Fairy, Towradgi and Hewitts / Tramway Creeks Estuary Management Study and Plan

Report Prepared For

Wollongong City Council

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FOREWORD

The management of Fairy, Towradgi and Hewitts/Tramway Creeks is undertaken principally by Wollongong City Council and the Department of Natural Resources (DNR). The management process falls under the umbrella of the following policies:

- NSW Coastal Policy
- State Rivers and Estuaries Policy (of which the Estuary Management Policy is one component).

The NSW Coastal Policy (1997) has a central focus on the ecologically sustainable development (ESD) of the coastal zone. ESD refers to development that uses, conserves and enhances the community's resources so that the ecological processes upon which life depends are maintained and the total quality of life now and in the future can be increased.

One of the Policy's strategic actions is the preparation and implementation by local Councils of detailed management plans for estuaries in accordance with the NSW Estuary Management Policy. The Estuary Management Policy is defined in the Estuary Management Manual (NSW Government, 1992). The policy outlines a structured management process leading to the implementation of an Estuary Management Plan. In developing the plan all values and uses of the estuary are considered. The plan aims to be a balanced long-term management framework for the ecologically sustainable use of the estuary and its catchment.

The Estuary Management Manual recommends an eight-step process in order to implement an Estuary Management Plan, as follows: -

1. form an estuary management committee;
2. assemble existing data (data compilation study);
3. undertake an estuary processes study;
4. **undertake an estuary management study;**
5. **prepare draft estuary management plan;**
6. **public review of the draft plan;**
7. adopt and implement the estuary management plan; and
8. monitor and review the management process as necessary.

In line with this policy, Wollongong City Council formed an Estuary Management Committee in June 2003.

Wollongong City Council commissioned Lawson and Treloar Pty Ltd, in association with Nelson Consulting, to undertake the second and part of the third stage of the process, which also included an analysis and review of the available data compiled. A portion of the further studies recommended to be undertaken as part of the Estuary Processes investigations are documented in Cardno Lawson Treloar (2005a). This study and plan represents Stages 4, 5 and 6 of the process.

This study was funded equally by Wollongong City Council and the Department of Natural Resources.

EXECUTIVE SUMMARY

The estuaries of Fairy Creek, Towradgi Creek and Hewitts/Tramway Creeks consist of the estuarine reaches of these systems. The creeks are located approximately in the northern portion of the Wollongong Local Government Area, within the Illawarra Region of NSW.

The three systems can be referred to as intermittently opening and closing lakes or lagoons (ICOLLs). The tidal influence of the creek systems varies depending on entrance conditions. The catchment areas are as shown:

- Fairy Creek 20.76 km^2
- Towradgi Creek 7.50 km^2
- Hewitts/Tramway (including Woodlands) Creek 4.28 km^2.

Complex interactions occur within the waterways. They are governed by a variety of factors including climate, creek morphology and bathymetry, tides, ocean conditions and the impacts of human intervention over time in both the catchment and the estuary.

A range of options are available for the management of the estuaries including:

- Statutory planning controls
- Education
- Works.

In general, the cost of management actions are usually in an increasing order associated with the above list of actions.

Figures ES1, ES2 and ES3 show an outline of the range of possible options specifically identified for the four systems. Other options, which are more generic in nature, are listed along with all of the options for the systems in Appendix B.

Following the consideration of an extensive list of options, the options were evaluated using a common scoring and ranking system based on a range of factors including environmental, social and economic. The outcomes of the ranking informed the preparation of a draft plan which was followed by community consultation. This process has informed the final management plan, outlined in this document (Section 9), which recommends those actions selected for implementation.

Fairy Creek Entrance (Looking Upstream)

Puckeys Boat Ramp (Fairy Creek)

Towradgi Creek (Looking Downstream from Footbridge)

Hewitts Creek (Looking Upstream from Footbridge)

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1. INTRODUCTION

1.1 Study Area

The study area comprises the tidal waterways, foreshores, surrounding open space and adjacent lands of Fairy Creek (including Cabbage Tree Creek and the Towradgi Arm), Towradgi Creek (including the tributary which runs from Cawley Street described as the Parker Road Arm in this report) and Hewitts / Tramway Creeks (including Woodlands Creek). Consideration of the wider catchment and freshwater reaches has been included in this report where they impact on estuarine processes.

A locality map of the study area is shown in Figure 1.1 and details of the catchments and creeks are shown in Figure 1.2.

1.2 Estuary Management Process

The Estuary Management Policy is defined in the Estuary Management Manual (NSW Government, 1992). The policy outlines a structured management process leading to the implementation of an Estuary Management Plan. In developing the plan all values and uses of the estuary are considered. The plan aims to be a balanced long-term management framework to promote the ecologically sustainable use of the estuary and its catchment.

The Estuary Management Manual recommends an eight (8) step process in order to implement an Estuary Management Plan, as follows:-

1. Form an estuary management committee;
2. Assemble existing data;
3. Undertake an estuary processes study;
4. **Undertake an estuary management study;**
5. **Prepare a draft estuary management plan;**
6. **Public review of the draft plan;**
7. Adopt and implement the estuary management plan; and
8. Monitor and review the management process as necessary.

In line with this policy, Wollongong City Council formed an Estuary Management Committee in June 2003. A *Data Analysis and Review* study has been completed (Lawson and Treloar, 2005) and has informed this stage of the process. A separate report (*Further Processes Studies*, Cardno Lawson Treloar, 2005) represents Step 3 in the process for high priority processes investigations (as identified by the Data Analysis and Review).

This report represents the fourth, fifth and sixth steps in the estuary management process.

1.3 Management Principal Aim

The principal aim for the management program as adopted by the Estuary Management Committee is:

'to achieve an integrated, balanced, socially responsible and ecologically sustainable use of local estuaries'.

1.4 Study Objectives

The overall objectives of the Study and Plan are to describe some of the processes operating within the Creeks and prepare a study and plan to guide the management of the estuary into the future.

2. CONSULTATION

An initial meeting was held with Council to discuss the project and gain an appreciation of Council's current initiatives and management processes for the catchments and estuaries.

Consultation was undertaken with the following agencies to discuss the options/strategies proposed and to gain an overview of the works either proposed or being undertaken by the respective stakeholders who may be relevant to this Management Study:

- Department of Lands (DL)
- Sydney Water Corporation (SWC)
- Roads and Traffic Authority (RTA)
- Department of Primary Industries (NSW Fisheries)
- Department of Environment and Conservation (DEC).

Given the partnership role played by DNR for this project through the life of the project, specific consultation was not undertaken with that organisation.

Meetings were held with various departments and divisions within Wollongong City Council to discuss options/strategies and to commence the process of gaining 'in-principle' approval of these departments in regard to relevant management options that would require funding and/or implementation by that group. Divisions and areas involved in the process include:

- Environment & Health (Environmental Education, Environmental Projects)
- Design (Floodplain Management, Landscape Architecture)
- Recreation and Natural Resources (Natural Resources)
- Property (Statutory)
- Strategic Planning
- Works.

Other divisions and areas with related responsibilities include:

- Engineering Services (Buildings)
- Development Assessment & Compliance
- Environment & Health (Environmental Management and Ranger Services)
- Design (Projects, Structural).

Endeavours were made by Council to coordinate a meeting with Indigenous representatives during the course of the project. A suitable opportunity to consult with representatives of the Wadi Wadi, Korewal and Gundungara people was identified during the exhibition period of the draft report on 10 October 2005 and written submissions were also received.

Additionally, other traditional owner groups were contacted in relation to the exhibition of the plan including Korewal Elouera Jerrungarugh (KEJ), Wodi Wodi Elders Corporation and Illawarra Local Aboriginal Land Council. Council indicated its willingness to meet separately with each of these groups. However, the opportunities were not realised during the course of this study.

Details of the outcomes of the consultation are outlined in the *Submissions in Reply* report (Cardno Lawson Treloar, 2005b). Reference has also been made to the consultation conducted in October 2003 during the course of the *Data Analysis and Review* phase of the project where 10 Aboriginal community members were surveyed in regard to indigenous heritage and current uses for the estuaries.

Estuary Management Committee Meetings have been undertaken periodically during the course of the project to discuss the various options identified and ensure the committee was regularly updated with the progress of this study. These meetings were also used as an opportunity to acquire feedback from committee members.

Table 2.1 lists the various stakeholders consulted for the project.

Table 2.1 List of Consulted Stakeholders

Organisation	Department / Title	Name
Department of Lands	Manager	Phil Priestly
Department of Primary Industries (NSW Fisheries)	Senior Conservation Manager	Allan Lugg
Sydney Water Corporation	Strategic Operations Wastewater Illawarra	Steve Znautas
Roads and Traffic Authority	Environmental Advisor	Terry McCoy
Department of Environment and Conservation	National Parks and Wildlife Service	Jamie Ersken
Department of Natural Resources	Estuaries – DNR and Committee Member	Kerryn Stephens
Wollongong City Council	Floodplain Management	Robert Dinaro
Wollongong City Council	Floodplain Management	Lance Hazell
Wollongong City Council	Landscape Architect	John Madry
Wollongong City Council	Assistant Manager Environmental Education	Ellen O'Brien
Wollongong City Council	Community Liaison Officer (Towradgi)	Rose Cronin
Wollongong City Council	Recreation and Natural Resources	Paul Formosa
Wollongong City Council	Strategic Planning	David Green
Wollongong City Council	Assistant Manager Landscape Architecture	Andrew Goldie
Wollongong City Council	Works Central Depot	John Bubb
Wollongong City Council	Works Bulli Depot	Kathleen Packer
Committee Member	Chairperson	Ron West
Committee Member	Community Representative (Towradgi)	Laurie Walder
Committee Member	Community Representative (Towradgi)	Ray Robinson
Committee Member	Community Representative (Fairy)	Peter Barnes
Committee Member	Community Representative (Fairy)	Elizabeth Gregory
Committee Member	Community Representative (Hewitts)	Denise Russell
Committee Member	Community Representative (Hewitts)	Don Stazic
Committee Member	Wollongong City Council Ward 1	Cr Alice Cartan

Community meetings were held during the draft report exhibition. All submissions related to the draft report exhibition are included and addressed in the *Submissions in Reply* report (Cardno Lawson Treloar, 2005b). The recommendations of this report have been included in this final version of the Estuary Management Study and Plan.

3. SUMMARY OF PROCESSES

3.1 Overview

Key processes within the estuaries are shown in Figures 3.1 – 3.4 for the four systems considered for this project. These processes are plotted in a longitudinal section along the 'thalweg' (or deepest portion) of the estuary.

Processes were considered in a preliminary manner in the *Data Analysis and Review* report (Lawson and Treloar, 2005). This report identified a series of further studies required to fill in the data gaps and amplify the understanding of the overall interactions in the estuaries.

Some of the further studies recommended in the report were undertaken concurrently with this project and are reported in Cardno Lawson Treloar (2005a).

The further studies undertaken include:

- Berm characteristics analysis
- Bank conditions assessment
- Sediment quality analysis
- Snapshot physico-chemical data collection (including vertical profiling where depth permitted).

Additionally, other studies are in progress at the time of preparation of this report by a range of groups including:

- Historical rate of sedimentation study through analysis of sediment cores by ANSTO (2005)
- Sediment nutrient flux studies by the Department of Environment and Conservation (preliminary results were supplied during the preparation of this report).

A combined summary of processes has been included in this report based on the information contained in the available studies including:

- Hydrological Processes (Section 3.2)
- Hydrodynamic Processes (Section 3.3)
- Entrance Behaviour (Section 3.4)
- Flora and Fauna (Section 3.5)
- Water Quality (Section 3.6).

The implications of these processes have been considered in the identification and evaluation of the management options (Section 8).

A summary of further studies required is provided in Section 3.7.

3.2 Hydrological Processes

Understanding the hydrological processes driven by catchment runoff is integral to understanding the overall processes within the estuaries as the systems are dominated by hydrological inputs. Hydrological processes can affect a number of the estuary characteristics, including water quality and the frequency of opening of the estuaries to the ocean.

An analysis was undertaken of the hydrological processes in each of the estuaries. A summary of the information presented in the *Further Processes Studies* report (Cardno Lawson Treloar, 2005) is outlined in this Section.

The volume of each of the estuaries was determined by merging bathymetric survey undertaken by DNR (February 2005) with survey data from other sources (eg survey for flood studies, other Council data). This information was used to produce 'stage-storage' curves (level versus volume) for each of the estuaries.

Runoff volumes for each of the catchments draining to the estuaries for the 1 year ARI design storm were estimated using simplified calculation methods. These volumes were used as a basis for estimating the likely displacement of water within each estuary.

Table 3.1 summarises the relevant hydrological and estuary characteristics. Key characteristics include the area of the catchment and the volume of the estuary.

Table 3.1 indicates that in the absence of more complex hydrodynamic analyses, complete displacement of the waters within the estuaries is likely to occur in relatively frequent storm events. This is particularly true for Hewitts Creek, which has a greater catchment area than it would otherwise have had (associated with the diversion of flows from the Woodlands Creek catchment).

Table 3.1 Hydrological Processes Summary

Catchment	Catchment Area (ha)	Estuary Volume at 'High' Berm Level [1] (m^3)	Ratio of Inflow Volume to Estuary Volume for 24 Hour, 1 year ARI storm	Rainfall Excess to 'Flush' Estuary[2] (mm)
Fairy Creek	2076	210 000	6.5	10
Towradgi Creek	750	83 500	6	11
Tramway Creek	53	4 200	8	8
Hewitts Creek	380	6 800	37	< 2

1. 'High' berm level corresponds to the highest observed berm level. 'High' berm level is estimated from analysis reported in the *Data Analysis and Review* Study (Lawson & Treloar, 2005). 'High' berm level for Hewitts and Tramway Creeks was estimated from photogrammetric analysis of historical aerial photographs undertaken by DNR.
2. Refers to the rainfall excess in a storm event (i.e. with infiltration losses removed) required to produce a runoff volume equal to the 'high' berm level estuary volume.

3.3 Hydrodynamic Processes

Hydrodynamic modelling of tidal processes was undertaken using SOBEK 1D/2D (WL|Delft Hydraulics Laboratory). A summary of the information presented in the *Further Processes Studies* report (Cardno Lawson Treloar, 2005) is outlined in this Section.

Modelling was undertaken for Fairy and Towradgi Creeks using the terrain model generated for the stage-storage analysis (Section 3.2). Hewitts and Tramway Creeks were not analysed to the same level of detail as both of these estuaries are considerably smaller than Fairy and Towradgi Creeks and initial enquiries indicated that the estuary entrances did not open regularly to the ocean due to substantial berm areas and the superelevation of bed levels. However, information provided by the community and supporting data collection at the Hewitts Creek entrance by the Department of Natural Resources indicates that the Hewitts Creek entrance does open periodically to the ocean and a tidal signal has been observed in the available data.

Both a representative spring and neap tide were applied to the models for Fairy Creek and Towradgi Creek, along with an estimated low flow of 0.1 m^3/s at each of the major inputs to the estuaries. It was assumed that both estuaries were in an 'open' entrance condition (i.e. the maximum observed width of channel open and depth scoured to 0m AHD). Table 3.2 shows the results of this analysis.

Table 3.2 Tidal Inflows during 'Open' Entrance Conditions

Catchment	Volume in Estuary (berm at 0m AHD) (m^3)	Width of Berm (m)	Spring Tide Inflow (m^3)	Neap Tide Inflow (m^3)
Fairy Creek	10 600	40	61 300	10 800
Towradgi Creek	2 400	35	24 500	4 130

The Towradgi Arm of Fairy Creek was noted to have a shallow berm area downstream of the footbridge in the DNR (February 2005) bathymetric survey. The level of this shallow berm level is in the range of 0.5m AHD. The presence of this berm reduces the tidal influence that can extend into the Towradgi Arm which in turn is likely to limit the potential for saline intrusion to this area and reduce the potential for tidal flushing. Flushing of the Towradgi Arm is more likely to occur as a result of catchment runoff inflow.

The northern arm of the Towradgi Creek Estuary (the Parker Road Arm) also has a relatively shallow area which is potentially an area where sediment has accumulated. The inverts at this location are in the range of 0.55 to 0.6m AHD. In an 'open' entrance condition, this area would be inundated only partially during tidal conditions.

Whilst modelling of the Hewitts/Tramway Creek systems was not undertaken, it is understood that the three watercourses (Hewitts Creek, Woodlands Creek and

Tramway Creek) have naturally connected with each other at varying times during the past 200 years. Limited time series water level data collected in 2005 also indicate that Hewitts Creek is tidal from time to time. Further data is being collected to provide a greater understanding of the entrance conditions and the tidal influences at this location.

3.4 Entrance Behaviour

The entrance behaviour of the systems has been analysed in detail as a part of the *Further Processes Studies* report (Cardno Lawson Treloar, 2005). An analysis of both the DNR (February 2005) survey data and the historical photogrammetric survey of the berms was undertaken. A visual analysis of the available historical aerial photography and other literature was also undertaken.

A summary of the information presented in the *Further Processes Studies* report is outlined below.

Fairy Creek

An analysis of the Fairy Creek data has been undertaken for the Flood Study and Floodplain Risk Management Study and Plan (WBM/Bewsher Consulting, *in prep*) as well as by the Department of Natural Resources (Specialist Flood Unit). At the time of preparation of this document both analyses were in progress. It is understood that the information will be available for publication in early 2006.

As a consequence, a repetition of the analysis for this study was not undertaken in the *Further Processes Study* and reference should be made to the analysis (when published) in the *Fairy and Cabbage Tree Creek Flood Study and Floodplain Risk Management Study*.

Council has identified that a manual opening of the estuary was conducted on an "as required" basis up until two years ago. This opening occurred when the water level in the Lagoon reached part way up the pipe across the creek upstream of Squires Way and further rainfall was expected. Further details are outlined in Appendix C.

Preliminary assessments have been completed of the historical opening characteristics via an analysis of continuous water level information for the estuary (Lawson & Treloar, 2005). This study indicates that, on average, when the entrance is open, the duration is of the order of 4.5 weeks. The maximum length of time that the berm has been recorded to be open was 22 weeks in 1998 (a particularly wet year). The minimum length of time that the berm is open is generally half a week. There are approximately six periods of tidal inundation per year.

Towradgi Creek

The construction of the training walls on the Towradgi Creek entrance has prevented movement of the entrance to the estuary upstream of the gabions. In general, the entrance area seaward of the gabions has a tendency to deviate towards the south.

No available data suggests that the entrance seaward of the gabions proceeds any further north than the northern training wall.

Data suggest that the presence of the training walls may have resulted in an increase in the net volume of sediment stored in the berm (due to the stabilised berm conditions). Additionally, there appears to be a greater volume of sediment accumulating on the northern side of the training walls. This suggests that complex coastal processes may be interfering with the typical net northern littoral drift (i.e. the movement of sediment along the coastline in a pre-dominantly northward direction) observed along this portion of the NSW coast.

Council has identified that manual opening of the estuary was conducted on an "as required" basis up until two years ago. This would generally occur twice a year. During these times, it was noted that the entrance would generally remain open for a period of a few weeks.

In a similar fashion to the water level data for Fairy Creek, an analysis of the Towradgi Creek water level recorder information has been completed (Lawson & Treloar, 2005). On average, the entrance is open for a period of approximately 8 days. The maximum length of time on record that the entrance was open was 8.5 weeks in 1995. The minimum length of time that the entrance is open is generally half a week. There are approximately ten periods of tidal inundation (associated with open entrance conditions) per year.

Hewitts/Tramway Creeks

The Hewitts/Tramway Creek berms have generally been stable in recent history, following a recovery after severe ocean storms in 1974. While Hewitts Creek opens to the ocean, and hence is influenced by ocean tides periodically, it is expected that Tramway Creek may not be exposed to ocean tides. No berm height data was available for an 'open' Hewitts Creek entrance condition.

Other information that supports the conclusion that the Tramway Creek system does not open to the ocean includes:

- The current diversion of Woodlands Creek into Hewitts Creek, which increases the effective catchment area of Hewitts, and reduces the available runoff volume entering the Tramway Creek Estuary
- However, Slacky Creek diverts to Tramway Creek which could have impacts that offset the diversion from Woodlands to Hewitts Creek. A flow duration analysis may support whether the offsets are comparable.
- The type of vegetation in the estuaries, which is indicative of more brackish to fresh water areas.

Whilst Tramway Creek does not appear to open to the ocean, this does not preclude the potential for the berm to be overtopped by wave action from the seaward side.

3.5 Flora and Fauna

Urban development of the catchments, resulting in clearing of vegetation, is for the most part limited to the coastal plain, with the majority of this area having been cleared for urban, recreational and agricultural uses. Native vegetation has been retained in far greater proportions on the steeper sloping and less fertile escarpment. Vegetation communities within the catchments have been categorised by NPWS (2002). A mixture of Moist Coastal White Box Forest and Coachwood Warm Temperate Rainforest can be found in the upper reaches of the catchments.

The available fauna data indicates that most species recorded are introduced. The catchments provide habitat for some resilient native species such as the Bush Rat and Brown Antechinus. Other native mammals noted within the study area include the Short Beaked Echidna, Eastern Pygmy Possum, Bandicoot and Large-Footed Myotis 'Fishing Bat'. A number of significant bird species have also been identified within the catchments.

Further details on flora and fauna can be found in Section 4.

3.6 Water and Sediment Quality

In general, estuary water quality processes are dominated by catchment inputs (including point sources and diffuse sources) oceanic inputs and in-estuary processes (including biological interactions and interactions with sediments and the atmosphere, generally strongly affected by climate and hydrodynamic processes).

Physical, chemical and biological water quality parameters were analysed for the study catchments (Lawson and Treloar, 2005). This analysis indicated issues commonly associated with urban estuarine systems and indicates:

- possible disturbance of acid sulfate soils, with acid pH levels recorded in Fairy Lagoon;
- elevated conductivity in some urban catchment areas, suggesting bank erosion and the influence of slag landfill leachate;
- litter from anthropogenic sources has been collecting at various points in the estuaries;
- inflow of seaweed and marine flotsam into the lagoons can occur on flood tide;
- low dissolved oxygen saturation levels and elevated nutrient concentrations identified on may occasions; and
- elevated Faecal Coliform levels in the creeks and tidal reaches of the lagoons.

In addition to estuarine sediments, there are two sources of sediment delivered to the estuary; fluvial sediments and marine sediments. Fluvial sediments are delivered to the estuary via freshwater flows. Sources include creek bed erosion, bank erosion and erosion of exposed surfaces in the catchment. Marine sediment is a dynamic shaper of the estuary entrance area. The entrances are generally located within a section of the coastline that is subject to high littoral drift rates.

There is some local concern that the study lagoons are becoming infilled due to sedimentary processes. However, there are no reports of dredging to counter this issue in any of the systems. Of the potential sediment sinks, large amounts of sediment supplied to the estuaries during flooding are likely to be flushed out to sea. In terms of the sediment quality elevated metal concentrations were found to some extent in the sediments of all the study lagoons. As outlined above potential and possible acid sulfate soils are present in the lagoon.

Further studies by ANSTO (2005) provide data on the composition of bed sediments and the likely rate of sedimentation at a range of locations.

Sediment quality is generally reasonable and recent studies of sediment quality (surface sediments) were completed (Cardno Lawson Treloar, 2005).

A number of samples collected exceeded the ANZECC (2000) sediment quality 'low' trigger values for heavy metals. However, in most cases the samples recorded values below 'severe' levels. The following heavy metal ANZECC (2000) trigger values were exceeded:

- **Cadmium** trigger value was exceeded at both sampling sites within the Fairy Estuary. However, the trigger value of 1.5 mg/Kg was only slightly exceeded with both sites recording a concentration of 2 mg/kg.
- **Copper** trigger value was exceeded at Fairy Lagoon and Towradgi Creek sampling sites.
- **Lead** trigger value was also exceeded at Fairy Lagoon and Towradgi Creek sampling sites.
- **Nickel** trigger value was exceeded at Towradgi Lagoon. A value of 82 mg/Kg was recorded at the sampling site. The 'severe' ANZECC guideline value for Nickel is 52 mg/Kg.
- **Zinc** trigger value was exceeded at both Fairy Estuary sites and in Towradgi Lagoon. The levels recorded at all three sites were elevated but were below the ANZECC (2000) 'severe' guideline value.

One site in Fairy Creek and one site in Towradgi Creek exceeded a number of ANZECC (2000) trigger values. Both sites were identified to be downstream of road bridges. These structures are likely to contribute to sediment deposition in these locations.

3.7 Human User Processes

Human user processes are described in Section 4 with respect to recreational usage and cultural heritage in the context of values and significance of the estuaries.

3.8 Further Studies

Further studies of the ecology of the estuaries are recommended to provide further understanding of the processes occurring in the estuaries. These studies should include:

- the mapping of aquatic vegetation (seagrass, saltmarsh, mangroves)
- evaluation of aquatic fauna (including fish and benthic fauna).

Other studies of value to provide a better understanding of the estuaries are outlined in the recommendations for further studies in the Data Analysis and Review report (Lawson and Treloar, 2005) and include:

- FS5.1 – Climate Change - Specific impacts on the Lagoons need to be quantified
- FS6.2 – Stormwater monitoring to assess sediment contributions from diffuse sources
- FS9.1 – More intensive water quality monitoring to identify low pH
- FS9.2 – Use water quality monitoring data to evaluate the possible locations of disturbed ASS
- FS12.1 – Water quality monitoring for Hewitt's/Tramway Lagoon areas
- FS12.2 – Vertical profiling of physico-chemical properties
- FS12.5 – Nutrient budget for loads to be prepared when sufficient data is available
- FS12.3 – Further salinity and conductivity sampling
- FS12.6 – Wet weather water quality monitoring
- FS14.1 - To account for the limitations in fauna studies it is recommended that updated detailed surveys and mapping should be undertaken within the study region for, Fish, Avifauna, Macro invertebrates, Microphytobenthos, phytoplankton, zooplankton and macro algae
- FS15.1 – Assess the threats associated with wetlands
- FS18.1 – Additional study on tourism/recreational impacts.

4. FEATURES/USES, VALUES AND SIGNIFICANCE

There are a range of features, uses and values of the creeks and their catchments. The current features contribute to the significance of the creeks. For the purposes of this study, these have been split into:

- historical uses and features of the catchment and creeks
- current uses, features and values of the catchment and creeks
- significance at local, regional and national levels
- proposed future uses of the catchment and creeks.

The significance of the creeks have been evaluated based on the information compiled in the following sections.

4.1 Historical Uses and Features

Information for the period prior to European settlement is limited. Information from traditional owner groups (Cardno Lawson Treloar, 2005b) indicates that Sandon Point was a meeting place for people of the Wadi Wadi, Korewal and Gundungaragh people. Major corroborees were held there every 10 years with other more frequent gatherings also held. A variety of leaves were burnt on the site to produce smoke signals of different colours to signify event such as funerals, marriages and Corrborees.

The turpentine forest between Tramway and Woodlands Creek was a sacred place for women.

Organ (1990, 1993) produced a compilation of historical records (dating back to 1770) of contact with the Illawarra and South Coast Aborigines and listings of archaeological surveys. During March 1796, George Bass and Matthew Flinders sailed to the Illawarra aboard the *Tom Thumb* and encountered Aborigines near Towradgi, Red Point and at Lake Illawarra.

An account by Martin Lynch, around 1830, refers to the 'Battle of Fairy Meadow' between the Wollongong and Bong Bong Aboriginal tribes. The battle took place in a clearing on the north and east of what is now the junction of the Princes Highway and Mt Ousley Road. A number of warriors from both sides were killed and their bodies buried in Tea Tree scrub between the two arms of Fairy Creek. It was noted that this was not a usual burial place, these being in sandy bushland on the south side of Fairy Creek (now Stuart Park) and the sand banks of various waterways, including Towradgi.

In the 1840s the Reverend W. B. Clarke provided a description of a corroboree held near Towradgi. In another account it was noted that, in the 1860s, a group of Aborigines (approximately 50 individuals) camped at Fairy Creek and Corrimal. They hunted for wallabies along the mountain range and collected shellfish and prawns from the coastal creeks.

However, Organ notes that *by the 1850s the original inhabitants/tribes of central and northern Illawarra were either destroyed, decimated, or dispersed along the coastline to the north and south, and even west inland.* In addition, during the next 50 years, Aborigines from other areas of NSW and Victoria settled in the district.

Navin Officer (1993) noted that the Illawarra region falls into the tribal area delineated by Tindale (1974) as Wodi Wodi. This area extends from Wollongong to north of the Shoalhaven, and west as far as Picton, Marulan and Moss Vale. Eades (1976) (also cited in Navin Officer, 1993) defines the language spoken by Wodi Wodi as Dharawal.

Bayley (1975) produced a book focusing on the history of coal mining and the development of transport, infrastructure and services in the Bulli District. It provides a description of the tramways and railways constructed from the 1850s to transport coal to Bellambi Harbour and later to Port Kembla.

In a report accompanying a Development Application for Sandon Point, Graham Brooks and Associates (2001) described the transport of coal for shipping and establishment of coke ovens (the report includes a map showing the route of historic, privately operated railways along the coastal strip between Wollongong and Stanwell Park).

The railway to the Bulli Jetty from the Bulli Coal Mining Company's operations was completed in 1863. It traversed a level crossing over the old South Coastal Road (Princes Highway) and then along the southern slopes of the valley of Tramway Creek. In 1878 a new pit (tunnel) was opened at Bulli north of the original pit, and a new incline constructed with the railway forking to serve both pits.

In 1889, the Bulli Coke Company leased land from the Bulli Coal Company, with the first 20 coke ovens being in operation by 1890. In the following decade several coke ovens were established along the coast but these were later closed and the coal sent direct to the Port Kembla ovens, after the steel works opened in 1927.

The Bulli jetty was constructed north of Bulli Point (Sandon Point – see section below for further discussion) and damaged and repaired several times due to its exposed location. It was destroyed in June 1864, rebuilt, and again destroyed in 1912. The jetty was finally abandoned in 1943, with the remaining pylons removed in the 1990s.

4.2 Current Uses, Features and Values

4.2.1 Uses and Features

Current uses are defined in the following:

- Land Use
- Indigenous Uses
- Recreational Uses.

Land Use

Land use in the catchment, derived from the Wollongong Local Environment Plan (LEP, 1990) is shown in Figure 4.1. There are a number of Community and Crown Land designated areas within the catchment (Figure 4.2).

Indigenous Uses, Sites and Places

Aboriginal uses of the estuaries include collecting bait, fishing and cultural practices (Kelly and Doherty, 2004).

Recreational Activities

Kelly and Doherty (2004) identified a number of activities associated with the estuaries including:

- Fishing and Collecting Bait
- Prawning
- Swimming
- Boating
- Kayaking
- Canoeing
- Model boat sailing
- Running
- Cycling
- Dog exercise
- Walking
- Picnicking
- Appreciating nature
- Birdwatching.

Additional, adjacent uses to the estuary have been included for completeness (such as surfing).

Water Based Activities:

Surfing: On the beach side of the creeks. There are surf clubs at Thirroul Beach, Bulli Point, Fairy Meadow Beach, Corrimal Beach and Towradgi Beach.

Swimming / Wading: Primarily at the shallow entrance area of Fairy Creek. Swimming and wading would also take place on the beach side Fairy, Towradgi and Hewitts / Tramway Creeks. However, given known health risks related to faecal contamination, it is unlikely that this activity would be extensive.

Fishing and Prawning: Recreational fishing occurs in Fairy and Towradgi Creeks. Children or tourists sometimes fish near the entrances. The indigenous community use the estuaries for collecting bait and fishing.

Small Watercraft (Canoeing / Kayaking): Kayakers regularly use Towradgi Creek. The other Creeks would have occasional canoers and kayakers.

Remote Control Boats: Fairy and Towradgi Creeks occasionally have remote control boat enthusiasts utilising the waterways. Hewitts / Tramway Creeks would be less likely to be used for this activity due to more difficulty with access.

Land Based Activities:

Walking / Jogging / Cycling: All three creeks have pathways that run through the surrounding landscape. Fairy Creek has a boardwalk, which partially follows the creek line from the entrance to approximately 500m upstream. The pathways surrounding the creeks are used by joggers, walkers (dog walking, pram walking).

Organised Team Sports: There are sportsfields surrounding Towradgi Creek, which are used mainly for soccer in the winter and cricket during the summer. Stuart Park lies just south of Fairy Creek and Thomas Dalton Park is to the north along with Brandon Park to the west (all in close vicinity). Towradgi Park also caters for lawn bowling.

Picnicking: There are several reserves that are used for picnics. Stuart Park Reserve (includes BBQ facilities), Puckey's Estate Park and Thomas Dalton Park all within the vicinity of Fairy Creek. Towradgi Beach Park (includes BBQ facilities) and Corrimal Beach Park in the vicinity of Towradgi Creek and Sandon Point Reserve which is on the southern side of Hewitts / Tramway Creeks. The adjacent beach area may also be used for picnics.

Children's Playground: Stuart Park Reserve and Towradgi Park includes formalised children's playgrounds. There is also a small playground at the end of Cassel Street (Towradgi Creek).

Birdwatching: Puckey's Estate Nature Reserve and other areas of remnant and regenerated vegetation (such as Sandon Point Endangered Ecological Community (EEC) and Towradgi Creek bush regeneration areas) provide habitat for bird species and hence birdwatching.

Educational: There are various educational purposes for these areas, including ecological walking groups, school groups and interpretive walks around the Creeks and Puckeys Estate.

Landing area for skydiving: Stuart Park Reserve provides a landing zone for sky diving enthusiasts.

Model Railway: The Illawarra Live Steamers Co-op operates a model railway facility at Virginia Street, North Wollongong, adjacent to Fairy Creek.

4.2.2 Values

This section highlights features of the Creek environments that are valued at a local, regional or national level (values being defined as what is important and essential about Fairy, Towradgi and Hewitts / Tramway Creeks). Features and values have been determined based on a review of existing information, including the Data Analysis and Review (L&T, 2005).

Kelly and Doherty (2004) identified community values associated with the estuaries through resident workshops and a questionnaire survey. The Community Values Survey undertaken utilised the value of importance ranging from 'not important' to 'very important' for the rating of the creeks and features. Based on this, values have been interpreted as follows:

- Habitat for flora and fauna, including endangered species
- Role as floodplain
- Natural link between the escarpment and coast
- Provide a range of recreational opportunities
- Provide educational opportunities, including those relating to cultural heritage
- Attractiveness to tourists (e.g. visitors to caravan park near Towradgi Creek), venue for events (e.g. Stuart Park)
- Accessible public open space, family orientated
- Scenic values, views, visual amenity.

Natural Environment – residents expressed a high value for the natural environment in both the workshops and surveys. Expressions of this value included recognition of the estuaries as habitat for native flora and fauna, its role in mitigating flooding, to help preserve / conserve endangered species, as a natural linkage between the escarpment and coast, as an important part of recreational activities and as an educational tool to learn about the environment.

Recreation – the importance of the estuaries and surrounding areas for recreational purposes were raised repeatedly during the workshops. Residents mentioned a diverse range of recreation activities and the surveys provided an indication of the frequency of some of these. Currently, there are societal concerns about sedentary life-styles and related human health issues such as obesity. Thus, ensuring the estuaries can continue to provide opportunities for recreation is vital now and for future generations.

Aesthetics – the aesthetic value of the estuaries to local residents was another major theme. The areas' closeness to the beaches, views to the mountain, water views and natural bush are very important to residents. Community members linked the aesthetic value of the lagoons to spirituality, relaxation and economic security (property value). This could play an important part in people's mental health.

Aboriginal respondents to the survey of October 2003 indicate the use of the estuaries for cultural practices and therefore cultural and spiritual values of the sites from an indigenous perspective are of significance.

4.3 Significance of the Creeks

4.3.1 Local Significance

The local significance of the creeks is described in terms of:

- Cultural heritage significance
- Natural environment significance (flora and fauna)
- Visual amenity significance.

Cultural Heritage

Indigenous Heritage
A search of the National Parks and Wildlife Service (NPWS) Aboriginal Heritage Information Management System (AHIMS) for this study identified approximately 37 recorded Aboriginal objects / places in the general study area, from the southern catchment boundary of Fairy Creek to the Northern boundary of Hewitts Creek and west to the Illawarra Escarpment. Note that the AHIMS only contains information from individual archaeological surveys etc and other unrecorded sites may be located within the study area.

Recorded site types include burials, open campsites, middens and potential archaeological deposits. There is also a record of a battle in the Fairy Creek area (see Section 4.1 for details). Two Indigenous sites are listed on the Register of the National Estate, one at Thirroul and the other at Bulli. It is understood that the investigations for the Sandon Point Commission of Inquiry revealed that both of these places have been removed.

The Sandon Point area has been identified by local Aboriginal community representatives as being significant, particularly as the burial place of a Kuradji (Clever Man). The area also contains a tool-making site and midden and has been identified as a camping ground and meeting place for Aborigines from the coast and from over the mountains. The Sandon Point Aboriginal Tent Embassy is located on the foreshore of McCauleys Beach, adjacent to Tramway Creek (Dept. of Environment and Heritage, 2003).

Professor Peter Hiscock of the School of Archaeology and Anthropology, Australian National University has prepared a report for Allan Carriage and the Sandon Point Aboriginal Tent Embassy entitled *Appraisal of archaeological studies at Sandon Point*, NSW (2002). This report contains further information on the available information for the Sandon Point area.

Non-Indigenous Heritage
There are a number of non-indigenous heritage items of particular interest within the study area and include the following:

- Towradgi Creek Corridor (local landscape significance)
- Thirroul Beach Reserve (local landscape significance).

In addition to the surf club and Battery Park (Smith Hill Fort) which are listed in the LEP, a study for Stuart Park and North Beach Reserve also identified the following items of conservation value:

- Kiosk and caretakers residence
- North Beach Pavilion (Bathers' Pavilion) and precinct
- Site of Puckey's experimental works
- Former Mount Pleasant train line (the route of the current cycle / pedestrian path)
- Gentlemen's Bath (cut into rock platform) (WCC 2000).

Sandon Point also contains items of non-indigenous heritage interest. The remains of the Bulli Cokeworks (late nineteenth century to early twentieth century) are situated along the southern margin and southwestern corner, and the remains of the Bulli to Sandon Point (Bulli Jetty) Tramway and Railway are situated along the entire southern margin, including sections of the mid slopes down to Tramway Creek (Navin Officer, 1993).

A Wollongong chemist, Courtney Puckey bought land north of the mouth of Fairy Creek in 1905. The site of the family residence, *Seafield* (which is in ruins today) is marked by the large Norfolk Island Pines on the southern peninsula. Puckey used the flat area near the residence to construct an experimental graduation salt making works. The works consisted of a windmill on top of a two walled graduation tower, with walls made of bundles of tea tree branches through which water pumped from the windmill slowly percolated. Much of the salt water evaporated during this process, leaving brine which was heated by a furnace and the salt extracted. The works are in ruins with only the concrete bases of the tower remaining (Place Details Australian Heritage Database).

Puckey's Estate is also recognised for its natural heritage values, as it contains locally rare remnants of dunal and reed/saltmarsh vegetation which supports six locally uncommon bird species. Kevin Mills (1986) identified the natural heritage values of Puckeys Estate and adjacent areas (including the coastal parks of the current study area) as being:

- *Example of an estuarine system and dune vegetation now largely destroyed in the Wollongong area*
- *Habitat for significant bird species, in an urban setting these are accessible to bird-watches and school groups*
- *The vegetation sequence from beach, through dune to estuary provides a good 'outdoor classroom'*
- *Provides wetland habitat for waterbirds*
- *Only natural area in the centre of Wollongong.*

Natural Environment

Fairy Creek

Fairy Creek has been greatly modified by urbanisation. However, there are extensive examples of alluvial forest, particularly Melaleuca Forest and Swamp Oak Forest (an Endangered Ecological Community) present. The vegetation surrounding Puckey Nature Reserve is one of few remaining examples of coastal dune and estuarine vegetation successions left on the highly urbanised Illawarra coast and makes up part of the Keira Green Corridor as discussed by Graham, undated, in *The Keira Green Corridor*.

The southern arm of Fairy Creek shows signs of degradation with the small section of riparian vegetation that remains consisting primarily of exotic species. However, there is a small segment of saltmarsh and mangroves in the vicinity of Puckey's Estate. Saltmarsh is listed under the *Threatened Species Conservation Act, 1995* and protected as an Endangered Ecological Community. The remnant saltmarsh vegetation includes the species *Juncus krausii* and *Baumea juncae*, which in turn supports six locally uncommon bird species (Australian Heritage Council, 2004).

The seagrass *Zostera capricorni* occurs in patches near the southern shore of Fairy Creek Lagoon (Minchinton & Whelan, 1996) and both *Zostera capricorni* and *Ruppia megacarpa* formed scattered patches in the body of the lagoon and tributaries (Shiau, 1996).

Fairy Creek provides habitat for the seagrass species *Zostera carpricornia* and *Ruppia megacarpa.* Due to the seagrass habitat Fairy Creek has the highest species richness and abundance of fish of the four systems which are the subject of this plan (Centre for Estuarine and Coastal Catchment Studies, 1998).

The Fairy Creek catchment provides habitat for a variety of birds (49 species identified). Migratory birds listed under an international agreement that Australia is a signatory of such as Migratory Bird Agreements with Japan (JAMBA) and China (CAMBA) include shorebirds, seabirds (Terns, Shearwaters, Boobies and Frigate birds) and some species of swallow and wedgetail (Ball, 2001). This site is not listed as protected habitat under these agreements however migratory species may visit this area from time to time.

Towradgi Creek

The upper Towradgi Creek catchment passes through tall eucalypt forest. The middle and lower sections of the creek pass through urbanised areas before reaching the estuary entrance. There is potential for the establishment of a green corridor from the escarpment to the sea due to the large amount of public open space beside the watercourse.

The area surrounding Towradgi Creek consists of open space to the north of the entrance, which includes parkland and natural areas (vegetation). The southern side of Towradgi Creek includes Towradgi Park with various playing fields. Further upstream is Cassel Park, which includes natural areas (vegetation) along the

southern creek foreshore (with formal walking tracks) and parkland (picnic area on the northern side of the creek "u" bend). There is a section of bushland near Cawley Street which is classified as an endangered ecological community.

Introduced plants are a widespread issue within this catchment, however there have been a number of indigenous plant species recorded including remnant saltmarsh (an endangered ecological community). The estuary provides habitat for many species of fauna including 83 bird species and 3 frog species.

As for Fairy Creek, the site is not listed under any international migratory bird agreements. However, there may be the occasional migratory bird which may visit this area from time to time. Residents report that the Great Egret (listed on both JAMBA and CAMBA) seasonally visits the tidal flats of the Parker Road Arm.

Hewitts / Tramway Creeks

The area surrounding the beach entrance to Hewitts Creek includes open space, recreational areas, cycle / pedestrian path and an endangered ecological community. The northern side of the entrance includes a carpark and pedestrian bridge. Open space to the south of the bridge is largely undeveloped. There is potential for a green corridor along Woodlands Creek.

Sandon Point swamp wetland is amongst some of the most undisturbed remnant vegetation within this catchment and occurs along Tramway Creek. There are a significant number of characteristic species belonging to the Sydney Coastal Estuary Swamp Forest Complex - an Endangered Ecological Community, now replaced by three new communities (see threatened species below). Hewitts / Tramway Creeks provide habitat for a variety of flora and fauna species including 125 bird species and several frog species.

The study sites have not been listed as protected habitats under any of the international agreements Australia is a signatory to. However, significant species have been found to inhabit Sandon Point and nearby areas (in particular the grassland areas). The site is highly valuable for its significant coastal wildlife habitat. The Brown Quail has been found to be breeding on the site, the Southern Emu-wren and White-cheeked Honeyeaters have been identified as resident 'refugee' species at Sandon Point Wetlands (Wollongong City Library, 2004).

Threatened Species

Threatened Flora

The following species, listed as endangered or vulnerable, have been identified as or potentially occurring within the estuarine areas of the region. Compiled from available data the list is not necessarily all-encompassing. Species include:

- Sydney Coastal Estuary Swamp Forest Complex (SCESFC) – Endangered Ecologicial Community (Connell Wagner, 2001). The SCESFC has since been replaced with three new communities all of which are known to exist within the Wollongong LGA:

  - River-flat eucalypt forest on coastal floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions.
  - Swamp oak floodplain forest of the NSW North Coast, Sydney Basin and South East Corner bioregions.
  - Swamp sclerophyll forest on coastal floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions.
- Coastal Saltmarsh, listed as an Endangered Ecological Community by the NSW Scientific Committee, 2004.
- White Cynanchum (*Cynanchum elegans)* (Kevin Mills and Associates, 2002).

Threatened Fauna

The following species, listed as endangered or vulnerable, have been identified as or potentially occurring within the estuarine areas of the region. This list has been compiled from available data and is not all-encompassing. Species include:

Avifauna

- Southern Emu-wren (*Stipiturus malachurus*) (Connell Wagner, 2001)
- White-cheeked Honeyeater (*Phylidonyris nigra*) (Connell Wagner, 2001)
- Australian Bittern (*Botaurus poiciloptilus*) (Kevin Mills and Associates, 2002)
- Barred Cuckoo-shrike (*Coracina lineata*) (Kevin Mills and Associates, 2002)
- Black Bittern (*Ixobrynchus flavicollis*) (Kevin Mills and Associates, 2002)
- Black-browed Albatross (*Diomedea melanophrys*) (Kevin Mills and Associates, 2002)
- Lathams Snipe (*Gallinago hardwickii)* (Connell Wagner, 2001)
- Olive Whistler (*Pachycephala olivacae*) (Kevin Mills and Associates, 2002)
- Sooty Owl (*Tyto tenebrisca*) (Kevin Mills and Associates, 2002)
- Superb Fruit Dove (*Malurus cyaneus*) (Kevin Mills and Associates, 2002)
- Swift Parrot (*Lathamus discolor*) (Kevin Mills and Associates, 2002)
- Turquoise Parrot (*Neophema pulchella*) (Kevin Mills and Associates, 2002)
- Wandering Albatross (*Diomedea exulans*) (Kevin Mills and Associates, 2002)

Mammals

- Bearded Bush-Pea (*Pultenaea aristata)* (Kevin Mills and Associates, 2002)
- Eastern Pygmy Possum (*Cercartetus nanus*) (Kevin Mills and Associates, 2002)
- Grey-headed Flying-fox (*Pteropus poliocephalus*) (Kevin Mills and Associates, 2002)
- Koala (*Phacolarctos cinereus*) (Kevin Mills and Associates, 2002).

Fish

- Australian Greyling *(Prototroctes maraena)* (Minchinton & Whelan, 1996)

Amphibians

- Green and Golden Bell Frog (*Litoria aurea*) (Connell Wagner, 2001)
- Red-crowned Toadlet (*Pseudophryne australis*) (Kevin Mills and Associates, 2002).

Visual Amenity
The open space of the water body of Fairy, Towradgi and Hewitts / Tramway Creeks and adjacent open space and vegetation contribute to the visual amenity of the area.

The aesthetic value of the creeks, beaches and coastline and the peaceful setting add to the visual amenity of the surrounding urban catchments.

4.3.2 Regional and National Significance

The study estuaries are an important recreational resource for residents and visitors. In particular, Fairy Creek (due to its proximity to Puckey's Estate, Stuart Park/North Beach Reserve and a range of tourist accommodation at North Wollongong) and Towradgi Creek (in part due to the provision of visitor accommodation at the nearby Corrimal Beach Holiday Park). These areas attract significant numbers of tourists and recreational users from outside the local area.

Recorded Indigenous heritage sites within the catchments include burials, open camp sites, middens and potential archaeological deposits. As outlined above, two Indigenous Places are listed on the Register of the National Estate, one at Thirroul and the other at Bulli. A number of residences, churches and other buildings of local heritage value were identified in the Wollongong Heritage Study (McDonald McPhee Pty Ltd 1991).

The sites are not listed specifically under migratory bird agreements that Australia is a signatory to, however they have value for occasional visitors (in particular the Sandon Point area).

Regionally, the creeks are uncommon with respect to being the receiving waters for escarpment catchment conditions. Examples of similar coastal lagoon and creek systems are located across the length of the NSW coast (Healthy Rivers Commission, 2002).

Overall, the creeks are not considered to be of national significance. Nonetheless, their value should not be diminished in any way as a result of this.

4.4 Future Uses

The likely future development adjacent to and within the catchments of these creeks, (particularly Hewitts / Tramway Creeks) is generally planned to increase. This has the potential to cause an additional cumulative impact to the creeks and decrease in water quality, an increase in sedimentation and a general compromise on the character of these areas. It is critical that future uses are evaluated for their sustainability.

Council is currently undertaking a review of land use through the revision of the Local Environment Plan. The likely future development within the catchments includes:

- Fairy Creek Catchment – University of Wollongong Innovation Campus. This development will include the rehabilitation of a section of the Para Creek bank

and the creation of a riparian zone. The development has had significant Council review from the Masterplan stage.

- Towradgi Creek Catchment – No specific development has been identified at present.
- Hewitts and Tramway Creek Catchments – the Sandon Point development is currently proceeding in part and the areas between the two creeks is the subject of a complex Commission of Inquiry (CoI). The results of the CoI will shape the future of the land use in this area. The RTA is also planning for the extension of the northern distributor which is west of the railway line.
- All catchments – infill development, subdivision and redevelopment are expected to be the dominant future development. It would be expected that in some parts of the catchments the density of development would increase to accommodate population growth in the region. Pockets of industrial development within the catchments may eventually be redeveloped for commercial or residential development.
- Many natural areas in coastal settings are currently zoned 6(a) Public Recreation and consideration is being given to rezoning that land to an appropriate environmental protection zone.

With respect to the estuaries, the LEP review will involve a review of zonings associated with the waterways and riparian land. For example as mentioned above, consideration is being made of rezoning land that is currently 6(a) Public Recreation Zone to 7(a) Special Environmental Protection Zone, 7(b) Environmental Protection Conservation Zone or 7(c) Environmental Protection Residential Zone. This rezoning would afford a greater protection of the estuaries and their riparian zones. Section 8 - Management Options discusses this option further.

Future disturbances to the creeks may occur due to:

- redevelopment,
- flood events,
- works associated with flood risk management,
- management intervention (eg entrance management, bank stabilisation works, revegetation, installation of stormwater quality improvement devices)
- climate change (alteration of rainfall patterns and sea level rise, change in flood-dominated and drought-dominated cycles).

Of all these potential future disturbances, the effects of climate change are outside of the control of Council and agencies. Engineers Australia (2004) provide an engineering estimate for projected sea level increases as a result of the 'greenhouse effect' to 2100 with a central figure of 0.5 m (a range of 0.1 – 0.9 m). These estimates are produced from a range of scenarios. Engineers Australia (2004) also report a central projected sea level rise for a 20 year planning period (i.e. to 2030) to be of the order of 0.1 m.

Forward planning with respect to appropriate development setbacks and habitable floor levels for development in the affected region is required. It is most likely that the design floor levels driven by the Floodplain Risk Management Process will result in

habitable floor levels for dwellings in affected areas that can cope with climate change factors. However, there may be some areas that would be inundated where land is lower lying reducing the useability of the lower lying land. It will necessary for flood planning levels to be estimated by Floodplain Risk Management Plans that take into account climate change factors.

There are very limited quantitative studies to produce likely rainfall patterns under climate change scenarios. Hennessy et al (2004) considered events from the 1 in 5 year event through to a 1 in 40 year event for the whole of NSW for a 1 day event duration and a 3 day event duration.

For the south-east region, Hennessy et al (2004) found that there are likely to be increases in 1 day event rainfall (~10%) out to 2070 in spring, summer and autumn and decreases in winter. In the case of 3 day events, a projected decrease in intensity was identified for coastal regions for autumn, winter and spring but an increase (~20%) for summer to 2070.

5. LEGISLATIVE AND MANAGEMENT CONTEXT

5.1 Overview

The objective of this chapter is to establish the context for the estuary management plan in terms of legislative requirements, policy directions and related management plans and actions.

5.2 Relevant Environmental Legislation

It is important to note the following legislation would need to be considered in any future development proposed as a management action or otherwise.

5.2.1 Local Planning Legislation

Wollongong Local Environmental Plan 1990

The *Wollongong Local Environmental Plan (LEP) 1990* is the principal planning instrument for the City. The LEP guides what development is permitted in different parts of the City through land use tables, which corresponds to the zoning of each parcel of land. The LEP also identifies subdivision standards, floor space ratio and lists heritage items in the City. The LEP has been amended over 220 times since gazettal in 1990. The LEP is currently subject to a number of minor amendments and is undergoing a major review.

5.2.2 Local Policies and Guidelines

Wollongong Futures Draft Strategy Report 2025 (2005)

Wollongong Futures is an important strategic planning initiative designed to provide a long-term vision for the City of Wollongong. The Wollongong Futures strategy document will guide Council's long term Strategic Plan and Corporate Plan, and is a key input into the Wollongong Local Environmental Plan (LEP) review. This document is also intended to inform relevant planning decisions of State and Federal government agencies, non-government organisations and businesses throughout the City.

Following extensive community consultation a *Draft Wollongong Futures Strategy* report has been prepared. This report incorporates an expression of the community vision for the way Wollongong should develop over the next 20 years, in the context of economic, social and environmental research findings. The overall vision is for Wollongong to develop as a sustainable city by the Year 2025. Sustainability is the defining feature at the core of this vision, with a focus on the quadruple bottom line approach to planning (a holistic approach involving economic, social, environmental and governance considerations).

The principal LEP being prepared by Council for the LGA under the planning reforms being implemented by the Department of Planning and Council would be the ideal way to implement any zoning changes. This LEP will have to be in the Standard LEP

format and Council will need to consider what zones are to be contained in the LEP, including zone objectives.

Draft Corporate Plan 2005 – 09 (2005)

The draft Corporate Plan contains Council's values, mission and goals. These statements underpin the way in which we manage and conduct our operations. You will have the opportunity to directly influence the range and nature of services and will also be able to comment on issues such as financial management policies and capital works programs.

The plan has recently been adopted.

Illawarra Escarpment Strategic Management Plan

The *Illawarra Escarpment Management Plan* has been prepared by Wollongong City Council (WCC) with input from the NSW Department of Environment and Conservation (DEC), Department of Infrastructure Planning and Natural Resources (DIPNR) (now the Department of Natural Resources), the Illawarra Escarpment Community Reference Group, representatives of the local Aboriginal community and the broader community.

The Plan has been developed with the principle aim and objective of natural and cultural resource protection, conservation and management. These themes were clearly the outcome of a Commission of Inquiry (COI) into planning and management of the escarpment and the subsequent endorsement of the findings and recommendations of the COI by the State Government. Provision for limited residential development must, according to the COI findings, be considered within the context of active conservation and be considered as a secondary outcome. The plan assesses the current condition of the Illawarra escarpment, identifies the threatening processes that degrade the asset and outlines proposed planning, management and implementation strategies to plan and manage the escarpment into the future.

The plan draws together a number of studies designed to provide information on a range of constraints and/or attributes and include:

- Bioregional Assessment (flora and fauna) Parts 1-3 - NSW Department of Environment and Conservation;
- Riparian (Creek) Corridor Management Study - Department of Infrastructure Planning and Natural Resources;
- Draft Native Vegetation Management Issues Paper - Department of Infrastructure Planning and Natural Resources,
- Update of landslip maps - University of Wollongong and Wollongong City Council; and
- Preliminary Heritage Assessment Report - External consultant report.

The plan has been structured around the 'pressure-state-response' model common to natural resource management. Whereby the resources are managed once the current state of the resource is determined, the pressures or threats against that resource are identified and then management and planning policies are then developed to improve the state and mitigate the pressure.

Riparian Corridor Management Study (DIPNR, 2004)

The *Riparian Corridor Management Study* provides management guidance and principles to the many stakeholders involved in the management of riparian land.

The *Riparian Corridor Management Study* develops a three tier process that:

- Develops three levels of environmental objectives for riparian land based on the relative importance of the watercourse and assigns a value (i.e. Category 1, 2 or 3) for all streams within a catchment in a map form.
- Develops a mapping technique to delineate the actual riparian boundaries for major watercourses.
- Delineates idealised cross-sections and plan views of the implemented riparian outcomes.

To ensure improved consideration occurs, key environmental requirements need to be identified and provided for at the outset. Allowance needs to be made for three key features which are as follows:

- Core riparian zone
- Vegetated buffer
- Asset protection zone.

Development Control Plan 54 Managing Our Flood Risks (2004)

The *Development Control Plan (DCP) 54 Managing our Flood Risks* was developed by Wollongong City Council in accordance with the *EP&A Act 1979*. This DCP is consistent with the state government's *Flood-Prone Land Policy* and the *Floodplain Development Manual* 2005.

This plan is an application of the state policy, which reflects local circumstances, as identified for some floodplains, through the preparation of Floodplain Risk Management Studies (FRMSs) and Floodplain Risk Management Plans (FRMPs).

Development Control Plan DCP 94/17 – For Land Between Sandon Point and East Thirroul

This DCP applies to the land north of Tramway Creek. It should be noted that that land is subject to the outcomes of the Commission of Inquiry and the DCP is likely to be changed or superseded once the Minister's determination is made.

Draft Landscape Guidelines Technical Policy No 98/4 (2002)

The *Draft Landscape Guidelines Technical Policy* has been developed to assist applicants with the preparation of Landscape Plans for Development Applications (DAs) and Construction Certificates.

When submitting a DA to Wollongong City Council, it may be required to prepare a Concept Landscape Plan. The plan would need to be further developed into a Detailed Landscape Plan and Documentation to be submitted with the Construction Certificate.

The objectives of the *Landscape Guidelines* are as follows:

- Clarify the responsibilities of developers and Landscape Consultants in providing landscaping for new developments.
- Encourage quality landscape design and construction.

Southern Councils Group Regional Water Sensitive Urban Design Policy - Draft

The objective of this policy is to ensure that building design and development incorporates effective water and soil management measures that:

- Minimise adverse impacts on the natural water cycle (where post development conditions mimic the natural hydrologic regime for the broadest range of storm events practicable);
- Manage flooding and stormwater drainage impacts;
- Reduce potable water demand and promote more efficient use of water;
- Remove water-borne pollutants prior to stormwater discharge to receiving waters.
- Minimise maintenance and infrastructure costs of new development where possible;
- To protect the biodiversity and ecosystems of local waterways by retaining watercourses, remnant native vegetation, and habitat where possible;
- Avoid concentration of flows prior to discharge into natural streams / receiving waters;
- Meet the Ecologically Sustainable Development requirements set out under the *Water Management Act 2000* and the *Local Government Act 1993*.

