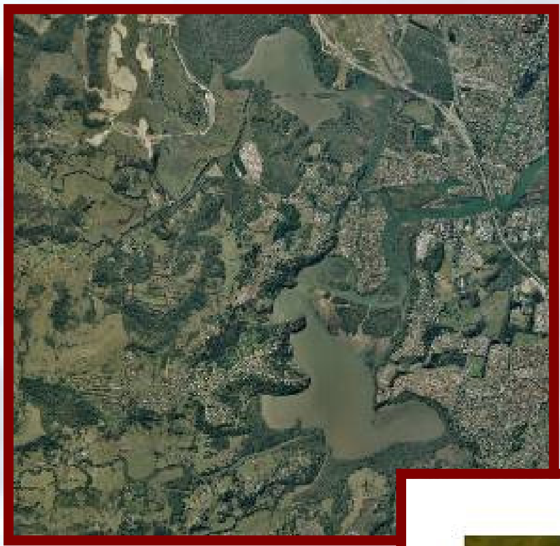
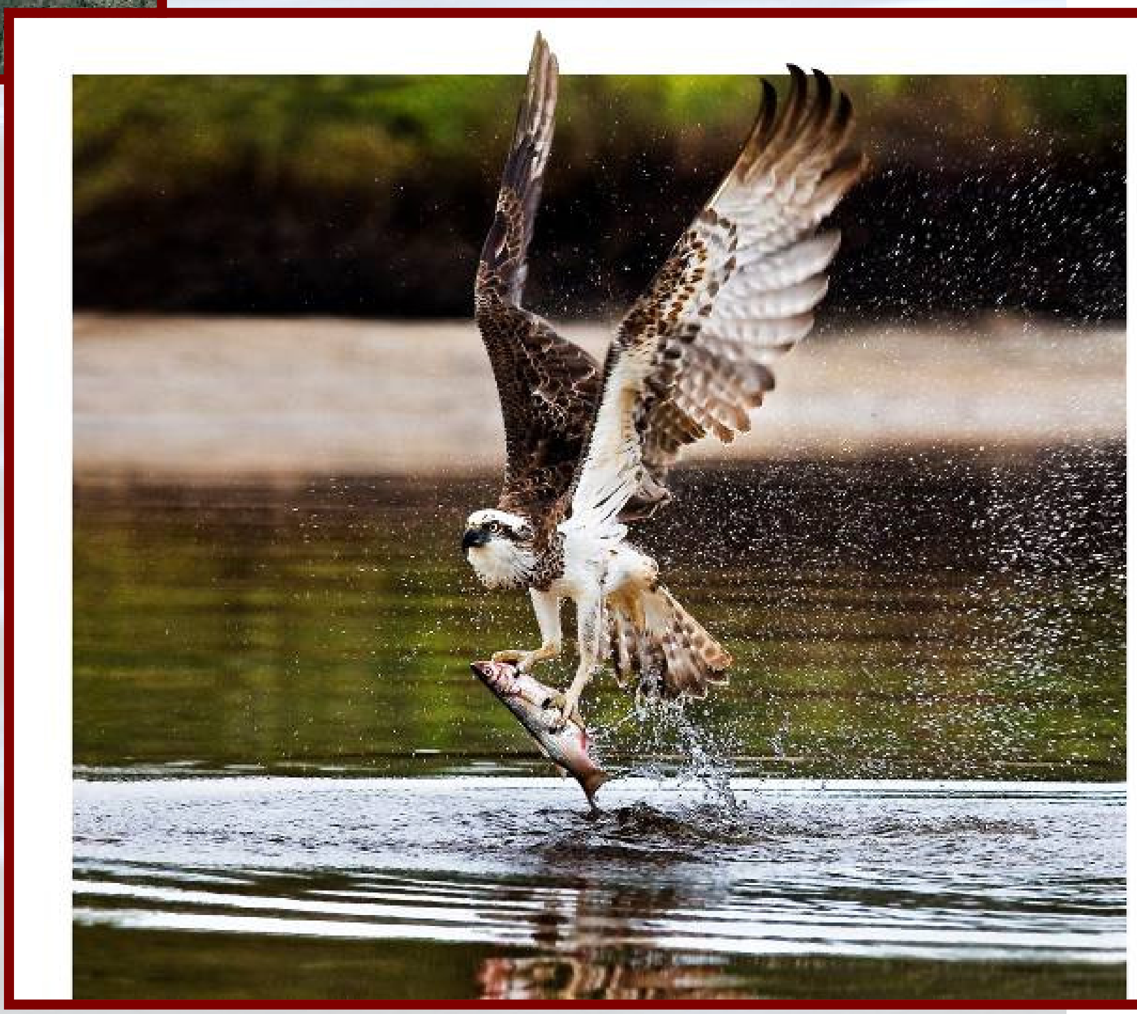
COASTAL ZONE MANAGEMENT PLAN FOR COBAKI BROADWATER AND TERRANORA BROADWATER





Australian Wetlands

Prepared for:
TWEED SHIRE COUNCIL

JUNE 2012
Ref: BB071d

TWEED SHIRE COUNCIL

Project Identification

Project Name: Coastal Zone Management Plan for Cobaki Broadwater and Terranora Broadwater

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Photo on cover page: The Osprey; high order food chain predator and threatened species (John van den Broeke).

Executive Summary

Introduction

Australian Wetlands and ABER have been commissioned to prepare a Coastal Zone Management plan (CZMP) for the Cobaki and Terranora Broadwaters.

Existing estuary management plans for the Cobaki and Terranora Broadwaters, implemented over the past decade, are in need of revision to incorporate new scientific knowledge, changes to the physical environment and recent legislative and policy changes. A revision of the management plans is also timely given the proposed large scale urban development planned for the catchment. The Plans have been updated in accordance with the NSW Coastal Policy 1997, consistent with all other relevant environmental planning instruments, and aim to provide strategies that will contribute to meeting relevant targets in the Northern Rivers Catchment Action Plan.

An integrated approach to the management of the two broadwaters and their catchments was proposed in recognition of the fact that there is hydrological connectivity between the two systems, and that they share similar physical characteristics and are affected by the same degrading impacts. This approach is consistent with the first principle for managing coastal lakes i.e. that each coastal lake and its catchment is to be managed as a whole system (NSW Coastal Lakes Strategy, 2002).

The objective of the project is to develop a management plan that addresses the unique characteristics and interrelationships of ecosystems and human activities for Cobaki and Terranora Broadwaters, taking into account the degree of existing modification and future impacts.

The aim of this CZMP is to provide a scheduled sequence of recommended activities that need to be undertaken to achieve the estuary management objectives. The objectives of the CZMP for Cobaki Broadwater and Terranora Broadwater are:

- To improve water quality and ecosystem health by revegetation/regeneration of riparian vegetation, prioritising the mid – transition zones of all creeks and their ephemeral drainage lines.
- To improve rural stormwater discharge quality and ecosystem health by facilitating and supporting best practice land management and functional On-site Sewage System Facilities (OSSF).
- To improve urban stormwater discharge quality by implementing a Stormwater Quality Improvement Device (SQID) retrofitting strategy in existing priority areas, and ensuring future development does not contribute further to the existing pollutant loads.
- To restore riparian habitat to enhance connectivity of wildlife corridors.
- To protect and enhance shorebird habitat and provide additional high tide roosting sites.
- To increase and enhance public access to foreshores and low-impact recreation activities.
- To protect viable commercial fishery industries by preserving and improving fish habitat, including marine vegetation such as seagrass and saltmarsh and improving fish passage.

- To stabilise degraded creek bed and banks, to restore their natural values, improve downstream instream health, and reduce the infilling of the broadwaters.
- To increase community awareness and protection of areas important to Aboriginal cultural heritage.

Catchment Values

The Cobaki and Terranora Broadwaters lie in Tweed Shire, in the far north eastern corner of New South Wales, adjacent to the Queensland border. A small part of the Cobaki Broadwater catchment crosses the Queensland border. These estuarine systems fall within the NSW North Coast bioregion, recognised as one of Australia's most diverse in terms of natural terrain, flora and fauna.

There are two broadwater systems that are fed, in total, by four main tributaries and six sub-catchments. Both broadwaters are influenced by tidal flows from the Tweed River Estuary and freshwater inputs from the western sub-catchments. The Terranora and Cobaki Broadwaters are shallow estuarine lakes that discharge into Terranora Creek. The Broadwaters are shallow, approximately 0.5 – 1.5m depth and act as the receiving waters for the freshwater catchment. Cobaki Broadwater receives freshwater discharge from Cobaki and Piggabeen Creeks and Terranora Broadwater receives freshwater from Bilambil and Duroby Creeks.

Ecological Values

Vegetation Communities
All vegetation remnants surrounding Cobaki and Terranora Broadwaters are of High Conservation Value (HCV) and are classed as 'Very High' ecological status and 'High' ecological sensitivity in the Tweed Vegetation Management Strategy (Ecograph, 2004). The riparian vegetation of both broadwater foreshores is in generally good condition (IWC, 2009). These remnants are extremely valuable habitat and are included in the Regional Corridor as a key habitat linkage (Ecograph, 2004). There are multiple land managers of the Cobaki foreshore remnants who have agreed to a Memorandum of Understanding (MoU) regarding the management of these lands. Council manages most of the foreshore remnants of Terranora Broadwater.

The riparian vegetation of the rural subcatchments has been largely cleared of native vegetation, particularly throughout the transition and mid zones. The upper reaches of the Cobaki Broadwater catchment is primarily Early Regrowth Rainforest, however the upper reaches of the Terranora Broadwater catchment (Bilambil Creek) is well-forested with Rainforest, Brush Box, Tallowwood and Grey Ironbark/White Mahogany/ Grey Gum Forest Complex. The remaining remnants form the Regional Corridor, providing Key Habitat Linkages.

Habitat
The two broadwaters and their catchments incorporate a number of terrestrial and aquatic habitats under both private and public ownership. Both catchments contain habitat for a number of rare or threatened flora and fauna species and provide an, albeit

fragmented, corridor connecting lowland coastal ecosystems with the Terranora Hills in the hinterland.

Some of the habitats important to the survival of local flora and fauna communities, and the health of the broadwaters include:

- Shallow-water vegetated habitats, notably saltmarsh, mangrove communities (identified as SEPP 14 wetlands) and seagrass communities
- Freshwater wetlands
- Rainforests
- Riparian corridor
- In-stream habitat

The protection and improvement of catchment habitat is vital to ensure a healthy, functioning ecosystem.

Shorebirds

Shorebirds are an important component of estuarine systems, representing higher order consumers of intertidal invertebrates. The Tweed Estuary is one of the five most important sites in NSW for estuarine birds. The broadwaters are not used by an isolated population of shorebirds and individuals need to be able to move regularly between the main river channel and the broadwaters to roost and forage. Shorebirds utilising the habitat of the broadwaters are both local internationally significant migratory species.

There has been a significant decline in the migratory shorebird population during 1997 – 2003, with evidence that the decline is continuing. One of the likely reasons for the decline is the decreasing availability of roosting sites in close proximity to the broadwaters. Management of shorebird roosting and foraging habitat in the broadwaters is critical to ensure that the Tweed River Estuary shorebird population remains viable.

Cultural Heritage Values

The region has a rich and continuing Aboriginal heritage. Historic records demonstrate a history of regular large gatherings of traditional Aboriginal people along the Tugun sand plain, Lower Tweed Estuary, and adjacent broadwater shorelines. The significant number of remaining middens and campsites within the area support the historic record (Fox, 2006). Site types include: open campsites, isolated artefacts, occupational deposits in rock shelters and caves, middens, quarries, grinding grooves, scarred trees, fish traps, burial sites, rock art, ceremonial sites, and natural sacred sites.

There are extensive areas of the creeks' catchments with a high probability for containing sites of cultural significance. Areas of cultural significance which contain registered sites are primarily along the foreshores of the broadwaters and include:

- The eastern and north-eastern foreshore of Terranora Broadwater;
- The southern bank of Terranora Creek;
- Areas near the confluence of Cobaki Creek and Terranora Creek;
- The area to the east of the Cobaki Broadwater in the vicinity of the alignment of the Tugun Bypass.

Socio-economic Values

Recreation

The foreshores of the Terranora and Cobaki Broadwaters are mapped as being of high, or the highest scenic quality (Tweed Vegetation Management Strategy, 2004) and are important recreation areas for locals and tourists. Existing recreation facilities include: boat ramps, jetties / public wharves, boat mooring areas, parks and public reserves, estuarine swimming areas, exercise trails, walking tracks / boardwalks, cycle paths.

Popular boating activities in the Tweed Estuary include: cruising/pleasure boating, water skiing, rowing, canoeing, sailing and kayaking (NSW Maritime, 2006, Boating plan). The Lower Tweed is used by large numbers of recreational fishers and has the reputation of being an excellent fishing area. The Cobaki and Terranora Broadwaters are a significant component of the Tweed system and directly contribute to the recreational catch from the Tweed (FRC, 2001 Tugun Bypass EIS - Technical Paper 12)).

There are existing paths and cycleways adjacent to the study area waterways that are promoted by Council as part of the Tweed Cycleways network. The network is a combination of off road and on road cycleways, footpaths and boardwalks.

Commercial

The Tweed River Estuary comprises one of the most productive estuaries for finfish and crustaceans in northern NSW (FRC, 2001). The estuary supports an extensive commercial fishery. The Terranora Creek system hosts a number of fish species of commercial and recreational importance (GHD, 2005).

There are currently four active oyster farms, all operating in Bingham Bay in Terranora Broadwater. There have been short term closures of the oyster industry in Terranora Broadwater due to concerns about sewage discharge in the past.

Tourism

Tourism is important value of the Broadwaters, with two commercial operators currently operating cruises for an estimated 15,000 tourists each year, the majority being international visitors. Cruises focus on recreational fishing, bird feeding and general nature appreciation/sight seeing, providing visitors with local historical information as well as educational information relating to the native local flora and fauna. These cruises are valued due to the serenity and natural beauty of the Broadwaters, the lack of houses in many areas of the Broadwater and the opportunity to catch crabs.

Catchment Investigations

Ecosystem Health Monitoring Program

Tweed Shire Council commissioned the International Water Centre (IWC) to coordinate an Ecosystem Health Monitoring Program (EHMP) to investigate the health of the Cobaki and Terranora Broadwater and their catchments. The program involved an assessment of the freshwater creeks, broadwaters and Terranora Creek in November 2007 – November 2008. The assessment of ecosystem health included the following indicators: physicochemical, nutrient cycling, chlorophyll a, processed nitrogen tracking, seagrass depth range, ecosystem processes, aquatic macroinvertebrates, fish and riparian habitat assessment.

The ecosystem health of each creek and broadwater was provided in a scorecard format. A summary of the findings and key ecosystem health issues for each sub catchment are provided in Table 0.1.

Riparian Zone – Vegetation and Geomorphology

The updated Management Plan includes catchment rehabilitation strategies that are intended to, in part, offset the impacts of increasing point source discharges from the upgraded Banora Point Wastewater Treatment Plant into Terranora Creek. The Management Plan identifies how and where urban and rural catchment rehabilitation should be undertaken to mitigate catchment impacts on the two broadwater systems with the aim of ensuring the assimilative capacity and water quality objectives of the receiving broadwaters are not exceeded. Clear recommendations on buffer distances to protect streams and riparian zones from the impacts of existing agricultural land use or proposed development have been included in the plan.

The recommended minimum buffer distance to any waterway or wetland vegetation in the catchment is 10m. This will provide for filtering of runoff, increased bank stability and improved water quality. On agricultural land, increasing riparian buffers to a width of 30m will provide for effective filtering of runoff and accommodate bed and bank morphological change, as well as provide value as a wildlife habitat and corridors. It is recognised that buffers of this width will not be practical in all cases, and that buffers will generally not be a uniform width along a stream reach.

In areas where development is proposed, anywhere adjacent to the broadwater foreshores, Terranora Creek or Bilambil, Durroby, Cobaki and Piggabeen Creeks, a minimum 50m buffer is recommended. The recommended buffer distance to rural lnduse in non-tidal sections of Bilambil, Durroby, Cobaki and Piggabeen Creeks is 30m. Generally, buffers should be fully revegetated with appropriate local native riparian species.

A riparian and geomorphic assessment of the four main creeks (Piggabeen Creek, Cobaki Creek, Bilambil Creek and Duroby Creek) was undertaken to assist with the identification of priority rehabilitation areas throughout the catchment that are both highly likely to be pollutant sources and suitable for rehabilitation. The assessment of creek bank structural stability and vegetation was undertaken in two stages to assist selection and prioritisation of suitable rehabilitation sites. The aim of the assessment was to select sites, which once rehabilitated, will provide the greatest enhancement to the sustainability of the broadwaters. These sites form the rehabilitation priority areas in the Management Plan.

Table 0.1. Summary of ecosystem health of Cobaki and Terranora Broadwater and catchment

Source: EHMP (IWC, 2009)

Water Body	EHMP Score	Ecosystem Health Summary	Key Ecosystem Health Issues
Piggabeen Creek	C- (Fair)	Ecological health is compromised by high levels of nutrients and the loss of streamside vegetation. There is evidence of a breakdown of nutrient cycling processes.	• There is a significant source of nitrogen likely from on-site wastewater treatment systems and/or manure from livestock within the catchment. • Clearing of riparian vegetation and proliferation of weeds can significantly alter ecosystem processes. • High silt loads – often contributed to by livestock. • Large number of fish passage barriers.
Cobaki Creek	C- (Fair)		
Bilambil Creek	C- (Fair)		
Duroby Creek	D (Poor)	Duroby Creek has the poorest health condition of all four freshwater creeks due to elevated levels of nutrients and low biological indicator scores.	• Low dissolved oxygen • Poor aquatic macroinvertebrate and fish populations.
Terranora Broadwater	D+ (Poor)	The water quality in the broadwater deteriorates during the wetter months due to sediment and nutrient inputs from the catchment. Water quality improves with distance away from the two creeks. The riparian vegetation is in good to very good condition.	The particulate load (with associated organic and nutrient load) during rainfall events is likely to be the main driver affecting water quality in the estuary.
Cobaki Broadwater	C (Fair)	The water quality in the broadwater deteriorates during the wetter months due to sediment and nutrient inputs from the catchment. The riparian vegetation is in good to very good condition.	
Terranora Creek	C+ (Fair)	Water quality is influenced by the two broadwaters and tends to improve with distance towards the Tweed River mouth. Wastewater discharges into the creek don't appear to have influenced the results of monthly water quality monitoring. However the presence of sewage related nitrogen has been mapped and occurs along the entire length of the creek. The riparian vegetation has been assessed as fair to good condition.	
Tweed River Mouth	B- (Good)	Water quality is good to excellent due to the high level of ocean exchange. This riparian condition is poor due to development along much of the river banks.	This area is beyond the extent of the catchment.

Key Findings

The common goal for all stakeholders and managers is to ensure a healthy, functional ecosystem that maintains the capacity to assimilate pollutants so that its values can be enjoyed into the future. The broadwaters' shallow conditions and reduced flushing mean they act like a retention pond to the surrounding rural and urban catchment, and by nature absorb the stormwater runoff impact by assimilating catchment-derived pollutants. The question is: how much longer can the broadwaters assimilate these pollutants and support ecosystem health?

The quality of material delivered to the broadwaters can impact upon the internal recycling and assimilative ability of the system. Once the assimilative capacity is exceeded, internal recycling will be inefficient (as suggested by nutrient cycling data from the EHMP study (IWC, 2009), impacting upon the foodchain including macrofauna such as the local bird populations.

Examples of conditions/scenarios that promote the delivery of poor quality material to the broadwater system include:

- Areas of the catchment that have been cleared (in particular the riparian zone)
- Tweed Shire Council's Banora Point Wastewater Treatment plant discharge
- Bank erosion
- Stock accessing waterways
- Instances of construction erosion and sediment control failure
- Insufficient treatment of urban stormwater.

The aim of recent investigations was to understand the current condition of ecosystem health and run an assimilative model to determine whether the Broadwaters can continue to act as a sink for nutrients under existing and future anticipated loadings, or if the assimilative capacity is likely to be exceeded.

Current Scenario

The current condition of ecosystem health has been described as Fair – Poor (IWC, 2009), with data suggesting the streams are moderately to highly stressed and the system is on the threshold of major impacts. Chlorophyll *a* targets are already being exceeded on occasion. If no action is taken, there are likely to be detrimental impacts on the ecology of the broadwaters such as compromised health and loss of seagrass, and subsequent impacts on aquatic fauna and higher order fauna including bird populations (Figure 0.1).

The health of the system is currently impacted by:

- Recycling of nutrients from sediments and nutrients from STP effluent tidally moving upstream to the broadwaters
- Urban stormwater, particularly from the Western Drainage Scheme
- Rural catchment runoff.

Significant work needs to be undertaken if the current health of the system is to be improved. The pollutant of greatest concern to ecosystem health is dissolved inorganic nitrogen (DIN) loading as it is the primary driver of phytoplankton biomass (chlorophyll-*a*, an indicator of algal blooms). To keep the chlorophyll-a concentration low enough to ensure a healthy functioning ecosystem, it is necessary to reduce total catchment DIN loads by approximately 30% in both the Terranora and Cobaki Broadwater catchments.

Future Scenario

The relatively large scale of all proposed developments and their proximity to the most poorly flushed reaches of the system combine to pose a major threat to the ecological sustainability of the Cobaki - Terranora Broadwater system. Given the existing stress caused by urban and agricultural runoff and sewage discharge and the extreme sensitivity of both broadwaters to increases in DIN loading, it is vital that future urban development strives to minimise DIN loads to the system.

The impact of development is likely to be heightened due to proximity to the broadwaters and the relatively long residence times of freshwater runoff. The shallowness of Cobaki Broadwater means light penetration will not limit phytoplankton production, thus enhancing the likelihood of rapid development of large algal blooms which are likely to have a major impact on the ecology of the system (Figure 0.1).

Impending large scale development increases the urgency to implement measures now that will reduce current DIN concentrations. Rural catchment rehabilitation alone, while important, is not sufficient to offset the impacts of the large scale development planned. The implementation of best practice site-specific Water Sensitive Urban Design is of paramount importance to maintaining at least the current status of the broadwaters.

Future sustainability of the broadwaters will depend largely on community and government commitment to the immediate implementation of priority CZMP recommendations. A collaborative effort is required now to improve urban stormwater quality + rehabilitate the rural riparian zone + minimise as far as possible any impact from development, to maintain a healthy, functional ecosystem for future generations.

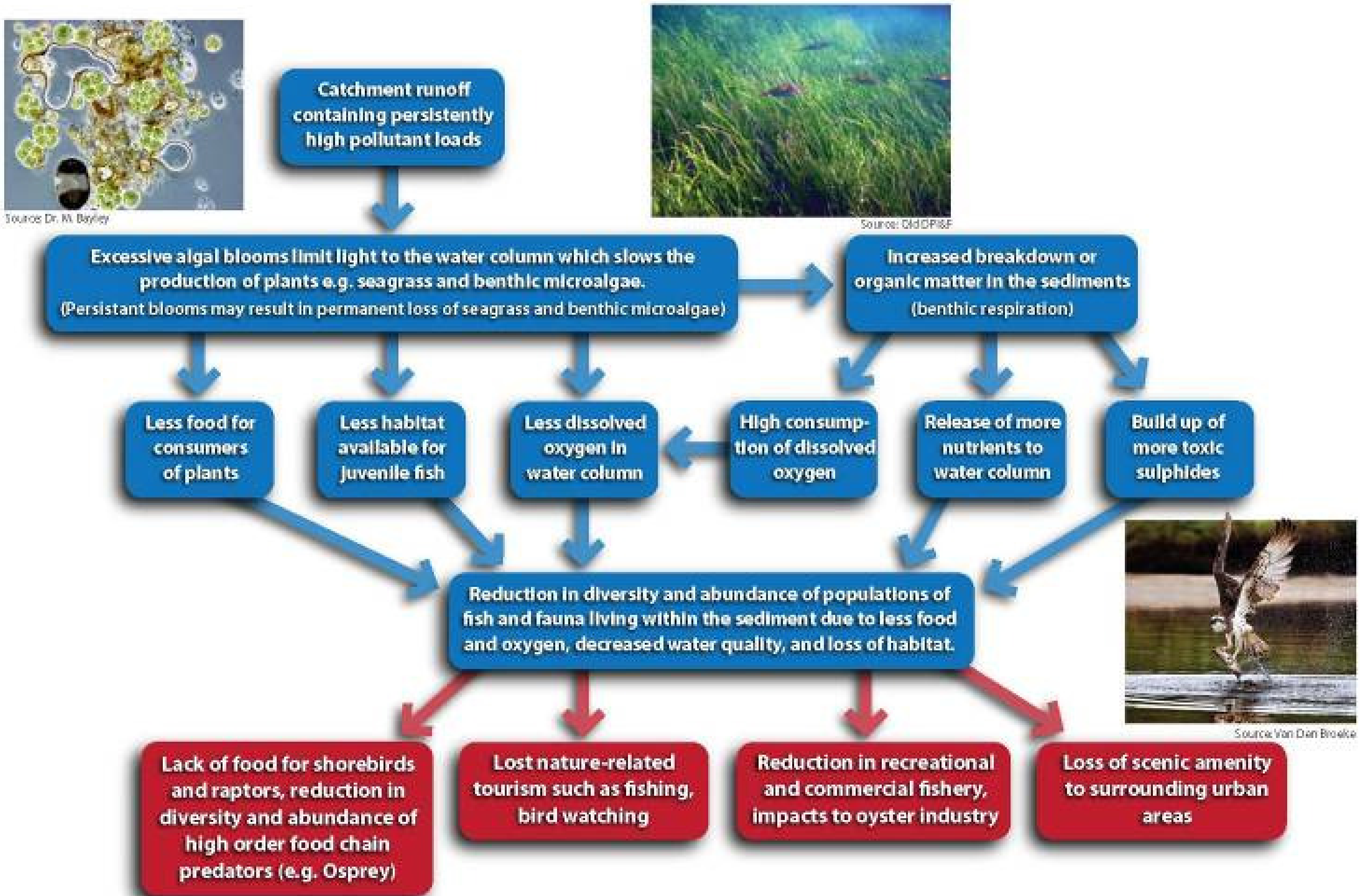

Figure 0.1. Diagrammatic representation of the detrimental impact on the ecology of the broadwaters if no action is taken to reduce catchment pollutant loads.

Management Strategy

The development of management strategies has been informed by research, field investigations in consultation with stakeholders including the community, the Tweed Shire Council, the Tweed River Committee, NSW Maritime, DECC, and local oyster farmers. There are a range of stakeholders who value the system in a variety of ways, for example, for its visual amenity, recreational opportunities, nature appreciation, fishery, cultural attributes, and as a water source. Some ways in which the system is valued conflict and require careful natural resource management.

The common goal for all stakeholders is to ensure a healthy, functional ecosystem that maintains the capacity to assimilate pollutants so that its values can be enjoyed into the future.

The Tweed Shire has some great examples of collaborative rehabilitation projects where the Council has worked with rural landholders to achieve win/win outcomes for the environment and landholder. This kind of commitment between stakeholders is required to ensure the health of the system is improved, particularly given that the great majority of riparian lands are privately owned. To ensure intergenerational equity, ecosystem health must be improved and protected. The management plan provides actions that will:

- Improve the nutrient cycling within the creeks and broadwaters
- Reduce nutrients derived from on-site wastewater treatment systems
- Reduce nutrients derived from livestock
- Improve the condition of cleared and degraded riparian areas and reduce weeds
- Repair creek bed and banks in priority locations that are likely to be contributing high sediment loads downstream
- Remove fish passage barriers from priority locations
- Improve landuse management practices via education and extension officer liaison with the community and landowners
- Improve the quality of urban stormwater pollutant discharge in existing and new development
- Increase shorebird roosting habitat

Long term management targets for riparian vegetation cover, ecosystem health and water quality are provided in Table 0.2. A summary of catchment management issues, potential impacts and some key management responses from the Action Plan in Chapter 12 are provided in Table 0.3. More detail about strategy rationale and implementation is provided in Chapter 13.

