchment: All Lagoons

Primary Subject Matter:

Secondary Subject Matter:

Description:

The most recent water quality assessment available which samples oxygen levels, salinity, suspended solids, turbidity, light penetration, pH, levels of plant nutrients, silicate values and chlorophyll 'a' levels. Analysis of sediment samples and comparison with 1975 data including tests for heavy metal levels and hydrocarbon pollution. All lagoons found to have very little seagrass species or macroalgae present at the time of the survey (March 1991). Suggests that salinity and therefore rainfall patterns would be important controlling factors, also frequency and timing of lagoon openings.

Concludes with summary of findings, in particular that absence of sizeable community of seagrasses may have adverse ecological implications such as lack of habitats, fish and other aquatic fauna and increase turbidity further impeding recolonisation of macrophytes. Suggests that the development of superhaline conditions in Wamberal Lagoon may be a possible causal factor in seagrass die-off and that lagoon opening procedures be reviewed. Also suggests that swimming be restricted to the mouths of the lagoons, that the high turbidity and low transparency of the lagoons could be improved if the seagrasses were to recolonise, that efforts be made to control input of phosphorus and nitrogen to minimise risk of eutrophication and algal blooms, that source of thick layer of anaerobic mud in Cockrone Lagoon be investigated, and finally that regular ongoing monitoring is essential for development of long term management strategy. Cheng notes that the study was of short duration only and that regular ongoing water monitoring is essential.

Reference Number: 10

Title: Coastal Lagoons Development Control Plan Consultancy Brief Discussion Paper

Author: Environmental Office, Gosford City Council

Year: Date unknown

Source: Gosford City Council Planning Department

Catchment: All Lagoons

Primary Subject Matter:

Secondary Subject Matter:

Description:

A brief discussion paper that notes that development controls for the four lagoons were commissioned in 1990. The aims of each plan (in alignment with corporate plan) were specifically to reduce and minimise: the amount of erosion occurring in catchment areas, the amount of sediment being deposited, the bacterial pollution of the water, the level of plant nutrients entering lagoon waters, and to minimise the impact of flood management procedures and the adverse impact of human activity on the lagoon's ecology. Lists specific issues for each area that have been identified both in commissioned studies and by the public/media.

Reference Number: 46

Title: An Estuarine Inventory of NSW Australia

Author: R.J. West, C. Thorogood, T. Walford, R.J. Williams

Year: 1985

Source: Fisheries Bulletin No 2 NSW Division of Fisheries

Catchment: All Lagoons

Primary Subject Matter:

Secondary Subject Matter:

Description:

Contains maps of estuarine seagrass vegetation mapped onto 1:250000 CMA sheets from aerial photographs, January 1984. Information is limited due to point in time of survey, scale of photographs and extent of aerial photography. Reveals at time of survey that *Ruppia* sp. was dominant in Wamberal Lagoon with tiny patches of *Zosteraceae* near lagoon opening, thin margins of *Zosteraceae* around Terrigal Lagoon perimeters, large areas of *Ruppia* sp. in Avoca Lake and perimeters of Bulbararing Lagoon and no species present in Cockrone.

Reference Number: 9

Title: A Position Statement of the Coastal Lagoons of Gosford City Council

Author: M.G. Alsop

Year: 1984

Source: Gosford City Council Planning Department

Catchment: All Lagoons

Primary Subject Matter:

Secondary Subject Matter:

Description:

Discusses Council's 'duty of care' to open lagoons, flood levels, causes and preventive actions. Gives recommended minimum floor levels for future buildings as future building controls are considered the most satisfactory way that Council can prevent future flooding of residences. Describes how system of standing waves is created once the lagoons break out. Provides figures for average openings per year. Lake let out levels and flood levels are provided for estimated one-in-100 year flood. Discussion of emergency procedures, possibility of closing openings to fill lagoons during holiday periods and mechanical means of artificially opening the lagoon.

