TUROSS ESTUARY
WATER QUALITY IMPROVEMENT PLAN
MARCH 2016

eurobodalla shire council

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EXECUTIVE SUMMARY

Tuross Lake is a complex estuary with a linked network of channels and lake systems fed by a Catchment area of over 1850km^2 largely comprised of steep, forested terrain extending 147km from the headwaters in the south-west through to undulating hills and low-lying floodplains to the coast.

The Eurobodalla Shire Council (Council) monitors estuary water quality monitoring across six major estuaries within the Eurobodalla Local Government Area as part of the Eurobodalla Estuary Health Monitoring Program. Following an external review of the program it was noted that the Tuross River estuary can suffer from poorer water quality relative to other local major estuaries and a catchment model was recommended to assist in identifying sources of sediment and nutrients.

Pollutant export modelling prepared by the Office of Environment and Heritage (OEH) combined land use data along with other topographic and climate parameters to estimate areas of potential high pollutant load. The pollutant modelling showed the areas of higher risk correspond with catchments where forestry, rural residential development, grazing and agricultural practices are occurring. In particular the areas around the estuary and along the main channel immediately upstream are all classified by OEH as high risk areas, due to their proportionally higher contribution of TSS, TN and TP.

The modelling results align with several past studies and management plans which recommend rehabilitation actions to be undertaken in the lower reaches of the Tuross catchment. It is also generally acknowledged that rehabilitation works should be targeted where they are most likely to have ongoing monitoring and complementary efforts to maximise long term outcomes.

OEH and Council have undertaken detailed field mapping to groundtruth areas of the lower catchment that are likely to be relatively high contributors of sediments and nutrients. The mapping identified over 80 sites in and around the estuary and lower main channel and assigned a preliminary priority to each based on previous foreshore mapping from the Tuross Estuary Management Plan and site observations (existing riparian vegetation, surrounding land use and scale of erosion).

Following a review of the recent catchment modelling, field investigations and past studies undertaken for the Tuross, prioritisation of water quality management sites was undertaken using four major site attributes associated with potential for water quality impacts at each site. These attributes have been assessed based on available information from previous estuary studies and site investigations and include:

- Vegetation Condition
- Degree of Exposure
- Adjacent Land Use
- Stock Impact

A section of river bank along Cambathin Island was an exception to the above methodology. This site was specifically identified as having the potential for a breakthrough that would alter flow patterns in the mid-estuary in a major way, with potential for serious and long lasting impacts to estuary health.

Following a review of all the sites, three main water quality issues were frequently identified, either occurring in isolation, or in combination:

- Sediment and nutrient loads associated with agricultural activities, including cropping with no, or limited buffers before runoff reaches watercourses
- Stock access to the top of bank and/or water's edge with little to no riparian buffer and associated erosion, pollution and nutrient addition effects.
- Steep banks (sub-vertical) with high exposure to main channel flows (i.e. located on outside bend or other areas where flows are greatest directly alongside the bank) and associated erosion / sedimentation and property loss

From the prioritisation, water quality management projects that incorporate a range of management approaches from stock access, buffers for water quality and stabilisation works have been developed and costs for works estimated, a summary is shown below.

Works are unlikely to be undertaken solely by land owners. Projects are most likely to be undertaken with funding and collaboration either with Council or LLS and administered grant schemes.

As discussed at the community workshop (attended by landowners, Council, State Agency staff including OEH and Local Land Services (LLS)) identification of land owners and key contacts that have water quality management priorities on their land is a critical first step to initiating these projects.

Once connection is made, discussions and negotiations around what form a project could take can then commence. LLS are actively engaging with landowners where current funding is available, however there is potential for further liaison between Council, LLS and landowners on the Tuross estuary.

One of the key messages to come out of the meeting was that communication and ongoing dialogue between Council and landowners is critical to creating lasting partnerships and developing sound projects.

Priority project cost estimates

Site	Assumptions	Total cost estimate *	Contribution in kind**	Grant funding
4.2a	Revegetation and fencing along the full length.	$270,259	$ 139,720	$ 130,539
4.3	Revegetation and fencing along the full length.	$104,511	$ 54,183	$ 50,328
4.2b	Revegetation and fencing along the full length. 100m of large woody debris as bank stabilisation.	$322,374	$ 159,091	$ 163,284
4.20	Revegetation and fencing along the full length. 20m of coir log bank stabilisation	$ 73,429	$ 37,865	$ 35,564
5.1	Revegetation and fencing along the full length.	$230,288	$ 119,279	$ 111,008
5.2a	Revegetation and fencing along the full length.	$341,192	$ 177,043	$ 164,149
5.2b	Revegetation and fencing along the full length.	$311,737	$ 161,696	$ 150,041
5.9a	Revegetation and fencing along the full length.	$349,642	$ 181,498	$ 168,144
5.9b	Allowance of $15000 for drainage management 50m of fencing	$ 19,934	$ 917	$ 19,017
6.2, 6.3 and 6.4	Allowance of $5000 for assessment of landscape and flow paths. 120m of revegetation as a riparian buffer. 500m of fencing	$ 80,670	$ 34,588	$ 46,082
7.3	Allowance of $5000 for assessment of landscape and flow paths. 150m of revegetation as a riparian buffer. 500m of fencing	$ 96,025	$ 42,901	$ 53,124

Site	Assumptions	Total cost estimate *	Contribution in kind**	Grant funding
Cambathin Island - Revegetation, Investigation and Monitoring	400m of revegetation. Site investigation & survey $4000 Photogrammetry comparison allowance $3000	$111,060	$ 55,797	$ 55,263
Cambathin Island - Toe Protection Works	Detailed Design 100m of rock toe protection works Barge establishment & disestablishment & hire Crane hire	$363,608	$ 15,809	$ 347,799

* Total costs include a project management and contingency component. All revegetation projects include maintenance costs over 5years.

** Potential contributions in kind can include time, materials, plants, labour etc. Estimates based on:

- 40% of revegetation supply and install costs in kind
- 100% of revegetation maintenance costs in kind
- 100% fencing maintenance costs in kind
- 40% of coir supply and installation costs in kind
- 50% of project management costs in kind

1.0 INTRODUCTION

1.1. Background

Eurobodalla Shire Council (Council) undertakes estuary water quality monitoring across six major estuaries within the Eurobodalla Local Government Area. As part of this program, Council with the assistance of the office of the Office of Environmental and Heritage (OEH), now produce regular estuary health and water quality report cards. A review of historic monitoring data (*Eurobodalla Estuary Health Monitoring Program Review*, BMT WBM, 2011) highlighted that the Tuross River estuary can suffer from poorer water quality relative to the other major estuaries and recommended "a catchment model of the Tuross River Catchment be constructed to identify potential sources of sediment and nutrients". This report further recommended that "pollution hot spots and sources should be identified and potential management actions identified to address this long term management of this estuary".

OEH have since completed nutrient export modelling for the Tuross River catchment and in conjunction with Council have undertaken extensive field investigations throughout the estuary to identify sites that are likely to contribute significant sediment and nutrient loads to the estuary. These field investigations also outlined preliminary actions to address issues at each site.

Southeast Engineering and Environmental were commissioned by Council to develop a Water Quality Improvement Plan (Plan) for the Tuross Estuary based on the recent catchment modelling, field investigations and past studies undertaken for the Tuross River.

Specifically, the Plan aims to develop a robust methodology for prioritising sites for water quality management measures. The Plan outlines a range of treatment measures to reduce pollutant export and improve the receiving estuaries water quality. The details of the typical treatment measures include drawings and cost estimates to enable Council to plan and resource projects, as and when funds become available.

The goal is to improve estuary health either by managing bank erosion and sedimentation and/or by reducing possible inputs of nutrients to the estuary.

1.2. Project boundaries

OEH and Council through catchment modelling and field investigations have identified foreshore stabilisation and rural runoff impacts around the estuary as the primary focus for this investigation. Water quality impacts further upstream within the Tuross River catchment are not part of this project.

The Study Area extends from the Tuross Estuary, upstream to the tidal limit (approximately the confluence of Swamp Creek and the Tuross River) just upstream of Silo Farm Bridge on Comerang Forest Road, refer Figure 1.1 and Figure 1.2.

The subcatchment land uses surrounding the estuarine part of the Tuross River comprise dairy farms, grazing and cropping, rural residential properties, some urban catchments and forested areas.

Additionally, based on discussions with Council we understand that management options for the purpose of this study do not extend to matters such as domestic on-site sewage management or dairy farm on-site operations which are addressed through other Council and State Authority programs, or other operational changes such as education and enforcement around erosion and sediment control during construction.