Table 0.2. Long term management targets for the rural riparian zone

Indicator	Piggabeen Creek	Cobaki Creek	Bilambil Creek	Duroby Creek
Riparian Vegetation Cover	Increase the riparian vegetation width (to >10m) and cover (to > 50% FPC) in the 74% of the riparian zone ranked 1 and 2 to an equivalent ranking of at least 7 or 8. **Equates to approximately 10km of rehabilitation*.**	Increase the riparian vegetation width (to > 10m) and cover (to > 50% FPC) in the 62% of the riparian zone ranked 1 and 2 to an equivalent ranking of least 7 or 8. **Equates to approximately 8.8km of rehabilitation*.**	Increase the riparian vegetation width (to > 10m) and cover (to > 50% FPC) in the 60% of the riparian zone ranked 1 and 2 to an equivalent ranking of least 7 or 8. **Equates to approximately 10.9km of rehabilitation.**	Increase the riparian vegetation width (to > 10m) and cover (to > 50% FPC) in the 38% of the riparian zone ranked 1 and 2 to an equivalent ranking of least 7 or 8. **Equates to approximately 5.7km of rehabilitation.**
Ecosystem Health	Improve EHMP Grade from C- to B.	Improve EHMP Grade from C- to B.	Improve EHMP Grade from C- to B.	Improve EHMP Grade from D to B.
Water Quality	Compliance with Tweed River Water Quality Objectives for freshwater creeks and estuaries.			

* The length of riparian rehabilitation applies to separate banks of the creek throughout the estuarine and transition zones. Where the creek channel narrows in the mid zone, a single kilometre value incorporates both banks (mid – upper freshwater zone) where delineation between banks is not useful or possible for rehabilitation purposes.

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1 Introduction

1.1 Background

Australian Wetlands and ABER have been commissioned to prepare a Coastal Zone Management Plan for Cobaki Broadwater and Terranora Broadwater (CZMP).

The objective of the project is to develop a management plan that addresses the unique characteristics and interrelationships of ecosystems and human activities for Cobaki and Terranora Broadwaters, taking into account the degree of existing modification and future impacts.

The management plan will identify how and where urban and rural catchment rehabilitation should be undertaken to mitigate impacts on the two broadwater systems.

Tweed Shire is an area of high population growth, with demand for the provision of services and infrastructure to support the growing population being one of the greatest pressures on natural habitats (Ecograph, 2004). Recent trends suggest that the population will grow by approximately 7 – 10,000 every five years, with a population of 110-120,000 likely by 2024 (Tweed Shire Council, 2004).The vast majority of this growth is expected to occur along the coastal strip, with significant development commitments adjacent to both the Cobaki and Terranora Broadwaters.

The true value of the ecosystem services of the broadwaters is difficult to capture. Costanza *et. al.* (1997) valued the annual ecosystem services of different wetland types, as defined by the Ramsar Convention, as a first attempt at valuing wetlands from an economic perspective. The study was based on parameters such as nutrient cycling, habitat, food production and recreation. Using the values determined in this study over ten years ago, the following is a conservative approximation of the annual ecosystem services provided by the broadwaters and Terranora Creek (Table 1.1), with a total annual value of almost $20,000,000. This estimate does not include the rest of the catchment.

Table 1.1. Conservative approximation of the annual ecosystem services provided by the broadwaters and Terranora Creek

Biome	Approx. Area (ha)			$US/ha (as per study)	Total Ecosystem Services Value $AUD / year
	Cobaki Broadwater	Terranora Broadwater	Terranora Creek		
Mangrove	61.8	100.5	110.7	$9,990	$3,313,633
Saltmarsh	2.9	0.7	16.6	$9,990	$245,185
Seagrass	0.9	23.3	37.8	$19,004	$1,325,529
Estuaries	360	120	70	$22,382	$14,956,772
Total					**$19,841,119**

Note: Areas of mangrove, saltmarsh and seagrass are taken from Saintilan *et. al.* (2006).

The Cobaki and Terranora Broadwaters are classified as coastal lakes, which have been identified as the most sensitive of all estuaries to human interventions (HRC, 2002). Pollutants enter the broadwaters from both point sources and diffuse sources. Point sources (such as sewage treatment plant discharge) tend to dominate water quality processes during the dry months. While the results of the EHMP (IWC, 2009) indicate that STP discharge is not affecting water quality, sewage-related nitrogen has been found throughout the system. Conversely, diffuse loads from the whole catchment tend to influence water quality during rainfall.

Point source: To meet the effluent treatment needs of the increasing population and proposed large-scale developments, the Banora Point Waste Water Treatment Plant is being upgraded. While the quality of effluent discharged will be improved, the quantity discharged will increase.

Diffuse source: Given that 79 – 90% of variation in water quality in the lower Tweed Estuary and Terranora Creek has been correlated to catchment rainfall, improvements to water quality in the broadwaters need to address diffuse, stormwater-derived catchment runoff (DEC Science, 1998 as cited in EIS STP, GHD, 2005).

Existing estuary management plans for the Cobaki (1998) and Terranora Broadwaters (1994), implemented over the past decade, are in need of revision to incorporate new scientific knowledge, changes to the physical environment and recent legislative and policy changes. An integrated approach to the management of the two broadwaters and their catchments has been proposed by Council in recognition of the fact that there is hydrological connectivity between the two systems, and that they share similar physical characteristics and are affected by the same degrading impacts. This approach is consistent with the first principle for managing coastal lakes i.e. that each coastal lake and its catchment is to be managed as a whole system (HRC, 2002).

This updated management plan includes a catchment rehabilitation program that is intended to, in part, offset the impacts of increasing point source discharges into Terranora Creek. The Management Plan will identify how and where urban and rural catchment rehabilitation should be undertaken to mitigate diffuse source impacts on the two broadwater systems with the aim of ensuring the assimilative capacity and water quality objectives of the receiving broadwaters are not exceeded.

1.2 Estuary Management Plan Process

A coordinated planning approach has been developed to incorporate the inter-relationships between the estuary processes themselves and to consider all catchment activities that affect the estuary and broadwaters. In accordance with the Estuary Management Policy (1992), an Estuary Management Plan should be developed to reflect the agreed position of all regulatory authorities and interested parties in relation to the future nature conservation, rehabilitation and development of the estuary.

> The current estuary management plans do not include the upper catchments.

In 1998 and 1994, Tweed Shire Council prepared Estuary/Broadwater Management Plans, in accordance with the guidelines of the Draft Estuary Management Manual (NSW Government, 1992), for Cobaki and Terranora Broadwater respectively. These plans were adopted and implemented by Council during the past decade.

The eighth part of the estuary management process acknowledges that a management plan is not a static instrument and that it may be necessary to amend existing management plans (NSW Government, 1992). The need to review the existing Cobaki and Terranora Broadwater Management Plans was driven by several factors including:

- The desire to incorporate the results of significant recent scientific research;
- To recognise the impact of the broadwaters' catchment on the system by incorporating the catchment within the Estuary Management Plan;
- To promote the incorporation of whole of catchment management into the proposed Terranora Creek reclaimed water release strategy;
- To allow for a greater emphasis on catchment rehabilitation and riparian habitat protection to achieve sustainable long term management;
- To ensure the Plan is consistent with recent legislative and policy changes;
- To ensure part or whole implementation of the NRCAP Management Target C2: *a sustainability assessment and management plan is completed for all coastal lakes and estuaries, and priority actions identified by the NRCAP are implemented.*

Tweed Shire Council decided to integrate the review of the Cobaki and Terranora Broadwater Management Plans based on the following factors:

- In acknowledgement of the similar physical characteristics and impacts;
- The fact that the Cobaki Broadwater drains into Terranora Inlet, influencing water quality of the Terranora system;
- To take a more holistic view of water quality within this system;
- As a means of seeking greater efficiency and consistency in the review process.

The estuary management planning process can be summarised into the subsections presented in Figure 1.1. The process of updating the existing management plans is in accordance with Step 8 of the estuary management planning process.

The Estuary Management Manual (1992) is due to be replaced with the new Coastal Zone Management Planning Guidelines for local councils in the near future.

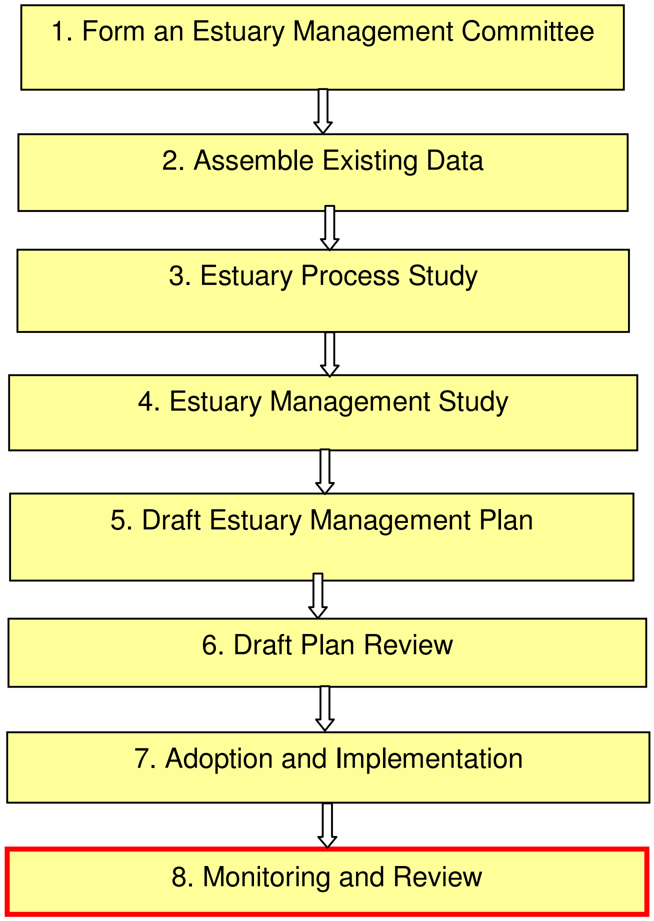


Figure 1.1. Estuary management planning process (NSW Government, 1992).

1.3 Objectives of the Coastal Zone Management Plan for Cobaki Broadwater and Terranora Broadwater

The primary outcome for the Cobaki and Terranora Broadwaters, as listed in the NSW Coastal Lakes Strategy (2002) is that *'key natural and/or highly valued modified ecosystem processes are rehabilitated and retained'*. Attaining this outcome is consistent with the statewide Catchment Action Plan coastal catchment theme target '*that by 2015, there is an improvement in the condition of estuaries and coastal lake systems'* (NRCMA, 2006).

A key outcome of this Coastal Zone Management Plan is the long term sustainability of the broadwaters.

The aim of this Estuary Management Plan, as defined in the Estuary Management Manual (NSW Government, 1992), is to provide a *'scheduled sequence of recommended activities that need to be undertaken to achieve the estuary management objectives'*. The objectives of the CZMP are consistent with the provisions and objectives of current legislation and policy.

The objectives are as follows:

- To **improve water quality and ecosystem health** by revegetation/regeneration of riparian vegetation, prioritising the mid – transition zones of all creeks and their ephemeral drainage lines
- To **improve rural stormwater discharge quality** and ecosystem health by facilitating and supporting best practice land management and functional OSSF
- To **improve urban stormwater discharge quality** by implementing a SQID retrofitting strategy in existing priority areas, and ensuring future development does not contribute to existing pollutant loads
- To **restore riparian habitat** to enhance connectivity of wildlife corridors
- To **protect and enhance shorebird habitat** and provide additional high tide roosting sites
- To **increase and enhance public access to foreshores** and low-impact recreation activities
- To **protect viable commercial and recreational fishing industries** by preserving and improving fish habitat, including marine vegetation such as seagrass and saltmarsh and improving fish passage
- To **stabilise degraded creek bed and banks**, to restore their natural values and/or improve downstream instream health
- To **increase** community **awareness and protection of** areas important to **Aboriginal cultural heritage**
- To prepare for any future impacts of **climate change** in the catchment.

1.4 Scope

Tasks completed to prepare this plan were:

1. Identification of the project mission and measures of success of the project.
2. A concise summary of research relating to Cobaki and Terranora Broadwater's, including:
   - Review of ecological investigations and mapping undertaken in association with development applications;
   - Review of existing Council and State Government studies relating to catchment and waterway management;
   - Review of current legislation and policy changes relating to estuary and coastal management in the context of the CZMP for Cobaki Broadwater and Terranora Broadwater.
3. An audit of the implementation of the existing Estuary Management Plans for Cobaki and Terranora Broadwater's in order to:
   - Compile a list of actions that have been implemented to date;
   - Review success/failure of actions implemented;
   - Gain an understanding of timeframes required for implementing the remaining actions and reasons why these have not yet been implemented;
   - Incorporate the outcomes of the audit into the Implementation Plan for the new CZMP.
4. Stakeholder Consultation Strategy development and implementation, to include:
   - Initial scoping with the community and with adjacent landholders to identify new or emerging management issues and to identify community objectives for catchment water quality and ecological health;

- Workshops/information exchange meetings with adjacent landholders (Tugun Bypass, Gold Coast Airport and Leda) as necessary to incorporate outcomes of a proposed integrated foreshore management plan for Cobaki Broadwater.
- Opportunities to encourage interest and participation in sustainable catchment management.

5. A model of catchment pollutant exports (N, P and SS) in order to:
    - Assess the assimilative capacity of the Cobaki and Terranora Broadwater's (ie. their ability to function as a sink for nutrients);
    - Determine the level and spatial extent of urban and rural catchment rehabilitation necessary to manage diffuse pollutant loads under existing levels of catchment development;
6. Recommendations relating to sustainable levels of development within the Cobaki and Terranora catchments, to incorporate:
    - The intent of legislative and policy changes in the sphere of estuary and coastal management;
    - Reference to existing strategic plans including the Far North Coast Regional Strategy, Tweed LEP, approvals and DCPs.
    - Recommendations of relevant environmental management plans prepared by key Cobaki Broadwater landholders and, if available, outcomes of the proposed Integrated Foreshore Management Plan for Cobaki Broadwater;
    - Comments on the sustainability and consequences of probable future development scenarios.
7. A detailed Action Plan for the conservation and rehabilitation of terrestrial and aquatic ecosystems, to include:
    - A prioritised list of suitable sites for rehabilitation and revegetation, including riparian areas and previously drained wetlands on public and private lands;
    - Measurable targets of rehabilitation and revegetation;
    - Opportunities and targets for the retrofitting of SQIDS in urban catchments to protect and enhance water quality;
    - Management actions for agricultural land uses, such as low lying wet grazing pastures.
8. Recommendations for the management of Cobaki and Terranora Broadwater catchments and estuaries, addressing:
    - Requirements of legislative and policy changes relating to the management of the Cobaki and Terranora catchments;
    - New and emerging management issues arising from community consultation, including community objectives for water quality and ecological health;
    - Management issues, commitments and recommendations arising from landholder consultation, particularly with reference to existing environmental management plans and the proposed integrated foreshore management plan for Cobaki Broadwater;
    - Environmental objectives for water quality and ecological health, including outcomes of the Terranora and Cobaki Broadwater Ecosystem Health Monitoring Program and ecosystem health report cards;

- Future estuary process studies required to develop a comprehensive, accurate understanding of the interaction between development, physical and biological processes affecting the Cobaki and Terranora systems (based on a review of the outputs of the Coastal Lakes Assessment and Management Tool – CLAM);
- The potential impact of sea level rise, storm surge and climate change on the Cobaki and Terranora systems;

9. An Implementation Plan to deliver the recommendations of the CZMP, to include:
   - Costings for recommended projects;
   - Prioritisation of projects and rehabilitation sites;
   - Project responsibilities;
   - Funding opportunities for recommended projects;
   - Where relevant, legislative and policy requirements for the implementation of recommended projects.

2 Planning Framework

One of the difficulties in managing environmental assets is the large body of relevant legislation, which continues to change over time. In order to provide a cohesive policy framework within which the CZMP can be developed, current legislation and policy relating to estuary, coastal, catchment and vegetation management has been reviewed. This section provides a summary of the most relevant legislation and policy relating to the Cobaki and Terranora catchments. These planning documents emphasise the requirement of Councils to successfully implement management plans for catchments, estuaries and coastal lakes.

2.1 Federal Planning

The Environment Protection and Biodiversity Conservation Act, 1999 focuses Australian Government interests on the protection of matters of national environmental significance. Of relevance to the study area are the Bilateral Migratory Bird Agreements.

Bilateral Migratory Bird Agreements – JAMBA, CAMBA, ROKAMBA

The conservation of migratory birds and their habitats has been agreed upon between Government of Australia and the Governments of Japan (JAMBA, 1974), China (CAMBA, 1986) and Korea (ROKAMBA, 2007). The agreements list terrestrial, water and shorebird species which migrate between Australia and the respective countries, the majority of the listed species being shorebirds.

The agreements require the parties to protect migratory birds by:

- Limiting the circumstances under which migratory birds are taken or traded;
- Protecting and conserving important habitats;
- Exchanging information; and
- Building cooperative relationships.

These agreements are particularly relevant to Tweed Shire Council as the broadwaters provide significant shorebird habitat. The protection of habitat includes SEPP 14 wetlands, foreshores and other roosting sites. Many species listed on JAMBA and CAMBA utilise the broadwaters, however the broadwaters do not satisfy the Ramsar waterbird criteria. DECC prioritised major wetlands in NSW for Ramsar nomination and the Tweed was not included as a priority area.

2.2 State Planning

The Environmental Planning and Assessment Act, 1979 is the overarching environmental legislation for NSW. It aims to encourage the proper management, development and conservation of natural resources, protection of environment and ecologically sustainable development. The following are some key state planning tools of particular relevance to the study area.

State Environmental Planning Policies (SEPPs)

The CZMP is consistent with the aims and objects of the following SEPPs, all of which are relevant to the study area:

- SEPP 71 – Coastal Protection
- SEPP 14 – Coastal Wetlands

- SEPP 26 – Littoral Rainforests
- SEPP 44 – Koala Habitat
- SEPP 35 – Maintenance of Tidal Waterways
- SEPP 62 – Sustainable Aquaculture

Coastal Protection Act, 1979

The objects of this Act are to provide for the protection of the coastal environment of the State for the benefit of both present and future generations. The objects of the Act incorporate protection of the environment, ecosystem, ecological processes, biological diversity and water quality, the use of ecologically sustainable development, the fostering of social and economic benefits of the coastal environment, access, community involvement and the integration of management activities.

Section 55B of this Act states that a council whose area is included within the coastal zone must make a coastal zone management plan, which includes estuary management plans, if directed by the Minister.

Section 55C states the matters to be dealt with in a coastal zone management plan. Relevant matters that this management plan must make provision for include:

(a) protecting and preserving beach environments and beach amenity, and
(c) ensuring continuing and undiminished public access to beaches, headlands and waterways, particularly where public access is threatened or affected by accretion.

The CZMP will satisfy the requirements of the Coastal Protection Act and will be submitted to the Minister for approval and subsequent gazettal in the Government Gazette.

NSW Coastal Policy, 1997

The NSW Coastal Policy, 1997 – A Sustainable Future for the New South Wales Coast sets the direction for coastal zone management, planning and conservation in NSW. The policy philosophy is based on the principles of ecologically sustainable development. This policy provides the framework needed to balance and coordinate the management of the coasts' unique physical, ecological, cultural and economic attributes. This policy is relevant as it applies to areas within one km of bays, estuaries, coastal lakes, lagoons and tidal waters of coastal rivers to the limit of mangroves.

Local councils are obliged to take into account the Strategic Actions of this policy in the preparation of their own policies and programs. The following are examples of Strategic Actions that will be partly or wholly implemented by the adoption of the CZMP:

Table 2.1. Strategic Actions in the NSW Coastal Policy, 1997 that will be partly or wholly implemented by the adoption of the Coastal Zone Management Plan for Cobaki Broadwater and Terranora Broadwater

Goal 1: To protect, rehabilitate and improve the natural environment		
Objective: 1.1		To identify coastal lands and aquatic environments with conservation values and devise and implement acquisition policies, management strategies and controls to ensure that those values are protected.
Strategic Action	1.1.7	Seagrass, mangrove, saltmarsh and other wetland associated species will be conserved and managed as valuable components of the coastal ecosystem by effectively implementing existing controls (e/g/ SEPP 14, fish Habitat Protection Plans, Ramsar listing of important wetlands) and through controlling runoff, sedimentation and other water quality impacts.
	1.1.11	Regional open space networks/corridors (including water areas) should, where possible, be used to protect natural habitats and environments.
Objective: 1.3		To improve water quality in coastal and estuarine waters and coastal rivers where it is currently unsatisfactory and to maintain water quality where it is satisfactory.
Strategic Action	1.3.2	Problems of non-point source pollution (eg resulting from urban development) will be addressed through a range of actions including the setting of ambient water quality objectives; the development of stormwater management plans; the promulgation of environmental guidelines; and encouraging the adoption and implementation by industry and developers of 'best management practices' for minimising pollution.
	1.3.3	Water quality monitoring programs and environmental studies in coastal river systems, estuaries, inshore marine waters and coastal aquifers will be undertaken, as necessary, and regular reporting on the state of the environment for these ecosystems will take place.
	1.3.8	The discharge of contaminated stormwater to coastal waters will be minimised, with the aim being to ensure environmentally sound management of stormwater and prevent contamination in the future.
Objective: 1.4		To manage the coastline and estuarine environments in the public interest to ensure their health and vitality.
Strategic Action	1.4.3	Detailed management plans for the coastline and estuaries, as provided for in the Coastline Management Manual and Estuary Management Manual, will continue to be prepared and implemented.
Objective 1.5:		To foster new initiatives and facilitate the continued involvement of the community in programs aimed at the restoration and rehabilitation of degrade coastal areas.

Strategic Action	1.5.1	Local government and the Department of Land and Water Conservation, through programs such as Landcare, Coastcare and Rivercare, will continue to involve the community in implementing measures to protect and rehabilitate natural areas.
	1.5.2	Catchment management committees and trusts will continue to play an influencing role in the protection and restoration of coastal environments.
Goal 2: To recognise and accommodate natural process and climate change.		
Objective 2.1:		To give the impacts of natural processes and hazards a high priority in the planning and management of coastal areas.
Strategic Action	2.1.1	Coastline, estuary and floodplain management plans will continue to be prepared by local councils and integrated into local environmental plans to address planning and development issues in accordance with the Coastline, Floodplain and Estuary Management Manuals.
Objective 2.2		To recognise and consider the potential effects of climate change in the planning and management of coastal development.
Strategic Action	2.2.2	Appropriate planning mechanisms will be considered for incorporating sea level change scenarios set by the Inter-governmental Panel on Climate Change.
Goal 3: To protect and enhance the aesthetic qualities of the coastal zone.		
Objective 3.1:		To identify and protect areas of high natural or built aesthetic quality.
Strategic Action	3.1.2	Provision to protect areas or items of high aesthetic value will continue to be considered when preparing planning instruments and plans of management.
Goal 5: To promote ecologically sustainable development and use of resources.		
Objective 5.1:		To identify and facilitate opportunities for the sustainable development and use of resources.
Strategic Action	5.1.11	Nature-based tourism and ecotourism operators should have regard to the Department of Urban Affairs and Planning publication 'Guidelines for Tourism Development Adjacent to Natural Areas'.
Objective 5.2:		To develop land use and management plans which ensure the sustainable development and use of resources.
Strategic Action	5.2.2	Local councils will include in their management plans prepared under the Local Government Act, a statement of activities to be undertaken to protect environmentally sensitive coastal areas and to promote ecological sustainability of the council's coastal area.
	5.2.3	Management plans prepared for coastal areas will be considered in the preparation of REPs, LEPs and DCPs, so as to achieve integrated, responsible and ecologically sustainable development and use of resources.

Objective 5.3:		To develop and implement 'best practice' approaches to achieving sustainable resource management.
Strategic Action	5.3.1	Sustainable land and water management practices for the community will continue to be promoted through catchment management committees and trusts.
Goal 7: To provide for appropriate public access and use.		
Objective 7.1:		To increase public access to foreshores when feasible and environmentally sustainable options are available.
Strategic Action	7.1.2	Public facilities will be provided at appropriate locations and with appropriate safety standards to facilitate fair and equitable access to and enjoyment of the recreational amenity of the coast and estuary foreshores.
Goal 8: To provide information to enable effective management.		
Objective 8.4:		To develop adequate formal and informal education and awareness programs addressing coastal management issues.
Strategic Action	8.4.1	Coastal management issues and programs will be published throughout the community, through a variety of media such as brochures, awareness campaigns and school material.

NSW Rivers and Estuaries Policy, 1992

The intent of this policy is to ensure that rivers and estuaries can continue to support responsible, economic and social uses in the long term. This policy is the first natural resources policy within the Total Catchment Management framework to focus on river and estuarine resources. It compliments the State Soils, State Trees and State Groundwater Policies.

An Estuary Management Program was implemented as a component of the NSW Government's Rivers and Estuaries Policy. The Department of Environment and Climate Change (DECC) administers an Estuary Management Program, which allows local communities to develop and implement their own plans to restore and protect estuaries. The program focuses on improving or maintaining the overall health and functioning of an estuary, and maintaining the environmental, economic, recreational and aesthetic values of the whole system.

DECC works with local councils to establish an Estuary Management Committee, which includes representatives from the local community, industry, environmental interest groups, researchers, and state and local government. The committees work together to identify problems in the estuary and create and implement a formal management plan. These plans aim to:

- Improve the environmental health and condition of estuaries
- Protect important coastal habitats, features and heritage items
- Rehabilitate degraded areas
- Improve public access and amenity
- Accommodate sustainable population growth and resource utilisation.

The development of the CZMP has been overseen by the Tweed River Committee.

Threatened Species Conservation Act, 1995

The Threatened Species Conservation Act outlines aims to protect the threatened species, communities and critical habitat in New South Wales. The Act lists species, populations and ecological communities as endangered, vulnerable or extinct under this act, and provides a schedule of key threatening processes.

This Act is relevant to the Tweed Shire Council as the area within and surrounding Cobaki and Terranora Broadwaters contains many threatened flora, fauna and endangered ecological communities. This CZMP, while focussed on improvements to estuary health and sustainability, will be consistent with the protection of threatened species.

Fisheries Management Act, 1994

The objects of this Act are to conserve, develop and share the fishery resources of the State for the benefit of present and future generations.

In particular, the objects of this Act include:

a) to conserve fish stocks and key fish habitats, and
b) to conserve threatened species, populations and ecological communities of fish and marine vegetation, and
c) to promote ecologically sustainable development, including the conservation of biological diversity.

d) to promote viable commercial fishing and aquaculture industries, and
e) to promote quality recreational fishing opportunities, and
f) to appropriately share fisheries resources between the users of those resources, and
g) to provide social and economic benefits for the wider community of New South Wales.

The Tweed River Estuary comprises one of the most productive estuaries for finfish and crustacean in northern NSW (FRC, 2001) and supports an extensive recreational and commercial fishery. The CZMP addresses the need to preserve and improve fish habitat, including marine vegetation such as seagrass and saltmarsh. The Plan also acknowledges the commercial importance of the fishery, in terms of professional and recreational fishing.

Native Vegetation Act, 2003

The objects of this Act are:

- 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
- to prevent broadscale clearing unless it improves or maintains environmental outcomes, and
- 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
- to improve the condition of existing native vegetation, particularly where it has high conservation value, and
- to encourage the revegetation of land, and the rehabilitation of land, with appropriate native vegetation, in accordance with the principles of ecologically sustainable development.

The focus of the CZMP is one of improving sustainability of the broadwaters, a key element of which is water quality. The implementation of the Plan will improve the condition and extent of native vegetation throughout the catchment consistent with the objectives of this Act. The conservation of native vegetation is further addressed in the Tweed Vegetation Management Strategy (Ecograph, 2004).