Reference Number: 48

Title: A Soil Survey of the Terrigal Area for Hydrologic Purposes

Author: F.C. Bell and P.J. Lee

Year: 1975

Source: No 10 Occasional Papers December 1975, School of Geography, University of NS

Catchment: All Lagoons

Primary Subject Matter:

Secondary Subject Matter:

Description:

Results of research included in P.A. Consultants 1975 report, provides detail on sampling methods and results. Survey of soils in areas zoned residential in catchment areas of Wamberal, Terrigal, Avoca and Cockrone Lagoons. Maps soil types and assesses hydrologic properties with particular reference to infiltration characteristics.

Field testing at 97 sites, data included horizon depths, soil textures, structure, colour, surface slope and vegetation cover. Most frequently sampled soil was duplex soil with hard setting A horizon and yellow or brown mottled B horizon of clayey texture. This was found in a wide range of topographic positions including relatively steep slopes, however the depth of the A horizon varied and was sometimes virtually absent.

Reference Number: 8

Title: Engineer's Report. Beach Improvement Plan

Author: M. G. Alsop

Year: 1986

Source: Gosford City Council Planning Department

Catchment: All Lagoons

Primary Subject Matter:

Secondary Subject Matter:

Description:

Discusses Beach Improvement Plan that was prepared through co-operation with City Engineers' and Town Planners' Department. Covers sand retention by dune stabilisation works and works to be carried out by beachfront residents. Also discusses public improvements such as car parking arrangements.

Reference Number: 50

Title: Environmental Impact Assessment Advisory Paper No 1. State Environmental Planning Policy No 14 - Coastal Wetlands

Author: Department of Environment and Planning

Year: 1987

Source: Department of Environment and Planning

Catchment: All Lagoons

Primary Subject Matter:

Secondary Subject Matter:

Description:

Advisory paper on State Environmental Planning Policy No 14 - Coastal Wetlands (SEPP 14). Describes procedures that apply to development proposals in SEPP 14 wetland areas, describes why policy was introduced and environment impacts of development activities in wetland areas.

Reference Number: 7

Title: Coastal Erosion and Beach Management in the Gosford City Council Area. A Position Statement

Author: City Engineer's Department

Year: 1986

Source: Gosford City Council Planning Department

Catchment: All Lagoons

Primary Subject Matter:

Secondary Subject Matter:

Description:

Details history of coastal erosion and progressive actions taken by Council and regulatory bodies. Describes storms of 1974 and 1978 which affected Wamberal and Avoca beach residences. Also discusses changes to beachfront rezonings and Council's responsibilities for protection of private property. Coastal Committee established in 1984 to study problems of beachfronts at Wamberal and Avoca. Development Policy Plan for Wamberal, Terrigal and Avoca Beaches (1985) outlines planning guidelines for future beachfront development.

Reference Number: 25

Title: Study of Wamberal, Terrigal and Avoca Lagoons Report on Phase 1

Author: Gosford City Council Environmental Services Division; P.A. Management Consultants Pty Ltd

Year: 1973

Source: Gosford City Library G.628.16869/442

Catchment: All Lagoons

Primary Subject Matter:

Secondary Subject Matter:

Description:

Wamberal, Terrigal and Avoca - Part 1 in a 3 phase programme, this report recommended short term solutions to problem of water pollution in the Wamberal, Avoca and Terrigal Lagoons. Describes results of water sampling programme for E. coli. Also contains results of soil tests taken to determine the suitability of soils for disposal of septic effluent. Discusses the need to install a public sewerage scheme, policy of opening and closing lagoons to ensure they are full during peak holiday periods for health reasons and reopening of lagoons for swimming.

Also contains a study of the septic tank pumpout and disposal system, collation and analysis of information of human population dynamics to determine peak human effluent loads and a study of climatic data influencing pollution levels and collection of data on recreation use. A short term management plan recommended weekly water sampling, restriction of bathing to ocean ends of lagoons until further information was obtained, and management practices such as ensuring lagoons were full during peak holiday periods and were drained at the end of these times.

Reference Number: 23
Title: Beach Management Study South Avoca
Author: Sinclair Knight and Partners Consulting Engineers
Year: 1987
Source: Gosford City Council (LS 333 91715 Sinc.)
Catchment: Avoca

Primary Subject Matter:

Secondary Subject Matter:

Description:

Following on from PWD Coastal Engineering Report (1983) and Gosford City Council Beach Management Strategy Report (1985) several management strategies were selected for more detailed examination to address problems of coastal erosion. Discusses dredging of sand in Bulbararing Lagoon, construction of sea wall at Avoca and possible changes to zoning.