Technical Policy for the Management of All Wastes Associated with Building Sites

This policy formalises Council's expectations with regard to the management of building sites. It is also intended to be used as an educational resource for all those involved in the construction and demolition industry to facilitate the practical implementation of on-site environmental controls.

The aim of this policy is to protect our environment by:

- Minimising the impact of building sites on the surrounding environment.

- Ensuring all building sites are maintained in a clean and tidy condition.
- Minimising any pollution from building sites.
- Encouraging waste minimisation practices during the construction and demolition phases of development.

Planning People Policies – A Strategic Framework for Open Space, Recreation Facilities and Community Facilities

'Planning People Places' was commissioned by Wollongong City Council to provide a strategic direction for open space, key recreation facilities such as swimming pools and indoor sport and recreation centres and key community facilities including community and neighbourhood centres.

The study aims to identify community needs and issues, consider opportunities for enhancing open space and facilities and determine the priorities for the future. The study will guide Council in its future policy and decision making, assist in determining the appropriate allocation of resources and provide a framework for partnerships with the community and other levels of government. This will include identifying opportunities for regional facilities and initiatives in line with Department of Tourism, Sport and Recreation regional planning.

The study will also provide a strategic direction for future Section 94 Contribution planning and contribute to the Wollongong Local Environmental Plan (WLEP, 1990). In particular it will identify higher level facilities that can be included in Section 94 Contribution Plans and identify land requirements that should be reflected in the WLEP.

'Planning People Places' is a 20 year strategy document that will be used across Council to achieve a consistent and sound approach to planning and to support existing and future communities through diverse and quality places and activity opportunities.

5.2.3 Plans of Management

Southern Catchment Blueprint 2003

The Southern Blueprint was prepared by the Southern Catchment Management Board (CMB). The Southern CMB and South Eastern CMB have been merged and are now the Southern Rivers Catchment Management Authority (CMA). The Blueprints prepared by the CMB's form the basis of the CMA's three year investment strategy.

The Blueprints are currently being combined and updated into a Catchment Action Plan that will guide long term investment in natural resource management in the region.

Hewitts Creek Floodplain Risk Management Study & Plan (2002)

Chapter 9 of this document sets out a series of risk management schemes, which are recommended as the basis of a Floodplain Risk Management Plan for the Slacky, Tramway, Woodlands, Hewitts and Thomas Gibson Creek systems. The recommended risk management schemes comprise a number of non-structural and structural flood management measures specifically developed for the study area.

Towradgi Creek, Wollongong Floodplain Risk Management Study and Plan (2003)

Chapter 9 of this document presents a draft Floodplain Risk Management Plan, showing the preferred floodplain risk management measures, for the Towradgi Creek catchment.

Adopted recommendations include the following:

- In accordance with Clause 19 of the Wollongong LEP 1990, Council resolved to adopt a foreshore building line (FSBL) along all creeks in the study area which accords with the boundaries of the High Flood Risk Precinct (FRP), and other environmental and erosion risk criteria necessitating setbacks from creeks. The FSBL should be identified on Council's LEP maps. This process should also involve a review of the appropriateness on the zoning of individual land parcels, should the combined flood risk and environmental criteria result in FSBL, which substantially affects reasonable development expectations.
- That Council prepare and implement a Riverine Corridor Strategy for the creek corridors within the study area, to improve corridor linkages and restore their ecological value and remove inappropriate vegetation which impedes the flow of water or forms a source of debris which exacerbates flooding impacts. This should be undertaken in consultation with DNR.
- That Council investigates the feasibility of a policy of formalizing the creek corridors within publicly owned land or with drainage easements held to the benefit of Council when dealing with development applications involving the development of redevelopment of flood affected lands. This will require further research of the extent of easement of land acquisition required, the likelihood of redevelopment in areas where such acquisition is required, the impact on the functioning of individual properties and the potential costs to Council.

Stormwater Management Plan – Wollongong Coastal Catchment (2000)

The purpose of the '*Wollongong Coastal Catchment – Stormwater Management Plan*' is to facilitate the coordinated management of urban stormwater within a catchment to maximise ecological, social and economic benefits, in a sustainable way, with sound management practices.

Puckeys Estate Draft Plan of Management (1991)

The location of Puckey's Estate makes it an important passive recreation area with opportunities for bird watching, walking, jogging and nature appreciation. The

cultural heritage significance of the area, with its remains of saltmaking ventures and early house site provide an interesting link with Wollongong's past. The development of Puckey's Estate as an educational resource for local schools and tertiary institutions will provide Wollongong with a unique natural asset, which is easily accessible. This Management Plan sets out to establish guidelines through which Puckey's Estate can be maintained in order to preserve its natural communities whilst at the same time providing sympathetic educational and recreational opportunities.

Natural Resource Management Plan (in preparation)

Council will be preparing a natural Resource Management Plan for the entire coastal plain. This EMP will be a component of the NRM program.

Sandon Point – A Community Vision: Bushland Management Strategy 2003 and beyond.

This strategy is a vision and a statement of guidance for the future wellbeing of the natural resources of Sandon Point. This document has two main purposes. The first is to highlight the existing conservation values of the natural features of Sandon Points. The second is to strengthen community involvement in the custodianship of Sandon Point through a clear statement of management and planning that is aimed at consolidating ongoing community consultation.

Masterplan for the Innovation Campus (Brandon Park)

The masterplan provides objectives and controls for the development of the Wollongong Innovation Campus, located alongside the University of Wollongong Campus East and Science Centre and the area formerly known as Brandon Park, Fairy Meadow.

Towradgi Park Landscape Masterplan (in progress)

The Towradgi Park Landscape Masterplan is to document the general direction for this area.

Generic Plan of Management for Community Land Categorised as Natural Areas 2002

This plan will enable management of natural areas to proceed in an efficient and sustainable manner, help reconcile competing interests, and in conjunction with the proposed Natural Area Strategic Action Plan it will identify priorities for the allocation of available resources and facilitate public understanding and education of the City's natural areas.

The purpose of the classification is to identify clearly that land which should be retained for use by the general public (community) and that land which can be managed by Council for operational and commercial purposes (operational).

Generic Plan of Management for Community Land Categorised as Sportsgrounds 2001

The Local Government Act 1993 requires Council to manage all community land with regard to the principles and philosophies of Ecological Sustainable Development in accordance with a plan of management. This generic Plan of Management for Sportsgrounds has been prepared for this purpose.

This plan of management has been developed to ensure compliance with these requirements by reviewing the 1994 plan of management, ensuring that all areas of community land are categorised appropriately and the future management of those areas is consistent with the core objectives as set down by the Act. Upon adoption by Council, the provisions of the 1994 plan of management will no longer apply to the areas of community land covered by this plan.

Generic Plan of Management for Community Land Categorised as Park 2001

The Local Government Act 1993 requires Council to manage all community land with regard to the principles and philosophies of Ecological Sustainable Development in accordance with a plan of management and this generic Plan of Management for Parks has been prepared for this purpose.

5.2.4 State Legislation

A summary of state legislation is presented in Table 5.1 with further details in Appendix A.

Table 5.1 State Legislation Summary

Act/Regulation	Details
Environmental Planning and Assessment Act 1979	The NSW environmental planning system operates under *the Environmental Planning and Assessment Act, 1979* (as amended in 1997 and 2005) (*EP&A Act*). It is the primary legislation controlling development activity in the State of NSW and is administered by the Department of Planning Council and other consent or determining authorities. One of its purposes is to ensure that appropriate authorities assess environmental impacts of new developments before development commences.
Protection of the Environment Operations Act 1997	The need for licences or approvals from the NSW Environment Protection Authority is specified under the *Protection of the Environment Operations Act 1997*.
Threatened Species Conservation Act 1995	The provisions of this Act would be complied with for any future development proposals in or around the Creeks likely to affect or have the potential to impact threatened species. The Department of Environment and Conservation (National Parks and Wildlife Service) administer this Act.
Noxious Weeds Management Act 1993	Any proposed rehabilitation proposal for Fairy, Towradgi and Hewitts / Tramway Creeks must be compliant with the *Noxious Weeds Management Act 1993*.
Rivers and Foreshores Improvement Act, 1948	The Rivers and Foreshores Improvement Act 1948 aims to control excavations, the placement of fill and other works in or near rivers, estuaries and lakes. The Act is administered by the Department of Natural Resources. At the time of preparation of this document, licences and approvals associated with this Act were still in force and the Water Management Act, 2000 had not

Act/Regulation	Details
	yet been become operational with regard to licences and approvals.
Water Management Act, 2000	The Water Management Act 2000 controls the extraction of water, the use of water, the construction of works such as dams and weirs and the carrying out of activities in or near water sources in New South Wales. The Act creates: • mechanisms for protecting and restoring water sources and their dependent ecosystems • improved access rights to water • partnership arrangements between the community and the government for water management.
Disabilities Services Act 1993	For any proposed development such as improvements to walkways or the like, the infrastructure and services provided must comply with the provisions of this Act.
Fisheries Management Act 1994	The provisions of this Act would be complied with for any future development proposals in or around the Creeks. Approvals are required from the Department of Primary Industries (NSW Fisheries) for developments see Appendix A.
Native Vegetation Act 2003	The provisions of this Act would be complied with for any future works which may affect native vegetation. Exemptions to the Act include 'Land within a zone designated 'residential' (but not rural residential), 'village', 'township', 'industrial' or 'business' under an environmental planning instrument or having regard to the purpose of the zone, having the substantial character of a zone so designated.
Draft Native Vegetation Regulation 2004	The *Draft Native Vegetation Regulation, 2004* provides regulations for the protection of Native Vegetation. Given the nature of the land use zoning surrounding the subject waterways the regulation is unlikely to apply.

5.2.5 State Policies and Guidelines

A summary of state policies and guidelines is presented in Table 5.2 with further details in Appendix A.

Table 5.2 State Policy and Guidelines Summary

Policy	Details
NSW Coastal Policy	The *NSW Coastal Policy* provides a framework for the balanced and co-ordinated management of the coastal zone in accordance with the principals of ecologically sustainable development and applies to the area under study due to proximity to the coast.
Estuary Management Manual and Policy	The Estuary Management Policy is defined in the Estuary Management Manual (NSW Government, 1992). The policy outlines a structured management process leading to the implementation of an Estuary Management Plan. This document provides the overarching framework for the Estuary Management Study and Plan.
State Environmental Planning Policy (SEPP) No 71 – Coastal Protection	SEPP No.71 aims to protect and manage the natural, cultural, recreational and economic attributes of the NSW coastal zone. The policy applies to land within the 'coastal zone' as defined in section 4A of the *Coastal Protection Act 1979* (CP Act).
Flood Prone Land Policy	The policy promotes the use of a merit approach, which balances social, economic, environmental and flood risk parameters to determine whether particular development or use of the floodplain is appropriate and sustainable.
Coastal Design Guidelines for NSW	The coastal design guidelines have been prepared with reference to the NSW Government's Coastal Policy 1997 and complement the Government's

Policy	Details
(2003)	Coastal Protection Package released on the 26th June 2001 and SEPP 71 which came into effect in November 2002. The coastal design guidelines are based on the principles of ecologically sustainable development (ESD).
Biodiversity Planning Guide for NSW Local Government 2001	This Guide aims to assist Wollongong Council to carry out biodiversity conservation as part of their day-to-day functions, especially those relating to planning and development. It provides Council with a 'good practice guide'.
Policy and Guidelines for Aquatic Habitat Management and Fish Conservation 1999	This document has been prepared by NSW Fisheries in order to improve the conservation and management of aquatic habitats in NSW. It is targeted at local and state government authorities, proponents of developments and their advisors, and individuals or organisations concerned with the planning and management of our aquatic resources, including conservation organisations.
Policy and Guidelines for Fish Friendly Waterway Crossings 2004	This Fishnote provides a summary of the specific legislation and policy requirements that must be observed by those intending to plan design and construct waterway crossings in NSW.
Water Quality and River Flow: Interim Environmental Objectives	This document outlines the Water Quality and River Flow Objectives for different catchments, in this case within the Illawarra catchment. Achieving water quality objectives and river flow objectives will mean improving poor water quality and maintaining existing good water quality.
Managing Urban Stormwater Guidelines 2004	This manual provides guidelines to minimise land degradation and water pollution at urban development sites in New South Wales. Any future works around the estuaries in question would require the necessary precaution to be undertaken in accordance to this manual.

5.2.6 Commonwealth Legislation

Commonwealth Environment Protection and Biodiversity Conservation Act 1999

The Environment Protection and Biodiversity Conservation Act 1999 (EPBC) provides for the protection of the environment and the conservation of biodiversity for those aspects of the environment that are matters of national environmental significance.

5.2.7 Commonwealth Policies and Strategies

A summary of commonwealth policies and strategies is presented in Table 5.3 with further details in Appendix A.

Table 5.3 Commonwealth Policies and Strategies Summary

Policy	Details
Natural Heritage Trust	The Natural Heritage Trust (NHT) was set up by the Australian Government in 1997 to help restore and conserve Australia's environment and natural resources. Since then, thousands of community groups and organisations have received funding for environmental and natural resource management projects.
Australia's Oceans Policy	Australia's Oceans Policy sets in place the framework for integrated and ecosystem-based planning and management for all of Australia's marine jurisdictions.
National Strategy for Ecologically	This document sets out the broad strategic and policy framework under which governments will cooperatively make decisions and take actions to

Sustainable Development	pursue ESD in Australia.
National Strategy for the Conservation of Australia's Biological Diversity	This strategy sets out a number of principles which have been adopted as a basis for the strategy's objectives and actions in conserving Australia's biological diversity.
National Water Quality Management Strategy	The main policy objective of the NWQMS is, "to achieve sustainable use of the nation's water resources by protecting and enhancing their quality while maintaining economic and social development.
Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000	This document outlines the important principles, objectives and philosophical basis underpinning the development and application of the guidelines. It outlines the management framework recommended for applying the water quality guidelines to the natural and semi-natural and freshwater resources in Australia and New Zealand.
The Wetlands Policy of the Commonwealth Government of Australia	The Wetlands Policy of the Commonwealth Government of Australia (Environment Australia 1997) provides strategies to ensure that the activities of the Commonwealth Government promote the conservation, ecologically sustainable use and enhancement, where possible, of wetlands functions.
Department of the Environment and Heritage Compliance and Enforcement Policy	The Policy recognises a range of mechanisms are necessary for an effective and flexible regulatory system that allows the most appropriate response to be chosen for a given issue or incident.
People with Disabilities	Australian Standards are required to be implemented for all design and construction. Redevelopment of any facility must take into consideration the requirements with respect to people with disabilities.

6. MANAGEMENT OBJECTIVES

6.1 Identification

Wollongong City Council has established an Estuary Management Committee for the purpose of preparing and implementing an Estuary Management Plan in accordance with the NSW Government's Estuary Management Policy.

Existing data has been assembled and a *Data Analysis and Review Study* (Lawson & Treloar, 2005) has been completed. Community issues and values were identified through a series of facilitated workshops (CSIRO, 2004). The Committee has agreed to proceed from this stage to an Estuary Management Study and Preparation of an Estuary Management Plan. Where further process studies are required, these are to be identified as actions within the plan.

The previous Community Workshops (Fairy Creek 2 December 2003; Towradgi Creek 13 November 2003 and Hewitts / Tramway Creeks 3 December 2003) and *Data Analysis and Review Study* described above have identified a series of issues, knowledge gaps and proposed further studies and management actions. The Estuary Management Committee has recommended priorities for the studies and actions. This information is summarised in Table ES1 of the *Data Analysis and Review Study*.

Council and DNR prepared a preliminary detailed series of objectives for consideration for this study. These objectives were taken as draft objectives at the commencement of the study.

The draft objectives were discussed at a meeting of the Estuary Management Committee and then forwarded for consideration and comment. The comments for the objectives were updated and compiled and presented as a final draft of objectives to a second committee meeting. The objectives were further refined at this second meeting for adoption.

The adopted objectives are presented in Section 6.2.

6.2 Adopted Objectives

Table 6.1 outlines the objectives adopted by the Committee as an objective statement accompanied by a series of explanatory notes.

Table 6.1 Adopted Objectives by the Committee

Objective	Notes
Habitat and Species Conservation Objective: *Protect and retain existing pockets of valuable habitat, rehabilitate degraded habitat and connect habitat where necessary and practicable. Re-establish agreed native aquatic, wetland and foreshore species.*	The following notes accompany this objective: • In the achievement of this objectives there is a need for a recognition of the existing constraints (e.g. existing land use) • The Committee agreed that the re-establishment process would seek to 'match' a comparative example as a reference point for terrestrial communities – for example the use of NPWS data for terrestrial flora reference communities. This approach would be for both remnant & connected systems • In the case of 'endangered' ecological communities – the objective is to seek to manage existing communities rather than re-establish a new community of endangered species • The Committee recognises that there is variability in aquatic ecology and therefore there is difficulty in establishing a constant condition to 'match' in the reestablishment process. The objective in this case is to provide an environment suitable for fish communities including prawns • Where clear objectives have been set and adopted by Council (eg. Riparian Objectives) they need to be considered not just in terms of planning & development controls but also to guide on-ground works. • Replanting to resemble some desired condition (previous or existing elsewhere) would be a testable management strategy for flora. In contrast, a management strategy to 're-establish' aquatic fauna would probably be untestable because there is no data to identify past conditions and it would probably be impossible to achieve these conditions now even if they were known.
Water Quality Objective: *Achieve a standard of water quality that protects and promotes a healthy aquatic ecosystem and allows aesthetic enjoyment and appropriate recreational use*	The following notes accompany this objective: • The ultimate objectives are to be derived via a localisation of ANZECC (2000) guidelines (ie. using the ANZECC process to determine site specific objectives that link to management actions). The objectives should include gross pollutant objectives. • The ultimate objective is unlikely to be achieved in the short term and therefore incremental objectives are required. • With respect to objectives for pollutant loads from the catchment, the ultimate objective is the development of a strategic framework within which development is planned so that waterbody values can be identified. Data to support this include a study of relevant catchment processes and limits on the total load a waterbody can receive. Chapter 6 of *Australian Runoff Quality* (Engineers Australia, 2003) presents a methodology for such an assessment. • There is a need for the transparent development of objectives for licenced loads by DEC. In particular, objectives for sewer overflows could potentially be reviewed in the context of improved estuary processes information. It is noted that DEC sets objectives for Sydney Water Corporation to be met as part of the various SCAMPs. • The Committee acknowledges that some waterways are only suitable for recreation for part of the time and that this would be the case even if they were in an unmodified condition (e.g. some reference sites exceed the guidelines).

Objective	Notes
Sediment and Erosion Objective: *Minimise estuary sedimentation and erosion caused by the effects of human activity in the catchment, along streambanks and on the estuary foreshore*	The following notes accompany this objective: • The implementation of this objective requires the identification of an agreed 'natural' rate of sedimentation (Note that a separate study by ANSTO (2005) considers current and historical rates of sedimentation). • Additionally, in measuring the achievement of this objective and assumption is that the 'current condition' (i.e. that evaluated by DNR as at February 2005) is the baseline as there are insufficient data to support an alternate view at this time. • Furthermore, in measuring the achievement of this objective there is a need to consider active geomorphological processes which may mask or skew any accelerated sedimentation rate. • The committee noted that the ad-hoc construction of revetments and retaining walls along the foreshore of the estuaries may be contributing to the sediment and erosion rates – but that these rates may be minor compared to the effects of unchecked development of the catchment. Information from other urbanised areas indicates that sedimentation peaks during the first phase of urbanisation and then reduces. • The committee also noted that the human activity in the catchment also includes pastoral activity (such as horse adjistment and riding) and that these activities may have a direct effect on erosion and sedimentation in the estuaries.
Cultural Heritage Objective: *Acknowledge, conserve and commemorate (as appropriate) the Aboriginal and European heritage of the estuary and foreshore*	The following notes accompany this objective: • There is a need for the identification of heritage sites in a spatial (GIS) format to assist with implementing this objective. However, information related to indigenous heritage should be held in a 'limited access' layer within Council's GIS due to its sensitive nature and managed in accordance with appropriate cultural considerations. • Protection is currently afforded to both Aboriginal and European Heritage items by a range of planning instruments and development controls. However, the Committee considers that these have been inadequate in achieving their objectives in cases such as at Sandon Point. The achievement of this objective will therefore also involve a review of where controls have been unsuccessful or inadequate with consideration of potential improvements in planning processes. • Commemoration should be undertaken as appropriate and with consultation, particularly for Aboriginal Heritage items and places.
Sustainable Development Objective: *Promote ecologically sustainable development recognising the finite capacity of estuarine ecosystems. Recognise and report on inappropriate development.*	The following notes accompany this objective: • The purposes of this objective, development is defined as both land development for residential, commercial, industrial uses as well as tourist development (and educational establishments etc) • The process of 'redevelopment' will generally result in a more sustainable outcome than that which can be achieved with existing development. • The Committee noted that this objective may be constrained as expected redevelopment on the foreshore may not occur or may take some time to occur to achieve improved setbacks of existing development for riparian corridor requirements. • The Committee also noted that risks to aquatic vegetation such as seagrass will be difficult to evaluate at present without baseline

Objective	Notes
	data. • In the achievement of this objective there is a need for recognition of processes such as climate change. • The Committee acknowledges that the process of rezoning and consolidation of industrial areas may also aid in the achievement of this objective.
Recreation Objective: *Encourage and provide facilities for appropriate recreational use of the estuary, foreshore and catchment while maintaining ecosystem viability*	The following notes accompany this objective: • This objective has linkages with the *Water Quality* objective as the estuaries may not always be in a suitable condition for primary recreational contact usage • The Committee identified a means of achieving this objective via the removal and/or rectification of unsafe foreshore structures through possible partnerships with landholders. • There is a need for formalised access points to achieve this objective which are sympathetic to the need for a continuous riparian corridor.
Flooding Objective: *Minimise the impact of flooding on existing and future development while maintaining ecosystem viability in accordance with Council's Floodplain Risk Management Plans*	The following notes accompany this objective: • The Committee acknowledges that Floodplain Risk Management plans are the relevant plans to aid in the achievement of the management of flood risk. • The achievement of the objective will be primarily through the implementation of individual entrance management policies and therefore this objective is linked with the *Estuary Entrance* objective. An important component of these policies will be communication with the community of the details of the policies. • The Committee acknowledges that entrance management policies are only likely to reduce the risks associated with frequent, low level events.
Visual Amenity Objective: *Maintain or improve the natural integrity and visual experience of the landscape from the waterway and from catchment vantage points*	The following notes accompany this objective: • This objective is expected to be difficult to measure and there is a data gap to limit the meaningful application of this objective. • The Committee agreed that the achievement of this objective is a lower priority area for management action.
Estuary Entrance Objective: *Achieve an appropriate opening regime for each estuary to address flooding, water quality and ecological concerns.*	The following notes accompany this objective: • The Committee acknowledged that it would be unlikely that a 'natural opening regime' could be restored for the area since the definition of a 'natural opening' is not available for the systems in question apart from consideration of a similar or 'reference' Lagoon/Creek with monitoring data on breakout frequency.
Information and Communications Objective: *Regularly provide information to the public associated with the estuary including details of:* • *Current conditions of the estuaries (including aquatic ecosystem and human health indicators)* • *Current planning and development activities*	The following notes accompany this objective: • The Committee agreed on the need for an emphasis on education to achieve all of the objectives. • There is a need for the intensive use of GIS data given the substantial current data set for the catchment. • Linkages between the Estuary Management Plan and State of the Environment reporting by Council are to be established. • There is a need to develop and maintain awareness within public, public authorities and industry forums to communicate the objectives of the Estuary Management Committee.

Objective	Notes
• *The impact that all land and waterway uses currently have and proposed uses potentially have on the estuary and* • *The contribution that the community can make to reducing adverse impacts and improving ecosystem condition.*	
Implementation, Monitoring and Review Objective: *Develop a plan that is easily understood yet scientifically sound, sets performance targets and includes monitoring to audit performance and is readily adaptable.*	The following notes accompany this objective: • The Committee agreed that the achievement of this objective would be through the utilization of data from a number of programs already in place as well as new programs. • The achievement of this objective needs to be consistent with other Council processes (eg. Business Planning). • Monitoring will test the effectiveness of management strategies and provide valid information to modify the Estuary Management Plan when necessary. • Reporting of the agreed performance indicators is to occur as part of State of the Environment Annual Reporting (linked with the *Information and Communications* objective).

7. MANAGEMENT OPTIONS / STRATEGIES

7.1 Identification and Compilation of Options

The identification of management options occurred through the following process:

- Initial option development by Council/DNR (at the same time as the preliminary objective development outlined in Section 6). Over 80 options were identified in this process.
- Presentation of Initial Options List to the Committee for consideration and comment
- Compilation of Committee comments and refinement of options list
- Compilation of options/actions from other Management Plans (including Stormwater Management Plan, Floodplain Management Plan, Development Consent requirements for major developments, Landscape Masterplans and discussions with various stakeholders on future works such as Sydney Water Corporation and the RTA described in Section 7.2). Over 150 options were compiled into the list.
- Translation of preliminary list of on-ground works to GIS for a spatial representation of all on-ground works in the three areas (Figures 7.1 – 7.3)
- Discussion of preliminary list of options (on-ground works, planning strategies and educational strategies) with representatives from various Council divisions (Section 2)
- Refinement of the preliminary list of options from discussions and presentation of these options in this report
- Identification of additional options through the consultation process (Section 2) and inclusion of a range of additional options.

All options were directly linked with the agreed objectives outlined in Table 7.1. Each option has a unique identifier (Option ID). A total of 211 options were compiled.

Appendix B contains a complete list of options compiled for the project. The on-ground works shown in Figures 7.1 – 7.3 are colour coded to the objectives in the table in Appendix B to correspond to those options identified in the Figures.

7.2 Management Initiatives of Stakeholder Agencies

A range of agencies also manage various elements within the sphere of influence of the estuaries, including Sydney Water Corporation and the Roads and Traffic Authority. The management initiatives of these groups relevant to the creek systems are listed below.

Sydney Water

- Bellambi Sewage transfer to Wollongong is under construction as part of the Illawarra Wastewater Strategy – 75% of the construction is complete. The main pipeline is complete and has been operational since December 2004.

- An 'Actiflow' treatment system has been installed at Bellambi to treat wet weather flows that exceed the capacity of the new pipeline prior to discharge at Belambi.
- An investigation is proposed to provide an overflow solution for East Corrimal.
- Additionally, Sydney Water proposes to install 'duck bill' valves to prevent ingress of the creek into the sewer system when the water level in Towradgi Creek is elevated.
- Sewer Catchment Asset Management Plans (SCAMPs) are being prepared for the region. Bellambi Lagoon SCAMP will be finalised next year with others to follow.
- Sewer Trunk Asset Management Plans (STAMPs) are being prepared for the region which evaluates system environmental performance on three main factors:
  - No overflow (choke)
  - Odour complaints
  - Wet weather performance.

RTA

- Northern Distributor Extension proposed for Hewitts Creek Catchment
- Proposed Lawrence Hargraves Interchange with associated new bridges (four), creek works including several spill basins, riparian rehabilitation, inclusion of an indigenous cultural heritage component (project scheduled within the next 10 years).
- Proposed additional lane to be constructed on the down hill section – Mt Ousley.
- A new culvert on Mt Ousley Road in the upper catchment is proposed.
- Environmental safeguards for some new RTA works include spill control, stormwater quality improvement devices.

7.3 Detailed Consideration of 10 Options

In addition to the overall list of compiled options (over 200 options), a detailed assessment of 10 options was undertaken for this study.

The selection process for these 10 options was undertaken via consultation with Council and the Committee. The options selected for further assessment included:

- Relocation of the Towradgi Lagoon entrance southward (Option ID 147)
- Sediment removal for Towradgi Lagoon at the connection of the northern arm (the Parker Road arm) (Option ID 78)
- Bank Rehabilitation in Fairy Creek (a range of actions and locations) (Option IDs 86 - 91)
- Bank Rehabilitation in Towradgi Creek (a range of actions and locations) (Option IDs 17, 96-101)
- Bank Rehabilitation in Hewitts and Tramway Creeks (a range of actions and locations) (Option ID 28, 102-105)
- Riparian Corridor Development Control Plan (DCP) Recommendations (for estuarine portions) (Option ID 7)
- Entrance Management Policy for Fairy Creek (Option ID 143)

- Entrance Management Policy for Towradgi Creek (Option ID 144)
- Entrance Management Policy for Hewitts and Tramway Creeks (Option ID 145, 146)
- Benefits/Impacts of a catchment-wide water sensitive urban design (WSUD) Policy on the estuaries (including consideration of features for both riparian and non-riparian properties) (Option ID 60).

Appendix C contains the detailed evaluated of the 10 options which includes the following information for each option

- Background
- Concept details
- Benefits and Impacts
- Preliminary capital and recurrent cost estimates.

7.4 Option Costing

Detailed preliminary costs were evaluated for the 10 options (Section 7.2 and Appendix C) with a simple estimate of capital and recurrent cost undertaken for the remainder of the options based on experience.

Appendix D contains the ranked list of options with costings. The process of ranking is outlined in Section 8.

8. ASSESSMENT OF OPTIONS

8.1 Overview

For each option identified, an assessment of that option is required based on:

- Achievement of objective (i.e. does the option achieve one or more of the objectives set out in Section 6.2)
- Estimation of cost (both the capital and recurrent costs)
- An assessment of the impact of the option on estuary processes (positive or negative).

To assess each option on a common basis, a decision-making framework has been developed. This framework has been developed in order to make preliminary comparisons between each option and to provide a first pass ranking of options in an open and unbiased manner in order to identify those options that have the greatest benefit and value for money.

The assessment will be refined further by the Estuary Management Committee and Council and the final assessment will take into consideration comments received from the community during the exhibition period.

8.2 Decision Making Framework

A decision-making framework has been prepared using the following criteria:

- Capital Cost Estimate
- Recurrent Cost Estimate
- Estimated Life Cycle Cost of Implementation
- Technical Feasibility/Probability of Success
- Flora Impact – Aquatic and Terrestrial
- Fauna Impact – Aquatic, Terrestrial, Avifauna
- Water / Sediment Quality Impact
- Flooding Impact
- Human User Impact
- Cultural Heritage Impact
- Community Response.

A score was assigned for each option for each criteria by a team of scientists and engineers based on the scales detailed in Tables 8.1 – 8.5. In assigning scores to each of the options it is assumed that construction impacts will be assessed prior to any physical works and that appropriate mitigation measures will be implemented to ensure minimal ecological impact during works.

Details of the way in which the community responses from the public exhibition period (Section 2) were included are outlined below.

Table 8.1 Scores and Descriptors for Assessment – Flora and Fauna

Score	Descriptor
+ / - 5	Long term*, direct** and large area positive or negative impact
+ / - 4	Long term indirect / large area or direct / medium area positive or negative impact.
+ / - 3	Medium term, varying area, combination of direct and indirect positive or negative impacts.
+ / - 2	Short term indirect / large area or direct / medium area positive or negative impact.
+ / - 1	Indirect and small area positive or negative impact.
0	No / neutral impact.

*Long term 5 – 10 years, medium term 3 – 5 years and short term 1 – 2 years or less.
**Direct impacts would be actual works such as bush regeneration and indirect impacts would cover options like educational brochures or signage.

Table 8.2 Scores and Descriptors for Assessment – Human User

Score	Descriptor
+ / - 5	Long term*, direct** and large number of users positive or negative impact
+ / - 4	Long term indirect / large number of users or direct / medium number of users positive or negative impact.
+ / - 3	Medium term, varying number of users, combination of direct and indirect positive or negative impacts.
+ / - 2	Short term indirect / large number of users or direct / medium number of users positive or negative impact.
+ / - 1	Indirect and small number of users positive or negative impact.
0	No / neutral impact.

*Long term 5 – 10 years, medium term 3 – 5 years and short term 1 – 2 years or less.
**Direct impacts would be actual works such as bush regeneration and indirect impacts would cover options like educational brochures or signage.

Table 8.3 Scores and Descriptors for Assessment – Water and Sediment Quality

Score	Descriptor
+ / - 5	Long term*, direct** and multiple pollutants (dissolved and particulate) with significant concentration or load with positive or negative impact on Lagoon water and sediment quality.
+ / - 4	Long term indirect / multiple pollutant with significant load / concentration or direct / single critical pollutant with significant load / concentration positive or negative impact.
+ / - 3	Medium term, multiple or single critical pollutant with medium sized load positive or negative impacts.
+ / - 2	Short term indirect / multiple pollutant or direct / single pollutant and medium sized load concentration positive or negative impact.
+ / - 1	Indirect, single pollutant or small load positive or negative impact.
0	No / neutral impact.

*Long term 5 – 10 years, medium term 3 – 5 years and short term 1 – 2 years or less.
**Direct impacts would be actual works such as gross pollutant traps and wetlands and indirect impacts would cover options like educational brochure or signage.

Table 8.4 Scores and Descriptors for Assessment – Flooding

Score	Descriptor
+ / - 5	Long term*, direct** and large number of properties positive or negative impact
+ / - 4	Long term indirect / large number of properties or direct / medium number of properties positive or negative impact.
+ / - 3	Medium term, varying number of properties, combination of direct and indirect positive or negative impacts.
+ / - 2	Short term indirect / large number of properties or direct / medium number of properties positive or negative impact.
+ / - 1	Indirect and small number of properties positive or negative impact.
0	No / neutral impact.

*Long term 5 – 10 years, medium term 3 – 5 years and short term 1 – 2 years or less.
**Direct impacts would be actual works such as channel conveyance improvements, flood detention basins, extensive revegetation affecting floodplain roughness.

Table 8.5 Scores and Descriptors for Assessment – Cultural Heritage

Score	Descriptor
+ / - 5	Long term*, direct** and multiple heritage items with positive or negative impact on those items.
+ / - 4	Long term indirect / multiple heritage items or direct / single critical heritage item positive or negative impact.
+ / - 3	Medium term, multiple or single critical heritage item with positive or negative impacts.
+ / - 2	Short term indirect / multiple heritage or direct / single heritage item positive or negative impact.
+ / - 1	Short term, indirect, single heritage item positive or negative impact.
0	No / neutral impact.

*Long term 5 – 10 years, medium term 3 – 5 years and short term 1 – 2 years or less.
**Direct positive impacts would be protective or preservation works.

As outlined in Section 2, consultation on the options identified in the Draft Estuary Management Study and Plan was undertaken. Feedback on options is described in detail in the *Submissions in Reply* report (Cardno Lawson Treloar, 2005b). In terms of data received, the maximum number of positive responses was used as the benchmark for the scoring of the community responses. The community were requested to provide feedback on two types of options – location specific options and catchment-wide options (non-specific locations). The feedback received was normalised to score the same maximum score as the criteria outlined in Tables 8.1 – 8.5 (i.e. a maximum of +5). This ensured that the community feedback had the same weighting for each option as the technical considerations.

8.3 Summary of Score Assignment and Benefit Index Calculation

A summary of how the benefit index calculation has been undertaken is provided in Table 8.6 below, the detail of the value adopted and a short description of the method of arriving at the value or the descriptor. This assessment has been undertaken for all options.

Table 8.6 Summary of Assessment Method

Detail / Criteria	Method of Arriving at Value / Comment
Option Identifier	Arbitrarily assigned identifier code
Details of Option	Description
Capital Cost Estimate	Capital Cost assessment either from original plan the option was derived from (eg the Stormwater Management Plan) or based on judgement from experience.
Recurrent Cost Estimate	Annual cost (for maintenance or similar to operate the option). Assessment either from original plan the option was derived from (eg the Stormwater Management Plan) or based on judgement form experience.
Estimated Life Cycle Cost of Implementation	Net present value of cost.
Flora and Fauna Impact	See Table 8.1 – Value identified qualitatively
Human User Impact	See Table 8.2 – Value identified qualitatively

Detail / Criteria	Method of Arriving at Value / Comment
Water / Sediment Quality Impact	See Table 8.3 – Value identified qualitatively
Flooding Impact	See Table 8.4 – Value identified qualitatively
Cultural Heritage	See Table 8.5 – Value identified qualitatively
Community	Submissions received during public exhibition
Total Benefit	Sum of values Scoring
Cost: Benefit Index	Log of Estimated Life Cycle Cost of Implementation / Total Benefit
Rank	Rank in list of total options (options with same cost: benefit index are assigned the same rank and later ranked independently)

8.4 Cost:Benefit Index Ranking Approach

Using the decision-making framework defined above, all options were ranked on the same basis. A summary of the most cost-effective 20 options (with the highest log NPV cost / benefit index ratios) is listed in Table 8.7. The full list of ranked options can be found in Appendix D.

Table 8.7 Highest Ranked Options (Based on Calculated Benefit Index)

ID	Management Objective	Strategy Outline	Capital Cost	Recurrent Cost	Benefit index/ log NPV	Rank
2	Habitat and Species Conservation (Aquatic Habitats)	Rezoning of Crown Land from 6(a) to a New Conservation Waterway Zone	$2,000	0	4.24	1
56	Water Quality (Statutory Controls)	Localise water quality standards (as per ANZECC, 2000) for the estuaries for aquatic ecosystems and recreational use.	$15,000	1000	3.81	2
1	Habitat and Species Conservation (Aquatic Habitats)	Fairy Lagoon in Puckeys Estate - Rezoning of Crown Land from 6(a) to 7(b)	$2,000	0	3.734	3
127	Recreation (Education)	Prepare posters for display at caravan parks and other tourist accommodation on the need for foreshore users to dispose of bait bags, drink bottles and other litter appropriately.	$3,000	200	3.10	4
144	Estuary Entrance (Statutory Controls)	Towradgi Creek - Develop an entrance management policy considering location of past openings, flood mitigation (as per FMP's), water quality, fish and invertebrate recruitment, birdlife, threatened species, cultural sites and ecology.	$39,000	21000	3.08	5
8	Habitat and Species Conservation (Foreshore	Introduce appropriate zoning or an LEP clause requiring consent from Council for any development within reserves and buffer zones, except for	$5,000	0	2.97	6

ID	Management Objective	Strategy Outline	Capital Cost	Recurrent Cost	Benefit index/ log NPV	Rank
	and Riparian Zones)	fencing, revegetation or any works contained in an Estuary Management Plan and prohibiting certain development types altogether.				
55	Habitat and Species Conservation (Education)	Provide ongoing support and opportunities for the community to participate in restoration and management of aquatic, wetland and wildlife habitats (eg through WCC's Bushcare program).	$5,000	20000	2.93	7
59	Water Quality (New and Infill Development)	Establish water quality standards for stormwater runoff from new development considering the estuary's temporal response to pollutant inputs (daily, weekly or monthly) and within the framework of the cumulative impact assessment.	$10,000	1000	2.82	8
115	Development (Statutory Controls)	Consider implications of sea level rise projections for the estuaries	$30,000	1000	2.80	9
116	Development (Statutory Controls)	Include acid sulfate soil provisions in LEP.	$5,000	0	2.43	10
145	Estuary Entrance (Statutory Controls)	Tramway Creek - Develop an entrance management policy considering location of past openings, flood mitigation (as per FMP's), water quality, fish and invertebrate recruitment, birdlife, threatened species, cultural sites and ecology.	$19,500	10500	2.43	11
146	Estuary Entrance (Statutory Controls)	Hewitts Creek - Develop an entrance management policy considering location of past openings, flood mitigation (as per FMP's), water quality, fish and invertebrate recruitment, birdlife, threatened species, cultural sites and ecology.	$19,500	10500	2.43	11
96	Sedimentation and Erosion (Works)	Towradgi Creek Stabilise Eroding Banks (Code E in Appendix C)	$150,000	2000	2.41	13
84	Water Quality (Education)	Educate specific industry groups and developers of best management practices for minimising polluted runoff.	$10,000	2000	2.33	14
57	Water Quality (Statutory Controls)	Develop and adopt a system of cumulative impact assessment for land use planning and development control by undertaking pollutant inventories an budgets for existing land uses and preparing land and water capability assessments to establish total allowable pollutant loads and other relevant loads or	$40,000	1000	2.33	15

ID	Management Objective	Strategy Outline	Capital Cost	Recurrent Cost	Benefit index/ log NPV	Rank
		factors.				
97	Sedimentation and Erosion (Works)	Towradgi Creek Revegetate Banks (Code F in Appendix C)	$150,000	5000	2.31	16
3	Habitat and Species Conservation (Aquatic Habitats)	Change the use of land that will have an adverse effect on adjacent sensitive aquatic habitats through development controls or Crown Land classification revision	$10,000	1000	2.28	17
58	Water Quality (Statutory Controls)	Strictly control water quality impacts of development during construction phase.	$5,000	20000	2.26	18
153	Information and Comm's (Education)	Develop an education brochure outlining the impacts of human activity on estuary condition and the actions that can be taken at a personal level to maintain estuary health, distribute with rate notices and make available at frequent visitation points.	$5,000	1000	2.26	19
79	Water Quality (Existing Development)	Tramway Creek - Modify barrier to tidal flushing subject to ecological assessment	$150,000	5000	2.25	20

During the course of the project, Council commissioned a preliminary specialist investigation of Option 79 (Tramway Creek – Modifications to barrier to tidal flushing). This investigation identified that the option was unlikely to provide the ecological outcomes sought and thus this option was not included in the Plan.

The ranked list of options as a result of using the decision-making framework provides a scheduled sequence of recommended activities to go into the estuary management plan.

9. ESTUARY MANAGEMENT PLAN

The outcome of the analysis of the range of estuary management options has been distilled through the ranking and scoring process described in Section 8 to develop an estuary management plan. Some options have been reordered following this process to account for the need for some investigations to occur prior to others within the planning process. All of the monitoring 'options' were included automatically in the Plan.

Table 9.1 outlines the estuary management plan action list which shows the total cost for the plan actions for the first 10 years of implementation estimated at approximately $1.892 million and a total recurrent cost at the end of the 10 year period of $436,200. This Plan generally represents the 60 highest ranked options as shown in detail in Appendix D.

Table 9.2 lists those actions identified in other plans or to be undertaken by authorities or agencies independently of the estuary management process.

The process of implementation of the actions is likely to take the form of (for works):

- Further investigations of the proposed action
- Concept design of proposed action
- Exhibition of concept design for community feedback (where required)
- Detailed design of proposed action
- Preparation of documentation for development consent (where required)
- Consent from Council
- Construction of Works.

Concurrently with these tasks, funding applications to undertake the actual works or further studies are commonly prepared. For example, each year DPI makes available Fish Habitat rehabilitation grants of up to $30,000 for community groups and Councils to undertake fish habitat rehabilitation on a dollar for dollar basis (or in-kind contribution). A range of actions listed in this Plan may be suitable for such funding.

In the case of planning actions, the implementation process is likely to take the form of:

- Further investigations of the proposed action
- Preparation of draft planning document for public exhibition
- Exhibition of document
- Revision of document to include feedback
- Adoption by Council
- In the case of revision of the LEP or related matters that require approval from the Minister for Planning, application to the Department of Planning for consideration
- Approval by the Minister
- Implementation of Planning Instrument.

In the case of education actions, the implementation process is likely to take the form of:

- Further investigations of the proposed action
- Preparation of materials for education program
- Review of materials for education program
- Implementation of Education program.

It is important to note that there are tasks identified in the Plan which are the responsibility of agencies which are not represented on the Estuary Management Committee. Neither Council nor the Committee have any authority to require these agencies to meet the responsibilities assigned in this plan, rather, in the process of preparing this Plan the voluntary commitment of the organisations has been sought.

During the course of the preparation of this Plan, the State Government announced amendments to the Environmental Planning and Assessment Act, 1979, with respect to the revision of Local Environment Plans. Consequently, a new LEP for Wollongong will be drafted by Council over the next few years. This LEP being prepared by Council would be the ideal way to implement any zoning changes. This LEP is required to be in a Standard LEP format and Council will need to consider what zones are to be contained in the LEP, zone objectives etc.

With respect to those actions identified that are contingent on the outcomes of the Sandon Point Commission of Inquiry, Council is aware of the preliminary outcomes of the CoI and the Plan is in accordance with these outcomes. If there are any significant changes to the CoI findings when fully released, this Plan is to be updated to reflect any variations.

Following the adoption of the Plan by Council, it is recommended that the Plan be reviewed in detail once every five years to ensure that the actions remain relevant as new information and data becomes available.

Table 9.1 Implementation Action List

EMS ID	Management Objective/Source Management Plan	Strategy Outline	Responsibility	Capital Cost Estimate	Recurrent Cost Estimate	Priority
Habitat and Species Conservation						
2	Habitat and Species Conservation (Aquatic Habitats)	Rezoning of Crown Land from 6(a) to a New Conservation Waterway Zone	WCC, DP	$2,000	$0	High
1	Habitat and Species Conservation (Aquatic Habitats)	Fairy Lagoon in Puckeys Estate - Rezoning of Crown Land from 6(a) to 7(b)	WCC, DNR, DL, DP	$2,000	$0	High
3	Habitat and Species Conservation (Aquatic Habitats)	Change the use of land that will have an adverse effect on adjacent sensitive aquatic habitats through development controls or Crown Land classification revision	WCC, DL	$10,000	$1000	High
55	Habitat and Species Conservation (Education)	Provide ongoing support and opportunities for the community to participate in restoration and management of aquatic, wetland and wildlife habitats (eg through WCC's Bushcare program).	WCC	$5,000	$20000	High
50	Habitat and Species Conservation (Education)	Educate Council staff on the value of foreshore vegetation.	WCC	$5,000	$1000	High
49	Habitat and Species Conservation (Education)	Educate the community on the value of estuarine habitats and how they can contribute to their protection.	WCC	$10,000	$1000	High
8	Habitat and Species Conservation (Foreshore and Riparian Zones)	Introduce appropriate zoning or an LEP clause requiring consent from Council for any development within reserves and buffer zones, except for fencing, revegetation or any works contained in an Estuary Management Plan and prohibiting certain development types altogether.	WCC, DP, DNR	$5,000	$0	High

EMS ID	Management Objective/Source Management Plan	Strategy Outline	Responsibility	Capital Cost Estimate	Recurrent Cost Estimate	Priority
30	Habitat and Species Conservation (Foreshore and Riparian Zones)	Woodlands Creek Manage Watercourse and Riparian Zone in Accordance with CoI Findings	Landowner, DP, DNR, WCC?	$50,000	$5000	High
27	Habitat and Species Conservation (Foreshore and Riparian Zones)	Woodlands Creek South Manage Watercourse and Riparian Zones in Accordance with CoI Findings	Landowner, DP, DNR, WCC?	$50,000	$5000	High
28	Habitat and Species Conservation (Foreshore and Riparian Zones)	Hewitts Creek Rehabilitate Degraded Riparian and Aquatic Habitat on Community Land (Removal of exotic species and revegetation with natives where possible) - (Code F in Appendix C)	WCC	$30,000	$10000	High
35	Habitat and Species Conservation (Foreshore and Riparian Zones)	Blue Divers - Protect and Enhance Remnant Vegetation	WCC	$20,000	$5000	High
7	Habitat and Species Conservation (Foreshore and Riparian Zones)	Prepare and adopt Riparian Corridor Management DCP. Foreshore protection to control erosion conforms to the Visual Management Plan and be of a standardised type utilising local native plants with harder materials, such as timber or rock, only where necessary.	Landowner, DP, DNR, WCC	$47,000	$17000	High
29	Habitat and Species Conservation (Foreshore and Riparian Zones)	Hewitts Creek Manage Watercourse and Riparian Zones in Accordance with CoI Findings	Landowner, DP, DNR, WCC?	$100,000	$30000	Medium
26	Habitat and Species Conservation	Tramway Creek Manage Watercourse and Riparian Zones in Accordance with CoI Findings	Landowner, DP, DNR, WCC?	$100,000	$30000	Medium

EMS ID	Management Objective/Source Management Plan	Strategy Outline	Responsibility	Capital Cost Estimate	Recurrent Cost Estimate	Priority
	(Foreshore and Riparian Zones)					
11	Habitat and Species Conservation (Foreshore and Riparian Zones)	Negotiate property agreements and property management plans with owners of land with plant and animal species and / or ecological communities or populations of significant conservation value.	CMA, WCC, DEC(NPWS)	$10,000	$10000	Medium
34	Habitat and Species Conservation (Foreshore and Riparian Zones)	Towradgi South Bank - Protect and Enhance Remnant Vegetation	WCC	$10,000	$2000	Medium
9	Habitat and Species Conservation (Foreshore and Riparian Zones)	Hewitts/Tramway Creeks Protect and Enhance Open Grassland Area for Migratory Birds	WCC, DEC(NPWS)	$20,000	$10000	Medium
31	Habitat and Species Conservation (Foreshore and Riparian Zones)	Live Steamers Rehabilitate Remnant Vegetation	WCC	$40,000	$5000	Medium
10	Habitat and Species Conservation (Foreshore and Riparian Zones)	Tramway Creek - Manage Turpentine Forest on Private Land in accordance with CoI Finding	WCC, DEC(NPWS)	$10,000	$0	Medium
46	Habitat and Species Conservation (Works)	Identify any existing acid sulfate drainage, remediation and, if required, prepare a plan for ongoing management.	WCC, DNR	$60,000	$1000	Medium

EMS ID	Management Objective/Source Management Plan	Strategy Outline	Responsibility	Capital Cost Estimate	Recurrent Cost Estimate	Priority
48	Habitat and Species Conservation (Works)	Cabbage Tree Creek - Fish Passage Improvement	WCC, DPIF	$100,000	$1000	Medium
Water Quality						
84	Water Quality (Education)	Educate specific industry groups and developers of best management practices for minimising polluted runoff.	WCC	$10,000	$2000	High
83	Water Quality (Education)	Educate the community on environmentally responsible practices around the house that protect water quality such as: composting grass clippings; using organic rather than synthetic fertilisers; applying fertiliser sparingly and according to soil requirements; vegetating bare soil areas; using phosphate-free detergents; washing cars on grass; capturing pet droppings; promote livestock management; and not dumping refuse on the foreshores and in the bush.	WCC	$10,000	$1000	High
77	Water Quality (Existing Development)	Fairy Creek - Clear accumulated rubble and anthropogenic material (Code F in Appendix C)	WCC, DPIF	$50,000	$5000	High
64	Water Quality (Existing Development)	Revise Stormwater Management Plan for existing developed areas within the framework of the cumulative impact assessment - include maintenance of implemented SQIDs	WCC, DEC(EPA)	$20,000	$1000	High
76	Water Quality (Existing Development)	Conduct a foreshore pollutant audit and remediate inappropriate practices.	WCC	$50,000	$5000	High
59	Water Quality (New and Infill Development)	Establish water quality standards for stormwater runoff from new development considering the estuary's temporal response to pollutant inputs (daily, weekly or monthly) and within the framework of the cumulative impact assessment.	WCC	$10,000	$1000	High
61	Water Quality (New and Infill Development)	Require total water cycle strategies for major rezonings and Development Applications.	WCC, DNR	$0	$5000	High
62	Water Quality (New and Infill	Require submission of an environmental management plan with any Development Application for a proposal that has the	WCC	$0	$5000	High

EMS ID	Management Objective/Source Management Plan	Strategy Outline	Responsibility	Capital Cost Estimate	Recurrent Cost Estimate	Priority
	Development)	potential to pollute waterways.				
60	Water Quality (New and Infill Development)	Adopt Water Sensitive Urban Design principles, using the LEP or a separate LGA-wide DCP.	WCC	$66,000	$17000	High
56	Water Quality (Statutory Controls)	Localise water quality standards (as per ANZECC, 2000) for the estuaries for aquatic ecosystems and recreational use.	WCC	$15,000	$1000	High
58	Water Quality (Statutory Controls)	Strictly control water quality impacts of development during construction phase.	WCC	$5,000	$20000	High
57	Water Quality (Statutory Controls)	Develop and adopt a system of cumulative impact assessment for land use planning and development control by undertaking pollutant inventories an budgets for existing land uses and preparing land and water capability assessments to establish total allowable pollutant loads and other relevant loads or factors.	WCC	$40,000	$1000	Medium
78	Water Quality (Existing Development)	Towradgi Creek - Remove Constriction to Tidal Flow Via Dredging	WCC, DPIF	$114,000	$3000	Medium
Sedimentation and Erosion						
108	Sedimentation and Erosion (Education)	Educate the community on the need to prevent sediment generation at the source by drain stencilling, preventing soils being washed from yards, vegetation buffers etc.	WCC	$5,000	$2000	High
96	Sedimentation and Erosion (Works)	Towradgi Creek Stabilise Eroding Banks (Code E in Appendix C)	WCC	$150,000	$2000	High
97	Sedimentation and Erosion (Works)	Towradgi Creek Revegetate Banks (Code F in Appendix C)	WCC	$150,000	$5000	High
95	Sedimentation and Erosion (Works)	Towradgi Creek Stabilise Entrance Dunes (to include beach access track) (Code A in Appendix C)	WCC	$50,000	$10000	High
107	Sedimentation and Erosion (Works)	Review condition of existing stormwater drain outlets and repair, construct sediment traps or mini-wetlands where appropriate and space permits and remove sediment fans.	WCC	$30,000	$5000	Medium
Cultural Heritage						
111	Cultural Heritage	Identify sites of significant Aboriginal and European heritage	WCC	$40,000	$2000	High

EMS ID	Management Objective/Source Management Plan	Strategy Outline	Responsibility	Capital Cost Estimate	Recurrent Cost Estimate	Priority
	(Statutory Controls)	and protect through amendment of the LEP. (Note: Detailed study for Sandon Point area likely to be undertaken following the Commission of Inquiry).				
Development						
113	Development (Statutory Controls)	Review all zonings - where adjacent to the estuary, the catchment, to assess the potential for each development type to impact on estuarine habitats and their flora and fauna, water quality, sedimentation and erosion. Require development consent for all land uses that potentially have adverse impacts on estuarine ecosystems and prohibit development with impacts that cannot be reasonably mitigated.	WCC	$30,000	$1000	High
120	Development (Existing Development)	Conduct an analysis of the risk of damage to the estuarine ecosystem (i.e. a sensitivity assessment) by each existing land use or practice using environmental factors such as: soil erodibility; proximity to streams; estuary dilution, mixing and flushing ability; proximity to key estuarine habitats eg seagrass; geomorphic maturity of the estuary. Using the results of the risk analysis, either progressively change current land use practices, discourage them or phase them out.	WCC	$40,000	$2000	High
115	Development (Statutory Controls)	Consider implications of sea level rise projections for the estuaries	WCC	$30,000	$1000	High
116	Development (Statutory Controls)	Include acid sulfate soil provisions in LEP.	WCC, DNR, DP	$5,000	$0	High
119	Development (Existing Development)	Prepare a Development Control Plan which provides guidelines for tourist and recreational development and activities on public and privately owned land in and around the estuary and its tributaries with the aim of: protecting ecological communities; maintaining a satisfactory standard of water quality; preserving scenic quality; providing siting and design principles for new buildings and waterside structures; identifying locations with potential for foreshore	WCC	$30,000	$10000	Medium

EMS ID	Management Objective/Source Management Plan	Strategy Outline	Responsibility	Capital Cost Estimate	Recurrent Cost Estimate	Priority
		access.				
118	Development (New Development)	Require that a Local Environmental Study be prepared for a major LEP or rezoning proposal for any area within or adjoining an estuary. The LES should consider potential impacts on estuarine values including the ecosystem, threatened species, water quality, cultural heritage, foreshore and estuary access and usage, population levels with tourist influx, public amenity, fishing and acid sulfate soils.	WCC, DNR, DP	$5,000	$1000	Medium
Recreation						
127	Recreation (Education)	Prepare posters for display at caravan parks and other tourist accommodation on the need for foreshore users to dispose of bait bags, drink bottles and other litter appropriately.	WCC	$3,000	$200	High
121	Recreation (Waterway)	Survey public access points including beaches, jetties, boat ramps and parking and assess whether existing access is appropriately located considering environmental effects and proximity to waterway usage and whether the level of facilities is sufficient to satisfy demand. Ensure sufficient and appropriate foreshore land is reserved for access and facilities.	WCC	$10,000	$2000	Medium
Estuary Entrance						
144	Estuary Entrance (Statutory Controls)	Towradgi Creek - Develop an entrance management policy considering location of past openings, flood mitigation (as per FMP's), water quality, fish and invertebrate recruitment, birdlife, threatened species, cultural sites and ecology.	WCC	$39,000	$21000	High
145	Estuary Entrance (Statutory Controls)	Tramway Creek - Develop an entrance management policy considering location of past openings, flood mitigation (as per FMP's), water quality, fish and invertebrate recruitment, birdlife, threatened species, cultural sites and ecology.	WCC	$19,500	$10500	High
146	Estuary Entrance (Statutory Controls)	Hewitts Creek - Develop an entrance management policy considering location of past openings, flood mitigation (as per FMP's), water quality, fish and invertebrate recruitment, birdlife, threatened species, cultural sites and ecology.	WCC	$19,500	$10500	High

EMS ID	Management Objective/Source Management Plan	Strategy Outline	Responsibility	Capital Cost Estimate	Recurrent Cost Estimate	Priority
143	Estuary Entrance (Statutory Controls)	Fairy Creek - Develop an entrance management policy considering location of past openings, flood mitigation (as per FMP's), water quality, fish and invertebrate recruitment, birdlife, threatened species, cultural sites and ecology.	WCC	$39,000	$21000	High
Information and Communications						
150	Information and Communications (Education)	Develop an Estuary Management Plan summary to widely distribute to local residents and make the full plan available for public perusal at any time.	WCC	$5,000	$2000	High
154	Information and Communications (Education)	Use the local media to publicise the management plan, results of monitoring programs and issues of concern as they arise.	WCC	$5,000	$2000	Ongoing
211	Information and Communications	Periodic data transfer on sewer overflow incidents from Sydney Water database to Council database to allow for interpretation of water quality data	WCC, Sydney Water	$0	$500	Ongoing
153	Information and Communications (Education)	Develop an education brochure outlining the impacts of human activity on estuary condition and the actions that can be taken at a personal level to maintain estuary health, distribute with rate notices and make available at frequent visitation points.	WCC	$5,000	$1000	Medium
155	Information and Communications (Education)	Use Council's web site as a means of distributing all the above educational material.	WCC	$10,000	$5000	Medium
Implementation, Monitoring and Review						
156	Implementation, Monitoring and Review (*Statutory Controls*)	Identify how the recommendations of an Estuary Management Plan relating to statutory controls are to be incorporated into Council's planning and development control system, eg environmental planning instruments such as the LEP or else an estuary-specific or LGA-wide DCP.	WCC	$5,000	$1,000	High
157	Implementation, Monitoring and Review (Works)	Develop and implement a monitoring program for individual works to ensure that they performs as expected.	WCC	$10,000	$5,000	High
158	Implementation, Monitoring and	Develop and implement an overall monitoring program for the Management Plan to assess performance and enable plan	WCC	$20,000	$75,000	High