NSW Coastal Lakes Strategy, 2002

The final report for An Independent Public Inquiry into Coastal Lakes, undertaken by the Healthy Rivers Commission of NSW, was released in 2002. The Commission proposes a Coastal Lakes Strategy as an effective response to improved management of coastal lakes and their catchments. The Strategy advocates the adoption of the proposed principles, management framework, classification, and requirements for preparing and implementing Sustainability Assessment and Management Plans.

The strategy incorporates the following components with which the current CZMP will be consistent (Table 2.2).

Table 2.2. Summary of the components of the NSW Coastal Lakes Strategy

Principles

The strategy requires the following principles for managing coastal lakes be given effect:

- Each coastal lake and its catchment is to be managed as a whole system.
- Coastal lakes and their catchments are to be treated as assets with productive values to be sustained by carefully directed management.
- Management actions are to address the unique characteristics and interrelationships of ecosystems and human activities for each coastal lake, taking account of the degree of existing modification and the conditions sought.
- Management actions for coastal lakes must provide for further adaptation in light of the inherent scientific uncertainties and limited information bases.
- Management plans are to be sufficiently clear to create explicit obligations on the responsible public authorities with powers and resources that can be applied to coastal lake management.
- The responsibilities of public authorities and communities are to be clearly stated and outcomes achieved through partnership arrangements.
- The responsible public authorities are to be accountable for the condition of coastal lakes at the conclusion of each cycle of planning, action and assessment.

Classification

The Cobaki and Terranora Broadwaters have been classified as coastal lakes of high natural sensitivity and high conservation value, with a corresponding management orientation of 'Healthy Modified Conditions'.

Management Framework

The management framework requires preparation and implementation of a Sustainability Assessment and Management Plan for the coastal lake and its catchment.

The primary outcome for the Cobaki and Terranora Broadwaters is that **'key natural and/or highly valued modified ecosystem processes are rehabilitated and retained'.**

The Sustainability Assessment and Management Plan for each coastal lake and its catchment must include:

- Any outcomes for each coastal lake that are consistent with rehabilitating and retaining key natural processes and/or modified values and determining appropriate types and sustainable levels of human uses;
- How existing activities must be managed (ie encouraged, permitted, modified), drawing on (but not limited to) the types of indicative actions to achieve the intended outcomes;
- The capability and limitations of a lake and catchment to sustain new development (ie permitted or encouraged, permitted subject to conditions, not permitted pending further investigations, not permitted);
- Selection and design of the most appropriate set of management tools;
- Specification of the responsibilities, timing and resources for each action.

The CZMP for Cobaki and Terranora Broadwaters delivers this framework. **Future sustainability of the broadwaters will depend largely on community and government commitment to the implementation of the CZMP recommendations.**

NSW Water Quality Objectives 1999

The NSW Water Quality Objectives were adopted by the NSW Government in 1999 and use the ANZECC framework to establish and recognise the community's environmental values and uses for each catchment in NSW. They provide a framework for understanding the potential impact of a development on the community's values and allow planners in local councils to play a role in protecting or restoring environmental values through the strategic planning process (DECC, 1999).

The NSW Water Quality Objectives were established to ensure the long-term health of the waterways of New South Wales. The objectives have been developed to guide plans and actions to achieve healthy waterways. Integration of the objectives into strategic, catchment and land use planning activities is intended to assist the community in achieving an acceptable balance between environmental, social and economic needs. The process of determining the catchment values and objectives involved extensive community consultation by DECC which identified the major issues that people felt needed progressive action to achieve a healthy and viable Tweed River and coastal lagoon system. Table 2.3 summarises the relevant water quality and river flow objectives for the Cobaki and Terranora Broadwaters, Piggabeen Creek, Cobaki Creek, Bilambil Creek and Duroby Creek.

The catchment is mapped as follows (Figure 2.1):

- Broadwater foreshores are predominantly classed 'Waterways affected by urban development'
- Estuaries (includes the broadwaters)
- Uncontrolled streams

The water quality objectives for aquatic ecosystem health apply to all natural waterways and areas greatly affected by human use where continual improvement is needed towards healthier, more diverse aquatic ecosystems. While water quality in artificial watercourses (such as drainage channels) should be adequate to protect the native species that use them as well as for the desired human uses, full protection of aquatic ecosystems may not be achievable in the short-term in some artificial watercourse (DECC, 1999). However, artificial watercourses should meet the objectives (including protection of aquatic ecosystems) applying to natural waterways *at any point where water from the artificial watercourse flows into a natural waterway'.* (DECC, 1999). This is particularly relevant in large subdivisions that may contain several artificial waterbodies.

The DECC state-adopted water quality objectives for estuaries, including the broadwaters are provided below (Tables 2.4 – 2.7). One of the long term measures of success of this CZMP is to maintain or improve compliance with these objectives.

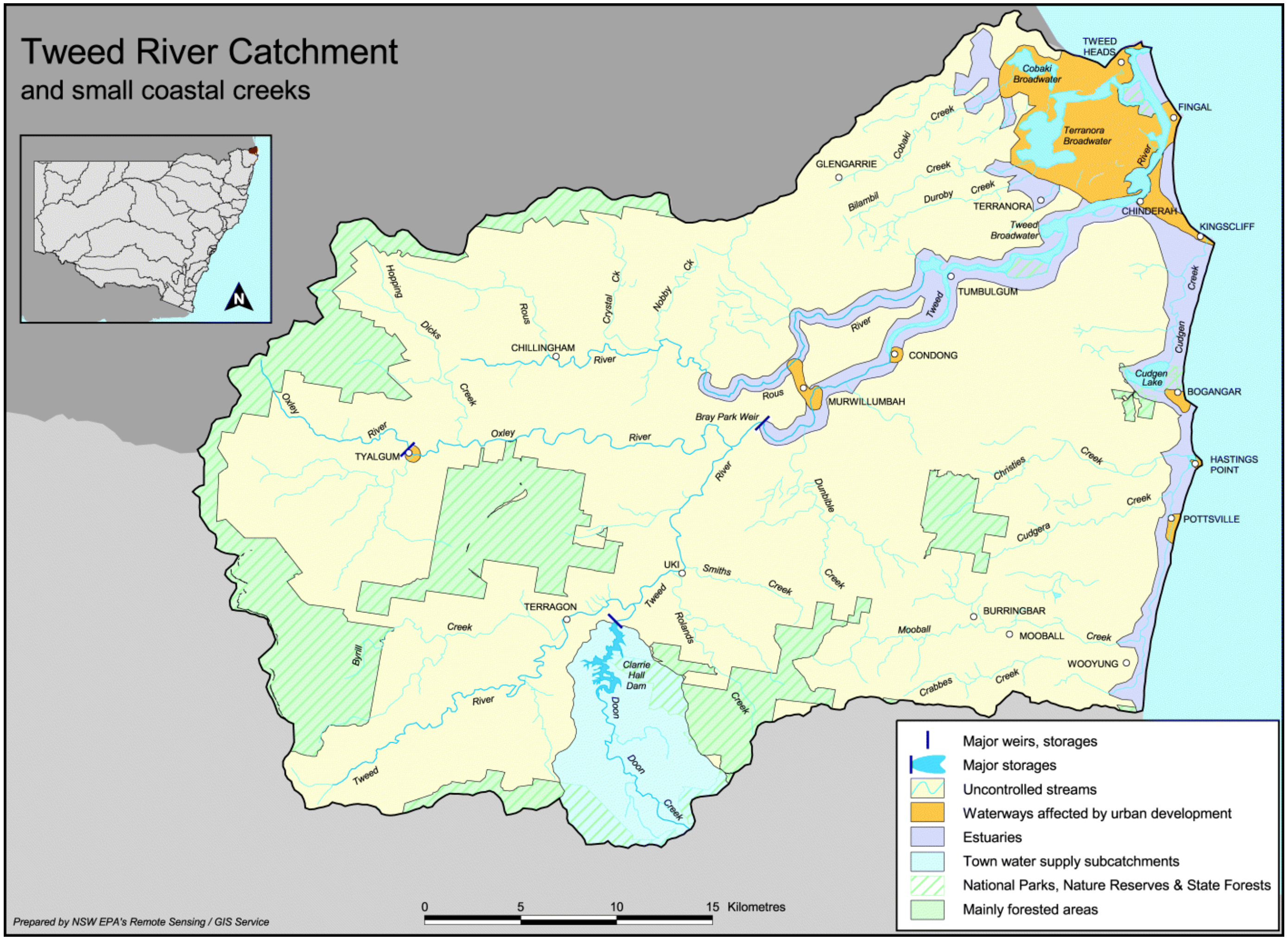


Figure 2.1. Classification of waterways in Tweed Shire by DECC.

Table 2.3. Water quality objectives for Cobaki and Terranora Broadwaters and creeks

Water Quality Objectives

Waterway	Aquatic ecosystems	Visual amenity	Secondary contact recreation	Primary contact recreation	Livestock water supply	Irrigation water supply	Homestead water supply	Drinking water – disinfection only	Drinking water – clarification and disinfection	Drinking water – groundwater	Aquatic foods (to be cooked before eating)
Waterways affected by urban development	✓	✓	✓ <5	✓ <10							
Uncontrolled streams (Freshwater reaches of all creeks)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Estuaries (Estuarine reaches of all creeks, including Broadwaters)	✓	✓	✓	✓							✓

River Flow Objectives

Waterway	Protect pools in dry times	Protect natural low flows	Protect important rises in water levels	Maintain wetland and floodplain inundation	Mimic natural drying in temporary waterways	Maintain natural flow variability	Maintain natural rates of change in water levels	Manage groundwater for ecosystems	Minimise effects of weirs and other structures	Minimise effects of dams on water quality	Make water available for unforeseen events	Maintain or h\rehabilitate estuarine processes and habitats
Waterways affected by urban development					✓	✓	✓	✓	✓			
Uncontrolled streams (Freshwater reaches of all creeks)	✓	✓	✓		✓	✓			✓			
Estuaries (Estuarine reaches of all creeks, including Broadwaters)				✓				✓	✓			✓

< 5 = for achievement within 5 years. <10 = for achievement in 10 years or more

Table 2.4. DECC Water quality objectives for Cobaki and Terranora Broadwater - protection of aquatic ecosystem health

Aquatic Ecosystem Health – Estuaries / Broadwaters		
Indicator	DECC Criteria (trigger values)	
	Lowland rivers	Estuaries
TP	25ug/L	30ug/L
TN	350ug/L	300ug/L
Chlor a	5ug/L	4ug/L
DO	85-110%	80-110%
pH	6.5-8.5	7.0-8.5
Turbidity	6-50 NTU	0.5-10 NTU
Salinity	125-2200 uS/cm	-

Table 2.5. Water quality objectives for Cobaki and Terranora Broadwater – protection of visual amenity

Visual Amenity – Estuaries / Broadwaters	
Indicator	**Numerical criteria (trigger values)**
Visual clarity and colour	Natural visual clarity should not be reduced by more than 20%. Natural hue of the water should not be changed by more than 10 points on the Munsell Scale. The natural reflectance of the water should not be changed by more than 50%.
Surface films and debris	Oils and petrochemicals should not be noticeable as a visible film on the water, nor should they be detectable by odour. Waters should be free from floating debris and litter.
Nuisance organisms	Macrophytes, phytoplankton scums, filamentous algal mats, blue-green algae, sewage fungus and leeches should not be present in unsightly amounts.

Table 2.6. Water quality objectives for Cobaki and Terranora Broadwater – protection of primary contact recreation

Primary Contact Recreation – Estuaries / Broadwaters	
Indicator	**Numerical criteria (trigger values)**
Turbidity	A 200mm diameter black disc should be able to be sighted horizontally from a distance of more than 1.6m (approximately 6 NTU)
Faecal coliforms	Beachwatch considers waters are unsuitable for swimming if: • The median faecal coliform density exceeds 150 colony forming units per 100 millilitres (cfu/100mL) for five samples taken at regular intervals not exceeding one month, or • The second highest sample contains equat to or greater than 600 cfu/100mL (faecal coliforms) for five samples taken at regular intervals not exceeding one month. ANZECC 2000 Guidelines recommend: • Median over bathing season of < 150 faecal coliforms per 100mL, with 4 out of 5 samples < 600/100mL (minimum of 5 samples taken at regular intervals not exceeding one month).

Primary Contact Recreation – Estuaries / Broadwaters	
Indicator	**Numerical criteria (trigger values)**
Enterococci	Beachwatch considers waters are unsuitable for swimming if: • The median enterococci density exceeds 35 cfu/100mL for five samples taken at regular intervals not exceeding one month, or • The second highest samples contains equal to or greater than 100 cfu/100mL (enterococci) for five samples taken at regular intervals not exceeding one month. ANZECC 2000 Guidelines recommend: • Median over bathing season f < 35 enterococci per 100mL (maximum number in any one sample: 60-100 organisms/100mL).
Protozoans	Pathogenic free-living protozoans should be absent from bodies of fresh water.
Algae and blue-green algae	< 15,000 cells/mL
Nuisance organisms	Use visual amenity guidelines. Large numbers of midges and aquatic worms are undesirable.
pH	5.0 -9.0
Temperature	15 0 to 350 for prolonged exposures
Chemical contaminants	Waters containing chemicals that are either toxic or irritating to the skin or mucus membranes are unsuitable for recreation. Toxic substances should not exceed the concentrations provided in talbes 5.2.3 and 5.2.4 of the ANZECC Guidelines 2000.
Visual clarity and colour	Use visual amenity guidelines
Surface films	Use visual amenity guidelines

Table 2.7. Water quality objectives for Cobaki and Terranora Broadwater – protection of aquatic foods

Primary Contact Recreation – Estuaries / Broadwaters		
Indicator	**Numerical criteria (trigger values)**	
Algae and blue-green algae	No guideline is directly applicable, but toxins present in blue-green algae may accumulate in other aquatic organisms.	
Faecal coliforms	Guideline in water for shellfish: The median faecal coliform concentration should not exceed 14 MPN/100mL; with no more than 10% of the samples exceeding 43 MPN/100mL.	Standard in edible tissue: Fish destined for human consumption should not exceed a limit of 2.3 MPN E Coli/g of flesh with astandard plate count of 100,000 organisms /g.
Metals	Copper: less than 5 ugm/L Mercury: less than 1 ugm/L Zinc: less than 5 ugm/L Organochlorines: Chlordane: less than 0.004 ugm/L (saltwater production) PCB's: less than 2 ugm/L.	
Physico-chemical indicators (as applied to aquaculture activities)	Suspended solids: less than 40 micrograms per litre (freshwater) Temperature: less than 2 degrees Celcius change over one hour.	

These guidelines are intended to be used in conjunction with the Food Standards Code. The Tweed Shellfish Quality Assurance Program requires that water quality and oyster meat testing is undertaken regularly, especially in response to rainfall. The Shellfish Program is administered by the NSW Food Authority under the Food Act, 2003.

NSW Oyster Industry Sustainable Aquaculture Strategy, 2006

This Strategy applies to the NSW edible oyster aquaculture industry and identifies areas within NSW estuaries where oyster aquaculture is a suitable and priority outcome. The Strategy also includes the following:

- Documentation and promotion of environmental, social and economic best practice for NSW oyster farming
- Formalises industry's commitment to environmental sustainable practices and a duty of care for the environment
- Provides a framework for an approval regime
- Identifies key water quality parameters for sustainable oyster aquaculture (see Table 7.1)
- Ensures water quality requirements are considered in the State's land and water management and strategic planning framework (see below).

The following water quality guidelines have been established in the NSW Oyster Industry Sustainable Aquaculture Strategy (NSW DPI, 2006) to support healthy oyster growth and oysters that are safe to eat following harvest under the NSW Shellfish Program.

Table 2.8. Water quality guidelines for oyster aquaculture areas

Parameter	Guideline
Faecal coliforms	90th percentile of randomly collected faecal coliform samples do not exceed 43 MPN or 21 MF/100mL.
pH	6.75 – 8.75
Salinity	20.0 – 35.0 g/L
Suspended solids	< 75 mg/L
Aluminium	< 10 ug/L
Iron	< 10 ug/L
Other parameters	Refer to Section 4.4 and 9.4 of the ANZECC Guidelines (2000)

Council's key role in the local aquaculture industry includes the management of estuarine water quality, resolving land and water use conflicts through estuary management planning and land use planning and development control. Recognition of oyster aquaculture in land and water use planning involves the following:

- When preparing statutory environmental management plans that govern activities (both upstream and downstream) that may influence priority oyster aquaculture areas the relevant agency is required to:

    - Consider the potential impact of the activity or plan on oyster aquaculture areas, and
    - Include specific actions that will contribute to the protection and/or improvement of water quality for oyster aquaculture.
- In determining applications for consent or approval under the Environmental Planning and Assessment Act, 1979 the consent or determining authority needs to consider the potential impacts of the activity on oyster aquaculture areas in the locality. Of particular concern is that catchment or foreshore development will reduce the suitability of an oyster aquaculture area for its intended purpose.
- The NSW oyster industry is recognised as a neighbour/stakeholder and will be notified of relevant applications for approvals and consents and natural resource plan making activities.

The CZMP has been developed in consultation with a representative of the oyster industry. All the actions proposed in the plan are consistent with the improvement of water quality and the mitigation of processes and activities that threaten the health of oyster growth and human health.

2.3 Regional Planning

Northern Rivers Catchment Action Plan, 2006

The Northern Rivers Catchment Action Plan (NRCAP) is a statutory but non-regulatory strategic plan that takes into account changes in legislation and policy since the Blueprints were developed including the Native Vegetation Act 2003, macro water planning under the Water Management Act 2000, and the Coastal Planning and Healthy Commission findings.

The CAP is the central mechanism to prioritise and deliver natural resource management investments and outcomes in the Northern Rivers and incorporates Statewide Targets developed from the Statewide Standards. *The Northern Rivers Catchment Management Authority sees Local Government as the key partner to help attain the management targets.* One of the ways the local councils will contribute to the attainment of the Targets is via the development and implementation of estuarine management plans.

Management Target C2 – *Estuaries and Coastal Lakes* requires complete management plans for all estuaries and sustainability assessment and management plans for all coastal lakes by 2016 (65% by 2009), and implementation of the identified priority actions that contribute to improved natural resource conditions. The following are examples of management targets and associated priorities that will be partly or wholly achieved by the adoption of the CZMP (Table 2.9).

Table 2.9. Management targets of the NRCAP that will be partly or wholly achieved by the adoption of the Coastal Zone Management Plan for Cobaki Broadwater and Terranora Broadwater

Theme: Biodiversity	
Catchment Resource Condition Target:	By 2016, improve the condition of native terrestrial and aquatic ecosystems.
Target B1	Secure protection of high conservation value ecosystems
Target B2	Provide connectivity and reverse fragmentation by rehabilitating corridor habitats.
Target B3	Reduce impact of threats (invasive weeds, pest species and disturbance to natural systems) on biodiversity/habitat quality).
Target B5	Maintain extent and improve condition of native terrestrial and aquatic ecosystem in multiple resource use systems.
Target B6	Increase the extent and quality of native terrestrial and aquatic ecosystem through revegetation and rehabilitation.
Theme: Water	
Catchment Resource Condition Target:	By 2016, river and aquifer condition is improved.
Target W1	Rehabilitation and protection of stream health in terms of river structure, riparian vegetation and fish passage.
Target W2	Encourage and promote efficient, effective and productive use of urban water resources through appropriate planning, management and education.
Target W3	Increased community awareness and understanding of how catchments work and how human activities impact upon them via environmental education.
Theme: Coastal	
Catchment Resource Condition Target:	By 2016 there is an improvement in the condition of Coastal Zone natural resources.
Target C2	Completion and implementation of Estuary Management Plans and coastal lake Sustainability Assessment and Management Plans through identification of priority locations, facilitation of the completion and/or review of plans; and provision of investment incentives for implementation of priority NRM actions within management plans.
Theme: Soil/Land Resource	
Catchment Resource Condition Target:	By 2016, 500,000 ha of agricultural land is actively managed to improve soil health (166,666 ha by 2009).

L1	Enhance agricultural sustainability and associated natural ecosystem functions. Recognition and appreciation of soil condition and the impact of the management of the land use practices upon it.
L2	Active management of areas of ASS to address a significant natural resource management issue. Recognition of land use practices an the implications for the maintenance and/or enhancement of agricultural sustainability, infrastructure and associated natural ecosystem functions.
L3	Stabilisation of degraded land to promote restoration of degraded landscapes and to restore their natural values.

Far North Coast Regional Strategy, 2006-2031

This Strategy is the overriding strategic planning document of the Region and applies to the period 2006 – 2031. The Far North Coast Regional Strategy incorporates six local government areas: Ballina, Byron, Kyogle, Lismore, Richmond Valley and Tweed. The Strategy aims to manage the high growth rate expected throughout the Region by protecting the unique environmental assets, cultural values and natural resources.

A major outcome of the Strategy is the protection of the areas of high biodiversity value and productive natural resources from development pressures. The Strategy advocates that land use planning objectives address the objectives of the Catchment Action Plan and other NRM plans such as Water Sharing Plans and Estuary Management Plans.

The outcomes of the Strategy for the environment and natural resources include:

- LEPs to protect and zone land with State or regional environmental, agricultural, vegetation, habitat, waterway, wetland or coastline values;
- Urban development will be directed away from areas considered important for conservation or be designed to minimise impacts or provide offsets by protecting and enhancing the long term viability of priority vegetation and habitat corridors as well as rehabilitating degraded priority areas;
- The values and functions of riparian corridors, coastal wetlands, lakes, estuaries and fishery habitats be protected;
- Where rural residential development is located in the Environmental Asset and Rural Land area, it will be appropriately planned and developed to ensure groundwater/surface water, farmland and extractive resources will be protected through the provision of appropriate buffers when development occurs near these resources. Limits on growth due to rural residential subdivisions and extraction of water for stock and domestic purposes.

The aim of CZMP is consistent with the Far North Coast Regional Strategy, 2006 – 2031. In particular, its implementation will protect the values and functions of the riparian corridor, coastal wetlands, lakes, estuaries and fishery habitats.

2.4 Tweed Shire Council Planning

Tweed 4/24 Strategic Plan 2004 – 2024

The Tweed 4/24 is the strategy that sets broad directions and provides a framework for more detailed plans and policies for the 20 year period from 2004 – 2024. Key elements of the Strategy that are particularly relevant to this plan include:

- Sustainability: Retain the special character of the Tweed. Sustainability as an over-arching, guiding principle for all decision-making. Introduce sustainability indicators and a new annual 'State of the Shire' report.
- Triple Bottom Line: Balance economic, social and environmental objectives.
- Economic Growth: Link economic growth to education and to the Tweed's environmental quality.
- Water Resources: Conserve water resources. Maintain and improve water quality in rivers and estuaries.
- Urban Development: Retain green belts or buffers between settlements.
- Partnerships: Council to form partnerships with government agencies and other parties to tackle priority issues.

Tweed Local Environmental Plan, 2000 and Development Control Plans

The Tweed Local Environmental Plan (TLEP) is the primary planning tool used to guide and control future development by the division of land into zones. The zones designate where development can be carried out and the type of approvals required.

Riparian Buffers

Sections of the Tweed Development Control Plan (DCP) Section A5 Subdivision Manual relevant to riparian zone management and buffers include:

- Development in or adjacent to waterways, water bodies, wetlands or within their catchments must:
  - Ensure preservation of fish and aquatic habitat;
  - Not create barriers to fish passage;
  - Ensure development does not result in pollution or adversely effect quality or quanittiy of flows of waqter into the water way, water body, wetland or habitat;
  - Provide public foreshore reserves and public access to those reserves;
  - Provide a riparian buffer of 50m along major streams (Tweed Rivcer, Rouse River, Oxley River, Cudgen Creek, Cudgera Creek, Mooball Creek and major tributaries) and a width along other streams in accordance with the following:

Upstream Catchment Area (ha) of streams or drains	Buffer Distance (m) (either side of high bank)
< 100 ha	Nil
➢ 100 ha and < 500 ha	10m
➢ 500 ha and < 1000 ha	20m
➢ 1000 ha and < 5000 ha	30m
➢ 5000 ha and < 10000 ha	40m
➢ 10000 ha	50m
Environmentally sensitive*	50m

* > 75% of the catchment and > 1000ha is land zoned "Environmental Protection" 7a, 7f, or 7l or "National Parks and Nature Reserves" 8.

Tweed Local Environment Plan Review

Council is in the process of reviewing the Local Environment Plan (2000). Council have prepared Draft LEP (2008) zonings. These are subject to change, not yet re-issued with Section 65 Certificates, not yet endorsed by Council and not yet exhibited. Draft LEP mapping indicates the following zones:

- foreshores of both broadwaters are zoned E2 – Environmental Conservation
- the instream area of the main creeks are zoned W1 – Natural Waterway
- the instream area of both broadwaters is zoned W2 – Recreational Waterway
- parts of the estuarine riparian zone only are zoned E2 – Environmental Conservation
- the majority of riparian zone is zoned RU2 – Rural Landscape (i.e. it is not protected by E2 zoning).

Based on the high conservation value of both broadwaters, it is recommended that both Cobaki and Terranora Broadwaters are zoned W1 – Natural Waterway. This justification for zoning the broadwater as W1 is clear as W1 is to be applied to *those areas of a waterway with high value aquatic vegetation, threatened species habitat, nursery or other identified environmental value*. Chapters 4 – 6 of this report detail the ecological significance of the broadwaters. While low impact recreation is an important value of the broadwaters, they are largely unnavigable and unsuitable for most water-based recreation. Their primary values are associated with ecological significance.

The Draft LEP waterways zones do not extend onto adjoining riparian land which fails to protect the vital function this area plays in protecting the waterway itself. It is recommended that riparian lands of waterways (at least W1 and W2) be included within the waterway zoning.

Riparian areas could also be protected via zoning and a supporting local clause or a map overlay clause. For example, riparian areas of Piggabeen Creek, Cobaki Creek, Bilambil Creek and Duroby Creek containing a proposed zoning of RU2 could be either included in zoning E2 – Environmental Protection or targeted for the 'Riparian Protection Area' zoning given their importance to ecosystem health and health of the broadwaters generally. The preparation of a 'Riparian Protection Area' map overlay and suggested content for its associated clause is a mechanism to protect riparian areas that are not already protected under E2/E3 zoning. The 'Riparian Protection Area' is to be defined by mapped stream order as follows (Table 2.10):

Table 2.10. Riparian Protection Area designation based on mapped stream orders

Watercourse	**Riparian Protection Area** Watercourse plus distance from watercourse or in tidal reaches from mapped waterway Zone
Mapped 1st order stream Mapped 2nd order stream Mapped 3rd order stream Mapped 4th order stream and above	10 metres 20 metres 30 metres (Major creeks in the catchment) 40 metres

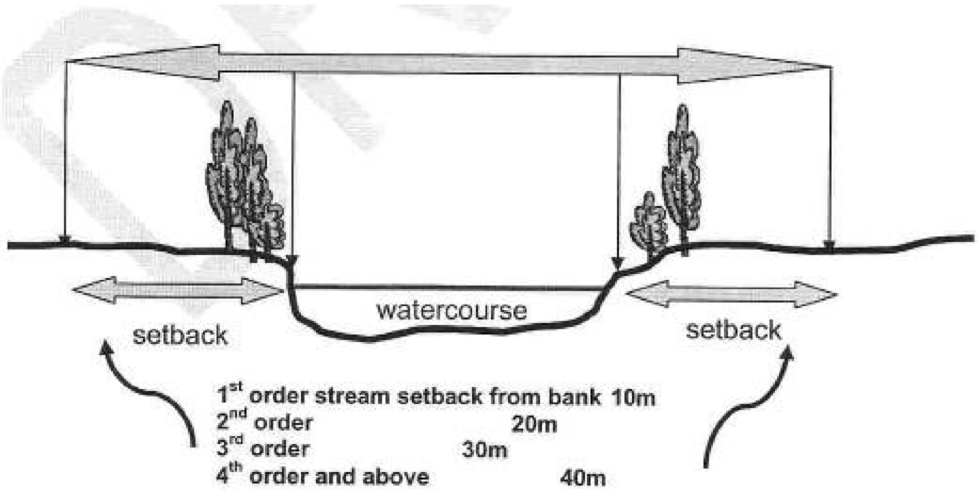


Figure 2.2. Watercourse setback distance requirements

Source: DECC, 2007.