Reference Number: 16
Title: Environmental Impact Statement Lot 99 Tramway Road, Avoca for Paul De Fina and Associates Pty Ltd
Author: Andrews.Neil
Year: 1990
Source: Andrews.Neil
Catchment: Avoca

Primary Subject Matter:

Secondary Subject Matter:

Description:

EIS prepared in support of application for residential building on land that included wetland and adjoined public reserve on the foreshore of Bulbararing Lagoon with a SEPP 14 provision. Contains species list for flora and fauna observed both on site and in nearby waters and reedlands. Also contains water pollution figures and suggests that no development intrude into wetlands.

Reference Number: 17

Title: Avoca Lake Draft Development Control Plan

Author: P. Hughes, J. Hancock, S. Wearing

Year: 1984

Source: Gosford City Library (G333.78099/442 Avoc.)

Catchment: Avoca

Primary Subject Matter:

Secondary Subject Matter:

Description:

Study in 3 parts. Part 1 is a background report on the lake and it contains a description of geomorphology with map of catchment showing depositional and erosion surfaces. Other maps from 1975 P.A. report. Discusses human and natural factors affecting vegetation. Contains a survey of benthic flora and fauna conducted in 1982 over 19 sites and lists species and population numbers. Compares benthic faunal communities with other recent studies such as P.A. Management Study (1975). Both studies indicated a fauna dominated by species capable of surviving extreme fluctuations in salinity. List of bird species from 11 surveys 1981/82. Maps for council zoning, stormwater drainage lines and flood levels. Discusses levels of E. coli giving figures for Council testings 83/84, any effect of Council policy not to close lagoons once they have been opened.

States that available evidence suggests artificial lake opening causes detrimental long term environmental effects. Contains lake bed composition analysis that was carried out for the dredging proposal. Discusses recreational use of lagoon with map of appropriate uses (such as watercraft, bird watching, jogging and cycling) in particular areas. Proposes acquisition of some land to form open space system with a link from the coast to the Avoca Ridge which is protected as public reserve. Part 2 is a management strategy for the Lake divided into four sections; land management, recreation, water management and management practices in table format with fairly general management actions. Includes concept of creating artificial wetland islands as habitat refuges and as additional natural filters of sediment and water.

Reference Number: 26

Title: EIS Restoration and Improvement of Avoca Lake and Bulbararing Lagoon
(Commonly known as Avoca Lake)

Author: F. Barry-Cotter and Associates for Bay River Sands Pty Ltd

Year: 1983

Source: Q 711.5 58 BAR(b) DEP Library

Catchment: Avoca

Primary Subject Matter:

Secondary Subject Matter:

Description:

Prepared in support of dredging operations by Bay River Sands Pty Ltd in Bulbararing Lagoon and Avoca Lake to obtain commercially saleable sand. Other aims were to increase water surface area, water capacity, water quality, as well as restoration of former water channels. Proposal was to be to a depth of 2 - 3m below existing base and all material was to be removed from work area (70% saleable and 30% as fill at cost price). Proposal to dredge 40% of lagoon and leave 30% swamplands to act as filtering system for upland contaminants. Study outlines where material will be sold and other details of dredging operation such as size of plant and noise levels. Description of core samples and water sampling for salinity, temperature variations and E. coli. Study found wide fluctuations throughout the year, often there were extensive weekly fluctuations. The E. coli levels averaged much below the recommended level however readings occasionally exceeded this, usually after heavy rainfall when septic tanks overflowed and salinity levels dropped. Study argues that dredging will increase the salinity of the water and that the higher pH will lead to a reduction in E. coli numbers and improved water quality. Also argues that during wet weather gradual mixing of fresh water with more saline water and the provision of permanent water will result in longer transitional period and will consequently have a less adverse effect on benthic fauna.