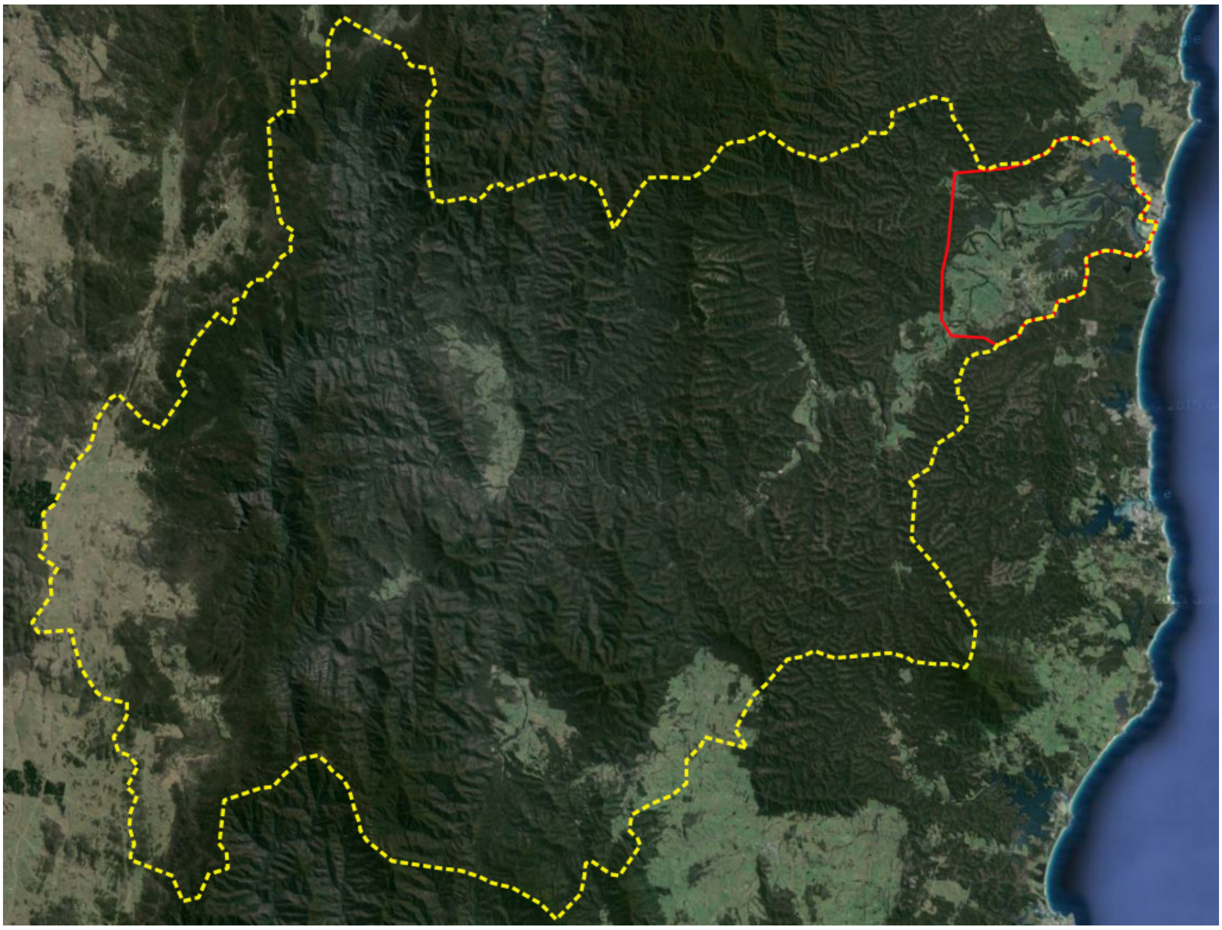

Figure 1.1 Tuross Catchment (yellow) and Project study area (red)

Figure 1.2 Project study area

2.0 BACKGROUND INFORMATION

2.1. Key catchment and estuary features

Following a review of previous reports and findings, the catchment scale issues include:

- Catchment area 1850km^2 largely comprised of steep, forested terrain extending 147km from the headwaters in the south-west through to undulating hills to the coast. The lower catchment comprises broad low-lying floodplains.
- Much of the western catchment comprises granite-based soils which are readily erodible. The Wandella Creek, Belimbla Creek, Wadbilliga River and Mellion Creek sub-catchments are the main potential suppliers of sandy sediments from grey granite soils (*Brierley 1995 - reported in Brown and Root 2001*).
- Unconsolidated alluvial deposits of relatively recent age occur along the Tuross floodplain and estuary interbedded in sand deposits. These are readily eroded and produce estuarine muds.
- The main threat to further infilling of the Tuross estuary is the reworking of large sand volumes within the bed, bars and floodplain of the Tuross River downstream of Waterhole Flat (*Brown and Root 2001*).
- Varied land use within the catchment including forestry, National Park and agriculture (cropping, beef and dairy farming)
- The key threats to water quality include sediment and nutrient mobilisation:
    - Sediment sources include erosion (occurring naturally) but also exacerbated through land-use (land clearing, unsealed roads, forestry, stock access to banks, lack of vegetation).
    - Sediment derived from the upstream catchment is deposited in the estuary at a rate higher than the long term geological average. Sediment infill is leading to readjustment of channel banks.
    - Nutrient sources include those temporarily bound to sediments (mobilised through the processes above), direct stock access to waterways, and runoff from the catchment. In addition phosphorus can be released from estuarine muds under low oxygen conditions.

2.2. Relevant estuary processes

The estuary environment has evolved over thousands of years as a result of interactions between ocean and catchment processes. The ocean entrance allows clean ocean water to be introduced into the lower estuary on incoming tides. Volumes of ocean water, and hence tidal flushing, are dependent on the entrance condition. The tidal range in the lake can vary between a metre and 0.1 metres depending on the condition of the entrance bar. During an unusually extended dry period with low freshwater inflows, the bar has been known to close completely.

Figure 2.1 Tuross Estuary ocean entrance (SIX Viewer Feb 2016)

Tuross Lake is a complex estuary with a linked network of channels and lake systems. Water quality under tidal conditions will naturally vary with location within the estuary. Tidal flushing in the lower lake is usually good unless the entrance is restricted. Flushing of the main lake body reduces with distance upstream. So the tidal water quality in the upper reaches of the lake can be poor. However after heavy rainfall, water quality in the whole estuary can reflect the quality of runoff from the catchment, and will be poor regardless of proximity to the entrance.

One unique attribute of this estuary is a number of backwater lakes such as Trunketabella Lagoon, Borang Lake and Bumbo Lake which have poor tidal flushing due to their restricted connection to the main lake body (Brown and Root 2001). These vulnerable water bodies are thought to be functioning independent of the remainder of the estuary. They routinely display signs of elevated nutrients concentrations and algal blooms in warmer months. Their water quality is determined by internal chemical processes that self-sustain them despite an elevated level of nutrients. These systems are still vulnerable to overload from catchment inputs, but their water quality has little impact on the main lake body due to low tidal exchange rates (Brown and Root 2001 and WBM Oceanics 2002).

Figure 2.2 Tuross Estuary with backwater lakes

Water quality in the main estuary is a function of pollutant inputs from the catchment. Sediments and nutrients enter the estuary from the Tuross River catchment and from local catchment runoff. Calculations suggest an increase in nutrient inputs since European settlement of around 1 ½ to 2 times. This is an inevitable result of replacement of native vegetation with pasture grasses and agricultural runoff.

Bank erosion is mostly a natural process as a result of sedimentation and channel widening. However this can be accelerated by human inputs. Channel shallowing from sediment deposition results in the channel readjusting its width to compensate for reduced depth, which can lead to bank erosion. Erosion is most evident on the outside of bends which are affected by high tidal velocities and/or by wind waves.

Bank erosion in the lower estuary adds sediment to the system, and the finer sediments can include nutrients such as phosphorus. Rapid sediment deposition can smother estuarine habitat such as seagrasses.

Discussion with Council staff confirms that of all the major waterways in the Shire, heavy rainfall has the greatest impact on water quality in the Tuross estuary.

Figure 2.3 Example of an exposed sandy sub vertical bank with active erosion

Figure 2.4 Example of recent bank failure as a result of flows being directed at this bank

Figure 2.5 Example of seagrasses in the lower reaches of the Tuross estuary.

2.3. Previous studies

Numerous investigations have been undertaken in relation to the Tuross Estuary, including:

Tuross Estuary and Coila Lake Estuary Processes Study (2001)

The Estuary Processes Study detailed hydraulic, sedimentation, water quality and ecological processes occurring within the estuary, and the impacts of human activities on these processes. This provided the necessary understanding of physical and biological processes for the development of an Estuary Management Study.

Tuross Estuary and Coila Lake Estuary Management Study (2004)

This identified the essential features and the current uses of the estuary, and determines the overall objectives required for management of the estuary. The Management Study also identified options for meeting these objectives, and determines hydraulic and ecological impacts of the proposed options.

Tuross Estuary and Coila Lake Estuary Management Plan (2005)

The Estuary Management Plan (EMP) describes how the estuary will be managed, provides recommended solutions to management problems, and details a schedule of activities for the implementation of the recommendations.

There are a number of high priority strategies in the EMP relevant to this project which are perhaps best illustrated in EMP Foreshore Management Mini Masterplan (**Figure 2.6**). This mini masterplan focuses on the need for revegetation and stabilisation of foreshores around the estuary. It should be noted that similar findings (priority areas and proposed measures) were outlined in the recent OEH/Council mapping.