TSC recommends riparian buffers should be 50m from top of the creek. Riparian buffer areas designated within these zones/map overlay areas should be protected by the following clauses:

- No development of roads, buildings or other infrastructure within buffer areas.
- Riparian buffers should be rehabilitated to achieve a fully vegetated under-storey, mid-storey and canopy of native vegetation.
- Riparian buffers should be fenced to prevent cattle accessing waterways.

Tweed Urban Stormwater Quality Management Plan, 2000

This Plan was developed by Tweed Council pursuant to the Protection of the Environment Administration Act, 1991. The stormwater management objectives are based on the principles of Ecologically Sustainable Development and aim to protect nominated Environmental Values by achieving the water quality objectives determined for each urban area of the catchment. The Environmental Values are similar to those subsequently nominated by DECC (1999) (see Table 2.3), however the Interim Water Quality Objectives adopted by TSC in 1998 differ to those set by DECC (1999) (Table 2.11), with the DECC objectives being more stringent.

The Plan sets out the short and long term stormwater management objectives for existing urban areas, for new urban development and for the post construction phase of new development. The short term stormwater management objectives for existing urban areas were expected to be achieved within five years of the adoption of the plan in 2000. Examples of short term objectives include:

- compliance with the estuarine physico-chemical water quality criteria set by ANZECC, and
- no exceedance of pre-development physico-chemical pollutant loading from developing sub-catchments.

The TSC water quality objectives are in the process of being upgraded as part of the update of the Tweed Urban Stormwater Quality Management Plan.

Table 2.11. Tweed Shire Council Interim Water Quality Objectives

Parameter	Fresh Segments		Estuarine Segments	
	TSC (1998)	DECC (1999)*	TSC (1998)	DECC (1999)*
pH	6.5 – 9	6.5 – 8.5	7 – 9.0	7.0 – 8.5
Dissolved Oxygen	>6 mg/L	85-110%	>6 mg/L	80-110%
Suspended Solids	<20 mg/L		<10 mg/L	
Total Phosphorus	**<0.10 mg/L**	**0.025**	**<0.05 mg/L**	**0.03 mg/L**
Total Nitrogen	**<0.75 mg/L**	**0.35**	**<0.5 mg/L**	**0.3 mg/L**
Chlorophyll a	**<10 mg/L**	**0.005**	**<10 mg/L**	**0.004 mg/L**
Faecal Coliforms	<150 No/100mL		<14 No/100mL	

*Water quality objectives for Cobaki and Terranora Broadwater – protection of aquatic ecosystem health.

Aspects of this Plan relevant to post construction stormwater quality treatment measures are discussed further in Section 14.5 of this document.

Tweed Vegetation Management Strategy, 2004

The Tweed Vegetation Management Strategy provides an integration of the Tweed LEP 2000 with the Nature Vegetation Act, providing detailed vegetation mapping, assessment of ecological values and recommendations covering a wide range of Council interests. The Management and Rehabilitation Framework provides strategic direction and priorities for:

1. The recovery of existing bushland areas
2. Restoration of previously cleared areas
3. Threatened species recovery
4. Management of threatening processes, and
5. Education, monitoring , planning and research.

The prioritisation of restoration sites throughout the rural riparian zone and broadwater foreshore has been undertaken with consideration of the principles within the Tweed Vegetation Management Strategy 2004, such as:

- Ensure that 'rehabilitation' means the restoration of degraded vegetation to as near as is practical the previous naturally occurring native vegetation on that site
- Fencing along but not across any vegetation corridor is desirable
- In rehabilitation areas, the removal of stock, fencing and re-establishment of a forest buffer around the area should be a priority
- Proposals for management and rehabilitation works should make provision for ongoing maintenance in addition to establishment costs
- Prioritisation of HCV vegetation remnants, areas subject to land degradation processes, and management of threatening processes such as processes leading to the sedimentation and eutrophication of waterways and management of acid sulphate soils.

The Strategy recognises the setting of overall rehabilitation priorities is dependent on strategic opportunities such as sources of funding, the commitment and willingness of landholders, the track record of the proponents and the level of protection of the site. The mapping contained with this Strategy was utilised in the review of existing data in the development of the CZMP.

Development Control Plans

The following TSC Development Control Plans (DCPs) are discussed in more detail in Sections 14.5 and 14.10:

- DCP D7 – Stormwater Quality (Development Design Specifications)
- DCP A6 – Biting Midge and Mosquito Control

3 Catchment Description

The Cobaki and Terranora Broadwaters lie in Tweed Shire, in the far north eastern corner of New South Wales, adjacent to the Queensland border. A small part of the Cobaki Broadwater catchment crosses the Queensland border. These estuarine systems fall within the NSW North Coast bioregion, recognised as one of Australia's most diverse in terms of natural terrain, flora and fauna. Tweed River has three major tributaries: Oxley River, Rous River and Terranora Creek. There are two broadwater systems that are fed, in total, by four main tributaries and six sub-catchments. Both broadwaters are influenced by the tidal flows to the east of the Tweed River Estuary and the freshwater inputs delivered from the western sub-catchments.

The upper catchments of both systems occur largely within the Terranora Hills physiographic region (Morand, 1996), which is characterised by long north easterly trending ridges interspersed by narrow alluvial plains. The low-lying estuarine landscapes of the two broadwaters have formed in the narrow coastal plain where rivers and streams enter large bodies of water, dissipating channel flow (Ecograph, 2004). (Figure 3.1).

The Terranora and Cobaki Broadwaters are shallow estuarine lakes that discharge into Terranora Creek. The broadwaters are shallow, approximately 0.5 – 1.5m depth and act as the receiving waters for the freshwater catchment. Cobaki Broadwater receives freshwater discharge from Cobaki and Piggabeen Creeks and Terranora Broadwater receives freshwater from Bilambil and Duroby Creeks (Figure 3.1).

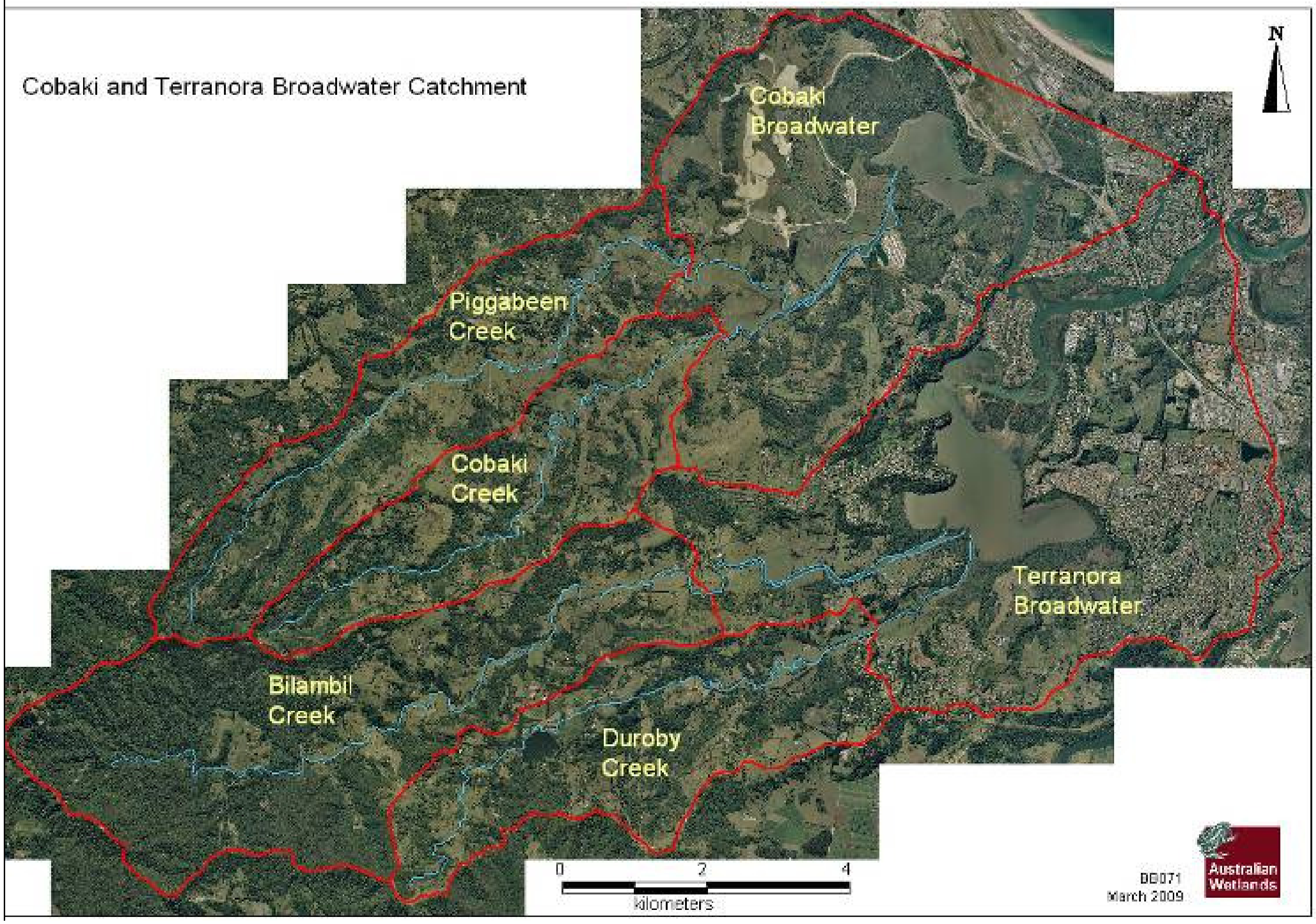


Figure 3.1. Cobaki and Terranora Broadwater catchment

3.1 The Cobaki Broadwater Catchment

From the north-west of the catchment, Piggabeen Creek flows east, almost parallel with Cobaki Creek to the south until it flows into Cobaki Creek approximately 11km from its headwaters. From here, Cobaki Creek estuary, flows east for approximately 2.5km before discharging into Cobaki Broadwater.

The Cobaki Broadwater has been defined as a coastal lake (HRC, 2002). The broadwater is characterised by shallow, saline, often turbid water due to resuspension of the sediment by wind. Water discharges from Cobaki Broadwater into Terranora Inlet, approximately 3.7km upstream of its confluence with the Tweed River. Flows are then directed around a series of SEPP 14 islands into the north-eastern corner of Terranora Broadwater.

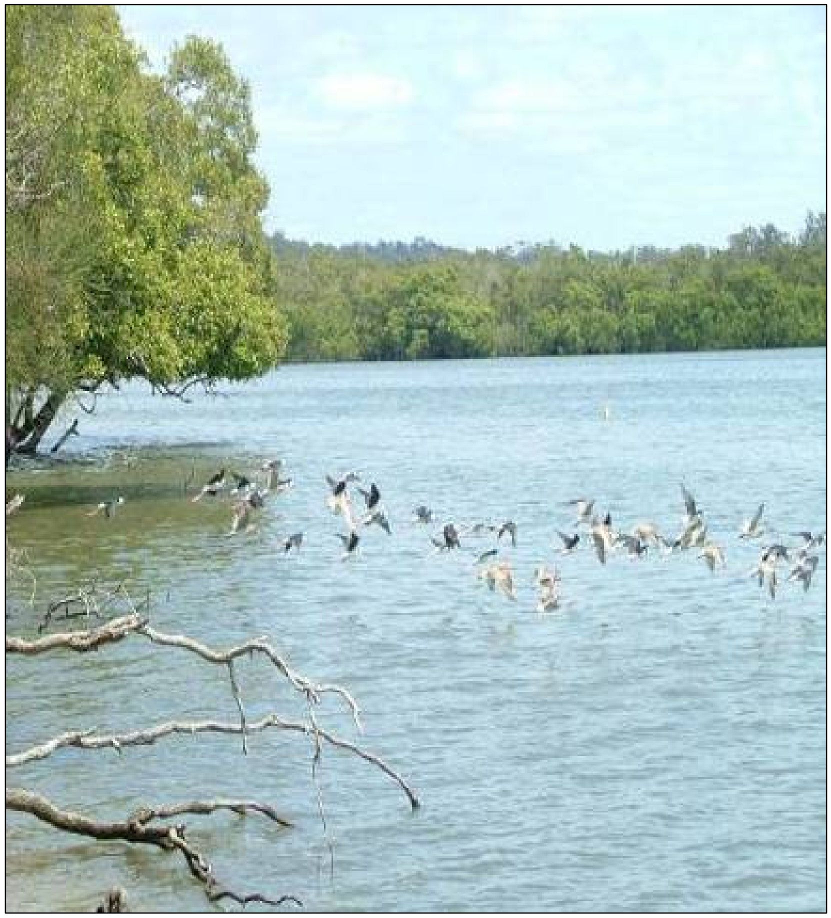


Figure 3.2. Cobaki Broadwater

The Cobaki Broadwater has high conservation, cultural, tourism and economic values and provides habitat for a variety of threatened species including migratory birds and endangered ecological communities. The area contains pristine bushland, rainforest communities and wetland areas including endangered ecological communities and forms part of important regional fauna corridors. The waters provide valuable nursery and breeding grounds for fisheries. The values of the broadwater are provided in more detail in the following sections.

There are a variety of conservation lands around the Cobaki Broadwater being managed by a range of government agencies, organisations and community groups. In the interests of promoting a coordinated approach to the management of the Cobaki Broadwater and surrounding conservation lands, the process of establishing a Memorandum of Understanding (MOU) was initiated in June, 2007. The process is being facilitated by the NSW Department of Environment and Climate Change (DECC) and incorporates a diverse group of stakeholders and participating parties. The MOU will guide and influence the management of the Cobaki Foreshore area via the adoption of overarching principles that promote coordinated sustainable management. Further details of meetings attended as part of the development of this Plan are provided in Appendix A.

Landuse

The majority of the western catchment is currently zoned rural (1a) and incorporates Cobaki Broadwater Village for the Over 50's and Woodlands Lakeside Golf Course. The areas in close proximity to the broadwater are subject to major development pressures. There are several major infrastructure/urban development projects that have been recently completed or are currently underway that are in close proximity to the Cobaki Broadwater which may impact the ecology and sustainability of the broadwater. These include:

- The construction of the Pacific Highway Tugun Bypass;
- The Gold Coast Airport runway extension;
- The construction of the de-salination plant;
- The development of Cobaki Lakes Estate;
- The development of Bilambil Heights;
- Construction of the Piggabeen Road realignment.

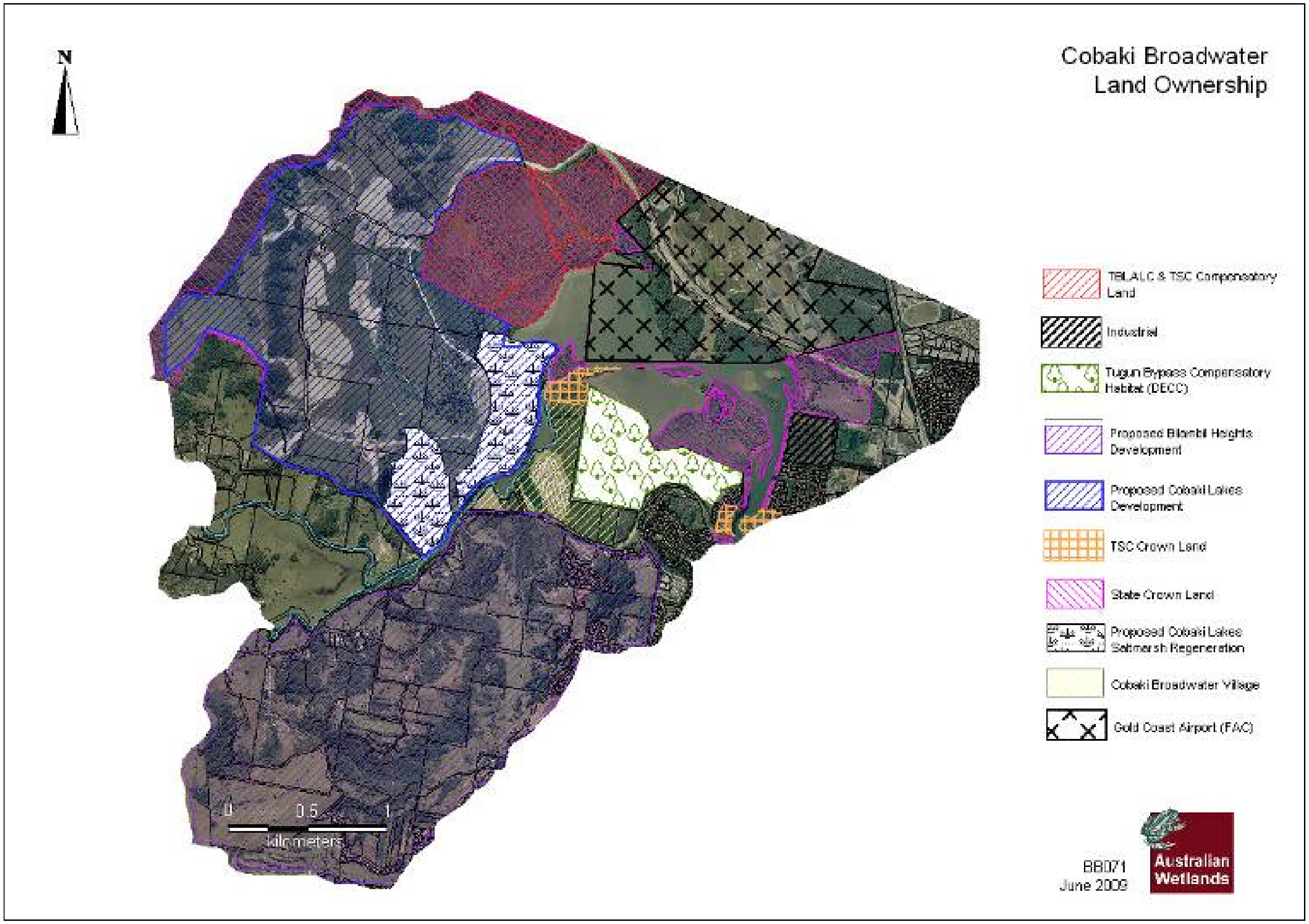


Figure 3.3. Cobaki Broadwater land ownership

3.2 The Terranora Broadwater Catchment

From the south-west of the catchment, Bilambil Creek flows east for 14km, almost parallel with Duroby Creek to its south which flows for approximately 9km. Both creeks discharge into the south-west corner of Terranora Broadwater south of Charles Bay. Terranora. Broadwater is also a shallow, turbid coastal lake (HRC, 2002) that consists of several large bays.

Figure 3.4. Terranora Broadwater

The main catchment inputs to the Terranora Broadwater are delivered via these two creeks from the western rural catchments, the Tweed River, and urban stormwater discharged to Trutes Bay. Trutes Bay is situated in the south-east corner of Terranora Broadwater and receives stormwater discharged from the large urban catchment of Tweed Heads South via the ‘Western Drainage Scheme’ which incorporates a series of stormwater drains connected to Vintage Lakes. The other major source of discharge to the system is the Banora Point Waste Water Treatment Plant which releases treated effluent (including that of West Tweed Waste Water Treatment Plant) to Terranora Creek on the ebb tide on the south side of the Pacific Highway Bridge.

The Terranora Broadwater is one of the few remaining rich and diverse habitats in the Tweed River System (TSC 1994, cited in Area E LES p.60). Terranora Broadwater has high conservation value, providing significant aquatic habitat with extensive wetland vegetation including seagrass, mangroves, saltmarsh and freshwater swamp communities. The inter-tidal flats provide important feeding and roosting areas for migratory birds. Trutes Bay is recognised as supporting the highest diversity of wader birds in the area.

The broadwater is also highly valued for its cultural, tourism, recreational and economic values. There are many highly significant Aboriginal shell midden sites, particularly along the eastern foreshore. The Terranora Creek system provides habitat for a number of commercial and recreationally important fish species (STP EIS). The values of the broadwater are provided in more detail in the following sections.

Landuse

Terranora Broadwater's catchment is largely rural to the west, however the eastern urban catchment is heavily developed, encompassing Tweed Heads South, Banora Point, Club Banora Golf Course, Tweed Sewage Treatment Works, Banora Point Sewage Treatment Works, two canal estates and Seagull's Estate.

Most of the foreshore land is publicly owned, with a great percentage designated as 'Community Land' (Figure 3.5). The four main estuarine islands (Caddys, Daveys, Big and Womgin Islands) are managed as part of the Tweed Estuary Nature Reserve. There are several Crown Land areas managed by TSC, the largest being Charles Bay Reserve.

Most of the urban land to the east of the broadwater is zoned for Urban Expansion. There are plans for a large housing estate immediately to the south of the broadwater, known as 'Area E', the construction of which will need to be carefully conducted and impacts mitigated to prevent any loss to sustainability of the Terranora Broadwater.

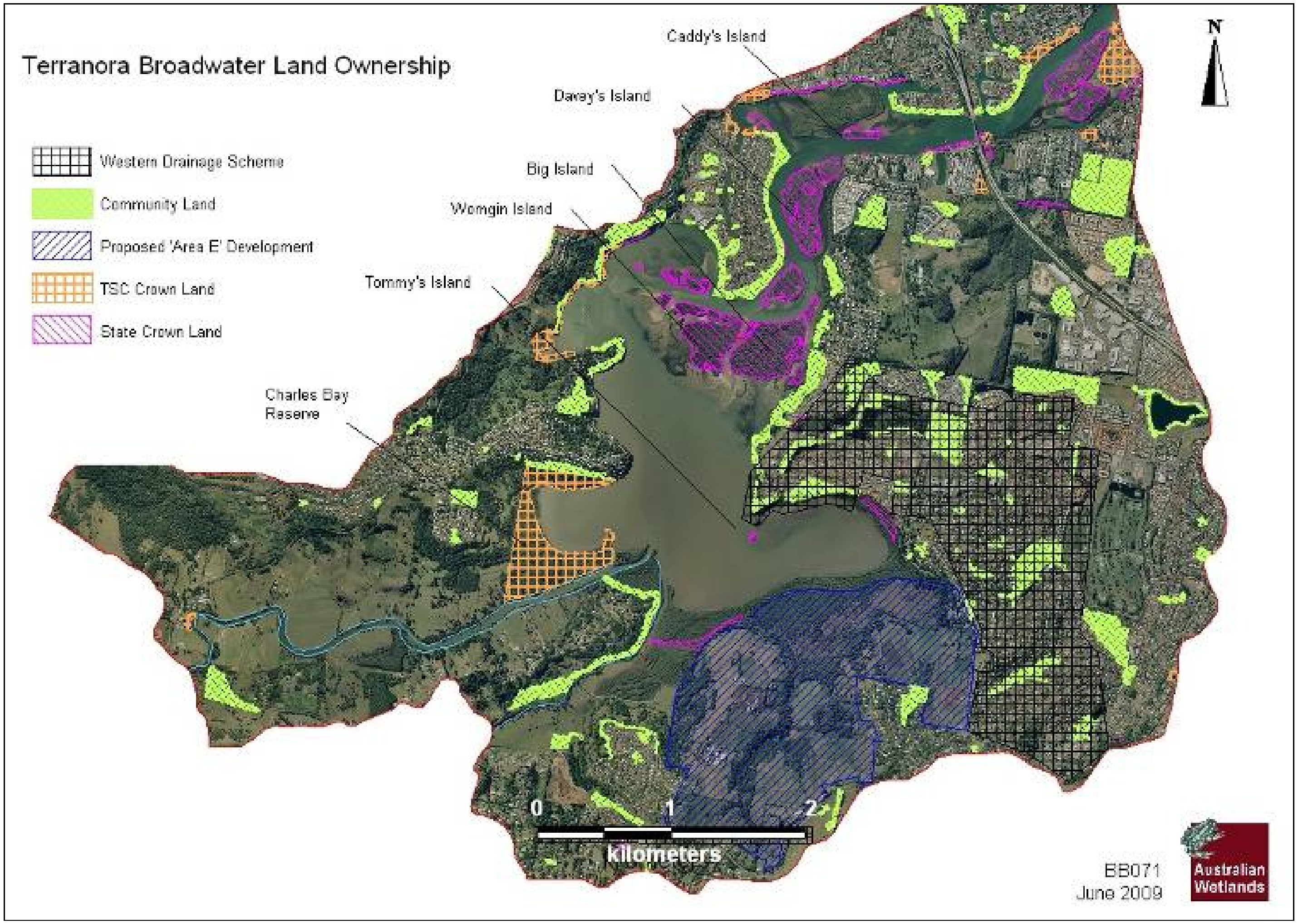


Figure 3.5. Terranora Broadwater land ownership

3.3 The Cobaki – Terranora Broadwater Functional Zones and Ecosystem Ecology

The Cobaki – Terranora Broadwater ecosystem is regarded as a continuum of interconnected aquatic, riparian and catchment zones containing diverse ecological communities. Ecological communities include all the organisms that occur in that particular area. An ecological community may also be recognised as a group of animal species that occur together in a particular area, such as an endangered shorebird community in Terranora Broadwater.

The survival of each species relies on complex interactions amongst all of the inhabitants of an ecological community, through biotic mechanisms such as food webs, mutualisms and pollination, as well as abiotic mechanisms such as water, nitrogen and carbon cycles (DECC, 2005). Consequently, the loss of any species or long term disruption to internal recycling may have detrimental flow-on effects for the ecological functioning of the whole community.

To ensure the sustainability of the system, including the maintenance of water quality, a whole of catchment approach is needed as each component of the system impacts upon the other. An understanding of each component and associated processes is therefore necessary. To do this, the catchment has been divided into Functional Zones based on the progressive changes in catchment characteristics (vegetation, geomorphology, in-stream processing) from the fresh waters of the headwaters to the saline lowland broadwaters (Figure 3.6).

A conceptual overview of the catchment zonation and progression from upland slopes to estuarine broadwaters is illustrated in plan view and cross section in Figure 3.7 below.