Comments on the proposal to dredge Avoca/Bulbararing Lagoon by Kenneth Robinson, School of Zoology, University of NSW are included in the report. This contains results from sampling salinity and temperature fluctuations over a 11 month period. Also a survey of benthic flora and fauna conducted on May 17/18 1982 at twenty sites. List of water birds and discussion of environmental effects of dredging. Robinson found that faunal species were more abundant in the predominantly sand habitat in Avoca Lagoon rather than the sites in Bulbararing. He suggested that there may be a considerable change in species composition over time. Robinson concluded that reedbeds were more extensive as a result of sedimentation, stating that the process was common in low salinity areas. He also stated that dredging would cause immediate loss of flora and fauna and that recolonisation rate difficult to determine. Argued that dredging may restrict ability of seagrasses to colonise and result in deposition of silt in areas that were previously sand. Refers to EIS Narrabeen Lagoon (J. Laxton) as another lagoon made saline by human activities. Concludes that an increase and stabilisation of salinity levels will probably eventually lead to an increase in diversity and abundance of benthic fauna in lagoon.

Reference Number: 29
Title: Avoca Lake Crossing Brief No. G22 Report No 79019
Author: Manly Geomechanics Lab. Design Control Branch
Year: Undated
Source: PWD NSW Coastal Branch
Catchment: Avoca

Primary Subject Matter:

Secondary Subject Matter:

Description:

Report that was requested by Gosford Regional Sewerage. Contains soil investigation for sewage rising main crossing Avoca Lake. Seven test pits were dug to a depth of 3 metres with samples taken at 1m intervals.

Reference Number: 30
Title: Avoca Beach Lagoon Entrance and Beach Management Study
Author: PWD NSW Coastal Branch
Year: Undated
Source: PWD NSW Coastal Branch
Catchment: Avoca

Primary Subject Matter:

Secondary Subject Matter:

Description:

Aims to provide Council with advice to enable preparation of management strategy. Review of historical data, previous investigations and reports and assessment of the stability of Avoca Beach foreshore with respect to potential coastal hazard risks of erosion and inundation during storm events. Identifies existing and future foreshore usage patterns and problems and outlines alternative engineering options for management. Contains table of aerial photography taken after storm events (1941 - 81) of Avoca Beach and observations made from these. One conclusion is that dredging of the lagoon would have to be conducted at regular intervals and would incur substantial long term costs.

Reference Number: 49

Title: The Sedimentology and Water Quality of Avoca Lake (Master of Science Research Thesis)

Author: Kelvin John Lambkin

Year: 1991

Source: Department of Geography, University of Newcastle

Catchment: Avoca

Primary Subject Matter:

Secondary Subject Matter:

Description:

Thesis that explores the possible effects of restoration dredging of Avoca Lake on water quality and sedimentology. Study was initiated and sponsored by Bay River Sands Pty Ltd. Thesis explores two major hypothesis:

1. That infilling of the lake is a function not only of fluvial sedimentation but also of marine influences and reworking of back barrier deposits.
2. That water quality has not been adversely affected by dredging.

Field work was carried out between February 1988 and August 1989. Study traced caesium-137 isotopes in sediment samples to study deposition sites in the lagoon. Scientific data includes topographic profile of lake bed, measurement of relative levels along 5 locations on the beach to examine changes in beach plan and what influence this may have on the sedimentology of the lake and sediment sampling. Sediment sampling included parameters for skewness, sorting and grain size.

Water sampling carried out at 8 sites, 5 times over 6 months during 1988. Measurements included temperature, turbidity, salinity, secchi depth (transparency), dissolved oxygen, nutrients and suspended sediment. Report C contains a literature review noting studies on environmental impacts of dredging with particular reference to environment problems of disposal of dredge spoil. The author found that water did not have excess nutrients, however the secchi disc measurements indicated that if dredging was to a depth greater than 4 metres then there will be problems created by anaerobic conditions caused by lack of light at that depth, leading to a decrease in water quality.

The data suggested that the Lake is filling from the edges although the author states there is no simple predictive model and suggests that ultimately the system may evolve to a coastal freshwater swamp behind a sand barrier. Caesium-137 readings in the sediment show that the floodplain was a site of depositional material brought down from Saltwater Creek. The most important findings of the study were that the lagoon was not primarily being filled with catchment derived sediment but with marine sand and erosion from back barrier deposits. Also states that dredging does not appear to be decreasing surface water quality however there is minimal analysis of the effects on estuarine and terrestrial flora and fauna.