The EMP recommended a total of 28 strategies to maintain the existing values of the estuary. The first six prioritised strategies are outlined below in Table 2.1 highlighting the emphasis on foreshore management.

Eurobodalla Estuary Ecosystem Health and Water Quality Monitoring Program (2010 - ongoing)

Council run a comprehensive ecosystem health monitoring program for the six major estuaries across the shire that includes both estuary health and recreational health indicators. The Tuross River estuary report cards have identified that this estuary can suffer from poorer water quality in comparison to the other 5 estuaries. Refer Appendix A for full report cards.

Eurobodalla Estuary Health Monitoring Program Review (2011)

This review recommended that "*A catchment model of the Tuross River Catchment should be constructed to identify potential sources of sediment and nutrients that give this estuary lower water quality rankings than for other estuaries. Pollution hot spots and sources should be identified and potential management actions identified to address this long term management of this estuary*"

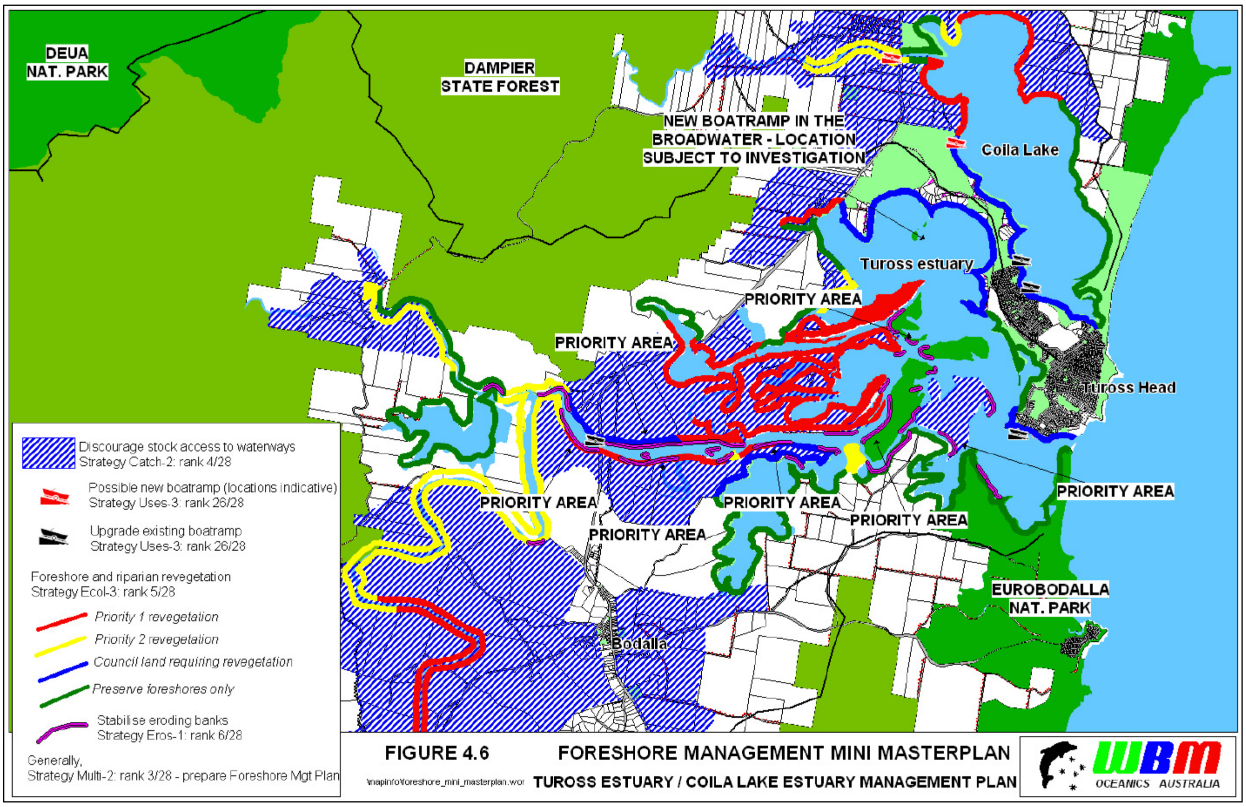

Figure 2.6 Foreshore Management Mini Masterplan taken from the 2005 Tuross Estuary and Coila Lake Estuary Management Plan – note Priority 1 revegetation areas highlighted red

Table 2.1: Extract of the priorities strategies recommended in the EMP (2005) – note emphasis on foreshore management

Priority Ranking	Management Strategy Description
1/28	Carry out a desktop and field-based assessment to identify and map areas within the Tuross and Coila Lake estuaries and their catchments that are considered “critical habitat areas”, existing environmentally “sensitive areas”, and existing “degraded sensitive areas”.
2/28	Develop and implement a rural community education and consultation program specifically targeting upstream landholders, covering topics such as stock fencing, alternative watering sources, revegetation, weed management, efficient use of water allocations, foreshore protection, erosion control, riparian vegetation, and continued use of Best Management Practices within the Tuross Valley and Coila Lake catchments.
3/28	Prepare a Tuross estuary / Coila Lake Foreshore Management Plan, addressing bank stabilisation, riparian revegetation and conservation, and sustainable recreational use of foreshores.
4/28	Discourage stock access to natural waterways and foreshores of the Tuross estuary and Coila Lake by fencing, revegetation of riparian zones and providing alternative water sources, as appropriate.
5/28	Revegetation and preservation of foreshores and riparian zones around the Tuross estuary and Coila Lake.
6/28	Stabilise and rehabilitate eroding banks around the foreshores of the Tuross estuary and Coila Lake.

2.4. Sediment and nutrient mapping

As per the recommendations of the *Eurobodalla Estuary Monitoring Program Review* (2011), estimation of sediment and nutrient loads generated by various land uses within the catchment was undertaken by OEH. The export modelling used standard export rates based on land use along with other parameters including soil type and climate to estimate the Total Suspended Solids (TSS), Total Phosphorus (TP) and Total Nitrogen (TN) loads being exported within the Tuross catchment. No calibration with field data was undertaken. Rather than a water quality processes model, the modelling provides an indication of the potential relative contribution of nutrient and sediment loads in different sub-catchments.

The risk to the Tuross River catchment at a large sub-catchment scale was assessed based on the relative estimated sediment and nutrient load contributions.

The diffuse pollution risk assessment map from this modelling is shown in Figure 2.7 with separate TSS, TP and TN load maps shown in Appendix B.

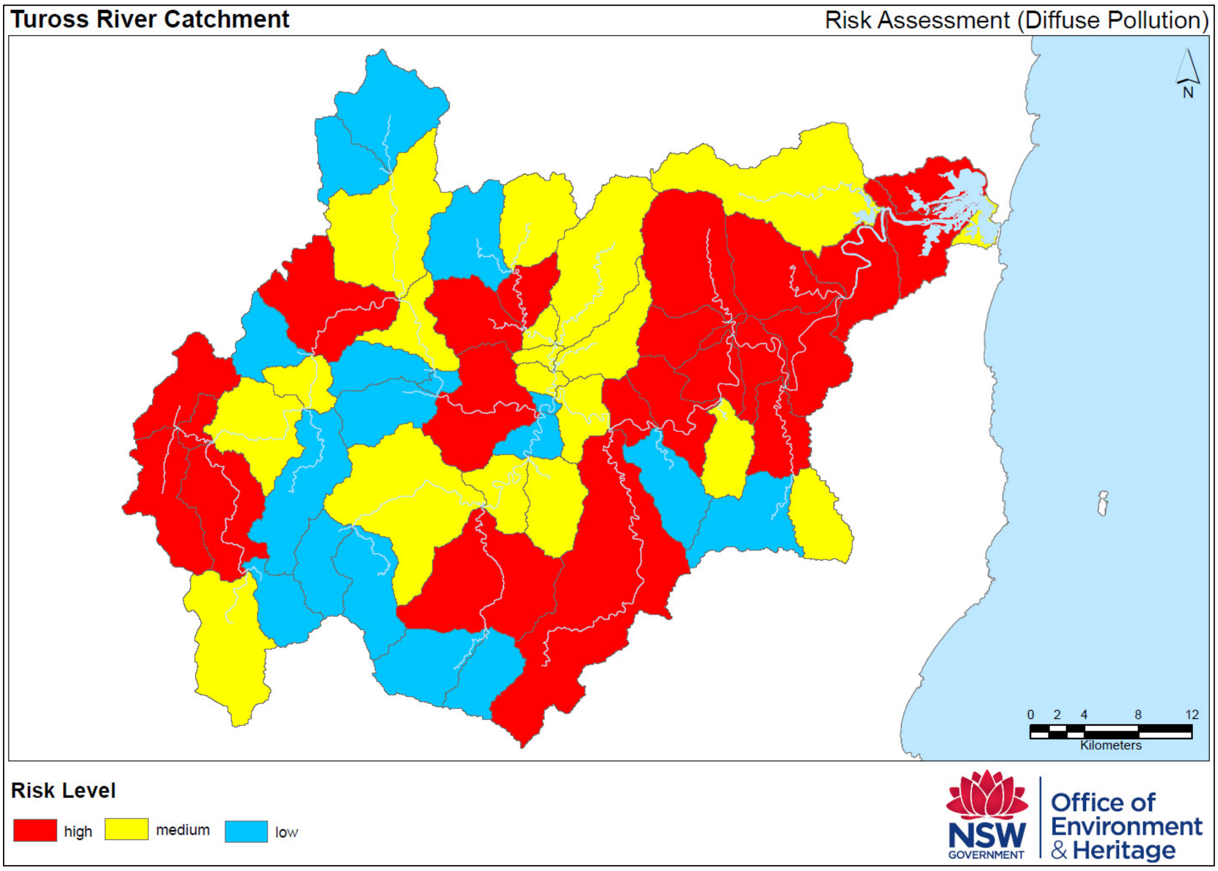

Figure 2.7 OEH Tuross River catchment modelling output map - Risk Assessment (Diffuse Pollution)