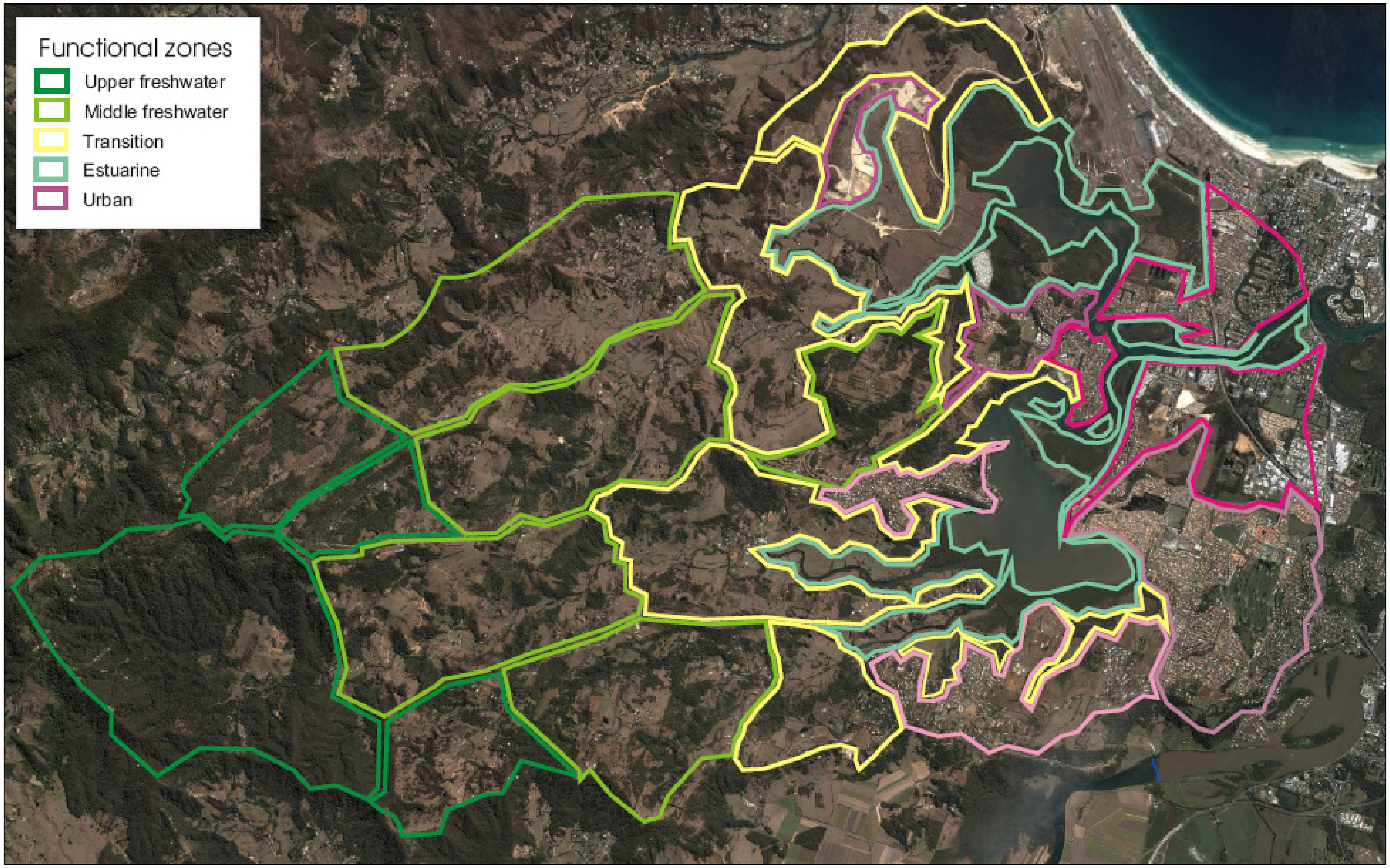


Figure 3.6. Functional zones of the Cobaki – Terranora Broadwater catchments

Source: ABER, 2009

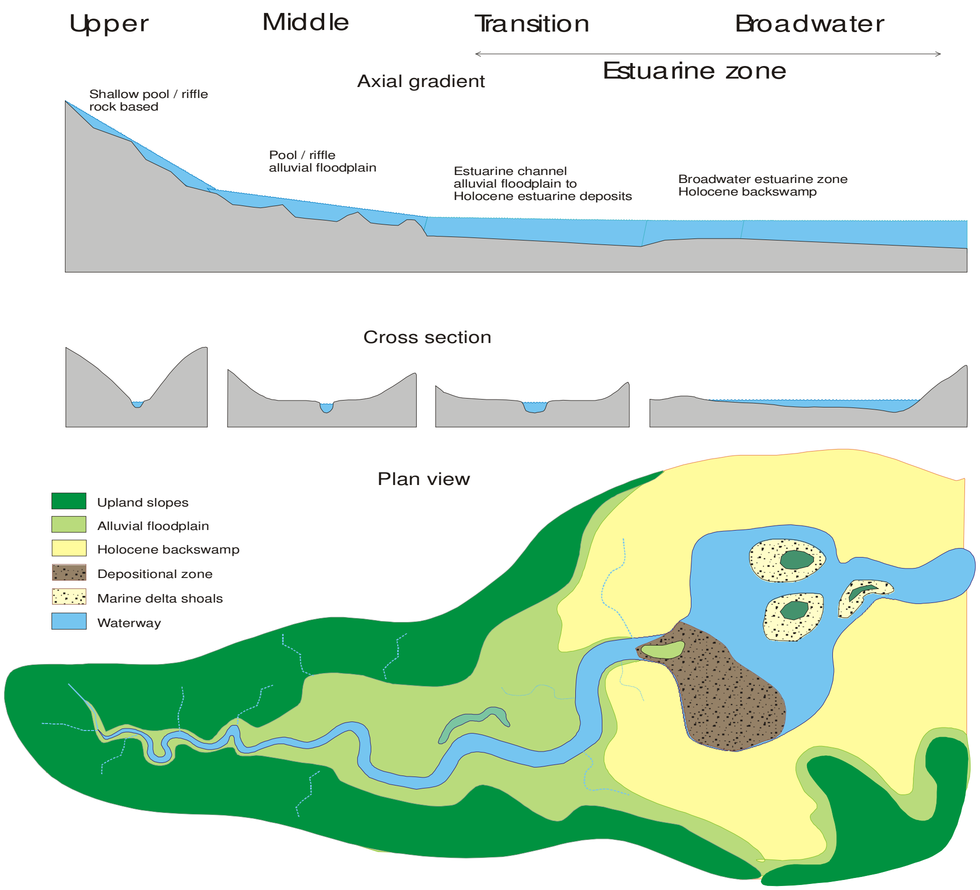


Figure 3.7 Conceptual diagram of catchment zonation in cross section and plan view.

Source: ABER, 2009

3.3.1 Upper Freshwater Zone

The upper catchment contains the headwaters of each creek and is characterised by steeper upland slopes and remnant or early regrowth rainforest vegetation communities. The creek bed is rocky and the channel is typically narrow, shallow and fast flowing with a series of pools and riffles. Riparian vegetation overhangs the creek, providing shade and lower water temperate.

Figure 3.8. Bilambil Creek upper zone (Site 9)

Table 3.1. Primary ecosystem attributes and threats of the upper zone

Primary Ecosystem Attributes	Threats to Ecosystem Health
Pool-riffle (rock based) continuum	Lack of riparian vegetation cover
Low baseflows with episodic high flow events	Stock access to waterways
Overland runoff via ephemeral channels	Sediment/nutrient loads from erosion zones such as landslips
Dense over-hanging riparian vegetation, commonly rainforest	Point source pollution such as septic systems
Low light aquatic habitat	Weed invasion
Organic carbon inputs are driven by the riparian zone	Water extraction

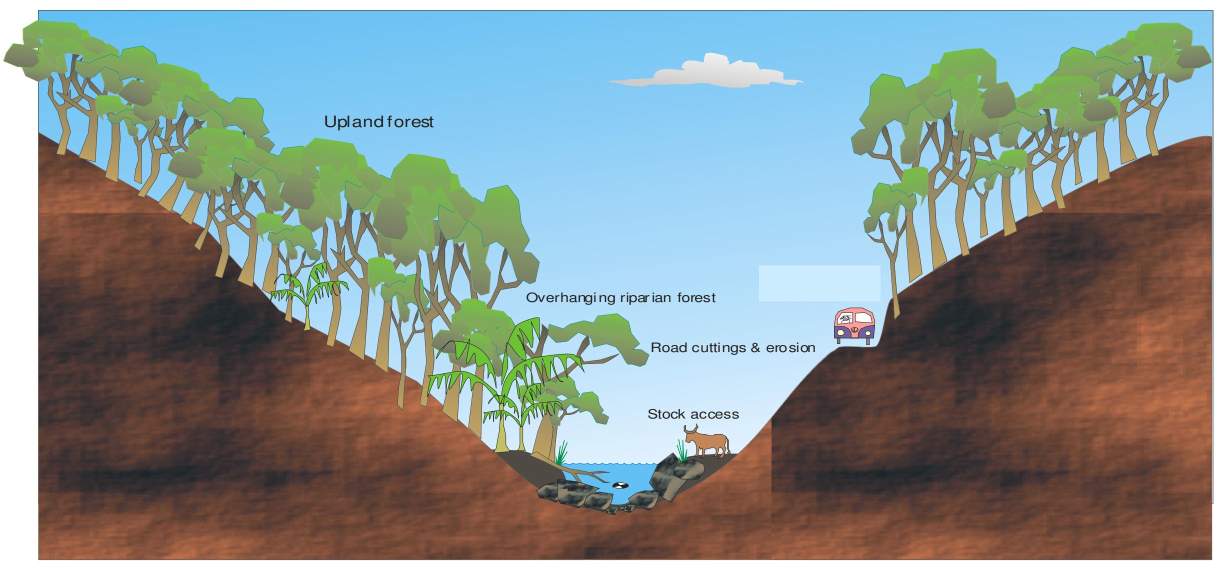


Figure 3.9. Conceptual representation of the primary ecosystem attributes (left bank) and examples of threats to ecosystem health (right bank) typical of the upper catchment functional zone.

Source: ABER, 2009

3.3.2 Mid Freshwater Zone

Throughout the mid catchment, the gradient of the creek bed decreases, slowing flow as it flows through the alluvial floodplain. The channel remains relatively narrow as it flows through the widening floodplain which marks the start of widespread catchment clearing for stock grazing and rural residential areas. Remnant rainforest overhangs the creek, grading back to wetlands and then upland forest. Camphor Laurel dominated forest is often found in the mid – transition zones.

Figure 3.10. Piggabeen Creek mid zone (Site 17).

Table 3.2. Primary ecosystem attributes and threats to the mid zone

Primary Ecosystem Attributes	Threats to Ecosystem Health
Pool-riffle continuum (alluvial floodplain)	Lack of riparian vegetation cover
Low baseflows with episodic high flow events	Stock access to waterways
Overland runoff via ephemeral channels	Sediment/nutrient loads from erosion zones
Dense over-hanging riparian vegetation, commonly rainforest	Point source pollution such as septic systems
Low light aquatic habitat	Weirs and other instream obstructions
Organic carbon inputs are driven by the riparian zone	Weed invasion
	Water extraction

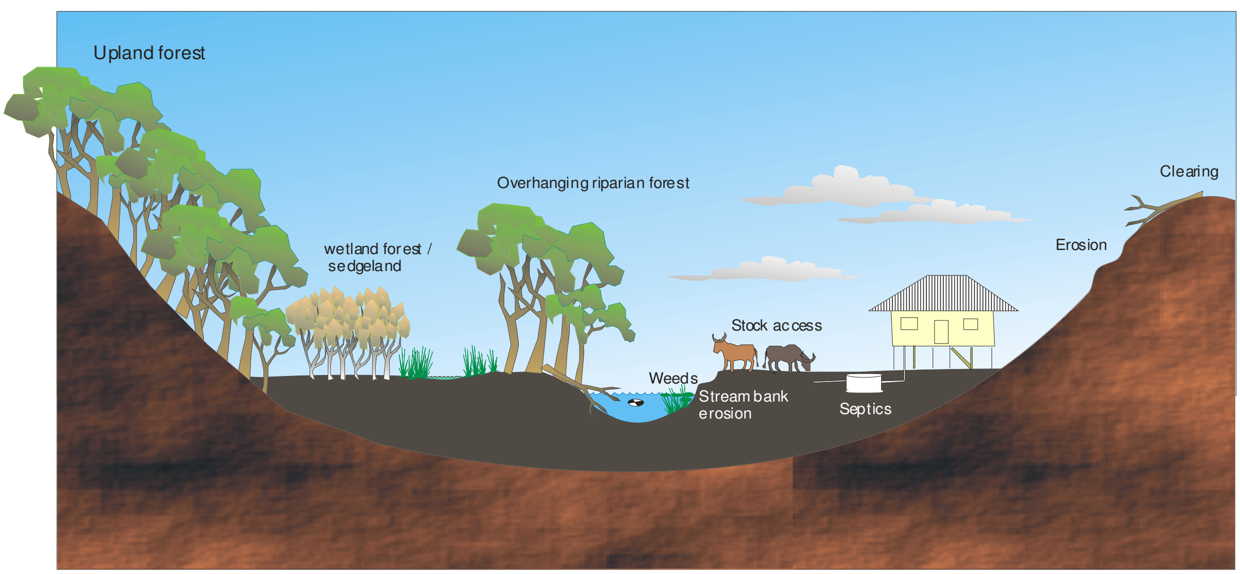


Figure 3.11. Conceptual representation of the primary ecosystem attributes (left bank) and examples of threats to ecosystem health (right bank) typical of the mid catchment functional zone.

Source: ABER, 2009

3.3.3 Transition Zone

The transition zone is the section of the catchment that marks the transition between the upper freshwater reaches to the estuarine zone and as such contains characteristics of both the mid and lower/estuarine zones. The channel widens throughout this zone and overlies alluvial floodplain to Holocene estuarine deposits and water flow slows. The vegetation is a mixture of mangroves, saltmarsh and ephemeral freshwater wetlands and is typically a highly degraded area of the catchment.

Figure 3.12, Piggabeen Creek transition zone (Site 20)

Table 3.3. Primary ecosystem attributes and threats to the transition zone

Primary Ecosystem Attributes	Threats to Ecosystem Health
Floodplain with relic cut-off channels	Lack of riparian vegetation cover
Freshwater-estuarine transition area	Stock access to waterways
Low flows with episodic high flow events	Sediment loads derived from erosion zones
Catchment outlets	Point source pollution such as septic systems
Floodplain forest with semi-permanent wetlands	Weirs and other instream obstructions
Medium light aquatic habitat	Weed invasion
Organic carbon inputs are driven by the riparian zone and upper catchment	Acid sulphate runoff

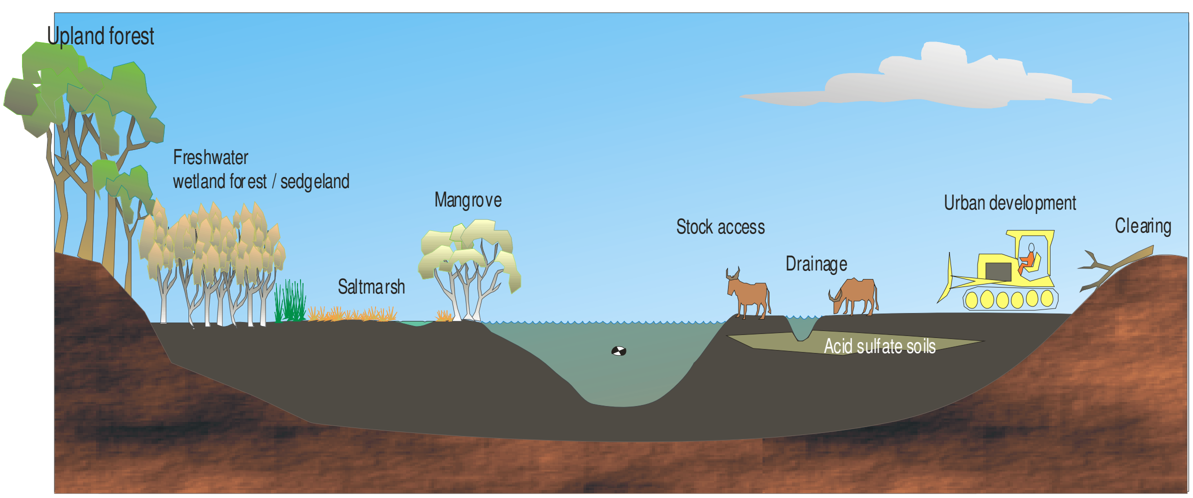


Figure 3.13. Conceptual representation of the primary ecosystem attributes (left bank) and examples of threats to ecosystem health (right bank) typical of the transition functional zone.

Source: ABER, 2009

3.3.4 Estuarine Zone

The lower zone is the true estuarine zone of the catchment. The creek channel widens again, slowing water flow before it discharges to the shallow broadwaters. Vegetation is primarily mangrove-dominant and the catchment is often cleared for urban development or cattle grazing.

Figure 3.14. Bilambil Creek estuarine zone (Site 5)

Table 3.4. Primary ecosystem attributes and threats to the estuarine zone

Primary Ecosystem Attributes	Threats to Ecosystem Health
Brackish estuarine channel with minor tidal tributaries	Lack of riparian vegetation cover
Mangrove-saltmarsh-wetland forest riparian zone	Stock access to waterways
Tidal influence	Sediment/nutrient loads from catchment
Medium light aquatic habitat	Point source pollution such as septic systems
Organic carbon inputs are driven by phytoplankton, the riparian zone and the upper catchment.	Weirs and other instream obstructions
	Weed invasion
	Acid drainage

3.3.5 Broadwater Zones

The broadwaters are Holocene backswamps characterised by shallow, more turbid depositional zones receiving discharge from the upper catchment and clearer, marine delta zones more influenced by estuarine/marine influences.

Figure 3.15. Terranora Broadwater, Bingham Bay

Table 3.5. Primary ecosystem attributes and threats to health of the broadwater zones

Primary Ecosystem Attributes		**Threats to Ecosystem Health**
Depositional Zone	**Marine Delta Zone**	
Shallow, infilling depositional basin	Shallow, inter-tidal and sub-tidal marine delta shoals	Lack of riparian vegetation cover
Brackish tidal	Brackish tidal	Urban stormwater (including construction)
Episodic pulses of freshwater	Episodic pulses of freshwater	Sediment/nutrient loads from the catchment
Longer residence times	Shorter residence times	Weirs and other instream obstructions
Mangrove – saltmarsh – wetland – rainforest riparian zone	Seagrass beds	Acid sulphate soils
Tidal and wind drive resuspension	Mangrove – rainforest riparian zone	Sewage spills, overflows and discharge
Medium light aquatic habitat	High light aquatic habitat	
Organic inputs driven by phytoplankton, benthic microalgae and upper catchment	Organic carbon inputs drive by phytoplankton, benthic microalgae and seagrass	

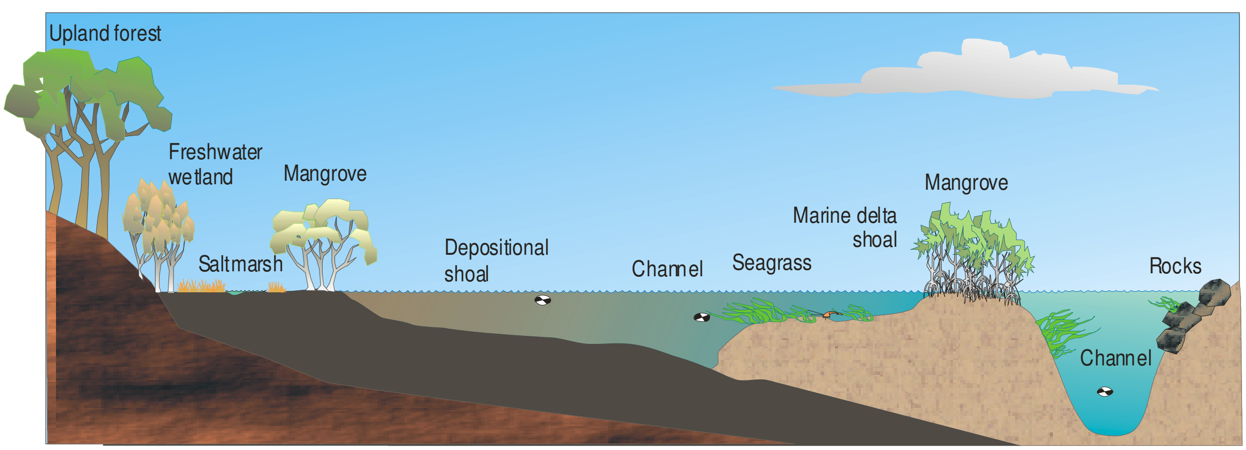


Figure 3.16 Conceptual representation of the primary ecosystem attributes typical of the depositional zone (left side) and the marine delta zone (right side).
Source: ABER, 2009

3.3.6 Internal Recycling within Functional Zones

In general, Australian systems are characterised by a predominance of organic nutrient inputs (e.g. leaf litter). Increasing inorganic nutrients (e.g. nitrate, phosphate) stimulates internal productivity (e.g. phytoplankton) which can result in foodchain shifts, poor light climate and low dissolved oxygen all of which impact on the health of the system and the aquatic life that depend upon these conditions. Internal recycling is an important process which determines the quality of material delivered to the broadwaters. The processes occurring differ between functional zone and under different flow scenarios.

Low Flow

During low flow, internal recycling processes become relatively more important due to the higher residence time of the water. This results in the consumption of inorganic nutrients and delivery of organic material (e.g. phytoplankton) to the broadwater. Phytoplankton are free-floating flora that convert inorganic compounds into complex organic compounds. Their cumulative energy fixation in carbon compounds (primary production) is the basis for the vast majority of marine and many freshwater food webs. Phytoplankton are dependant on a source of light, carbon and inorganic nutrients. Figure 3.17 shows the recycling interactions occurring throughout the catchment under low flow conditions which are the typical flow conditions for this catchment. Figure 3.18 illustrates the difference to recycling interactions during median flow conditions such as the increased contribution from groundwater flow, instream erosion and construction runoff. The lowest scoring indicator in freshwater creeks in the recent EHMP study (IWC, 2009) was Nutrient Cycling, due to a breakdown of natural nitrogen cycling processes and elevated TN and TP. As illustrated conceptually in Figure 3.20, internal recycling is important to the pelagic and benthic foodchain and therefore crucial to the ecological health of the system.

High Flow

Conversely, during high flow, the internal recycling processes are largely by-passed due to the low residence time of water, resulting in the delivery of large quantities of inorganic nutrients and suspended solids to the broadwaters. Figure 3.19 is a conceptual illustration of recycling interactions typical of a high flow event. The width of the arrows indicates the increasing contribution or impact, particularly from the upper catchment and overland flow.

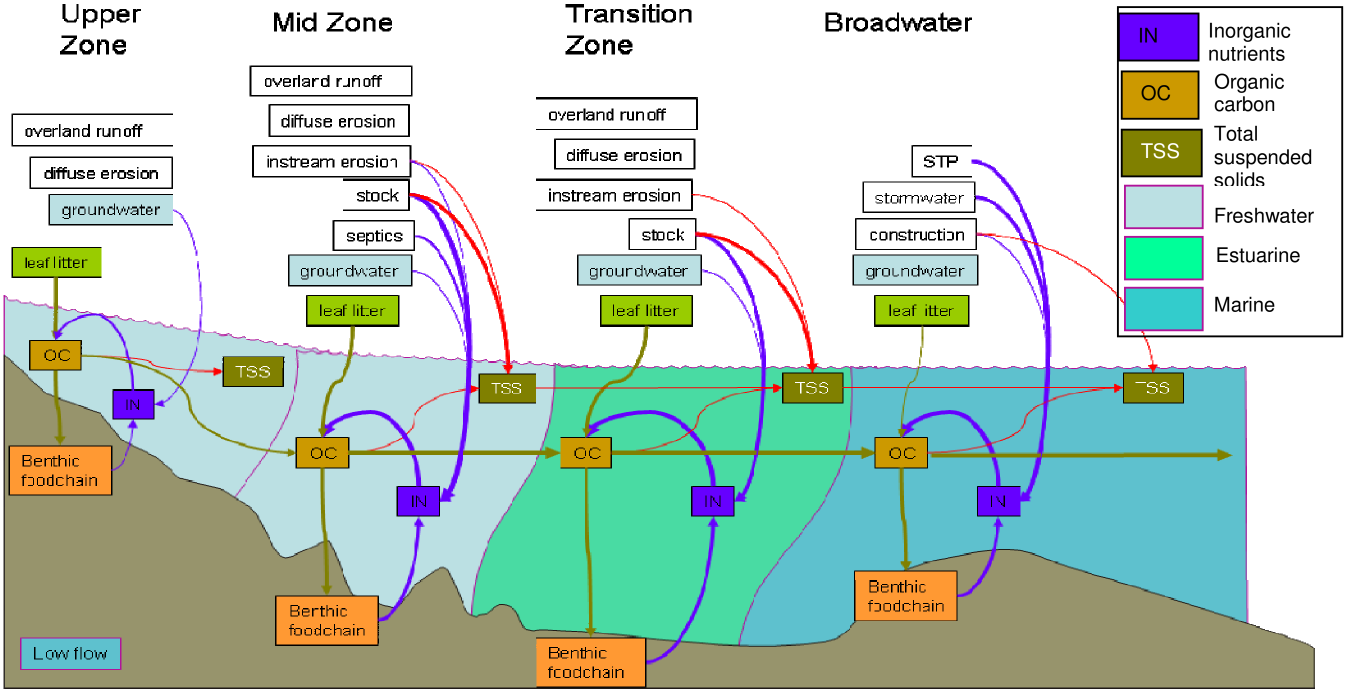


Figure 3.17. Recycling interactions within functional zones throughout the catchment under low flow conditions

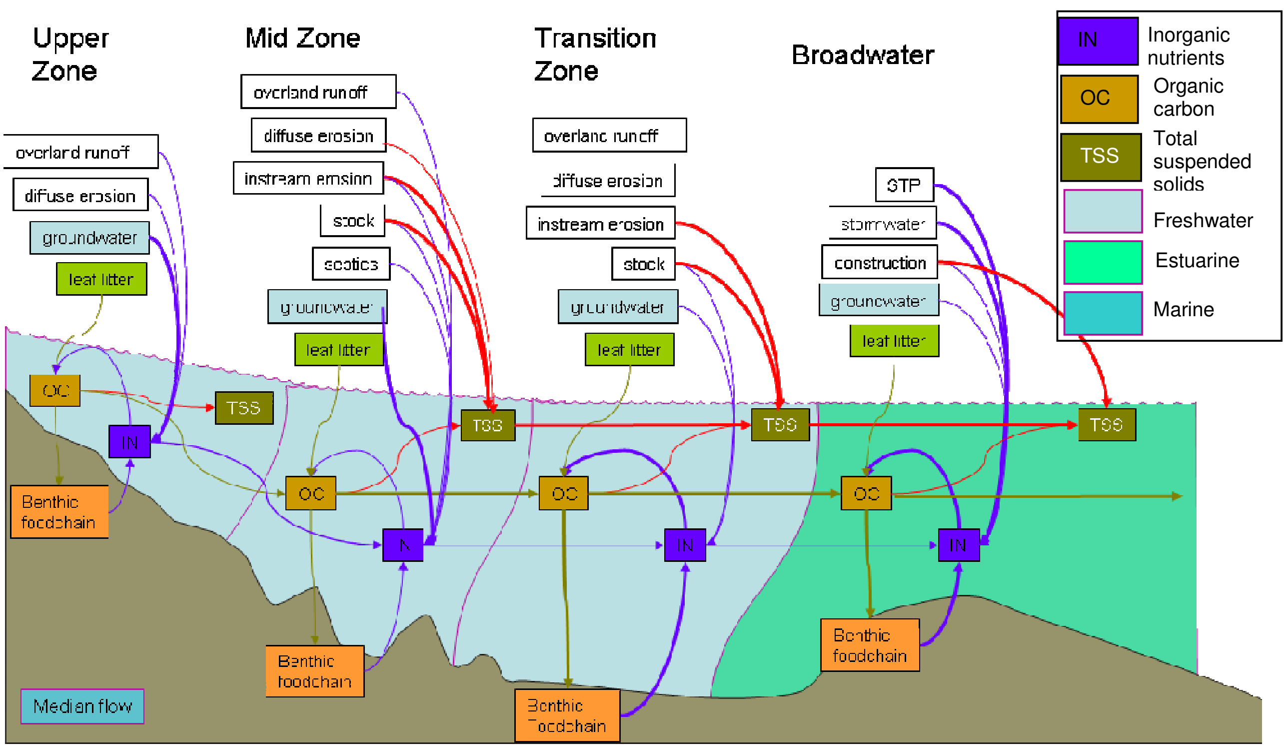


Figure 3.18. Recycling interactions within functional zones throughout the catchment under median flow conditions