Reference Number: 45

Title: Reconnaissance Urban and Rural Capability Survey Avoca Lake Catchment Area

Author: D.K. Thomas and G. Chapman

Year: 1987

Source: Soil Conservation Service of NSW (also on Council File 840-05.05)

Catchment: Avoca

Primary Subject Matter:

Secondary Subject Matter:

Description:

Soil survey of catchment area of Avoca Lake which assesses the physical limitations of the area for urban development and its capability for various levels of rural use. Also contains soil conservation recommendations that outline appropriate soil erosion mitigation and control measures necessary to maintain stability of the land surface for urban and rural land uses. Three maps of the area at 1:10000 are included with report, these are urban capability, rural capability and soil maps with accompanying classification tables. Appendix IV gives general recommendations for control of erosion and sedimentation, Appendix V gives information on grassed drainage reserves and stormwater retarding and sediment basins while Apperidix VI explains measures to reduce hazard of mass movement where applicable.

Reference Number: 33

Title: Submarine Pipeline Crossing of Cockrone Lake Macmasters Beach. An Assessment of Scour Depths. Report No PWD 88065

Author: M.N. Clarke and J. B. Hardie

Year: 1988

Source: PWD NSW Coastal Branch

Catchment: Cockrone

Primary Subject Matter:

Secondary Subject Matter:

Description:

Report to determine maximum scour levels for proposed pipeline. Contains results of various studies such as hammer coring, a land-based survey and study of photographic information that were used to estimate historic scour depths throughout the entrance channel. Core samples indicated maximum depths of scours during previous breakout events.

Reference Number: 24

Title: Statement of Environmental Effects. Site - Lot 72 DP 5739880 Copacabana for George Brand

Author: Paul De Fina and Associates

Year: 1991

Source: Gosford City Library (C 333.78414 DeFi)

Catchment: Cockrone

Primary Subject Matter:

Secondary Subject Matter:

Description:

Report prepared in support of proposal for Council to allow either rezoning or subdivision of hectares of private property which included dedication of 7.28 hectares as a "Wildlife Corridor". The area was identified for inclusion in Council's Coastal Open Space System. Wildlife corridor links proposed natural reserve along the northern shore of Cockrone Lagoon to existing public reserves at First Point and the coastal headland. Report contains specialist reports on vegetation, scenic qualities (EJE Landscape), soils, landform (Travers Morgan), hydrology (More McVey and Associates), Fauna (Travers Morgan) and bushfire risk (Eckford, Johnson and Partners). Description of remaining native vegetation. Discusses drainage patterns into Cockrone Lagoon and characteristics of gully catchment. Hydrology section contains calculations of run-off from property. Fauna assessment contains list of mammals, birds sighted in Bouddi Peninsula. Appendix A contains sections of Wildlife Inventory of the Gosford Coastal Ridgeland.

Reference Number: 32

Title: Coastal Process Assessment - 39 Ocean View Drive, Terrigal

Author: Nielsen Lord Associates Geomarine Report

Year: 1991

Source: PWD NSW Coastal Branch

Catchment: Terrigal

Primary Subject Matter:

Secondary Subject Matter:

Description:

Assesses the coastal process hazards relating to proposed beachfront development at 39 Ocean View Drive. Generalised report based on PWD information published elsewhere.

Reference Number: 6

Title: Management Plan for Terrigal Lagoon

Author: Energy Consultants of Australia Pty Ltd

Year: 1984

Source: Planning Department, Gosford City Council

Catchment: Terrigal

Primary Subject Matter:

Secondary Subject Matter:

Description:

Study of Terrigal Lagoon and immediate foreshore areas with recommendations for management, recreational and conservation aspects of the area, in particular dredging operations. Report states that Terrigal was dredged in 1960 east of Willoughby Road Bridge, the material was used to reclaim land. Argues that dredging would improve water volume by up to 6 times its present capacity. Includes results of a questionnaire of 135 households, water testing that was carried out at 11 sites on one day for salinity and E. coli and sediment sampling carried out by dredging company at three boreholes. Tests carried out for lagoon water depths on one day when the lagoon was almost empty. A report on control of the lagoon by ecological methods carried out by a separate consultant draws attention to the role of vegetative cover as a filter of sediments.