The risk assessment (diffuse pollution) map shows the areas of higher risk correspond with catchments where forestry, rural residential development, grazing and agricultural practices are occurring. In particular the areas around the estuary are all classified by OEH as high risk areas, due to their proportionally higher contribution of TSS, TN and TP based on the pollution export rates applied.

There are also several catchments considered high risk in the upper reaches associated with agriculture land use and forestry however these areas are unlikely to have as much direct impact on the estuary due to the dilution, sedimentation and assimilation within nutrient cycles that occurs between these areas and the estuary. However, upstream land use, particularly forestry does have a significant impact on sediment loads within the river.

Higher resolution modelling of the lower catchment was undertaken by OEH for TSS, TP and TN loads to gather more detail about potential sediment and nutrient sources and assist in highlighting areas where water quality management may be a priority. It should be noted that modelling is based on land use mapping, LEP zoning and standard pollution generation rates and is therefore indicative only. An example of pollutant load mapping for TN is shown in Figure 2.8.

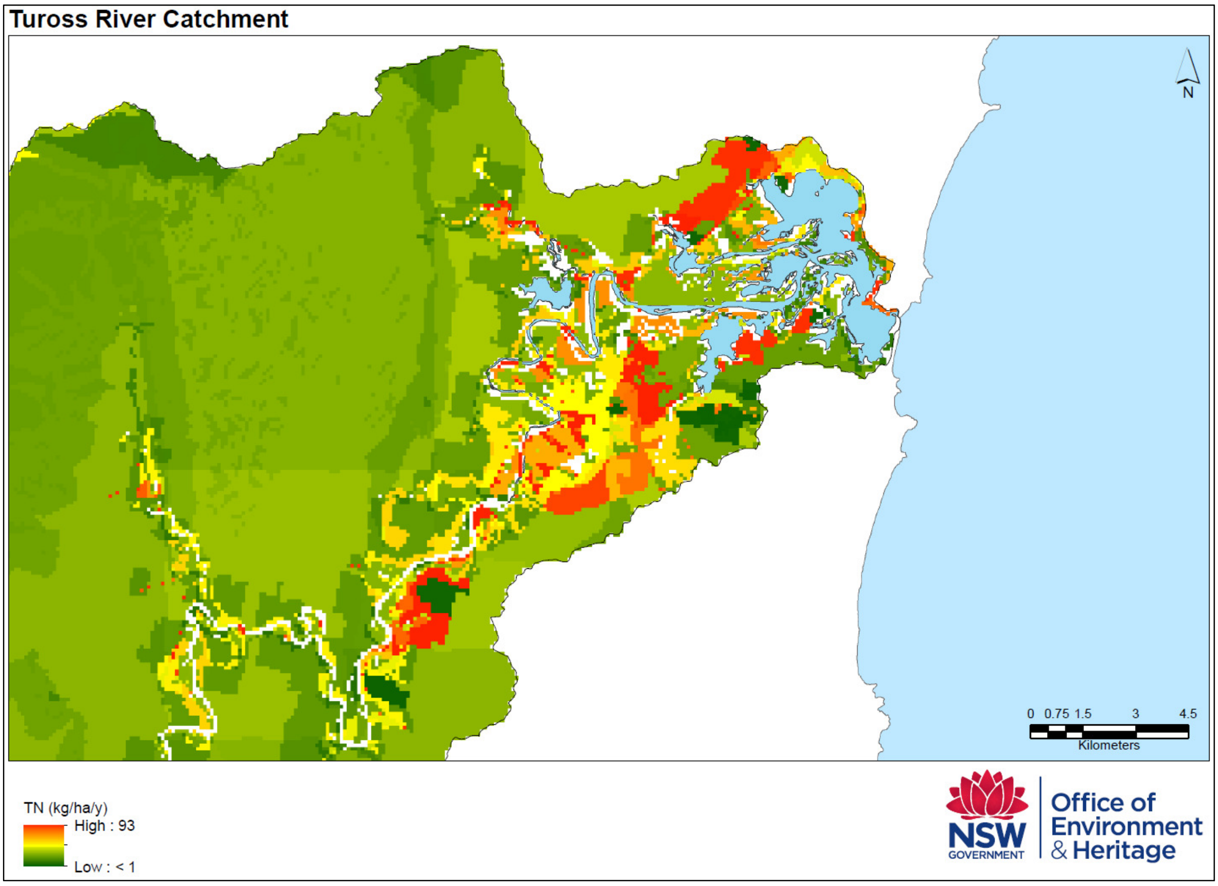

Figure 2.8 OEH lower Tuross River catchment modelling output map – TN (kg/ha/yr)

2.5. Fieldwork Mapping

Detailed fieldwork mapping was completed by Council and OEH in March 2014. The majority of this investigation was undertaken by boat to enable a thorough examination of the estuary foreshore. Some land based investigations were carried out where public access allowed however some areas were not mapped due to inability to gain boat or land based access. The full set of fieldwork maps is provided in Appendix C.

Based on a review of the information provided, typical scenarios observed included:

- Small sections of foreshore requiring revegetation infill
- Ongoing monitoring of existing works (no action)
- Minor erosion *
- Moderate erosion *
- Major erosion *
- Unvegetated banks in poor condition
- Limited riparian vegetation
- Foreshore unfenced and actively grazed
- Foreshore fenced but evidence of crash grazing
- Weeds/garden escapees
- Intensive cropping/Irrigated pasture to top of bank with limited riparian buffer

* Based on descriptions and site visit, erosion severity ranking is related to bank height, extent (i.e. length), presence or lack of foreshore vegetation and whether or not the erosion was active.

3.0 SITE ASSESSMENT AND PRIORITISATION

3.1. Background

This report looks at practical ways to progressively improve estuary health by reducing TSS, TN and TP loads entering the estuary. Investigation boundaries were defined by the estuary extent and the immediate surrounds. Land use beyond the estuary and local sub catchments does have an impact on water quality within the estuary, however, given the high diffuse pollution risk around the estuary, compared to the remaining catchment the focus of the investigation was on the estuary banks and adjacent land uses.

It is important to note that pollution sources such as domestic on-site sewage management or dairy farm on-site operations which are addressed through other Council and State Authority programs, or other operational changes such as education programs are excluded from this investigation.

The identification of water quality management sites and rehabilitation were targeted where they are most likely to have ongoing monitoring and complementary efforts to maximise long term outcomes. In addition, the planning of future works should complement past investment (Council, Local Land Services and other stakeholders), particularly where positive relationships exist with land owners.

3.2. Methodology

Once the investigation area was defined, a list of locations where water quality management was undertaken through the following steps:

1. Review of existing studies and investigations
2. Review of OEH pollutant export modelling
3. Review of Council and OEH site investigations
4. Additional site investigations

A list of sites was developed and four key site attributes were used to prioritise sites based around their potential for water quality impact.

These attributes are outlined below. Each of the attributes is afforded a numerical score based on relevance and severity of impact (refer Table 3.1).

The scores are summed to provide an overall priority for each site as outlined in Appendix D.

1. **Vegetation Condition**

Vegetation along a river or estuary bank serves three purposes related to water quality. Firstly, its deep root system can help to hold a bank together. Secondly a healthy riparian buffer can assist to absorb flood flows, reducing velocity locally close to banks. And thirdly, a healthy vegetation strip forms a buffer or filter for runoff and shallow groundwater flows, intercepting sediment and some nutrients before they reach the waterway. Overhanging vegetation can also provide shading of the watercourse which aids in habitat, although this is of less relevance to this project.

Figure 3.1 Many areas along the estuary are void of mature vegetation

2. **Degree of Exposure**

The degree of exposure of riverbanks to the natural forces that cause erosion can be predicted or measured. For this study we applied rates of bank erosion from the Estuary Processes Study where possible. This study measured erosion rates from all causes, whether related to tidal or flood flows, wind or boat wash or from a shallowing reach causing a channel to spread laterally. It inherently includes soil attributes such as sandy collapsing banks versus more resistant clay or rocky sites.