Source: ABER, 2009

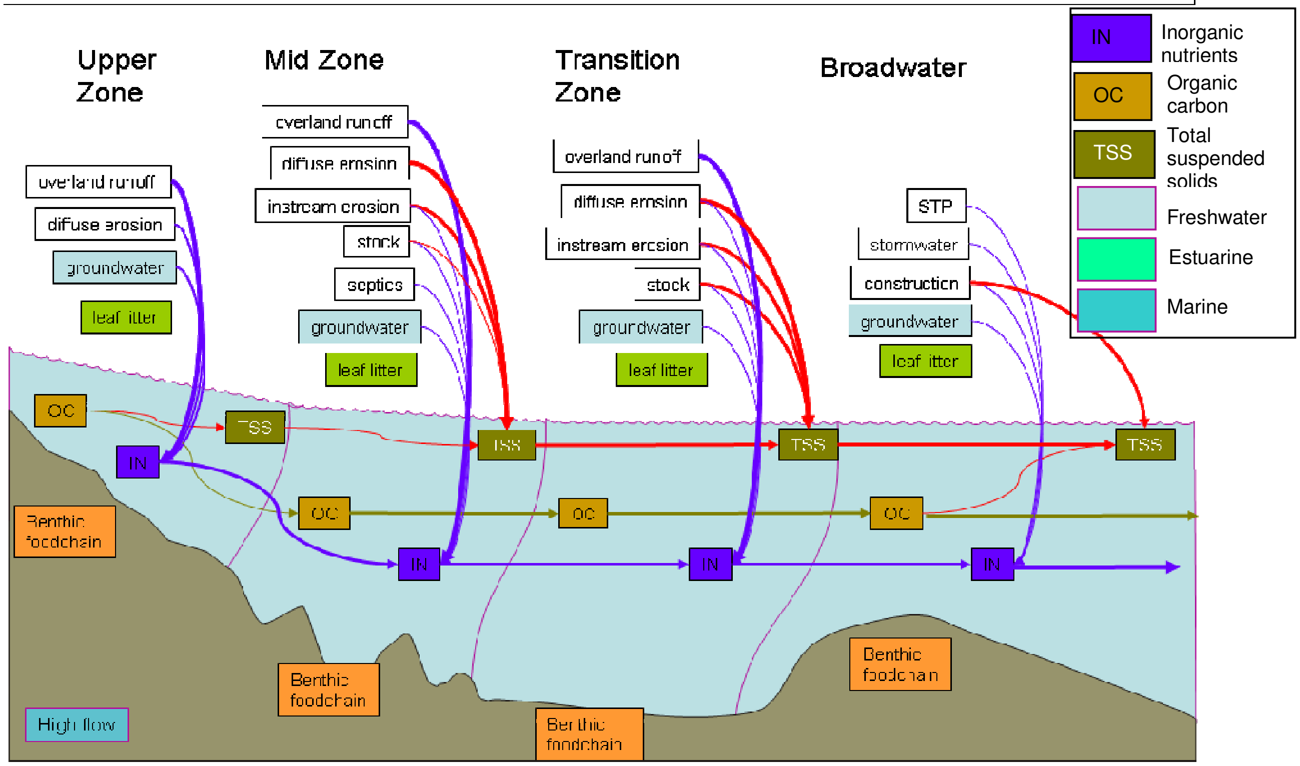


Figure 3.19. Recycling interactions within functional zones throughout the catchment under high flow conditions

Source: ABER, 2009

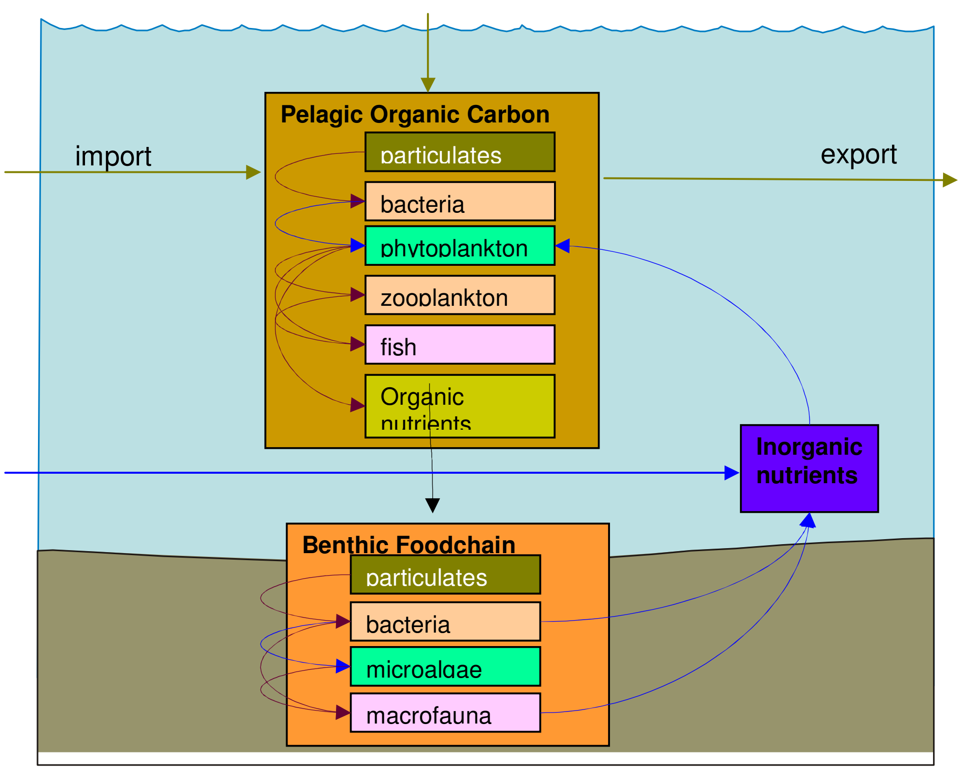


Figure 3.20. Primary components of the pelagic organic carbon and benthic foodchain compartments and internal recycling interactions.

Source: ABER

Impact of Catchment Management

An excess of inorganic nutrients in the shallow, high residence environment of the broadwaters could create an undesirable increase in phytoplankton, i.e. an algal bloom. Typical sources of inorganic nutrients from the catchment include:

- STP discharge
- Stock accessing waterways (including ephemeral drainage channels)
- Instream and diffuse erosion
- Septic systems
- Urban stormwater
- Groundwater
- Overland runoff

An excess of suspended solids can inhibit the light environment required by phytoplankton and seagrass to photosynthesise, thus reducing the ability of internal recycling of inorganic nutrients and organic carbon and decreasing dissolved oxygen. In addition to ecological health impairment, increasing the delivery of suspended solids to the broadwater accelerates the infilling of the broadwaters.

Areas of the catchment (and in particular the riparian zone) that have been cleared, where bank erosion is occurring, where stock enter the waterways, where wastewater is discharged as a point or diffuse source, where construction erosion and sediment controls fail and where urban stormwater is insufficiently treated all contribute to the disruption of the internal recycling of the system, determine the quality of material delivered to the broadwaters and ultimately the remaining assimilative capacity of the system. Once the assimilative capacity is exceeded, internal recycling will be inefficient (as suggested by nutrient cycling data from the EHMP study (IWC, 2009), impacting upon the foodchain including macrofauna such as the local bird populations (which are showing signs of decline). A healthy, well vegetated riparian zone is imperative to healthy internal recycling and thus ecosystem health. Section 4.2.4 discusses the riparian zone further.

Once the assimilative capacity is exceeded, internal recycling will be inefficient (as suggested by nutrient cycling data from the EHMP study (IWC, 2009), impacting upon the foodchain including macrofauna such as the local bird populations.

An understanding of the ecological nature of these zones and the processes that sustain them is central to the development of the management plan's strategies.

4 Ecological Values

4.1 Vegetation Communities

There are several factors that highlight the importance of undertaking assisted natural regeneration of the high quality remnants, rehabilitating degraded/cleared sites and maintaining those newly regenerating sites. Some key factors include:

- A great majority of the catchment has been significantly cleared of native vegetation in both urban and rural areas (Figure 4.1).
- All remaining native vegetation on the coastal floodplain has been identified as threatened and listed as an Endangered Ecological Community under the Threatened Species Conservation Act 1995.
- All remnant wetlands surrounding the broadwaters are SEPP14.
- Throughout the catchment, remaining vegetation plays a crucial role as a wildlife corridor (Tweed Vegetation Management Strategy, 2004).

4.1.1 Cobaki Broadwater Sub-catchments

All vegetation remnants surrounding Cobaki Broadwater are of High Conservation Value (HCV) and are classed as ‘Very High’ ecological status and ‘High’ ecological sensitivity in the Tweed Vegetation Management Strategy (Ecograph, 2004). The riparian vegetation of the Cobaki Broadwater foreshore is in generally good condition (IWC, 2009). These remnants are extremely valuable habitat and are included in the Regional Corridor as a key habitat linkage (Ecograph, 2004). There are multiple land managers of these foreshore remnants that comprise the following native vegetation communities (Ecograph, 2004):

- Mangrove Low Closed Forest to Woodland
- Swamp She-oak Closed Forest to Woodland
- Broad-leaved Paperbark/Swamp She-oak Closed Forest to Woodland
- Broad-leaved Paperbark Closed Forest to Woodland
- Coastal Scribbly Gum Open Forest to Woodland
- Wet Heathland to Shrubland
- Coastal Swamp Mahogany Open Forest to Woodland
- Broad-leaved Paperbark + Eucalyptus spp. +/- Swamp box Closed Forest to Woodland
- Coastal Pink Bloodwood Open Forest to Woodland
- Coastal Acacia Communities
- Blackbutt Open Forest Complex
- Lowland Rainforest on Floodplain
- Coastal Forest Red Gum Open Forest to Woodland
- Littoral Rainforest
- Saltmarsh

The large Lower/Estuarine zone to the north-west of the broadwater has been substantially cleared of native vegetation (Figure 4.1). The Transition zone to the north-west of the broadwater contains remnant Blackbutt Open Forest Complex which combined with Sedgeland, Tallowwood Open Forest and Brush Box Open Forest is the only remaining native bushland in the largely cleared Transition Zone of Cobaki and Piggabeen Creeks.

The lower reaches of the mid zones of Cobaki and Piggabeen Creeks have also been substantially cleared of native vegetation (Figure 4.1), however the vegetation remnants of the mid-upper zones form part of the Regional Corridor providing Key Habitat Linkages. The north bank of the upper mid reach of Piggabeen Creek contains a large remnant of Grey Ironbark/White Mahogany/Grey Gum Open Forest Complex (very high ecological sensitivity) while the south bank has small patches of Early Regrowth Rainforest (HCV Bushland) grading into a large remnant of Tallowwood Open Forest (very high ecological status). The upper mid zone of Cobaki Creek contains remnant Brush Box Open Forest and Sub-tropical/Warm Temperate Rainforest on Bedrock Substrates (HCV Bushland, very high ecological status, high ecological sensitivity) areas of Early Regrowth Rainforest (high ecological sensitivity). The upper zone of both creeks is primarily Early Regrowth Rainforest.

4.1.2 Terranora Broadwater Sub-catchments

All vegetation remnants surrounding Terranora Broadwater are of High Conservation Value (HCV) and are classed as ‘Very High’ ecological status and ‘High’ ecological sensitivity in the Tweed Vegetation Management Strategy (Ecograph, 2004). The riparian vegetation of Terranora Broadwater is in generally good condition (IWC, 2009). These remnants are extremely valuable habitat and are included in the Regional Corridor as a key habitat linkage (Ecograph, 2004). Almost all these remnants are owned/administered by TSC.

There are several significant remnants of bushland surrounding Terranora Broadwater (Figure 4.1). There is a large remnant of Mangrove Low Closed Forest to Woodland along the southern boundary of Terranora Broadwater that is classed HCV Bushland, high ecological sensitivity and of very high ecological status. This area requires rehabilitation in association with the development of Area E and is adjacent to remnant Broad-leaved Paperbark Closed Forest to Woodland, Brush Box Open Forest, Broad-leaved Paperbark/Swamp She-oak Closed Forest to Woodland, Shedgeland/Rushland, Lowland Rainforest on Floodplain and Saltmarsh.

The south-western corner of the broadwater contains a mosaic of:

- Mangrove Low Closed Forest to Woodland
- Coastal Forest Red Gum Open Forest to Woodland
- Swamp She-oak Closed Forest to Woodland
- Broad-leaved Paperbark/Swamp She-oak Closed Forest to Woodland
- Broad-leaved Paperbark Closed Forest to Woodland
- Early Regrowth Rainforest
- Sub-tropical/Warm Temperate Rainforest on Bedrock Substrates
- Grey Ironbark/White Mahogany/Grey Gum Open Forest Complex

The north-west area of the broadwater is remnant Brush Box Open Forest and Tallowwood Open Forest and the eastern zone has a narrow strip of Grey Ironbark/White Mahogany/Frey Gum Open Forest Complex. The islands of the broadwater contain Mangrove Low Closed Forest to Woodland, Swamp She-oak Closed Forest to Woodland and Saltmarsh communities (Figure 4.1).

The Lower/Estuarine and Transition Zones of Bilambil and Duroby Creeks have been substantially cleared of native vegetation and have small remnants of Early Regrowth Rainforest. The Transition Zone of these sub-catchments is also substantially cleared and has large stands of Camphor Laurel Dominant Closed to Open Forest. The mid riparian zone of Duroby Creek is primarily a large remnant of Early Regrowth Rainforest (high ecological sensitivity) moving into Sub-tropical/Warm Temperate Rainforest on Bedrock Substrates (very high ecological status and high ecological sensitivity) upstream. The mid riparian zone of Bilambil Creek is also Early Regrowth Rainforest but it has been more substantially cleared.

Upper Duroby Creek has been substantially cleared, with only small pockets of Flooded Gum Open Forest and Early Regrowth Rainforest (Figure 4.1). Upper Bilambil Creek is well-forested with Sub-tropical / Warm Temperate Rainforest on Bedrock Substrates (very high ecological status and high ecological sensitivity), some Early Regrowth Rainforest (high ecological sensitivity), Brush Box Open Forest, Tallowwood Open Forest (very high ecological status) and Grey Ironbark/White Mahogany /Grey Gum Open Forest Complex.

4.2 Habitat

The two broadwaters and their catchments incorporate a number of terrestrial and aquatic habitats under both private and public ownership. Ecological communities present include freshwater and estuarine wetlands, coastal woodland, wet sclerophyll forest, swamp forest, and littoral rainforest, ranging in condition from relatively pristine to degraded. Key fish habitat, as mapped by the Department of Industry and Investment (2007) incorporates the broadwaters, creeks and riparian zones, including those areas tidally inundated (Figure 4.1). The key habitat values of the catchment are described below.

The Cobaki Broadwater is considered to provide Class 1 or major fish habitat under NSW Fisheries Guidelines (NSW Fisheries, 1999), significant as the majority of commercially and recreationally important fish species of eastern Australia rely on the estuarine environment for at least part of their life cycle. Most of the species taken from the broadwaters and surrounding coastal waters of the Tweed rely on the mangroves and shallow waters (FRC Environmental, 2001). There are also well developed benthic communities within Cobaki Broadwater (Bilambil Heights Environmental Constraints Analysis, 2007).

Vegetation communities dominated by Swamp Mahogany and/or Forest Red Gum are considered to provide primary habitat for Koalas (FRC Environmental, 2001). The larger remnant Coastal Swamp Mahogany Forests occur on land owned by Gold Coast Airport and another in the bushland to the north-west of Cobaki Broadwater. The most significant remnants of Coastal Forest Red Gum Forest are on Gold Coast Airport land and along riparian lands of lower Bilambil and Duroby Creeks.

Both catchments contain habitat for a number of rare or threatened flora and fauna species (refer to Section 4.3), and provide an, albeit fragmented, corridor connecting lowland coastal ecosystems with the Terranora Hills in the hinterland. A description of estuarine wetlands, freshwater wetlands, rainforests and the riparian corridor is provided.

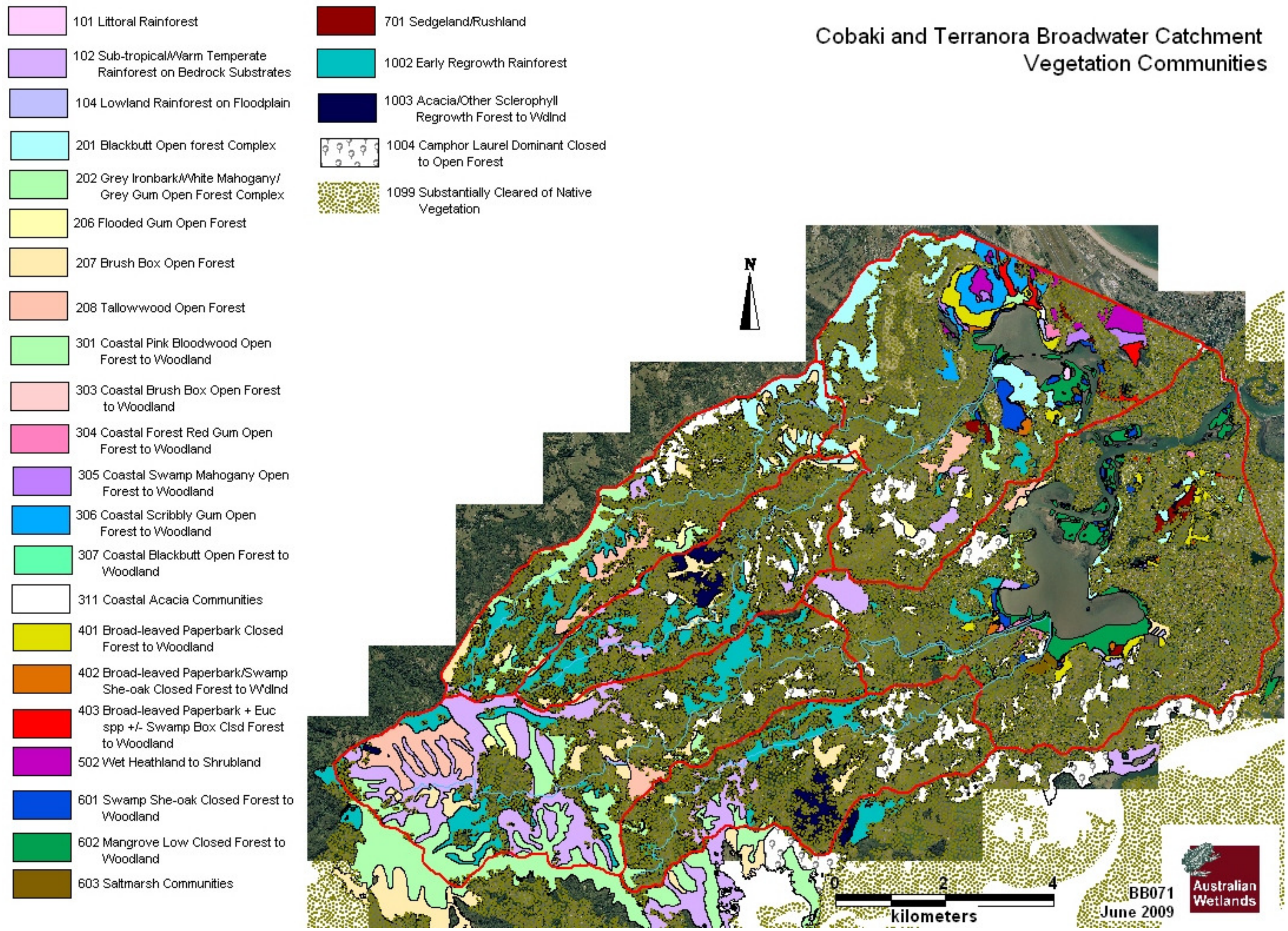


Figure 4.1. Vegetation communities of Cobaki and Terranora Broadwater catchment

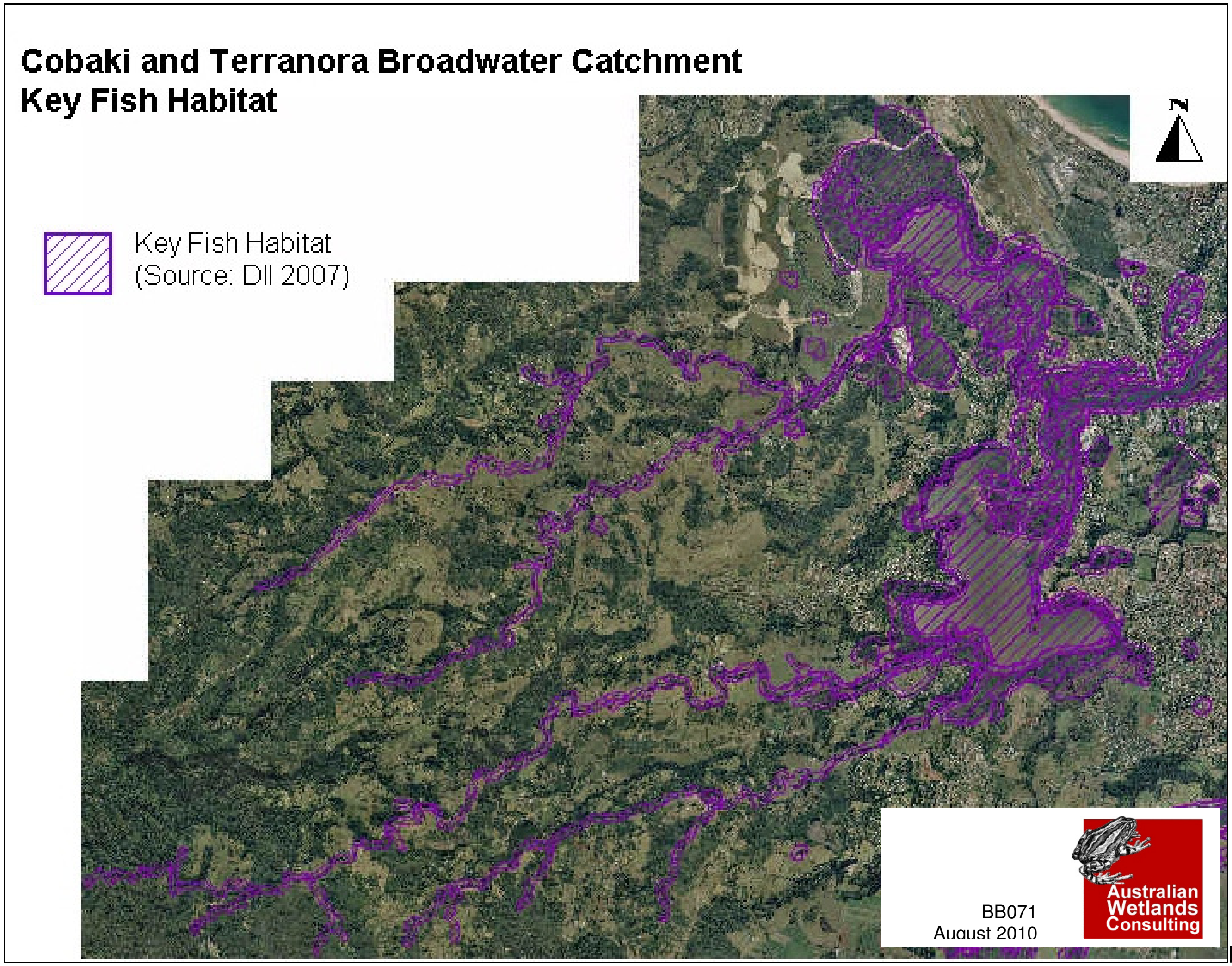


Figure 4.2. Key fish habitat

4.2.1 Estuarine Habitat

Shallow-water vegetated estuarine habitats, notably saltmarsh, mangrove and seagrass are known to be important habitats for many species of small or juvenile fish and invertebrates in Australia. Figures 4.3 and 4.4 show the indicative location of seagrass beds and SEPP 14 wetlands that are typically comprised of Mangrove Forests, Swamp She-oaks Forests, Saltmarsh, Littoral Rainforest, Broad-leaved Paperbark Forest and sedgelands.

Historically, there has been a proliferation of mangroves within the estuarine environments of south-eastern Australia with a trend of mangrove encroachment onto saltmarsh plains. Reasons for this are uncertain, but theories include sea level rise, marsh subsidence, increased sedimentation rates and elevated nutrients (Saintilan *et al*., 2006). This trend is also apparent in the Lower Tweed River. During the period 2000 – 2005, estuarine vegetation (seagrass, mangroves and saltmarsh) was studied as part of the Tweed River Estuarine Vegetation Monitoring Program (2006) in Cobaki and Terranora Broadwaters and Terranora tidal and fluvial channels. The change in intertidal vegetation community cover was estimated using photogrammetric mapping and ground-truthing.

The results of the change in cover from 2000 – 2005 are summarised below (Table 4.1). During this period, Cobaki Broadwater had increasing mangrove cover (2%), seagrass (35%) and mudlflat, but decreasing saltmarsh (28%). Terranora Broadwater had increasing mangrove cover (8%) and mudflat, but decreasing saltmarsh (55%) and seagrass (11%). Terranora tidal channel had increasing mangrove cover (0.4%) and seagrass (19%) and decreasing saltmarsh (2.5%). Of particular note are the following findings:

- The decrease in saltmarsh in all areas
- The particularly large decline in saltmarsh in Terranora Broadwater (55%)
- Terranora Broadwater is the only area showing a decline in seagrass

Table 4.1. Results from Tweed River Estuarine Vegetation Monitoring Program showing change in estuarine vegetation cover (source, year).