Extensions to football oval and golf links discussed with recommendation for half sized field to be constructed. Proposal for controlling the lagoon opening included mechanical gate structure and weir. Also provides basic costings for proposals. Strongly recommends that dredging be carried out. Also that Council implement the ecological proposals contained in the report such as removal of exotic plant species, purchase and revegetation of main stormwater drainage lines, no removal or addition of earth and clay from slopes in excess of 20 per cent and that a tree planting programme be carried out along lagoon foreshores. Recommends regular and ongoing monitoring programme for testing for bacterial contamination, salinity and turbidity.

Has some interesting historical base data and information on sediment and water quality in 1984. No analysis of effects of dredging on plant or animal populations although additional Consultant's report states that disturbance of littoral vegetation be avoided. States that anecdotal information suggests many houses, such as those used as holiday homes, let out or owned by pensioners, may still not be connected to the sewer.

Reference Number: 37
Title: Terrigal Lagoon Stormwater Drainage Study
Author: Willing & Partners Pty Ltd
Year: 1982
Source: Department of Environment and Planning
Catchment: Terrigal

Primary Subject Matter:

Secondary Subject Matter:

Description:

Report that aims to assess the drainage and flood liability problems affecting land in two catchments which drain to Terrigal Lagoon. The first sections describe the existing physical environment of the catchment, availability of rainfall and flooding. The remainder of the report deals with the rainfall - runoff model, flood estimates, alternative trunk drainage schemes and the recommended system of trunk drainage for the valleys.

States that the likelihood of flooding around the lagoon is governed by the sand barrier and by the total volume runoff and the rate at which it reaches the lagoon. Possible lagoon management options to alleviate flooding around the lagoon were briefly examined and included regular clearing of the sand barrier, installation of telemetry alarms and construction of a permanent opening.

Contains hydraulic modelling with engineering solutions such as use of retarding basins to slow down runoff and reduce flooding, and regular clearing of the sand barrier.

Reference Number: 43

Title: Reconnaissance Urban Capability Survey, Terrigal, Gosford

Author: K.E. Lindbeck

Year: 1978

Source: Soil Conservation Service Gosford

Catchment: Terrigal

Primary Subject Matter:

Secondary Subject Matter:

Description:

Results of a site inspection carried out in December 1978. Survey defined slopes, check characteristics of drainage lines and by auger sampling and observation of cuttings, identified salient characteristics of soil. Site approximately 33 hectares.

States that 2 soil types were defined: Alluvial and gravelly duplex sandy loams overlying plastic medium-heavy clay. States that the periodic inundation which occurs along the drainage lines will be a particular hazard and gives the alluvial soils an extreme erodibility if disturbed. Also states that seasonally high water tables may be a particular hazard of this soil type.

Report notes that soil drainage is impeded by the clay subsoils, resulting in seasonally high water tables and lateral water movement down through the surface soils and that these soils, if disturbed, present a very high to extreme erosion hazard. Concludes that particular emphasis should be placed by Council on the recommendations to developers.

Reference Number: 47

Title: Catchment Hydrology and Urban Development. A Case Study.

Author: F.C. Bell and P.C. Vorst

Year: 1976

Source: No 11 Occasional Paper March 1976, School of Geography, University of NSW

Catchment: Terrigal

Primary Subject Matter:

Secondary Subject Matter:

Description:

Report on research by members of the School of Geography that looked at possible consequences of continued urban expansion. Streamflow gauging stations were established on 3 streams flowing into Terrigal Lagoon and rainfall data was used to calculate total runoff. Study found that runoff into Terrigal Lagoon is dependent on rainfall intensity and duration, size, slope and percentage of development in the catchment, soil type, antecedent soil moisture and vegetation type and cover.