Figure 3.2 Snake Flat - Example of an outer bend (now with toe protection) that was previously susceptible to high rates of erosion due to location (outside bend) and recreational uses (popular with fishing and water skiing)

3. Adjacent Land Use

Land use adjacent to the estuary was incorporated into the prioritisation by using the Pollutant export mapping and visual inspection to assist in estimating the connectedness of the land use to the estuary.

As an example, land used for cropping can contribute nutrient pollution through the application of fertilisers or land used for dairy farming can contribute nutrient pollution through stock manure, (both sources rich in nitrogen and phosphorus).

Figure 3.3 Intensive agricultural practices can result in higher nutrient export in runoff compared to a natural catchment

4. Stock Impact

Impacts of uncontrolled stock access could range from direct defecation into the estuary, to simply destabilising riparian vegetation and wear of banks from regular track use and the erosion associated with this.

Figure 3.4 Direct stock access can have a detrimental impact to water quality and can also be a safety issue for stock

Table 3.1: Site attributes breakdown used for prioritisation of sites

Site Attribute				
Score	**Vegetation Condition**	**Degree of Exposure**	**Adjacent Land Use**	**Stock Impact**
1	Dominated by native trees etc., buffer at least 10m wide.	Low - banks stable	Largely undisturbed, stable native vegetation (i.e. national park)	Low - no evidence of stock impact
2	Thin band of vegetation along bank but no buffer behind	Moderate - minor undercutting and slumping	Cleared farm land with stock	Medium - few tracks but minimal impact (low erosion/banks stable)
3	Exposed banks, dominated by pasture grasses, scattered trees may be present but intermittent, no buffer	High - actively eroding, actual or potential for mass failure and sediment liberation	Intense agricultural cropping	High - numerous access tracks, evidence of erosion, no understorey

3.3. Cambathin Island

There is one site on the estuary that is an exception to the above assessment methodology. The Estuary Processes Study (Brown and Root 2001) identified the eroding bank on the outside of a bend at Cambathin Island as particularly vulnerable to a breakthrough (Figure 3.5, Figure 3.6, Figure 3.7 and Figure 3.8). Termed an avulsion, a breakthrough here would alter flow patterns in the mid-estuary in a major way. Mangrove wetlands behind the island would be lost as tidal flows were diverted. Fine, nutrient-rich sediments amongst the mangroves and in the back channel behind the island would be disturbed as areas of low flow became a major tidal flow path. Conversely, areas of high flow would become almost quiescent as flow was diverted away from the Four Ways channel.

The result would be increased turbidity, ongoing expansion of the back channel behind the island causing bank erosion and sedimentation elsewhere. Water quality would change rapidly as nutrient-rich sediments were disturbed. Systems such as the Tuross estuary are not accustomed to such rapid changes in geochemistry and channel flows. The impact on estuary health could be serious and long lasting (Brown and Root 2001).

Erosion rates at this site are estimated to be up to 1.0m per year (Brown and Root 2001). The possibility of this avulsion occurring is high during a major flood, or progressively from tidal flows and wind waves over the next ten years or so. Given the scale of potential impacts on the broader estuary, we have prioritised this site as top priority regardless of its individual scores under the assessment process.

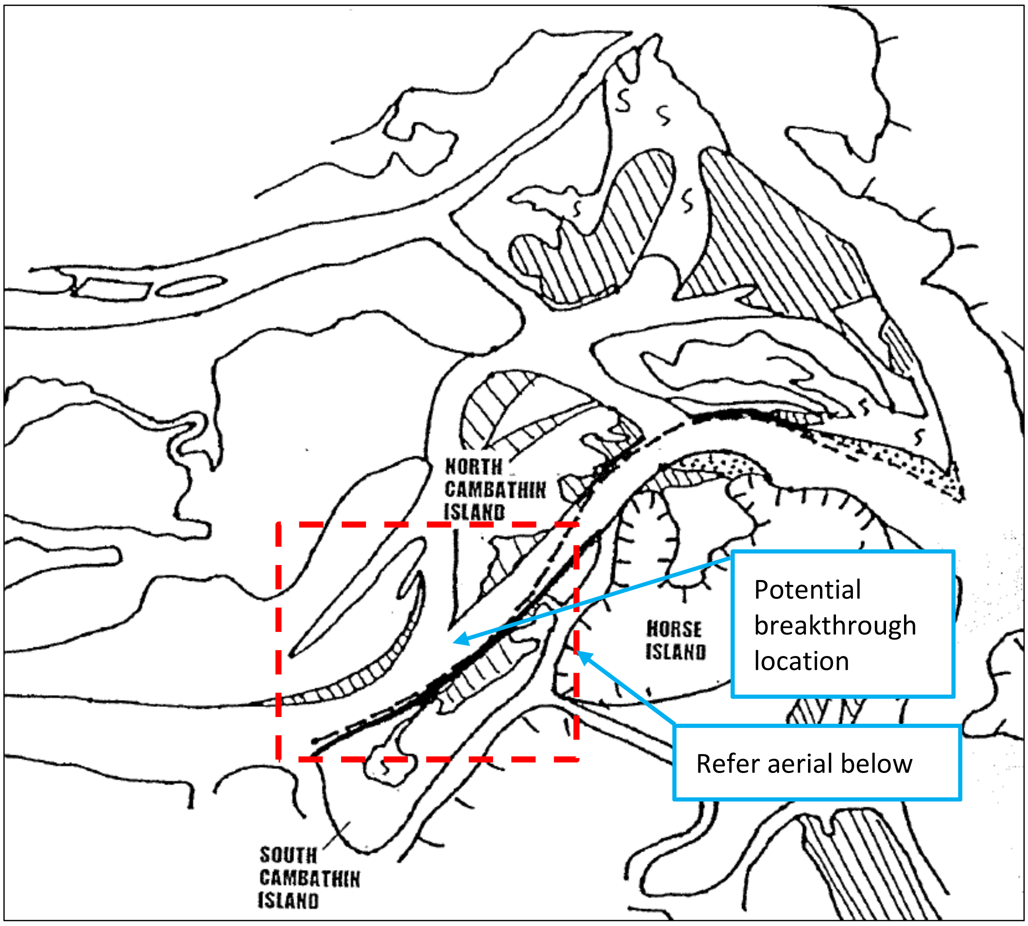

Figure 3.5 Schematic highlighting potential breakthrough at Cambathin Island (Brown and Root 2001)

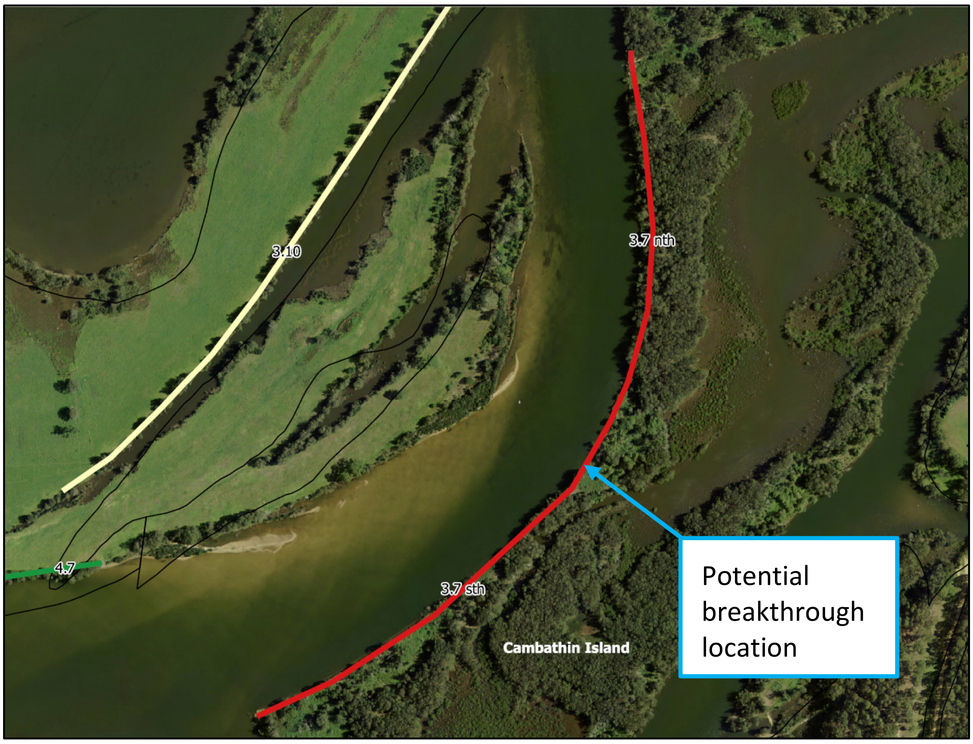

Figure 3.6 Aerial photo of Cambathin Island highlighting potential breakthrough location

Figure 3.7 Bank erosion on north-west side of Cambathin Island

Figure 3.8 Bank erosion on north-west side of Cambathin Island

3.4. Priority sites

Based on the methodology outlined above, sites were prioritised. The ranking for the top 13 sites plus the Cambathin Island site are listed in Table 3.2 and highlighted in Figure 3.9.