Veg Type	Cobaki BW (%)	Fluvial Channel (%)	Terranora BW (%)	Terranora Tidal Channel (%)	All (%)
Mangrove	+ 2.44	**+ 15.51**	+ 7.71	+ 0.38	+ 4.23
Saltmarsh	- 28.10	- 7.77	**- 55.38**	- 2.48	- 12.03
Seagrass	+ 34.77	+ 34.99	**- 11.08**	+ 18.99	+ 7.04

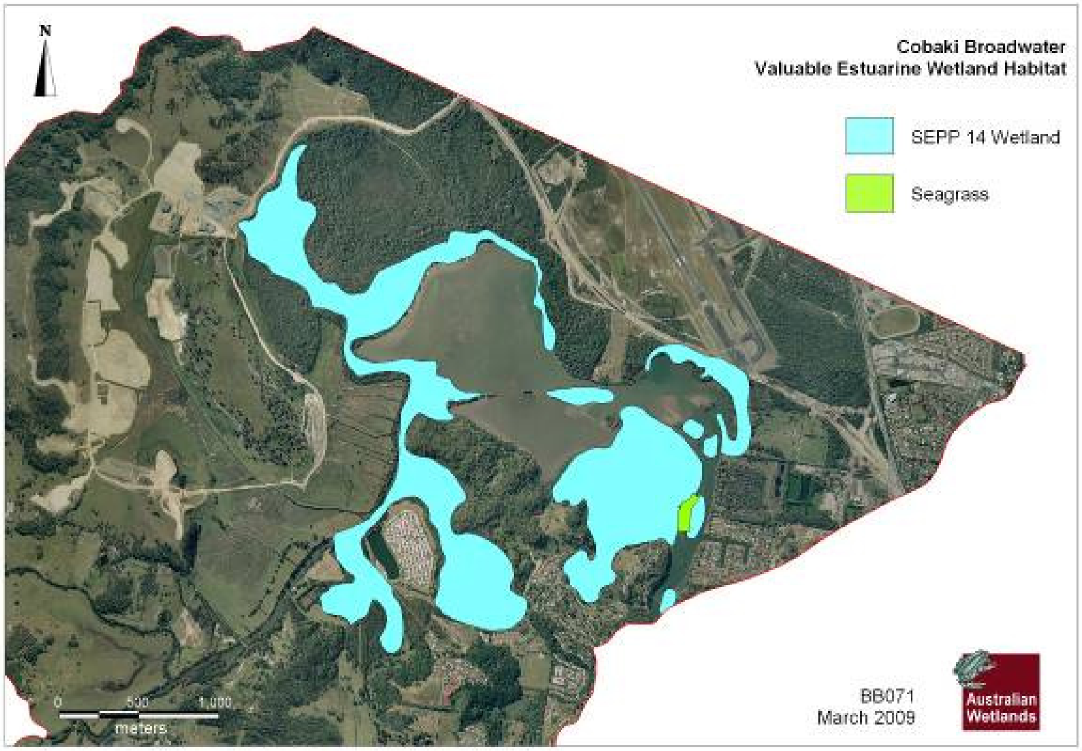


Figure 4.3.SEPP 14 wetlands and seagrass habitat of Cobaki Broadwater

Source mapping: TSC GIS mapping and Saintilan *et al*. (2006)

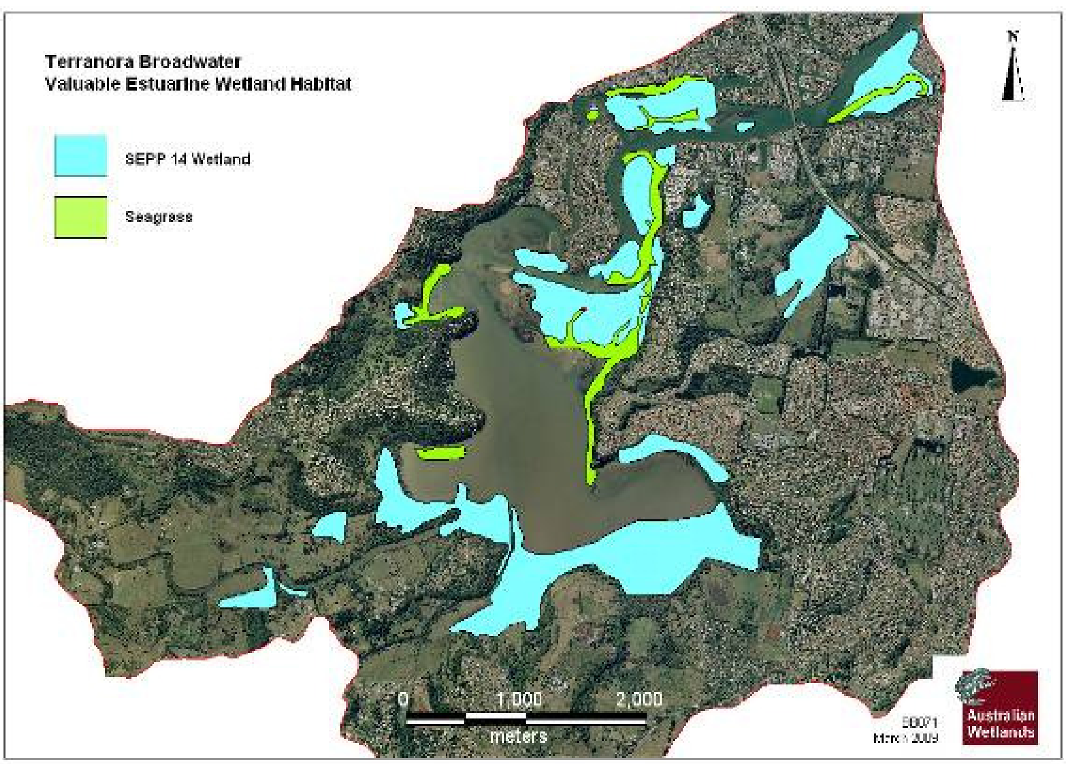


Figure 4.4. SEPP 14 wetlands and seagrass habitat of Terranora Broadwater

Source mapping: TSC GIS and NSW Maritime (2006)

Saltmarsh

Saltmarshes commonly occur in the upper inter-tidal zones between the mangrove fringe and terrestrial vegetation. Saltmarshes are important inter-tidal wetland communities comprising a mosaic of succulents, grasses, low shrubs and saltpans. Saltmarshes are usually not subject to daily inundation by tides but are flooded on king or spring tides. Due to the irregularity of flushing, saltmarsh areas contain high levels of salt and low levels of oxygen in the soil, giving rise to halophytic (salt tolerant) vegetation such as succulents, sedges, grasses and algae. The use of saltmarsh by wildlife is heavily dependent on the maintenance of tidal flows and clear passage for tides (Johns, 2006). Given the significance of the inundation regime to the survival of saltmarsh, climate change presents a challenge in the preservation of this vegetation community. Other challenges include encroaching development and mangrove communities.

The food web cycle in areas adjacent to saltmarsh is contributed to by the production of detritus and nutrients within saltmarsh (Connolly, 1999 as cited in Johns, 2006). Crab and gastropod larvae are released within the saltmarsh and provide an important source of food for juvenile fish (Hollingsworth and Connolly, 2004, as cited in Johns, 2006). This is significant to the survival of commercial and recreational fish species living within saltmarshes including bream, whiting, mullet, mangrove jack, barramundi, mud crab, leader and banana prawns. The presence and extent of use of saltmarsh by these species is dependent on the maintenance of tidal flows and clear passage for fish during high tides. Birdlife in saltmarshes can also be diverse, taking advantage of habitat, feeding areas and high tide roosts (refer to Section 5 for discussion of shorebird habitat). Saltmarsh is also key habitat for insects, bats and wallabies (Johns, 2006).

Studies have found that fish move from the seagrass to adjacent mangrove and saltmarsh vegetation during spring tides to prey on the abundant zooplankton and use seagrass as a refuge during lower tides (Saintilan *et al.,* 2007). Figure 4.5 shows some of the habitat values of saltmarsh (Queensland DPI&F, 2006).

Saltmarsh habitat covers approximately 18ha of the lower Tweed Estuary, with 16ha in Terranora Creek including an extensive area of Ukerebagh Island and limited cover on Boyds Island and Big Island. Saltmarsh within the Terranora and Cobaki Broadwaters covers approximately 5ha (GHD, 2005). The most significant area mapped as saltmarsh is on the southern side of Duroby Creek near Charles Bay adjacent to the Area E development.

Mangroves

Mangrove communities also receive intermittent inundation by the sea, between the average sea level and the high tide mark and can tolerate a wide range of salinities from fresh to seawater and anaerobic conditions. Mangroves provide habitat for a high diversity of marine fauna in their sheltered waters and mazes of exposed roots and in the underlying mud including invertebrates (crustaceans, worms and other benthic animals) and fish. Mangrove wetlands are particularly important as fish nurseries.

Mangrove leaves and roots provide important ecological services by providing carbon and nutrients that are broken down by organisms such as fungi, bacteria and crabs and the nutrients released to support plankton (Joyce, 2006). The roots and trunks reduce the speed of water, trapping suspended sediments, reducing siltation in other marine wetlands.

Mangrove habitat currently occupies approximately 303 ha of the lower Tweed Estuary with approximately 31 ha in the Terranora Creek and the broadwaters, most extensively on Ukerebah Island (a nature reserve managed by NSW NPWS). Mangrove forest occurs around the western corner of Cobaki Broadwater, on all islands and riparian areas of tributary creeks.

There is an extensive area of mangrove forest occupying the south-east corner of Cobaki Broadwater and along the southern boundary of Terranora Broadwater.

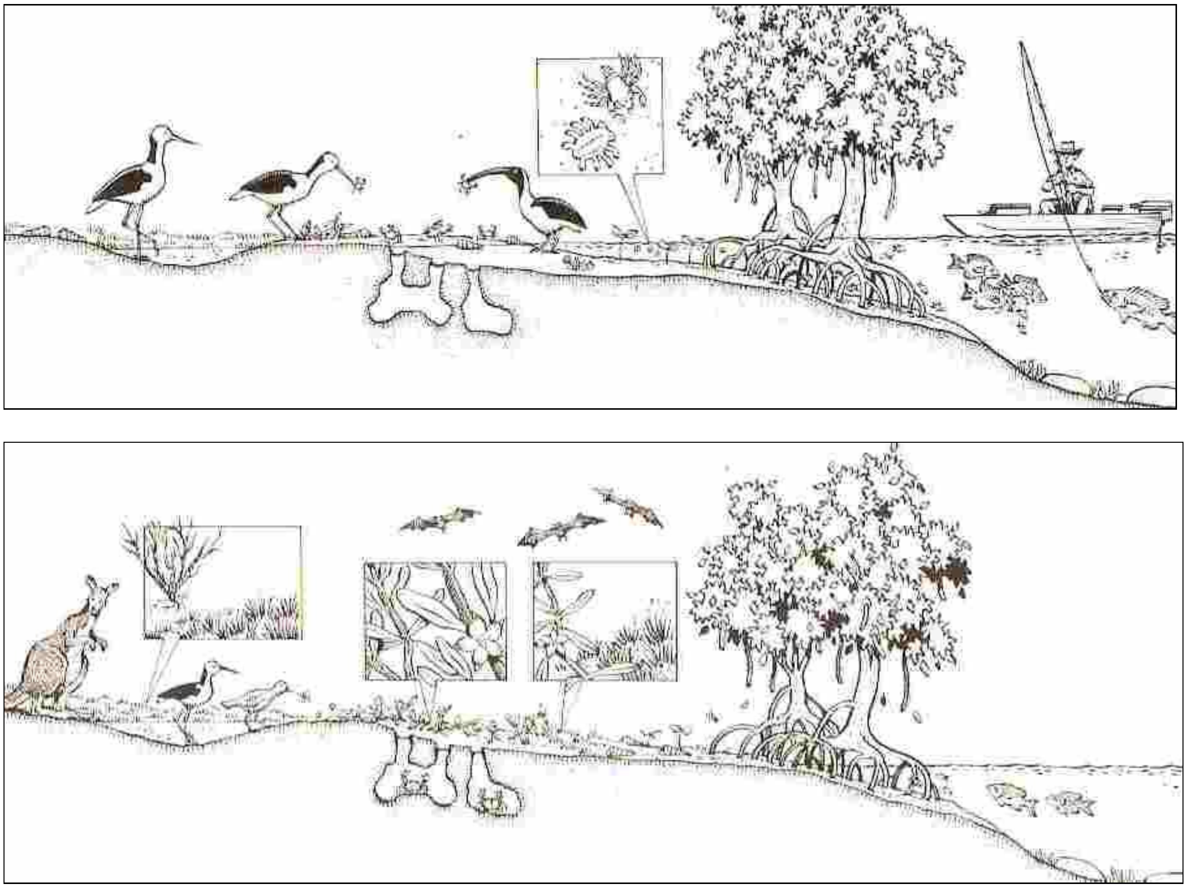


Figure 4.5. Saltmarsh at high tide (above) and low tide (below).

Seagrass

Seagrasses are plants that grow in soft mud or sand, underwater in shallow, calm, salt waters of estuaries, bays, lagoons and lakes. Seagrasses are extremely important to the health of estuarine ecosystem and habitats. They contribute large amounts of organic material to the food chain, provide food and shelter for many aquatic animals and nursery grounds for many important commercial and recreational fish and crustacean species including mullet, whiting, tailor, luderick, bream, flathead, prawns and crabs. The majority of fish caught in surveys in Cobaki Broadwater were juveniles, confirming the broadwater as a breeding habitat with highest catches in the vicinity of seagrass beds (FRC Environmental, 2001).

As the depth of seagrass growth is dependent on light penetration through the water column, the distribution of seagrass is a good indication of water quality, particularly turbidity (Tweed River Committee, 2002). Seagrass relies on suitable light conditions to allow for photosynthesis and suitable salinity regimes.

Seagrass currently occupies approximately 63 ha of the Tweed Estuary. Seagrass habitat condition in the Terranora Creek has been described as fair to excellent (UQ, 2003) although there has been a reported decline in the cover of seagrass in the Ukerebagh Passage attributed to stormwater discharges from two stormwater outfalls (Tweed Urban Stormwater Quality

Management Plan, 2000). Seagrass occurs throughout the lower estuarine reach of Cobaki Creek extends around the west and northern fringe of the broadwater with another patch adjacent to Gold Coast Airport. Seagrass occurs around Caddy's Island and Davey's Island continuing adjacent to the eastern shore of Terranora Broadwater to Tommy's Island. There are patches mapped near the northern shore of Charles Bay and within Bingham Bay (Figure 4.3).

4.2.2 Freshwater Wetlands

Freshwater wetlands occur around lagoons, rivers, creeks, billabongs or dams and can be permanently or intermittently water-logged. These wetlands are characterised by Paperbark Forest as Melaleuca species can tolerate the often water-logged conditions. These wetlands provide nesting or roosting sites for range of bird and bat species, habitat for frogs, and are a significant food resource for migratory species. Additionally, they play a critical role in the hydrological regime of the coastal plain by providing a protective buffer against erosion, absorbing and filtering runoff before it enters the broadwaters, mangrove swamps or estuaries and acts as a nutrient sink.

Surrounding lowland at Trutes Bay and Bilambil Creek are the only freshwater swamps in the Lower Tweed (Tweed Shire Council, 1994). The lower portions of the significant area of land to be developed known as Area E contains remnant Broad-leaved Paperbark Forest and Sedgeland/Rushland. There are three remnant Broad-leaved Paperbark Forests in the transition/lower zone of Bilambil Creek. Two of these are on a large private land parcel and the other is within Tweed Shire Council Crown Reserve land (Charles Bay Reserve). Freshwater swamps are crucial to the ecology of the bird and marine life of the Tweed River (Tweed River Management Plan Advisory Committee, 1994).

4.2.3 Rainforest

Upper Bilambil Creek is well-forested with Sub-tropical / Warm Temperate Rainforest on Bedrock Substrates (Figure 4.1). However rainforest is very sparse in the lower catchment. There are several remnants of Sub-tropical / Warm Temperate Rainforest on Bedrock Substrates on land owned by Bilambil Heights developers, the largest of which is approximately 45ha. The other significant remnant of this rainforest community occurs in Tweed Shire Council Crown Reserve land (Charles Bay Reserve). There are several small remnants of Lowland Rainforest on Floodplain most of which occur on land owned by Area E developers, and another on land owned by Gold Coast Airport. The only remaining Littoral Rainforest remnants are found on the southern side of Cobaki Broadwater (owned by Department of Lands) and at Razorback Lookout, Toonbarabah.

4.2.4 Riparian Vegetation Corridor

The riparian zone provides extremely high value habitat, and has been extensively degraded throughout the catchment. Riparian land is land that adjoins or directly influences a body of water and includes:

- The land immediately alongside small creeks and rivers, including the river bank;
- Gullies and dips which sometimes run with water;
- Areas surrounding lakes and broadwaters; and
- Wetlands and river floodplains which interact with the river in times of flood.

Important to the habitat value of the riparian zone is lateral connectivity from in-stream to the upper bank and beyond, and longitudinally with adjacent riparian vegetation forming a corridor through which fauna can move between larger areas of bushland. Riparian vegetation remnants form part of the Riparian Linkage Habitat Corridor and parts of the Regional Corridor, providing key habitat linkages from the upper catchment to the broadwaters. They are mapped as rehabilitation priorities in the Tweed Vegetation Management Strategy (2004).

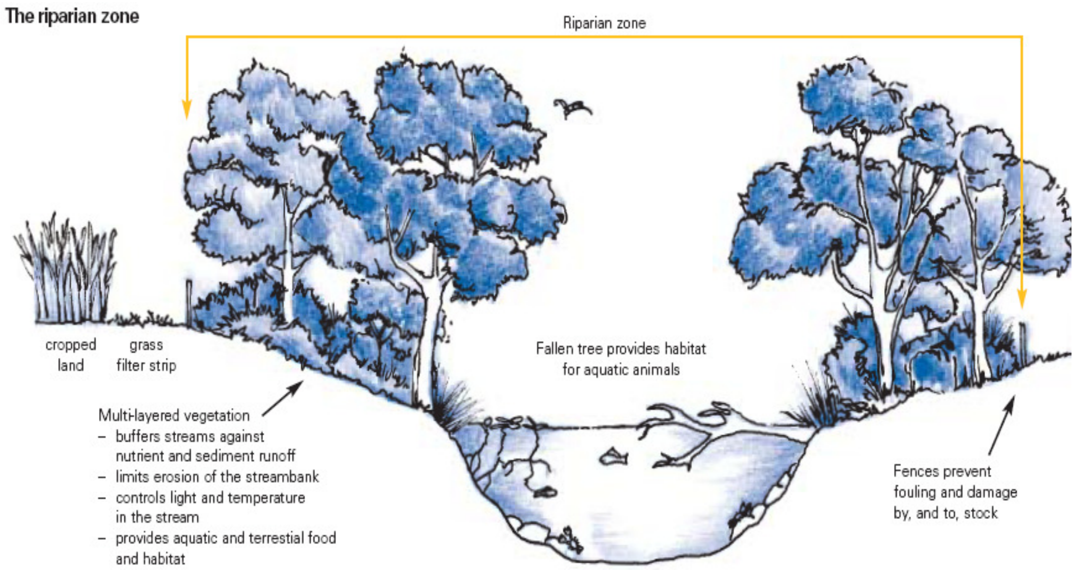


Figure 4.6. The riparian zone incorporating the mid-upper section, bank toe and in-stream habitats.

Source: Land and Water Australia, 2002

Riparian vegetation forms an important part of a healthy functioning ecosystem (e.g. nutrient cycling) and has numerous ecological benefits including the provision of crucial habitat features required by many wildlife species. Riparian vegetation provides the important components of food, water, shelter from predators and from harsh physical conditions and safe sites for nesting and roosting (DLWC, 2002) in the canopy, understorey and bank toe. It is often characterised by better soils, higher moisture and different plant species in comparison with adjacent land. Figure 4.7 shows a contrast between an intact, healthy riparian zone and a degraded, heavily impacted riparian zone.

Figure 4.7. Example of a healthy riparian zone (left) and a degraded riparian zone (right)

Riparian vegetation also contributes to the aquatic food chain by supplying leaves, fruits, insects and other organic matter, as well as the creation of aquatic habitat (Figure 4.8). It provides a source of large woody debris which is important habitat for many native fish species. It also provides shade and buffers temperature and provides important habitat for the platypus (*Ornithorhynchus anatimus*) which can only exist in areas where the riparian zone is intact.

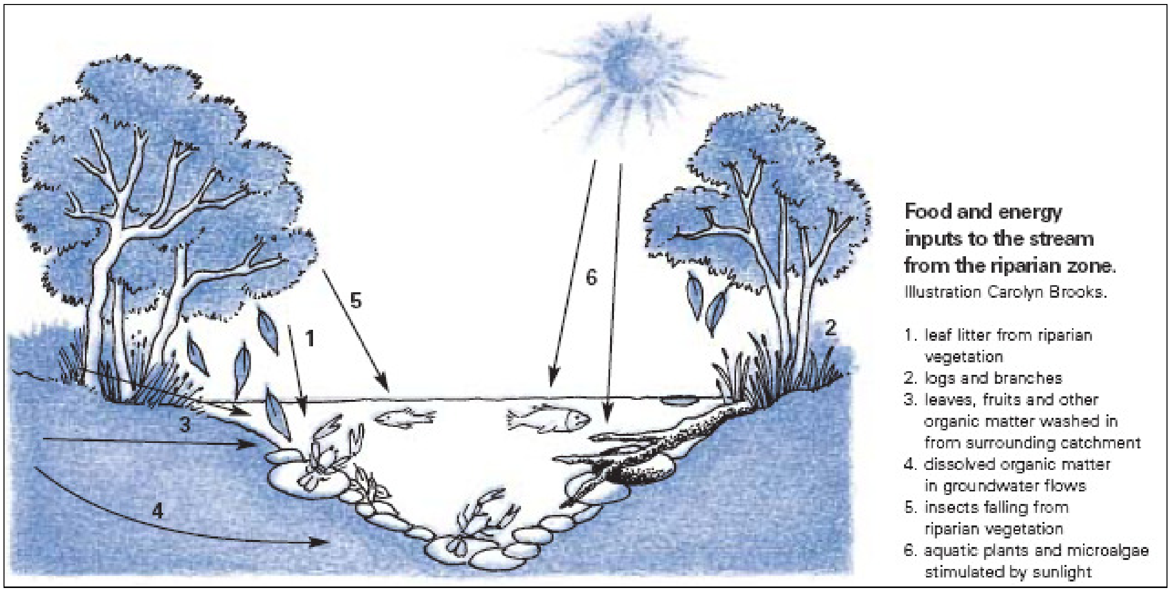


Figure 4.8. Important contributions of food and energy by the riparian zone to aquatic ecosystems.

Source: Land and Water Australia, 2002

Apart from the important ecological functions of riparian vegetation, a significant benefit of a healthy riparian zone is improved water quality and the stabilisation of river banks to reduce bank erosion. One of the primary causes of streambank erosion is removal of native riparian vegetation as it weakens the ability of streambanks to resist the erosive forces of increased flood flows. As such, well-vegetated stream banks are more resistant to under-cutting and slumping.

Riparian lands throughout the catchment have been heavily impacted by rural and urban landuse and development. The NSW Department of Primary Industries lists the degradation of native riparian vegetation along NSW water courses as a key threatening process that adversely affects threatened species populations or ecological communities, or could cause them to become threatened. The degradation of riparian vegetation can impact threatened native flora and fauna in the following ways (NSW DPI, 2005):

- Introduced vegetation reduces the diversity of native invertebrate communities
- Altered timing and quality of organic debris
- Erosion due to altered channel structure
- Increased nutrient and sediment runoff
- Loss of food and habitat for aquatic and terrestrial fauna.

In-stream Habitat

Important in-stream habitats include the presence of pools and woody debris. Large woody debris (LWD) includes tree trunks and large limbs, or accumulations of smaller woody debris and can slow the flow of water in small stream sections creating a deeper pool with supplies important habitat to aquatic plants and animals. Larger branches and trunks provide habitat, refuge, spawning sites and resting places for important fish species.

Niches and habitats for small invertebrates can also be provided by LWD. Logs can provide an important stable base for micro flora and fauna, benthic plants, algae and invertebrates which are a crucial part of the aquatic food web. Large Woody Debris also provides organic enrichment by capturing fallen leaves and other detritus and assists in preventing erosion by stabilising stream banks and streambeds. In many creeks, deep pools provide critical fish habitat and refuge areas. As the flow in the creek decreases in drought, fish retreat to these pools to wait for the higher flows.

NSW Department of Primary Industries lists removal of LWD from NSW rivers and streams as a key threatening process that adversely affects threatened species populations or ecological communities. The removal of LWD can impact on threatened native flora and fauna in the following ways (NSW DPI, 2005):

- Loss of habitat for benthic plants, algae invertebrates and microorganisms
- Loss of refuge and resting places
- Decreased stabilisation of stream banks and stream beds
- Fewer spawning sites, which are essential for successful reproduction.

4.3 Significant Flora and Fauna

There have been many flora and fauna investigations undertaken within the catchment, largely in association with the development in the vicinity of Cobaki Broadwater. The following provides a summary of significant or threatened flora and fauna sourced from these recent investigations and from the NPWS Atlas of NSW Wildlife.

Of most concern with regard to the future management of the Cobaki Broadwater, is the Tweed Heads West Population of Long-nosed Potoroo which is located on the north-western side of the broadwater. This population of Potoroo is listed as an endangered population in Part 2 of Schedule 1 of the *Environment Protection and Biodiversity Conservation Act 1999*. The population is located on a small area of Crown land between the northern shore of Cobaki Broadwater and the NSW-Queensland border. There are estimated to be fewer than 100 individuals on an area of forest-heathland 100-150ha in size. This population is completely disjunct from other southern and western populations.

It is the view of the Scientific Committee that ... “the Cobaki and Tweed West population of Long-nosed Potoroo *Potorous tridactylus* (Kerr 1792) in the Tweed Local Government Area is facing a high risk of becoming extinct in nature in New South Wales, it is disjunct and near the limit of its geographic range, and it is not a population of a species already listed on Schedule 1. Consequently, the Scientific Committee considers that the population is eligible for listing as an endangered population on Part 2 of Schedule 1 of the Act.”

Nine activities to help recover this endangered population are described in the Priority Action Statement (NSW DECC 2005). Any activities undertaken in the immediate vicinity of this population will be required to conform to the requirements of the PAS for conservation of existing habitat and population.

The Pouched Frog (*Assa darlingtoni*) has been recorded in Duroby Nature Reserve. It may be necessary to obtain further information regarding this record from DECC prior to undertaking any works on properties in the vicinity of this species.

Table 4.2. Significant/threatened flora within the catchment.

Source: NPWS Atlas of NSW Wildlife (January, 2009) and existing studies undertaken as part of the Tugun Bypass EIS.

Scientific Name	Common Name	Legislation listed under
Acacia bakeri	Marblewood	TSC(V)
Acronychia littoralis	Scented Acronychia	TSC (E1)
Amorphospermum whitei	Rusty plum	TSC(V)
Archidendron hendersonii	White Lace Flower	TSC(V)
Bosistoa transversa	Yellow satinheart	TSC(V), EPBC(V)
Cassia brewsteri var. marksiana	Brush Cassia	TSC (E)
Centranthera cochinchinensis	Swamp Foxglove	TSC (E1)
Cryptocarya foetida	Stinking Cryptocarya	TSC(V), EPBC(V)
Cryptocarya foetida	Stinking Cryptocarya	TSC(V); NVRI; EPBC(V); ROTAP
Davidsonia johnsonii	Smooth Davidson's Plum	TSC (E1)
Diploglottis campbellii	Small-leaved tamarind	TSC(E), EPBC(E)
Endiandra Floydii	Crystal Creek Walnut	TSC (E1)
Endiandra muelleri subsp. Bracteata	Green-leaved rose walnut	TSC (E)
Geijera paniculata	Axe-breaker	TSC(E)
Gossia fragrantissima	Sweet myrtle	TSC(E)
Grevillea hilliana	White silky oak	TSC(E)
Hicksbeachia pinnatifolia	Red Boppel Nut	TSC (V)
Lepiderema pulchella	Fine-leaved tuckeroo	TSC(V)
Macadamia tetraphylla	Rough-shelled bush nut	TSC(V), EPBC(V)
No common name	*Geodorum densifolorum*	TSC(E)
Phaius australis	Southern swamp orchid	TSC(E), EPBC(E)
Phyllanthus microcladus	Brush Sauropus	TSC (E1)
Randia moorei	Spiny gardenia	TSC(E), EPBC(E)
Syzygium moorei	Durobby	TSC(V), EPBC(V)

TSC = NSW Threatened Species Conservation Act 1995
EPBC = Commonwealth Environmental Protection and Biodiversity Conservation Act 1999

Table 4.3. Significant/threatened fauna within the catchment

Source: GCAL, Tugun Bypass EIS, David Rohweder, NPWS Atlas of NSW Wildlife (January, 2009), NSW DPI threatened fish of Northern Rivers. Species searches were confined to study area for all terrestrial fauna and to the Northern Rivers for fish.