EMS ID	Management Objective/Source Management Plan	Strategy Outline	Responsibility	Capital Cost Estimate	Recurrent Cost Estimate	Priority
	Review (Monitoring)	auditing at regular intervals and subsequent adaptation of the plan.				
159	Implementation, Monitoring and Review (Monitoring)	Encourage community involvement in monitoring including, for example: water quality; foreshore pollutant sources; bank erosion; riparian vegetation; stormwater outlet sedimentation rates; aquatic plant growth, eg sedges, reeds, seagrass & algae; entrance opening and closing; recreational fish catches; damage to foreshore access points.	WCC	$10,000	$10,000	Medium
Flooding						
165	Flood Risk Management Plans (Catchment Wide Measures)	Policy for Management of Escarpment Runoff.	WCC	$50,000	$1000	High
160	Flooding (Statutory Controls)	Require water quality, as well as quantity, be considered in the design of any flood detention structures.	WCC	$1,000	$500	High
Visual Amenity						
141	Visual Amenity (Education)	Encourage residents of waterfront properties to purchase native plants through Council's Green Plan program	WCC	$0	$5000	Medium
133	Visual Amenity (Statutory Controls)	Apply sound landscape design principles to achieve ecological and recreational objectives while giving consideration to the visual amenity of residents and visitors.	WCC	$0	$1000	Medium
TOTAL COSTS				**$1,892,000**	**$436,200**	

*Implementation is dependent on the availability of funds and Council resources
**High – 2 – 5 years for implementation
**Medium 5 – 10 years for implementation

Table 9.2 Complementary Actions Funded Under Other Plans or Actions with Non-Specific Implementation

EMS ID	Management Objective	Strategy Outline	Responsible Agency	Source Management Plan/Location
6	Habitat and Species Conservation (Foreshore and Riparian Zones)	Bring significant / important foreshore and riparian areas into public ownership whenever opportunities arise through rezoning, development approvals or acquisition. (See FPMP Actions)	WCC	FPMP
99	Sedimentation and Erosion (Works)	Towradgi Creek Near Upstream Footbridge Stabilise Steep Banks (Code H in Appendix C)	WCC	FPMP
166	Flood Risk Management Plans (Catchment Wide Measures)	Voluntary house purchase - 5 properties.	WCC	FPMP
167	Flood Risk Management Plans (Catchment Wide Measures)	Voluntary reconstruction / redevelopment - 3 properties.	WCC	FPMP
170	Flood Risk Management Plans - South Angels Creek (Towradgi Catchment)	Voluntary reconstruction / redevelopment - 1 property.	WCC	FPMP
171	Flood Risk Management Plans - North Angels Creek (Towradgi Catchment)	Voluntary house raising - 1 property	WCC	FPMP
172	Flood Risk Management Plans - North Corrimal Creek (Towradgi Catchment)	Voluntary house purchase - 4 properties.	WCC	FPMP
173	Flood Risk Management Plans - North Corrimal Creek (Towradgi Catchment)	Voluntary reconstruction / redevelopment - 1 property.	WCC	FPMP
174	Flood Risk Management Plans - North Corrimal Creek (Towradgi Catchment)	Debris control structures - 4 locations.	WCC	FPMP
175	Flood Risk Management Plans - Carr Creek (Towradgi Catchment)	Voluntary house raising - 13 properties.	WCC	FPMP
176	Flood Risk Management Plans - Parker Creek (Towradgi Catchment)	Voluntary house raising - 2 properties.	WCC	FPMP
177	Flood Risk Management Plans - Parker Creek (Towradgi Catchment)	Voluntary reconstruction / redevelopment - 4 properties.	WCC	FPMP
178	Flood Risk Management Plans - Slacky Creek	Old mine rail: Formalise diversion to Tramway and Hobart St: Formalise diversion to Tramway.	WCC	FPMP
179	Flood Risk Management Plans -	William St to Hobart St: Sediment basin	WCC	FPMP

EMS ID	Management Objective	Strategy Outline	Responsible Agency	Source Management Plan/Location
	Slacky Creek			
180	Flood Risk Management Plans - Slacky Creek	Coarse Debris Trap	WCC	FPMP
181	Flood Risk Management Plans - Tramway Creek	Princes Highway to Rail line: Property Purchase (2 properties).	WCC	FPMP
182	Flood Risk Management Plans - Woodlands Creek	Diversion to Hewitts: Re-divert Woodlands Creek to Tramway Creek and close existing gabion lined connection	Landowner, DNR, WCC?	FPMP
184	Flood Risk Management Plans - Hewitts Creek	Adjacent to Corbett Ave: Levee north bank.	Landowner, DNR, WCC?	FPMP
185	Flood Risk Management Plans - Hewitts Creek	Lawrence Hargraves Drive to the Rail line: Voluntary purchase offer (no 419 Lawrence Hargraves Drive).	WCC	FPMP
186	Flood Risk Management Plans - Hewitts Creek	Lawrence Hargraves Drive to the Rail line: Rehabilitate creek channel.	WCC	FPMP
187	Flood Risk Management Plans - Hewitts Creek	Bangalow Rd to Kelton Ln: Coarse Debris trap.	WCC	FPMP
188	Flood Risk Management Plans - Hewitts Creek	Stream 4 - Deborah Ave: Coarse debris trap.	WCC	FPMP
205	Flooding (Statutory Controls)	Adopt a foreshore building line along all creeks which accords with the boundaries of the High Flood Risk Precinct and other environmental and erosion risk criteria necessitating setbacks from creeks. The FSBL should be identified on Council's maps. This process should also involve a review of the appropriateness of the zoning of individual land parcels, should the combined flood risk and environmental criteria result in a FSBL which substantially affects reasonable development expectations.	WCC	FPMP
206	Flooding (Statutory Controls)	Council to prepare and implement a Riverine Corridor Strategy for the creek corridors within the study area, to improve corridor linkages and restore their ecological value and remove inappropriate vegetation which impedes the flow of water or forms a source of debris which exacerbates flooding impacts.	WCC	FPMP
207	Flooding (Statutory Controls)	Council to investigate a policy of formalising creek corridors within publicly owned land or with drainage easements held to the benefit of Council	WCC	FPMP

EMS ID	Management Objective	Strategy Outline	Responsible Agency	Source Management Plan/Location
		when dealing with development applications involving the redevelopment of flood affected lands. This will require further research of the extent of easement of land acquisition required, the likelihood of redevelopment in areas where such acquisition is required, the impact on the functioning of individual properties and the potential costs to Council.		
4	Habitat and Species Conservation (Aquatic Habitats)	Where alternative siting is not appropriate, adopt the principle of environmental compensation in the approval process for any activity that causes unavoidable damage to any estuarine habitat or catchment that is of importance to the estuary.	WCC, DEC(NPWS)	NI
5	Habitat and Species Conservation (Aquatic Habitats)	Towradgi Creek - Bring significant / important foreshore and riparian areas into public ownership through development opportunity	WCC	NI
73	Water Quality (Existing Development) Various	Install CDS units in high profile locations upstream of important wetlands and recreational facilities	WCC	NI
74	Water Quality (Existing Development) Various	Rework surface drainage of playing fields to provide long linear wetlands along field perimeter. Stormwater from adjacent housing to be directed through these wetlands	WCC	NI
75	Water Quality (Existing Development) Fairy Lagoon	Replacement of existing lined trunk drainage system with natural open channel systems with riparian vegetation (at priority high profile locations such as Stuart Park)	WCC	NI
114	Development (Statutory Controls)	Adopt a precautionary approach of accepting a lower level of risk (i.e. a wider safety margin) for managing existing and proposed land and waterway uses affecting highly valued environmentally sensitive components of the estuarine ecosystem.	WCC	NI
123	Recreation (Foreshore Open Space)	Maximise public ownership and appropriate access to Council and Crown foreshore land.	WCC	NI
125	Recreation (Works)	Restrict public access to defined alignments (eg access trails, boardwalks) and control environmental damage.	WCC	NI
126	Recreation (Works)	Based on the access and demand survey, provide facilities such as parking, litter collection, amenities and walking trails.	WCC	NI
148	Estuary Entrance (Works)	Where required survey low-lying assets (including wetlands).	WCC	NI
162	Flooding (Works)	Install rainfall/water level/other gauges as required	DNR	NI
25	Habitat and Species Conservation (Foreshore and Riparian Zones)	Rehabilitation in Accordance with VMP prep by Sandon Pt Developer	Stockland, DNR, WCC	SPdev

EMS ID	Management Objective	Strategy Outline	Responsible Agency	Source Management Plan/Location
80	Water Quality (Existing Development) Towradgi Creek	East Corrimal - Address Sewerage Issues with Creek Inflow Prevention	SWC	SydWater
81	Water Quality (Existing Development) Towradgi Creek	Towradgi Creek - Address Sewer Wet Weather Flow Capacity Issues	SWC	SydWater
82	Water Quality (Existing Development)	SCAMPS in all catchments where faecal contamination is an issue	SWC	SydWater

FPMP – Floodplain Management Plan, SPDev – Sandon Point Developer, NI – Not identified as yet, SydWater/SWC – Sydney Water Corporation.

10. PERFORMANCE INDICATORS AND MONITORING PLAN

To evaluate the effectiveness of the Plan outlined in Section 9 as well as the overall health of the estuaries monitoring is required.

A detailed review of appropriate 'indicators' was undertaken as part of the *Further Processes Studies* (Cardno Lawson Treloar, 2005a) which was conducted concurrently with the preparation of the Estuary Management Plan. Full details of the rationale for the selection of the indicators can be found in the *Further Processes Studies* report.

Table 10.1 shows the selected performance indicators and the frequency and details of the monitoring required to evaluate the performance indicators. The indicators have been linked to the management objectives which are outlined in detail in Section 6.

Table 10.1 Selected Indicators and Performance (Alphabetically Ordered)

Management Objective(s)	Indicator	Monitoring Requirements
Water Quality **Recreation** **Visual Amenity**	*Algal Blooms*	Algal monitoring should be carried out during the summer months, in conjunction with the water quality monitoring campaign, near popular recreational sites. Additional samples should be taken during the monthly sampling at WWWQ sites following visual evidence of blooms. Sampling may be required following a report logged into the "Incident Register". **Performance:** Number of exceedences of 15,000 cells/mL annually.
Habitat and Species Conservation	*Animal Disease/Lesions*	Animal disease/lesions will most often be reported by the public through the "Incident Register". Monitoring may also be carried out, as necessary, at locations where environmental stressors are known/thought to be impacting on the animals present. **Performance:** Number of incidents per year.
Habitat and Species Conservation	*Animal Kills*	Animal kills will most often be reported by the public through the "Incident Register". Monitoring may also be carried out, as necessary, at locations where environmental stressors are known/thought to be impacting on the animals present.

Management Objective(s)	Indicator	Monitoring Requirements
		Performance: Number of incidents per year.
Habitat and Species Conservation	*Animal or plant species abundance*	Species abundance monitoring should be undertaken in a specified area which is considered representative of the estuary (this should be done for each estuary). The monitoring should be carried out monthly for an annual cycle to determine variability with a repeat of the process once every five years or at a rate to be determined depending on the outcomes of the first annual monitoring period. Where possible the monitoring should be undertaken at at least one fully open condition and one fully closed condition. The establishment of a standardised monitoring plot at selected rehabilitation sites at which details concerning the species composition and structure of the vegetation is collated on an annual basis, including information concerning the pre-rehabilitation works vegetation. Standardised fauna surveys could also be carried out on a six monthly basis to collate information concerning the native fauna species utilising the subject areas and their response to changes induced by the rehabilitation works. **Performance:** Change in composition of structure from baseline data and reference site.
Habitat and Species Conservation	*Animals killed or injured by litter (entanglement, starvation, suffocation)*	Animals killed or injured by litter will be reported by the public through the "Incident Register". In addition to this if any of such incidences are noted during Council sampling campaigns, these can also be included in the Database. **Performance:** Number of incidents per year.
Water Quality	*Chlorophyll a*	Monitored monthly at all WWWQ sites. **Performance:** Number of exceedences of localised guideline per year.
Water Quality	*Dissolved Oxygen (DO)*	Monitored monthly at all WWWQ sites (mid-depth of water column) **Performance:** Number of exceedences of localised guideline per year.
Estuary Entrance	*Estuary mouth opening/closing*	All estuary opening and closing should be recorded by visual inspection (to form part of the entrance management policy). The automatic water level gauges can be used to trigger a visual inspection of the entrance. **Performance:** Annual number of times entrance inspected, manually opened and annual number of resident

Management Objective(s)	Indicator	Monitoring Requirements
		complaints for nuisance flooding.
Habitat and Species Conservation	*Extent/distribution of key habitat types*	An annual systematic photographic or satellite image analysis of each of the catchments to investigate any changes in extent/distribution of key habitat and vegetation types that occurs within the catchments. **Performance:** Change in condition from baseline data.
Water Quality	*Faecal Coliforms*	Monitored monthly at all WWWQ sites. Faecal coliforms should also be monitored during/after known sewer overflow events. Sydney Water holds a register of both wet and dry overflow events which can be checked to trigger monitoring (see "Sewer Overflows" indicator). **Performance:** Number of exceedences of localised guideline per year.
Water Quality	*Heavy Metals in the water column (Cu, Zn, Pb, Mn, As and Fe).*	Monitored monthly at all WWWQ sites. **Performance:** Number of exceedences of localised guidelines per year.
Water Quality	*Heavy Metals in sediments (Cu, Zn, Pb, Mn, As and Fe).*	Three sites within Fairy Creek, two sites in Towradgi Creek, one site in Tramway Creek and one site in Hewitts Creek once every five years. **Performance:** Number of exceedences of localised guidelines per year.
Water Quality	*pH*	Monitored monthly at all WWWQ sites (mid-depth of water column). **Performance:** Number of exceedences of localised guidelines per year.
Water Quality **Visual Amenity** **Recreation**	*Load of Gross Pollutants Removed from Traps and on 'Clean up Australia Day'*	As a minimum, this program should be run in conjunction with the annual Clean up Australia Day campaign. **Performance:** Change in Gross Pollutant load over time.
Flooding	*Properties flooded*	After all flood events all overfloor and overground flooding should be recorded. Additional details such as depth and duration of flood should be included as available. **Performance:** N/A – used for interpretation of other data.

Management Objective(s)	Indicator	Monitoring Requirements
Water Quality	*Salinity*	Monitored monthly at all WWWQ sites. **Performance:** N/A – used for interpretation of other data.
Sediment and Erosion	*Sedimentation/erosion rates*	Bed sediment composition and comparison with historical sedimentation rates evaluated by ANSTO.
Water Quality **Recreation** **Visual Amenity**	*Sewer Overflows*	Transfer of Sydney Water records of dry and wet weather sewer overflows to a Council Database for comparison with water quality data. **Performance:** Number of overflows per year.
Water Quality	*Total nutrients in sediments with dissolved nutrient in the sediments*	Studies completed by DEC should be undertaken on a five yearly cycle with additional data showing seasonal changes and a greater spatial distribution of sites. **Performance:** Change in baseline data.
Water Quality	*Total nutrients in the water column with dissolved nutrients in the water column (TN, TKN NOx, NH4+, TP and TRP)*	Monitored monthly at all WWWQ sites and automatic sampling triggered by a wet weather event at at least one location in each catchment. **Performance:** Number of exceedences of localised guidelines per year.
Water Quality	*Turbidity/water clarity*	Monitored monthly at all WWWQ sites. Turbidity should be measured at the surface and bottom of the water column. **Performance:** Number of exceedences of localised guidelines per year and change in baseline data.
Water Quality	*Water temperature*	Monitored monthly at all WWWQ sites (at mid depth). **Performance:** Any significant variation from local baseline data. Generally used for the interpretation of other data.

This monitoring plan provides a framework and guidelines for a comprehensive and integrated biophysical monitoring program. The overall goal of the monitoring program is to assess the long-term health and integrity of the Estuaries, and the effectiveness of the implementation of the Estuary Management Plan initiatives. The program will collect and build upon monitoring efforts that are ongoing. Figure 10.1 details the existing and proposed regular monitoring sites.

It should be noted that ANZECC (2000) makes reference to indicators of global processes of sea level and sea surface temperature. These have not been included specifically in the performance indicators for the Estuaries. It is recommended that

consideration of the impacts of these processes be included on a periodic basis (once every 5 years). Reports on sea level change can be obtained from a range of groups (including the National Tidal Facility) and reports on sea surface temperature can be obtained from the CSIRO (Division of Marine Research).

Overall, with the progressive implementation of the various components of the Estuary Management Plan (Section 9) the performance indicators should show an improvement in the overall health of the estuaries. Where improvement is not observed, a review of the effectiveness of the management strategies implemented is recommended and the Plan updated in an adaptive management fashion. It is recommended this occur on a five yearly cycle following the completion of the monitoring cycles identified in Table 10.1.

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12. QUALIFICATIONS

This report has been prepared to cover a wide range of issues and as such, detailed focus on some specific issues for the estuary was not undertaken. The estuarine system is a complex one and limitations within available data result in the requirement for further research and analysis over time.

The report relies on data from a range of sources including Wollongong City Council electronic geographic information system data and bathymetric survey by DNR.

13. GLOSSARY*

AASS	Actual Acid Sulfate Soil
Algae	Non-rooted aquatic plants, specifically non-vascular photosynthetic organisms with unicellular reproductive organs, including phytoplankton and seaweeds.
Advective Transport	The transport of dissolved material by water movement.
Aerobic Bacteria	Bacteria that obtain metabolic energy by aerobic (oxygen requiring) respiration.
Australian Height Datum (AHD)	A common national plane of level corresponding approximately to mean sea level.
Algal Bloom	The excessive growth of phytoplankton, generally caused by high nutrient levels. Can result in deoxygenation of the water mass, leading to the death of aquatic flora and fauna.
Amenity	Those features of an estuary that foster its use for various purposes, e.g. clear water and sandy beaches make beach-side recreation attractive.
Amphibian	Any frog or other member of the class amphibia that is native to Australia, including the eggs and the young thereof.
Amphipods	Laterally compressed crustacea, e.g. sand hoppers.
Anaerobic Bacteria	Bacteria that obtain metabolic energy by a variety of non-aerobic (not oxygen dependent) pathways, including the reduction of nitrates ('denitrification') and/or sulfates.
ANC	Acid Neutralising Capacity
Animal	Any animal, whether vertebrate or invertebrate, and at whatever stage of development, but does not include fish within the meaning of the Fisheries and Oyster Farms Act, 1935, other than amphibians or aquatic or amphibious mammals or aquatic or amphibious reptiles'.
Annual Exceedence Probability (AEP)	Refers to the probability or risk of an event (e.g. a flood) of a given size occurring or being exceeded in any given year. A 90% AEP flood has a high probability of occurring or being exceeded; it would occur quite often and would be relatively small. A 1%AEP flood has a low probability of occurrence of being exceeded; it would be rare but it would be relatively large.
Anoxic Conditions	Conditions typified by very low to zero dissolved oxygen concentrations.
ANZECC Guidelines	Australian and New Zealand standards and parameters of water quality for protection of ecosystems and other aquatic environments.
ARI	Average Recurrence Interval
ASS	Acid sulfate Soil

Baseline Monitoring	A monitoring program aimed at determining long-term and possibly pre-disturbance levels and variation in some parameter of interest, e.g. dissolved oxygen.
Bathymetry	The topography of the bed of the estuary. Generally determined by hydrographic survey depth soundings.
BBQ	Barbecue
Bed Load	That portion of the total sediment load that flowing water moves along the bed by the rolling or saltating of sediment particles.
Benthos, Benthic Organisms	Organisms living in or on the bed of a waterbody.
Biological Oxygen Demand (BOD)	Oxygen required by aerobic bacteria in metabolising detritus.
Biomass	The mass of living material contained in a system of interest (includes both plant and animal matter).
Biota	Living organisms.
Bird	Any bird that is native to, or is of a species that periodically or occasionally migrates to, Australia, and includes the eggs and the young thereof and the skin, feathers or any other part thereof.
BOD	Biological Oxygen Demand
Calibration	The process by which the results of a computer model are brought to agreement with observed data.
CAMBA	China Australia Migratory Bird Agreement
Catchment	The area draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the main stream.
CD	Chart Datum
Chlorophyll-a (Chla)	Chlorophyll refers to the green pigments of plants. Chlorophyll a and b are the two most common green pigments in plants. Chlorophyll-a concentration is used as a surrogate measure for the concentration of phytoplankton biomass in the water column.
CoI	Commission of Inquiry (for Sandon Point)
DEC	Department of Environment and Conservation
Degradation	A reduction in the area of estuarine habitat; or in the well-being, health and viability of estuarine ecosystems; or in estuarine amenity.
Denitrification	See anaerobic bacteria.
Depauperate	A condition which is generally poor or impoverished.

Detritus	All non-living organic material, including animal waste products and the remains of animals' plants and micro-organisms/ together with the associated microbial community (bacteria and fungi).
Detention	Detention systems have the effect of storing runoff and releasing it at a rate no greater than the pre-development peak discharge.
Diatoms	Single celled water plants.
Diffuse Source Pollution	Pollution originating from a widespread area, e.g. urban stormwater runoff, agricultural runoff.
DIP	Dissolved Inorganic Phosphorus
Discharge	The rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow which is a measure of how fast the water is moving rather than how much is moving.
Dispersive Transport	The transport of dissolved matter through the estuary by vertical, lateral and longitudinal mixing associated with velocity shear.
Dissolved Oxygen	Atmospheric oxygen that dissolves in water. The solubility of oxygen in water depends upon temperature and salinity.
Diurnal	A daily variation, as in day and night.
DIPNR	Department of Infrastructure, Planning and Natural Resources (now the Department of Natural Resources and the Department of Planning)
DLWC	Department of Land and Water Conservation (now the Department of Natural Resources)
DNR	Department of Natural Resources
DO	Dissolved Oxygen
DON	Dissolved Organic Nitrogen
DPWS	Department of Public Works and Services (now the Department of Commerce)
Drogue	Commonly a floating device used to track water movement. In the field the drogue usually floats on the surface weighted by a skirt made of mesh material set at the depth of interest. Drogues can be simulated in numerical modelling for the same purpose as in the field.
Ebb Tide	The outgoing tidal movement of water within an estuary.
Ecologically Sustainable Development	Development that does not interfere with the short and long term well-being, health and viability of estuarine ecosystems.
Ecosystem	A community of living organisms, together with the environment in which they live and with which they interact.

Eddies	Large, circular, swirling movements of water, often metres or tens of metres across.
EIS	Environmental Impact Statement
EMC	Event-Mean Concentration. The average concentration over a period of time. It is determined by measuring the concentration and flowrate of a particular chemical in a stream or creek, and then dividing the total load by the volume of water. It can then be used to evaluate long-term pollutant loads from a catchment.
Endangered Fauna	Protected Fauna of a species under Schedule 1 of the Threatened Species Conservation Act, 1995.
Entrance Bar	A deposit of sand or silt across the entrance to an estuary. The material may be either fluvial or marine in origin.
Environmental Impact Assessment	An assessment of the impact of a proposed development.
Epibiota	Organisms (plants and animals) attached to other organisms.
Epiphytic	(Of living organisms) attached to and growing on the surface of a plant, but not obtaining food or nutrients from the plant.
Estuarine Processes	Those processes that affect the physical, chemical and biological behaviour of an estuary, e.g. predation, water movement, sediment movement, water quality, etc.
Estuary	An enclosed or semi-enclosed body of water having an open or intermittently open connection to coastal waters in which water levels vary in a periodic fashion in response to ocean tides.
Estuary Management Process	A sequence of activities starting with the formation of an Estuary Management Committee and culminating in the implementation of an Estuary Management Plan that will foster the balanced and sustainable use of estuaries.
Eutrophication	The build-up of nutrient levels in a water body leading to the excessive growth of aquatic plants, which in turn depletes dissolved oxygen levels in the waterbody.
Fauna	Any mammal, bird, reptile or protected amphibian.
FC	Faecal Coliforms
Fish (In the context of the Fisheries & Oyster Farms Act, 1935)	All or any of the varieties of marine, estuarine or freshwater fishes (whether indigenous or not) and their young, fry and spawn, and unless the contrary intention be expressly stated or the context otherwise requires, includes crustacea and oysters and all marine, estuarine and freshwater animal life, and any part of a fish as herein before defined, but does not include any species of whales.
Flocculate	The coalescence, through physical and chemical processes, of individual suspended partides into larger particles ('floes').

Flood Mitigation Works	Structures that are designed to manage floodwaters (e.g. levees, retarding basins).
Flood Tide	The incoming tidal movement of water within an estuary.
Fluvial	Pertaining to non-tidal flows.
Fluvial Processes	The erosive and transport processes that deliver terrestrial sediment to creeks, rivers, estuaries and coastal waters.
Fluvial Sediments	Land-based sediments carried to estuarine waters by rivers.
Foraminiferida	Benthic Fauna – Order of testate, amoeboid Protozoa, in which the cell is protected by a test, consisting of one too many chambers
Foreshore	The area of shore between low and high tide marks and land adjacent thereto.
Fortnightly Tides	The variation in half-tide levels caused by the monthly cycle of Spring and Neap Tides.
Geomorphology	The study of the origin, characteristics and development of land forms.
GPT	Gross Pollutant Trap
Habitat	The places in which an organism lives and grows. Many estuarine organisms require different habitats at different stages of their life cycles.
Half-Tide Level	The average of successive high tide and low tide levels.
Halocline	A zone in the water column where the vertical change of salinity is relatively sharp.
Heavy Metals	Generally, those metals that occur in Groups IS to VIIIB of the Periodic Table with atomic numbers between 21 and 84, but excluding Rare Earth elements. Heavy metals generally have a specific gravity of 5.0 or more and include chromium, iron, nickel, copper, zinc, silver, cadmium, platinum, gold, mercury and lead. Although essential in trace concentrations, some heavy metals are toxic to aquatic organisms at higher concentrations, e.g. mercury, lead, copper and zinc. Even when present in sub-lethal concentrations, heavy metals may adversely affect the health of aquatic organisms.
Herbivores	Grazing animals.
H_s (Significant Wave Height)	H_s may be defined as the average of the highest 1/3 of wave heights in a wave record ($H_{1/3}$), or from the zeroth spectral moment (H_{mo}), though there is a difference of about 5 to 8%.
Humic Acid	Acidity resulting from the decomposition of organic materials.
HWOST	High Water Ordinary Spring Tides

Hydraulic Regime	The variation of estuarine discharges in response to seasonal freshwater inflows and diurnal tides.
Hydrolyse	Decompose by chemical reaction with water.
Hypersaline	Having salinity greater than seawater (i.e. above 35 parts per thousand) (generally caused by salt concentration through evaporation).
Induration	The cementing together of sand particles by natural physical and chemical processes.
Intertidal	Pertaining to those areas of land covered by water at high tide, but exposed at low tide, e.g. intertidal habitat.
Invertebrate	Animal without a backbone, e.g. jellyfish.
ISLW	Indian Springs Low Water. A commonly used basis for the lowest tide level recorded at a site.
Isohaline	A line connecting parts of the water mass having the same salinity i.e. a contour of equal salinity levels.
ISQG	Interim Sediment Quality Guidelines
JAMBA	Japan Australia Migratory Bird Agreement
LEP	Local Environment Plan
Levee	A man-made embankment or wall built to exclude floodwaters, or a natural embankment adjacent to a waterway built by the deposition of silt from floodwaters.
LGA	Local Government Area
Littoral Zone	An area of the coastline in which sediment movement by wave, current and wind action is prevalent.
Littoral Drift Processes	Wave, current and wind processes that facilitate the transport of sediments along a shoreline.
Macroalgae	Small to large attached algae of several types (red, brown and green). Green algae may become detached and accumulate in shallow waters.
Macrophytes (aquatic)	Rooted aquatic plants, e.g. Eelgrass.
Mangroves	An intertidal plant community dominated by trees.
Marine Sediments	Sediments in coastal waters moved along the coast by littoral processes.
Mathematical/ Computer models	The mathematical representation of the physical processes involved in runoff and stream flow. These models are often run on computers due to the complexity of the mathematical relationships. In this report, the models referred to are mainly involved with rainfall, runoff and stream flow.

MHL	Manly Hydraulics Laboratory
ML	Megalitres
MNT	Mean Neap Tide
Mollusc	A large phylum of animals, mostly aquatic, including mussels, snails and octopus, which are soft-bodied, often with a hard shell, unsegmented, and having a head and muscular foot.
Morphology	The characteristics, configuration and evolution of rocks and land forms.
MSL	Mean Sea Level
MST	Mean Spring Tide
MUSIC	Model for Urban Stormwater Improvement Conceptualisation
N/A	Not Applicable
NAGP	Net Acid Generating Potential
Neap Tides	Tides with the smallest range in a monthly cycle. Neap tides occur when the sun and moon lie at right angles relative to the earth (the gravitational effects of the moon and sun act in opposition on the ocean).
NPWS	National Parks and Wildlife Service (now within the Department of Environment and Conservation)
NPV	Net Present Value (evaluated using a 7% discount rate and a 50 year life of implementation)
NSW	New South Wales
NTU	Nephelometric Turbidity Units
Numerical Model	A mathematical representation of a physical, chemical or biological process of interest. Computers are often required to solve the underlying equations.
NWQMS	National Water Quality Management Strategy
Ostracoda	A Bivalve of small size which can swim freely about
PASS	Potential Acid sulfate Soil
Pelagic Organisms	Organisms living in the water column of the ocean and capable of moving independently of currents.
Phase Lag	Difference in time of the occurrence between high (or low water) and maximum flood (or ebb) velocity at some point in an estuary.
Phytoplankton	Microscopic free-floating aquatic plants (algae).

Pneumatophores	Air breathing roots.
Point-Source Pollution	Specific localised source of pollution, e.g. sewage effluent discharge, industrial discharge.
Polychaete	A segmented worm with bristles.
Protected Amphibian	An amphibian of a species in the NPWS Act, 1974
Protected Fauna	Fauna of a species under the NPWS Act, 1974
Protected Native Plant	A native plant of a species under the NPWS Act, 1974
PWC	Personal Water Craft
Rainfall Excess	The amount of rainfall after initial and continuing losses to the ground (eg depression storage, infiltration) is removed from the recorded rainfall.
Receiving Waters	Waters into which effluent or waste streams are discharged or discharge.
Reptile	"A snake, lizard, crocodile, tortoise, turtle or other member of the class reptilia (whether native, introduced or imported), and includes the eggs and the young thereof and the skin or any other part thereof".
Residual Sediment Flux	The net upstream or downstream movement of sediment over a tidal cycle, often determined by tidal distortion and gravitational circulation.
Revetments	Walls built parallel to the shoreline to limit shoreline recession.
Riparian Vegetation	Vegetation growing along banks of rivers, including the brackish upstream reaches of an estuary.
RL	Reduced Level
Runoff	That proportion of rainfall that drains off the land's surface.
Salinity	The total mass of dissolved salts per unit mass of water. Seawater has a salinity of about 35g/kg or 35 parts per thousand.
Salinity Limit	The landward limit of salinity intrusion along an estuary. The location of the salinity limit changes with freshwater discharge, high freshwater inflows moving the limit downstream, whilst low flows allow salt and the salinity limit to migrate upstream.
Saltation	The movement of sediment particles along the bed of a waterbody in a series of 'hops' or 'jumps'. Turbulent fluctuations near the bed lift sediment particles off the bed and into the flow where they are carried a short distance before falling back to the bed.
Saltmarsh	A coastal wetland subject to tidal flooding and vegetated by grasses, herbs and low shrubs that are tolerant of high salinity.
Sediment Load	The quantity of sediment moved past a particular cross-section in a specified time by estuarine flow.

Semi-diurnal	A twice-daily variation, e.g. two high waters per day.
SEPP	State Environmental Planning Policy
Shear Strength	The ability of the bed to accommodate flowing water without the movement of bed sediments. The shear strength of the bed depends upon bed material, degree of compaction, armouring,
Shear Stress	The stress exerted on the bed of an estuary by flowing water. The faster the velocity of flow' the greater the shear stress.
Shoals	Shallow areas in an estuary created by the deposition and build up of sediments.
Slack Water	The period of still water before the flood tide begins to ebb (high water slack) or the ebb tide begins to flood (low water slack).
SOI	Southern Oscillation Index
Spring Tides	Tides with the greatest range in a monthly cycle, which occur when the sun, moon and earth are in alignment (the gravitational effects of the moon and sun act in concert on the ocean)
SPS	Sewage Pumping Station
SQID	Stormwater Quality Improvement Device
SS	Suspended Solids
Storm Surge	The increase in coastal water levels caused by the barometric and wind setup effects of storms. Barometric setup refers to the increase in coastal water levels associated with the lower atmospheric pressures characteristic of storms. Wind setup refers to the increase in coastal water levels caused by an onshore wind driving water shorewards and piling it up against the coast.
STP	Sewage Treatment Plant
Stratigraphy	That branch of geology dealing with the ordering of rocks into their relative ages.
Sub-Aereal Sand Barrier	A sand barrier with crest level above high tide; usually vegetated.
Super-Elevation	See Storm Surge.
Surface Pollutants	Floating pollutants that do not mix effectively with water, e.g. Oil.
Suspended Sediment Load	That portion of the total sediment load held in suspension by turbulent velocity fluctuations and transported by flowing water.
Swale	A topographic depression that may retain water.
Tidal Amplification	The increase in the tidal range at upstream locations caused by the tidal resonance of the estuarine waterbody, or by a narrowing of the estuary channel.

Tidal Celerity	The speed of travel of the tidal wave along estuaries. Celerity depends upon the depth of water; the deeper the water, the greater the celerity.
Tidal Delta	The build-up of shoals in the lower reaches of an estuary due to the gradual accumulation of marine sands transported into the estuary through its entrance.
Tidal Distortion	The distortion of the tidal variation of water levels in shallow estuaries caused by the differences in the celerity of rising (faster) and falling (slower) water levels.
Tidal Exchange	The proportion of the tidal prism that is flushed away and replaced with 'fresh' coastal water each tide cycle.
Tidal Excursion	The distance travelled by a water particle from low water slack to high water slack and vice versa.
Tidal Lag	The delay between the state of the tide at the estuary mouth (e.g. high water slack) and the same state of tide at an upstream location.
Tidal Limit	The most upstream location where a tidal rise and fall of water levels is discernible. The location of the tidal limit changes with freshwater inflows and tidal range.
Tidal Planes	A series of water levels that define standard tides, e.g. 'Mean High Water Spring' (MHWS) refers to the average high water level of Spring Tides.
Tidal Prism	The total volume of water moving past a fixed point on an estuary during each flood tide or ebb tide.
Tidal Propagation	The movement of the tidal wave into and out of an estuary.
Tidal Pumping	The generation of Elevated Half-Tide Levels because of the greater celerity of the flood tide compared to the ebb tide.
Tidal Range	The difference between successive high water and low water levels. Tidal range is maximum during Spring Tides and minimum during Neap Tides.
Tidal Trapping	The process whereby a discrete body of water is trapped over shallow shoal areas on the flood tide and separated from other water moving up the estuary. This facilitates mixing.
Tidally Averaged Models	Models that predict estuarine behaviour over periods greater than a tidal cycle i.e. the temporal resolution is of the order of days, weeks or months.
Tidally Varying Models	Numerical models that predict estuarine behaviour within a tidal cycle i.e. the temporal resolution is of the order of minutes or hours.
Tides	The regular rise and fall in sea level in response to the gravitational attraction of the sun, moon and planets.
Tributary	Catchment, stream or river which flows into a larger river, lake or water body

TKN	Total Kjeldahl Nitrogen (Ammonia + Oxidised Nitrogen)
TN	Total Nitrogen
Total Catchment Management	The coordinated and sustainable use of land, water, vegetation and other natural resources on a water catchment basis so as to balance resource utilisation and conservation.
TO	Traditional Owner
TP	Total Phosphorus
TPR	Tidal Prism Ratio
Training Walls	Walls constructed at the entrances of estuaries to improve navigability.
Turbidity	A measure of the ability of water to absorb light.
Velocity Shear	The differential movement of neighbouring parcels of water brought about by velocity gradients. Velocity shear causes dispersive mixing, the greater the shear (velocity gradient), the greater the mixing.
Vertebrate	Animal with a backbone, e.g. fish, birds.
Water Quality	The suitability of the water for various purposes, as measured by the concentration or level of a wide variety of contaminants.
Well-Mixed Estuary	Estuary characterised by strong vertical mixing and weak or non-existent vertical salinity gradients.
Wind Shear	The stress exerted on the water's surface by wind blowing over the water. Wind shear causes the water to pile up, against downwind shores and generates secondary currents.

*A number of definitions have been derived from the Estuary Management Manual (1992).

APPENDIX A

Legislation and Policy Details

A1 State Legislation

Environmental Planning and Assessment Act 1979

The NSW environmental planning system operates under *the Environmental Planning and Assessment Act, 1979* (as amended in 1997 and 2005) (*EP&A Act*). It is the primary legislation controlling development activity in the State of NSW and is administered by the Department of Planning Council and other consent or determining authorities. One of its purposes is to ensure that appropriate authorities assess environmental impacts of new developments before development commences. The EP&A Act establishes two avenues in which the Environmental Impact Assessment (EIA) is employed.

- Part 4 developments: uses of land or developments for which consent is required under an environmental planning instrument (EPI); or
- Part 5 activities: uses of land or developments for which consent is not required.

The first stage in the development approval process is the decision by the proponent whether the development requires development consent under Part 4 or Part 5 of the Act. To answer this question, the local Council should be consulted and the Local Environmental Plan (LEP) for the area needs to be reviewed, along with any relevant EPIs, being Sydney Regional Environmental Plans (SREPs) or State Environmental Planning Policies (SEPPs).

Protection of the Environment Operations Act 1997

The need for licences or approvals from the NSW Environment Protection Authority is specified under the *Protection of the Environment Operations Act 1997*.

The requirement for an EPL is triggered by undertaking or proposing a scheduled activity or operating scheduled premises. Scheduled activities are typically those which are likely to generate significant quantities of air, water or noise pollution or waste. , an environment protection licence would be applied for under this Act, which would regulate all forms of pollution within an integrated licensing system.

The PoEO also gives Council the power to enforce pollution control laws for many premises and activities which are not licensed by EPA.

Threatened Species Conservation Act 1995

The provisions of this Act would be complied with for any future development proposals in or around the Creeks likely to affect or have the potential to impact threatened species. The Department of Environment and Conservation (National Parks and Wildlife Service) administer this Act. The objectives of this Act are as follows:

- To conserve biological diversity and promote ecologically sustainable development;
- To prevent the extinction and promote the recovery of threatened species, populations and ecological communities;
- To protect the critical habitat of those threatened species, populations and ecological communities that are endangered;
- To eliminate or manage certain processes that threaten the survival or evolutionary development of threatened species, populations and ecological communities;
- To ensure that the impact of any action affecting threatened species, populations and ecological communities is properly assessed; and
- To encourage the conservation of threatened species, populations and ecological communities by the adoption of measures involving co-operative management.

Noxious Weeds Management Act 1993

Any proposed rehabilitation proposal for Fairy, Towradgi and Hewitts / Tramway Creeks must be compliant with the *Noxious Weeds Management Act 1993*. The objectives of this Act are set out below:

- To identify noxious weeds in respect of which particular control measures need to be taken;
- To specify those control measures;
- To specify the duties of public and private landholders as to the control of these noxious weeds; and
- To provide a framework for the State – wide control of these noxious weeds by the Minister and local control authorities.

Wollongong Council and community groups presently undertake bush regeneration and weed removal works in the vegetated areas surrounding Fairy, Towradgi and Hewitts / Tramway Creeks and these activities need to consider the objectives of this Act.

Under this Act, Council may also be obliged to manage some high priority weed species (depending on their classification) if they are present on land under its care and control.

Disabilities Services Act 1993

For any proposed development such as improvements to walkways or the like, the infrastructure and services provided must comply with the provisions of this Act. The objectives of the Act are as follows:

a) To ensure the provision of services necessary to enable persons with disabilities to achieve their maximum potential as members of the community,
b) To ensure the provision of services that:
    i. Further the integration of persons with disabilities in the community and complement services available generally to such persons in the community, and
    ii. Enable persons with disabilities to achieve positive outcomes, such as increased independence, employment opportunities and integration in the community; and
    iii. Are provided in ways that promote in the community a positive image of persons with disabilities and enhance their self-esteem;
c) To ensure that the outcomes achieved by persons with disabilities by the provision of services for them are taken into account in the granting of financial assistance for the provision of such services;
d) To encourage innovation in the provision of services for persons with disabilities;
e) To achieve positive outcomes, such as increased independence, employment opportunities and integration in the community, for persons with disabilities; and
f) To ensure that designated services for persons with disabilities are developed and reviewed on a periodic basis through the use of forward plans.

Fisheries Management Act 1994

The provisions of this Act would be complied with for any future development proposals in or around the Creeks. Approvals are required from the Department of Primary Industries (NSW Fisheries) for developments including:

- Any dredging or reclamation in any waters (permanent or intermittent, mad-made or natural, public or private) will require a permit from NSW Fisheries, whether carried out by a developer or Council itself. The definitions of dredging or reclamation under the *Fisheries Management Act 1994* (FM Act*)* are very broad and essentially can be interpreted as any works within a waterway. This potentially includes stormwater control devices, waterway crossings, sea walls or similar structures. Reclamation includes the piping or channelising of waterways. NSW Fisheries will not approve the piping or channelising of waterways.
- Any potential harm to marine vegetation, macroalgae, seagrasses or mangroves will require a permit from NSW Fisheries, including shading by structures built over the waterway.
- Any blockage to fish passage.

- Removal or movement of snags including vegetation or boulders.

In addition, any proposal that would potentially impact an aquatic threatened species, population or ecological community would require assessment in accordance with the *Fisheries Management Act 1994*. In determining whether or not a proposal is likely to impact an aquatic threatened species, population or ecological community, an eight part test would be required to be undertaken. An eight part test would be required if there is likely to be an aquatic threatened species present in the area due to the presence of suitable habitat, historical range or siting of the species. The outcome of the eight part test must be forwarded to NSW Fisheries for advice regarding whether or not a Species Impact Statement is required.

State Environmental Planning Policy (SEPP) No 71 – Coastal Protection

SEPP No.71 aims to protect and manage the natural, cultural, recreational and economic attributes of the NSW coastal zone. The policy applies to land within the 'coastal zone' as defined in section 4A of the *Coastal Protection Act 1979* (CP Act). A recent amendment to the CP Act redefined the land that comprises the coastal zone. Within Wollongong local government area, the coastal zone is defined as areas affected by, or likely to affect, coastal processes. SEPP No.71 will not apply to the Wollongong local government area until mapping of the area has been completed. It is understood that the maps are likely to be gazetted in the 2005-2006 financial year.

A number of provisions of SEPP No.71 may relate to the management of Fairy, Towradgi and Hewitts / Tramway Creeks. SEPP No.71 makes the Minister for Planning the consent authority for 'State significant development', which includes landfill, recreational establishments, and structures greater than 13m in height. The policy also provides that the Minister may make himself or herself the consent authority for a development application (DA), where the Minister is of the opinion that a DA is of State or regional significance.

The most relevant provision of SEPP No.71 in relation to Fairy, Towradgi and Hewitts / Tramway Creeks is the requirement that a copy of all DAs for any 'significant coastal development' be referred to the Director-General for review and comment. The Director-General may specify matters that Council must consider in determining the DA or may require that Council refer the DA to the Minister for determination. Significant coastal development includes any development on, or partly on, land within a sensitive coastal location. Fairy, Towradgi and Hewitts / Tramway Creeks and the surrounding area (including land within 100 m of the Creeks and within 100 m above mean high water mark of the sea) are defined as sensitive coastal locations.

Native Vegetation Act 2003

The provisions of this Act would be complied with for any future works which may affect native vegetation within the vicinity of the estuaries.

The objects of this Act are:

(a) To provide for, encourage and promote the management of native vegetation on a regional basis in the social, economic and environmental interests of the State, and
(b) To prevent broadscale clearing unless it improves or maintains environmental outcomes, and
(c) To protect native vegetation of high conservation value having regard to its contribution to such matters as water quality, biodiversity, or the prevention of salinity or land degradation, and
(d) To improve the condition of existing native vegetation, particularly where it has high conservation value, and
(e) To encourage the revegetation of land, and the rehabilitation of land, with appropriate native vegetation, in accordance with the principles of ecologically sustainable development.

Draft Native Vegetation Regulation 2004

The *Draft Native Vegetation Regulation, 2004* provides regulations for the protection of Native Vegetation. Providing provisions for protecting and investing in healthy and productive landscapes for the people of New South Wales. This regulation would apply to any areas surrounding the estuaries

where native vegetation exists, with the exemption of 'Land within a zone designated "residential" (but not "rural residential"), "village", "township", "industrial" or "business" under an environmental planning instrument or, having regard to the purpose of the zone, having the substantial character of a zone so designated'.

As such the Regulation is unlikely to apply in many areas surrounding the subject waterways.

Rivers and Foreshores Improvement Act, 1948

The Rivers and Foreshores Improvement Act 1948 aims to control excavations, the placement of fill and other works in or near rivers, estuaries and lakes. The Act is administered by the Department of Natural Resources. At the time of preparation of this Plan, licences and approvals associated with this Act were still in force and the Water Management Act, 2000 had not yet been become operational with regard to licences and approvals.

Water Management Act, 2000

The Water Management Act 2000 controls the extraction of water, the use of water, the construction of works such as dams and weirs and the carrying out of activities in or near water sources in New South Wales.

The Act creates:
- mechanisms for protecting and restoring water sources and their dependent ecosystems
- improved access rights to water
- partnership arrangements between the community and the government for water management.

A2 State Policies

NSW Coastal Policy

The *NSW Coastal Policy* provides a framework for the balanced and co-ordinated management of the coastal zone in accordance with the principals of ecologically sustainable development and applies to the area under study due to proximity to the coast.

The policy essentially operates through a set of strategic actions, which are derived from a set of objectives, which in turn are derived from goals that establish the desired overall long-term outcomes for the policy. These strategic actions provide the context for both local government and State government decision-making, and make local councils responsible for a range of actions that should be implemented for the protection of the natural and cultural environment.

Floodplain Development Manual (2005)

The primary objective of the *NSW Government's Flood Prone Land Policy* is to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property, and to reduce private and public losses resulting from floods. At the same time, the policy recognizes the benefits flowing from the use, occupation and development of flood prone land.

The policy promotes the use of a merit approach, which balances social, economic, environmental and flood risk parameters to determine whether particular development or use of the floodplain is appropriate and sustainable.

The primary objective of the *New South Wales Flood Prone Land Policy*, as outlined below, recognises the following two important facts:

- Flood prone land is a valuable resource that should not be sterilised by unnecessarily precluding its development; and

- If all development applications and proposals for rezoning of flood prone land are assessed according to rigid and prescriptive criteria, some appropriate proposals may be unreasonably disallowed or restricted, and equally, quite inappropriate proposals may be approved.

Coastal Design Guidelines for NSW (2003)

The coastal design guidelines have been prepared with reference to the NSW Government's Coastal Policy 1997 and complement the Government's Coastal Protection Package released on the 26th June 2001 and SEPP 71 which came into effect in November 2002. The coastal design guidelines are based on the principles of ecologically sustainable development (ESD).

Estuary Management Manual and Policy

The Estuary Management Policy is defined in the Estuary Management Manual (NSW Government, 1992). The policy outlines a structured management process leading to the implementation of an Estuary Management Plan. This document provides the overarching framework for the Estuary Management Study and Plan.

Healthy Rivers Commission - Coastal Lakes Inquiry 2002

The *Coastal Lakes Strategy* is an over-arching set of arrangements designed to improve the management (by all relevant parties) of coastal lakes and their catchments so that progress towards the long term goal of healthier coastal lakes is achieved in a timely and cost effective manner. The strategy incorporates the following:

- Principles for managing coastal lakes;
- A framework for managing major classes of coastal lakes;
- A classification of coastal lakes;
- Requirements for preparing and implementing Sustainability Assessment and Management Plans for each coastal lake;
- Implementation arrangements; and
- A range of supporting initiatives.

Biodiversity Planning Guide for NSW Local Government 2001

This Guide aims to assist councils to carry out biodiversity conservation as part of their day-to-day functions, especially those relating to planning and development. It provides councils with a 'good practice guide'.

Ecologically sustainable development (ESD) and biodiversity conservation are firmly established as core business for local councils. Both issues have wide implications for local government administration, and are also subject to increasing political interest.

The Guide highlights the importance of plan making for biodiversity conservation, as well as the need to integrate both regulatory and positive approaches. It shows how councils can conserve biodiversity through their existing regulatory and operational functions. The Guide *does not* create new plan making processes, but presents a package of strategies and tools that can be applied within existing frameworks.

Policy and Guidelines for Aquatic Habitat Management and Fish Conservation 1999

This document has been prepared by NSW Fisheries in order to improve the conservation and management of aquatic habitats in NSW. It is targeted at local and state government authorities, proponents of developments and their advisors, and individuals or organisations concerned with the planning and management of our aquatic resources, including conservation organisations.

Policy and Guidelines for Fish Friendly Waterway Crossings 2004

This Fishnote provides a summary of the specific legislation and policy requirements that must be observed by those intending to plan design and construct waterway crossings in NSW.

Waterway crossings such as bridges, roads, causeways, culverts and similar structures have an impact on fish and aquatic habitats. Habitats can be damaged during the construction of waterway crossings by the removal of riparian and in-stream vegetation as well as disturbance to the bed and bank of the waterway. Other impacts can include the creation of long-term barriers to fish movement, bed and bank erosion and continuing pollution from erosion and sedimentation.

Other factors should also be considered in addition to providing fish passage, such as public safety, social and budgetary constraints, and therefore each crossing must be assessed on a case-by-case basis.

Water Quality and River Flow: Interim Environmental Objectives

This document outlines the Water Quality and River Flow Objectives for different catchments, in this case within the Illawarra catchment. Achieving water quality objectives and river flow objectives will mean improving poor water quality and maintaining existing good water quality.

The Water Quality Objectives (WQOs) for each part of the Illawarra catchments are listed in Section 3 of the document. In total, there are eleven WQOs. They provide benchmarks or reference levels to guide water quality planning and management.

Achieving each WQO will mean improving poor water quality or maintaining existing good water quality.

Objectives consist of three parts: *environmental values*, their *indicators* and their *numerical criteria*. For example, if the objective is to protect *secondary contact recreation* (environmental value), we need to keep the *faecal coliform levels* in the water (the indicator) below a *specified number* (the criterion). The objectives comprise community-based environmental values and their associated national criteria. They provide the statewide context for taking this work forward into the water management process. Many catchment management committees have developed more detailed information on WQOs for their rivers.

The River Flow Objectives (RFOs) for each part of the Illawarra catchments are listed in Section 3. In total, there are twelve coastal river flow objectives, each one dealing with a critical element of natural river flows.

Flow patterns in many rivers have been significantly altered and will not return to natural flow regimes. The NSW Government is not attempting to restore completely natural flow patterns where the community benefits significantly from altered flow patterns. Communities and the Government have identified important areas where we can make adjustments to maintain or improve river health while continuing to benefit from water use.

Water management plans (WMPs) will contain integrated actions and timeframes to achieve objectives and implement identified actions in consultation with the community. Different approaches and outcomes will apply across different parts of the catchment.

Managing Urban Stormwater Guidelines 2004

This manual provides guidelines to minimise land degradation and water pollution at urban development sites in New South Wales. Any future works around the estuaries in question would require the necessary precaution to be undertaken in accordance to this manual.

If implemented the guidelines will help:

- Reduce pollution to downstream areas and receiving waters.

- Reduce land degradation.
- Raise awareness of ecologically sustainable development (ESD) principles and their application to development.

A3 Commonwealth Legislation

Commonwealth Environment Protection and Biodiversity Conservation Act 1999

The Environment Protection and Biodiversity Conservation Act 1999 (EPBC) provides for the protection of the environment and the conservation of biodiversity for those aspects of the environment that are matters of national environmental significance.

Matters of environmental significance under this Act fall under the following categories:

- World Heritage;
- National Heritage Places
- Ramsar Wetlands of International Significance;
- Nationally Listed Threatened Species and Ecological Communities;
- Nationally Listed Migratory Species;
- Commonwealth Marine Areas;
- Nuclear Actions;
- Commonwealth Land;
- Land Clearing.

Species listed under the Japan Australia Migratory Bird Agreement (JAMBA) and China Australia Migratory Bird Agreement (CAMBA) are protected under the migratory species provisions of the Act.

A4 Commonwealth Policies

Natural Heritage Trust

The Natural Heritage Trust (NHT) was set up by the Australian Government in 1997 to help restore and conserve Australia's environment and natural resources. Since then, thousands of community groups and organisations have received funding for environmental and natural resource management projects.

Australia's Oceans Policy

Australia's Oceans Policy sets in place the framework for integrated and ecosystem-based planning and management for all of Australia's marine jurisdictions. It includes a vision, a series of goals and principles and policy guidance for a national Oceans Policy. Building on existing effective sectoral and jurisdictional mechanisms, it promotes ecologically sustainable development of the resources of our oceans and the encouragement of internationally competitive marine industries, while ensuring the protection of marine biological diversity.

National Strategy for Ecologically Sustainable Development

This document sets out the broad strategic and policy framework under which governments will cooperatively make decisions and take actions to pursue ESD in Australia. It will be used by governments to guide policy and decision making, particularly in those key industry sectors which rely on the utilisation of natural resources.

The Strategy plays the critical role of setting the scene for the broad changes in direction and approach that governments will take to ensure that Australia's future development is ecologically sustainable.

The Strategy also aims to be accessible to industry, business and the broader community. It should provide these groups with a good understanding of government approaches to a wide range of

economic and environment policies. Governments encourage industry and business to use this document as a basis on which to develop processes, resource use and management techniques which contribute to Australia's national goal for ESD.

Similarly, we believe that community groups will find this Strategy a useful information source and we encourage them to promote its goal, objectives and principles and to develop community-based and individual actions to pursue ESD.

National Strategy for the Conservation of Australia's Biological Diversity

The following principles have been adopted as a basis for the Strategy's objectives and actions and should be used as a guide for implementation:

- Biological diversity is best conserved in-situ.
- Although all levels of government have clear responsibility, the cooperation of conservation groups, resource users, indigenous peoples, and the community in general is critical to the conservation of biological diversity.
- It is vital to anticipate, prevent and attack at source the causes of significant reduction or loss of biological diversity.
- Processes for and decisions about the allocation and use of Australia's resources should be efficient, equitable and transparent.
- Lack of full knowledge should not be an excuse for postponing action to conserve biological diversity.
- The conservation of Australia's biological diversity is affected by international activities and requires actions extending beyond Australia's national jurisdiction.
- Australians operating beyond our national jurisdiction should respect the principles of conservation and ecologically sustainable use of biological diversity and act in accordance with any relevant national or international laws.
- Central to the conservation of Australia's biological diversity is the establishment of a comprehensive, representative and adequate system of ecologically viable protected areas integrated with the sympathetic management of all other areas, including agricultural and other resource production systems.
- The close, traditional association of Australia's indigenous peoples with components of biological diversity should be recognised, as should the desirability of sharing equitably benefits arising from the innovative use of traditional knowledge of biological diversity.

National Water Quality Management Strategy

The main policy objective of the NWQMS is, "to achieve sustainable use of the nation's water resources by protecting and enhancing their quality while maintaining economic and social development."

The process for water quality management involves the community working with government to set and achieve local environmental values and water quality objectives for water bodies and to develop management plans for catchments, aquifers, estuarine areas, coastal waters or other water bodies. Management of water resources is mainly a State and Territory responsibility and implementation of the NWQMS will involve the Strategy guidelines, State and Territory water policies and community preferences.

Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000

This document outlines the important principles, objectives and philosophical basis underpinning the development and application of the guidelines. It outlines the management framework recommended for applying the water quality guidelines to the natural and semi-natural and freshwater resources in Australia and New Zealand.

Specifically, this document:

- Outlines the important principles, objectives and philosophical basis underpinning the development and application of the guidelines;
- Outlines the management framework recommended for applying the water quality guidelines to the natural and semi-natural marine and fresh water resources in Australia and New Zealand;
- Provides a summary of the water quality guidelines proposed to protect and manage the environmental values supported by the water resources;
- Provides advice on designing and implementing water quality monitoring and assessment programs;
- Has been revised using data, relevant literature, and other information available to at least 1996.

The Wetlands Policy of the Commonwealth Government of Australia

The Wetlands Policy of the Commonwealth Government of Australia (Environment Australia 1997) provides strategies to ensure that the activities of the Commonwealth Government promote the conservation, ecologically sustainable use and enhancement, where possible, of wetlands functions. The Policy forms an essential platform for the development of a national framework of wetland policies and strategies.

An Implementation Plan for the Commonwealth Wetlands Policy (Environment Australia, 1999) was developed to ensure actions are addressed in an effective manner and within appropriate timeframes.

Department of the Environment and Heritage Compliance and Enforcement Policy

The Department of the Environment and Heritage (formerly Environment Australia) administers a range of Commonwealth environment and heritage laws, many of which contain penalties that can be invoked if there is a breach of the law. The Compliance and Enforcement Policy provides the general framework to guide the Department of the Environment and Heritage's approach to achieving compliance with the law and our response should breaches occur.

The Policy recognises a range of mechanisms are necessary for an effective and flexible regulatory system that allows the most appropriate response to be chosen for a given issue or incident. These include measures to encourage compliance, such as communication and education, monitoring, and ensuring timely information and assistance is available where possible. However, final responsibility for complying with the law always rests with the individual person or organization concerned.

People with Disabilities

Australian Standards are required to be implemented for all design and construction. Redevelopment of any facility must take into consideration the requirements with respect to people with disabilities. Collection 005 of the Australian Standards contains 22 Australian Standards printed as an A5-sized book. The collection has been assembled to provide a guide to the range of Standards available concerning access and mobility for people with disabilities. The Collection contains Standards covering topics such as design for access and mobility, tactile ground surface indicators, parking facilities, public information symbols and other selected topics.