Reference Number: 44
Title: Reconnaissance Urban Capability Survey Wamberal
Author: Keldare Pty Ltd
Year: 1987
Source: Soil Conservation Service, Gosford
Catchment: Wamberal

Primary Subject Matter:

Secondary Subject Matter:

Description:

Survey was prepared to determine the physical capability of a parcel of land at Wamberal for urban development where all runoff from the site is into Terrigal Lake. Soil samples were taken at 14 sites. Soils in three groups: alluvial, sandy loam top soil and sandy clay sub soil. States that soil permeability is only moderate and that on-site effluent absorption techniques would not be very efficient and could lead to seepage problems in downslope areas. Soils were considered relatively stable and no special building specifications were considered necessary up to 20% slope. However much of the subsoils were considered subject to slaking and fretting and, when coupled with run on water from higher slopes, present a high erosion hazard potential.

Recommends that erosion and sediment control measures be implemented in conjunction with construction activities to reduce sedimentation and pollution of Terrigal Lake. Discusses design of drainage reserves, installation of stormwater retarding basins and sediment basins.

Conclusion states that careful control of development on the margins of the drainage reserve and within the respective catchment areas, and the use of retarding and sediment basins as part of the planning and development process will control the velocity of flow of runoff and peak discharges.

Reference Number: 51
Title: Wamberal Lagoon 1986
Author: Karen Eardley
Year: 1986
Source: NPWS Head Office Library, Hurstville
Catchment: Wamberal

Primary Subject Matter:

Secondary Subject Matter:

Description:

Study carried out in conjunction with K. Nash under supervision of A/Professor D. Cheng. Same results as published in Nash but contains map showing percentage of aquatic plant cover and dominant plant species which were Triglochia, Eleocharis, Lepironia articulata, Ulva, Ruppia spiralis, Enteromorpha intestinalis and Chara sp. Discussion that Ruppia and Enteromorpha have evidently competed successfully to become the dominant macrophytes. Ruppia dominated Forresters Creek while Enteromorpha prevailed in the lagoon. Both species declined as the water depth increased. Chara was the major species near the lagoon mouth while Ulva and Zostera capricornii were found around the edge of the lagoon in small quantities. Author suggests that depth of water and transparency were more crucial to the distribution and species of vegetation present than salinity changes.

The sites with higher vegetative cover had a higher dissolved oxygen content and a higher total phosphorus content in the soil which may suggest a relationship between sediment type and plant distribution. Study also found 2 polychaetes, 2 snails and a mussel. The polychaete Neris and the Sanil Tatea were the most abundant organisms in the soil.

Reference Number: 11
Title: Wamberal Lagoon Nature Reserve Plan of Management March 1993
Author: Central Coast District National Parks and Wildlife Services
Year: 1991
Source: National Parks and Wildlife Service
Catchment: Wamberal

Primary Subject Matter:

Secondary Subject Matter:

Description:

Plan of Management that establishes that Nature Reserve has regional significance as a natural coastal lagoon and local significance in terms of educational value. Contains policies regarding water quality, dune stabilisation, control of introduced animal and plant species, fire management, promotion of environmental education and low impact recreational use of the area. Seven species of migratory birds are identified and one species of endangered fauna that have their habitat in the reserve.

Plan notes that over 90% of lagoon catchment lies outside the nature reserve and that protection of the lagoon depends, in particular, on the co-operation of neighbours and Gosford City Council. Plan therefore proposes a Catchment Management Committee to reduce the impact of human land use on water quality. The Committee will address the impact of diffuse pollution into the lagoon, the establishment of a new flood marker if warranted, actions to maintain water quality and encouragement of future research into sedimentation rates, water quality linked to rainfall rates and the catchment drainage system.