Appendix D shows the locations of all mapped sites on the estuary. The top thirteen sites are mapped in detail in Appendix D together with options for management, Appendix D also contains a full list of sites with their ranking.

Table 3.2 Top priority sites based on ranking methodology

Priority project location	Vegetation Condition	Degree of Exposure	Adjacent Land Use	Stock Impact	Total
4.2a	3	3	3	2	11
4.2b	3	3	3	2	11
4.3	3	3	3	2	11
4.20	3	3	2	2	10
5.1	3	2	3	2	10
5.2a	3	2	3	2	10
5.2b	3	2	3	2	10
5.9a	3	2	3	2	10
5.9b	3	2	3	2	10
6.2, 6.3 and 6.4	2	2	3	3	10
7.3	2	2	3	3	10
3.7nth and 3.7sth Cambathin Island	1	3	1	1	6 *

* Cambathin Island is a top priority as the implications of major erosion are high.

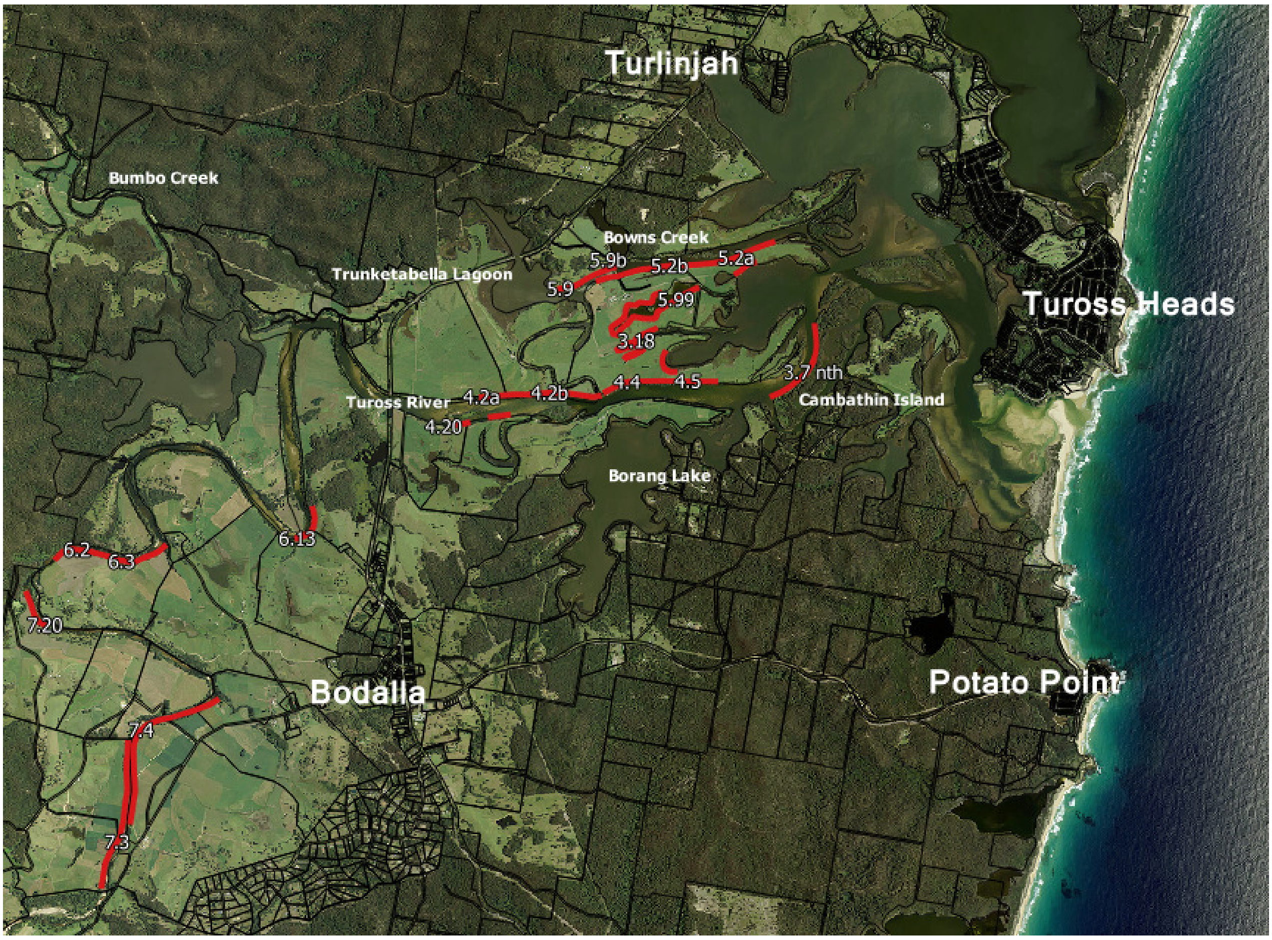

Figure 3.9 Location of top priority sites

4.0 MANAGEMENT MEASURES

4.1. Issues

There are three main water quality issues identified over a range of sites along the estuary, either occurring in isolation, or in combination. These are:

- Sediment and nutrient loads associated with agricultural activities, including cropping with no, or limited buffers before runoff reaches watercourses
- Stock access to the top of bank and/or water's edge with little to no riparian buffer and associated erosion, pollution and nutrient addition effects.
- Steep banks (sub-vertical) with high exposure to main channel flows (i.e. located on outside bend or other areas where flows are greatest directly alongside the bank) and associated erosion / sedimentation and property loss

Table 4.1 outlines possible management options to address these key issues.

Sediment and nutrient loads from various land use management approaches reach the estuary and river in surface runoff, in small and large runoff events, and also through the movement of groundwater and interflow through the soil profile and river and creek banks after a period of overbank flows.

Treatment selection will also depend on safety, funding availability and experience. The applicability, and the pros and cons of potential for bank stabilisation approaches are explained in Section 6.0.

A number of typical details for these management approaches have been provided to assist in the repair and restoration of sites over time, refer to Appendix E. These typical details also include information on their suitability under different conditions and examples of their application.

The intention of providing typical details is not to lock in one solution but rather to provide a suite of tools and information that can be used to identify suitable solutions for potential projects. In some cases further detailed design will be required particularly where major earthworks and/or large material is proposed.

Table 4.1 Water quality issue and management approach

<table>
<tr><th>Water Quality Issue</th><th>Management Approaches</th></tr>
<tr><td>High pollutant loads adjacent to river associated with intensive agriculture and limited buffer between nutrient source and river / estuary.</td><td>Buffer between pollutant source and the estuary.

A vegetated buffer relies on slowing flow and requires sheet flow to provide for effective removal. Groundcover and grasses to intercept flows, along with deep rooted plants to assist with denitrification in saturated zones.

Revegetation of all riparian areas is encouraged and will contribute to management of runoff and associated pollutants. In addition to revegetation of the main river foreshore, plantings along smaller drainage lines and bodies of water that only become connected to the main channel in times of significant rainfall can also be highly advantageous and is encouraged.

Refer to Section 5.0 for more detail.</td></tr>
<tr><td>Stock Access</td><td>Fencing to prevent access with managed access at key and necessary crossing points. Fencing should be planned in conjunction with the land owner, and issues such as fence type and flood impacts need to be resolved.

Plant out where necessary to assist with stabilization.</td></tr>
<tr><td rowspan="4">Bank Erosion (refer to Section 6.0 for more detail)</td><td>Toe protection (i.e. log revetment, root balls, rock).</td></tr>
<tr><td>Piles / groynes to encourage sediment accumulation and associated log revetment as stabilization.</td></tr>
<tr><td>Sand bags and mangroves.</td></tr>
<tr><td>Reshaping of banks and revegetation.</td></tr>
</table>

4.2. Cambathin Island

Cambathin Island is a particular case where immediate water quality issues are not high. However, as discussed, the implications of a breakthrough occurring would have significant water quality impacts for the estuary. A staged management approach is proposed for this particular location.

Stage 1

Revegetate top of bank with deep rooted vegetation behind scarp (Casuarina) particularly where only groundcovers are present.

Undertake field investigation of the embankment to identify potential breakthrough points. Undertake a bank edge survey as a reference to compare future bank movement to allow estimation of erosion rates over time. Where possible compare aerial photogrammetry to determine recent erosion rates against flood events.

Stage 2

Depending on evidence and investigations from Stage 1 design and construct protection to prevent breakthrough; using a groyne field, rock armoured embankment or other. This requires detailed consideration of extents and tie-in with natural bank to prevent outflanking. Priority should be given to protection of bank where narrowest band of island exists and where breakthrough is most likely.

Figure 4.1 Cambathin Island, note clump of casuarinas adjacent to section of failing bank. This may a suitable location to start rock and reduce the risk of outflanking.