APPENDIX B

Options/Strategies List

ID	Management Objective	Responsibility	Strategy Outline	Comments	Capital Cost	Maintenance/ Recurrent Cost	NPV	Human Uses	Flooding	Sediment and Water Quality	Flora & Fauna	Cultural Heritage	Community Response - Strategic Options* (Raw)	Community Response - Individual Options (Raw)	Community Response - Strategic Options* (Scaled)	Community Response - Individual Options (Scaled)	Benefit Index	benefit index/ log NPV	Rank
1	**Habitat and Species Conservation** (*Aquatic Habitats*)	WCC, DNR, DL, DP	Fairy Lagoon in Puckeys Estate - Rezoning of Crown Land from 6(a) to 7(b)	Co-Option 113	$2,000	$0	$2,000	0	0	4	4	4		1	0.00	0.33	12.33	3.74	3
2	**Habitat and Species Conservation** (*Aquatic Habitats*)	WCC, DP	Rezoning of Crown Land from 6(a) to a New Conservation Waterway Zone	Co-Option 113	$2,000	$0	$2,000	0	0	4	4	4	6		2.00	0.00	14.00	4.24	1
3	**Habitat and Species Conservation** (*Aquatic Habitats*)	WCC, DL	Change the use of land that will have an adverse effect on adjacent sensitive aquatic habitats through development controls or Crown Land classification revision	Co-Option 113	$10,000	$1,000	$23,801	0	0	4	4	0	6		2.00	0.00	10.00	2.28	17
4	**Habitat and Species Conservation** (*Aquatic Habitats*)	WCC, DEC(NPWS)	Where alternative siting is not appropriate, adopt the principle of environmental compensation in the approval process for any activity that causes unavoidable damage to any estuarine habitat or catchment that is of importance to the estuary.		NI	NI	N/A	-3	0	4	-1	-5	6		2.00	0.00	-3.00	NI	NI
5	**Habitat and Species Conservation** (*Aquatic Habitats*)	WCC	Towradgi Creek - Bring significant / important foreshore and riparian areas into public ownership through development opportunity		NI	NI	N/A	0	0	4	4	0		5	0.00	1.67	9.67	NI	NI
6	**Habitat and Species Conservation** (*Foreshore and Riparian Zones*)	WCC	Bring significant / important foreshore and riparian areas into public ownership whenever opportunities arise through rezoning, development approvals or acquisition. (See FPMP Actions)		FPMP	FPMP	N/A	0	0	4	4	0	6		2.00	0.00	10.00	FPMP	FPMP
7	**Habitat and Species Conservation** (*Foreshore and Riparian Zones*)	Landowner, DP, DNR, WCC?	Prepare and adopt Riparian Corridor Management DCP. Foreshore protection to control erosion conforms to the Visual Management Plan and be of a standardised type utilising local native plants with harder materials, such as timber or rock, only where necessary.	Co-Option 113	$47,000	$17,000	$281,613	0	0	4	3	0	10		3.33	0.00	10.33	1.90	40
8	**Habitat and Species Conservation** (*Foreshore and Riparian Zones*)	WCC, DP, DNR	Introduce appropriate zoning or an LEP clause requiring consent from Council for any development within reserves and buffer zones, except for fencing, revegetation or any works contained in an Estuary Management Plan and prohibiting certain development types altogether.	Co-Option 113	$5,000	$0	$5,000	0	1	4	4	0	6		2.00	0.00	11.00	2.97	6
9	**Habitat and Species Conservation** (*Foreshore and Riparian Zones*)	WCC, DEC(NPWS)	Hewitts/Tramway Creeks Protect and Enhance Open Grassland Area for Migratory Birds		$20,000	$10,000	$158,007	-1	0	1	4	3		4	0.00	1.33	8.33	1.60	58
10	**Habitat and Species Conservation** (*Foreshore and Riparian Zones*)	WCC, DEC(NPWS)	Tramway Creek - Manage Turpentine Forest on Private Land in accordance with CoI Finding		$10,000	$0	$10,000	-1	0	1	4	0		7	0.00	2.33	6.33	1.58	61
11	**Habitat and Species Conservation** (*Foreshore and Riparian Zones*)	CMA, WCC, DEC(NPWS)	Negotiate property agreements and property management plans with owners of land with plant and animal species and / or ecological communities or populations of significant conservation value.		$10,000	$10,000	$148,007	1	0	1	5	0	6		2.00	0.00	9.00	1.74	47
12	**Habitat and Species Conservation** (*Foreshore and Riparian Zones*)	WCC	Puckeys Estate and Surrounds - Protect and Enhance Vegetation		$0	$40,000	$552,030	3	0	1	4	0		0	0.00	0.00	8.00	1.39	76
13	**Habitat and Species Conservation** (*Foreshore and Riparian Zones*)	WCC	Rehabilitate Degraded Sections of Cabbage Tree Creek	Some portions undertaken associated with development	$30,000	$5,000	$99,004	1	0	1	4	0		0	0.00	0.00	6.00	1.20	86
14	**Habitat and Species Conservation** (*Foreshore and Riparian Zones*)	WCC	Cabbage Tree Creek Near Innovation Campus - Restore Degraded Aquatic Habitat as Part of Campus Development	Primary Cost would be borne by landholder/developer.	$0	$5,000	$69,004	0	0	1	4	0		0	0.00	0.00	5.00	1.03	101
15	**Habitat and Species Conservation** (*Foreshore and Riparian Zones*)	WCC	Cabbage Tree Creek - Protect and Enhance Vegetation in Campus East Area	Some portions undertaken associated with development	$30,000	$5,000	$99,004	1	0	1	4	0		0	0.00	0.00	6.00	1.20	86
16	**Habitat and Species Conservation** (*Foreshore and Riparian Zones*)	WCC	Rehabilitate Vegetation - Western Side Cabbage Tree Creek		$50,000	$5,000	$119,004	1	0	1	4	0		0	0.00	0.00	6.00	1.18	91
17	**Habitat and Species Conservation** (*Foreshore and Riparian Zones*)	WCC	Towradgi Creek South Bank - Rehabilitate Degraded Aquatic and Riparian Habitat (Code B in Appendix C)		$100,000	$15,000	$307,011	1	0	1	4	0		6	0.00	2.00	8.00	1.46	72
18	**Habitat and Species Conservation** (*Foreshore and Riparian Zones*)	WCC	South Bank Upstream of Pioneer Road - Rehabilitate Degraded Riparian Habitat (Code G in Appendix C)		$40,000	$5,000	$109,004	1	0	1	4	0		1	0.00	0.33	6.33	1.26	84
19	**Habitat and Species Conservation** (*Foreshore and Riparian Zones*)	WCC	North Bank Upstream Pioneer Road - Rehabilitate Degraded Riparian Habitat (Code G in Appendix C)		$40,000	$5,000	$109,004	1	0	1	4	0		1	0.00	0.33	6.33	1.26	84
20	**Habitat and Species Conservation** (*Foreshore and Riparian Zones*)	WCC	North Bank Upstream Towradgi Footbridge - Rehabilitate Degraded Riparian Habitat (Code I in Appendix C)		$50,000	$5,000	$119,004	0	0	1	4	0		1	0.00	0.33	5.33	1.05	99
21	**Habitat and Species Conservation** (*Foreshore and Riparian Zones*)	WCC	South Bank Upstream Footbridge Rehabilitate Degraded Riparian Habitat (Code I in Appendix C)		$50,000	$5,000	$119,004	0	0	1	4	0		0	0.00	0.00	5.00	0.99	116
22	**Habitat and Species Conservation** (*Aquatic and Riparian Zones*)	WCC	Parker Road Arm Rehabilitate Degraded Aquatic and Riparian Habitat		$60,000	$5,000	$129,004	1	0	1	4	0		5	0.00	1.67	7.67	1.50	66
23	**Habitat and Species Conservation** (*Foreshore and Riparian Zones*)	WCC	Towradgi North Restore Degraded Riparian Habitat by Revegetation		$50,000	$5,000	$119,004	1	0	1	4	0		3	0.00	1.00	7.00	1.38	78
24	**Habitat and Species Conservation** (*Foreshore and Riparian Zones*)	WCC	Upstream Lake Parade Rehabilitate Degraded Riparian Habitat		$50,000	$5,000	$119,004	1	0	1	4	0		6	0.00	2.00	8.00	1.58	63
25	**Habitat and Species Conservation** (*Foreshore and Riparian Zones*)	Stockland, DNR, WCC	Rehabilitation in Accordance with VMP prep by Sandon Pt Developer		SPdev	SPdev	SPdev	1	1	1	4	0		5	0.00	1.67	8.67	SPdev	SPdev
26	**Habitat and Species Conservation** (*Foreshore and Riparian Zones*)	Landowner, DP, DNR, WCC?	Tramway Creek Manage Watercourse and Riparian Zones in Accordance with CoI Findings		$100,000	$30,000	$514,022	1	1	2	4	0		7	0.00	2.33	10.33	1.81	45
27	**Habitat and Species Conservation** (*Foreshore and Riparian Zones*)	Landowner, DP, DNR, WCC?	Woodlands Creek South Manage Watercourse and Riparian Zones in Accordance with CoI Findings		$50,000	$5,000	$119,004	1	1	2	4	0		7	0.00	2.33	10.33	2.04	30
28	**Habitat and Species Conservation** (*Foreshore and Riparian Zones*)	WCC	Hewitts Creek Rehabilitate Degraded Riparian and Aquatic Habitat on Community Land (Removal of exotic species and revegetation with natives where possible) - (Code F in Appendix C)		$30,000	$10,000	$168,007	1	1	2	4	0		7	0.00	2.33	10.33	1.98	35
29	**Habitat and Species Conservation** (*Foreshore and Riparian Zones*)	Landowner, DP, DNR, WCC?	Hewitts Creek Manage Watercourse and Riparian Zones in Accordance with CoI Findings		$100,000	$30,000	$514,022	1	1	2	4	0		8	0.00	2.67	10.67	1.87	43
30	**Habitat and Species Conservation** (*Foreshore and Riparian Zones*)	Landowner, DP, DNR, WCC?	Woodlands Creek Manage Watercourse and Riparian Zone in Accordance with CoI Findings		$50,000	$5,000	$119,004	1	1	2	4	0		8	0.00	2.67	10.67	2.10	26
31	**Habitat and Species Conservation** (*Foreshore and Riparian Zones*)	WCC	Live Steamers Rehabilitate Remnant Vegetation		$40,000	$5,000	$109,004	1	0	1	4	0	6		2.00	0.00	8.00	1.59	60
32	**Habitat and Species Conservation** (*Foreshore and Riparian Zones*)	WCC	South Fairy Creek - Rehabilitate Remnant Vegetation		$20,000	$5,000	$89,004	0	0	1	4	0		0	0.00	0.00	5.00	1.01	104
33	**Habitat and Species Conservation** (*Aquatic Habitat*)	WCC	Towradgi Arm - Protect Mangrove Area		$5,000	$2,000	$32,601	0	0	0	4	0		0	0.00	0.00	4.00	0.89	123
34	**Habitat and Species Conservation** (*Foreshore and Riparian Zones*)	WCC	Towradgi South Bank - Protect and Enhance Remnant Vegetation		$10,000	$2,000	$37,601	0	0	1	4	0		8	0.00	2.67	7.67	1.68	57
35	**Habitat and Species Conservation** (*Foreshore and Riparian Zones*)	WCC	Blue Divers - Protect and Enhance Remnant Vegetation		$20,000	$5,000	$89,004	2	0	1	4	0		8	0.00	2.67	9.67	1.95	37
36	**Habitat and Species Conservation** (*Foreshore and Riparian Zones*)	WCC	Cawley Street - Protect and Enhance Remnant Vegetation		$1,000	$1,000	$14,801	1	0	0	3	0		3	0.00	1.00	5.00	1.20	89
37	**Habitat and Species Conservation** (*Works*)	WCC	Towradgi Entrance Area - Provide Stabilised Access Point		$5,000	$500	$11,900	2	0	1	1	0		6	0.00	2.00	6.00	1.47	69
38	**Habitat and Species Conservation** (*Works*)	WCC	Blue Divers - Provide Stabilised Access Point to include fishing access point		$5,000	$500	$11,900	2	0	0	1	0		8	0.00	2.67	5.67	1.39	77
39	**Habitat and Species Conservation** (*Works*)	WCC	Fairy Creek South - Erect Barriers to Prevent Mowing		$10,000	$100	$11,380	0	0	1	3	0		0	0.00	0.00	4.00	0.99	109
40	**Habitat and Species Conservation** (*Works*)	WCC	Towradgi South Erect Barriers to Prevent Mowing		$10,000	$100	$11,380	0	0	1	3	0		0	0.00	0.00	4.00	0.99	109
41	**Habitat and Species Conservation** (*Works*)	WCC	Towradgi South Upstream Pioneer Road - Erect Barriers to Prevent Mowing		$10,000	$100	$11,380	0	0	1	3	0		-1	0.00	0.00	4.00	0.99	109
42	**Habitat and Species Conservation** (*Works*)	WCC	Towradgi South Upstream - Erect Barrier to Prevent Mowing		$10,000	$100	$11,380	0	0	1	3	0		-1	0.00	0.00	4.00	0.99	109
43	**Habitat and Species Conservation** (*Works*)	WCC	Towradgi North Upstream - Erect Barrier to Prevent Mowing		$10,000	$100	$11,380	0	0	1	3	0		-1	0.00	0.00	4.00	0.99	109
44	**Habitat and Species Conservation** (*Works*)	WCC	Towradgi North Upstream Pioneer Road - Erect Barriers to Prevent Mowing		$10,000	$100	$11,380	0	0	1	3	0		-1	0.00	0.00	4.00	0.99	109
45	**Habitat and Species Conservation** (*Works*)	WCC	Towradgi North - Erect Barriers to Prevent Mowing		$10,000	$100	$11,380	0	0	1	3	0		0	0.00	0.00	4.00	0.99	109
46	**Habitat and Species Conservation** (*Works*)	WCC, DNR	Identify any existing acid sulfate drainage, remediation and, if required, prepare a plan for ongoing management.		$60,000	$1,000	$73,801	0	0	4	3	0	6		2.00	0.00	9.00	1.85	44
47	**Habitat and Species Conservation** (*Works*)	WCC	Hewitts Creek - Remove snag causing bank erosion. (Note that available information indicates that this snag has been removed, but not by WCC).		D	D	N/A	0	1	0	1	0		3	0.00	1.00	3.00	D	D
48	**Habitat and Species Conservation** (*Works*)	WCC, DPIF	Cabbage Tree Creek - Fish Passage Improvement		$100,000	$1,000	$113,801	3	0	0	3	0	6		2.00	0.00	8.00	1.58	62
49	**Habitat and Species Conservation** (*Education*)	WCC	Educate the community on the value of estuarine habitats and how they can contribute to their protection.		$10,000	$1,000	$23,801	0	0	4	2	0	8		2.67	0.00	8.67	1.98	34
50	**Habitat and Species Conservation** (*Education*)	WCC	Educate Council staff on the value of foreshore vegetation.		$5,000	$1,000	$18,801	0	0	4	2	0	8		2.67	0.00	8.67	2.03	32
51	**Habitat and Species Conservation** (*Education*)	WCC	Erect Interpretive Signage to Direct Pedestrians to Puckeys Estate		$5,000	$500	$11,900	2	0	0	2	0		0	0.00	0.00	4.00	0.98	117
52	**Habitat and Species Conservation** (*Education*)	WCC	Erect Interpretive Signage for Valuable Habitat at Puckeys Estate		$2,000	$500	$8,900	1	0	0	3	0		0	0.00	0.00	4.00	1.01	102
53	**Habitat and Species Conservation** (*Education*)	WCC	Erect Interpretive Signage for Valuable Habitat at Confluence of Fairy and Cabbage Tree Creeks		$2,000	$500	$8,900	1	0	0	3	0		0	0.00	0.00	4.00	1.01	102
54	**Habitat and Species Conservation** (*Education*)	WCC	Towradgi Creek - Erect Interpretive Signage for Valuable Habitat		$2,000	$500	$8,900	1	0	0	3	0		2	0.00	0.67	4.67	1.18	92
55	**Habitat and Species Conservation** (*Education*)	WCC	Provide ongoing support and opportunities for the community to participate in restoration and management of aquatic, wetland and wildlife habitats (eg through WCC's Bushcare program).	Co-Option ID 159	$5,000	$20,000	$281,015	3	0	4	4	0	15		5.00	0.00	16.00	2.94	7
56	**Water Quality** (*Statutory Controls*)	WCC	Localise water quality standards (as per ANZECC, 2000) for the estuaries for aquatic ecosystems and recreational use.		$15,000	$1,000	$28,801	4	0	5	4	0	12		4.00	0.00	17.00	3.81	2
57	**Water Quality** (*Statutory Controls*)	WCC	Develop and adopt a system of cumulative impact assessment for land use planning and development control by undertaking pollutant inventories an budgets for existing land uses and preparing land and water capability assessments to establish total allowable pollutant loads and other relevant loads or factors.		$40,000	$1,000	$53,801	0	0	5	4	0	6		2.00	0.00	11.00	2.33	15
58	**Water Quality** (*Statutory Controls*)	WCC	Strictly control water quality impacts of development during construction phase.		$5,000	$20,000	$281,015	3	0	5	1	0	10		3.33	0.00	12.33	2.26	18
59	**Water Quality** (*New and Infill Development*)	WCC	Establish water quality standards for stormwater runoff from new development considering the estuary's temporal response to pollutant inputs (daily, weekly or monthly) and within the framework of the cumulative impact assessment.	Co-Option ID 57	$10,000	$1,000	$23,801	3	0	5	1	0	10		3.33	0.00	12.33	2.82	8
60	**Water Quality** (*New and Infill Development*)	WCC	Adopt Water Sensitive Urban Design principles, using the LEP or a separate LGA-wide DCP.	Note: Option 163 from the Floodplain Risk Management Plans is a replicate of this option	$66,000	$17,000	$300,613	0	0	5	1	0	10		3.33	0.00	9.33	1.70	55

ID	Management Objective	Responsibility	Strategy Outline	Comments	Capital Cost	Maintenance/ Recurrent Cost	NPV	Human Uses	Flooding	Sediment and Water Quality	Flora & Fauna	Cultural Heritage	Community Response - Strategic Options* (Raw)	Community Response - Individual Options (Raw)	Community Response - Strategic Options* (Scaled)	Community Response - Individual Options (Scaled)	Benefit Index	benefit index/ log NPV	Rank
61	**Water Quality** (*New and Infill Development*)	WCC, DNR	Require total water cycle strategies for major rezonings and Development Applications.	Primary Cost would be borne by landholder/developer.	$0	$5,000	$69,004	0	0	4	1	0	10		3.33	0.00	8.33	1.72	51
62	**Water Quality** (*New and Infill Development*)	WCC	Require submission of an environmental management plan with any Development Application for a proposal that has the potential to pollute waterways.	Primary Cost would be borne by landholder/developer.	$0	$5,000	$69,004	0	0	4	1	0	10		3.33	0.00	8.33	1.72	51
63	**Water Quality** (*New and Infill Development*)	WCC	Permit development on unsewered urban or rural lots only where there is sufficient area of suitable soil away from drainage lines to satisfactorily dispose of septic effluent on site.	Co-Option 113	$0	$5,000	$69,004	0	0	0	0	0	10		3.33	0.00	3.33	0.69	135
64	**Water Quality** (*Existing Development*)	WCC, DEC(EPA)	Revise Stormwater Management Plan for existing developed areas within the framework of the cumulative impact assessment - include maintenance of implemented SQIDs	Co-Option ID 57	$20,000	$1,000	$33,801	1	0	5	1	0	6		2.00	0.00	9.00	1.99	33
65	**Water Quality** (Existing Development) Fairy Creek	WCC	Fairy Creek at Beaton Park - Wetland		$50,000	$10,000	$188,007	0	0	1	4	0		0	0.00	0.00	5.00	0.95	121
66	**Water Quality** (Existing Development) Fairy Creek	WCC	Fairy Creek - Install Litter Boom and Maintain on Regular Basis		$40,000	$5,000	$109,004	0	0	1	1	0		1	0.00	0.33	2.33	0.46	148
67	**Water Quality** (Existing Development) Fairy Creek	WCC	Stormwater Quality Improvement Device at Fairy Creek Entrance		$150,000	$15,000	$357,011	0	0	1	1	0		1	0.00	0.33	2.33	0.42	153
68	**Water Quality** (Existing Development)	WCC	Maintain existing SQIDs on a regular basis		$0	$20,000	$276,015	0	1	4	1	0			0.00	0.00	6.00	1.10	94
69	**Water Quality** (*Existing Development*) Cabbage Tree Creek	WCC	Litter Control downstream of Gateway Complex (Cabbage Tree Creek)		$80,000	$5,000	$149,004	0	0	1	1	0		1	0.00	0.33	2.33	0.45	149
70	**Water Quality** (*Existing Development*) Fairy Creek	WCC	Retrofit various detention basins to include stormwater treatment measures in Fairy Creek catchment		$50,000	$5,000	$119,004	0	0	4	1	0		1	0.00	0.33	5.33	1.05	99
71	**Water Quality** (Existing Development) Towradgi Creek	WCC	GPT Downstream of Corrimal Shopping Centre - Towradgi Creek		$150,000	$15,000	$357,011	0	0	1	1	0		5	0.00	1.67	3.67	0.66	136
72	**Water Quality** (Existing Development) Towradgi Creek	WCC	Parker Road Arm - Stormwater Quality Improvement Device (Wetland and SQID)		$150,000	$15,000	$357,011	0	0	1	1	0		5	0.00	1.67	3.67	0.66	136
73	**Water Quality** (*Existing Development*) Various	WCC	Install CDS units in high profile locations upstream of important wetlands and recreational facilities		NI	NI	N/A	1	0	1	3	0	10		3.33	0.00	8.33	NI	NI
74	**Water Quality** (*Existing Development*) Various	WCC	Rework surface drainage of playing fields to provide long linear wetlands along field perimeter. Stormwater from adjacent housing to be directed through these wetlands		NI	NI	N/A	1	0	1	1	0	6		2.00	0.00	5.00	NI	NI
75	**Water Quality** (*Existing Development*) Fairy Lagoon	WCC	Replacement of existing lined trunk drainage system with natural open channel systems with riparian vegetation (at priority high profile locations such as Stuart Park)		NI	NI	N/A	1	0	1	3	0		1	0.00	0.33	5.33	NI	NI
76	**Water Quality** (Existing Development) Towradgi Creek	WCC	Conduct a foreshore pollutant audit and remediate inappropriate practices.		$50,000	$5,000	$119,004	0	0	4	3	0		5	0.00	1.67	8.67	1.71	54
77	**Water Quality** (Existing Development)	WCC, DPIF	Fairy Creek - Clear accumulated rubble and anthropogenic material (Code F in Appendix C)		$50,000	$5,000	$119,004	1	1	5	3	0		1	0.00	0.33	10.33	2.04	30
78	**Water Quality** (Existing Development)	WCC, DPIF	Towradgi Creek - Remove Constriction to Tidal Flow Via Dredging		$114,000	$3,000	$155,402	0	2	2	0	0		15	0.00	5.00	9.00	1.73	48
79	**Water Quality** (Existing Development)	WCC, DPIF, Landowner (Col Dependent)	Tramway Creek - Modify barrier to tidal flushing subject to ecological assessment		$150,000	$5,000	$219,004	1	1	5	3	0		6	0.00	2.00	12.00	2.25	20
80	**Water Quality** (Existing Development) Towradgi Creek	SWC	East Corrimal - Address Sewerage Issues with Creek Inflow Prevention		SydWater	SydWater	N/A	3	0	3	1	0		14	0.00	4.67	11.67	SydWater	SydWater
81	**Water Quality** (Existing Development) Towradgi Creek	SWC	Towradgi Creek - Address Sewer Wet Weather Flow Capacity Issues		SydWater	SydWater	N/A	3	0	3	1	0		11	0.00	3.67	10.67	SydWater	SydWater
82	**Water Quality** (Existing Development)	SWC	SCAMPS in all catchments where faecal contamination is an issue		SydWater	SydWater	N/A	4	0	5	3	0		12	0.00	4.00	16.00	SydWater	SydWater
83	**Water Quality** (*Education*)	WCC	Educate the community on environmentally responsible practices around the house that protect water quality such as: composting grass clippings; using organic rather than synthetic fertilisers; applying fertiliser sparingly and according to soil requirements; vegetating bare soil areas; using phosphate-free detergents; washing cars on grass; capturing pet droppings; promote livestock management; and not dumping refuse on the foreshores and in the bush.		$10,000	$1,000	$23,801	0	0	5	2	0	8		2.67	0.00	9.67	2.21	21
84	**Water Quality** (*Education*)	WCC	Educate specific industry groups and developers of best management practices for minimising polluted runoff.		$10,000	$2,000	$37,601	1	0	5	2	0	8		2.67	0.00	10.67	2.33	14
85	**Sedimentation and Erosion** (*Statutory Controls*)	WCC	Require that an Erosion and Sediment Control Plan be submitted with any Development Application or, for projects not requiring a DA, incorporate appropriate conditions from the Erosion and Sediment Control Policy in the approval.	Review of DA's allowed for in the recurrent cost	$0	$5,000	$69,004	0	0	4	1	0	10		3.33	0.00	8.33	1.72	51
86	**Sedimentation and Erosion** (*Works*)	WCC, DNR	Fairy Creek - Removal of weeds and revegetation with natives (Code G in Appendix C)		$200,000	$20,000	$476,015	1	0	2	5	0		1	0.00	0.33	8.33	1.47	70
87	**Sedimentation and Erosion** (*Works*)	WCC, DNR	Fairy Creek Rock Armouring of Stormwater Outlet Headwalls (Code E in Appendix C)		$40,000	$5,000	$109,004	0	0	2	2	0		1	0.00	0.33	4.33	0.86	125
88	**Sedimentation and Erosion** (*Works*)	WCC, DNR	Fairy Creek - Battering and Revegetation (Code D in Appendix C)		$150,000	$5,000	$219,004	1	0	1	2	0		0	0.00	0.00	4.00	0.75	132
89	**Sedimentation and Erosion** (*Works*)	WCC, DNR	Fairy Creek Battering the slope and providing a gravel/cobble beach (Code C in Appendix C)		$80,000	$5,000	$149,004	1	0	1	2	0		0	0.00	0.00	4.00	0.77	131
90	**Sedimentation and Erosion** (*Works*)	WCC	Fairy Creek Stabilise Entrance Dunes (to include beach access track) (Code A in Appendix C)		$50,000	$10,000	$188,007	1	0	1	4	0		1	0.00	0.33	6.33	1.20	88
91	**Sedimentation and Erosion** (*Works*)	WCC	Fairy Creek - Stabilise Surrounds of Puckeys Boat Ramp (Code B in Appendix C)		$20,000	$2,000	$47,601	1	0	0	1	0		0	0.00	0.00	2.00	0.43	151
92	**Sedimentation and Erosion** (*Works*)	WCC	Cabbage Tree Creek Rock Armouring Around Trees (Code H in Appendix C)		$20,000	$2,000	$47,601	0	0	0	2	0		0	0.00	0.00	2.00	0.43	151
93	**Sedimentation and Erosion** (*Works*)	WCC	Reorietate Gravel Bars on Cabbage Tree Creek (Code I in Appendix C)		$30,000	$1,000	$43,801	3	1	0	0	0		0	0.00	0.00	4.00	0.86	124
94	**Sedimentation and Erosion** (*Works*)	WCC	Towradgi Arm Battering the slope and providing a gravel/cobble beach that could also be re-vegetated (Code K in Appendix C)		$100,000	$5,000	$169,004	0	0	1	2	0		0	0.00	0.00	3.00	0.57	145
95	**Sedimentation and Erosion** (*Works*)	WCC	Towradgi Creek Stabilise Entrance Dunes (to include beach access track) (Code A in Appendix C)	Co-Option to 144	$50,000	$10,000	$188,007	3	0	1	3	0		9	0.00	3.00	10.00	1.90	41
96	**Sedimentation and Erosion** (*Works*)	WCC	Towradgi Creek Stabilise Eroding Banks (Code E in Appendix C)		$150,000	$2,000	$177,601	3	0	3	3	0		11	0.00	3.67	12.67	2.41	13
97	**Sedimentation and Erosion** (*Works*)	WCC	Towradgi Creek Revegetate Banks (Code F in Appendix C)		$150,000	$5,000	$219,004	3	0	3	3	0		10	0.00	3.33	12.33	2.31	16
98	**Sedimentation and Erosion** (*Works*)	WCC	Parker Road Arm Stabilise Gabions (Code C in Appendix C)		$40,000	$1,000	$53,801	1	0	0	1	0		1	0.00	0.33	2.33	0.49	147
99	**Sedimentation and Erosion** (*Works*)	WCC	Towradgi Creek Near Upstream Footbridge Stabilise Steep Banks (Code H in Appendix C)		FPMP	FPMP	N/A	1	0	1	1	0		4	0.00	1.33	4.33	FPMP	FPMP
100	**Sedimentation and Erosion** (*Works*)	WCC	Towradgi Creek Upstream Revegetate and Stabilise Banks (Code I in Appendix C)		$100,000	$5,000	$169,004	0	0	2	4	0		5	0.00	1.67	7.67	1.47	71
101	**Sedimentation and Erosion** (*Works*)	WCC	Towradgi Creek North Bank - Rehabilitate Ad-hoc Bank Stabilisation Works		$100,000	$10,000	$238,007	-1	0	1	3	0		6	0.00	2.00	5.00	0.93	122
102	**Sedimentation and Erosion** (*Works*)	Landowner, DNR, WCC?	Tramway Creek Entrance - Revegetate Dunes (Code A in Appendix C)		$20,000	$2,000	$47,601	0	0	1	2	0		5	0.00	1.67	4.67	1.00	107
103	**Sedimentation and Erosion** (*Works*)	Landowner, DNR, WCC?	Tramway Creek - Rock armouring for support and to protect the immediately surrounding bank (Code B in Appendix C)		$5,000	$1,000	$18,801	0	0	1	1	0		3	0.00	1.00	3.00	0.70	134
104	**Sedimentation and Erosion** (*Works*)	WCC	Hewitts Creek Entrance - Revegetate Dunes and Stabilise Access Track (Code C in Appendix C)		$20,000	$2,000	$47,601	0	0	1	2	0		5	0.00	1.67	4.67	1.00	107
105	**Sedimentation and Erosion** (*Works*)	Landowner, DNR, WCC?	Formalisation of Crossing of Hewitts Creek (Code H in Appendix C)	Land ownership to be considered before option proceeds.	$40,000	$1,000	$53,801	2	0	1	1	0		5	0.00	1.67	5.67	1.20	90
106	**Sedimentation and Erosion** (*Works*)	WCC	Undertake and erosion and sedimentation survey (including catchment, in-stream and foreshores) assessing sediment yield of sources, sediment quality and rate of infilling. Remediate sources of high risk to the estuary.		$50,000	$10,000	$188,007	0	0	4	1	1	6		2.00	0.00	8.00	1.52	65
107	**Sedimentation and Erosion** (*Works*)	WCC	Review condition of existing stormwater drain outlets and repair, construct sediment traps or mini-wetlands where appropriate and space permits and remove sediment fans.		$30,000	$5,000	$99,004	3	0	0	3	0	6		2.00	0.00	8.00	1.60	59
108	**Sedimentation and Erosion** (*Education*)	WCC	Educate the community on the need to prevent sediment generation at the source by drain stencilling, preventing soils being washed from yards, vegetation buffers etc.		$5,000	$2,000	$32,601	0	0	4	3	0	8		2.67	0.00	9.67	2.14	24
109	**Cultural Heritage** (*Works*)	WCC	Protect Boatramp in Accordance with Heritage Conservation Plan for Puckeys Estate		$10,000	$4,000	$65,203	-1	0	0	0	5		0	0.00	0.00	4.00	0.83	129
110	**Cultural Heritage** (*Works*)	WCC	Protect Non-Indigenous Heritage Items in Puckeys Estate in Accordance with Heritage Conservation Plan		$10,000	$4,000	$65,203	-1	0	0	0	5		0	0.00	0.00	4.00	0.83	129
111	**Cultural Heritage** (*Statutory Controls*)	WCC, DEC(NPWS), DNR, DP	Identify sites of significant Aboriginal and European heritage and protect through amendment of the LEP. (Note: Detailed study for Sandon Point area likely to be undertaken following the Commission of Inquiry).	Co-Option 113	$40,000	$2,000	$67,601	2	0	0	0	5	4		1.33	0.00	8.33	1.73	49
112	**Cultural Heritage** (*Education*)	WCC	Erect interpretative signage for both indigenous and non-indigenous heritage elements		$40,000	$1,000	$53,801	2	0	0	0	2	8		2.67	0.00	6.67	1.41	73
113	**Development** (*Statutory Controls*)	WCC	Review all zonings - where adjacent to the estuary, the catchment, to assess the potential for each development type to impact on estuarine habitats and their flora and fauna, water quality, sedimentation and erosion. Require development consent for all land uses that potentially have adverse impacts on estuarine ecosystems and prohibit development with impacts that cannot be reasonably mitigated.		$30,000	$1,000	$43,801	0	0	0	4	4	6		2.00	0.00	10.00	2.15	23
114	**Development** (*Statutory Controls*)	WCC	Adopt a precautionary approach of accepting a lower level of risk (ie a wider safety margin) for managing existing and proposed land and waterway uses affecting highly valued environmentally sensitive components of the estuarine ecosystem.	Co-Option 113	NI	NI	N/A	1	0	0	4	0	6		2.00	0.00	7.00	NI	NI
115	**Development** (*Statutory Controls*)	WCC	Consider implications of sea level rise projections for the estuaries		$30,000	$1,000	$43,801	1	4	0	3	3	6		2.00	0.00	13.00	2.80	9
116	**Development** (*Statutory Controls*)	WCC, DNR, DP	Include acid sulfate soil provisions in LEP.	Co-Option 113	$5,000	$0	$5,000	0	0	4	3	0	6		2.00	0.00	9.00	2.43	10
117	**Development** (*Waterway*)	WCC	Conduct an analysis of the risk of damage to the estuarine ecosystem (ie a sensitivity assessment) by each existing waterway use using environmental factors such as: bank erosion; trampling, propeller furrows or other physical disturbance; noise to birdlife. Using the results of the risk analysis, either progressively change current waterway use practices, discourage them or phase them out.		$10,000	$2,000	$37,601	-3	0	0	4	0	6		2.00	0.00	3.00	0.66	138
118	**Development** (*New Development*)	WCC, DNR, DP	Require that a Local Environmental Study be prepared for a major LEP or rezoning proposal for any area within or adjoining an estuary. The LES should consider potential impacts on estuarine values including the ecosystem, threatened species, water quality, cultural heritage, foreshore and estuary access and usage, population levels with tourist influx, public amenity, fishing and acid sulfate soils.	Primary Cost would be borne by landholder/developer	$5,000	$1,000	$18,801	1	0	2	2	2	6		2.00	0.00	9.00	2.11	25
119	**Development** (*Existing Development*)	WCC	Prepare a Development Control Plan which provides guidelines for tourist and recreational development and activities on public and privately owned land in and around the estuary and its tributaries with the aim of: protecting ecological communities; maintaining a satisfactory standard of water quality; preserving scenic quality; providing siting and design principles for new buildings and waterside structures; identifying locations with potential for foreshore access.		$30,000	$10,000	$168,007	-1	0	4	4	0	6		2.00	0.00	9.00	1.72	50
120	**Development** (*Existing Development*)	WCC	Conduct an analysis of the risk of damage to the estuarine ecosystem (ie a sensitivity assessment) by each existing land use or practice using environmental factors such as: soil erodibility; proximity to streams; estuary dilution, mixing and flushing ability; proximity to key estuarine habitats eg seagrass; geomorphic maturity of the estuary. Using the results of the risk analysis, either progressively change current land use practices, discourage them or phase them out.	Co-Option 113	$40,000	$2,000	$67,601	0	0	4	4	0	6		2.00	0.00	10.00	2.07	28
121	**Recreation** (*Waterway*)	WCC	Survey public access points including beaches, jetties, boat ramps and parking and assess whether existing access is appropriately located considering environmental effects and proximity to waterway usage and whether the level of facilities is sufficient to satisfy demand. Ensure sufficient and appropriate foreshore land is reserved for access and facilities.		$10,000	$2,000	$37,601	5	0	0	1	1	6		2.00	0.00	9.00	1.97	36
122	**Recreation** (*Waterway*)	DL	Survey private foreshore structures and assess whether the location and extent is appropriate.		$10,000	$2,000	$37,601	3	0	0	1	1	6		2.00	0.00	7.00	1.53	64
123	**Recreation** (*Foreshore Open Space*)	WCC	Maximise public ownership and appropriate access to Council and Crown foreshore land.		NI	NI	N/A	5	0	0	0	0	6		2.00	0.00	7.00	NI	NI
124	**Recreation** (*Foreshore Open Space*)	WCC	Classify land with open space or conservation value as community land under the Local Government Act. (Currently all / most open space conservation land is generally classified as "community land" - some sites with restaurants will be "operational land" and some areas are not in public ownership. Could also recommend that the land be categorised as "natural area" with subsets of "bushland", "wetland", "watercourse" or "foreshore").		$10,000	$2,000	$37,601	3	0	0	0	0	6		2.00	0.00	5.00	1.09	95
125	**Recreation** (*Works*)	WCC	Restrict public access to defined alignments (eg access trails, boardwalks) and control environmental damage.		NI	NI	N/A	-1	0	0	2	2	6		2.00	0.00	5.00	NI	NI
126	**Recreation** (*Works*)	WCC	Based on the access and demand survey, provide facilities such as parking, litter collection, amenities and walking trails.		NI	NI	N/A	4	0	-1	1	1	6		2.00	0.00	7.00	NI	NI

ID	Management Objective	Responsibility	Strategy Outline	Comments	Capital Cost	Maintenance/ Recurrent Cost	NPV	Human Uses	Flooding	Sediment and Water Quality	Flora & Fauna	Cultural Heritage	Community Response - Strategic Options* (Raw)	Community Response - Individual Options (Raw)	Community Response - Strategic Options* (Scaled)	Community Response - Individual Options (Scaled)	Benefit Index	benefit index/ log NPV	Rank
127	**Recreation** (*Education*)	WCC	Prepare posters for display at caravan parks and other tourist accommodation on the need for foreshore users to dispose of bait bags, drink bottles and other litter appropriately.		$3,000	$200	$5,760	4	0	4	1	0	8		2.67	0.00	11.67	3.10	4
128	**Recreation** (*Education*)	WCC	Fairy Creek - Erect signage at waterway access points on the need to protect the waterway from litter.		$5,000	$100	$6,380	0	0	3	1	0		0	0.00	0.00	4.00	1.05	98
129	**Recreation** (*Education*)	WCC	Towradgi Creek - Erect signage at waterway access points on the need to protect the waterway from litter.		$5,000	$100	$6,380	0	0	3	1	0		4	0.00	1.33	5.33	1.40	75
130	**Recreation** (*Education*)	WCC	Towradgi Creek Blue Divers - Erect signage at waterway access points on the need to protect the waterway from litter.		$5,000	$100	$6,380	0	0	3	1	0		3	0.00	1.00	5.00	1.31	81
131	**Recreation** (*Education*)	WCC	Tramway Creek - Erect signage at waterway access points on the need to protect the waterway from litter.		$5,000	$100	$6,380	0	0	3	1	0		5	0.00	1.67	5.67	1.49	67
132	**Recreation** (*Education*)	WCC	Hewitts Creek - Erect signage at waterway access points on the need to protect the waterway from litter.		$5,000	$100	$6,380	0	0	3	1	0		5	0.00	1.67	5.67	1.49	67
133	**Visual Amenity** (*Statutory Controls*)	WCC	Apply sound landscape design principles to achieve ecological and recreational objectives while giving consideration to the visual amenity of residents and visitors.		$0	$1,000	$13,801	4	0	0	1	0	6		2.00	0.00	7.00	1.69	56
134	**Visual Amenity** (*Statutory Controls*)	WCC	Prepare a Visual Management Plan (VMP) to maintain significant views and vistas and require, through planning instruments, development control plans and design guidelines that all building and development applications conform to the VMP.		$10,000	$1,000	$23,801	4	0	0	0	0	6		2.00	0.00	6.00	1.37	80
135	**Visual Amenity** (*Works*)	WCC	Fairy Creek - Provide foreshore viewing platform.		$40,000	$1,000	$53,801	3	0	0	0	0		0	0.00	0.00	3.00	0.63	139
136	**Visual Amenity** (*Works*)	WCC	Towradgi Creek - Provide foreshore viewing platform		$40,000	$1,000	$53,801	3	0	0	0	0		1	0.00	0.33	3.33	0.70	133
137	**Visual Amenity** (*Works*)	WCC	Towradgi Creek Upstream - Provide foreshore viewing platform		$40,000	$1,000	$53,801	3	0	0	0	0		-1	0.00	0.00	3.00	0.63	139
138	**Visual Amenity** (*Works*)	WCC	Towradgi Creek Upstream - Provide foreshore viewing platform		$40,000	$1,000	$53,801	3	0	0	0	0		-1	0.00	0.00	3.00	0.63	139
139	**Visual Amenity** (*Works*)	WCC	Hewitts Creek - Provide foreshore viewing platform		$40,000	$1,000	$53,801	3	0	0	0	0		3	0.00	1.00	4.00	0.85	127
140	**Visual Amenity** (*Education*)	WCC	Educate the community and, in particular, the landholders adjacent to the waterway or in the first row of houses behind foreshore roadways, on the value of not clearing their land or waterfront reserves to improve their own views and the penalties for illegal clearing. Regenerate illegally cleared areas and erect highly visible fencing (eg orange safety fencing) and signage deterrents.		$10,000	$20,000	$286,015	2	0	0	3	0	8		2.67	0.00	7.67	1.41	74
141	**Visual Amenity** (*Education*)	WCC	Encourage residents of waterfront properties to purchase native plants through Council's Green Plan program		$0	$5,000	$69,004	2	0	0	3	0	15		5.00	0.00	10.00	2.07	29
142	**Estuary Entrance** (*Statutory Controls*)	WCC	Establish a monitoring program to record date of opening and closing, nature of opening (natural or manual), location and width across the entrance dune, ocean water level, width and depth of channel development with time, estuary water levels through time and water velocities.		$5,000	$10,000	$143,007	0	1	0	0	0	12		4.00	0.00	5.00	0.97	118
143	**Estuary Entrance** (*Statutory Controls*)	WCC	Fairy Creek - Develop an entrance management policy considering location of past openings, flood mitigation (as per FMP's), water quality, fish and invertebrate recruitment, birdlife, threatened species, cultural sites and ecology.		$39,000	$21,000	$328,816	0	0	4	3	3		1	0.00	0.33	10.33	1.87	42
144	**Estuary Entrance** (*Statutory Controls*)	WCC	Towradgi Creek - Develop an entrance management policy considering location of past openings, flood mitigation (as per FMP's), water quality, fish and invertebrate recruitment, birdlife, threatened species, cultural sites and ecology.	Co-Option 95	$39,000	$21,000	$328,816	0	2	4	3	3		15	0.00	5.00	17.00	3.08	5
145	**Estuary Entrance** (*Statutory Controls*)	WCC	Tramway Creek - Develop an entrance management policy considering location of past openings, flood mitigation (as per FMP's), water quality, fish and invertebrate recruitment, birdlife, threatened species, cultural sites and ecology.		$19,500	$10,500	$164,408	0	0	4	3	3		8	0.00	2.67	12.67	2.43	11
146	**Estuary Entrance** (*Statutory Controls*)	WCC	Hewitts Creek - Develop an entrance management policy considering location of past openings, flood mitigation (as per FMP's), water quality, fish and invertebrate recruitment, birdlife, threatened species, cultural sites and ecology.		$19,500	$10,500	$164,408	0	0	4	3	3		8	0.00	2.67	12.67	2.43	11
147	**Estuary Entrance** (*Works*)	WCC	Retrain Towradgi Creek entrance to the south		$1,912,000	$10,000	$2,050,007	0	4	0	0	0		14	0.00	4.67	8.67	1.37	79
148	**Estuary Entrance** (*Works*)	WCC	Where required survey low-lying assets (including wetlands).		NI	NI	N/A	0	1	0	3	3	6		2.00	0.00	9.00	NI	NI
149	**Estuary Entrance** (*Education*)	WCC	Educate the community on the importance of not illegally opening an estuary entrance and the consequent liability to prosecution if caught.		$5,000	$1,000	$18,801	0	0	0	1	0	8		2.67	0.00	3.67	0.86	126
150	**Information and Communications** (*Education*)	WCC	Develop an Estuary Management Plan summary to widely distribute to local residents and make the full plan available for public perusal at any time.		$5,000	$2,000	$32,601	0	0	0	3	3	8		2.67	0.00	8.67	1.92	38
151	**Information and Communications** (*Education*)	WCC	Maintain an action plan including progress in the form of a spreadsheet or database to be updated after each Management Committee meeting and distributed to interested parties, including the media, on request.		$1,000	$2,000	$28,601	0	0	0	0	0	6		2.00	0.00	2.00	0.45	150
152	**Information and Communications** (*Education*)	WCC	Maintain a Geographical Information System of the Plan Actions, to be used in conjunction with the spreadsheet-based actions showing land and waterway uses and current planning and development activities occurring in the estuary and the catchment.		$2,000	$5,000	$71,004	0	0	0	0	0	6		2.00	0.00	2.00	0.41	154
153	**Information and Communications** (*Education*)	WCC	Develop an education brochure outlining the impacts of human activity on estuary condition and the actions that can be taken at a personal level to maintain estuary health, distribute with rate notices and make available at frequent visitation points.		$5,000	$1,000	$18,801	1	1	4	1	0	8		2.67	0.00	9.67	2.26	19
154	**Information and Communications** (*Education*)	WCC	Use the local media to publicise the management plan, results of monitoring programs and issues of concern as they arise.		$5,000	$2,000	$32,601	0	0	0	3	3	8		2.67	0.00	8.67	1.92	38
155	**Information and Communications** (*Education*)	WCC	Use Council's web site as a means of distributing all the above educational material.		$10,000	$5,000	$79,004	1	1	0	3	3	8		2.67	0.00	10.67	2.18	22
156	**Implementation, Monitoring and Review** (*Statutory Controls*)	WCC	Identify how the recommendations of an Estuary Management Plan relating to statutory controls are to be incorporated into Council's planning and development control system, eg environmental planning instruments such as the LEP or else an estuary-specific or LGA-wide DCP.	Co-Option 113	$5,000	$1,000	$18,801	M	M	M	M	M	6		2.00	0.00	2.00	M	M
157	**Implementation, Monitoring and Review** (Works)	WCC	Develop and implement a monitoring program for individual works to ensure that they performs as expected.		$10,000	$5,000	$79,004	M	M	M	M	M	12		4.00	0.00	4.00	M	M
158	**Implementation, Monitoring and Review** (Monitoring)	WCC	Develop and implement an overall monitoring program for the Management Plan to assess performance and enable plan auditing at regular intervals and subsequent adaptation of the plan.		$20,000	$75,000	$1,055,056	M	M	M	M	M	12		4.00	0.00	4.00	M	M
159	**Implementation, Monitoring and Review** (Monitoring)	WCC	Encourage community involvement in monitoring including, for example: water quality; foreshore pollutant sources; bank erosion; riparian vegetation; stormwater outlet sedimentation rates; aquatic plant growth, eg sedges, reeds, seagrass & algae; entrance opening and closing; recreational fish catches; damage to foreshore access points.	Co-Option ID 55	$10,000	$10,000	$148,007	M	M	M	M	M	15		5.00	0.00	5.00	M	M
160	**Flooding** (*Statutory Controls*)	WCC	Require water quality, as well as quantity, be considered in the design of any flood detention structures.		$1,000	$500	$7,900	1	0	1	3	0	6		2.00	0.00	7.00	1.80	46
161	**Flooding** (*Works*)	DNR	Hewitts Creek - Install water level gauge at footbridge		D	D	N/A	0	0	0	0	0	12		4.00	0.00	4.00	D	D
162	**Flooding** (*Works*)	DNR	Install rainfall/water level/other gauges as required		NI	NI	N/A	0	0	0	0	0	12		4.00	0.00	4.00	NI	NI
163	**Flood Risk Management Plans** (*Catchment Wide Measures*)	WCC	Recommend to Council the development of a Water Sensitive Urban Design Policy.	Included in Option 60	Co-Option	Co-Option	N/A	Co-Option	Co-Option	Co-Option	Co-Option	Co-Option	Co-Option		Co-Option	Co-Option	Co-Option	Co-Option	Co-Option
164	**Flood Risk Management Plans** (*Catchment Wide Measures*)	WCC	Riverine Corridor Strategy for areas upstream of the estuary, including: preparation of a Vegetation Management Plan; study of stream geomorphology; investigation into restoration of creek systems; investigation into rectification of in-stream and creek bank erosion; identification of options for managing illegal structures; preparation of a Riverine Corridor Maintenance Program.		$100,000	$2,000	$127,601	0	0	0	4	0	6		2.00	0.00	6.00	1.18	93
165	**Flood Risk Management Plans** (*Catchment Wide Measures*)	WCC	Policy for Management of Escarpment Runoff.		$50,000	$1,000	$63,801	0	4	0	4	0	6		2.00	0.00	10.00	2.08	27
166	**Flood Risk Management Plans** (*Catchment Wide Measures*)	WCC	Voluntary house purchase - 5 properties.		FPMP	FPMP	N/A	-1	3	0	0	0	10		3.33	0.00	5.33	FPMP	FPMP
167	**Flood Risk Management Plans** (*Catchment Wide Measures*)	WCC	Voluntary reconstruction / redevelopment - 3 properties.		FPMP	FPMP	N/A	-1	3	0	0	0	10		3.33	0.00	5.33	FPMP	FPMP
168	**Flood Risk Management Plans** (*Catchment Wide Measures*)	WCC	Removal and raising of Colgong Crescent footbridge in its current location.		D	D	N/A	0	5	0	3	0		2	0.00	0.67	8.67	D	D
169	**Flood Risk Management Plans**	WCC	Prosser Close Erosion Study.		$10,000	$1,000	$23,801	0	0	0	0	0		0	0.00	0.00	0.00	0.00	160
170	**Flood Risk Management Plans** - South Angels Creek (Towradgi Catchment)	WCC	Voluntary reconstruction / redevelopment - 1 property.		FPMP	FPMP	N/A	-1	1	0	0	0		0	0.00	0.00	0.00	FPMP	FPMP
171	**Flood Risk Management Plans** - North Angels Creek (Towradgi Catchment)	WCC	Voluntary house raising - 1 property		FPMP	FPMP	N/A	-1	1	0	0	0		0	0.00	0.00	0.00	FPMP	FPMP
172	**Flood Risk Management Plans** - North Corrimal Creek (Towradgi Catchment)	WCC	Voluntary house purchase - 4 properties.		FPMP	FPMP	N/A	-1	3	0	0	0		0	0.00	0.00	2.00	FPMP	FPMP
173	**Flood Risk Management Plans** - North Corrimal Creek (Towradgi Catchment)	WCC	Voluntary reconstruction / redevelopment - 1 property.		FPMP	FPMP	N/A	-1	1	0	0	0		0	0.00	0.00	0.00	FPMP	FPMP
174	**Flood Risk Management Plans** - North Corrimal Creek (Towradgi Catchment)	WCC	Debris control structures - 4 locations.		FPMP	FPMP	N/A	0	4	1	0	0		4	0.00	1.33	6.33	FPMP	FPMP
175	**Flood Risk Management Plans** - Carr Creek (Towradgi Catchment)	WCC	Voluntary house raising - 13 properties.		FPMP	FPMP	N/A	-3	3	0	0	0		0	0.00	0.00	0.00	FPMP	FPMP
176	**Flood Risk Management Plans** - Parker Creek (Towradgi Catchment)	WCC	Voluntary house raising - 2 properties.		FPMP	FPMP	N/A	-1	1	0	0	0		0	0.00	0.00	0.00	FPMP	FPMP
177	**Flood Risk Management Plans** - Parker Creek (Towradgi Catchment)	WCC	Voluntary reconstruction / redevelopment - 4 properties.		FPMP	FPMP	N/A	-1	1	0	0	0		0	0.00	0.00	0.00	FPMP	FPMP
178	**Flood Risk Management Plans** - Slacky Creek	WCC	Old mine rail: Formalise diversion to Tramway and Hobart St: Formalise diversion to Tramway.		FPMP	FPMP	N/A	0	5	0	0	0		4	0.00	1.33	6.33	FPMP	FPMP
179	**Flood Risk Management Plans** - Slacky Creek	WCC	William St to Hobart St: Sediment basin		FPMP	FPMP	N/A	0	1	1	2	0		5	0.00	1.67	5.67	FPMP	FPMP
180	**Flood Risk Management Plans** - Slacky Creek	WCC	Coarse Debris Trap		FPMP	FPMP	N/A	0	1	1	2	0		4	0.00	1.33	5.33	FPMP	FPMP
181	**Flood Risk Management Plans** - Tramway Creek	WCC	Princes Highway to Rail line: Property Purchase (2 properties).		FPMP	FPMP	N/A	-1	1	0	0	0		3	0.00	1.00	1.00	FPMP	FPMP
182	**Flood Risk Management Plans** - Woodlands Creek	Landowner, DNR, WCC?	Diversion to Hewitts: Re-divert Woodlands Creek to Tramway Creek and close existing gabion lined connection. Fish habitat options to be considered by retaining a portion of the diversion as a wetland area.	In accordance with the findings of the CoI.	FPMP	FPMP	N/A	0	4	0	0	0		5	0.00	1.67	5.67	FPMP	FPMP
183	**Flood Risk Management Plans** - Woodlands Creek	WCC	Princes Highway: Sediment basin / debris control structure.		$30,000	$10,000	$168,007	0	1	1	2	0		3	0.00	1.00	5.00	0.96	120
184	**Flood Risk Management Plans** - Hewitts Creek	Landowner, DNR, WCC?	Adjacent to Corbett Ave: Levee north bank.		FPMP	FPMP	N/A	0	4	0	0	0		3	0.00	1.00	5.00	FPMP	FPMP
185	**Flood Risk Management Plans** - Hewitts Creek	WCC	Lawrence Hargraves Drive to the Rail line: Voluntary purchase offer (no 419 Lawrence Hargraves Drive).		FPMP	FPMP	N/A	-1	1	0	0	0		2	0.00	0.67	0.67	FPMP	FPMP
186	**Flood Risk Management Plans** - Hewitts Creek	WCC	Lawrence Hargraves Drive to the Rail line: Rehabilitate creek channel.		FPMP	FPMP	N/A	0	0	1	4	0		2	0.00	0.67	5.67	FPMP	FPMP
187	**Flood Risk Management Plans** - Hewitts Creek	WCC	Bangalow Rd to Kelton Ln: Coarse Debris trap.		FPMP	FPMP	N/A	0	1	1	2	0		2	0.00	0.67	4.67	FPMP	FPMP
188	**Flood Risk Management Plans** - Hewitts Creek	WCC	Stream 4 - Deborah Ave: Coarse debris trap.		FPMP	FPMP	N/A	0	1	1	2	0		2	0.00	0.67	4.67	FPMP	FPMP
189	**Sedimentation and Erosion** (*Works*)	RailCorp, WCC	Review accumulation of ballast in freshwater sections of Towradgi Creek (immediately downstream of the railway crossing) and remove if required		$30,000	$0	$30,000	1	1	1	1	0		5	0.00	1.67	5.67	1.27	83
190	**Habitat and Species Conservation** (Planning)	WCC	Review Council's Policy on response to illegal tree removal activities including temporary measures where trees have been removed		$2,000	$0	$2,000	0	0	0	1	0		1	0.00	0.33	1.33	0.40	155
191	**Habitat and Species Conservation** (Planning)	WCC	Apply landscape design principles to all proposals which may affect visual amenity (in particular views from existing dwellings)		$0	$1,000	$13,801	1	0	0	1	0		1	0.00	0.33	2.33	0.56	146
192	**Estuary Entrance** (*Works*)	WCC, DNR, DL	Towradgi Creek - Removal of the gabion baskets and replacement with a more natural training wall (~180 m length)		$550,000	$1,000	$563,801	0	-1	0	0	0		0	0.00	0.00	-1.00	-0.17	161
193	**Estuary Entrance** (*Works*)	WCC, DNR, DL	Towradgi Creek - Removal of the gabion baskets entirely (~180 m total length)		$140,000	$2,000	$167,601	0	-1	0	0	0		5	0.00	1.67	0.67	0.13	159
194	**Estuary Entrance** (*Works*)	WCC, DNR, DL	Towradgi Creek - Removal of the Southern training wall only (~70 m length)		$85,000	$2,000	$112,601	0	-1	0	0	0		5	0.00	1.67	0.67	0.13	158
195	**Habitat and Species Conservation** (*Foreshore and Riparian Zones*)	WCC	Review Dog Exercise Areas and designate appropriate dog exercise areas that are compatible with habitat objectives (particularly bird habitat). Identify areas where restrictions are required. Facilities such as dog faeces bins and bags to be provided within designated exercise areas.		$5,000	$0	$5,000	0	0	0	1	0		1	0.00	0.33	1.33	0.36	156
196	**Information and Communications** (*Education*)	WCC	Placement of signage for Bush Care projects and areas of activity.		$0	$1,000	$13,801	0	0	0	1	0		1	0.00	0.33	1.33	0.32	157

ID	Management Objective	Responsibility	Strategy Outline	Comments	Capital Cost	Maintenance/ Recurrent Cost	NPV	Human Uses	Flooding	Sediment and Water Quality	Flora & Fauna	Cultural Heritage	Community Response - Strategic Options* (Raw)	Community Response - Individual Options (Raw)	Community Response - Strategic Options* (Scaled)	Community Response - Individual Options (Scaled)	Benefit Index	benefit index/ log NPV	Rank
197	**Information and Communications** (*Education*)	WCC	Develop an educational tour for the Estuaries.	Recurrent costs assumed to be re-couped through fees associated with tours	$10,000	$0	$10,000	1	0	1	1	1		1	0.00	0.33	4.33	1.08	96
198	**Sedimentation and Erosion** (*Works*)	WCC, DNR, DPI	Towradgi Creek - Identify extent of rubble downstream of Blue Divers Bridge and consider feasibility of removal	Removal costs not included.	$2,000	$0	$2,000	1	1	1	1	0		1	0.00	0.33	4.33	1.31	82
199	**Sedimentation and Erosion** (*Works*)	WCC	Restrict vehicular access to northern foreshore of Towradgi Creek (between the Surf Club and the Parker Road Arm) and to only a small portion of Blue Divers Reserve.		$5,000	$0	$5,000	0	0	1	1	0		1	0.00	0.33	2.33	0.63	142
200	**Visual Amenity** (*Works*)	WCC	Hewitts/Tramway Creek - Review the future of spoil deposit known as "Thirroul Hill" or 'Hannah's Hill		$5,000	$0	$5,000	1	0	0	0	1		1	0.00	0.33	2.33	0.63	142
201	**Water Quality** *(Works)*	WCC, DNR, DL	Towradgi Creek - Build a diversion channel to the East of the saltmarsh/tidal flats on the Parker Road Arm and on the western side of the bike track.		$200,000	$1,000	$213,801	-1	0	0	-1	0		1	0.00	0.33	-1.67	-0.31	162
202	**Habitat and Species Conservation** (*Aquatic Habitats*)	WCC, DNR, DEC	Review water extraction licence and stormwater discharge licences held by Corrimal Coking Works (issued by DNR and DEC respectively) and its implications for environmental flows for Towradgi Creek.		$5,000	$0	$5,000	0	0	1	1	0		1	0.00	0.33	2.33	0.63	142
203	**Water Quality** *(Planning)*	Sydney Water, DEC, WCC	Review licence conditions and environmental impacts associated with sewer overflows in light of additional information on estuary behaviour.		$10,000	$0	$10,000	1	0	1	1	0		1	0.00	0.33	3.33	0.83	128
204	**Cultural Heritage** *(Education*)	WCC, DEC	Prepare an oral history of indigenous heritage for the estuaries (CD and Book formats)	Presume any recurrent costs could be re-couped through the sale of the book.	$30,000	$0	$30,000	0	0	0	0	4		1	0.00	0.33	4.33	0.97	119
205	**Flooding** (*Statutory Controls*)	WCC	Adopt a foreshore building line along all creeks which accords with the boundaries of the High Flood Risk Precinct and other environmental and erosion risk criteria necessitating setbacks from creeks. The FSBL should be identified on Council's maps. This process should also involve a review of the appropriateness of the zoning of individual land parcels, should the combined flood risk and environmental criteria result in a FSBL which substantially affects reasonable development expectations.	Co-Option 113	FPMP	FPMP	N/A	0	2	2	2	0			0.00	0.00	6.00	FPMP	FPMP
206	**Flooding** (*Statutory Controls*)	WCC	Council to prepare and implement a Riverine Corridor Strategy for the creek corridors within the study area, to improve corridor linkages and restore their ecological value and remove inappropriate vegetation which impedes the flow of water or forms a source of debris which exacerbates flooding impacts.		FPMP	FPMP	N/A	1	1	1	1	0			0.00	0.00	4.00	FPMP	FPMP
207	**Flooding** (*Statutory Controls*)	WCC	Council to investigate a policy of formalising creek corridors within publicly owned land or with drainage easements held to the benefit of Council when dealing with development applications involving the redevelopment of flood affected lands. This will require further research of the extent of easement of land acquisition required, the likelihood of redevelopment in areas where such acquisition is required, the impact on the functioning of individual properties and the potential costs to Council.		FPMP	FPMP	N/A	0	2	1	2	0			0.00	0.00	5.00	FPMP	FPMP
208	**Cultural Heritage** (*Works*)	WCC, DEC, TO's	Investigate the potential for the establishment of a keeping place for Aboriginal artefacts disturbed (particularly from the Sandon Point site).	Subject to further consultation with Traditional Owners	$10,000	$0	$10,000	0	0	0	0	4			0.00	0.00	4.00	1.00	105
209	**Cultural Heritage** (*Works*)	WCC, DEC	Identification of an appropriate route for a heritage walking trail through the estuarine area to connect with the overall concept of a trail from Bulli Tops to Sandon Point.	Subject to further consultation with Traditional Owners	$10,000	$0	$10,000	0	0	0	0	4			0.00	0.00	4.00	1.00	105
210	**Cultural Heritage** (*Works*)	WCC, DNR	Investigate the potential for the installation of boardwalks to protect middens and other significant sites from disturbance at Hewitts/Tramway Creek.	Subject to further consultation with Traditional Owners	$5,000	$0	$5,000	0	0	0	1	3			0.00	0.00	4.00	1.08	97
211	**Information and Communications**	WCC, Sydney Water	Periodic data transfer on sewer overflow incidents from Sydney Water database to Council database to allow for interpretation of water quality data		$0	$500	$6,900	M	M	M	M	M			0.00	0.00	M	M	M

Legend	
FPMP	To be funded under the relevant Floodplain Management Plan
*	Weighted score to match maximum scores for community response to specific options
	Eg. Community Involvement = 15, Monitoring = 12, Development Control = 10, Education = 8, Strategic Planning = 6, Cultural Heritage = 4
Co-Option	This option is either a co-option to another option or has been identified for implementation elsewhere in the options list.
M	Monitoring - This action is automatically included in the Plan
D	Done. The action had been implemented during the course of the preparation of the Study and Plan
NI	No location identified for this option

	Data Analysis and Review Actions		
MA1.1	**Estuary Entrance** (*Statutory Controls*)	WCC	Develop entrance management policies as per Floodplain Management Plans
MA2.1	**Flooding** (*Statutory Controls*)	WCC	Flood Controls: Administrative controls such as development controls flood mitigation works (e.g. detention basins).
MA2.2	**Flooding** (*Statutory Controls*)	WCC	Recommend to Council the development of a Water Sensitive Urban Design Policy.
MA4.1	**Flooding** (*Statutory Controls*)	WCC	Recommend to Council the development of a Water Sensitive Urban Design Policy
MA5.1	**Development** (*Statutory Controls*)	WCC	Consider projections in development controls and other planning, policy and management decisions.
MA6.1	**Sedimentation and Erosion** (*Works*)	WCC	Remediation of erosion due to flooding is dependent on measures commonly associated with flood mitigation and bank stabilisation works. (Eg. Hewitts, bank stabilisation & Tramway Creeks, development controls)
MA6.2	**Sedimentation and Erosion** (*Works*)	WCC	To ensure that all developments in the lagoon catchments have appropriate Soil and Water Management practices.
MA9.1	**Water Quality** (*Statutory Controls*)	WCC	Incorporate model ASS provisions into LEP
MA10.1	**Water Quality** (*Works*)	WCC	Advocate for improved sewerage infrastructure and performance to Sydney Water (e.g. SCAMPs in all catchments where faecal coliform contamination is an issue).
MA11.1	**Water Quality** (*Works*)	WCC	Implementation of Gross Pollutant Traps such as the small traps that have been installed on the Towradgi arm of Fairy Creek.
MA11.2	**Implementation, Monitoring and Review** (Monitoring)	WCC	Improve monitoring and collection of litter from lagoon foreshores, especially near recreational facilities such as parks and sports fields.
MA12.1	**Water Quality** (*Statutory Controls*)	WCC	Promote livestock management techniques to reduce water pollution.
MA12.2	**Water Quality** (*Works*)	WCC	Review public health risks associated with FC contamination and propose appropriate actions.
MA13.1	**Habitat and Species Conservation** (*Works*)	WCC	Implement on-ground actions consistent with the objectives of the Riparian Corridor Management Study
MA13.2	**Habitat and Species Conservation** (*Statutory Controls*)	WCC	Apply appropriate zonings to riparian corridors in LEP
MA15.1	**Habitat and Species Conservation** (*Works*)	WCC	Once potential threats have been identified, conservation measures should be implemented which deal directly with the identified threats.
MA15.2	**Habitat and Species Conservation** (*Statutory Controls*)	WCC	Implement planning controls (SEPP 14, rezoning) to protect wetland communities.
MA15.3	**Habitat and Species Conservation** (*Statutory Controls*)	WCC	Generate maps of endangered ecological communities and habitats of threatened species
MA16.1	**Information and Communications** (*Education*)	WCC	Ongoing consultation with the community.
MA17.1	**Information and Communications** (*Education*)	WCC	Ongoing consultation required.
RTA1	**RTA Plans**	RTA	Extension of the Northern Distributor (works in the vicinity of the proposed retarding basin at Hewitts Creek)

APPENDIX C

Detailed Assessment of Ten Options

C.1. Overview

A detailed analysis of a series of 10 management options from the complete list of possible options (Appendix B) was undertaken as part of the overall assessment. These options were selected in consultation with Council following an assessment of the overall options list by the Committee.