Reference Number: 28

Title: An Ecological Investigation of Wamberal Lagoon (10 August to 15 October 1986)
Final Year Environmental Biology Report

Author: S. Nash

Year: 1986

Source: The New South Wales Institute of Technology, Gosford City Library (Local Studies)

Catchment: Wamberal

Primary Subject Matter:

Secondary Subject Matter:

Description:

Final year Environmental Biology report that aimed to determine the present state of the water quality of the lagoon system, major sources and extent of disturbance to the system and to formulate management strategies to minimise disturbance. During the course of the study the lagoon naturally opened to the sea and closed again. Water samples were taken from nine lagoon sites and seven drain sites on three occasions (after different weather conditions). Water quality analysis included tests for dissolved oxygen, temperature, turbidity, pH, phosphate and nitrogen levels, ammonia content and chlorophyll a. Sediment samples were also taken from seven sites on one day. Contains provisional floristic list by P. Clark and D. Benson (Royal Botanic Gardens), also list of birds and reptiles from NPWS. Wet and dry weights for macrophyte biomass were high and showed that the lagoon at the time was a very productive system.

The values for standing crops were inversely proportional to depth and were highest at sites with the highest total phosphorus readings. Observation of very rapid and extensive regeneration of attached macroflora that had died back after a natural break-out occurred. Nash noted that a "salt wedge" occurred after heavy rain with a layer of fresh water overlying a layer of more saline water. This lack of mixing resulted in little deposition at the stream ends and instead sediment was carried to the centre of the lagoons. Nash found high levels of nitrogen and phosphorus in the water quality tests, particularly after heavy rain. Nitrogen was considered to be a limiting factor in plant growth as it was quickly depleted in the water. Gives specific management recommendations but notes that the study is only a first stage examination and that more research is necessary.

Reference Number: 13
Title: Wamberal Lagoon Catchment Study 1987
Author: Gosford City Council
Year: 1987
Source: Gosford City Council
Catchment: Wamberal

Primary Subject Matter:

Secondary Subject Matter:

Description:

Outlines development constraints and land use planning options. Maps on geomorphology, geology, slopes, soils, stormwater drainage lines from P.A. study (1975). Water quality tests by Nash (1986) were included. Description of indigenous vegetation, marine flora and fauna, fish populations and terrestrial wildlife listings provided by NPWS and NSW Fisheries. The main issues that were identified were:

- Erosion in catchment.
- Siltation of tributaries and lagoon.
- Pollution by E. coli bacteria.
- High levels plant nutrients and algal growth.
- Flooding residential properties.
- Environmental implications.

Discussion of previous land use, zoning, erosion and siltation, hydrology and in particular Council policy on artificial opening of lagoons. The report suggested that artificial lagoon openings be assessed using 3 criteria:

- Life cycles and spawning habits of fish and prawns.
- Effect on aqua-flora communities.
- Extent of lagoon water pollution.

Also contains discussion of future urban development including amusement park/recreation development on the Entrance Road. Concludes that main issues are erosion, siltation, flooding of residential properties, pollution by E. Coli bacteria and increased algal growth. Gives specific and detailed management strategies including silt traps and nutrient filters which have since been installed. Report suggested that "litter-racks" be used to collect urban litter before it reaches the lagoon. Suggests rezoning of some Crown Reserves and Nature Reserves.

Reference Number: 36
Title: Gosford Council ats Egger
Author: A.F. Nielsen
Year: 1984
Source: PWD NSW Coastal Branch
Catchment: Wamberal

Primary Subject Matter:

Secondary Subject Matter:

Description:

Technical advice prepared by PWD regarding coastal engineering aspects of a statement of claim arising from storm damage to property at Wamberal. Includes judgement for case brought against Gosford City Council, Egger v Gosford Shire Council and Anon. Judgement Friday 10 July 1987. Property was irreparably damaged due to collapse of sand dune on 20 June 1978. Plaintiff contended that erosion in both 1974 and 1978 was partly attributable to the interaction of the sea during periods of high tides and storms with beach works (including a seawall) that Council carried out in front of block of homeunits. His Honour concluded that there was no negligence on the part of Council but that the seawall did have certain adverse effects on the coastal erosion.

Reference Number: 12
Title: A Guide to Wamberal Lagoon Nature Reserve (A Natural Area on the Central Coast of New South Wales)
Author: A. Strom
Year: 1982
Source: NPWS
Catchment: Wamberal

Primary Subject Matter:

Secondary Subject Matter:

Description:

Outlines the natural and historial development of the area around Wamberal Lagoon. Discusses management problems associated with reserve, the development of the dunal landscape and land-use since 1825. Parish maps and information on original landowners document changing land-use.