5.0 DESIGN OF RIPARIAN BUFFERS FOR WATER QUALITY MANAGEMENT

Vegetated buffers have the ability to remove sediment and nutrients in runoff and groundwater. Buffers remove pollutants by physically slowing water movement and through the assimilation of nutrients through biological and physical processes.

'Guideline D; Using buffers to reduce sediment and nutrient delivery to streams' (Prosser et al, 1999) from the Riparian Land Management Technical Guidelines and *'Managing riparian lands to improve water quality: optimizing nitrate removal via denitrification'* (Hunter et al., 2006) both provide important detail on the key design aspects of correctly designing buffers for sediment and nutrient removal. These references should be used when designing buffer plantings with landholders.

Key design parameters from the above references are listed below for pollutant removal from surface flows and sub-surface flows.

Surface flows

- Identify location sediment and nutrient sources
- Focus on low intensity sources where there is diffuse overland flow of less than 1cm depth.
- Look at all low relief areas and drainage depressions for potential buffer locations in addition to the river bank
- Do not confine, or deflect flow. Avoid tussocks, clumpy vegetation, tree trunks
- Dense spreading grass species are preferred over grass species with tussock or bunch habit
- For areas of slopes greater than 5% increase the buffer width

Sub surface flows (nitrate removal)

- Buffers should be at least 10m wide from the top of bank
- Maintain a mixture of vegetation types with different decay rates to maintain carbon source
- Plant riparian vegetation in areas of low relief and low gradients where groundwater flow will be slow

6.0 STABILISATION TECHNIQUES

Riverbank stabilisation techniques are grouped into several approaches that stabilise the banks directly or indirectly - refer Table 6.1.

Direct stabilisation modifies the bank to mitigate hydraulic forces. **Indirect stabilisation** redirects the flow or modifies sediment transport to reduce the erosive forces acting on a bank or on the river bed.

6.1. General Description

The following provides a general description of commonly used techniques, potential applications and suitability for the Tuross estuary.

Direct stabilisation approaches typically include works to the actual banks and include:

- Revegetation - re-establishing local native vegetation to stabilise bank sediments by generating a network of roots and partially absorbing wave and current forces.
- Bioengineering - using a mix of vegetation, wood and biodegradable products to reduce surface erosion and provide toe protection while revegetation is established.
- Walling - generally rigid or semi-rigid vertical structures installed to provide a physical barrier to reduce the loss of material from the bank.
- Revetment - a structure that provides a protective covering on an embankment designed to maintain slope stability or protect it from erosion.

Indirect stabilisation approaches typically result in flow modification and include:

- Groynes - constructing narrow structures perpendicular to the shore that reduce alongshore sediment transport, capturing sediment on the updrift side of the structure.
- Baffles or large woody debris – placing baffles or large woody debris on the bed or lower bank to deflect or dissipate erosive currents and encourage sediment accumulation.

Note that a number of these techniques can be combined. For instance revegetation combines well with most approaches. Revegetation and bioengineering approaches in particular are compatible and can lead to sound environmental outcomes.

Table 6.1: Possible techniques for bank stabilisation - Tuross River estuary

Direct Approaches	**Techniques**
Revegetation	Sedges/reeds/mangroves
	Trees and shrubs
	Ground covers
Bioengineering (with revegetation)	Coir logs
	Jute matting
	Brushing/bundling
	Brush matting
Walling	Baffles
	Fixed hardwood logs
	Sand bag walls
Revetments	Rock toe (with bank reshaping)
	Sand bag
	Geotextile
	Tipped Rock
Indirect Approaches	**Techniques**
Flow modification	Single short groynes
	Short groyne field
	Flow baffles
	Large woody debris (including root balls)

(Ref: Swan River Trust December 2009)

6.2. Applicability of Techniques

6.2.1. Revegetation

This is commonly used to protect low banks and to improve riparian habitat by shading the waterway. Revegetation requires a 3 to 5 year lead time for plant root systems to establish sufficiently to protect riverbanks. This may require planning for bank loss in the intervening period, or use in combination with other 'soft' techniques.

Revegetation would normally be accompanied by fencing off the bank if stock access was an issue. Weed management particularly kikuyu can be an issue in the intervening period before plantings establish and will need to be ongoing.

The riparian vegetation communities considered for revegetation works along the Tuross River should include River flat eucalypt forest, Swamp oak floodplain forest and Bangalay sand forest.

Figure 6.1 Large Bangalays in the lower reaches of the Tuross Estuary

Additionally, endemic littoral and aquatic species locally native to Tuross River should be used where possible. The following is a list of species that would have occurred along the river and many of the minor watercourses within the catchment and can be used as a guide for revegetation projects.

Important.
Where the objective of buffers is for pollutant removal it is important to cross reference plant characteristics with the desired plant attributes for pollutant removal in buffers. For example, for sloping of shallow surface flows grasses with a spreading, rather than clumping habit should be selected, and plants that deflect flows should be avoided. In the case of nitrate removal through denitrification, a mixture of grasses, shrubs and deep rooted species is important to provide a carbon source and intercept groundwater. Refer to Section 5.0.

Table 6.2: Revegetation - Bank Plantings

Botanical name	Common name
BANK PLANTINGS (above high tide mark)	
Groundcovers	
Carex appressa	Tall Sedge
Dianella caerulea	Blue Flax Lily
Ficinia nodosa	Knobby Club-rush
Gahnia species	Saw Sedge
Isolepis inundata	Swamp Club-sedge
Juncus kraussii	Sea Rush
Lomandra longifolia	Spiny-headed Mat-rush
Phragmites australis	Common Reed
Rhagodia candolleana	Sea Berry Saltbush
Schoenus melanostachys	Black Bog-rush
Trees/Shrubs	
Melaleuca ericifolia	Swamp Paperbark
Myoporum acuminatum	Boobialla
Casuarina glauca	Swamp Oak

Table 6.3: Revegetation - Floodplain Plantings

Botanical name	Common name
FLOODPLAIN	
Groundcovers	
Carex appressa	Tall Sedge
Carex longebrachiata	A Sedge
Dianella caerulea	Blue Flax Lily
Lomandra longifolia	Spiny-headed Mat-rush
Trees/Shrubs	
Acacia floribunda	White Sally Wattle
Acacia irrorata	Green Wattle
Acacia longifolia subsp. sophorae	Coastal Wattle
Acacia mearnsii	Black Wattle
Angophora floribunda	Rough-barked Apple
Casuarina glauca	Swamp Oak
Eucalyptus botryoides	Bangalay
Eucalyptus tereticornis	Forest Red Gum

6.2.2. Bioengineering

The term bioengineering in relation to bank protection and erosion control refers broadly to the application of natural solutions using engineering principle. A number of manufactured products are available that are based on natural materials.

The Coir Log is a roll of organic coir fibre enclosed in a robust coir mesh. Coir Logs provide erosion and wave control structures in riparian zones, and sediment capture in drainage lines and swales. Coir Logs provide protection while vegetation establishes and takes over the long-term stabilisation. These are particularly useful where machinery access is limited as they can be carried and placed by hand.

Figure 6.2 Example of coir log installation (http://www.hrwc.org/2010/05/building-a-natural-alternative-to-breakwalls/)

Jute or coir matting acts as a mulch, providing weed suppression and moisture retention to enhance plant establishment, while protecting the topsoil from erosion. Check that the product is 100% organic and will biodegrade over time. Installation techniques should consider the dominant direction of flow and possibility of flooding. Coir logs are better suited to low energy environments such as the backwaters of the estuary.

6.2.3. Walling

Walling to protect a bank from impact can take the form of sandbags or log structures. These would protect the toe of an embankment where bank slumping was an issue.

Figure 6.3 Example of a log structure at Snake Flat

6.2.4. Revetments

Revetments protect the face of an embankment by placement of a physical barrier. This can be placed rock over geotextile, or sandbags although these techniques are unlikely to be appropriate for the Tuross due to the scale of erosion and subsequent cost of works.

Figure 6.4 Example of a rock revetment in the main channel of the Tuross River

Reshaping a vertical bank can be appropriate to decrease an unstable steep batter slope. This helps to makes a bank more stable but then requires protection by geotextile matting or coir matting combined with mass plantings. Often this is combined with tipped rock or logs at the toe to prevent undercutting of the bank.

6.2.5. Groynes

Groynes provide indirect protection to eroding banks by diverting flow and encouraging sediment deposition. They should be engineered for a particular site to determine the most appropriate spacing along the bank. Groynes can be rock or logs depending on the water depth.

Figure 6.5 Example of timber groynes in the Murrah River

Groynes are difficult to apply where deep water is close to the bank and/or where boating and navigation issues are present.

6.2.6. Baffles or large woody debris

Baffles or large woody debris aim to baffle or deflect flow such that a bank is not subject to the full brunt of erosive velocities.

Flow deflectors can be installed where there is a shallow tidal beach in front of an eroding bank. Logs or sandbags can be installed roughly parallel to the flow direction. These can be combined with groynes to collect sediment. This method is more difficult in deep water and may not be suited to the typical erosion found on the Tuross.