The options span works and planning type options to include:

- Relocation of the Towradgi Lagoon entrance southward (Option ID 147)
- Sediment removal for Towradgi Lagoon at the connection of the northern arm (the Parker Road arm) (Option ID 78)
- Bank Rehabilitation in Fairy Creek (a range of actions and locations) (Option IDs 86 - 91)
- Bank Rehabilitation in Towradgi Creek (a range of actions and locations) (Option IDs 17, 96-101)
- Bank Rehabilitation in Hewitts and Tramway Creeks (a range of actions and locations) (Option ID 28, 102-105)
- Riparian Corridor Development Control Plan (DCP) Recommendations (for estuarine portions) (Option ID 7)
- Entrance Management Policy for Fairy Creek (Option ID 143)
- Entrance Management Policy for Towradgi Creek (Option ID 144)
- Entrance Management Policy for Hewitts and Tramway Creeks (Option ID 145, 146)
- Benefits/Impacts of a catchment-wide water sensitive urban design (WSUD) Policy on the estuaries (including consideration of features for both riparian and non-riparian properties) (Option ID 60).

The options assessment consists of the following components:

- A description of the background to the proposed option and key features of the option
- A schematic diagram showing the option details (primarily for works-related options) (Figures C.1 – C.8)
- A commentary on the likely benefits/impacts of the proposed option for estuarine processes
- A breakdown of a preliminary costing of the capital and recurrent costs.

C.2. Option Assessment

C.2.1 Relocation of the Towradgi Lagoon Entrance South-ward (Option ID 147)

Background

The Towradgi Lagoon entrance was partly trained in the late 1970's. The community has a perception that flooding has increased and the hydraulics of the system altered since these works were completed.

An analysis of the changes to the entrance from available historical aerial photography and photogrammetric analysis of the entrance conditions indicates the entrance was highly mobile prior to being trained. The mobility of the entrance was related to the following:

- Limited or no coastal dune system to contain the entrance at a specific location in the period until 1977. In the available discrete instants of time where information is available, the entrance discharges to the north of its current location, at its current location and to the south of its current location. The lack of the stabilizing vegetation and the mobile entrance threatened at times adjacent infrastructure such as the Corrimal Surf Club.
- Works to fix the entrance at a single location were undertaken in the late 1970's after a report was completed to identify an appropriate training strategy. The training works primarily involved the construction of gabion baskets on the northern and southern sides and coastal dune stabilization planting. Similar works were undertaken at other ICOLLs in NSW such as Dee Why lagoon where gabion baskets were constructed and the adjacent dunes stabilized with vegetation. However, the works at this comparable site were constructed below the top water level of the lagoon and were generally submerged unless the entrance was opened. The stabilization works were undertaken downstream of the footbridge over the entrance and provide a fixed point for the footbridge abutments.
- Council adopted an informal entrance management policy that involved the opening of the entrance at a level when the local area was being inundated. This informal policy was in breach of the requirements under Wollongong LEP 1990 which requires the preparation of a Review of Environmental Factors (REF) to support the manual opening of the entrance to consider the potential impacts on the environment. In 2003, the estuary management committee was formed and the informal policy was temporarily suspended until such time as a better understanding of the estuarine processes was available to allow for Council to allow for the preparation of an REF for manual opening of the estuaries.
- During the time following 2003, residents were concerned that the lack of entrance intervention by Council would result in an increased flood risk to adjacent property. Additionally, residents have identified a potential link between the water level in Towradgi Creek and the backflow of sewerage within residential properties. Local residents have identified a potential solution to address this issue to lower the water level in the estuary by having a permanently open entrance condition, based on observed conditions of the entrance when mobile in a southwards direction.
- An option for the construction of a permanent entrance to the south was submitted by the Towradgi Creek community representatives on the estuary management committee for consideration by the Committee.

Concept Details

This assessment has utilized the concept originally proposed by the community representatives and has been modified to include considerations of coastal processes. The option is referred to as Option 147 in Appendix B and involves the following works:

- Excavation of approximately 15 m wide (at the bed) and 280 m long channel along the front of the southern dune to a depth of 0.0 mAHD with an outlet at the southernmost point of the local coastal embayment adjacent to the rocky point at Towradgi Point. This approach will provide for the least ingress of longshore driven sand movement from the south (as the entrance will be protected by the rocky shore except when sediment transport is in a north-south direction). Entrances of estuaries along the NSW coast where the entrance is to the south and adjacent to a headland include Bermagui River, Congo Creek, Hastings River, Lake Macquarie, Sandon River and Tuggerah Lakes among others. However, none of these estuaries has a channel which was transverses the beach in front of the foredune area. This would involve some excavation works and the removal of vegetation from the existing dune system adjacent to Towradgi Park
- Establishment of a coastal dune system to protect the channel along the eastern side of the channel. This would be created by cut to fill works associated with the placement of the cut material from the channel works onto the dune.
- The creation of a potential overflow point (i.e. a slightly lower point in the dune) that could be breached in times of severe flood to reduce the distance that flood flows would have to travel if the southern channel was the only exit point to the ocean. This area would need to be reinstated following any breaches to prevent the new southward entrance being cut-off permanently. As an example, a similar cut off process can be activated in the Shoalhaven River whereby the river can breach the beach dune at the southern end of Seven Mile Beach in times of extreme flood.

A schematic of the proposed works is shown in Figure C.1.

Benefits and Impacts

Key benefits and impacts of the proposal would be:

- Restriction of pedestrian access to the beach – however, this may potentially be of value as the patrolled section of the beach is further northwards in front of the Corrimal Surf Club
- Loss of beach amenity in the vicinity of the proposed works
- Change in the ecology of the Towradgi Creek system via the increase in tidal range over a longer period of time (i.e. a shift in seagrass species from *Ruppia sp* where present to *Zostera sp* and an increase in mangroves including *Avicennia Marina*). In the condition where a more frequently open entrance is installed the bed level at which saltmarsh is viable would alter to a more predictable level if the entrance is more frequently open.
- A potential reduction in water level in the Parker Road arm may potentially reduce the incidence of sewer overflow events within private properties. However, at present, the issues associated with the ingress of Lagoon waters into the sewerage system are being addressed via the testing of the benefits of the installation of tideflaps (duckbill valves) on the manholes which are currently affected by inflows. However, issues associated with sewage ingress to private properties in the East Corrimal area are also associated with the local capacity of

the main carrier which is beyond the impact of any water level change in the Lagoon. These issues are being addressed via Option 33 currently being considered in detail by Sydney Water Corporation for implementation.

- Potential increase in the cyclic wetting and drying processes on the banks of the Lagoon as a result of the increased tidal water level changes with the associated unvegetated bank erosion being potentially exacerbated by this process. The stabilization of these bank areas via the recommended actions in Section C2.4 is recommended to occur prior to the entrance works to reduce the risk of the additional bank weakening
- The consultation process (Cardno Lawson Treloar, 2005b) yielded information that the proposal may affect the foraging habitat of the Sooty Oystercatcher which can be seen at the southern end of Corrimal Beach at low tide.

The presence of aquatic vegetation such as mangroves in the Parker Road arm would tend to indicate that the previous informal policy of manually opening the entrance by Council has allowed for these areas to be viable. In general, the presence of mangroves in an ICOLL is unlikely as the tidal flushing and wetting and drying processes that are common to mangrove environments is limited as the entrances close off relatively quickly. The dominant aquatic vegetation species are commonly those can tolerate the full range of conditions, but the predominate condition being that of a closed brackish system where the salinity is commonly at the fresh end of the brackish range.

The proposed option was modelled using the SOBEK model established for Towradgi Lagoon (Section 3). The option was modelled in concept with a reduced length of channel with a similar bathymetric profile to that observed when the entrance migrated to the south in 1990 (Cardno Lawson Treloar, 2005).

Table C.1 shows the spring and neap tide inflows to the Towradgi estuary during an open condition (with a berm assumed to be at 0m AHD) for both an estimated existing condition (described in Section 3) and the proposed option. From these results, it appears as though the impact on the inflow volumes is minimal. However, this analysis does not take into account mixing and exchange within the estuary.

It would be expected, based on the longer entrance length of the option, that the tidal exchange in the area of the footbridge and further upstream would be less than in the existing condition. This would result in less ocean inflow to the estuary body. However, the flushing rates were not analysed directly as part of the modelling.

Table C.1 Tidal Inflows during Open Entrance Conditions for Towradgi Estuary Option

Towradgi Creek	Volume in Estuary (berm at 0m AHD) (m^3)	Width of Berm (m)	Spring Tide Inflow (m^3)	Neap Tide Inflow (m^3)
Existing Condition (Fully Open Entrance)	2 400	35	24 500	4 130
Option Condition (Fully Open Entrance)	2 400	14	24 400	4 030

A detailed estimate of the likely rate of closure of the proposed entrance conditions is beyond the scope of this assessment. However, it is likely that when the ocean wave conditions result in a net-southerly longshore transport (for example when the wave conditions are nor-easterly swells such as that which occurs from time to time, commonly in the summer period) that the entrance could be closed. Additionally the entrance could potentially close with limited net-southerly transport due to limited catchment baseflow.

A benefit index for the works was evaluated using the scoring system outlined in Section 9. The benefit average for the works is 0.8.

Capital and Recurrent Costs

An estimate of the cost of the works is outlined at the end of this Appendix. The capital cost of the works is of the order of $1.9 million and the recurrent cost of the works is of the order of $10,000/year. Presuming a discount rate of 7% and a life of the works to be 50 years the net present value of the option is $2.05 million.

Further studies in particular required would be a flood study to evaluate the likely impacts of the works.

C.2.2. Dredging of Towradgi Lagoon at the connection of the northern arm (the Parker Road arm)

Background

The recent bathymetric survey of Towradgi Lagoon (undertaken by DNR in February 2005) indicates that a 'sill' of sediment is apparent at the confluence of the Parker Road Arm and the main Lagoon (Figure C.2). The maximum level of the sill is of the order of 0.8 mAHD and the minimum level of the sill is of the order of 0.5 mAHD.

No records of water levels are available for the Parker Road Arm. However, field inspections undertaken on a range of occasions for this project indicate that the water level in the Parker Road Arm is commonly such that the culverts under Lake Parade near the Corrimal Tourist Park are partly submerged.

Detailed analyses of the history of the sediment at this location are currently being undertaken by ANSTO for Council and the results of which are expected to be available at the end of 2006. Consequently, any proposal for the removal of the sill is pending the outcome of the sedimentation rate analysis in progress to confirm the origin of the sill and the rate of its deposition.

Concept Details

This option has been proposed to alleviate elevated water levels in the Parker Road Arm during periods of rainfall and increase the flushing of the Arm when the entrance is open. The option is referred to as Option 32 in Appendix B and involves the following works:

- Dredging of approximately 110 m^3 of bed material. This material would be removed from the reach of the Parker Road arm from the confluence with Towradgi Lagoon and up to the Parker Road culverts.
- The removal of this material will reduce bed levels to approximately 0 mAHD. This would allow the runoff from the Parker Arm catchment to flow out into the Towradgi Lagoon, thereby reducing the levels in the upper reaches of the Parker Road Arm.
- A detailed geotechnical survey would be carried out to determine the sediment quality and any Potential Acid Sulfate Soils that may be present.
- Pending the results of the geotechnical survey, the dredged material may require treatment and possible disposal. This could either be done on site or the material could be removed and treated as aqueous waste.

A schematic of the option is shown in Figure C.2.

Benefits and Impacts

The expected benefits and impacts associated with this option are:

- Improvements to fish passage up the Parker Road Arm
- Increased tidal flushing of the Parker Road arm
- Reduction in flood levels during minor events.

Capital and Recurrent Costs

An estimate of the cost of the works is outlined at the end of this Appendix. The capital cost of the works is of the order of $114,000 and the recurrent cost of the works is of the order of $3,000/year. Presuming a discount rate of 7% and a life of the works to be 50 years the net present value of the option is $155,000.

C.2.3. Bank Rehabilitation in Fairy Creek

Background

The riparian zone of Fairy Lagoon forms a critical component in the functioning of the estuarine system. The riparian zone provides a transition between the estuary

waterway and the surrounding urban areas and also acts as a filter for locally generated overland flow. Commonly, where the banks of the estuary are in a degraded state, the riparian zone is compromised. The stabilisation of the banks is commonly the first stage in the overall rehabilitation of the riparian zone. This is of particular relevance from a works perspective where equipment and machinery to undertake substantial works can damage the riparian zone if planting away from the banks is commenced reducing access to locations where works are required.

Detailed information from inspections of the banks of the estuarine portions of Fairy Creek can be found in Cardno Lawson Treloar (2005a). The findings of the inspections included a list of proposed options to be implemented as a works program for the creek.

It is anticipated that the materials derived from the erosion of the banks result in sedimentation in the main Lagoon, or the materials are potentially transported to the coast when the entrance opens during both major and minor flood events.

Any bank works carried out in the Fairy Creek Estuary will be dependant on the outcomes of an indigenous cultural heritage study. Aboriginal burial sites are commonly found in sand dunes and creek banks, as graves were more easily dug than in harder ground. For this reason it is important to ensure that the cultural heritage study first identifies any potential burial sites in the areas of the proposed works.

Concept Details

Table C.2 is a summary of the recommended actions for Fairy Creek from Cardno Lawson Treloar (2005a). Reference should also be made to Cardno Lawson Treloar (2005a) for schematic details of the recommended management techniques. Figure C.3 outlines the various locations for the options.

Table C.2 Bank Management Options for Fairy Creek

ID#	Location	Issue	Recommended Action or Management Technique*
A	Fairy Lagoon Entrance (Right Bank)	Low erosion scarp at the interface between the Stuart Park area (mowed grass area) and the lagoon beach.	Stabilise Entrance Dunes (to include beach access track). Establish a vegetative barrier in front of the scarp and limit public access to defined points. Alternatively a low timber retaining wall would also be effective in limiting any further bank retreat.
B	Puckey's Estate Boat Ramp	The banks surrounding the boat ramp have been eroded.	The banks should be stabilised such that the works are sensitive to the historical significance of the structure. (Technique 5)
C	Fairy Creek (upstream of Squires Way)	Undercutting of the bank.	Battering the slope and providing a gravel/cobble beach that could also be re-vegetated. Alternatively, providing there is a suitably wide bench, a low rock berm or permeable fence constructed landward of the bank that was subsequently backfilled and vegetated would also be expected to stabilise the bank.

ID#	Location	Issue	Recommended Action or Management Technique*
			(Technique 3 or 8)
D	Fairy Creek (between Squires Way and Flinders Street)	Attempts to stabilise the banks appear to be un-coordinated and piecemeal resulting in unsightly and only partly successful works. In some locations the isolated bank works appear to have had a detrimental effect by directing more concentrated flows onto unprotected areas.	Deteriorated bank revetment works should be removed. Where possible banks should be stabilised by battering and revegetating. (Technique 1 or 2) Alternatively, where space is restricted, retaining walls could be implemented. (Technique 6)
E	Fairy Creek (between Squires Way and Flinders Street)	There are several stormwater outlets constructed using traditional concrete headwalls that are now being seriously undermined.	The headwalls require rock armouring for support and to protect the immediately surrounding bank. Where the outlets are not fitted with hinged floodgates it would be preferable to reconstruct the stormwater outlets by supporting the end pipes using piles and collars that are then hidden behind a rock apron that extends below the low water line. Valve type floodgates could be used for sites where large exposed headwalls are not present.
F	Fairy Creek (downstream of Flinders Street)	A fair amount of debris has accumulated at this location, choking the flow and degrading the banks.	The litter and debris should be removed from the channel.
G	Fairy Creek and Para Creek (majority of estuarine reaches)	The vegetation on the banks of these creeks is predominately exotic species.	Removal of weeds and revegetation with natives.
H	Para Creek (between junction with Fairy Creek and Puckey Avenue)	There are a number of potentially unstable large trees at or near the top of the bank in this reach.	Rock armouring placed around the base of some of the overhanging trees would reduce the risk of falling trees and associated future maintenance issues. (Technique 7)
I	Para Creek (Downstream of Puckey Avenue)	There are a series of partly submerged gravel bars of uncertain origin. At low flows the diagonal bars would direct stream currents onto the right bank.	Removal of the bars or a perpendicular re-orientation across the creek so as to form a series of riffle structures would assist in reducing stress on the right bank. This would also provide some aeration to the creek flow. Any allowance for fish passage past the riffles should be located in the central third of the creek channel.
J	Para Creek (at a number of locations between junction with Fairy Creek and Puckey Avenue)	Undercutting of the bank.	Battering the slope and providing a gravel/cobble beach that could also be re-vegetated. Alternatively, providing there is a suitably wide bench, a low rock berm or permeable fence constructed landward of the bank that was subsequently backfilled and vegetated would also be expected to stabilise the bank. (Technique 3 or 8)

ID#	Location	Issue	Recommended Action or Management Technique*
K	Towradgi Arm	Undercutting of the bank.	Battering the slope and providing a gravel/cobble beach that could also be re-vegetated. Alternatively, providing there is a suitably wide bench, a low rock berm or permeable fence constructed landward of the bank that was subsequently backfilled and vegetated would also be expected to stabilise the bank. (Technique 3 or 8)

#Location shown in Figure C3
*Where applicable treatment techniques from Appendix A of the Further Processes Studies Report have been suggested in brackets.

Benefits and Impacts

Well managed riparian lands can result in a range of benefits including:

- Decreased bank erosion
- Improved creek water quality
- Healthy riparian and aquatic ecosystems
- Decrease in insect pests
- Increase in house and property capital values
- Shelter effects
- Opportunities for diversification
- Retention of nutrients
- Lowered water tables
- Increased fish stocks
- Landscape refuge
- Decreased algal growth
- Increased opportunities for ecotourism.

With particular reference to the Fairy Creek Estuary these benefits would be:

- Protection of properties along Fairy and Cabbage Tree Creeks that are currently threatened by bank erosion.
- Further protection and management of the Towradgi Arm would further enhance the riparian lands within Puckeys Estate. This reach of the Fairy Estuary is already an important area of refuge for riparian and aquatic ecosystems. It is vital to ensure that this area is protected and riparian values are enhanced to their full extent.
- A reduction in the source of sediment being delivered to the estuary and depositing on the bed
- A reduction in the source of sediment being delivered to the estuary and being held in suspension and reducing water clarity
- A reduction in the physical loss of the riparian zone due to shoreline erosion.

Capital and Recurrent Costs

An estimate of the cost of the works is outlined at the end of this Appendix. The capital cost of the works is of the order of $626,000 and the recurrent cost of the works is of the order of $33,000/year. Presuming a discount rate of 7% and a life of the works to be 50 years the net present value of the option is $1.08 million.

C.2.4. Bank Rehabilitation in Towradgi Creek

Background

The riparian zone of Towradgi Creek Estuary forms a critical component in the functioning of the estuarine system. The riparian zone provides a transition between the estuary waterway and the surrounding urban areas and also acts as a filter for locally generated overland flow. Commonly, where the banks of the estuary are in a degraded state, the riparian zone is compromised. The stabilisation of the banks is commonly the first stage in the overall rehabilitation of the riparian zone. This is of particular relevance from a works perspective where equipment and machinery to undertake substantial works can damage the riparian zone if planting away from the banks is commenced reducing access to locations where works are required.

Detailed inspections of the banks of the estuarine portions of Towradgi Creek can be found in Cardno Lawson Treloar (2005a). The findings of the inspections included a list of proposed options to be implemented as a works program for the creek.

Any bank works carried out in Towradgi Estuary will be dependant on the outcomes of an indigenous cultural heritage study. Aboriginal burial sites are commonly found in sand dunes and creek banks, as graves were more easily dug than in harder ground. For this reason it is important to ensure that the cultural heritage study first identifies any potential burial sites in the areas of the proposed works.

Concept Details

Table C.3 is a summary of the recommended actions for Towradgi Creek from Cardno Lawson Treloar (2005a). Reference should also be made to Cardno Lawson Treloar (2005a) for schematic details of the recommended management techniques. Figure C.4 outlines the various locations for the options.

Table C.3 Towradgi Creek Estuary Bank Management Recommendations

ID#	Location	Issue	Recommended Action or Management Technique*
A	The Entrance	Limited vegetation on right bank.	Revegetate and stabilise entrance dunes at Towradgi Park.
B	Towradgi Creek (along Towradgi Park and Corrimal Beach Park)	Limited riparian corridor provides little protection for banks. There are pockets of erosion along this reach.	Revegetate and improve riparian corridor. Limit access to the creek to defined access points. Stabilise banks where erosion has occurred.
C	Towradgi	Degraded gabions.	Rehabilitate collapsing gabions.

ID#	Location	Issue	Recommended Action or Management Technique*
	Northern Tributary (Near footbridge at Tourist Park)		
D	Towradgi Creek (left bank frontage of Lake Parade properties)	Private foreshore works and structures cause discontinuities in riparian vegetation and conditions.	Removal or rehabilitation of bank works.
E	Towradgi Creek Right Bank (Blue Divers Reserve)	Severely eroded banks.	Stabilising banks (most of the techniques in Appendix A could be applied) and tree management (Technique 7). The banks are very severely degraded and will require major works to stabilise.
F	Towradgi Creek Left Bank (Blue Divers Reserve)	Exposed and degraded banks.	Revegetation of banks and limited access points.
G	Towradgi Creek (Street Park both banks)	The banks are generally stable. However, there is very limited environmental value due to limited riparian zone.	Revegetation of banks and allowance for a wider riparian zone. Limited access points should be allocated.
H	Towradgi Creek (Raymond Parade footbridge)	Exposed bank is eroded.	Stabilising steep banks. (Technique 3 or 4)
I	Towradgi Creek (between footbridge and railway crossing)	Riparian vegetation dominated by weeds, some sections of bank erosion.	Revegetate and stabilise banks.

#Location shown in Figure C3

*Where applicable treatment techniques from Appendix A of the Further Processes Studies Report have been suggested in brackets.

Benefits and Impacts

Well managed riparian lands can result in a range of benefits including:

- Decreased bank erosion
- Improved creek water quality
- Healthy riparian and aquatic ecosystems
- Decrease in insect pests
- Increase in house and property capital values
- Shelter effects
- Opportunities for diversification
- Retention of nutrients
- Lowered water tables
- Increased fish stocks
- Landscape refuge
- Decreased algal growth
- Increased opportunities for ecotourism.

With particular reference to the Towradgi Creek Estuary these benefits would be:

- Improved protection of properties in Lake Parade. The current bank works along the frontage of these properties would be enhanced allowing for protection of the properties and improved riparian corridor values.
- The Blue Divers Reserve is currently used on a regular basis. The protection of the banks and revegetation would result in increased visual amenity and decreased erosion among other riparian benefits.
- Revegetation and removal of weeds at identified locations will enhance the riparian and aquatic habitats and stabilise banks. This particularly applicable at the Parks along Towradgi Creek (Street Park, Corrimal Beach Park and Towradgi Park) where there is the space and capacity to provide substantial riparian corridor width.
- Revegetation and protection of the dunes will protect the beach and the fragile ecosystems which exist in the dunes.
- Bank works will generally result in a reduction in the source of sediment being delivered to the estuary and depositing on the bed, particularly at locations such as the entrance to the Parker Arm.
- A reduction in the source of sediment being delivered to the estuary and being held in suspension and reducing water clarity.

Capital and Recurrent Costs

An estimate of the cost of the works is outlined at the end of this Appendix. The capital cost of the works is of the order of $1,094,000 and the recurrent cost of the works is of the order of $20,000/year. Presuming a discount rate of 7% and a life of the works to be 50 years the net present value of the option is $1.37 million.

Further studies in particular required would be a flood study to evaluate the likely impacts of the works.

C.2.5. Bank Rehabilitation in Hewitts/Tramway Creeks

Background

The riparian zones of Hewitts and Tramway Creeks form a critical component in the functioning of the estuarine system. The riparian zone provides a transition between the estuary waterway and the surrounding urban areas and also acts as a filter for locally generated overland flow. Commonly, where the banks of the estuary are in a degraded state, the riparian zone is compromised. The stabilisation of the banks is commonly the first stage in the overall rehabilitation of the riparian zone. This is of particular relevance from a works perspective where equipment and machinery to undertake substantial works can damage the riparian zone if planting away from the banks is commenced reducing access to locations where works are required.

Detailed inspections of the banks of the estuarine portions of Hewitts/Tramway Creek systems can be found in Cardno Lawson Treloar (2005a). The findings of the

inspections included a list of proposed options to be implemented as a works program for the creek.

Any bank works carried out in Hewitts/Tramway Creek systems will be dependant on the outcomes of indigenous cultural heritage study. Aboriginal burial sites are commonly found in sand dunes and creek banks, as graves were more easily dug than in harder ground. For this reason it is important to ensure that the cultural heritage study first identifies any potential burial sites in the areas of the proposed works.

Concept Details

Table C.4 is a summary of the recommended actions for Hewitts and Tramway Creeks from Cardno Lawson Treloar (2005a). Reference should also be made to Cardno Lawson Treloar (2005a) for schematic details of the recommended management techniques. Figure C.5 outlines the various locations for the options.

Table C.4 Tramway and Hewitts Creeks Estuaries Bank Management Recommendations

ID#	Location	Issue	Recommended Action or Management Technique*
A	Tramway Creek entrance	Scour of the right bank.	Revegetate dunes and limit public access across the dunes.
B	Tramway Creek (culvert outlet from connecting branch from woodlands creek)	Scour at outlet of culvert	Rock armouring for support and to protect the immediately surrounding bank.
C	Tramway Creek (upstream of lagoon section)	The channel is densely vegetated with tall grasses.	The channel could be cleared and rehabilitated, however this would drastically change the current ecosystems existing in the creek, a full species study should be undertaken before decisions are made.
D	Tramway Creek (at footpath crossing)	The culvert under the footpath is restricting flow and tidal movement.	The culvert could be amplified to allow easy passage for flows. However, as above this would change the current ecosystems.
E	Hewitts Creek Entrance	Low erosion scarp at the interface between the Stuart Park area (which is mowed grass area) and the lagoon beach.	Stabilise Entrance Dunes (to include beach access track). Establish a vegetative barrier in front of the scarp and limit public access to defined points. Alternatively a low timber retaining wall would also be effective in limiting any further bank retreat.
F	Hewitts Creek	The vegetation on the banks is predominately exotic species (especially in the upper reaches).	Removal of exotic species and revegetation with natives where possible.
G	Hewitts Creek (near the end of Corbett Ave)	A fallen tree has removed part of the bank and is now redirecting flow onto the banks causing scour.	Removal or lopping of the tree to reduce scour on the bank below properties.

ID#	Location	Issue	Recommended Action or Management Technique*
H	Hewitts Creek (near the end of Corbett Ave)	An access path across the creek has caused degradation of banks.	The access path could either be blocked or a formal crossing of the creek could be implemented
I	Hewitts Creek (between the railway line and Lawrence Hargrave Drive	This section of creek is not severely degraded, however, weeds are prevalent and litter has accumulated in the overgrown sections.	Rehabilitation of this reach, induding bank stabilising through battering and revegetation and increasing the width of the riparian corridor.

#Location shown in Figure C4
*Where applicable treatment techniques from Appendix A of the Further Processes Studies Report have been suggested in brackets.

Benefits and Impacts

Well managed riparian lands can result in a range of benefits including:

- Decreased bank erosion
- Improved creek water quality
- Healthy riparian and aquatic ecosystems
- Decrease in insect pests
- Increase in house and property capital values
- Shelter effects
- Opportunities for diversification
- Retention of nutrients
- Lowered water tables
- Increased fish stocks
- Landscape refuge
- Decreased algal growth
- Increased opportunities for ecotourism.

With particular reference to the Hewitts and Tramway Creeks these benefits would be:

- Revegetation and protection of the dunes and creek entrances will protect the beach, dunes and the fragile ecosystems which exist in the dunes. Eroded banks at beach access points can also cause safety issues.
- Removal of vegetation from creek beds will improve conveyance and allow native species to re-establish.
- Removal of snags which are causing bank erosion will increase bank stability, reducing the sediment load being carried down the creek causing sedimentation on the bed and reducing water clarity.
- Protection and enhancement of riparian vegetation along the creeks will protect the banks and increase riparian and aquatic habitats.

Capital and Recurrent Costs

An estimate of the cost of the works is outlined at the end of this Appendix. The capital cost of the works is of the order of $596,000 and the recurrent cost of the works is of the order of $14,000/year. Presuming a discount rate of 7% and a life of the works to be 50 years the net present value of the option is $790,000.

Further studies in particular required would be a flood study to evaluate the likely impacts of the works.

C.2.6. Riparian Corridor DCP Recommendations

Background

A riparian corridor DCP is an important component of the implementation of riparian corridor requirements. At present, through Council's *Managing Our Flood Risks* DCP (DCP 54), an interim riparian corridor of 10 m has been included in the 'High Risk Precinct' mapping for all floodplain areas where mapping has been completed. To date this includes Towradgi Creek and Hewitts and Tramway Creeks. The mapping for Fairy Creek is currently in preparation.

The provision of a specific riparian corridor DCP to provide guidance as to the desired characteristics of the zone in private property will allow for a uniform approach to the redevelopment process for properties in the riparian zone.

This DCP is in light of the studies completed on Riparian Corridor Management (DIPNR, 2004). An example of the results of these studies for Towradgi Creek is shown in Figure C.6.

Concept Details

It is recommended that the DCP be prepared in a manner that is compatible with the Managing Our Flood Risks DCP54. To this end it is recommended that the DCP take on a catchment-specific form to account for local sensitivities in a matrix manner. Similarly, it is recommended that the DCP integrate the findings of the Riparian Corridor Management Strategy and extend those recommendations where required to achieve the optimum environmental outcome. DIPNR (2004) outlined three categories of management objective for corridor areas:

- Environmental corridor
- Terrestrial and aquatic habitat
- Bank Stability and water quality.

Given the variation of the nature of management of public and private land, it is recommended that where land is in public ownership, it be given the highest order of environmental outcome and rehabilitation works be undertaken as a priority in those areas.

Consequently, the DCP in outline form is recommended to include the following details:

- Introductory sections similar to other DCP's including:
    - What is this plan?
    - Why is this plan required?
    - To which applications does this plan apply?
    - Where does the plan apply?
    - How does this plan relate to other legislation and regulations (including an explanation of the inter-relationship between the Flood Risk DCP and the Riparian Corridor DCP)
    - How to use this plan
    - What are the aims and objectives of the Plan?
    - Glossary
- Details of the criteria for determining applications
    - General
    - Land use categories
    - Riparian Corridor Precincts – separated into:
        - Riparian Precinct A (Environmental Corridor - Public Land)
        - Riparian Precinct B (Environmental Corridor - Private Land)
        - Riparian Precinct C (Terrestrial and Aquatic Habitat)
        - Riparian Precinct D (Bank Stability and Water Quality)
    - Which controls apply to proposed developments?
        - Objectives
        - Performance Criteria
        - Specific Requirements
    - What requirements are there for landscaping?
        - Objectives
        - Performance Criteria
        - Specific Requirements
    - What requirements are there for fencing?
        - Objectives
        - Performance Criteria
        - Specific Requirements
- What information is required with an application to address this DCP?
- A series of schedules to accompany the DCP including:
    - Schedule 1 Land Use Categories
    - Schedule 2 Landscape Guidelines
    - Schedule 3 Catchment Specific Requirements – Towradgi Creek Riparian Corridor
    - Schedule 4 Catchment Specific Requirements – Hewitts/Tramway Creeks Riparian Corridor
    - Schedule 5 Catchment Specific Requirements – Fairy Creek Riparian Corridor
    - Other schedules as other studies for other areas are completed.

Table C.5 provides an example of the types of catchment specific requirements that could be implemented for each catchment.

Table C.5 Proposed Development Control Matrix

Planning Consideration	Riparian Corridor Precincts (RCP's)																			
	Bank Stability and Water Quality Precinct D^								Terrestrial and Aquatic Habitat Corridor Precinct C^								Environmental Corridor Precincts A and B^							
	Essential Community Facilities	Critical Utilities	Subdivision	Residential	Commercial & Industrial	Tourist Related Development	Recreation & Non-Urban	Concessional Development	Essential Community Facilities	Critical Utilities	Subdivision	Residential	Commercial & Industrial	Tourist Related Development	Recreation & Non-Urban	Concessional Development	Essential Community Facilities	Critical Utilities	Subdivision	Residential	Commercial & Industrial	Tourist Related Development	Recreation & Non-Urban	Concessional Development
Width of Corridor and Building Setbacks																								
Bank Treatment Requirements																								
Landscaping Density																								
Fencing																								
Management & Design			*								*								*					

	Not Relevant		Unsuitable Land Use	*	Refer to *'Management & Design'* planning consideration for subdivision

Width of Corridor and Building Setbacks	
1	No buildings/structures/roads within a setback of 5 m from top of bank
2	No buildings/structures/roads within a setback of 10 m from top of bank
3	No buildings/structures/roads within a setback of 15 m from top of bank
4	No buildings/structures/roads within a setback of 20 m from top of bank
Bank Treatment Requirements	
1	Bank Treatment Type 1
2	Bank Treatment Type 2
Landscaping Density	
1	Low shrubs only (planted at a density of 1 per m^2)
2	Low shrubs only (planted at a density of 4 per m^2)
3	No low shrubs – only canopy trees (Casuarinas or similar from the suitable species planting list) (planted at a density of 1 per m^2)
Fencing	
1	No fencing permitted
2	Open style fencing permitted only
3	No fencing restrictions
Management and Design	
1	Applicant to demonstrate that potential development as a consequence of a subdivision proposal can be undertaken in accordance with this DCP
2	Site Landscape Plan Required
3	Site Vegetation Management Plan Required

^ Riparian Corridor Precinct Definitions mapping to be prepared

Recommended DCP 54 Schedule of Land Use Types Consistent with the Wollongong City Council LEP, 1990 could be transferred to the document

Green cells to be evaluated in consultation with Community

The process of implementation is recommended to occur through the following stages:

- Draft generic sections of the DCP
- Draft tabulation of the catchment-specific requirements
- Prepare mapping of riparian areas for Towradgi Creek as the trial area
- Complete tabulation of riparian areas for each catchment as studies are completed making reference to mapping (using Towradgi Creek as the trial area)
- Exhibit draft DCP for comment
- Adopt DCP
- Prepare mapping of riparian areas for each catchment as studies are completed
- Complete tabulation of riparian areas for each catchment as studies are completed making reference to mapping
- Re-exhibit DCP as information for each catchment becomes available.

Benefits and Impacts

The key benefit of adopting such a DCP is the advantages of preparing for the future of the area as well as the integrated nature of the considerations with the Flood Risk DCP. The enhancements in the areas of environmental corridors (linking the escarpment to the ocean) for the passage of fauna is valuable in the overall sustainability of the system. Where this cannot be achieved in the short term, the provision of

A key potential impact of the DCP could occur if the landscaping requirements are not stringently followed due to the critical impact of different vegetation types on flood risks. It is recommended that considerations be made of the potential 'roughness' of vegetation types prior to their implementation.

An important component of the implementation of the DCP is the undertaking of random audits of properties where consent has been issued and works have been completed. Allowance has been made in the assessment of the recurrent costs for this option for undertaking 10 random audits per year as well as follow up with rectification notices.

Capital and Recurrent Costs

An estimate of the cost of the DCP preparation is outlined at the end of this Appendix. The capital cost of the preparation is of the order of $47,000 and the recurrent cost of the works is of the order of $17,000/year. Presuming a discount rate of 7% and a life of the works to be 50 years the net present value of the option is $280,000.

C.2.7. Entrance Management Policy for Fairy Creek

Background

The Fairy Creek system consists of a main lagoon body at approximately -0.8 m AHD (a maximum depth of around -2.5 mAHD) with a rock shelf control on the entrance at

around 0 mAHD. Thus, the maximum scour is to 0 mAHD when the entrance is fully open. A large portion of the Lagoon area (including the Towradgi Arm) is located above 0 mAHD and therefore when the entrance opens these areas become exposed and tidal.

Historically, Council Works Division has had an informal entrance management policy of opening the entrance of Fairy Creek when the water level reaches part way up the Sydney Water Corporation carrier which is suspended above the Creek immediately upstream of the Squires Way crossing. This opening has been in response to resident complaints largely associated with property inundation and fears of overfloor flooding. This level is of the order of 1.4 mAHD. The analysis of the maximum water levels at the Fairy Creek gauge further upstream at Flinders Street show that the maximum water level generally has not exceeded 1.47 mAHD which is consistent with the informal opening strategy previously employed.

This informal entrance management policy ceased in approximately 2003 when the estuary management committee was formed to consider the ecological effects of manual opening of the entrance.

Concept Details

Given the flood risks associated with the entrance at Fairy Creek and the adaptation of the Fairy Creek system to most likely an altered condition of opening, the following entrance management policy and process is recommended for implementation:

- Day to day operation of the Lagoon is likely to see the Lagoon closed for the majority of the time and opening up to seven times a year.
- Water level in the Lagoon is monitored via routine checks of the water level gauge at Bodes Bridge. The information on this webpage is normally only updated on a daily basis, usually between 4 – 6am. (http://www.mhl.nsw.gov.au/htbin/map_data_display.com?SITE=FAIR)
- Rainfall in the locality can be monitored via routine checks of the local rainfall gauge at Russell Vale. The information on this webpage is normally only updated on a daily basis, usually between 4 – 6am. (http://www.mhl.nsw.gov.au/htbin/map_data_display.com?SITE=RUSS)
- An alarm can be created in the monitoring system operated by MHL to send an automated email, fax or telephone a pre-registered list of telephone numbers (eg Area Works Depot Manager or Duty Operator) with a recorded message when a threshold level has been exceeded. It is recommended that Council contact MHL via DNR to have such an alarm system developed and activated. In the case of Fairy Creek it is recommended that this threshold be set at **1.6 mAHD**. This is consistent with the proposed flood planning assessments being undertaken for the Floodplain Risk Management Study and Plan. Consideration of the addition of a standby alarm to be triggered when the level reaches a lower level to indicate to Council to prepare for the opening may also be prudent.
- Once the threshold level is exceeded and rainfall is continuing in the catchment or expected in the following 24 hours, Area Works Manager to decide on whether to mobilize an excavator operator to undertake an assisted breakout. The estimated

time to mobilize an operator is of the order of one hour during business hours and 2 hours during non-business hours.

- Once a decision has been made to undertake an assisted breakout, advice to DPI (NSW Fisheries), DEC, DNR and the local media should be issued advising of the breakout with details of potential health impacts on recreational swimmers on the adjacent beach areas for the following three days.
- On arrival the excavator operator to dig a 'pilot' channel from the ocean-ward end toward the entrance approximately a bucket-width wide (commonly 1 m or less). The last section of the channel (at the entrance end) should be opened at the time of the next possible high tide (i.e. the highest possible tide of the day). (Ocean tide information in the form of predicted tides can be accessed at http://www.mhl.nsw.gov.au/www/sydp_tide.htmlx). Initiation of a breakout at this time is likely to result in the most effective and sustained assisted breakout due to the increasing head difference through the course of the breakout.
- Figure C.7 shows the recommended access point for the excavator operator to access the beach and the recommended orientation of the excavated channel and location of the material excavated from the pilot channel.
- Where access to the internet is not available (due to power loss associated with a storm event), checking of a water level marker (a 'tide board') at a visible location from Squires Way (to be installed on the upstream side of Squires Way) should be undertaken and white pole markers be placed in Puckey's Estate to direct the excavator operator as to the most appropriate pilot channel location and orientation.

The implementation of assisted breakout has generally been defined in other similar areas either as an action under State Environment Planning Policy No 35 (SEPP35) as Maintenance Dredging of Tidal Waterways or as a flood work under Council's Local Environment Plan, either of which actions are required to be supported by a Review of Environmental Factors under Part V of the EP&A Act 1979. The consent authority is then either the Department of Lands as the Crown Land manager or Council as the Trust Manager with the relevant stakeholders being DNR, DEC and DPI. Permits required for the activity may include a dredging permit from DPI under the Fisheries Management Act, 1994.

Benefits and Impacts

The benefits of an assisted breakout are primarily related to:

- reducing flood risks for properties immediately adjacent to the creek and
- maintenance of water quality.

The regular flushing through the opening of the entrance is likely to be one of the key reasons that the system has not been subject to more frequent phytoplankton and macro-algal blooms. As outlined in Section 3, even during minor events the volume on inflow from the catchment is sufficient to displace the entire volume of water in the estuary and thus loads of nutrients generated within the catchment are lost from the system to the ocean when the entrance is opened.

The limited mangroves and saltmarsh in the Fairy Creek system (in the Towradgi Arm) appear to be sustained by the frequency of entrance opening and the associated tidal conditions. If the entrance condition is returned to a reduced opening and closing regime (eg as a result of a cessation of intervention that Council has undertaken only in the last 2 – 3 years) then it might be expected that these species may not survive or may be reduced in their quality and health. It could be argued that these species are unsustainable in the systems if they were returned to a less open state.

Following a breakout the amenity associated with the area of beach within the entrance zone alters and is less usable for beach activities. Additionally, given the issues associated with elevated faecal coliforms in the inflows the Lagoon during wet weather and associated outflows to the beach, a breakout impacts on the quality of water in the beach area for recreational swimming. It is recommended that the surrounding beach areas be closed for at least three days following a breakout.

Capital and Recurrent Costs

An estimate of the cost of the preparation of an REF and associated works to formally implement an entrance assisted breakout policy is outlined at the end of this Appendix. The capital cost of the works is of the order of $39,000 and the recurrent cost of the works is of the order of $21,000/year. Presuming a discount rate of 7% and a life of the works to be 50 years the net present value of the option is $330,000.

C.2.8. Entrance Management Policy for Towradgi Creek

Background

As for Fairy Creek, the Towradgi Creek system consists of a main lagoon body at approximately -0.4 m AHD (a maximum depth of around -1.0 mAHD) with control on the entrance at around 0 mAHD (presumed to be a similar rock shelf to Fairy Creek). Thus, the maximum scour is approximately to 0 mAHD when the entrance is fully open. A large portion of the Lagoon area (including the Parker Road Arm) is located above 0 mAHD and therefore when the entrance opens these areas become exposed and some areas are tidal. The Parker Road Arm bed is generally above 0.5 m AHD and therefore is only inundated when the entrance is open when the tide is elevated above 0.5 mAHD (i.e. mean high water spring tide).

Historically, Council Works Division has had an informal entrance management policy of opening the entrance of Towradgi Creek when resident complaints are received associated with local street flooding in Lake Parade and surrounding areas. This level is of the order of 1.2 mAHD. The analysis of the maximum water levels at the Towradgi Creek gauge further upstream at Pioneer Road shows that the maximum water level generally has not exceeded 1.6 mAHD which is consistent with the informal opening strategy previously employed.

This informal entrance management policy ceased in approximately 2003 when the estuary management committee was formed to consider the ecological effects of manual opening of the entrance.

Concept Details

Given the flood risks associated with the entrance at Towradgi Creek and the adaptation of the Towradgi Creek system to most likely an altered condition of opening, the following entrance management policy and process is recommended for implementation:

- Day to day operation of the Lagoon is likely to see the Lagoon closed for the majority of the time and opening up to eight times a year.
- Water level in the Lagoon is monitored via routine checks of the water level gauge at Pioneer Road. The information on this webpage is normally only updated on a daily basis, usually between 4 – 6am. Note that this gauge can show information of limited assistance for entrance management once the entrance is open. (http://www.mhl.nsw.gov.au/htbin/map_data_display.com?SITE=TOWR)
- Rainfall in the locality can be monitored via routine checks of the local rainfall gauge at Russell Vale. The information on this webpage is normally only updated on a daily basis, usually between 4 – 6am. (http://www.mhl.nsw.gov.au/htbin/map_data_display.com?SITE=RUSS)
- An alarm can be created in the monitoring system operated by MHL to send an automated email, fax or telephone a pre-registered list of telephone numbers (eg Area Works Depot Manager or Duty Operator) with a recorded message when a threshold level has been exceeded. It is recommended that Council contact MHL via DNR to have such an alarm system developed and activated. In the case of Towradgi Creek it is recommended that this threshold be set at **1.6 mAHD** given the issues with road inundation in the Lake Parade and surrounding areas. This is consistent with the proposed flood planning assessments being undertaken for the Floodplain Risk Management Study and Plan. Consideration of the addition of a standby alarm to be triggered when the level reaches a lower level to indicate to Council to prepare for the opening may also be prudent.
- Once the threshold level is exceeded and rainfall is continuing in the catchment or expected in the following 24 hours, Area Works Manager to decide on whether to mobilize an excavator operator to undertake an assisted breakout. The estimated time to mobilize an operator is of the order of one hour during business hours and 2 hours during non-business hours.
- Once a decision has been made to undertake an assisted breakout, advice to DPI (NSW Fisheries), DEC, DNR and the local media should be issued advising of the breakout with details of potential health impacts on recreational swimmers on the adjacent beach areas for the following three days.
- On arrival the excavator operator to dig a 'pilot' channel from the ocean-ward end toward the entrance approximately a bucket-width wide (commonly 1 m or less). The last section of the channel (at the entrance end) should be opened at the time of the next possible high tide (i.e. the highest possible tide of the day). (ocean tide information in the form of predicted tides can be accessed at http://www.mhl.nsw.gov.au/www/sydp_tide.htmlx). Initiation of a breakout at this time is likely to result in the most effective and sustained assisted breakout due to the increasing head difference through the course of the breakout.

- Figure C.8 shows the recommended access point for the excavator operator to access the beach and the recommended orientation of the excavated channel and location of the material excavated from the pilot channel.
- Where access to the internet is not available (due to power loss associated with a storm event), checking of a water level marker (a 'tide board') at a visible location from the footbridge at the entrance (to be installed on the upstream side of footbridge) should be undertaken and white pole markers be placed in the dune system adjacent to the entrance (on the northern side) to direct the excavator operator as to the most appropriate pilot channel location and orientation.

As for Fairy Creek, the implementation of assisted breakout has generally been defined in other similar areas either as an action under State Environment Planning Policy No 35 (SEPP35) as Maintenance Dredging of Tidal Waterways or as a flood work under Council's Local Environment Plan, either of which actions are required to be supported by a Review of Environmental Factors under Part V of the EP&A Act 1979. The consent authority is then either the Department of Lands as the Crown Land manager or Council as the Trust Manager with the relevant stakeholders being DNR, DEC and DPI. Permits required for the activity may include a dredging permit from DPI under the Fisheries Management Act, 1994.

Benefits and Impacts

In the same manner as for Fairy Creek, the benefits of an assisted breakout are primarily related to:

- reducing flood risks for properties immediately adjacent to the creek and
- maintenance of water quality.

The regular flushing through the opening of the entrance is likely to be one of the key reasons that the system has not been subject to more frequent phytoplankton and macro-algal blooms. As outlined in Section 3, even during minor events the volume on inflow from the catchment is sufficient to displace the entire volume of water in the estuary and thus loads of nutrients generated within the catchment are lost from the system to the ocean when the entrance is opened.

The limited mangroves and saltmarsh in the Towradgi Creek system (in the Parker Road Arm) appear to be sustained by the frequency of entrance opening and the associated tidal conditions. If the entrance condition is returned to a reduced opening and closing regime (eg as a result of a cessation of intervention that Council has undertaken only in the last 2 – 3 years) then it might be expected that these species may not survive or may be reduced in their quality and health. It could be argued that these species are unsustainable in the systems if they were returned to a less open state.

Following a breakout the amenity associated with the area of beach within the entrance zone alters and is less usable for beach activities. Additionally, given the issues associated with elevated faecal coliforms in the inflows the Lagoon during wet weather and associated outflows to the beach, a breakout impacts on the quality of

water in the beach area for recreational swimming. It is recommended that the surrounding beach areas be closed for at least three days following a breakout.

Capital and Recurrent Costs

An estimate of the cost of the preparation of an REF and associated works to formally implement an entrance assisted breakout policy is outlined at the end of this Appendix. The capital cost of the works is of the order of $39,000 and the recurrent cost of the works is of the order of $21,000/year. Presuming a discount rate of 7% and a life of the works to be 50 years the net present value of the option is $330,000.

C.2.9. Entrance Management Policy for Hewitts and Tramway Creeks

Background

The Tramway Creek system consists of a small lagoon body above 0.0 m AHD (a maximum depth of around -0.1 mAHD) with wide entrance at around 1.0 mAHD. There is no evidence of the entrance opening to scour in a similar fashion to the Fairy and Towradgi Creek systems given the extended length of the entrance channel that would need to be scoured (Figure 3.3).

The Hewitts Creek system consists of an even smaller 'lagoon' area than the Tramway Creek system with primarily a linear creek system. The lagoon body area has a maximum bed level of -0.4 mAHD but with the majority of the bed above 0 mAHD. It would appear the entrance scour level is potentially controlled by the sewer carrier which crosses the beach downstream (or eastwards) of the footbridge (Figure 3.4). No details of the invert of this carrier were identified at the time of preparation of this report.

Historically, Council Works Division advises that there are no records of Council manually or artificially opening the entrance. The water level gauge on Hewitts Creek is well upstream of the entrance area and there is no gauge on Tramway Creek.

Concept Details

Given the absence of previous entrance opening at both the Hewitts and Tramway Creek entrances, no formal entrance opening policy is proposed for these systems. Instead, it is recommended that the beach berm level is managed through regular beach grooming. It is recommended that the beach levels be maintained at 1.0 mAHD in the vicinity of the Tramway Creek entrance and 1.0 mAHD in the vicinity of the Hewitts Creek.

The implementation of beach grooming requires no formal permits under State Environment Planning Policy No 35 (SEPP35) as Maintenance Dredging of Tidal Waterways.

Benefits and Impacts

The benefits of a beach grooming to maintain a constant berm level are primarily related to reducing flood risks for properties immediately adjacent to the creek.

Given that the systems have not been exposed to 'open' regimes in the same way as for Fairy and Towradgi Creeks it is considered that there is no further need for intervention which may otherwise alter the ecology of the system. As outlined in Section 3, even during minor events the volume on inflow from the catchment is sufficient to displace the entire volume of water in the estuary and the entrance appears to scour of its own accord to a control level.

Following discharge of flow from the creeks the amenity associated with the area of beach within the entrance zone alters and is less usable for beach activities. Additionally, given the issues associated with elevated faecal coliforms in the inflows the Lagoon during wet weather and associated outflows to the beach, a breakout impacts on the quality of water in the beach area for recreational swimming. It is recommended that the surrounding beach areas be closed for at least three days following a breakout.

Capital and Recurrent Costs

An estimate of the cost of periodic beach grooming is outlined at the end of this Appendix. The capital cost of the works is of the order of $8,000 and the recurrent cost of the works is of the order of $21,000/year. Presuming a discount rate of 7% and a life of the works to be 50 years the net present value of the option is $300,000.

C.2.10. Benefits/Impacts of a WSUD Policy

Background

Water Sensitive Urban Design (WSUD) is an approach to water management first proposed in Western Australia in 1993 (Whelans Consultants and Halpern Glick Maunsell, 1993) and now gaining wide acceptance and adoption in various forms in urban areas across Australia. The objective of WSUD is to maintain or replicate the pre-development water cycle through the use of design techniques to create a functionally equivalent hydrological landscape. When urban development occurs, the natural water cycle is altered to the extent that stormwater runoff from individual properties and roads intensify, flows usually increase and potential contaminants from residential and commercial activity and associated vehicle use flow into the streams and watercourses. New urban development commonly also exerts an additional potable water demand and an additional load on the sewerage system.

The development process (both new development, extensions to existing development and redevelopment) is commonly controlled by policies at a local and state level. Wollongong City Council is seeking to initiate and implement WSUD policies within the current development context. The NSW State Government has implemented the BASIX State Environmental Planning Policy for energy and water cycle management which provides a control to reduce potable water demands.

Fairy, Towradgi and Hewitts/Tramway Creeks catchments are highly urbanised and development occurs within these catchments as either new development (where land was otherwise vacant), extensions to existing development and redevelopment (eg the demolition of existing buildings and reconstruction). The effects of stormwater runoff from developed and developing areas on these receiving waters can be seen in decreased water quality, contaminated sediments and bank destabilization associated with increased flow velocities and erosion associated with unstabilised stormwater outlets.

A dedicated WSUD policy or development control plan (either as a Wollongong-wide policy or a catchment specific policy) or can be used to:

- Reduce potable water demand through water efficient appliances, rainwater and greywater reuse (also achieved through BASIX).
- Minimise wastewater generation and the treatment of any wastewater which is generated to a standard suitable for reuse and/or release to receiving waters.
- Treat urban stormwater to meet water quality objectives for reuse and/or discharge to surface waters.
- Use stormwater in the urban landscape to maximise the visual and recreational amenity of developments.
- Minimise the hydrologic impact of catchment urbanization on the ecosystem health of urban waterways by properly managing the frequent storm events.

Concept Details

This option involves the consideration of the implications of the implementation of a WSUD policy on the Fairy, Towradgi and Hewitts/Tramway Creeks estuaries.

The Southern Councils Group, of which Wollongong City Council is a member, has devised a *Draft Regional Water Sensitive Urban Design Policy* (2004) to ensure that building design and development incorporates effective water and soil management measures, which achieve WSUD objectives. The implementation of a variation of this policy has been used as the basis of this assessment.

It is important to note that a stormwater quality component of BASIX is currently in development and is likely to over-ride any specific targets set by Council for lot scale stormwater quality control. The date for the implementation of this next phase of the BASIX tool has not yet been identified at the time of preparation of this report.

The DCP within the Policy document aims to encourage better design of all scales of urban development through a performance method for design assessment. The DCP stipulates measurable objectives required for subdivision and lot level developments. These objectives are summarised in Table C.6. Table C.6 also details how these objectives are likely to impact on Fairy, Towradgi and Hewitts/Tramways Estuaries.

It is noted that the numerical target reduction objectives listed in the Draft DCP have generally been derived from the Draft *Australian Runoff Quality* (ARQ) document (Engineers Australia, 2003). The ARQ objectives were originally derived from the

Victorian Stormwater Committee (1999) which have their origin in the environmental assessment of Port Phillip Bay. Consequently it is recommended that a zero net increase over a reference condition be set as the objective as an alternative to the values proposed in the Draft Policy, or alternately, a site specific assessment (such as that outlined in Chapter 6 of ARQ) be undertaken to evaluate what is an appropriate load that can be delivered to the estuaries from individual urban lots.

Table C.6 - Water Sensitive Urban Design Policy Objectives and Associated Impacts

Subdivision Developments	**Lot Scale Developments**	**Impacts on Estuaries**
All Development		
-	Water Consumption within buildings to be minimized.	Reducing water consumption through in house fittings such as AAA shower heads and dual flush toilets is likely to have little direct effect on receiving waters. The reduction of water consumption within buildings is likely to slightly reduce the load on the wastewater system with associated benefits in the reduction in sewer overflows.
Large Scale Development (10 or greater dwelling subdivision or 1500 m^2 impermeable area)		
Quality of Stormwater discharging from the development shall meet the following targets. • Zero net increase over reference condition for TSS, TN, TP • Zero litter discharge.		Impaired water quality is an issue for all three estuaries. Contaminants are primarily sourced from urban stormwater flows and can have either a short or longer residence time in the estuaries (depending on the entrance condition and intensity of the storm event associated with their generation). If the quality of stormwater runoff is improved then it is expected that the receiving water quality will also improve in quality. An appropriate reference condition could be considered as either a fully forested catchment or lot (i.e. undeveloped conditions) or, where it is not possible to achieve the water quality objective under this stringent condition, the reference condition could be derived from a grassed lot condition.
Post development peak flows do not exceed those for pre-development for events from the 5 year ARI up to the 100 Year ARI event		Increased flood flows from the catchment can result in scouring and destabilizing of banks, such as the undercutting seen in Fairy, Cabbage Tree Creeks and the Towradgi Arm. WSUD features are unlikely to have any substantial effects on rare and extreme flood flows but more on the more frequent events that commonly have the greatest impact on bank stability (due to the altered wetting and drying processes). WSUD features (including rainwater tanks and grassed swales) are likely to attenuate peak discharges from urban development for the frequent events. It is important that low flows are not entirely removed by the use of WSUD features such as rainwater tanks as the important freshwater entrance scouring processes are necessary to ensure the ongoing sustainability of the estuaries (as periodic opening allows the estuaries to be partly flushed of accumulated contaminants).

Subdivision Developments	Lot Scale Developments	Impacts on Estuaries
Baseline mains water consumption is reduced by 40%.		Reducing water consumption through in house fittings such as AAA shower heads and dual flush toilets is likely to have little direct effect on receiving waters. The reduction of water consumption within buildings is likely to slightly reduce the load on the wastewater system with associated benefits in the reduction in sewer overflows.
Small Scale Development (less than 10 dwelling subdivision or less than 1500 m² impermeable area)		
Development adopts appropriate management measures to ensure adequate pollutant removal and mains water reduction.	Residential development to comply with BASIX targets.	As above.
	All other development adopts source controls to ensure adequate reductions in stormwater pollutants, volumes and peak loads discharging from the site.	
	All other development must aim to reduce mains water demand by 40%	
Post development peak flows do not exceed those for pre-development for events up to 100 Year ARI events.	-	As above.

The WSUD DCP (Southern Councils Group, 2004) details various WSUD measures which can be used to achieve the Objectives outlined in Table C.4.

Rainwater Tanks and stormwater management measures applied at smaller development scales generally do not mitigate off site flows in major floods. There is therefore a need to consider solutions on a catchment / sub-catchment basis for these less frequent major floods. Given the need to consider cumulative impacts and requirements of the NSW Governments Flood Prone Land Policy, this is best addressed strategically as part of a Floodplain Management Study/Plan. This approach will ensure implementation of effective measures in terms of total catchment response during major storm events.

Benefits and Impacts

Stormwater quantity objectives will generally have the following benefits for the receiving waters (Fairy, Towradgi and Hewitts/Tramway Creeks Estuaries):

- Reduction in bank-full flow duration to reduce the fretting of the banks (Options C3- C5)

- Reduction in flood risks and inundation of properties in more frequent events
- Minor reduction in potential sewer overflows due to reduction in volume of flow due to reduction in potable water demand.

Stormwater quality objectives will generally have the following benefits for the receiving waters (Fairy, Towradgi and Hewitts/Tramway Creeks Estuaries):

- Direct reduction in nutrient loads to the systems
- Direct reduction in suspended solids loads to the systems
- Indirect minor reduction in faecal matter loads to the systems.

An important component of the implementation of the DCP is the undertaking of random audits of properties where consent has been issued and works have been completed. Allowance has been made in the assessment of the recurrent costs for this option for undertaking 10 random audits per year as well as follow up with rectification notices.

Capital and Recurrent Costs

An estimate of the cost of the preparation of the DCP is outlined at the end of this Appendix. The capital cost of the preparation is of the order of $66,000 and the recurrent cost of the works is of the order of $17,000/year. Presuming a discount rate of 7% and a life of the works to be 50 years the net present value of the option is $300,000.

Preliminary Costing of Estuarine Management Option

Option 1: Relocation of the Towradgi Lagoon Entrance South-ward

ITEM	DESCRIPTION	UNIT	RATE $	QUANTITY	AMOUNT
Capital Costs					
1	Project Management	Item	50,000	1	$ 50,000
2	Survey, Geotech Investigations etc	Item	10,000	1	$ 10,000
3	Review of Environmental Factors	Item	20,000	1	$ 20,000
4	Permits	Item	2,000	1	$ 2,000
5	Site Establishment (Fencing/Office/amenities)	Item	10,000	1	$ 10,000
6	Erosion and Sediment Control Works	Item	10,000	1	$ 10,000
7	Clearing of Vegetation (dunes near Towradgi Park)	m^2	15	3,700	$ 55,500
8	Flood Assessment	Item	10,000	1	$ 10,000
9	Removal of existing training walls	m^3	100	60	$ 6,000
10	Excavation of channel	m^3	55	18500	$ 1,017,500
11	Sandstone blocks for bank stabilisation	m	250	500	$ 125,000
12	Revegetate/Landscape	m^2	20	6,500	$ 130,000
13	Disestablish Site	unit	2,000	1	$ 2,000
	GST (10%)				$ 144,800
	Contingency (20%)				$ 318,560
	Total				**$ 1,911,360**
				Say	**$ 1,912,000**

Recurrent Costs (Annual)					
1	Ongoing excavation/dredging of sediment build up in channel	Item	2,000	1	$ 2,000
2	Ongoing revegetation of dunes	Item	5,000	1	$ 5,000
	GST (10%)				$ 700
	Contingency (20%)				$ 1,540
	Total				**$ 9,240**
				Say	**$ 10,000**

Preliminary Costing of Estuarine Management Option

Option 2: Dredging of Towradgi Lagoon at the connection of the northern arm (the Parker Road arm)

ITEM	DESCRIPTION	UNIT	RATE $	QUANTITY	AMOUNT
1	Project Management	Item	10,000	1	$ 10,000
2	Survey, Geotech Investigations etc	Item	20,000	1	$ 20,000
3	Review of Environmental Factors	Item	10,000	1	$ 10,000
4	Permits	Item	2,000	1	$ 2,000
5	Site Establishment (Fencing/Office/amenities)	Item	10,000	1	$ 10,000
6	Erosion and Sediment Control Works	Item	5,000	1	$ 5,000
7	Flood Assessment	Item	10,000	1	$ 10,000
8	Dredging of Lagoon	m^3	55	110	$ 6,050
9	Treating dredged material and disposal	m^3	100	110	$ 11,000
10	Disestablish Site	unit	2,000	1	$ 2,000
	GST (10%)				$ 8,605
	Contingency (20%)				$ 18,931
	Total				**$ 113,586**
				Say	**$ 114,000**

Recurrent Costs (Annual)					
1	Annual Inspection of Bathymetry Survey	Item	2,000	1	$ 2,000
	GST (10%)				$ 200
	Contingency (20%)				$ 440
	Total				**$ 2,640**
				Say	**$ 3,000**

Preliminary Costing of Estuarine Management Option

Option 3: Bank Rehabilitation in Fairy Creek

ITEM	DESCRIPTION	UNIT	RATE $	QUANTITY	AMOUNT
1	Project Management	Item	20,000	1	$ 20,000
2	Survey, Geotech Investigations etc	Item	20,000	1	$ 20,000
3	Review of Environmental Factors	Item	20,000	1	$ 20,000
4	Indigenous Cultural Heritage Study	Item	40,000	1	$ 40,000
5	Permits	Item	10,000	1	$ 10,000
6	Site Establishment (Fencing/Office/amenities) at both Fairy and Para Creek	Item	10,000	2	$ 20,000
7	Erosion and Sediment Control Works	Item	20,000	1	$ 20,000
8	Flood Assessment	Item	15,000	1	$ 15,000
9	**Bank stabilisation works along Fairy and Parra Creeks**	-	-	-	-
9a	Removal of ad hoc stabilistion works	m^2	20	200	$ 4,000
9b	Site clearing	m^2	15	1000	$ 15,000
9c	Excavation of banks for batterring	m^3	55	600	$ 33,000
9d	River gravel fill for batterred banks	m^3	100	120	$ 12,000
9e	Gabions (where battering is not appropriate)	m	250	50	$ 12,500
9f	Revegetation	m^2	20	1100	$ 22,000
10	Estimated cost for other rehabilitation works [1]	Item	200,000	1	$ 200,000
11	Disestablish Sites	unit	10,000	1	$ 10,000
	GST (10%)				$ 47,350
	Contingency (20%)				$ 104,170
	Total				**$ 625,020**
				Say	**$ 626,000**

Recurrent Costs (Annual)					
1	Ongoing vegetation maintenance (annual)	Item	20,000	1	$ 25,000
2	Ongoing maintenance of banks (annual)	Item	5,000	1	$ 15,000
	GST (10%)				$ 4,000
	Contingency (20%)				$ 8,800
	Total				**$ 52,800**
				Say	**$ 53,000**

Note 1: Rehabilitation costs not itemised in this costing estimate include:

Indigenous Heritage Assessments and Archaeological Survey Costs
Stabilise entrance dunes
Stabilise banks surrounding Puckey's Boat Ramp
Remediation of Stormwater outlets along Fairy Creek
Addional removal of weeds and revegetation with natives.
Rock armouring placed around the base of some of the overhanging trees
Removal or reorientation of the gravel bars to form a series of riffle structures
Stabilise undercutting of the bank in The Towradgi Arm

Preliminary Costing of Estuarine Management Option

Option 4: Bank Rehabilitation in Towradgi Creek

ITEM	DESCRIPTION	UNIT	RATE $	QUANTITY	AMOUNT
1	Project Management	Item	20,000	1	$ 20,000
2	Survey, Geotech Investigations etc	Item	20,000	1	$ 20,000
3	Review of Environmental Factors	Item	20,000	1	$ 20,000
4	Permits	Item	10,000	1	$ 10,000
5	Site Establishment (Fencing/Office/amenities)	Item	20,000	1	$ 20,000
6	Erosion and Sediment Control Works	Item	20,000	1	$ 20,000
7	Flood Assessment	Item	15,000	1	$ 15,000
8	Revegetate riparian corridor along Towradgi Park, Corrimal Beach Park and Street Park	m^2	20	12000	$ 240,000
9	Removal of weeds along reach between Raymond Pde Footbridge and railway line	m^2	10	3000	$ 30,000
10	Revegetation of reach between Raymond Pde Footbridge and railway line	m^2	20	3500	$ 70,000
11	Revegetation of Blue Divers Reserve	m^2	20	2000	$ 40,000
12	Permanent boat ramps (river gravel)	m^3	100	12	$ 1,200
13	Estimated cost for other rehabilitation works[1]	Item	320,000	1	$ 320,000
14	Disestablish Site	unit	2,000	1	$ 2,000
	GST (10%)				$ 82,820
	Contingency (20%)				$ 182,204
	Total				**$ 1,093,224**
				Say	**$ 1,094,000**

Recurrent Costs (Annual)					
1	Ongoing vegetation maintenance (annual)	Item	10,000	1	$ 10,000
2	Ongoing maintenance of banks (annual)	Item	5,000	1	$ 5,000
	GST (10%)				$ 1,500
	Contingency (20%)				$ 3,300
	Total				**$ 19,800**
				Say	**$ 20,000**

Note 1: Rehabilitation costs not itemised in this costing estimate include:
Indigenous Heritage Assessments and Archaeological Survey Costs
Revegetate and stabilise entrance dunes at Towradgi Park
Rehabilitate collapsing gabions at footbridge on Northern Arm
Removal or rehabilitation of bank works (left bank frontage of Lake Parade properties)
Stabilising banks and tree management (right bank at Blue Divers reserve)
Stabilising steep banks at Raymond Pde Footbridge

Preliminary Costing of Estuarine Management Option

Option 5: Bank Rehabilitation in Hewitts/Tramway Creeks

ITEM	DESCRIPTION	UNIT	RATE $	QUANTITY	AMOUNT
1	Project Management	Item	15,000	1	$ 15,000
2	Review of Environmental Factors	Item	15,000	1	$ 15,000
3	Permits	Item	2,000	1	$ 2,000
4	Site Establishment (Fencing/Office/amenities)	Item	10,000	1	$ 10,000
5	Erosion and Sediment Control Works	Item	10,000	1	$ 10,000
6	Flood Assessment	Item	10,000	1	$ 10,000
7	Clearing of non-native species along Hewitts Creek (banks and in creek vegetation)	m^2	20	10,000	$ 200,000
8	Clearing of reeds in Tramway Creek	m^2	10	600	$ 6,000
9	Excavation of Hewitts Creek's Banks for battering	m^3	55	150	$ 8,250
10	Revegetation of Hewitts Creek	m^2	20	6,000	$ 120,000
11	Estimated cost for other rehabilitation works[1]	Item	50,000	1	$ 50,000
12	Disestablish Site	unit	5,000	1	$ 5,000
	GST (10%)				$ 45,125
	Contingency (20%)				$ 99,275
	Total				**$ 595,650**
				Say	**$ 596,000**

Recurrent Costs (Annual)					
1	Ongoing vegetation maintenance (annual)	Item	10,000	1	$ 10,000
2					$ -
	GST (10%)				$ 1,000
	Contingency (20%)				$ 2,200
	Total				**$ 13,200**
				Say	**$ 14,000**

Note 1: Rehabilitation costs not itemised in this costing estimate include:
Indigenous Heritage Assessments and Archaeological Survey Costs
Revegetate dunes at Tramway Creek and limit public access
Rock armouring of culvert outlet on Tramway Creek
Amplification of culvert under footpath on Tramway Creek
Stabilise Hewitts Creek Entrance Dunes (to include beach access track)
Removal or lopping of the fallen tree
Formalising Pedestrian Crossing of Hewitts Creek

Preliminary Costing of Estuarine Management Option

Option 6: Riparian Corridor DCP Recommendations

ITEM	DESCRIPTION	UNIT	RATE $	QUANTITY	AMOUNT
Capital Costs					
1	Project Management	Item	5,000	1	$ 5,000
2	Policy Preparation	Item	20,000	1	$ 20,000
3	Exhibition	Item	5,000	1	$ 5,000
4	Training for Developers and Development Assessment Officers	Item	5,000	1	$ 5,000
	GST (10%)				$ 3,500
	Contingency (20%)				$ 7,700
	Total				**$ 46,200**
				Say	**$ 47,000**
Recurrent Costs (Annual)					
1	Random Audits of Properties	Item	1,000	10	$ 10,000
2	Rectification Notices and Follow Up	Item	500	5	$ 2,500
	GST (10%)				$ 1,250
	Contingency (20%)				$ 2,750
	Total				**$ 16,500**
				Say	**$ 17,000**

Preliminary Costing of Estuarine Management Option

Option 7: Entrance Management Policy for Fairy Creek

ITEM	DESCRIPTION	UNIT	RATE $	QUANTITY	AMOUNT
Capital Costs					
1	Project Management	Item	5,000	1	$ 5,000
2	Preparation of Review of Environmental Factors for SEPP35	Item	20,000	1	$ 20,000
3	Establishment of local benchmark for excavator operator	Item	2,000	1	$ 2,000
4	Establishment of monitoring and reporting processes with Works Division	Item	2,000	1	$ 2,000
	GST (10%)				$ 2,900
	Contingency (20%)				$ 6,380
	Total				**$ 38,280**
				Say	**$ 39,000**
Recurrent Costs (Annual)					
1	Excavator Mobilisation and Labour	Item	2,000	5	$ 10,000
2	Observations of Entrance Before and After Mechanical Breakout and Transfer to Lagoon Book	Item	500	5	$ 2,500
3	Contact with DPI/DEC/DIPNR	Item	100	5	$ 500
4	Contact with Community and Media to advise of beach swimming restrictions	Item	500	5	$ 2,500
	GST (10%)				$ 1,550
	Contingency (20%)				$ 3,410
	Total				**$ 20,460**
				Say	**$ 21,000**

Preliminary Costing of Estuarine Management Option

Option 8: Entrance Management Policy for Towradgi Creek

ITEM	DESCRIPTION	UNIT	RATE $	QUANTITY	AMOUNT
Capital Costs					
1	Project Management	Item	5,000	1	$ 5,000
2	Preparation of Review of Environmental Factors for SEPP35	Item	20,000	1	$ 20,000
3	Establishment of local benchmark for excavator operator	Item	2,000	1	$ 2,000
4	Establishment of monitoring and reporting processes with Works Division	Item	2,000	1	$ 2,000
	GST (10%)				$ 2,900
	Contingency (20%)				$ 6,380
	Total				**$ 38,280**
				Say	**$ 39,000**
Recurrent Costs (Annual)					
1	Excavator Mobilisation and Labour	Item	2,000	5	$ 10,000
2	Observations of Entrance Before and After Mechanical Breakout and Transfer to Lagoon Book	Item	500	5	$ 2,500
3	Contact with DPI/DEC/DIPNR	Item	100	5	$ 500
4	Contact with Community and Media to advise of beach swimming restrictions	Item	500	5	$ 2,500
	GST (10%)				$ 1,550
	Contingency (20%)				$ 3,410
	Total				**$ 20,460**
				Say	**$ 21,000**

Preliminary Costing of Estuarine Management Option

Option 9: Entrance Management Policy for Hewitts and Tramway Creeks

ITEM	DESCRIPTION	UNIT	RATE $	QUANTITY	AMOUNT
Capital Costs					
1	Project Management	Item	5,000	1	$ 5,000
2	Preparation of Review of Environmental Factors for SEPP35	Item	20,000	1	$ 20,000
3	Establishment of local benchmark for excavator operator	Item	2,000	1	$ 2,000
4	Establishment of monitoring and reporting processes with Works Division	Item	2,000	1	$ 2,000
	GST (10%)				$ 2,900
	Contingency (20%)				$ 6,380
	Total				**$ 38,280**
				Say	**$ 39,000**
Recurrent Costs (Annual)					
1	Excavator Mobilisation and Labour	Item	2,000	5	$ 10,000
2	Observations of Entrance Before and After Mechanical Breakout and Transfer to Lagoon Book	Item	500	5	$ 2,500
3	Contact with DPI/DEC/DIPNR	Item	100	5	$ 500
4	Contact with Community and Media to advise of beach swimming restrictions	Item	500	5	$ 2,500
	GST (10%)				$ 1,550
	Contingency (20%)				$ 3,410
	Total				**$ 20,460**
				Say	**$ 21,000**

Preliminary Costing of Estuarine Management Option

Option 10: Benefits/Impacts of a WSUD Policy.

ITEM	DESCRIPTION	UNIT	RATE $	QUANTITY	AMOUNT
Capital Costs					
1	Project Management	Item	5,000	1	$ 5,000
2	Policy Preparation and Supporting Calculations	Item	35,000	1	$ 35,000
3	Exhibition	Item	5,000	1	$ 5,000
4	Training for Developers and Development Assessment Officers	Item	5,000	1	$ 5,000
	GST (10%)				$ 5,000
	Contingency (20%)				$ 11,000
	Total				**$ 66,000**
				Say	**$ 66,000**
Recurrent Costs (Annual)					
1	Random Audits of Implemented Systems	Item	1,000	10	$ 10,000
2	Rectification Notices and Follow Up	Item	500	5	$ 2,500
	GST (10%)				$ 1,250
	Contingency (20%)				$ 2,750
	Total				**$ 16,500**
				Say	**$ 17,000**

APPENDIX D

Ranked List of Options

ID	Management Objective	Responsibility	Strategy Outline	Comments	Capital Cost	Maintenance/ Recurrent Cost	benefit index/ log NPV	Rank
2	Habitat and Species Conservation (Aquatic Habitats)	WCC, DP	Rezoning of Crown Land from 6(a) to a New Conservation Waterway Zone	Co-Option 113	$2,000	0	4.24	1
56	Water Quality (Statutory Controls)	WCC	Localise water quality standards (as per ANZECC, 2000) for the estuaries for aquatic ecosystems and recreational use.		$15,000	1000	3.81	2
1	Habitat and Species Conservation (Aquatic Habitats)	WCC, DNR, DL, DP	Fairy Lagoon in Puckeys Estate - Rezoning of Crown Land from 6(a) to 7(b)	Co-Option 113	$2,000	0	3.74	3
127	Recreation (Education)	WCC	Prepare posters for display at caravan parks and other tourist accommodation on the need for foreshore users to dispose of bait bags, drink bottles and other litter appropriately.		$3,000	200	3.10	4
144	Estuary Entrance (Statutory Controls)	WCC	Towradgi Creek - Develop an entrance management policy considering location of past openings, flood mitigation (as per FMP's), water quality, fish and invertebrate recruitment, birdlife, threatened species, cultural sites and ecology.		$39,000	21000	3.08	5
8	Habitat and Species Conservation (Foreshore and Riparian Zones)	WCC, DP, DNR	Introduce appropriate zoning or an LEP clause requiring consent from Council for any development within reserves and buffer zones, except for fencing, revegetation or any works contained in an Estuary Management Plan and prohibiting certain development types altogether.	Co-Option 113	$5,000	0	2.97	6
55	Habitat and Species Conservation (Education)	WCC	Provide ongoing support and opportunities for the community to participate in restoration and management of aquatic, wetland and wildlife habitats (eg through WCC's Bushcare program).	Co-Option ID 159	$5,000	20000	2.94	7
59	Water Quality (New and Infill Development)	WCC	Establish water quality standards for stormwater runoff from new development considering the estuary's temporal response to pollutant inputs (daily, weekly or monthly) and within the framework of the cumulative impact assessment.	Co-Option ID 57	$10,000	1000	2.82	8
115	Development (Statutory Controls)	WCC	Consider implications of sea level rise projections for the estuaries		$30,000	1000	2.80	9
116	Development (Statutory Controls)	WCC, DNR, DP	Include acid sulfate soil provisions in LEP.	Co-Option 113	$5,000	0	2.43	10
145	Estuary Entrance (Statutory Controls)	WCC	Tramway Creek - Develop an entrance management policy considering location of past openings, flood mitigation (as per FMP's), water quality, fish and invertebrate recruitment, birdlife, threatened species, cultural sites and ecology.		$19,500	10500	2.43	11
146	Estuary Entrance (Statutory Controls)	WCC	Hewitts Creek - Develop an entrance management policy considering location of past openings, flood mitigation (as per FMP's), water quality, fish and invertebrate recruitment, birdlife, threatened species, cultural sites and ecology.		$19,500	10500	2.43	11
96	Sedimentation and Erosion (Works)	WCC	Towradgi Creek Stabilise Eroding Banks (Code E in Appendix C)		$150,000	2000	2.41	13
84	Water Quality (Education)	WCC	Educate specific industry groups and developers of best management practices for minimising polluted runoff.		$10,000	2000	2.33	14
57	Water Quality (Statutory Controls)	WCC	Develop and adopt a system of cumulative impact assessment for land use planning and development control by undertaking pollutant inventories an budgets for existing land uses and preparing land and water capability assessments to establish total allowable pollutant loads and other relevant loads or factors.		$40,000	1000	2.33	15
97	Sedimentation and Erosion (Works)	WCC	Towradgi Creek Revegetate Banks (Code F in Appendix C)		$150,000	5000	2.31	16
3	Habitat and Species Conservation (Aquatic Habitats)	WCC, DL	Change the use of land that will have an adverse effect on adjacent sensitive aquatic habitats through development controls or Crown Land classification revision	Co-Option 113	$10,000	1000	2.28	17
58	Water Quality (Statutory Controls)	WCC	Strictly control water quality impacts of development during construction phase.		$5,000	20000	2.26	18
153	Information and Communications (Education)	WCC	Develop an education brochure outlining the impacts of human activity on estuary condition and the actions that can be taken at a personal level to maintain estuary health, distribute with rate notices and make available at frequent visitation points.		$5,000	1000	2.26	19
79	Water Quality (Existing Development)	WCC, DPIF, Landowner (CoI Dependent)	Tramway Creek - Modify barrier to tidal flushing subject to ecological assessment		$150,000	5000	2.25	20
83	Water Quality (Education)	WCC	Educate the community on environmentally responsible practices around the house that protect water quality such as: composting grass clippings; using organic rather than synthetic fertilisers; applying fertiliser sparingly and according to soil requirements; vegetating bare soil areas; using phosphate-free detergents; washing cars on grass; capturing pet droppings; promote livestock management; and not dumping refuse on the foreshores and in the bush.		$10,000	1000	2.21	21
155	Information and Communications (Education)	WCC	Use Council's web site as a means of distributing all the above educational material.		$10,000	5000	2.18	22
113	Development (Statutory Controls)	WCC	Review all zonings - where adjacent to the estuary, the catchment, to assess the potential for each development type to impact on estuarine habitats and their flora and fauna, water quality, sedimentation and erosion. Require development consent for all land uses that potentially have adverse impacts on estuarine ecosystems and prohibit development with impacts that cannot be reasonably mitigated.		$30,000	1000	2.15	23
108	Sedimentation and Erosion (Education)	WCC	Educate the community on the need to prevent sediment generation at the source by drain stencilling, preventing soild being washed from yards, vegetation buffers etc.		$5,000	2000	2.14	24
118	Development (New Development)	WCC, DNR, DP	Require that a Local Environmental Study be prepared for a major LEP or rezoning proposal for any area within or adjoining an estuary. The LES should consider potential impacts on estuarine values including the ecosystem, threatened species, water quality, cultural heritage, foreshore and estuary access and usage, population levels with tourist influx, public amenity, fishing and acid sulfate soils.	Primary Cost would be borne by landholder/developer	$5,000	1000	2.11	25
30	Habitat and Species Conservation (Foreshore and Riparian Zones)	Landowner, DP, DNR, WCC?	Woodlands Creek Manage Watercourse and Riparian Zone in Accordance with CoI Findings		$50,000	5000	2.10	26
165	Flood Risk Management Plans (Catchment Wide Measures)	WCC	Policy for Management of Escarpment Runoff.		$50,000	1000	2.08	27
120	Development (Existing Development)	WCC	Conduct an analysis of the risk of damage to the estuarine ecosystem (ie a sensitivity assessment) by each existing land use or practice using environmental factors such as: soil erodibility; proximity to streams; estuary dilution, mixing and flushing ability; proximity to key estuarine habitats eg seagrass; geomorphic maturity of the estuary. Using the results of the risk analysis, either progressively change current land use practices, discourage them or phase them out.	Co-Option 113	$40,000	2000	2.07	28
141	Visual Amenity (Education)	WCC	Encourage residents of waterfront properties to purchase native plants through Council's Green Plan program		$0	5000	2.07	29
27	Habitat and Species Conservation (Foreshore and Riparian Zones)	Landowner, DP, DNR, WCC?	Woodlands Creek South Manage Watercourse and Riparian Zones in Accordance with CoI Findings		$50,000	5000	2.04	30
77	Water Quality (Existing Development)	WCC, DPIF	Fairy Creek - Clear accumulated rubble and anthropogenic material (Code F in Appendix C)		$50,000	5000	2.04	30

ID	Management Objective	Responsibility	Strategy Outline	Comments	Capital Cost	Maintenance/ Recurrent Cost	benefit index/ log NPV	Rank
50	Habitat and Species Conservation (Education)	WCC	Educate Council staff on the value of foreshore vegetation.		$5,000	1000	2.03	32
64	Water Quality (Existing Development)	WCC, DEC(EPA)	Revise Stormwater Management Plan for existing developed areas within the framework of the cumulative impact assessment - include maintenance of implemented SQIDs	Co-Option ID 57	$20,000	1000	1.99	33
49	Habitat and Species Conservation (Education)	WCC	Educate the community on the value of estuarine habitats and how they can contribute to their protection.		$10,000	1000	1.98	34
28	Habitat and Species Conservation (Foreshore and Riparian Zones)	WCC	Hewitts Creek Rehabilitate Degraded Riparian and Aquatic Habitat on Community Land (Removal of exotic species and revegetation with natives where possible) - (Code F in Appendix C)		$30,000	10000	1.98	35
121	Recreation (Waterway)	WCC	Survey public access points including beaches, jetties, boat ramps and parking and assess whether existing access is appropriately located considering environmental effects and proximity to waterway usage and whether the level of facilities is sufficient to satisfy demand. Ensure sufficient and appropriate foreshore land is reserved for access and facilities.		$10,000	2000	1.97	36
35	Habitat and Species Conservation (Foreshore and Riparian Zones)	WCC	Blue Divers - Protect and Enhance Remnant Vegetation		$20,000	5000	1.95	37
150	Information and Communications (Education)	WCC	Develop an Estuary Management Plan summary to widely distribute to local residents and make the full plan available for public perusal at any time.		$5,000	2000	1.92	38
154	Information and Communications (Education)	WCC	Use the local media to publicise the management plan, results of monitoring programs and issues of concern as they arise.		$5,000	2000	1.92	38
7	Habitat and Species Conservation (Foreshore and Riparian Zones)	Landowner, DP, DNR, WCC?	Prepare and adopt Riparian Corridor Management DCP. Foreshore protection to control erosion conforms to the Visual Management Plan and be of a standardised type utilising local native plants with harder materials, such as timber or rock, only where necessary.	Co-Option 113	$47,000	17000	1.90	40
95	Sedimentation and Erosion (Works)	WCC	Towradgi Creek Stabilise Entrance Dunes (to include beach access track) (Code A in Appendix C)		$50,000	10000	1.90	41
143	Estuary Entrance (Statutory Controls)	WCC	Fairy Creek - Develop an entrance management policy considering location of past openings, flood mitigation (as per FMP's), water quality, fish and invertebrate recruitment, birdlife, threatened species, cultural sites and ecology.		$39,000	21000	1.87	42
29	Habitat and Species Conservation (Foreshore and Riparian Zones)	Landowner, DP, DNR, WCC?	Hewitts Creek Manage Watercourse and Riparian Zones in Accordance with CoI Findings		$100,000	30000	1.87	43
46	Habitat and Species Conservation (Works)	WCC, DNR	Identify any existing acid sulfate drainage, remediation and, if required, prepare a plan for ongoing management.		$60,000	1000	1.85	44
26	Habitat and Species Conservation (Foreshore and Riparian Zones)	Landowner, DP, DNR, WCC?	Tramway Creek Manage Watercourse and Riparian Zones in Accordance with CoI Findings		$100,000	30000	1.81	45
160	Flooding (Statutory Controls)	WCC	Require water quality, as well as quantity, be considered in the design of any flood detention structures.		$1,000	500	1.80	46
11	Habitat and Species Conservation (Foreshore and Riparian Zones)	CMA, WCC, DEC(NPWS)	Negotiate property agreements and property management plans with owners of land with plant and animal species and / or ecological communities or populations of significant conservation value.		$10,000	10000	1.74	47
111	Cultural Heritage (Statutory Controls)	WCC, DEC(NPWS), DNR, DP	Identify sites of significant Aboriginal and European heritage and protect through amendment of the LEP. (Note: Detailed study for Sandon Point area likely to be undertaken following the Commission of Inquiry).	Co-Option 113	$40,000	2000	1.73	48
119	Development (Existing Development)	WCC	Prepare a Development Control Plan which provides guidelines for tourist and recreational development and activities on public and privately owned land in and around the estuary and its tributaries with the aim of: protecting ecological communities; maintaining a satisfactory standard of water quality; preserving scenic quality; providing siting and design principles for new buildings and waterside structures; identifying locations with potential for foreshore access.		$30,000	10000	1.72	49
61	Water Quality (New and Infill Development)	WCC, DNR	Require total water cycle strategies for major rezonings and Development Applications.	Primary Cost would be borne by landholder/developer.	$0	5000	1.72	50
62	Water Quality (New and Infill Development)	WCC	Require submission of an environmental management plan with any Development Application for a proposal that has the potential to pollute waterways.	Primary Cost would be borne by landholder/developer.	$0	5000	1.72	50
85	Sedimentation and Erosion (Statutory Controls)	WCC	Require that an Erosion and Sediment Control Plan be submitted with any Development Application or, for projects not requiring a DA, incorporate appropriate conditions from the Erosion and Sediment Control Policy in the approval.	Review of DA's allowed for in the recurrent cost	$0	5000	1.72	50
76	Water Quality (Existing Development) Towradgi Creek	WCC	Conduct a foreshore pollutant audit and remediate inappropriate practices.		$50,000	5000	1.71	53
60	Water Quality (New and Infill Development)	WCC	Adopt Water Sensitive Urban Design principles, using the LEP or a separate LGA-wide DCP.	Note: Option 163 from the Floodplain Risk Management Plans is a replicate of this option	$66,000	17000	1.70	54
34	Habitat and Species Conservation (Foreshore and Riparian Zones)	WCC	Towradgi South Bank - Protect and Enhance Remnant Vegetation		$10,000	2000	1.68	55
9	Habitat and Species Conservation (Foreshore and Riparian Zones)	WCC, DEC(NPWS)	Hewitts/Tramway Creeks Protect and Enhance Open Grassland Area for Migratory Birds		$20,000	10000	1.60	56
107	Sedimentation and Erosion (Works)	WCC	Review condition of existing stormwater drain outlets and repair, construct sediment traps or mini-wetlands where appropriate and space permits and remove sediment fans.		$30,000	5000	1.60	57
133	Visual Amenity (Statutory Controls)	WCC	Prepare and adopt a Visual Management System for the estuaries setting out the methodology for undertaking visual assessments.		$10,000	1000	1.60	58
31	Habitat and Species Conservation (Foreshore and Riparian Zones)	WCC	Live Steamers Rehabilitate Remnant Vegetation		$40,000	5000	1.59	59

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10	Habitat and Species Conservation (Foreshore and Riparian Zones)	WCC, DEC(NPWS)	Tramway Creek - Manage Turpentine Forest on Private Land in accordance with CoI Finding		$10,000	0	1.58	60
48	Habitat and Species Conservation (Works)	WCC, DPIF	Cabbage Tree Creek - Fish Passage Improvement		$100,000	1000	1.58	61
24	Habitat and Species Conservation (Foreshore and Riparian Zones)	WCC	Upstream Lake Parade Rehabilitate Degraded Riparian Habitat		$50,000	5000	1.58	62
78	Water Quality (Existing Development)	WCC, DPIF	Towradgi Creek - Remove Constriction to Tidal Flow Via Dredging		$114,000	3000	1.54	63
122	Recreation (Waterway)	DL	Survey private foreshore structures and assess whether the location and extent is appropriate.		$10,000	2000	1.53	64
106	Sedimentation and Erosion (Works)	WCC	Undertake and erosion and sedimentation survey (including catchment, in-stream and foreshores) assessing sediment yield of sources, sediment quality and rate of infilling. Remediate sources of high risk to the estuary.		$50,000	10000	1.52	65
22	Habitat and Species Conservation (Aquatic and Riparian Zones)	WCC	Parker Road Arm Rehabilitate Degraded Aquatic and Riparian Habitat		$60,000	5000	1.50	66
131	Recreation (Education)	WCC	Tramway Creek - Erect signage at waterway access points on the need to protect the waterway from litter.		$5,000	100	1.49	67
132	Recreation (Education)	WCC	Hewitts Creek - Erect signage at waterway access points on the need to protect the waterway from litter.		$5,000	100	1.49	67
37	Habitat and Species Conservation (Works)	WCC	Towradgi Entrance Area - Provide Stabilised Access Point		$5,000	500	1.47	69
86	Sedimentation and Erosion (Works)	WCC, DNR	Fairy Creek - Removal of weeds and revegetation with natives (Code G in Appendix C)		$200,000	20000	1.47	70
100	Sedimentation and Erosion (Works)	WCC	Towradgi Creek Upstream Revegetate and Stabilise Banks (Code I in Appendix C)		$100,000	5000	1.47	71
17	Habitat and Species Conservation (Foreshore and Riparian Zones)	WCC	Towradgi Creek South Bank - Rehabilitate Degraded Aquatic and Riparian Habitat (Code B in Appendix C)		$100,000	15000	1.46	72
112	Cultural Heritage(Education)	WCC	Erect interpretative signage for both indigenous and non-indigenous heritage elements		$40,000	1000	1.41	73
140	Visual Amenity (Education)	WCC	Educate the community and, in particular, the landholders adjacent to the waterway or in the first row of houses behind foreshore roadways, on the value of not clearing their land or waterfront reserves to improve their own views and the penalties for illegal clearing. Regenerate illegally cleared areas and erect highly visible fencing (eg orange safety fencing) and signage deterrents.		$10,000	20000	1.41	74
129	Recreation (Education)	WCC	Towradgi Creek - Erect signage at waterway access points on the need to protect the waterway from litter.		$5,000	100	1.40	75
12	Habitat and Species Conservation (Foreshore and Riparian Zones)	WCC	Puckeys Estate and Surrounds - Protect and Enhance Vegetation		$0	40000	1.39	76
38	Habitat and Species Conservation (Works)	WCC	Blue Divers - Provide Stabilised Access Point to include fishing access point		$5,000	500	1.39	77
23	Habitat and Species Conservation (Foreshore and Riparian Zones)	WCC	Towradgi North Restore Degraded Riparian Habitat by Revegetation		$50,000	5000	1.38	78
147	Estuary Entrance (Works)	WCC	Retrain Towradgi Creek entrance to the south		$1,912,000	10000	1.37	79
134	Visual Amenity (Statutory Controls)	WCC	Prepare a Visual Management Plan (VMP) to maintain significant views and vistas and require, through planning instruments, development control plans and design guidelines that all building and development applications conform to the VMP.		$10,000	1000	1.37	80
130	Recreation (Education)	WCC	Towradgi Creek Blue Divers - Erect signage at waterway access points on the need to protect the waterway from litter.		$5,000	100	1.31	81
198	Sedimentation and Erosion (Works)	WCC, DNR, DPI	Towradgi Creek - Identify extent of rubble downstream of Blue Divers Bridge and consider feasibility of removal	Removal costs not included.	$2,000	0	1.31	82
189	Sedimentation and Erosion (Works)	RailCorp, WCC	Review accumulation of ballast in freshwater sections of Towradgi Creek (immediately downstream of the railway crossing) and remove if required		$30,000	0	1.27	83
18	Habitat and Species Conservation (Foreshore and Riparian Zones)	WCC	South Bank Upstream of Pioneer Road - Rehabilitate Degraded Riparian Habitat (Code G in Appendix C)		$40,000	5000	1.26	84
19	Habitat and Species Conservation (Foreshore and Riparian Zones)	WCC	North Bank Upstream Pioneer Road - Rehabilitate Degraded Riparian Habitat (Code G in Appendix C)		$40,000	5000	1.26	84
13	Habitat and Species Conservation (Foreshore and Riparian Zones)	WCC	Rehabilitate Degraded Sections of Cabbage Tree Creek	Some portions undertaken associated with development	$30,000	5000	1.20	86
15	Habitat and Species Conservation (Foreshore and Riparian Zones)	WCC	Cabbage Tree Creek - Protect and Enhance Vegetation in Campus East Area	Some portions undertaken associated with development	$30,000	5000	1.20	86
90	Sedimentation and Erosion (Works)	WCC	Fairy Creek Stabilise Entrance Dunes (to include beach access track) (Code A in Appendix C)		$50,000	10000	1.20	88
36	Habitat and Species Conservation (Foreshore and Riparian Zones)	WCC	Cawley Street - Protect and Enhance Remnant Vegetation		$1,000	1000	1.20	89
105	Sedimentation and Erosion (Works)	Landowner, DNR, WCC?	Formalisation of Crossing of Hewitts Creek (Code H in Appendix C)		$40,000	1000	1.20	90
16	Habitat and Species Conservation (Foreshore and Riparian Zones)	WCC	Rehabilitate Vegetation - Western Side Cabbage Tree Creek		$50,000	5000	1.18	91
54	Habitat and Species Conservation (Education)	WCC	Towradgi Creek - Erect Interpretive Signage for Valuable Habitat		$2,000	500	1.18	92
164	Flood Risk Management Plans (Catchment Wide Measures)	WCC	Riverine Corridor Strategy for areas upstream of the estuary, including: preparation of a Vegetation Management Plan; study of stream geomorphology; investigation into restoration of creek systems; investigation into rectification of in-stream and creek bank erosion; identification of options for managing illegal structures; preparation of a Riverine Corridor Maintenance Program.		$100,000	2000	1.18	93
68	Water Quality (Existing Development)	WCC	Maintain existing SQIDs on a regular basis		$0	20000	1.10	94
124	Recreation (Foreshore Open Space)	WCC	Classify land with open space or conservation value as community land under the Local Government Act. (Currently all / most open space conservation land is generally classified as "community land" - some sites with restaurants will be "operational land" and some areas are not in public ownership. Could also recommend that the land be categorised as "natural area" with subsets of "bushland", "wetland", "watercourse" or "foreshore").		$10,000	2000	1.09	95

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197	Information and Communications (Education)	WCC	Develop an educational tour for the Estuaries.	Recurrent costs assumed to be re-couped through fees associated with tours	$10,000	0	1.08	96
128	Recreation (Education)	WCC	Fairy Creek - Erect signage at waterway access points on the need to protect the waterway from litter.		$5,000	100	1.05	97
20	Habitat and Species Conservation (Foreshore and Riparian Zones)	WCC	North Bank Upstream Towradgi Footbridge - Rehabilitate Degraded Riparian Habitat (Code I in Appendix C)		$50,000	5000	1.05	98
70	Water Quality (Existing Development) Fairy Creek	WCC	Retrofit various detention basins to include stormwater treatment measures in Fairy Creek catchment		$50,000	5000	1.05	98
14	Habitat and Species Conservation (Foreshore and Riparian Zones)	WCC	Cabbage Tree Creek Near Innovation Campus - Restore Degraded Aquatic Habitat as Part of Campus Development	Primary Cost would be borne by landholder/developer.	$0	5000	1.03	100
52	Habitat and Species Conservation (Education)	WCC	Erect Interpretive Signage for Valuable Habitat at Puckeys Estate		$2,000	500	1.01	101
53	Habitat and Species Conservation (Education)	WCC	Erect Interpretive Signage for Valuable Habitat at Confluence of Fairy and Cabbage Tree Creeks		$2,000	500	1.01	101
32	Habitat and Species Conservation (Foreshore and Riparian Zones)	WCC	South Fairy Creek - Rehabilitate Remnant Vegetation		$20,000	5000	1.01	103
102	Sedimentation and Erosion (Works)	Landowner, DNR, WCC?	Tramway Creek Entrance - Revegetate Dunes (Code A in Appendix C)		$20,000	2000	1.00	104
104	Sedimentation and Erosion (Works)	WCC	Hewitts Creek Entrance - Revegetate Dunes and Stabilise Access Track (Code C in Appendix C)		$20,000	2000	1.00	104
39	Habitat and Species Conservation (Works)	WCC	Fairy Creek South - Erect Barriers to Prevent Mowing		$10,000	100	0.99	106
40	Habitat and Species Conservation (Works)	WCC	Towradgi South Erect Barriers to Prevent Mowing		$10,000	100	0.99	106
41	Habitat and Species Conservation (Works)	WCC	Towradgi South Upstream Pioneer Road - Erect Barriers to Prevent Mowing		$10,000	100	0.99	106
42	Habitat and Species Conservation (Works)	WCC	Towradgi South Upstream - Erect Barrier to Prevent Mowing		$10,000	100	0.99	106
43	Habitat and Species Conservation (Works)	WCC	Towradgi North Upstream - Erect Barrier to Prevent Mowing		$10,000	100	0.99	106
44	Habitat and Species Conservation (Works)	WCC	Towradgi North Upstream Pioneer Road - Erect Barriers to Prevent Mowing		$10,000	100	0.99	106
45	Habitat and Species Conservation (Works)	WCC	Towradgi North - Erect Barriers to Prevent Mowing		$10,000	100	0.99	106
21	Habitat and Species Conservation (Foreshore and Riparian Zones)	WCC	South Bank Upstream Footbridge Rehabilitate Degraded Riparian Habitat (Code I in Appendix C)		$50,000	5000	0.99	113
51	Habitat and Species Conservation (Education)	WCC	Erect Interpretive Signage to Direct Pedestrians to Puckeys Estate		$5,000	500	0.98	114
142	Estuary Entrance (Statutory Controls)	WCC	Establish a monitoring program to record date of opening and closing, nature of opening (natural or manual), location and width across the entrance dune, ocean water level, width and depth of channel development with time, estuary water levels through time and water velocities.		$5,000	10000	0.97	115
204	Cultural Heritage(Education)	WCC, DEC	Prepare an oral history of indigenous heritage for the estuaries (CD and Book formats)	Presume any recurrent costs could be re-couped through the sale of the book.	$30,000	0	0.97	116
183	Flood Risk Management Plans - Woodlands Creek	WCC	Princes Highway: Sediment basin / debris control structure.		$30,000	10000	0.96	117
65	Water Quality (Existing Development) Fairy Creek	WCC	Fairy Creek at Beaton Park - Wetland		$50,000	10000	0.95	118
101	Sedimentation and Erosion (Works)	WCC	Towradgi Creek North Bank - Rehabilitate Ad-hoc Bank Stabilisation Works		$100,000	10000	0.93	119
33	Habitat and Species Conservation (Aquatic Habitat)	WCC	Towradgi Arm - Protect Mangrove Area		$5,000	2000	0.89	120
93	Sedimentation and Erosion (Works)	WCC	Reorietate Gravel Bars on Cabbage Tree Creek (Code I in Appendix C)		$30,000	1000	0.86	121
87	Sedimentation and Erosion (Works)	WCC, DNR	Fairy Creek Rock Armouring of Stormwater Outlet Headwalls (Code E in Appendix C)		$40,000	5000	0.86	122
149	Estuary Entrance (Education)	WCC	Educate the community on the importance of not illegally opening an estuary entrance and the consequent liability to prosecution if caught.		$5,000	1000	0.86	123
139	Visual Amenity (Works)	WCC	Hewitts Creek - Provide foreshore viewing platform		$40,000	1000	0.85	124
203	Water Quality (Planning)	Sydney Water, DEC, WCC	Review licence conditions and environmental impacts associated with sewer overflows in light of additional information on estuary behaviour.		$10,000	0	0.83	125
109	Cultural Heritage (Works)	WCC	Protect Boatramp in Accordance with Heritage Conservation Plan for Puckeys Estate		$10,000	4000	0.83	126
110	Cultural Heritage (Works)	WCC	Protect Non-Indigenous Heritage Items in Puckeys Estate in Accordance with Heritage Conservation Plan		$10,000	4000	0.83	126
89	Sedimentation and Erosion (Works)	WCC, DNR	Fairy Creek Battering the slope and providing a gravel/cobble beach (Code C in Appendix C)		$80,000	5000	0.77	128
88	Sedimentation and Erosion (Works)	WCC, DNR	Fairy Creek - Battering and Revegetation (Code D in Appendix C)		$150,000	5000	0.75	129
210	Cultural Heritage (Works)	WCC, DNR	Installation of boardwalks to protect middens and other significant sites from disturbance at Hewitts/Tramway Creek.	Subject to further consultation with Traditional Owners	$300,000	1000	0.73	130
208	Cultural Heritage (Works)	WCC, DEC, TO's	Establishment of a keeping place for Aboriginal artefacts disturbed (particularly from the Sandon Point site).	Subject to further consultation with Traditional Owners	$300,000	5000	0.72	131

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136	Visual Amenity (Works)	WCC	Towradgi Creek - Provide foreshore viewing platform		$40,000	1000	0.70	132
103	Sedimentation and Erosion (Works)	Landowner, DNR, WCC?	Tramway Creek - Rock armouring for support and to protect the immediately surrounding bank (Code B in Appendix C)		$5,000	1000	0.70	133
209	Cultural Heritage (Works)	WCC, DEC	Identification of an appropriate route for a heritage walking trail through the estuarine area to connect with the overall concept of a trail from Bulli Tops to Sandon Point.	Subject to further consultation with Traditional Owners	$500,000	5000	0.70	134
63	Water Quality (New and Infill Development)	WCC	Permit development on unsewered urban or rural lots only where there is sufficient area of suitable soil away from drainage lines to satisfactorily dispose of septic effluent on site.	Co-Option 113	$0	5000	0.69	135
71	Water Quality (Existing Development) Towradgi Creek	WCC	GPT Downstream of Corrimal Shopping Centre - Towradgi Creek		$150,000	15000	0.66	136
72	Water Quality (Existing Development) Towradgi Creek	WCC	Parker Road Arm - Stormwater Quality Improvement Device (Wetland and SQID)		$150,000	15000	0.66	136
117	Development (Waterway)	WCC	Conduct an analysis of the risk of damage to the estuarine ecosystem (ie a sensitivity assessment) by each existing waterway use using environmental factors such as: bank erosion; trampling, propeller furrows or other physical disturbance; noise to birdlife. Using the results of the risk analysis, either progressively change current waterway use practices, discourage them or phase them out.		$10,000	2000	0.66	138
135	Visual Amenity (Works)	WCC	Fairy Creek - Provide foreshore viewing platform.		$40,000	1000	0.63	139
137	Visual Amenity (Works)	WCC	Towradgi Creek Upstream - Provide foreshore viewing platform		$40,000	1000	0.63	139
138	Visual Amenity (Works)	WCC	Towradgi Creek Upstream - Provide foreshore viewing platform		$40,000	1000	0.63	139
199	Sedimentation and Erosion (Works)	WCC	Restrict vehicular access to northern foreshore of Towradgi Creek (between the Surf Club and the Parker Road Arm) and to only a small portion of Blue Divers Reserve.		$5,000	0	0.63	142
200	Visual Amenity (Works)	WCC	Hewitts/Tramway Creek - Review the future of spoil deposit known as "Thirroul Hill" or 'Hannah's Hill		$5,000	0	0.63	142
202	Habitat and Species Conservation (Aquatic Habitats)	WCC, DNR, DEC	Review water extraction licence and stormwater discharge licences held by Corrimal Coking Works (issued by DNR and DEC respectively) and its implications for environmental flows for Towradgi Creek.		$5,000	0	0.63	142
94	Sedimentation and Erosion (Works)	WCC	Towradgi Arm Battering the slope and providing a gravel/cobble beach that could also be re-vegetated (Code K in Appendix C)		$100,000	5000	0.57	145
191	Habitat and Species Conservation (Planning)	WCC	Apply landscape design principles to all proposals which may affect visual amenity (in particular views from existing dwellings)		$0	1000	0.56	146
98	Sedimentation and Erosion (Works)	WCC	Parker Road Arm Stabilise Gabions (Code C in Appendix C)		$40,000	1000	0.49	147
66	Water Quality (Existing Development) Fairy Creek	WCC	Fairy Creek - Install Litter Boom and Maintain on Regular Basis		$40,000	5000	0.46	148
69	Water Quality (Existing Development) Cabbage Tree Creek	WCC	Litter Control downstream of Gateway Complex (Cabbage Tree Creek)		$80,000	5000	0.45	149
151	Information and Communications (Education)	WCC	Maintain an action plan including progress in the form of a spreadsheet or database to be updated after each Management Committee meeting and distributed to interested parties, including the media, on request.		$1,000	2000	0.45	150
91	Sedimentation and Erosion (Works)	WCC	Fairy Creek - Stabilise Surrounds of Puckeys Boat Ramp (Code B in Appendix C)		$20,000	2000	0.43	151
92	Sedimentation and Erosion (Works)	WCC	Cabbage Tree Creek Rock Armouring Around Trees (Code H in Appendix C)		$20,000	2000	0.43	151
67	Water Quality (Existing Development) Fairy Creek	WCC	Stormwater Quality Improvement Device at Fairy Creek Entrance		$150,000	15000	0.42	153
152	Information and Communications (Education)	WCC	Maintain a Geographical Information System of the Plan Actions, to be used in conjunction with the spreadsheet-based actions showing land and waterway uses and current planning and development activities occurring in the estuary and the catchment.		$2,000	5000	0.41	154
190	Habitat and Species Conservation (Planning)	WCC	Review Council's Policy on response to illegal tree removal activities including temporary measures where trees have been removed		$2,000	0	0.40	155
195	Habitat and Species Conservation (Foreshore and Riparian Zones)	WCC	Review Dog Exercise Areas and designate appropriate dog exercise areas that are compatible with habitat objectives (particularly bird habitat). Identify areas where restrictions are required. Facilities such as dog faeces bins and bags to be provided within designated exercise areas.		$5,000	0	0.36	156
196	Information and Communications (Education)	WCC	Placement of signage for Bush Care projects and areas of activity.		$0	1000	0.32	157
194	Estuary Entrance (Works)	WCC, DNR, DL	Towradgi Creek - Removal of the Southern training wall only (~70 m length)		$85,000	2000	0.13	158
193	Estuary Entrance (Works)	WCC, DNR, DL	Towradgi Creek - Removal of the gabion baskets entirely (~180 m total length)		$140,000	2000	0.13	159
169	Flood Risk Management Plans	WCC	Prosser Close Erosion Study.		$10,000	1000	0.00	160
192	Estuary Entrance (Works)	WCC, DNR, DL	Towradgi Creek - Removal of the gabion baskets and replacement with a more natural training wall (~180 m length)		$550,000	1000	-0.17	161
201	Water Quality (Works)	WCC, DNR, DL	Towradgi Creek - Build a diversion channel to the East of the saltmarsh/tidal flats on the Parker Road Arm and on the western side of the bike track.		$200,000	1000	-0.31	162
163	Flood Risk Management Plans (Catchment Wide Measures)	WCC	Recommend to Council the development of a Water Sensitive Urban Design Policy.	Included in Option 60	Co-Option	Co-Option	Co-Option	Co-Option
47	Habitat and Species Conservation (Works)	WCC	Hewitts Creek - Remove snag causing bank erosion. (Note that available information indicates that this snag has been removed, but not by WCC).		D	D	D	D
161	Flooding (Works)	DNR	Hewitts Creek - Install water level gauge at footbridge		D	D	D	D
168	Flood Risk Management Plans (Catchment Wide Measures)	WCC	Removal and raising of Colgong Crescent footbridge in its current location.		D	D	D	D
6	Habitat and Species Conservation (Foreshore and Riparian Zones)	WCC	Bring significant / important foreshore and riparian areas into public ownership whenever opportunities arise through rezoning, development approvals or acquisition. (See FPMP Actions)		FPMP	FPMP	FPMP	FPMP
99	Sedimentation and Erosion (Works)	WCC	Towradgi Creek Near Upstream Footbridge Stabilise Steep Banks (Code H in Appendix C)		FPMP	FPMP	FPMP	FPMP
166	Flood Risk Management Plans (Catchment Wide Measures)	WCC	Voluntary house purchase - 5 properties.		FPMP	FPMP	FPMP	FPMP