Figure 6.6 Example of a woody debris in the Tuross to protect an exposed section of bank

Root balls are effectively a permeable form of walling or toe protection that modify the flow pattern by causing eddies at the bank. They can be a relatively cheap bank treatment to stabilise the toe of an eroding embankment provided the root ball material can be sourced and excavator access to the top of bank area is available.

The use of large woody debris is a useful technique that improves habitat by emulating natural snags in the river. There is a general shortage of suitable material on the river banks, such that this is an unlikely option unless material can be effectively imported and placed. If navigation is an issue nearby, this technique would not be appropriate.

6.3. Suitability of Techniques

In general the 'softer' techniques are preferred to 'harder' engineered bank structures. Softer methods blend with the rural landscape and maintain the ambience of this estuarine setting.

The techniques selected for sites on the Tuross estuary consider a range of factors.

6.3.1. Hydraulic Processes

Daily tidal currents dominate much of the mid Tuross estuary. The ebb and flow of the tide requires two directional flow to be considered. Tidal flow can be diverted by features such as the islands downstream of the highway bridge. Here the ebb flow direction is causing bank erosion.

In the riverine estuary reaches where tidal flows are weaker, river flow (including freshes and flood events) are dominant processes. Bank overtopping by floods requires consideration when selecting a bank treatment in the whole estuary.

6.3.2. Habitat Improvement

Works should aim to preserve or enhance habitat of riverbanks and the estuary shoreline. Well designed bank stabilisation can provide habitat for crabs and fish etc.

6.3.3. Scale and Extent of Erosion

Erosion may be isolated to a small section of foreshore (e.g. a stormwater or tributary outlet), constrained by control features such as existing vegetation or bank and channel alignments, or it may extend along a long straight river reach.

Both ends of a bank treatment can be vulnerable to bypassing or undercutting unless tied into a stable feature. It is important to access the potential impacts of a proposed treatment on the adjacent areas to ensure the problem is not transferred immediately upstream or downstream.

6.3.4. Bank Profile and Material

Bank height can vary from 3 - 4 metres of vertical or near-vertical sandy bank to very flatly graded low banks in silty material. These flatter low areas can contain fringing saltmarsh vegetation which prevents access by items of plant such as excavators.

6.3.5. Space Restrictions

These include a limited land area available for works, limited shore-based access, and / or a water based restriction such as deep water at the toe. Some techniques are noted as unsuitable if boat navigation is an issue, where the navigation channel passes close to an erosion site.

6.3.6. Life Cycle Costs

The design life may need to be extended in locations where access is difficult or opportunity for future maintenance is limited.

6.3.7. Availability of Materials

Root balls may not be available at the time of a project inception. Council could consider encouraging a storage facility in its landfills where root balls from approved land clearing could be tipped free of charge. This would develop a stockpile and save burning of the root balls which are a valuable resource.

Large woody debris similarly is generally unavailable on the estuary banks and is not practical to be stockpiled.

7.0 CONSULTATION

7.1. Consultation workshop

A community workshop was held at Kyla Park Hall, Tuross Head on the evening of 2 November 2015. This was attended by landowners, Council, State Agency staff including OEH and LLS and invited members of the public.

A presentation introduced the project background and described the methodology for prioritising sites. Discussion followed on how to develop projects, the impediments for landowners and some concerns about cost and time implications.

7.2. Outcomes

The types of works proposed in the presentation (primarily fencing and revegetation works along the River and estuary) was generally acknowledged to be a sensible approach however there were concerns including:

- "Too much red tape and process" therefore landowners may be reluctant to engage
- Can be more practical for them to do works themselves;
- Landowners not knowing who to approach in their local area;
- Existing bank vegetation threatening public infrastructure
- Large volumes of bank material at risk if leaning trees fall into the river
- Who has ultimate responsibility for the river?
- Flooding destroying new fencing used for revegetation
- Revegetation not surviving and being a waste of effort without proper maintenance
- Weeds smothering new revegetation if not maintained
- Grant funding requiring significant contributions from landowners
- Boat wash and water skiing being a significant cause of erosion

7.3. Recommendations

One of the key messages to come out of the meeting was that communication and ongoing dialogue between Council and landowners is critical to creating lasting partnerships and developing sound projects.

LLS are actively engaging with landowners where current funding is available. However there is potential for further liaison between Council, LLS and landowners on the Tuross estuary.

Council may consider facilitating this communication to expand relationships and knowledge for all parties.

It was noted that there have been successful projects in the Tuross (past Landcare projects, Snake Flat etc.). It is strongly recommended that both existing and future projects be promoted to encourage more activity and awareness throughout the catchment.

8.0 PRIORITIES, COSTS AND PLANNING

8.1. Project planning and landowners

Almost all of the water quality works sites are located wholly or partially on private land. Collaboration between land owners, LLS and Council is required to both get projects developed and to obtain funding.

The water quality works outlined here are very unlikely to be undertaken solely by land owners. Projects are most likely to be undertaken with funding and collaboration either with Council or LLS and administered grant schemes.

Identification of land owners and key contacts that have water quality management priorities on their land is a ***critical*** first step to initiating these projects. Once connection is made, discussions and negotiations around what form a project could take can then commence.

8.2. Cost estimates and accuracy

Unit rates used for cost estimates are summarised in Table 8.1. Cost estimates for the high priority sites are listed overleaf in Table 8.2.

The costs to undertake the projects identified are dependent on a range of factors. In particular, the location of most potential project sites is on private land and requires negotiation with land owners. Also an agreement on contributions is necessary, both in terms of land as well as materials and labour in kind. The cost estimates outlined below need to be treated in this context.

Cost estimates have been split into total costs and a reduced cost to allow for contributions in kind. In reality, the ultimate costs would be lower than the cost totals outlined here when landowner contributions in kind are factored in. Regardless, the cost estimates provide an indication of the relative cost between each site.

Cost estimates are based on existing knowledge, Council's experience and rates. Where possible the experience from recent projects of a similar nature by state agencies such as LLS has been used.

For detail regarding the assumptions used for cost estimates refer to Appendix F.

Table 8.1 Rates summary for cost estimates.

ITEM	DESCRIPTION	UNIT	RATE
1	Site establishment	LS	**8% of total costs**
2	Revegetation (supply and install)	m^2	**$ 26.21**
3	Revegetation (maintenance for 5yrs)	m^2	**$ 15.00**
4	Fencing (supply and install)	m	**$ 20.00**
5	Fencing (maintenance)	m	**$ 1.00**
6	Coir	m	**$ 48.00**
7	Large woody debris	m	**$ 137.20**
8	fixed logs	m	**$ 196.70**
9	Rock toe	m	**$ 1,427.60**
10	Timber piles	#	**$ 600.00**
11	Project management	LS	**10% of total costs**

Table 8.2 Priority project cost estimates

Site	Assumptions	Total cost estimate *	Contribution in kind**	Grant funding
4.2a	Revegetation and fencing along the full length.	$270,259	$ 139,720	$ 130,539
4.3	Revegetation and fencing along the full length.	$104,511	$ 54,183	$ 50,328
4.2b	Revegetation and fencing along the full length. 100m of large woody debris as bank stabilisation.	$322,374	$ 159,091	$ 163,284
4.20	Revegetation and fencing along the full length. 20m of coir log bank stabilisation	$ 73,429	$ 37,865	$ 35,564
5.1	Revegetation and fencing along the full length.	$230,288	$ 119,279	$ 111,008
5.2a	Revegetation and fencing along the full length.	$341,192	$ 177,043	$ 164,149
5.2b	Revegetation and fencing along the full length.	$311,737	$ 161,696	$ 150,041
5.9a	Revegetation and fencing along the full length.	$349,642	$ 181,498	$ 168,144
5.9b	Allowance of $15000 for drainage management 50m of fencing	$ 19,934	$ 917	$ 19,017

Site	Assumptions	Total cost estimate *	Contribution in kind**	Grant funding
6.2, 6.3 and 6.4	Allowance of $5000 for assessment of landscape and flow paths. 120m of revegetation as a riparian buffer. 500m of fencing	$ 80,670	$ 34,588	$ 46,082
7.3	Allowance of $5000 for assessment of landscape and flow paths. 150m of revegetation as a riparian buffer. 500m of fencing	$ 96,025	$ 42,901	$ 53,124
Cambathin Island - Revegetation, Investigation and Monitoring	400m of revegetation. Site investigation & survey $4000 Photogrammetry comparison allowance $3000	$111,060	$ 55,797	$ 55,263
Cambathin Island - Toe Protection Works	Detailed Design 100m of rock toe protection works Barge establishment & disestablishment & hire Crane hire	$363,608	$ 15,809	$ 347,799

* Total costs include a project management and contingency component. All revegetation projects include maintenance costs over 5years.

** Potential contributions in kind can include time, materials, plants, labour etc. Estimates based on:

- 40% of revegetation supply and install costs in kind
- 100% of revegetation maintenance costs in kind
- 100% fencing maintenance costs in kind
- 40% of coir supply and installation costs in kind
- 50% of project management costs in kind

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