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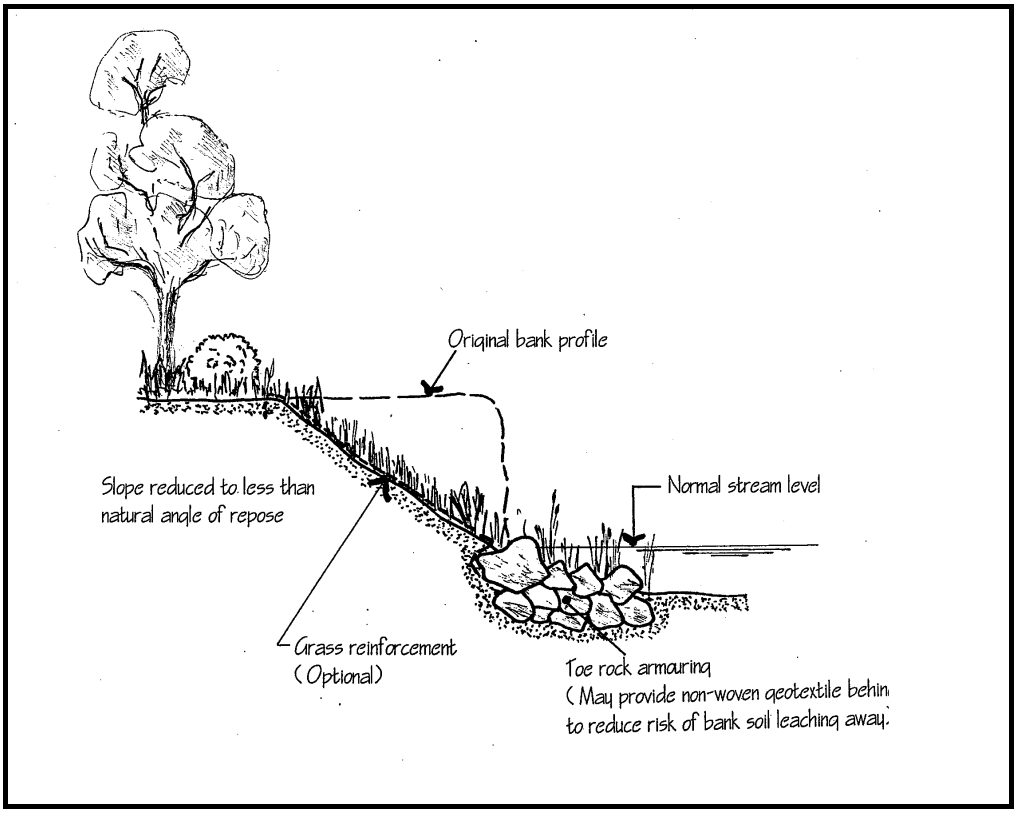
167	Flood Risk Management Plans (Catchment Wide Measures)	WCC	Voluntary reconstruction / redevelopment - 3 properties.		FPMP	FPMP	FPMP	FPMP
170	Flood Risk Management Plans - South Angels Creek (Towradgi Catchment)	WCC	Voluntary reconstruction / redevelopment - 1 property.		FPMP	FPMP	FPMP	FPMP
171	Flood Risk Management Plans - North Angels Creek (Towradgi Catchment)	WCC	Voluntary house raising - 1 property		FPMP	FPMP	FPMP	FPMP
172	Flood Risk Management Plans - North Corrimal Creek (Towradgi Catchment)	WCC	Voluntary house purchase - 4 properties.		FPMP	FPMP	FPMP	FPMP
173	Flood Risk Management Plans - North Corrimal Creek (Towradgi Catchment)	WCC	Voluntary reconstruction / redevelopment - 1 property.		FPMP	FPMP	FPMP	FPMP
174	Flood Risk Management Plans - North Corrimal Creek (Towradgi Catchment)	WCC	Debris control structures - 4 locations.		FPMP	FPMP	FPMP	FPMP
175	Flood Risk Management Plans - Carr Creek (Towradgi Catchment)	WCC	Voluntary house raising - 13 properties.		FPMP	FPMP	FPMP	FPMP
176	Flood Risk Management Plans - Parker Creek (Towradgi Catchment)	WCC	Voluntary house raising - 2 properties.		FPMP	FPMP	FPMP	FPMP
177	Flood Risk Management Plans - Parker Creek (Towradgi Catchment)	WCC	Voluntary reconstruction / redevelopment - 4 properties.		FPMP	FPMP	FPMP	FPMP
178	Flood Risk Management Plans - Slacky Creek	WCC	Old mine rail: Formalise diversion to Tramway and Hobart St: Formalise diversion to Tramway.		FPMP	FPMP	FPMP	FPMP
179	Flood Risk Management Plans - Slacky Creek	WCC	William St to Hobart St: Sediment basin		FPMP	FPMP	FPMP	FPMP
180	Flood Risk Management Plans - Slacky Creek	WCC	Coarse Debris Trap		FPMP	FPMP	FPMP	FPMP
181	Flood Risk Management Plans - Tramway Creek	WCC	Princes Highway to Rail line: Property Purchase (2 properties).		FPMP	FPMP	FPMP	FPMP
182	Flood Risk Management Plans - Woodlands Creek	Landowner, DNR, WCC?	Diversion to Hewitts: Re-divert Woodlands Creek to Tramway Creek and close existing gabion lined connection		FPMP	FPMP	FPMP	FPMP
184	Flood Risk Management Plans - Hewitts Creek	Landowner, DNR, WCC?	Adjacent to Corbett Ave: Levee north bank.		FPMP	FPMP	FPMP	FPMP
185	Flood Risk Management Plans - Hewitts Creek	WCC	Lawrence Hargraves Drive to the Rail line: Voluntary purchase offer (no 419 Lawrence Hargraves Drive).		FPMP	FPMP	FPMP	FPMP
186	Flood Risk Management Plans - Hewitts Creek	WCC	Lawrence Hargraves Drive to the Rail line: Rehabilitate creek channel.		FPMP	FPMP	FPMP	FPMP
187	Flood Risk Management Plans - Hewitts Creek	WCC	Bangalow Rd to Kelton Ln: Coarse Debris trap.		FPMP	FPMP	FPMP	FPMP
188	Flood Risk Management Plans - Hewitts Creek	WCC	Stream 4 - Deborah Ave: Coarse debris trap.		FPMP	FPMP	FPMP	FPMP
205	Flooding (Statutory Controls)	WCC	Adopt a foreshore building line along all creeks which accords with the boundaries of the High Flood Risk Precinct and other environmental and erosion risk criteria necessitating setbacks from creeks. The FSBL should be identified on Council's maps. This process should also involve a review of the appropriateness of the zoning of individual land parcels, should the combined flood risk and environmental criteria result in a FSBL which substantially affects reasonable development expectations.	Co-Option 113	FPMP	FPMP	FPMP	FPMP
206	Flooding (Statutory Controls)	WCC	Council to prepare and implement a Riverine Corridor Strategy for the creek corridors within the study area, to improve corridor linakges and restore their ecological value and remove inappropriate vegetation which impedes the flow of water or forms a source of debris which exacerbates flooding impacts.		FPMP	FPMP	FPMP	FPMP
207	Flooding (Statutory Controls)	WCC	Council to investigate a policy of formalising creek corridors within publicly owned land or with drainage easements held to the benefit of Council when dealing with development applications involving the redevelopment of flood affected lands. This will require further research of the extent of easement of land acquisition required, the likelihood of redevelopment in areas where such acquisition is required, the impact on the functioning of individual properties and the potential costs to Council.		FPMP	FPMP	FPMP	FPMP
156	Implementation, Monitoring and Review (Statutory Controls)	WCC	Identify how the recommendations of an Estuary Management Plan relating to statutory controls are to be incorporated into Council's planning and development control system, eg environmental planning instruments such as the LEP or else an estuary-specific or LGA-wide DCP.	Co-Option 113	$5,000	1000	M	M
157	Implementation, Monitoring and Review (Works)	WCC	Develop and implement a monitoring program for indivual works to ensure that they performs as expected.		$10,000	5000	M	M
158	Implementation, Monitoring and Review (Monitoring)	WCC	Develop and implement an overall monitoring program for the Management Plan to assess performance and enable plan auditing at regular intervals and subsequent adaptation of the plan.		$20,000	75000	M	M
159	Implementation, Monitoring and Review (Monitoring)	WCC	Encourage community involvement in monitoring including, for example: water quality; foreshore pollutant sources; bank erosion; riparian vegetation; stormwater outlet sedimentation rates; aquatic plant growth, eg sedges, reeds, seagrass & algae; entrance opening and closing; recreational fish catches; damage to foreshore access points.	Co-Option ID 55	$10,000	10000	M	M
211	Information and Communications	WCC, Sydney Water	Perioidic data transfer on sewer overflow incidents from Sydney Water database to Council database to allow for interpretation of water quality data		$0	500	M	M
4	Habitat and Species Conservation (Aquatic Habitats)	WCC, DEC(NPWS)	Where alternative siting is not appropriate, adopt the principle of environmental compensation in the approval process for any activity that causes unavoidable damage to any estuarine habitat or catchment that is of importance to the estuary.		NI	NI	NI	NI
5	Habitat and Species Conservation (Aquatic Habitats)	WCC	Towradgi Creek - Bring significant / important foreshore and riparian areas into public ownership through development opportunity		NI	NI	NI	NI

ID	Management Objective	Responsibility	Strategy Outline	Comments	Capital Cost	Maintenance/ Recurrent Cost	benefit index/ log NPV	Rank
73	Water Quality (Existing Development) Various	WCC	Install CDS units in high profile locations upstream of important wetlands and recreational facilities		NI	NI	**NI**	**NI**
74	Water Quality (Existing Development) Various	WCC	Rework surface drainage of playing fields to provide long linear wetlands along field perimeter. Stormwater from adjacent housing to be directed through these wetlands		NI	NI	NI	NI
75	Water Quality (Existing Development) Fairy Lagoon	WCC	Replacement of existing lined trunk drainage system with natural open channel systems with riparian vegetation (at priority high profile locations such as Stuart Park)		NI	NI	NI	NI
114	Development (Statutory Controls)	WCC	Adopt a precautionary approach of accepting a lower level of risk (ie a wider safety margin) for managing existing and proposed land and waterway uses affecting highly valued environmentally sensitive components of the estuarine ecosystem.	Co-Option 113	NI	NI	NI	NI
123	Recreation (Foreshore Open Space)	WCC	Maximise public ownership and appropriate access to Council and Crown foreshore land.		NI	NI	NI	NI
125	Recreation (Works)	WCC	Restrict public access to defined alignments (eg access trails, boardwalks) and control environmental damage.		NI	NI	NI	NI
126	Recreation (Works)	WCC	Based on the access and demand survey, provide facilities such as parking, litter collection, amenities and walking trails.		NI	NI	NI	NI
148	Estuary Entrance (Works)	WCC	Where required survey low-lying assets (including wetlands).		NI	NI	NI	NI
162	Flooding (Works)	DNR	Install rainfall/water level/other gauges as required		NI	NI	NI	NI
25	Habitat and Species Conservation (Foreshore and Riparian Zones)	Stockland, DPINR, WCC	Rehabilitation in Accordance with VMP prep by Sandon Pt Developer		SPdev	SPdev	SPdev	SPdev
80	Water Quality (Existing Development) Towradgi Creek	SWC	East Corimal - Address Sewerage Issues with Creek Inflow Prevention		SydWater	SydWater	SydWater	SydWater
81	Water Quality (Existing Development) Towradgi Creek	SWC	Towradgi Creek - Address Sewer Wet Weather Flow Capacity Issues		SydWater	SydWater	SydWater	SydWater
82	Water Quality (Existing Development)	SWC	SCAMPS in all catchments where faecal contamination is an issue		SydWater	SydWater	SydWater	SydWater

APPENDIX E

Examples of Bank Management Techniques

Technique 1: BANK BATTERING



Description: A stream bank is excavated to reduce the steepness of the face. The bank face is then normally re-vegetated. Frequently rock is placed along the toe to reduce the risk of toe scour.

Variations: Technique may only be applied to the upper bank with other techniques, such as rip-rap being used to protect the lower bank.

Application: Used to improve slope stability thus preventing mass failure. Maximum effectiveness is achieved in situations where the stream flow against the bank is not continuous.

Limitations: Toe scour often remains a problem especially where it is difficult to establish suitable vegetation.

Advantages

- Simple to implement
- Reduces fretting and attrition by allowing vegetation to establish on the bank face.

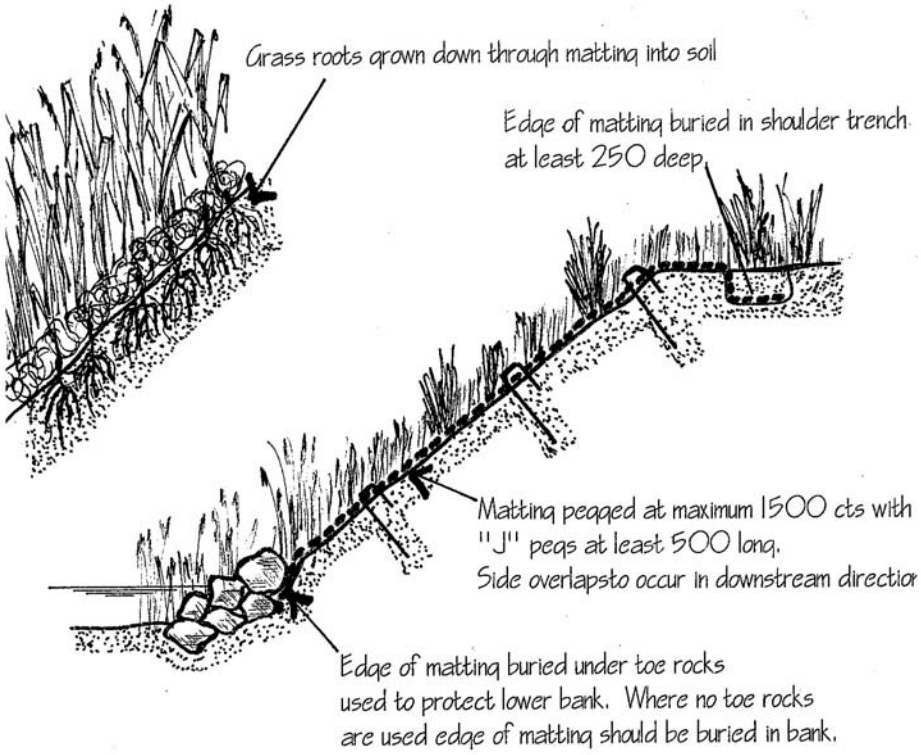
Disadvantages

- Not suitable for high velocity flows unless a suitable permanent reinforcement mat is used.
- Vulnerable until vegetation is established. Reinforcement matting can reduce the risk
- Generally ineffective below water.

Indicative Capital Cost: Low assuming there is good access for machinery. Cost is in low to medium range if toe rock protection is used.

Indicative Re-current Cost: Dependent upon frequency of flooding/submergence but may range from 2%pa to 5%pa of the capital cost.

Technique 2: REINFORCED VEGETATION [GRASS]



Description: Herbaceous vegetation, usually grass, is planted into a soil covered permanent matting [high density polyethylene [HDPE] which is secured to prepared bank using mild steel pegs. Frequently rock is placed along the toe to reduce the risk of toe scour.

Variations: Technique may only be applied to the upper bank with other techniques, such as rip-rap, being used to protect the lower bank.

Application: Used to improve slope stability thus preventing mass failure. Commonly used in conjunction with bank battering. Maximum effectiveness is achieved in situations where the stream flow against the bank is not continuous although scour resistance is improved by the matting.

Limitations: Toe scour often remains a problem especially where it is difficult to establish suitable vegetation.

Advantages

- Simple to implement
- Reduces fretting and attrition by allowing vegetation to establish on the bank face.
- When properly used and maintained can withstand moderately high velocities [3m/s to 4 m/s] for several hours with minimal damage.

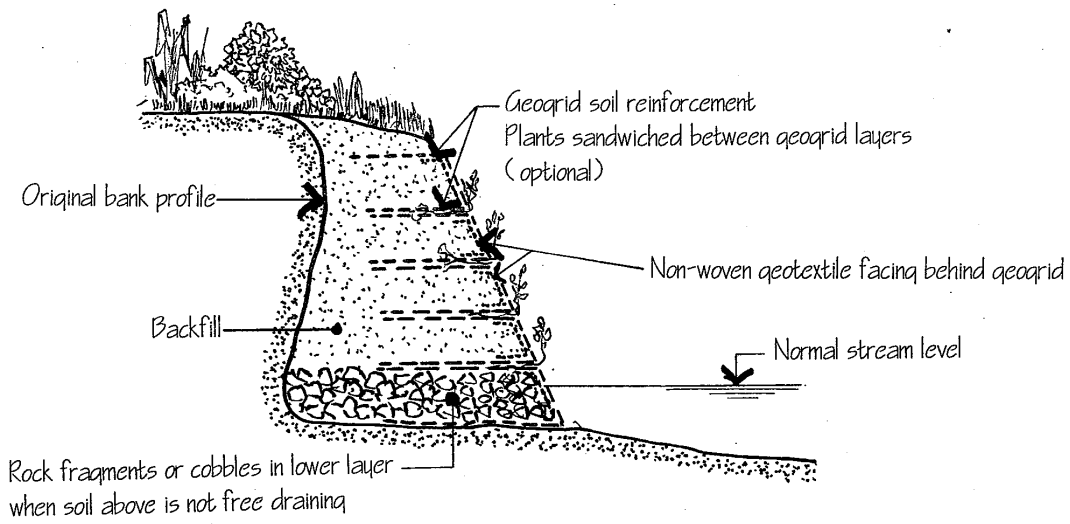
Disadvantages

- Not suitable for high velocity flows unless a suitable permanent reinforcement mat is used.
- Vulnerable until vegetation is established.
- Generally ineffective below water.

Indicative Capital Cost: Low to medium assuming there is good access for machinery. Cost is in medium range if toe rock protection is used.

Indicative Re-current Cost: Dependent upon frequency of flooding/submergence but may range from 2.5%pa to 5%pa of the capital cost.

Technique 3: BIO-REINFORCED EARTH



Description: A geo-grid is used to construct a reinforced earth bank in front of, or to replace the eroding bank. Suitable deep rooting vegetation is sandwiched between successive layer of geo-grid as the bank is constructed. A lightweight geo-grid or geo-textile is used to face the bank. Where necessary the geo facing is cut to permit the vegetation root stock to grow and cover the bank.

Variations: Reinforced earth bank may be near vertical or sloping. A concrete or timber crib wall may be used in lieu of reinforced earth. Where crib walling is used the lower lifts are usually filled with rock [cobble size or larger] if the wall is below water level or subject to wave action.

Application:
Provides bank protection against undermining, piping, and slumping failure modes.

Limitations: Requires a supply of suitable vegetative material. Toe scour may occur especially where the reinforced bank is terminated above the low water line. Rock armouring can reduce the risk of toe scour.

Advantages

- Suitable for a wide range of bank conditions.
- Provides protection while vegetation is becoming established.
- Flexible system that can yield and rebound under stress.
- Does not require specialised equipment.

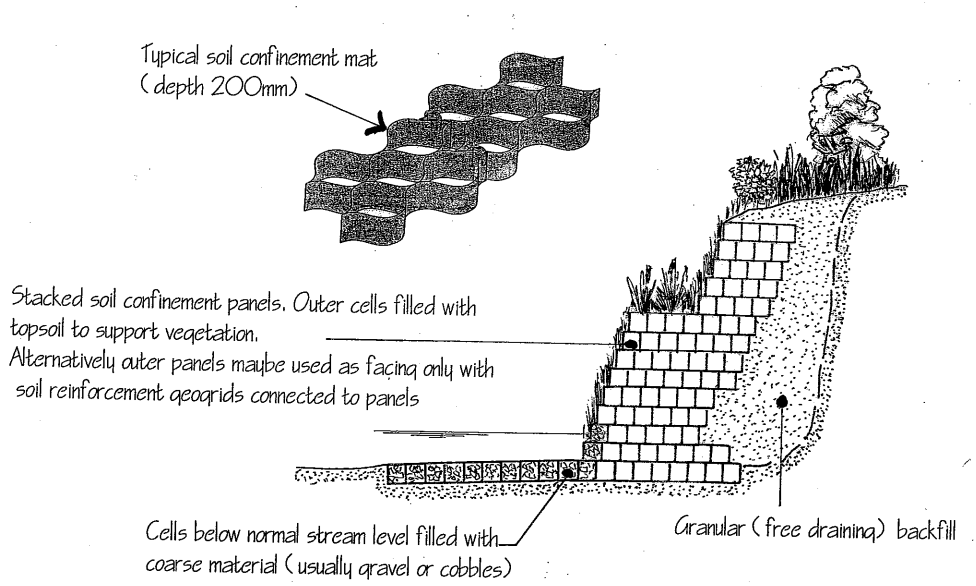
Disadvantages

- Labour intensive [placement of vegetation].
- Geotextile facing is prone to degradation if exposed to UV light for prolonged periods.

Indicative Capital Cost: Medium assuming there is good access for machinery. Cost can be high if rock protection along the toe is also required and/or coffer dams are required to enable construction.

Indicative Re-current Cost: Dependent upon frequency of flooding/submergence but may range from 1.5% pa to 3%pa of the capital cost.

Technique 4: CELLULAR REINFORCED EARTH



Description: A high density polyethylene [HDPE] cellular confinement mat is used in layers to construct a reinforced earth bank in front of, or to replace the eroding bank. The exposed cells are either filled with gravel or cobbles or suitable deep rooting vegetation to resist scour. The cellular mat is usually black but can be coloured to reduce the initial visual impact.

Variations: The cellular mat may comprise a single layer secured to the face of a sloping bank. The sloping bank should not be steeper than about 30^0 from the horizontal unless multi-layers of matting are used. Hooked anchor stakes and /or cables anchored to the top of the are required where the matting is used on a sloping surface.

Application:
Provides bank protection against undermining, piping, and slumping failure modes.

Limitations: May increase bank pore pressure unless permeable layers are introduced to act as weep holes.

Advantages

- Suitable for a wide range of bank conditions and soil types.
- Provides protection while vegetation is becoming established.
- Flexible system that can yield and rebound under stress.
- Does not require specialised equipment.
- Does not normally require rip rap at the toe.

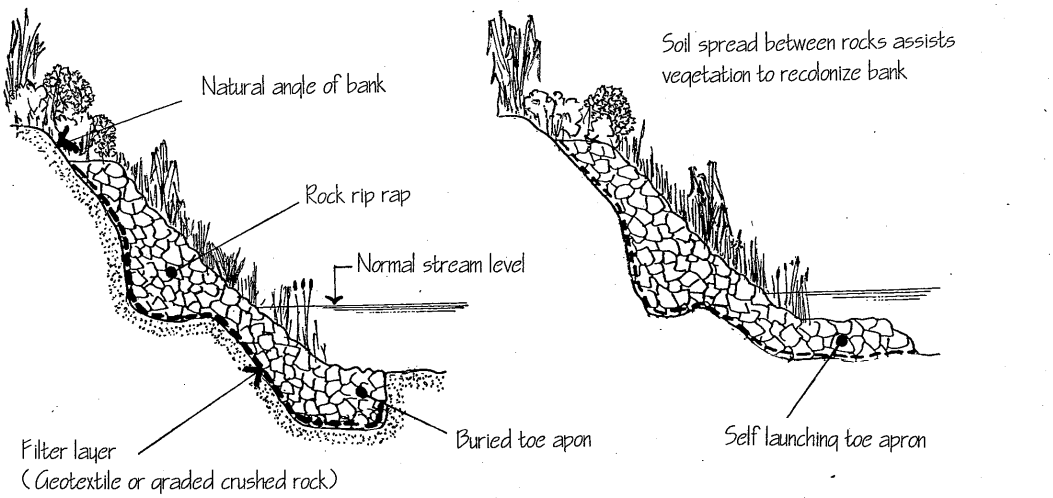
Disadvantages

- Labour intensive [placement of vegetation]. Cost maybe reduced if seed broadcast over the finished face.
- Maybe visually unattractive until vegetation is established.

Indicative Capital Cost: Medium assuming there is good access for machinery.

Indicative Re-current Cost: Dependent upon frequency of flooding/submergence but may range from 1.5% pa to 3% pa of the capital cost. Maybe 5% pa or higher if used as a single layer on a sloping surface in a harsh environment.

Technique 5: RIP-RAP ARMOURING



Description: Rock rip-rap is placed against a prepared bank to provide a physical barrier between the bank and the flowing water. Bank maybe battered before placing the rip-rap. A filter layer, either a non-woven geo-textile or a well graded rock layer is used to limit any leaching of the fine bank material.

Variations: Large rock boulders may be placed in lieu of dumping and spreading smaller rock. Broken concrete slabs are sometimes used but usually ineffectually. Specially designed concrete blocks maybe used but they make the project expensive. Maybe constructed with either a buried toe apron [cut-off] or a self-launching apron.

Application: Used to improve slope stability and to provide instant protection to an eroding bank. Commonly used in conjunction with bank battering. Depending on the shape and size of the rock works can withstand high velocities for prolonged periods.

Limitations:

- Application in severe hydraulic conditions may be limited by the available rock.
- Where the stream is prone to bed scour the rock maybe de-stabilised by undermining of the toe.
- Suitable access required for machinery to deliver and place the rock.

Advantages

- Simple to implement and a near permanent solution.
- Flexible
- Low maintenance
- Compatible with re-vegetation.
- Can be placed below water.

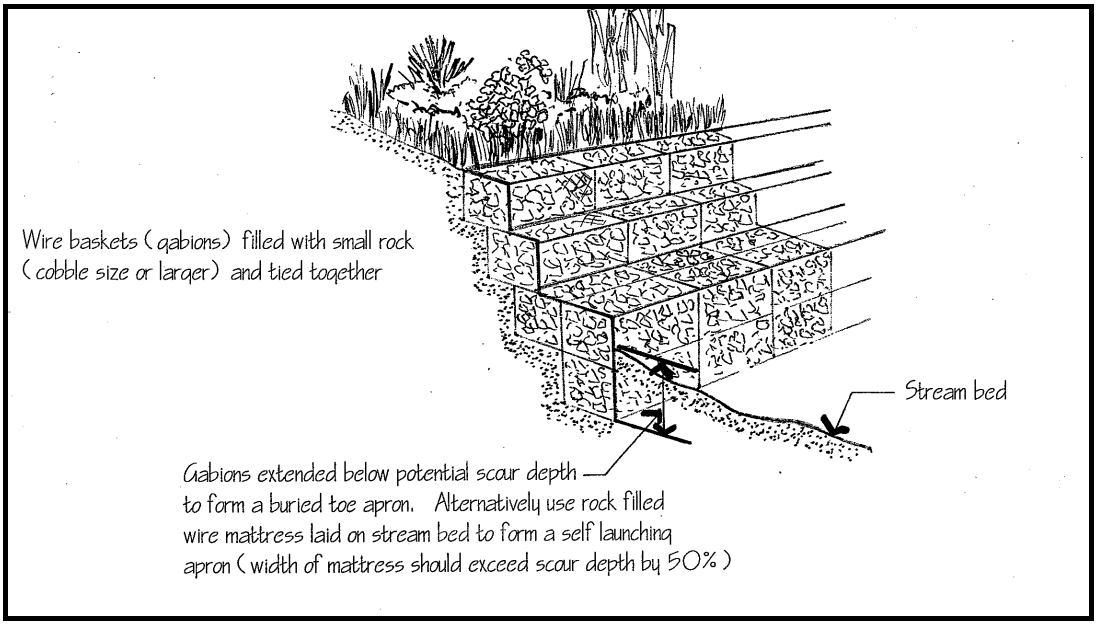
Disadvantages

- Cost maybe high if suitable rock is unavailable and concrete blocks are used.
- Visually harsh until vegetation is established.

Indicative Capital Cost: Usually low to medium depending on the availability of rock. Cost is high to very high if specially designed concrete blocks are used.

Indicative Re-current Cost: Dependent upon frequency of flooding/submergence but may range from 0.5%pa to 2%pa of the capital cost.

Technique 6: GABION RETAINING WALL



Description: Gabion wire baskets or mattresses are filled with rock or river cobbles and laid adjacent to or on the stream bank..

Variations: Bank may be battered before placing the gabions. The exposed gabions may be filed with earth to assist in establishing a vegetative cover. Maybe constructed with either a buried toe apron [cut-off] or a self-launching apron. Mattresses are usually used to form the self-launching apron.

Application: Provides immediate protection and increased stability to eroding banks. Suitable for addressing a wide range of bank failure modes including fretting, direct attrition, and undermining to sloughing [mass failure].

Limitations:

- Subject to premature failure by wire breakage due to high sediment loads carried by the stream.
- Often subject to vandalism.
- May be of public safety concern where wire breaks or by creation of steep vertical drops.
- Where the stream is prone to bed scour the gabion wall maybe de-stabilised by undermining of the toe.
- Suitable access required for machinery to deliver the rock infill.

Advantages

- Commonly understood by contractors and requires no specialised machinery.
- Provides immediate protection where suitable rock is available.
- Low maintenance if used where stream sediment loads are low.
- Can withstand high velocities for prolonged periods providing sediment and debris loads are small.

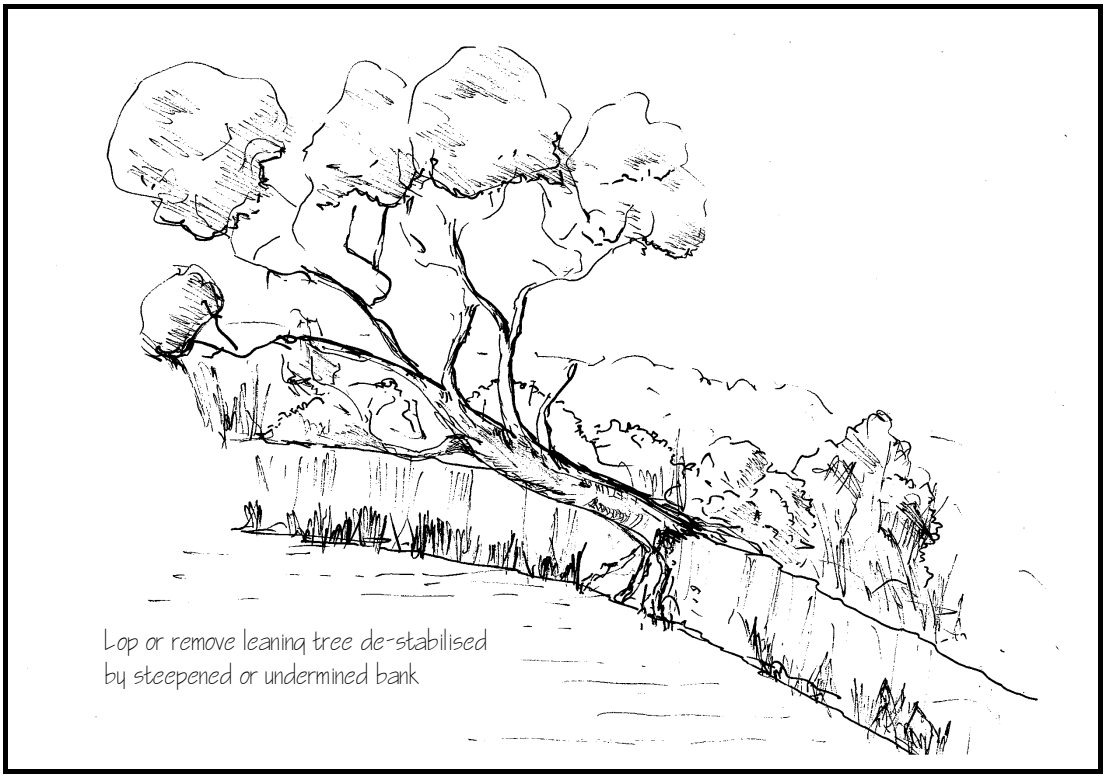
Disadvantages

- Requires a sacrificial facing when sediment and/or debris loads are moderate to high.
- Visually harsh.
- Limited Flexibility
- Limited compatibility with re-vegetation. Requires infilling of rock interstices to enable vegetation to establish.

Indicative Capital Cost: Medium to high depending on the availability and method of lacing the rock infill.

Indicative Re-current Cost: Dependent upon frequency of flooding/submergence but may range from 1.5%pa to 3%pa of the capital cost. Re-current cost will be 5% to 10% pa if used where high velocities and high sediment loads are present.

Technique 7: TREE MANAGEMENT



Description
Includes the following**:**

- Lopping or trimming of trees that have been undermined or are leaning precariously to remove public safety threat.
- Reducing the risk of tree collapse and resulting exposure of unprotected stream bank, or to reduce the surcharge load on a bank weakened by over steepening or undermining.
- Tree planting on suitable low bank terraces to assist in binding the soil and reducing the risk of erosion.

Application: Used to increase bank stability in localised areas.

Limitations:

- Localised rock protection placed around the base of the tree may be outflanked if more general erosion occurs over a wider front.
- Newly planted trees may be lost if high flows occur before they become sufficiently well established. Subject to premature failure by wire breakage due to high sediment loads carried by the stream.

Advantages

- Improves/maintains riparian habitat.
- Low cost and may therefore attract funding from a wider variety of sources.

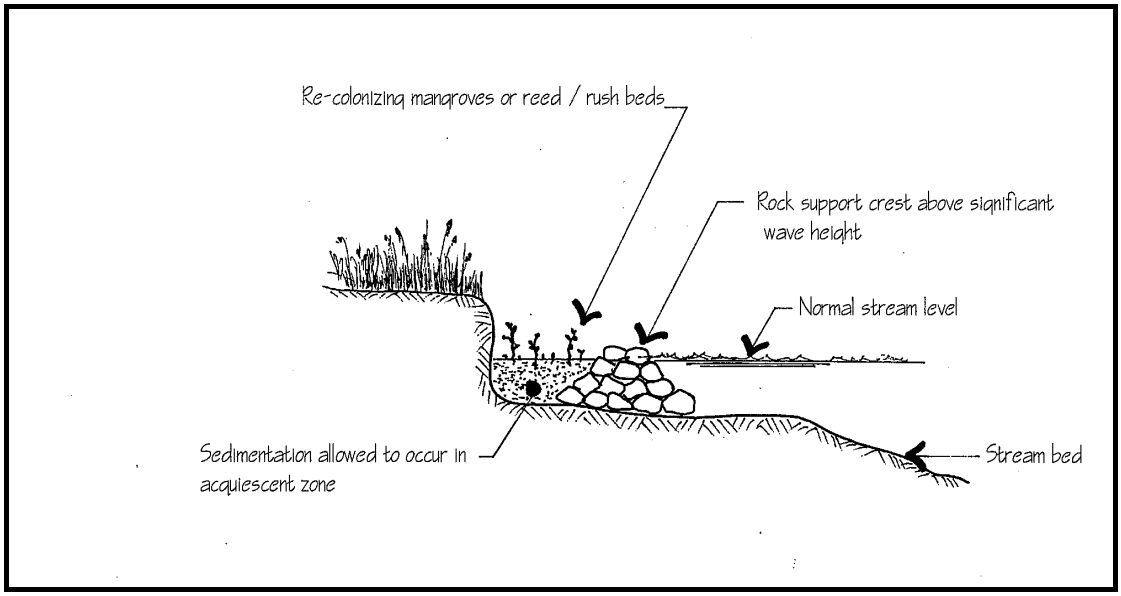
Disadvantages

- May require temporary hard structural protective measures to assist in establishing trees in areas of frequent and/or high flows.
- Newly planted trees or thinning or trees may create corridors of high velocity flow leading to unexpected scour.

Indicative Capital Cost: Low.

Indicative Re-current Cost: Dependent upon climate, growth rate of trees, and extent of re-colonisation by self seeding but usually in the range of 5% to 15% pa.

Technique 8: ROCK BERM



Description: An existing sub or inter-tidal bench is filled with a rock levee to absorb wave energy or to protect the toe of an eroding bank from frequent fast flowing water.

Variations:

- An artificial bench is created by using a rock berm, retaining wall, or by excavation.
- A permeable fence [timber, steel, or steel – concrete] similar to a small scale permeable training wall is used in lieu of the rock levee.

Application: Used to absorb wave energy and/or slow the velocity of water flowing against the bank. If the stream carries a high sediment load in some circumstances deposition may eventually be sufficient to support the toe of the bank.

Limitations:

- Normally only effective against wave action.
- Does not provide sufficient protection to bank below the crest height if frequent overtopping occurs.

Advantages

- Simple solution against wave action.
- When mature can improve access to water for boat launching.
- Readily combined with re-vegetation.

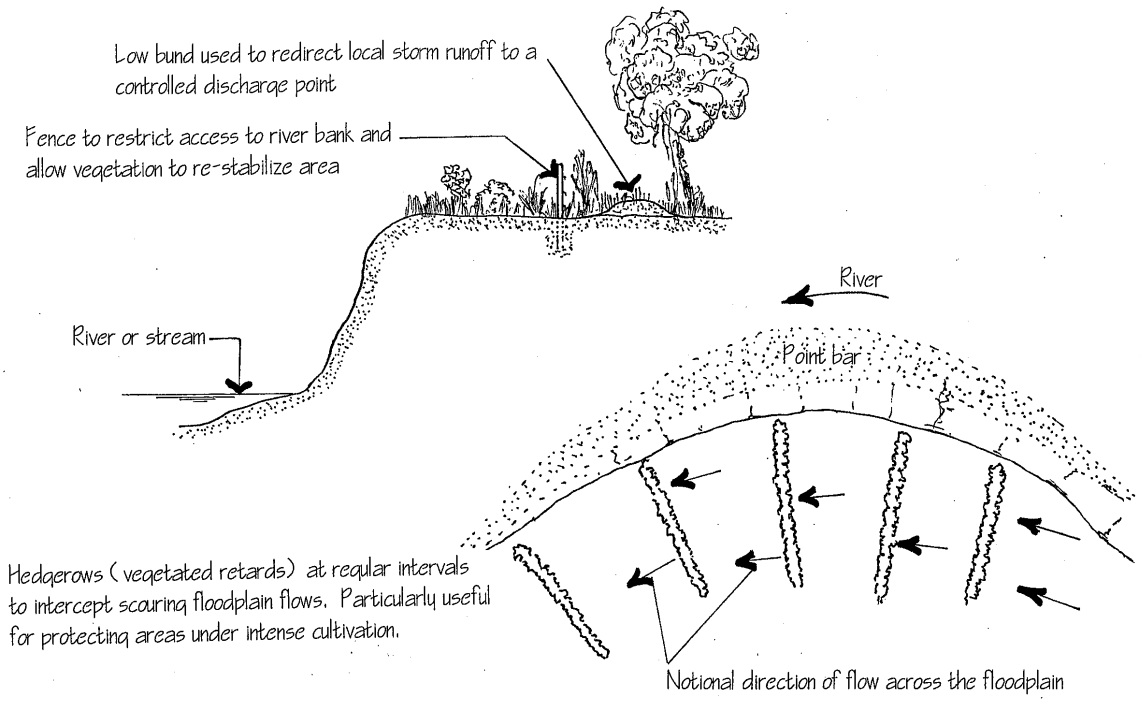
Disadvantages

- Generally only appropriate where banks are low and erosion is the result of wave action.
- Requires an existing stable bench or sufficient land to be able to create one.
-

Indicative Capital Cost: Medium. Higher cost range where a berm is excavated or a permeable fence is constructed.

Indicative Re-current Cost: Can vary widely but generally in the range 5% to 10% pa.

Technique 9: HEDGEROWS



Description: Lines of closely spaced woody vegetation or stiff herbaceous plants with deep root systems are planted across the direction of overland flow or at an oblique angle to the flow in order to re-direct flows away from vulnerable areas. The system is equivalent to windbreaks or retard fences used in a stream bed.

Variations: Permeable fencing may be used instead of or in conjunction with vegetation.

Application: Used to slow and/or re-direct overland flow.

Limitations:

- Normally only used in broad areas and where future access across the floodplain would not be unduly hampered by the series of hedgerows.
- Is most effective where depth of overland flow is less than the height of the vegetation.

Advantages

- Simple solution that is compatible with habitat creation.

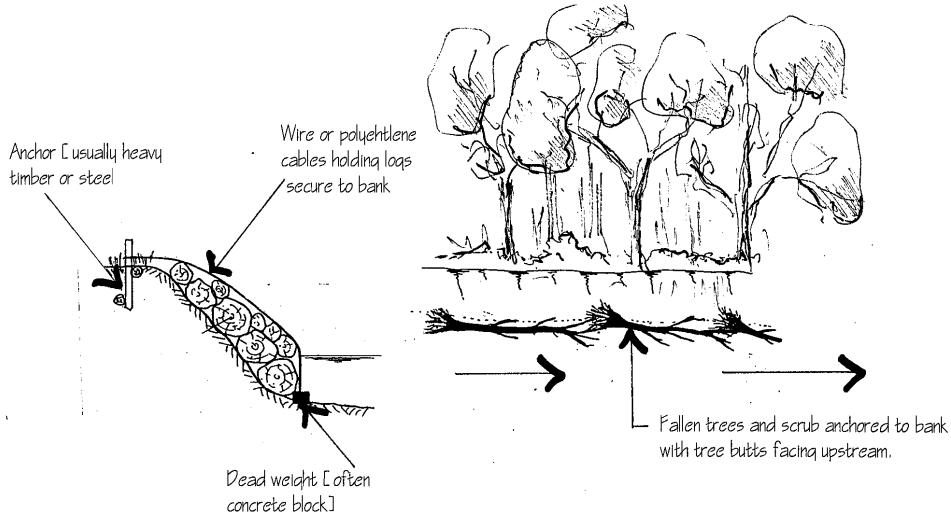
Disadvantages

- Generally only appropriate where overland flow depth is low.
- Vegetation can be damaged during a high flood and create corridors of high velocity that may result in scouring of the floodplain.

Indicative Capital Cost: Low. Medium cost range where a fence is used.

Indicative Re-current Cost: Can vary widely but generally in the range 2% to 5% pa.

Technique 10: SNAG MANAGEMENT & BRUSHING



Description: Cut or fallen trees and woody scrub are layered on an eroding bank, tied to anchors and weighted if necessary. Trees fallen into the river to form snags are hauled to the bank. Anchors may be buried logs or driven posts. Dead weights may be concrete blocks or wire mesh bags filled with river cobbles.

Variations:

- Bank may be battered before brushing is placed.
- Piles driven out from the bank can be used to secure the brush. Offset piles can be used to create a mini groyne. Willow spars or similar may be laid on the bank before placing the brushing to allow new tree growth to establish.
- Mattress brushing can utilise lighter material such as tea-tree or gum saplings by forming a mattress on the bank.

Application: Provides bank protection for a limited time to enable permanent vegetation to become established on the bank. Effective against bank erosion by fretting and attrition. May contribute to the prevention of mass failure by reducing the risk of material being scoured from the toe of the bank.

Limitations: Only provides short term protection.

Advantages

- Low material cost where suitable woody material is available.

Has a positive effect on the stream environment.

Simple concept requiring no specialised equipment unless driving piles is to be included.

Disadvantages

- When availability of suitable brushing is limited..
- Impact of cutting brush from living material can be detrimental.
- Labour intensive.
- Security of end result is variable.

Indicative Capital Cost: Low to medium cost range depending on effort required to gather brushing material.

Indicative Re-current Cost: Short term solution that is not usually maintained. Maintenance if implemented is likely to be in the order of 20% to 30% pa.

Cardno Lawson Treloar

Fairy, Towradgi and Hewitts/ Tramway Creeks
Estuary Managment Study and Plan

FIGURE 1.1
STUDY AREA

J2429/R2192/V4
25 November 2005

J2429 Fairy Towradgi Hewitts EMSP\Figures and Appendices\Report2192-v4\Figure 1.1 Study Area.Wor

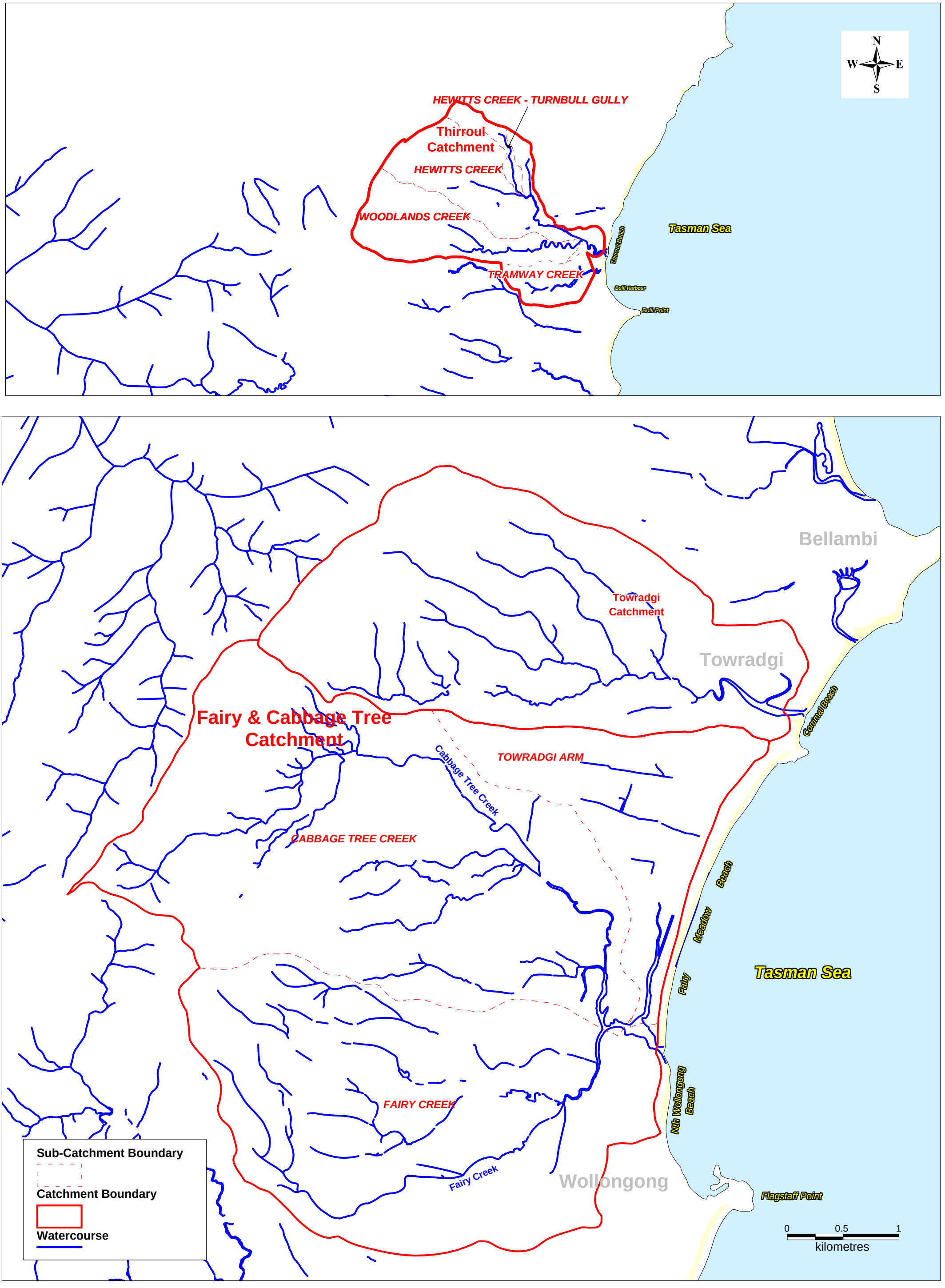


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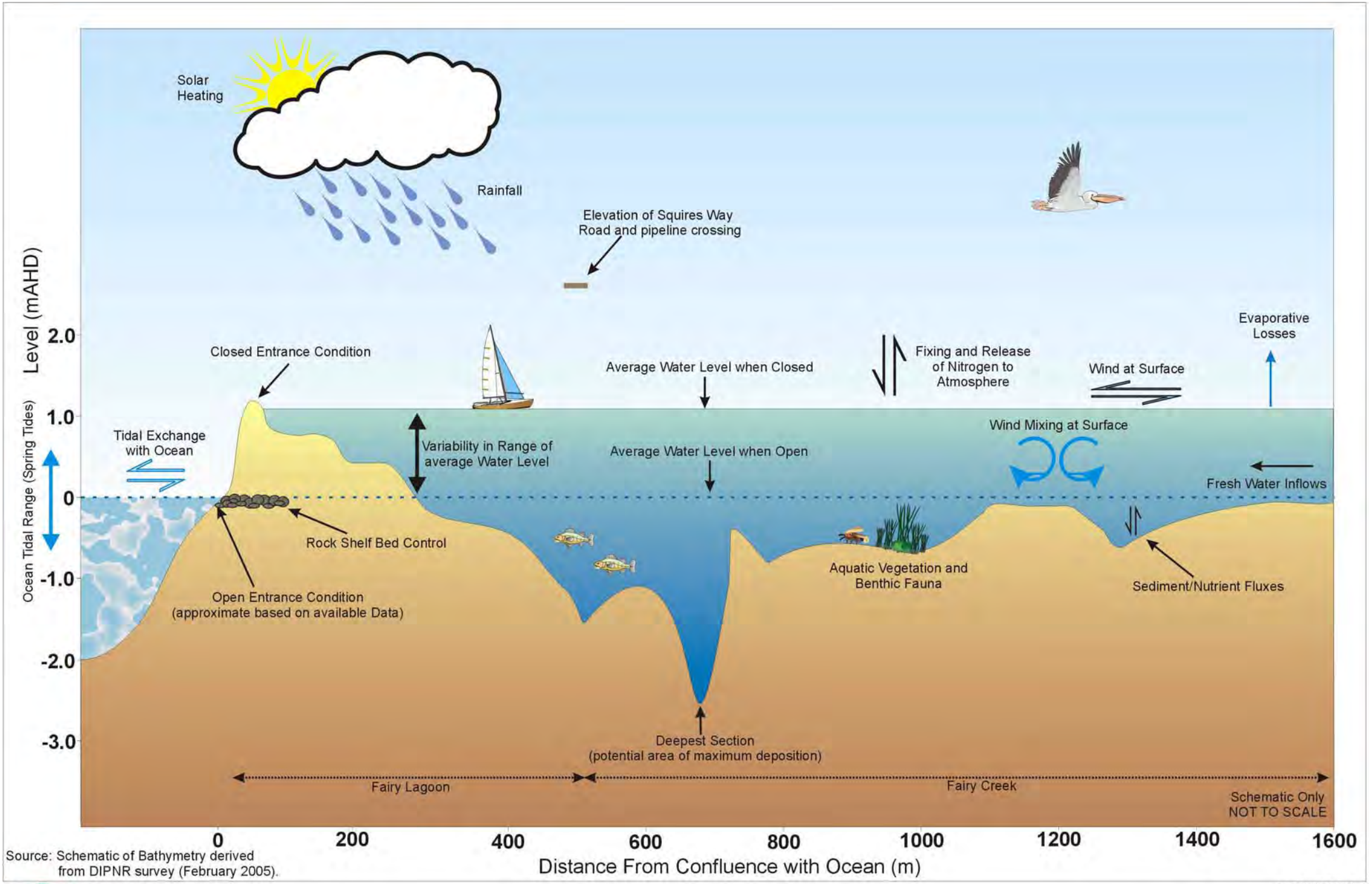
FIGURE 1.2
CATCHMENT BOUNDARIES AND WATER COURSES

J2429/R2192/V4
25 November 2005

Fairy, Towradgi and Hewitts/ Tramway Creeks
Estuary Managment Study and Plan

J2429 Fairy Towradgi Hewitts EMSP\Figures and Appendices\Report2192-v4\Figure 1.2 Catctment Boundaries.Wor



Source: Schematic of Bathymetry derived from DIPNR survey (February 2005).

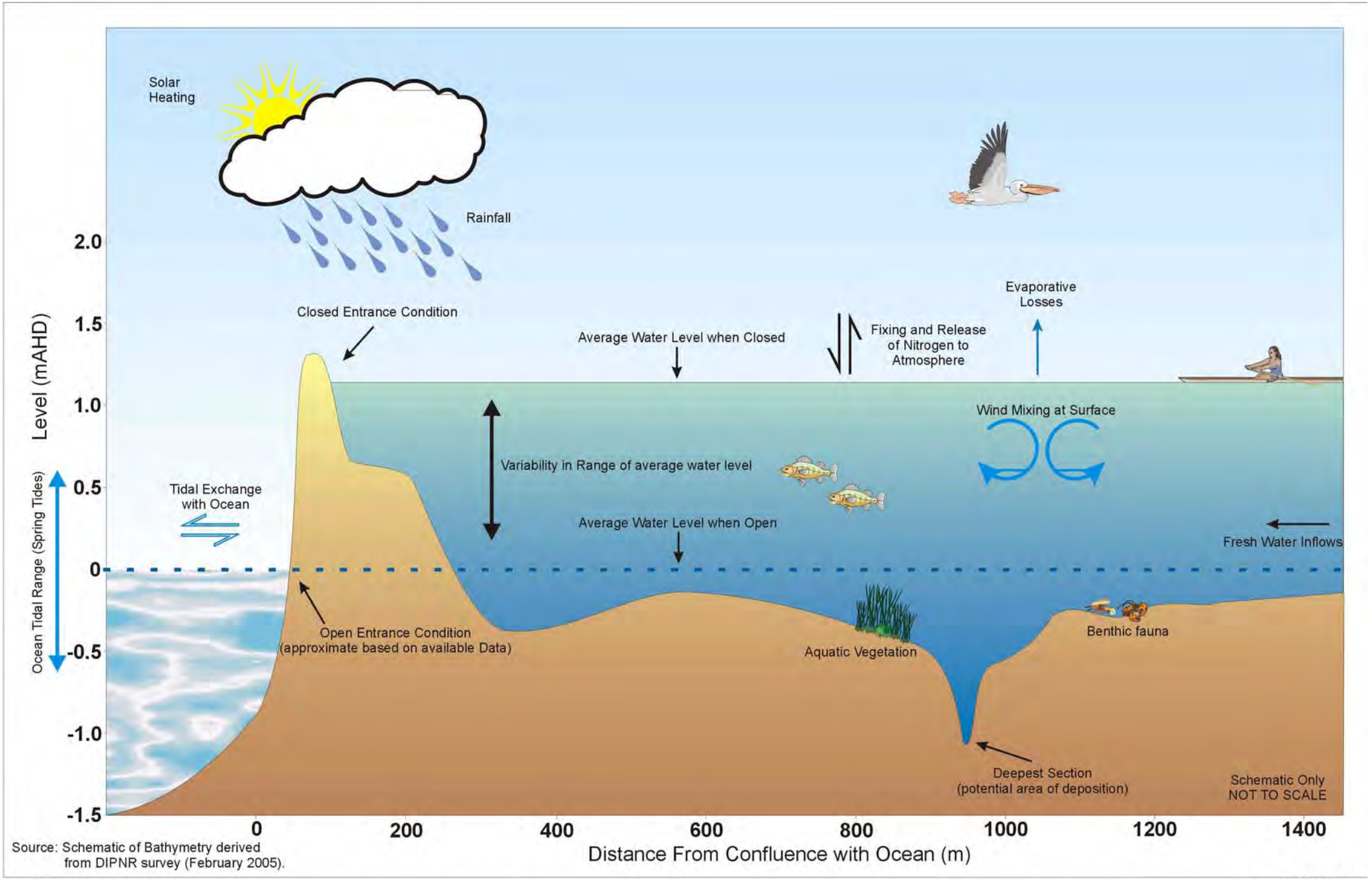
Cardno Lawson Treloar

J2429/R2192/V4
25 November 2005

Fairy, Towradgi and Hewitts/Tramway Creeks
Estuary Management Study and Plan

FIGURE 3.1
FAIRY CREEK THALWEG
KEY PROCESSES AND INTERACTIONS

J2429 Fairy Towradgi Hewitts EMSP\Figures and Appendices\Report 2192-v4\Fig 3.1 Fairy_Thalweg



Source: Schematic of Bathymetry derived from DIPNR survey (February 2005).

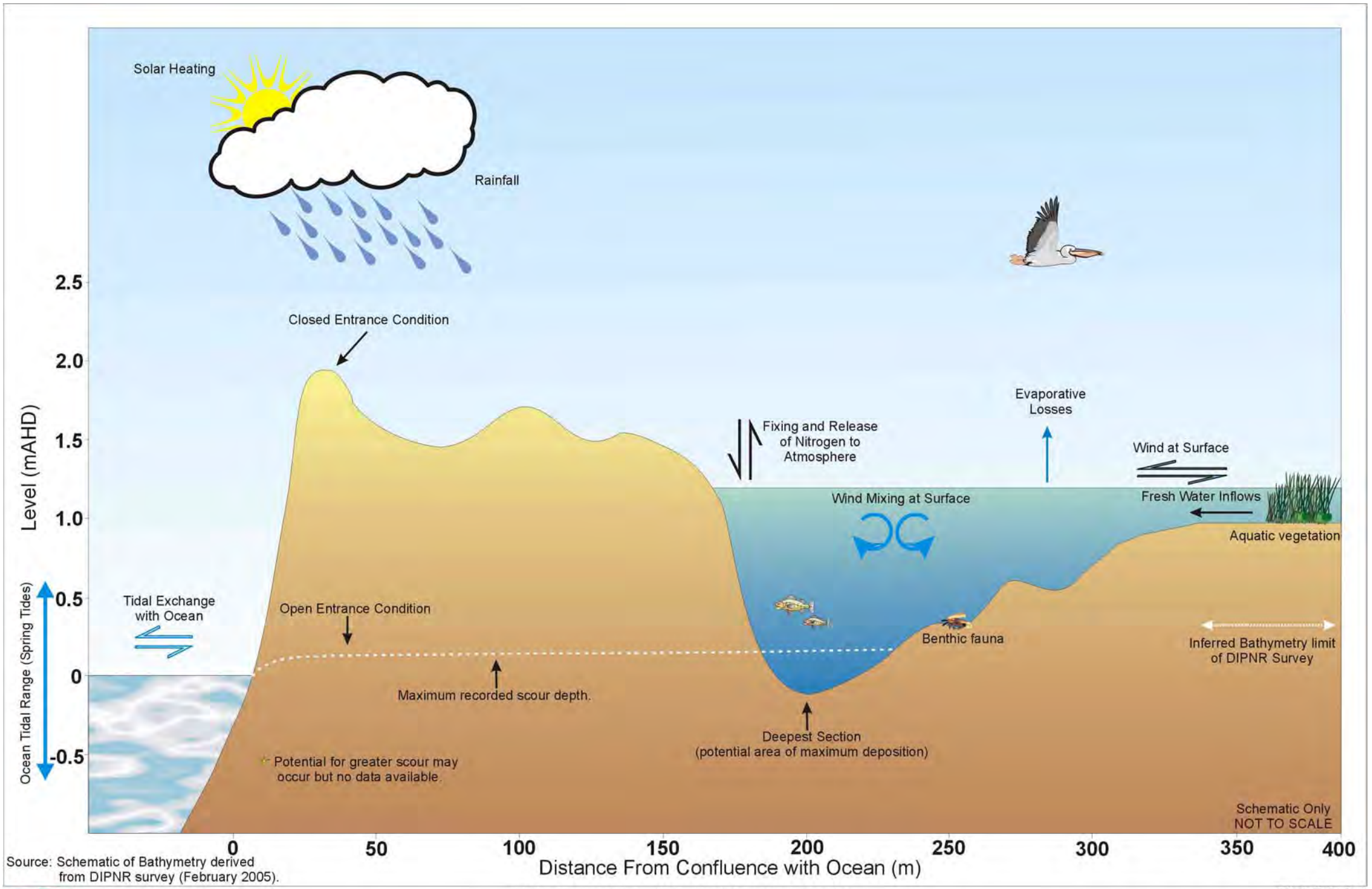
Cardno Lawson Treloar

J2429/R2192/V4
25 November 2005

Fairy, Towradgi and Hewitts/Tramway Creeks
Estuary Management Study and Plan

FIGURE 3.2
TOWRADGI CREEK THALWEG
KEY PROCESSES AND INTERACTIONS

J2429 Fairy Towradgi Hewitts EMSP\Figures and Appendices\Report 2192-v4\Fig 3.2 Towaradi_Thalweg



Source: Schematic of Bathymetry derived from DIPNR survey (February 2005).

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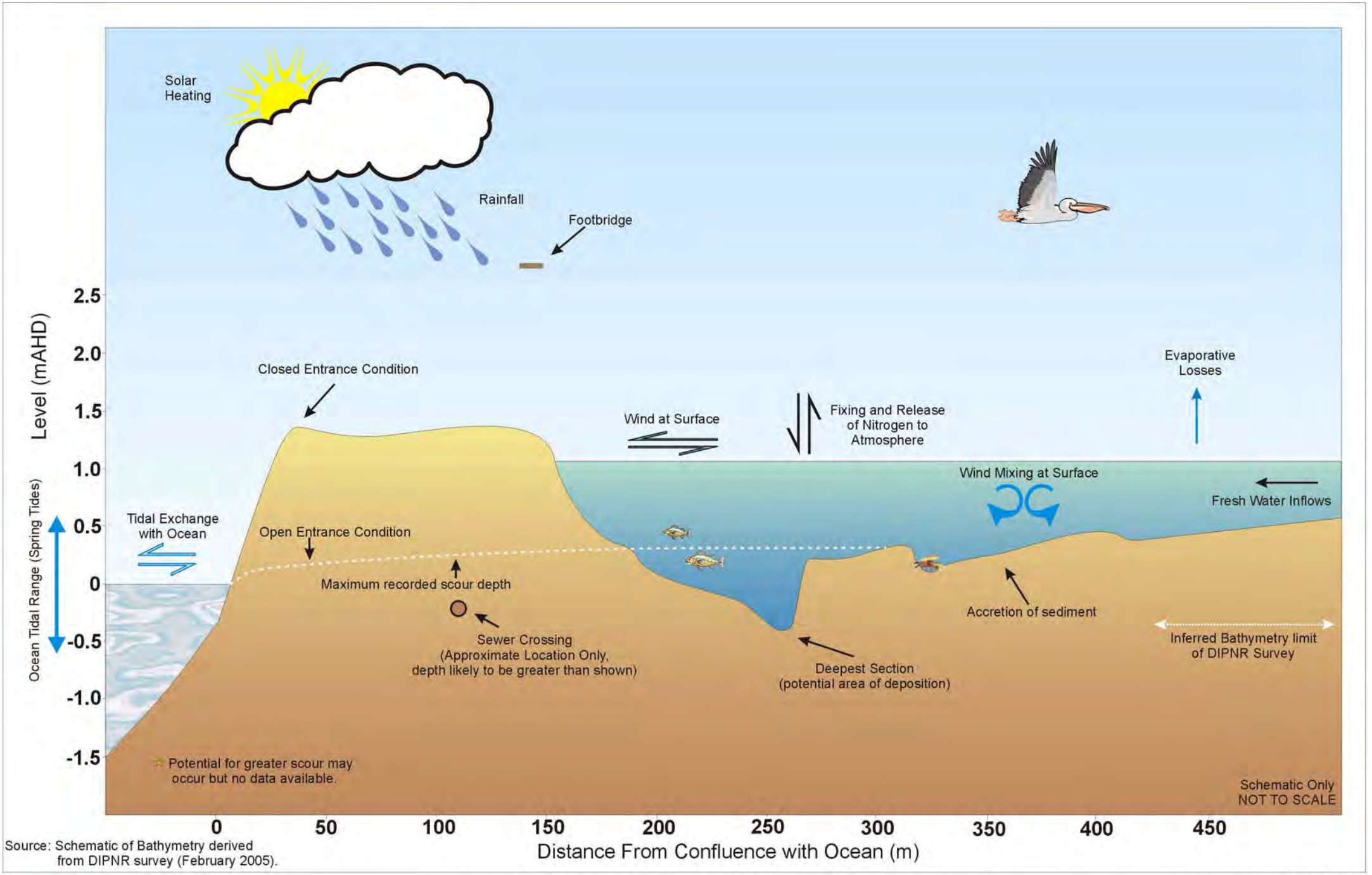
FIGURE 3.3
TRAMWAY CREEK THALWEG
KEY PROCESSES AND INTERACTIONS

J2429 Fairy Towradgi Hewitts EMSP\Figures and Appendices\Report 2192-v4\Fig 3.3 Tramway_Thalweg2



Source: Schematic of Bathymetry derived from DIPNR survey (February 2005).

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FIGURE 3.4
HEWITTS CREEK THALWEG
KEY PROCESSES AND INTERACTIONS

J2429 Fairy Towradgi Hewitts EMSP\Figures and Appendices\Report2192-v4\Fig 3.4 Hewitts_Thalweg2

LEP Zoning Regions

- 1. Non-Urban Zone
- 2A. Low Density Residential Zone
- 2A1. Special Low Density Residential Zone
- 2B. Medium Density Residential Zone
- 2C. High Density Residential Zone
- 3A. General Business Zone
- 3B. Neighbourhood Business Zone
- 3C. Regional Business Zone
- 3D. Commercial Services Zone
- 4A. Light Industrial Zone
- 4C. Extractive Industrial Zone
- 5A. Special Uses Zone
- 5B. Special Uses Zone
- 6A. Public Recreation Zone
- 6B. Private Recreation Zone
- 6C. Tourism Zone
- 7A. Special Environmental Protection Zone
- 7B. Environmental Protection Conservation Zone
- 7C. Environmental Protection Residential Zone
- 8B. State Recreation Areas Zone
- 9A. Special Uses Reservation Zone
- 9B. Arterial Roads Reservation Zone
- 9C. Local Roads Reservation Zone
- 9D. Open Space Rervation Zone

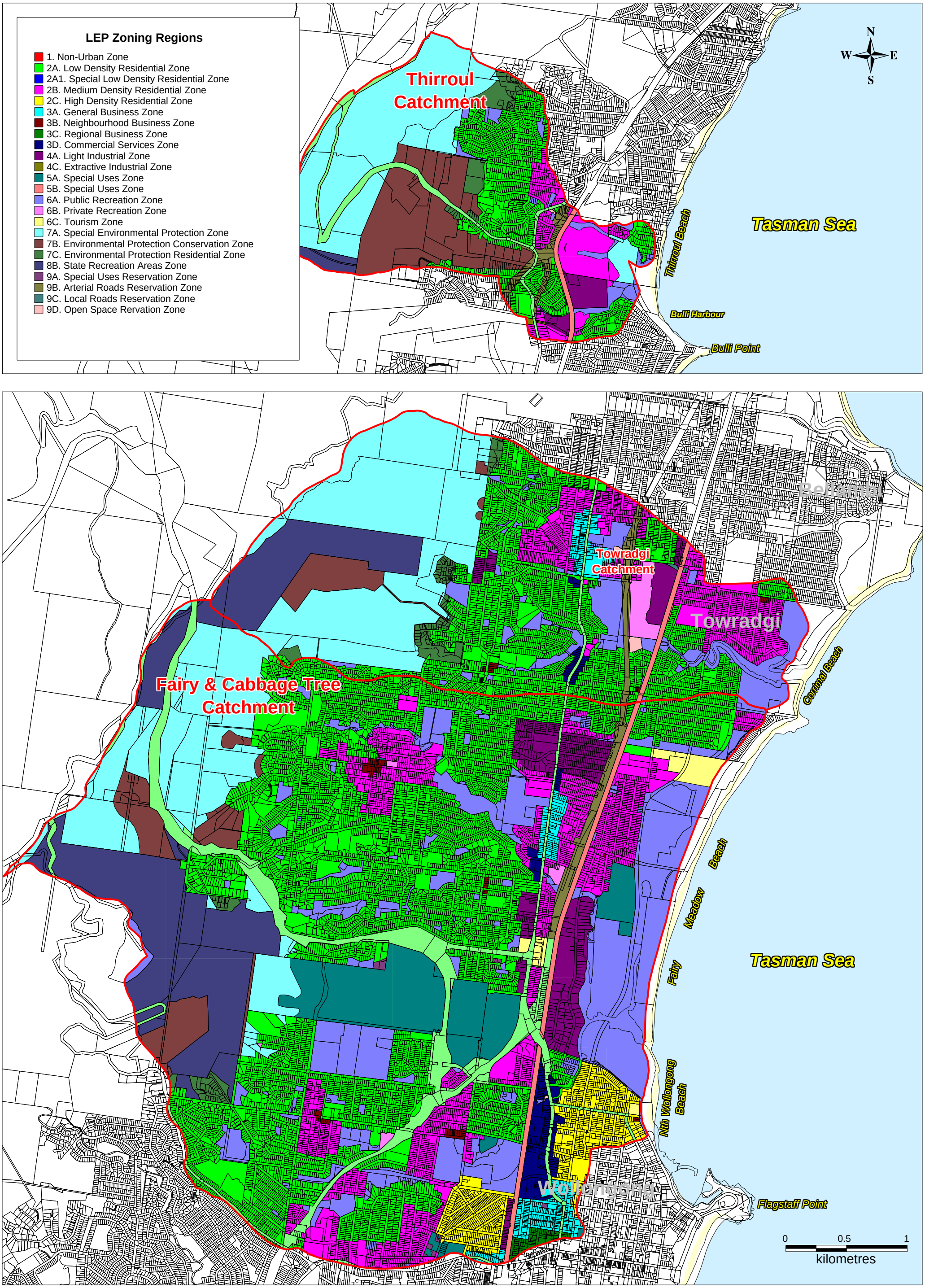

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FIGURE 4.1
LAND USE IN THE CATCHMENTS (LEP ZONES)

J2429 Fairy Towradgi Hewitts EMSP\Figures and Appendices\Report2192-v4\Figure 4.1 LEP zones.Wor

Thirroul Catchment

Fairy & Cabbage Tree Catchment

Towradgi Catchment

Crown Land

Community Land

N

W

E

S

Tasman Sea

Thirroul Beach

Bulli Harbour

Bulli Point

Bellambi

Towradgi

Corrimal Beach

Meadow Beach

Fairy

Nth Wollongong Beach

Wollongong

Flagstaff Point

0 0.5 1

kilometres

FIGURE 4.2
CROWN & COMMUNITY LAND

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J2429 Fairy Towradgi Hewitts EMSP\Figures and Appendices\Report2192-v4\Figure 4.2 Crown & Community Land.Wor

Habitat and Species Conservation
Water Quality
Sedimentation and Erosion Control
Cultural Heritage
Development
Recreation
Floodplain Risk Management Plan Actions
Entrance Management
Visual Amenity

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Option 69 SQID Near Gateway Complex Cabbage Tree Creek
Option 68 Maintain SQIDs on a regular basis
Option 13 Rehabilitate Degraded Sections of Cabbage Tree Creek
Option 48 Cabbage Tree Creek - Fish Passage Improvement
Option 94 Towradgi Arm Battering the slope and providing a gravel/cobble beach
Option 33 Towradgi Arm - Protect Mangrove Area
Option 58 Strict Control of Impacts on WQ During Construction
Option 16 Rehabilitate Vegetation - Western Side Cabbage Tree Creek
Option 110 Protect Non-Indigenous Heritage Items in Accordance with HCP
Option 14 Restore Degraded Aquatic Habitat as Part of Campus Development
Option 86 Fairy Creek Removal of weeds and revegetation with natives (Code G)
Option 93 Fairy Creek Reorientate Gravel Bars (Code I in Appendix C)
Option 12 Puckeys Estate and Surrounds - Protect and Enhance Vegetation
Option 2 Rezoning of Crown Land from 6(a) to a New Conservation Waterway Zone
Option 92 Cabbage Tree Creek Rock Armouring Around Trees (Code H)
Manage Redevelopment
Option 15 Protect and Enhance Vegetation in Campus East Area
Option 92 Cabbage Tree Creek Rock Armouring Around Trees (Code H)
Option 1 Rezoning of Crown Land from 6(a) to 7(b)
Option 53 Erect Interpretive Signage for Valuable Habitat at Confluence of Fairy
Option 89 Fairy Creek Battering the slope providing gravel/cobble beach (Code H)
Option 135 Provide Foreshore Viewing Platform
Option 109 Protect Boatramp in Accordance with Heritage Conservation Plan for PE
Option 32 South Fairy Creek - Rehabilitate Remnant Vegetation
Option 91 Fairy Creek - Stabilise Surrounds of Puckeys Boat Ramp (Code B)
Option 52 Erect Interpretive Signage for Valuable Habitat at Puckeys Estate
Option 39 Fairy Creek South - Erect Barriers to Prevent Mowing
Option 143 Entrance Management Policy
Option 31 Live Steamers - Rehabilitate Remnant Vegetation
Option 51 Erect Interpretive Signage to Direct Pedestrians to Puckeys Estate
Option 66 Fairy Creek - Install Litter Boom and Maintain on Regular Basis
Option 39 Fairy Creek South - Erect Barriers to Prevent Mowing
Option 77 Fairy Creek - Clear accumulated rubble and anthropogenic material.
Option 90 Stabilise Entrance Dunes (to include beach access track)
Option 86 Fairy Creek Removal of weeds and revegetation with natives (Code G)
Option 128 Erect Signage at Access Points re Litter and Swimming Risks
Option 88 Fairy Creek - Battering and Revegetation (Code D in Appendix C)
Option 67 Stormwater Quality Improvement Device at Fairy Creek Entrance
Option 87 Fairy Creek Rock Armouring of Stormwater Outlet Headwalls
Integrate Wollongong City Foreshore Masterplan for Stuart Park
Floodplain Management Works in Progress (Conveyance and Bank Stabilisation)
Option 65 Fairy Creek - Beaton Park Wetland

0 250 500
metres

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Fairy, Towradgi and Hewitts/Tramway Creeks
Estuary Management Study and Plan

FIGURE 7.1
FAIRY CREEK
ESTUARY MANAGEMENT OPTIONS

J2429 Fairy Towradgi Hewitts EMSP\Figures and Appendices\Report2192-v4\Figure 7.1 Fairy Options.Wor

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Option 71 GPT Downstream of Corrimal Shopping Centre
Option 34 Towradgi South Bank - Protect and Enhance Remnant Vegetation
Option 80 East Corimal - Address Sewerage Issues with Creek Inflow Prevention
Option 36 Cawley Street Protect and Enhance Remnant Vegetation
Option 122 Survey of Private Foreshore Structures
Option 202 Review water extraction licence and stormwater discharge licences
Option 54 Towradgi Creek - Erect Interpretive Signage for Valuable Habitat
Option 72 Stormwater Quality Improvement Device (Wetland and SQID)
Option 167 Voluntary Reconstruction or Redevelopment in this locality
Option 98 Parker Road Arm Stabilise Gabions (Code C in Appendix C)
Option 130 Erect Signage at Access Points re Litter and Water Quality
Option 38 Blue Divers - Provide Stabilised Access Point to include fishing acce
Option 81 Address Sewer Wet Weather Flow Capacity Issues
Option 189 Review accumulation of ballast in freshwater section
Option 35 Blue Divers - Protect and Enhance Remnant Vegetation
Option 101 Towradgi Creek North Bank - Rehabilitate Ad-hoc Bank Stabilisation
Option 43 Towradgi North Upstream - Erect Barrier to Prevent Mowing
Option 5 Bring Land into Public Ownership through Development Process
Option 24 Upstream Lake Parade Rehabilitate Degraded Riparian Habitat
Option 137 Provide Foreshore Viewing Platform
Option 21 South Upstream Footbridge Rehabilitate Degraded Riparian Habitat
Option 20 Upstream Towradgi Footbridge - Rehabilitate Degraded Riparian Habitat
Option 45 Towradgi North - Erect Barriers to Prevent Mowing
Option 42 Towradgi South Upstream - Erect Barrier to Prevent Mowing
Option 100 Towradgi Creek Upstream Revegetate and Stabilise Banks (Code I)
Option 201 Build a diversion channel to the East of the saltmarsh/tidal flats
Option 99 Towradgi Creek Near Upstream Footbridge Stabilise Steep Banks
Integrate Findings with the Corrimal Park Masterplan
Option 96 Stabilise Eroding Banks (Code E in Appendix C)
Option 168 Removal and Raising of Colgong Cresent Footbridge
Option 199 Restrict vehicular access
Option 129 Erect Signage at Access Points Re Litter and Water Quality
Option 198 Identify extent of rubble downstream of Blue Divers
Option 19 North Upstream Pioneer Road - Rehabilitate Degraded Riparian Habitat
Option 37 Towradgi Entrance Area - Provide Stabilised Access
Option 97 Revegetate Banks (Code F in Appendix C)
Option 192 Removal of the gabion baskets and replacement with more natural wall
Option 44 Towradgi Nth Upstream Pioneer Road - Erect Barriers to Prevent Mowing
Option 193 Removal of the gabion baskets entirely (~180 m total length)
Option 166 Voluntary Purchase of Properties in this locality
Option 18 South Upstream of Pioneer Road - Rehabilitate Degraded Riparian Habita
Option 136 Provide Foreshore Viewing Platform
Option 144 Entrance Management Policy
Option 78 Towradgi Creek - Remove Constriction to Tidal Flow Via Dredging
Option 41 Towradgi South Upstream Pioneer Road - Erect Barriers to Prevent Mowin
Option 194 Removal of the Southern training wall only (~70 m length)
Option 22 Parker Road Arm Rehabilitate Degraded Aquatic and Riparian Habitat
Option 40 Towradgi South Erect Barriers to Prevent Mowing
Option 95 Towradgi Creek Stabilise Entrance Dunes (Code A in Appendix C)
Option 17 South Bank - Rehabilitate Degraded Aquatic and Riparian Habitat
Option 147 Retrain Entrance to South for Permanent Condition
Integrate Findings with Towradgi Park Masterplan

- Habitat and Species Conservation
- Water Quality
- Sedimentation and Erosion Control
- Cultural Heritage
- Development
- Recreation
- Floodplain Risk Management Plan Actions
- Entrance Management
- Visual Amenity

0 200 400
metres

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Estuary Management Study and Plan

FIGURE 7.2
TOWRADGI CREEK
ESTUARY MANAGEMENT OPTIONS

J2429 Fairy Towradgi Hewitts EMSP\Figures and Appendices\Report2192-v4\Figure 7.2 Towradgi Options.Wor

Habitat and Species Conservation
Water Quality
Sedimentation and Erosion Control
Cultural Heritage
Development
Recreation
Floodplain Risk Management Plan Actions
Entrance Management
Visual Amenity

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Option 187 Coarse Debris Trap Bangalow Road
Option 29 Hewitts Creek Manage Watercourse and Riparian Zones
Option 28 Hewitts Creek Rehabilitate Degraded Riparian and Aquatic Habitat
Option 184 Levee and 200 m of Channel Relocation
Option 182 Fill Gabion Lined Channel
Option 104 Hewitts Creek Entrance - Revegetate Dunes (Code C in Appendix C)
Option 132 Erect Signage at Access Points re Litter and Water Quality
Option 185 and 186 Rehabilitate Creek between LHD & Rail & Purchase 2 Properties
Option 30 Woodlands Creek Manage Watercourse and Riparian Zone (Existing alignment shown)
RTA Actions - Northern Distributor Interchange including Sediment & Spill Basin
Option 146 Entrance Management Policy
Option 105 Formalisation of Crossing of Hewitts Creek (Code H in Appendix C)
Option 183 Flood Retarding Basin with Sediment Pond and Debris Control Structure (Note Project on Hold pending Discussions with RTA on integration with interchange)
Option 161 Install Water Level Recorder at Footbridge
Option 139 Provide Foreshore Viewing Platforms
Option 182 Reopen Tramway/Woodlands Diversion (Alignment is schematic only)
Option 104 Hewitts Creek Entrance - Revegetate Dunes (Code C in Appendix C
Option 103 Tramway Creek - Rock armouring for support and to protect the immedia
Option 10 Manage Turpentine Forest on Private Land in accordance with Col Findin
Option 9 Protect and Enhance Open Grassland Area for Migratory Birds
Option 180 Coarse Debris Trap Rex Avenue to William Street
Option 178 Formalise Diversion Overland Flow Path from Slacky Ck to Tramway Ck
Option 145 Entrance Management Policy
Option 27 Woodlands Creek South Manage Watercourse and Riparian Zones
Option 179 Sediment Basin Rex Avenue to William Street
Option 102 Tramway Creek Entrance - Revegetate Dunes (Code A in Appendix C
Option 131 Erect Signage at Access Points Re Litter and Water Quality
Option 26 Tramway Creek Manage Watercourse and Riparian Zones in Accordance with
Option 79 Tramway Creek - Modify barrier to tidal flushing
Option 25 Rehabilitation in Accordance with VMP prep by Sandon Pt Developer

0 250 500
metres

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Fairy, Towradgi and Hewitts/Tramway Creeks
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FIGURE 7.3
HEWITTS/TRAMWAY CREEKS
ESTUARY MANAGEMENT OPTIONS

J2429 Fairy Towradgi Hewitts EMSP\Figures and Appendices\Report2192-v4\Figure 7.3 Hewitts Options.Wor

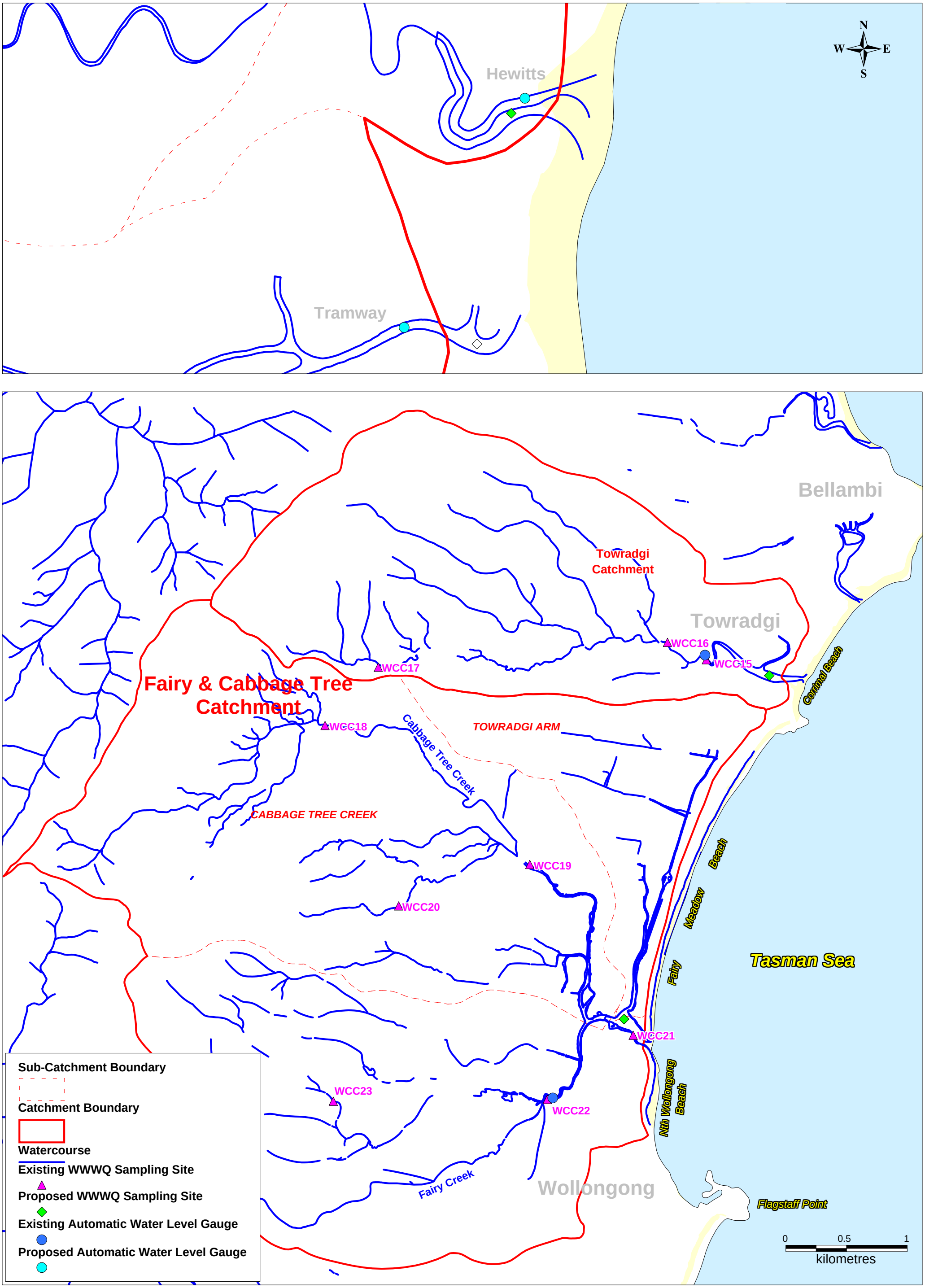

FIGURE 10.1
MONITORING LOCATIONS

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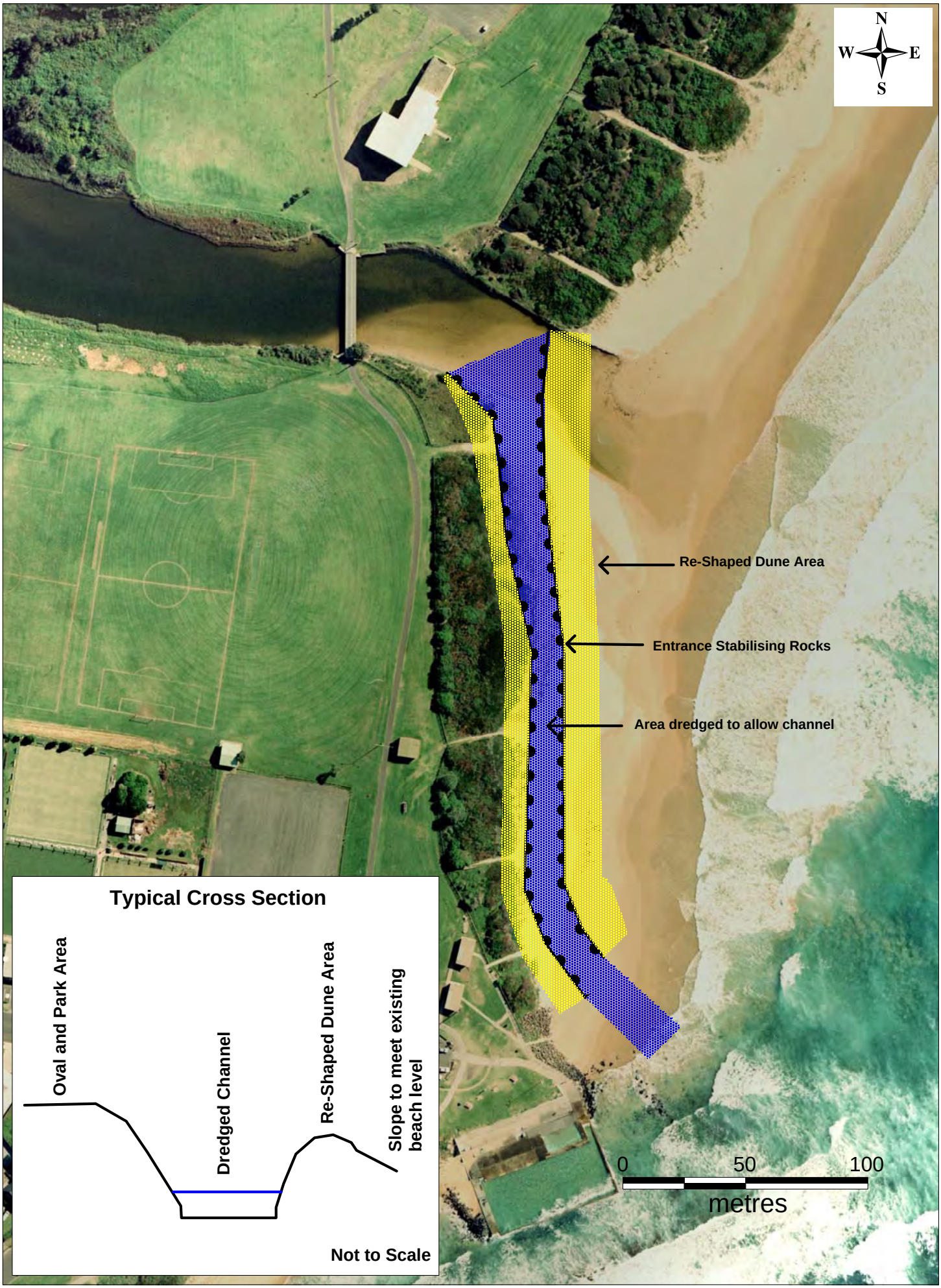
J2429 Fairy Towradgi Hewitts EMSP\Figures and Appendices\Report2192-v4/Figure 10.1 - Water Quality Sampling Locations.Wor



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Fairy, Towradgi and Hewitts/ Tramway Creeks
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FIGURE C1
TOWRADGI OPTION
SOUTH ENTRANCE

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J2429 Fairy Towradgi Hewitts EMSP\Figures and Appendices\Report2192-v4\Figure C1 Towradgi Entrance Design Option.WOR

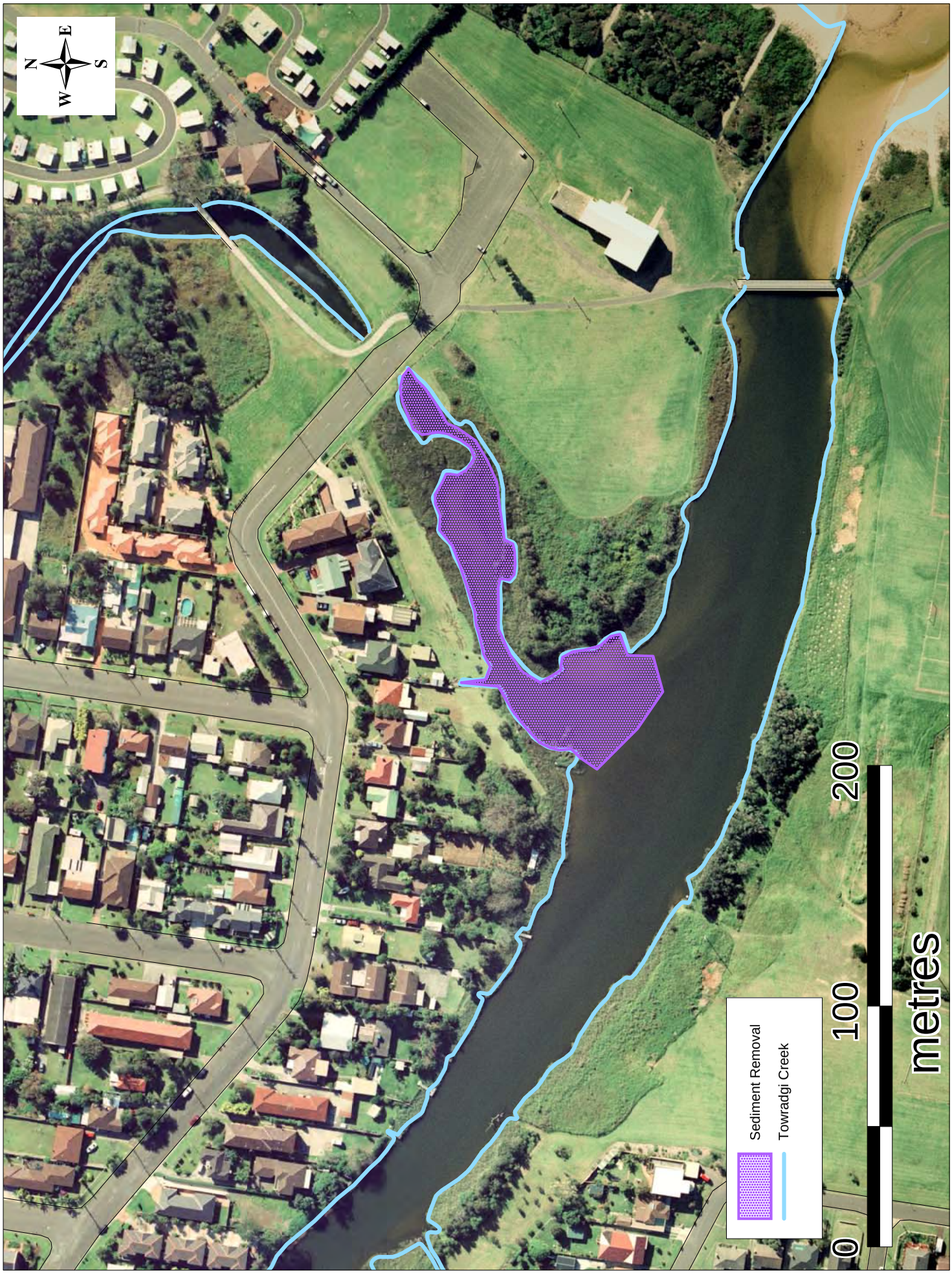

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FIGURE C2
PARKER ROAD ARM
SEDIMENT REMOVAL OPTION

J2429 Fairy Towradgi Hewitts EMSP\Figures and Appendices\Report2192-v4\Figure C2 Sed Rem Opt.Wor

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FIGURE C3
FAIRY CREEK BANK
STABILISATION OPTIONS

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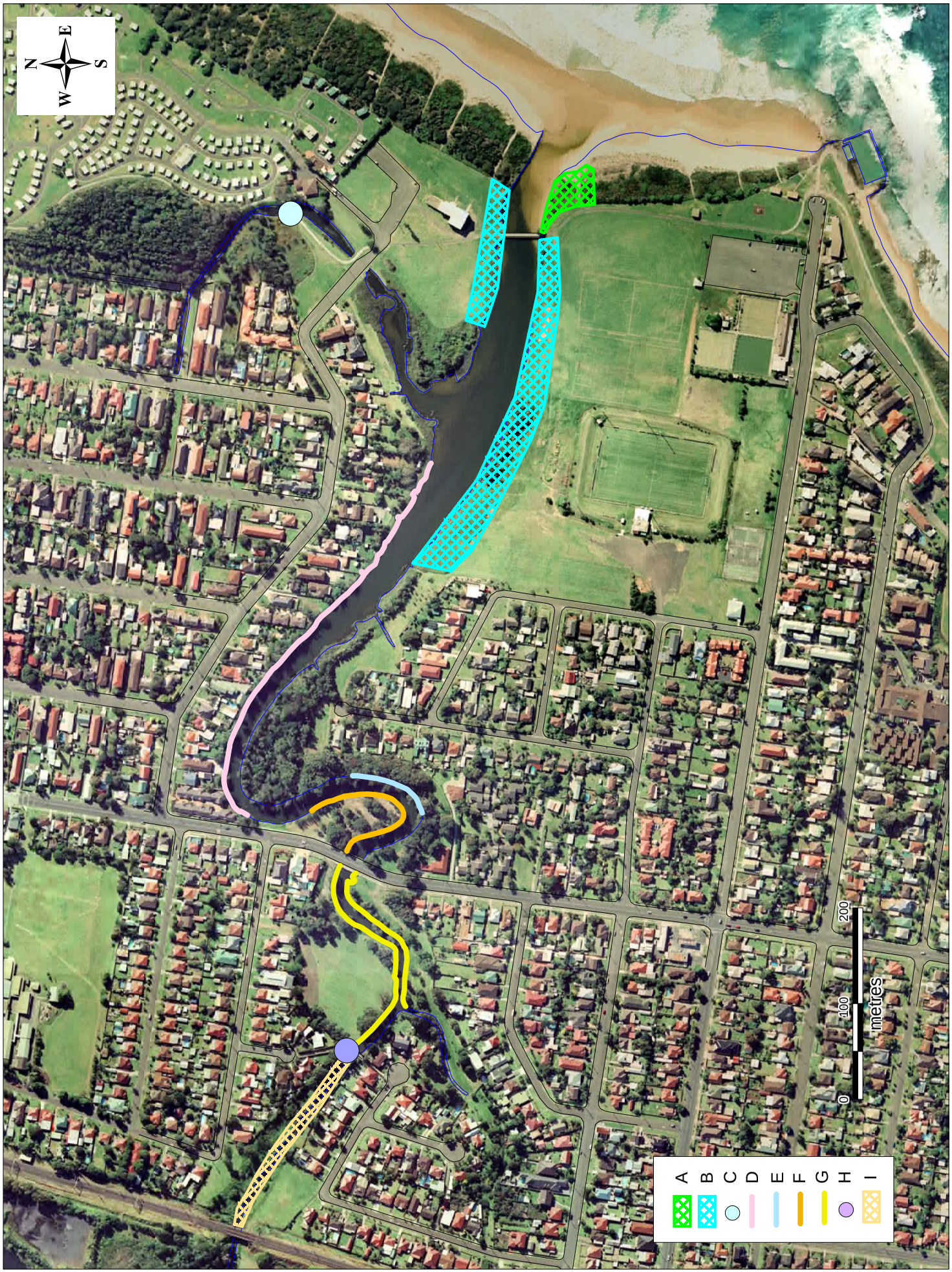
J2429 Fairy Towradgi Hewitts EMSP\Figures and Appendices\Report2192-v4\Figure C3 Fairy Bank Opt.Wor



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J2429 Fairy Towradgi Hewitts EMSP\Figures and Appendices\Report2192-v4\Figure C4 Towradgi Bank Opt.Wor

FIGURE C4
TOWRADGI CREEK BANK
STABILISATION OPTIONS

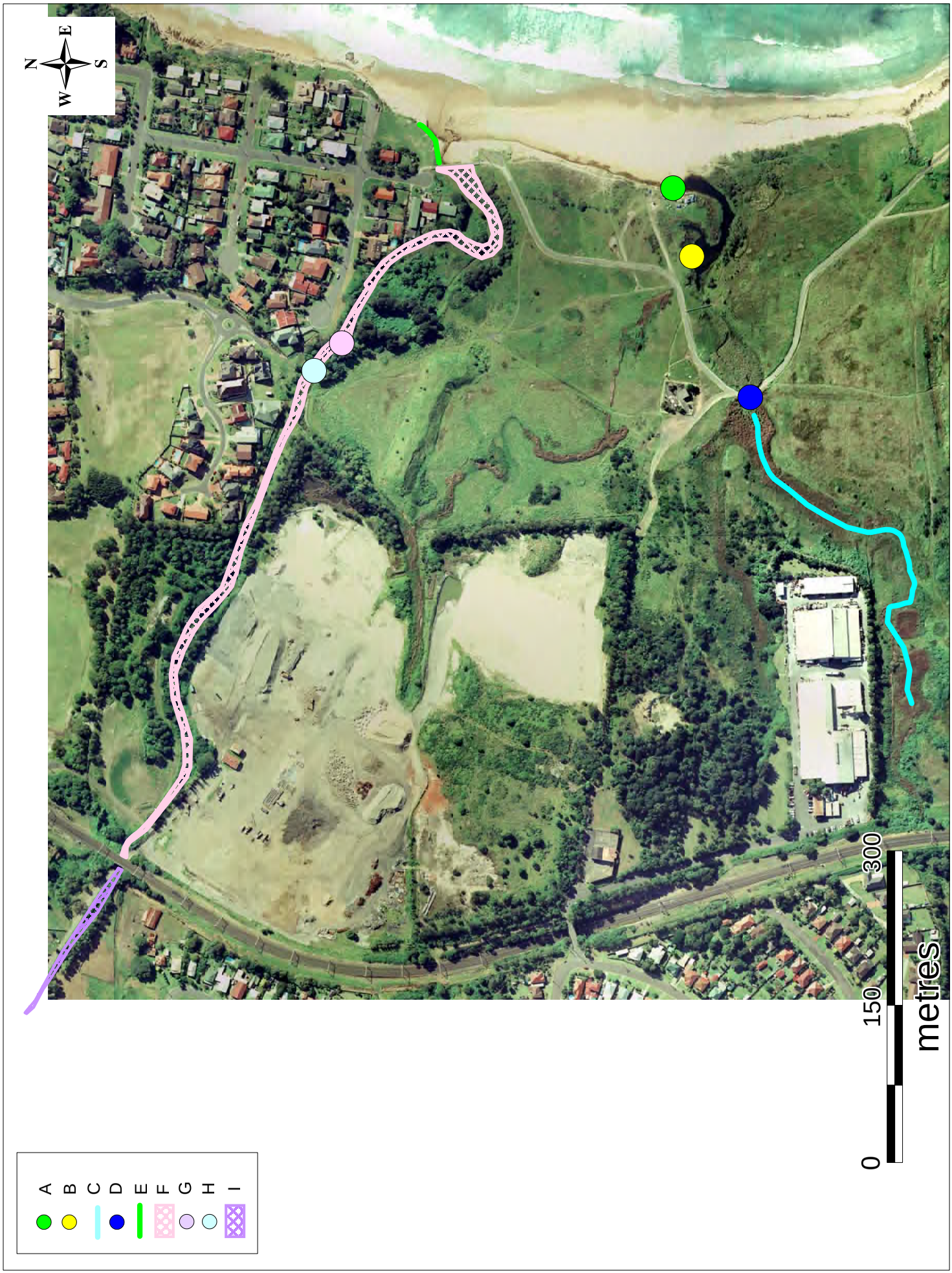

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FIGURE C5
HEWITTS/TRAMWAY CREEK BANK
STABILISATION OPTIONS

Fairy, Towradgi and Hewitts/ Tramway Creeks
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J2429 Fairy Towradgi Hewitts EMSP\Figures and Appendices\Report2192-v4\Figure C5 HewittsTram Bank Opt.Wor

FIGURE C6
MANAGEMENT RECOMMENDATIONS
FROM RIPARIAN CORRIDOR STUDY

Fairy, Towradgi and Hewitts/Tramway Creeks
Estuary Management Study and Plan

J2429 Fairy Towradgi Hewitts EMSP\Figures and Appendices\Report2192-v4\Figure C6 Management Rec.Wor

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BELLAMBI LAGOON

Towradgi Creek

Riparian Management Objectives
Map 4:

Legend:

Riparian Objectives
1 - Environmental corridor
2 - Terrestrial & aquatic habitat
3 - Bank stability & water quality

Airphotos ortho-rectified from 1998 photos sourced from Land and Property Information Divi Dept of Lands.

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Department of
Infrastructure, Planning and Natural Resou

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FIGURE C7
FAIRY CREEK OPENING

Fairy, Towradgi and Hewitts/ Tramway Creeks
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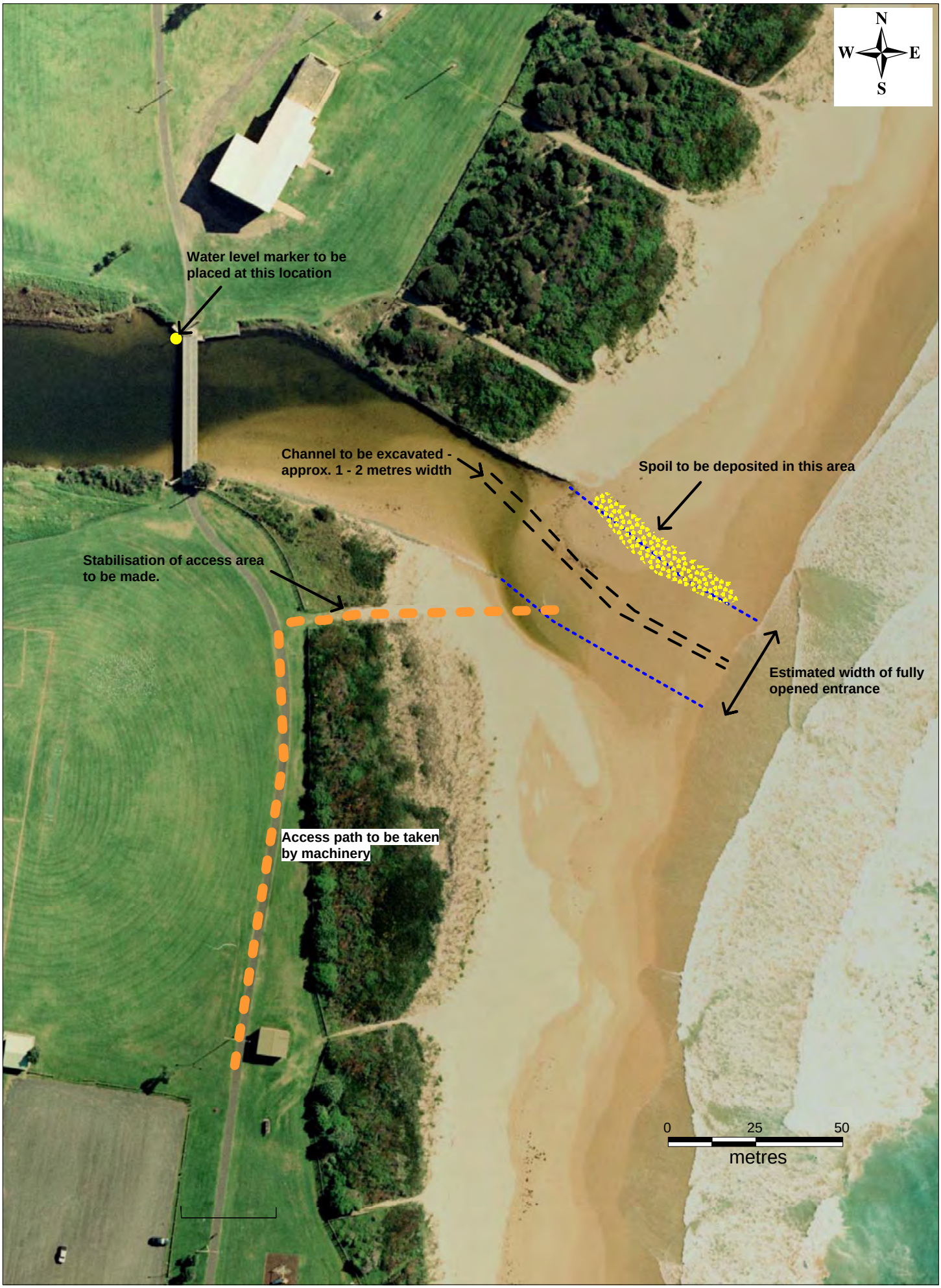
J2429 Fairy Towradgi Hewitts EMSP\Figures and Appendices\Report2192-v4\Figure C7 - FairyEntrance Opening.WOR



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Fairy, Towradgi and Hewitts/ Tramway Creeks
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FIGURE C8
TOWRADGI CREEK OPENING

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J2429 Fairy Towradgi Hewitts EMSP\Figures and Appendices\Report2192-v4/Figure C8 - Towradgi Entrance Opening.WOR

Habitat and Species Conservation
Water Quality
Sedimentation and Erosion Control
Cultural Heritage
Development
Recreation
Floodplain Risk Management Plan Actions
Entrance Management
Visual Amenity

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Option 69 SQID Near Gateway Complex Cabbage Tree Creek
Option 68 Maintain SQIDs on a regular basis
Option 13 Rehabilitate Degraded Sections of Cabbage Tree Creek
Option 48 Cabbage Tree Creek - Fish Passage Improvement
Option 94 Towradgi Arm Battering the slope and providing a gravel/cobble beach
Option 33 Towradgi Arm - Protect Mangrove Area
Option 58 Strict Control of Impacts on WQ During Construction
Option 16 Rehabilitate Vegetation - Western Side Cabbage Tree Creek
Option 110 Protect Non-Indigenous Heritage Items in Accordance with HCP
Option 14 Restore Degraded Aquatic Habitat as Part of Campus Development
Option 86 Fairy Creek Removal of weeds and revegetation with natives (Code G)
Option 93 Fairy Creek Reorientate Gravel Bars (Code I in Appendix C)
Option 12 Puckeys Estate and Surrounds - Protect and Enhance Vegetation
Option 2 Rezoning of Crown Land from 6(a) to a New Conservation Waterway Zone
Option 92 Cabbage Tree Creek Rock Armouring Around Trees (Code H)
Manage Redevelopment
Option 15 Protect and Enhance Vegetation in Campus East Area
Option 92 Cabbage Tree Creek Rock Armouring Around Trees (Code H)
Option 1 Rezoning of Crown Land from 6(a) to 7(b)
Option 53 Erect Interpretive Signage for Valuable Habitat at Confluence of Fairy
Option 89 Fairy Creek Battering the slope providing gravel/cobble beach (Code H)
Option 135 Provide Foreshore Viewing Platform
Option 109 Protect Boatramp in Accordance with Heritage Conservation Plan for PE
Option 32 South Fairy Creek - Rehabilitate Remnant Vegetation
Option 91 Fairy Creek - Stabilise Surrounds of Puckeys Boat Ramp (Code B)
Option 52 Erect Interpretive Signage for Valuable Habitat at Puckeys Estate
Option 39 Fairy Creek South - Erect Barriers to Prevent Mowing
Option 143 Entrance Management Policy
Option 31 Live Steamers - Rehabilitate Remnant Vegetation
Option 51 Erect Interpretive Signage to Direct Pedestrians to Puckeys Estate
Option 66 Fairy Creek - Install Litter Boom and Maintain on Regular Basis
Option 39 Fairy Creek South - Erect Barriers to Prevent Mowing
Option 77 Fairy Creek - Clear accumulated rubble and anthropogenic material.
Option 90 Stabilise Entrance Dunes (to include beach access track)
Option 86 Fairy Creek Removal of weeds and revegetation with natives (Code G)
Option 128 Erect Signage at Access Points re Litter and Swimming Risks
Option 88 Fairy Creek - Battering and Revegetation (Code D in Appendix C)
Option 67 Stormwater Quality Improvement Device at Fairy Creek Entrance
Option 87 Fairy Creek Rock Armouring of Stormwater Outlet Headwalls
Integrate Wollongong City Foreshore Masterplan for Stuart Park
Floodplain Management Works in Progress (Conveyance and Bank Stabilisation)
Option 65 Fairy Creek - Beaton Park Wetland

0 250 500
metres

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Fairy, Towradgi and Hewitts/Tramway Creeks
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FIGURE ES1
FAIRY CREEK
ESTUARY MANAGEMENT OPTIONS

J2429 Fairy Towradgi Hewitts EMSP\Figures and Appendices\Report2192-v4\Figure ES1 Fairy Options.Wor

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Option 71 GPT Downstream of Corrimal Shopping Centre
Option 34 Towradgi South Bank - Protect and Enhance Remnant Vegetation
Option 80 East Corimal - Address Sewerage Issues with Creek Inflow Prevention
Option 36 Cawley Street Protect and Enhance Remnant Vegetation
Option 122 Survey of Private Foreshore Structures
Option 202 Review water extraction licence and stormwater discharge licences
Option 54 Towradgi Creek - Erect Interpretive Signage for Valuable Habitat
Option 72 Stormwater Quality Improvement Device (Wetland and SQID)
Option 167 Voluntary Reconstruction or Redevelopment in this locality
Option 98 Parker Road Arm Stabilise Gabions (Code C in Appendix C)
Option 130 Erect Signage at Access Points re Litter and Water Quality
Option 38 Blue Divers - Provide Stabilised Access Point to include fishing acce
Option 189 Review accumulation of ballast in freshwater section
Option 35 Blue Divers - Protect and Enhance Remnant Vegetation
Option 101 Towradgi Creek North Bank - Rehabilitate Ad-hoc Bank Stabilisation
Option 81 Address Sewer Wet Weather Flow Capacity Issues
Option 43 Towradgi North Upstream - Erect Barrier to Prevent Mowing
Option 5 Bring Land into Public Ownership through Development Process
Option 24 Upstream Lake Parade Rehabilitate Degraded Riparian Habitat
Option 137 Provide Foreshore Viewing Platform
Option 21 South Upstream Footbridge Rehabilitate Degraded Riparian Habitat
Option 20 Upstream Towradgi Footbridge - Rehabilitate Degraded Riparian Habitat
Option 45 Towradgi North - Erect Barriers to Prevent Mowing
Option 42 Towradgi South Upstream - Erect Barrier to Prevent Mowing
Option 100 Towradgi Creek Upstream Revegetate and Stabilise Banks (Code I)
Option 201 Build a diversion channel to the East of the saltmarsh/tidal flats
Option 99 Towradgi Creek Near Upstream Footbridge Stabilise Steep Banks
Integrate Findings with the Corrimal Park Masterplan
Option 96 Stabilise Eroding Banks (Code E in Appendix C)
Option 168 Removal and Raising of Colgong Cresent Footbridge
Option 199 Restrict vehicular access
Option 129 Erect Signage at Access Points Re Litter and Water Quality
Option 198 Identify extent of rubble downstream of Blue Divers
Option 19 North Upstream Pioneer Road - Rehabilitate Degraded Riparian Habitat
Option 37 Towradgi Entrance Area - Provide Stabilised Access
Option 97 Revegetate Banks (Code F in Appendix C)
Option 192 Removal of the gabion baskets and replacement with more natural wall
Option 44 Towradgi Nth Upstream Pioneer Road - Erect Barriers to Prevent Mowing
Option 193 Removal of the gabion baskets entirely (~180 m total length)
Option 166 Voluntary Purchase of Properties in this locality
Option 18 South Upstream of Pioneer Road - Rehabilitate Degraded Riparian Habita
Option 136 Provide Foreshore Viewing Platform
Option 144 Entrance Management Policy
Option 78 Towradgi Creek - Remove Constriction to Tidal Flow Via Dredging
Option 41 Towradgi South Upstream Pioneer Road - Erect Barriers to Prevent Mowin
Option 194 Removal of the Southern training wall only (~70 m length)
Option 22 Parker Road Arm Rehabilitate Degraded Aquatic and Riparian Habitat
Option 40 Towradgi South Erect Barriers to Prevent Mowing
Option 95 Towradgi Creek Stabilise Entrance Dunes (Code A in Appendix C)
Option 17 South Bank - Rehabilitate Degraded Aquatic and Riparian Habitat
Option 147 Retrain Entrance to South for Permanent Condition
Integrate Findings with Towradgi Park Masterplan

- Habitat and Species Conservation
- Water Quality
- Sedimentation and Erosion Control
- Cultural Heritage
- Development
- Recreation
- Floodplain Risk Management Plan Actions
- Entrance Management
- Visual Amenity

0 200 400
metres

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Fairy, Towradgi and Hewitts/Tramway Creeks
Estuary Management Study and Plan

FIGURE ES2
TOWRADGI CREEK
ESTUARY MANAGEMENT OPTIONS

J2429 Fairy Towradgi Hewitts EMSP\Figures and Appendices\Report2192-v4\Figure ES2 Towradgi Options.Wor

Habitat and Species Conservation
Water Quality
Sedimentation and Erosion Control
Cultural Heritage
Development
Recreation
Floodplain Risk Management Plan Actions
Entrance Management
Visual Amenity

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S

Option 187 Coarse Debris Trap Bangalow Road
Option 29 Hewitts Creek Manage Watercourse and Riparian Zones
Option 28 Hewitts Creek Rehabilitate Degraded Riparian and Aquatic Habitat
Option 184 Levee and 200 m of Channel Relocation
Option 182 Fill Gabion Lined Channel
Option 104 Hewitts Creek Entrance - Revegetate Dunes (Code C in Appendix C)
Option 132 Erect Signage at Access Points re Litter and Water Quality
Option 185 and 186 Rehabilitate Creek between LHD & Rail & Purchase 2 Properties
Option 30 Woodlands Creek Manage Watercourse and Riparian Zone (Existing alignment shown)
RTA Actions - Northern Distributor Interchange including Sediment & Spill Basin
Option 146 Entrance Management Policy
Option 105 Formalisation of Crossing of Hewitts Creek (Code H in Appendix C)
Option 183 Flood Retarding Basin with Sediment Pond and Debris Control Structure (Note Project on Hold pending Discussions with RTA on integration with interchange)
Option 161 Install Water Level Recorder at Footbridge
Option 139 Provide Foreshore Viewing Platforms
Option 182 Reopen Tramway/Woodlands Diversion (Alignment is schematic only)
Option 104 Hewitts Creek Entrance - Revegetate Dunes (Code C in Appendix C
Option 103 Tramway Creek - Rock armouring for support and to protect the immedia
Option 10 Manage Turpentine Forest on Private Land in accordance with Col Findin
Option 9 Protect and Enhance Open Grassland Area for Migratory Birds
Option 180 Coarse Debris Trap Rex Avenue to William Street
Option 178 Formalise Diversion Overland Flow Path from Slacky Ck to Tramway Ck
Option 145 Entrance Management Policy
Option 27 Woodlands Creek South Manage Watercourse and Riparian Zones
Option 179 Sediment Basin Rex Avenue to William Street
Option 102 Tramway Creek Entrance - Revegetate Dunes (Code A in Appendix C
Option 131 Erect Signage at Access Points Re Litter and Water Quality
Option 26 Tramway Creek Manage Watercourse and Riparian Zones in Accordance with
Option 79 Tramway Creek - Modify barrier to tidal flushing
Option 25 Rehabilitation in Accordance with VMP prep by Sandon Pt Developer

0 250 500
metres

Cardno Lawson Treloar

J2429/R2192/V4
25 November 2005

Fairy, Towradgi and Hewitts/Tramway Creeks
Estuary Management Study and Plan

FIGURE ES3
HEWITTS/TRAMWAY CREEKS
ESTUARY MANAGEMENT OPTIONS

J2429 Fairy Towradgi Hewitts EMSP\Figures and Appendices\Report2192-v4\Figure ES3 Hewitts Options.Wor