Scientific Name	Common Name	Legislation listed under
Amphibians		
Crinia tinnula	Wallum Froglet	TSC(V); NCR(V)
Littoria olongburensis	Wallum Sedge-frog	TSC(V); NCR(V); EPBC(V)
Assa darlington	Pouched Frog	TSC(V)
Birds		
Shorebirds: refer to Table 5.2		
Hieraaetus morphnoides	Little Eagle	TSC (V)
Lophoictinia isura	Square-tailed Kite	TSC (V)
Pandion haliaetus	Osprey	TSC (V)
Todiramphus chloris	Collared Kingfisher	TSC (V)
Anseranas semipalmata	Magpie Goose	TSC (V)
Ixobrychus flavicollis	Black Bittern	TSC (V)
Esacus neglectus	Beach Stone-curlew	TSC (E4A)
Calyptorhynchus lathami	Glossy Black Cockatoo	TSC (V)
Coracina lineate	Barred Cuckoo-shrike	TSC (V)
Ephippiorhynchus asiaticus	Black-necked Stork	TSC (E1)
Ptilinopus regina	Rose-crowned Fruit Dove	TSC (V)
Irediparra gallinacean	Comb-crested Jacana	TSC (V)
Sterna albifrons	Little Tern	TSC (E1)
Lichenostomus fasciogularis	Mangrove Honeyeater	TSC (V)
Monarcha leucotis	White-eared Monarch	TSC (V)
Daphoenositta chrysoptera	Varied Sittella	TSC (V)
Glossopsitta pusilla	Little Lorikeet	TSC (V)
Amaurornis olivaceus	Bush-hen	TSC (V)
Tyto capensis	Grass Owl	TSC (V)
Tyto novaehollandiae	Masked Owl	TSC (V)
Mammals		
Planigale maculate	Common Planigale	TSC(V)
Myotis adversus	Large-footed Myotis	TSC(V)
Syconteris australis	Common Blossom Bat	TSC(V)
Pteropus poliocephalus	Grey-headed Flying Fox	TSC(V); EPBC(V)
Pteropus alecto	Black Flying Fox	TSC(V)
Miniopterus australis	Little Bent-wing Bat	TSC(V)
Nyctophilus bifax	Eastern Long-eared Bat	TSC(V)
Potorous tridactylus	Long-nosed Potoroo	TSC(E2), NCR(V), EPBC(V)
Dasyurus maculates	Spotted –tailed Quoll	TSC(V)
Saccolaimus flaviventris	Yellow-bellied Sheathtail-bat	TSC(V)
Mormopterus beccarii	Beccari's Freetail bat	TSC(V)
Phascolarctos cinereus	Koala	TSC(V)
Reptiles		
Chelonia mydas	Green Turtle	TSC(V)

Scientific Name	Common Name	Legislation listed under
Fish		
Pristis zijsron	Green sawfish	FMA (PE)
Nereia lophocladia	Marine brown alga	FMA (CE)
Nannoperca oxleyana	Oxleyan pygmy perch	FMA (E), EPBC (E)
Mogurnda adspersa	Purple spotted gudgeon	FMA (E)
Bidyanus bidyanus	Silver perch	FMA (V)

NCR = Qld Nature Conservation (Wildlife) Regulations 1994
TSC = NSW Threatened Species Conservation Act 1995
EPBC = Commonwealth Environmental Protection and Biodiversity Conservation Act 1999
CAMBA = China-Australia Migratory Birds Agreement
JAMBA = Japan-Australia Migratory Birds Agreement
(E4A = Critically Endangered, E = Endangered, V = Vulnerable)
FMA = Fisheries Management Act 1994
(PE = Presumed Extinct, CE = Critically Endangered, E = Endangered, V = Vulnerable)

5 Shorebirds

To ensure that the plan considers all aspects of the estuarine ecosystem it was proposed to include a chapter on shorebirds. Sandpiper Ecological Surveys was contracted by Tweed Shire Council to prepare a report on shorebird management. The contents of that report are presented in this section and in the management recommendations in Section 14. Data collected during estuarine bird monitoring between 1997 and 2003 and summarised by Sandpiper Ecological Surveys (2003) forms the basis of the report. This information was supplemented by field surveys on 5 August 2008 and 9 February 2009.

5.1 Background

Shorebirds, or waders as they are also known, are an important component of estuarine systems, representing higher order consumers of intertidal invertebrates. They belong to the sub-order Charadrii within the order Charadriiformes. Shorebirds can be divided into two groups, migrants, which breed elsewhere (mainly in the northern hemisphere) and spend the non-breeding season in Australia, and residents, which reside permanently in Australia. Resident shorebirds also undertake regular movements between coastal and inland wetlands and along the coast.

Many species of shorebird are of high conservation value due to their migratory habits, small population sizes, susceptibility to threatening processes and/or declining population size. All migratory species are listed on the *Environment Protection and Biodiversity Conservation (EPBC) Act 1999*. Numerous species are also listed as Endangered or Vulnerable on Schedules 1 and 2 of the EPBC Act and the New South Wales (NSW) *Threatened Species Conservation (TSC) Act 1995*. Migratory shorebirds are also protected by international treaties such as the Japan-Australia Migratory Bird Agreement (JAMBA) and the China-Australia Migratory Bird Agreement (CAMBA).

Shorebirds have three basic habitat requirements (Table 5.1):

1. Feeding areas – where they can forage in a manner that enables them to satisfy their daily energy requirements.
2. Roosts – where they can rest at high tide when foraging habitats are unavailable.
3. Nesting areas – where they can nest and raise chicks.

Breeding areas are relevant for resident shorebirds only. These species nest in a variety of different habitats. One typical feature of nest sites is that they are often situated just above the high tide line. In northern NSW shorebirds often breed on ocean beaches, sand islands and bars in estuaries, offshore islands and in saltmarsh. In coastal habitats shorebirds nest in pairs and often defend small territories.

The use of roost and foraging areas is governed by the tidal cycle and shorebirds forage irrespective of whether it is day or night. At night there is evidence that some species utilise different roost and foraging areas (Rohweder and Baverstock 1996; Rohweder 1998). At high tide shorebirds gather at sites called roosts which are typically located just above the high water mark and near preferred foraging habitats. There are several types of roosts. Spring tide roosts are used during spring tides, neap tide roosts are used during neap tides and staging roosts are sites where birds coalesce into flocks before moving to spring tide roosts. Shorebirds utilise a variety of habitats (and structures) for roosting and the type of roost used varies between species. Examples of roosts include; saltmarsh, sand and shingle beaches, sand bars and sand spits, mangroves, rock walls, rock platforms and oyster racks. Shorebirds are quite opportunistic in their selection of roosts often using recently cleared areas. Roosts provide a critical function as they enable birds to rest and conserve energy at a time when they are unable to feed.

As the tide recedes and intertidal sand and mudflats become exposed shorebirds leave roosts and begin foraging. Birds will often commence foraging at sites close to roosts and then move further away as other habitats become exposed. Shorebirds utilise a variety of intertidal habitats for foraging with individuals often selecting feeding areas where they can maximise food intake rates. Ideally foraging sites have a high abundance of preferred prey and low levels of predation and disturbance (Table 5.1). Types of foraging sites used by shorebirds include; ocean beaches, mudflats, sand flats, seagrass beds, saltmarsh, mangrove fringes and flooded pasture. The time spent feeding varies between species with larger species foraging for less time than small species.

Table 5.1. Summary of important habitat features required by shorebirds

Nesting	Roosting	Foraging
Areas of sand, shingle, or saltmarsh above spring high water and storm surge.	Areas of sand, shingle, rock or saltmarsh above spring high water.	A variety of intertidal habitats including, mudflats, sandflats, seagrass beds and ocean beaches.
Areas were canopy vegetation is sparse or absent.	A mix of spring and neap tide roosts.	
Adjoining intertidal habitat where adults can forage close to nest sites.	Areas free from human disturbance.	
Suitable abundance of preferred prey for adults and chicks that will enable birds to satisfy their daily energy requirements whilst staying close to nest sites.	Mangroves with exposed upper branches or an open midstorey with exposed branches.	Expansive areas of intertidal habitat situated close to high tide roosts.
Areas free from predators, particularly foxes. Small sand islands are ideal in this regard.	Adjoining shoreline or open expanse of low vegetation (i.e. saltmarsh) where birds have a clear line of sight.	An abundant supply of benthic invertebrate prey.
Areas with nil or low levels of human disturbance such as pedestrians, 4WD vehicles and dogs.	Situated close to intertidal foraging habitat where there are a variety of suitable prey species and where birds can forage immediately prior to and after high tide.	Low levels of human disturbance.
	A mix of nocturnal and diurnal sites.	A mix of diurnal and nocturnal sites.

5.2 Shorebirds in the Tweed River Estuary

5.2.1 Population and Status

The Tweed River Estuary is used by a small but diverse population of shorebirds and known shorebird habitat is distributed throughout the estuary (Table 5.2; Figure 5.1). Extensive intertidal mudflats occur in both broadwaters and sheltered embayments (i.e. Shallow and Chinderah Bays) in the Tweed River. These areas provide important foraging habitat for shorebirds. High tide roosts are distributed throughout the estuary. The most important (spring tide) roosts tend to occur in the Tweed River and most roosts in the broadwaters are suitable as mid-tide staging areas or during neap high tides.

Figure 5.1. Location of high tide roosts in the Tweed River Estuary.

Source: Sandpiper Ecological Surveys, 2009

Table 5.2. Species of migratory and resident shorebird recorded in the Tweed River Estuary between 1987 and 2009. M = Listed as a migratory species on the EPBC Act; V = Listed as Vulnerable species on the TSC Act; E = Listed as Endangered species on the TSC Act.

Group	Species Name	Common Name	Status
Migratory Shorebirds	*Gallinago hardwickii*	Latham's Snipe	M
	Limosa lapponica	Bar-tailed Godwit	M
	Limosa limosa	Black-tailed Godwit	M, V
	Numenius phaeopus	Whimbrel	M
	Numenius madagascariensis	Eastern Curlew	M
	Tringa stagnatilus	Marsh Sandpiper	M
	Tringa nebularia	Common Greenshank	M
	Xenus cinereus	Terek Sandpiper	M, V
	Actitis hypoleucos	Common Sandpiper	M
	Tringa brevipes	Grey-tailed Tattler	M
	Tringa incana	Wandering Tattler	M
	Arenaria interpres	Ruddy Turnstone	M
	Calidris ferrugenea	Curlew Sandpiper	M
	Calidris ruficollis	Red-necked Stint	M
	Calidris acuminata	Sharp-tailed Sandpiper	M
	Calidris alba	Sanderling	M, V
	Calidris canutus	Red Knot	M
	Calidris tenuirostris	Great Knot	M, V
	Pluvialis fulva	Pacific Golden Plover	M
	Charadrius leschenaulti	Greater Sand Plover	M, V
	Charadrius mongolus	Lesser Sand Plover	M, V
	Charadrius bicinctus	Double-banded Plover	M
Resident Shorebirds	*Esacus magnirostris*	Beach Stone-curlew	E
	Haematopus longirostris	Pied Oystercatcher	V
	Haematopus fuliginosus	Sooty Oystercatcher	V
	Himantopus himantopus	Black-winged Stilt	
	Recurvirostra novaehollandiae	Red-necked Avocet	
	Elseyornis melanops	Black-fronted Dotterel	
	Charadrius ruficapillus	Red-capped Plover	
	Erythrogonys cinctus	Red-kneed Dotterel	
	Vanellus miles	Masked Lapwing	

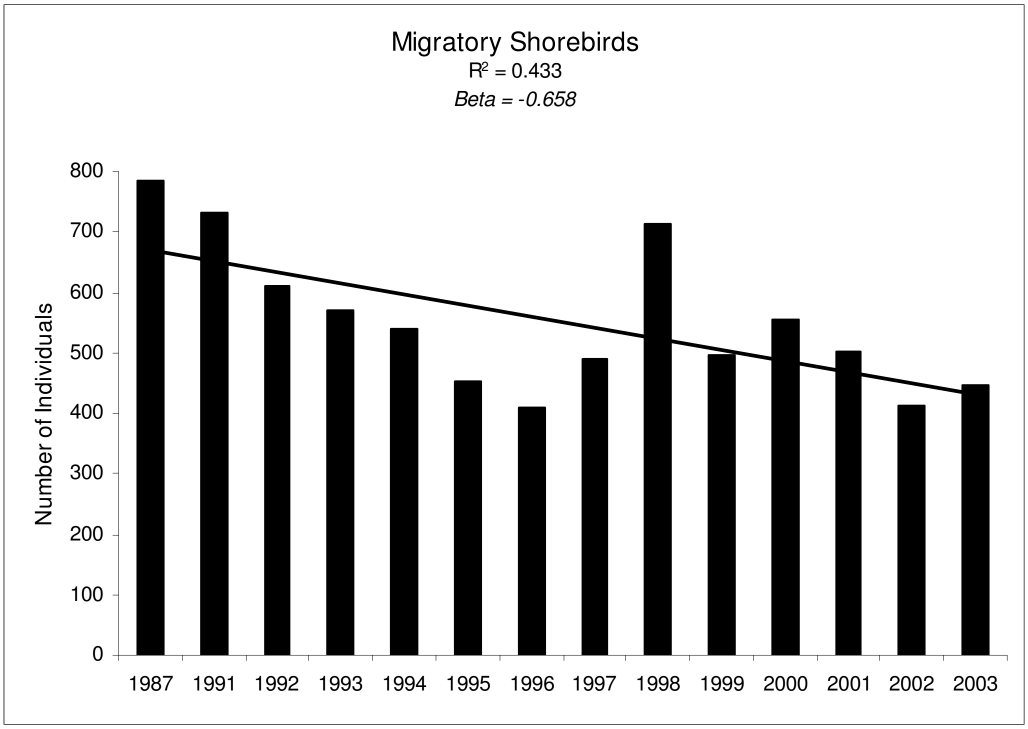
Over the 16 year period from 1987 to 2002 the estimated population of shorebirds in the Tweed River Estuary ranged from approximately 1000 to 600 individuals (Martindale 1987; WBM 1996; Sandpiper Ecological Surveys 2003). About 31 species of shorebird have been recorded during major studies, including 22 migratory species and nine resident species (Table 5.2). Nine threatened species listed on the TSC Act have been recorded, including six migratory species and three resident species (Table 5.2). The migratory shorebird population declined significantly between 1997 and 2003, although no such trend was evident for resident shorebirds (Figure 5.2; Rohweder 2007). Migratory species with substantial population declines included Bar-tailed Godwit (Limosa lapponica), Curlew Sandpiper (Calidris ferruginea) and Pacific Golden Plover (Pluvialis fulva). The resident shorebird population is dominated by Black-winged Stilt (Himantopus himantopus) and the population displays a distinct seasonal trend with peaks in autumn and winter (Sandpiper Ecologically Surveys 2003). The decline in migratory shorebirds appears to have continued since 2003 with 257 individuals recorded in February 2009. This population estimate fits the trend line identified by Rohweder (2007).

The relative importance of a shorebird site[1] is generally assessed against national and international criteria (Watkins 1993). The standard benchmarks are:

1. Areas that support 20,000 or more shorebirds are internationally important and areas that support 10,000 or more shorebirds are nationally important.
2. Areas that support 1% or more of the population of a species within the East-Asian Australasian Flyway are internationally important and 1% or more of the Australian population of a species are nationally important.

Watkins (1993) originally classified the Tweed River Estuary as being nationally important for Whimbrel (*Numenius phaeopus*); however, recent surveys have increased the national population estimate for Whimbrel which means that the Tweed no longer supports >1% of the national population. Smith (1991) suggested that the Tweed Estuary was of state significance for both Whimbrel and Pacific Golden Plover. Smith classified the Tweed River Estuary as a Priority 3 site (i.e. sites with counts >1% for one or two species) behind the Hunter, Richmond, Clarence and Shoalhaven River Estuaries, Port Stephens and Botany Bay. Sandpiper Ecological Surveys (2003) suggested that the Tweed Estuary was one of the five most important sites in NSW for estuarine birds. If shorebirds alone are considered then the Tweed River estuary is probably in the top 10 (i.e. ranking of about 8) most important sites in NSW but is less important in an Australian context.

[1] “Site” refers to a geographical area, such as an estuary, that supports a population of shorebirds.



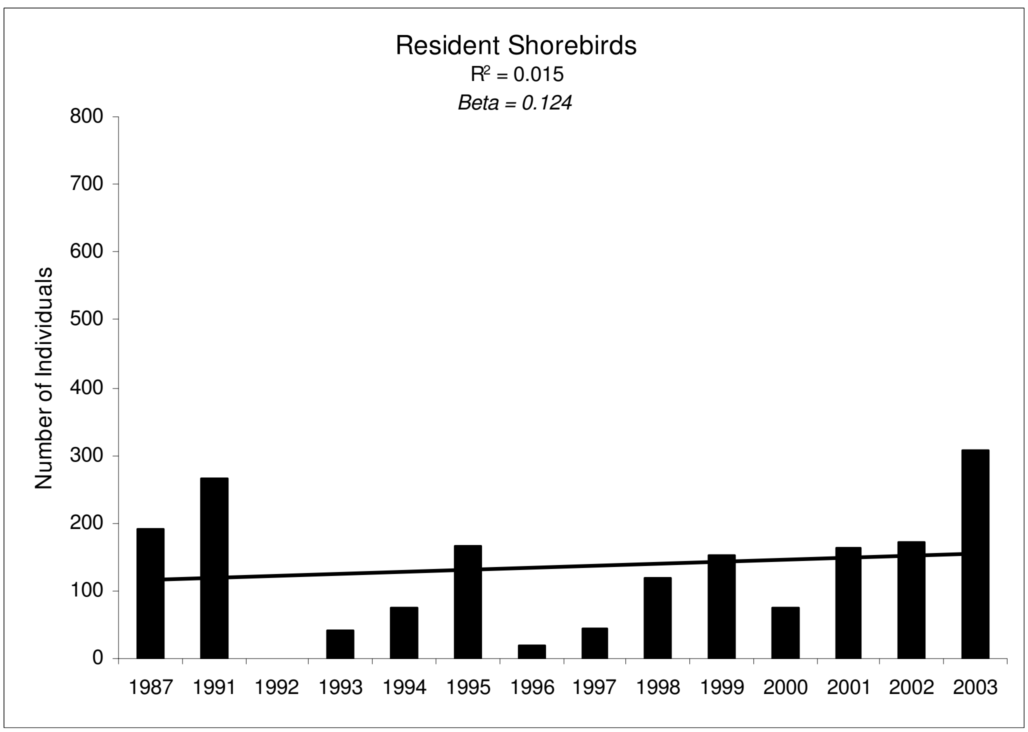


Figure 5.2. Temporal variation in summer population estimates of migratory and resident shorebirds in the Tweed River Estuary between 1987 and 2003.

5.3 Status of High Tide Roosts

5.3.1 General Assessment

Since estuary-wide surveys commenced in 1987 flocks of shorebirds have been recorded roosting at 28 sites (Figure 5.1). The number of roosts used is exceptionally high for an estuary in northern NSW where birds typically display strong roost fidelity. There are several reasons for the large number of sites used, including the absence of a good quality spring tide roost, human disturbance which forces birds to use other sites, temporal changes roost quality, the loss of roosts to development, and the opportunistic roosting behaviour of some shorebird species. Shorebirds often roost at sites created by disturbance, particularly wetlands that have been cleared and are situated near intertidal areas. Both the Pony Club and Sewage Drain roosts identified by Martindale (1987) may have been enhanced by earthworks. According to estuarine habitat mapping (i.e. mangrove, saltmarsh, seagrass) no estuarine habitat occurred at either site until 2000 (Russell & Batten 2005). Other examples of modified sites include Duroby Marsh, Trutes Marshland and a small wetland south of Trutes Bay which were made suitable for shorebirds after clearing of wetland habitat (Pers Obs; DPW 1991). Regrowth of vegetation after earthworks results in a steady decline in the suitability of habitat for shorebirds, although in the case of Trutes Marshland the site was developed. Although shorebirds have used numerous roosts not all of the roosts are of equal importance (Figure 5.1). Many are available during neap tides only whilst others are used only when all preferred sites are unsuitable. Nine roosts are no longer used whilst eight others are used during neap tides only.

5.3.2 Roost Assessment

The major features and status of 11 active roosts was assessed on 5 August 2008 and 9 February 2009. During the assessment each roost was inspected and notes taken on the major habitat features and sources of degradation. Site selection was based on previous estuarine bird monitoring surveys and included only those sites where shorebirds have been regularly recorded.

The assessment reinforces the concern expressed by Sandpiper Ecological Surveys (2003) about the quality of roosts in the estuary. The major findings of the roost assessment (Table 5.3 and 5.4) are:

- Five of the 11 roosts are situated in mangroves and consist of sites where birds perch on the dead mangrove crowns or on exposed branches within the midstorey.
- Mangrove roosts are suitable for small numbers of birds only.
- Mangrove roosts are used by two species only.
- The majority of roosts (7 of 11) are small, covering areas less than 150m^2 during spring high tides.
- Kerosene Inlet is the only roost that is suitable for large flocks during spring high tides.
- Cobaki Fringe has declined in suitability since goats were removed. Goats grazed grasses and mangrove seedlings opening the shoreline for roosting birds.
- Duroby Marsh is predominantly used by one species.
- Five roosts are typically used by one species only.
- Kerosene Inlet experiences very high levels of recreational disturbance.
- Two (of 7) ground or near ground roosts have greater than 180^0 of unobstructed view.

- Vegetation encroachment continues to affect the suitability of Pony Club, Duroby Marsh Tony's Bar and the rock groin at Kerosene Inlet for shorebirds.
- Vegetation growth around the Pony Club roost (mainly Swamp Oak) increased substantially between August 2008 and February 2009, further reducing the quality of that site.

5.3.3 Recent Impacts on Historically Important Roosts

Tony's Bar

Tony's Bar has been an important high tide roost for shorebirds since at least the late 1980's (Table 5.5). Since it became exposed at high tide the bar has been gradually colonised by mangroves. According to the mapping of Russell and Batten (2005) mangroves did not begin to colonise Tony's Bar until after 1985. The suitability of Tony's Bar peaked in the early 1990's when the site was characterised by small areas of juvenile mangrove, exposed sand and saltmarsh. Since then mangroves, mainly Grey Mangrove (Avicennia marina), have gradually colonised the upper tidal level reducing the area of roosting habitat. Increasing levels of human recreation cause frequent disturbance to roosting birds. Tony's Bar continues to be used as a neap tide and staging roost; however, its value as a spring tide roost has diminished.

DPW (1991) discussed both the effect of recreation and mangrove colonisation on shorebirds using Tony's Bar indicating that both factors would reduce the value of the site for avifauna within 10-20 years. They recommended that the site be modified to improve the condition of Shallow Bay and provide better quality shorebird habitat. The recommendation was not implemented and their predictions on roost quality have proven accurate.

Pony Club

"Pony Club" is the name given to the shorebird roost that is situated at the western end of the Tweed Heads Pony Club, on the eastern shore of Cobaki Broadwater (Figure 5.1). The site consists of saltmarsh and sedgeland with fringing mangrove forest and an open drain along the northern edge. The site name was first used by DPW (1991); however, various names and roost locations have been mapped along the eastern shore of Cobaki Broadwater. Martindale (1987) mapped two roosts (Cobaki & Sewerage Drain), north and south of the "Pony Club". Figure 1.2a in DPW showed the Pony Club south of its actual location and in the vicinity of the Sewerage Drain roost. Lawler (1994) identified two roosts (R4 and R2) which correspond to the Sewerage Drain and the Pony Club sites. WBM (1996) mapped the entire eastern shore as a roost site and labelled the site Cobaki Roost. The author was initially shown the Pony Club roost by a local ornithologist in 1994 and the site was situated at the western end of the Tweed Heads Pony Club land.

Table 5.3. Characteristics of 11 active shorebird roosts in the Tweed River Estuary on 5 August 2008. * = historically the roost was used during spring tides but mangrove encroachment has reduced the area of habitat available during spring tides. ** = site has been previously disturbed. SHW = Spring High Water; NHW = Neap High Water.

Site	Use	Type	Origin	Landform	Connectivity	Substrate	Area of habitat (m^2)		Degrees of unobstructed view (100m)
							SHW	NHW	
Tony's Bar	Primary	Neap tide*	Natural	sand bar	at low tide	sandy mud	140	1500	160
Rocky Point	Primary	Spring tide	Natural	mangrove & rocks	always connected	rock & vegetation	7	16	180
Shallow Bay	Primary	Spring tide	Natural	mangrove	always connected	mangrove	10	10	360
Kerosene Inlet	Primary	Spring tide	Natural	sand spit, sand bar, rock wall/groin	always connected	sand, rock	3240	7200	270
Pony Club	Secondary	Spring tide	Natural	saltmarsh	always connected	saltmarsh	1500	2000	0
Cobaki Mangroves	Secondary	Spring tide	Natural	mangroves	no connection	mud	10	10	360
Cobaki Fringe	Primary	Spring tide (low)	Natural	mangrove fringe	always connected	muddy sand	40	80	180
Womgin Mangroves	Secondary	Spring tide	Natural	mangroves	no connection	mud	10	10	180
Womgin Sandflat	Primary	Neap tide	Natural	sand bar	no connection	muddy sand			270
Big Island	Primary	Spring tide	Natural	mangrove	no connection	mud	20	20	360
Duroby Marsh	Primary	Spring tide	Natural**	saltmarsh	always connected	saltmarsh	3000	3000	180

Key:	Use	Primary – used regularly	Connectivity	always connected
		Secondary – occasional use		low tide connection
	Type	Spring tide		no connection
		Neap tide	Substrate	sand
		Staging		mud
	Origin	Natural		muddy/sand
		Constructed		sandy mud
	Landform	sand island/bar		rock
		sand spit		saltmarsh
		mangrove fringe		vegt other
		mangroves		ocean beach
		saltmarsh		
		rock wall/groin		
		rocky shore		
		wetland/other		

Table 5.4. Status of 11 active shorebird roosts in the Tweed River Estuary on 5 August 2008. * Area of mangrove has increased substantially since disturbance in the early 1990's. ** Mangroves and Swamp Oak.

Site	View of Water	Access to Shoreline	Roost Deterioration				Roost Quality	Roost Limitations
			Erosion	Mangroves	Human Disturbance	Effects		
Tony's Bar	yes	yes	nil	on-site; 90% cover	high	declining visibility; frequent disturbance	moderate	Small area; high disturbance; neap tide only
Rocky Point	yes	no	nil	N/A	medium	declining visibility	poor	Single species site; small number of birds
Shallow Bay	yes	no	nil	N/A	low	none obvious	good	Single species site
Kerosene Inlet	yes	yes	nil	on-site (rocks); 100% cover	high	declining visibility on rock groin; frequent disturbance; predators (dogs, foxes)	moderate	High disturbance level; mangrove growth on rock wall; predators
Pony Club	no	no	nil	on-site; 5% cover	low	declining visibility**	poor	Small area; limited visibility.
Cobaki Mangroves	yes	no	nil	N/A	low	none obvious	moderate	Small area; single species site.
Cobaki Fringe	yes	yes	nil	on-site; 5% cover	low	declining suitability	poor	Suitability enhanced by goats; habitat may decline since goats removed; limited visibility
Womgin Mangroves	yes	no	nil	N/A	medium	frequent disturbance during weekends	moderate	Birds easily disturbed; used by small numbers.
Womgin Sandflat	yes	yes	nil	nil	low	none obvious	good	Available during neap tides.
Big Island	yes	no	nil	NA	low	none obvious	good	Single species site and small numbers only.
Duroby Marsh	no	no	nil	on-site; 10% cover*	low	declining visibility; predators	moderate	Predominantly used by one species, visibility is declining.

Key:	Human disturbance		Roost quality	
		High = site is disturbed during more than 50% of spring high tides		Good – low levels of disturbance,; situated close to foraging areas; has sufficient space
		Medium = site is disturbed during 20-30% of spring high tides		Moderate – one of the above criteria is lacking.
		Low = site is disturbed on less than 20% of spring high tides		Poor – two or more of the above criteria are lacking

Table 5.5. Summer counts of shorebirds recorded at Tony's Bar and Pony Club at selected times between 1987 and 2002.

Summer Survey	Tony's Bar Individuals (species)	Pony Club Individuals (species)
Martindale (1987)	214 (8)	315 (9)
DPWS (1991)	submerged	149 (7)
Lawler (1994)	35 (3)	255 (10)
WBM (1996)	138	91
SES (1999)	116 (6)	89 (5)
SES (2002)	119 (6)	17 (2)
SES (2009)	22 (1)	3 (1)

It is unknown if the mapped variations in roost location are errors or reflect changes in the roost site over time. Both are feasible explanations. It is possible that clearing or disturbance of habitat during, or prior to, the 1980's, possibly as part of drainage work at the airport and Sewerage Treatment Plant, may have created suitable roost conditions north and south of the Pony Club. Over time the disturbed areas have regenerated making them unsuitable for shorebirds which have retreated to using the Pony Club. Areas to the north and south of the Pony Club presently consist of tall vegetation dominated by sedges (Juncus spp.), Common Reed (*Phragmites australis*) and Salt Couch (*Sporobolus* spp.) with a mangrove fringe.

In the 15 year period (1994-2009) that the Pony Club roost has been observed mangroves and sedges (*Juncus* spp.) have gradually encroached into saltmarsh and the fringing mangroves have grown. Vegetation growth, mainly Swamp Oak, has accelerated in the past six months. Declines in the quality of habitat have been reflected in the number of birds using the site. Over the past 5-8 years the roost has been used by a small number of individuals and species during high spring tides only (Table 5.5). Early surveys showed that similar numbers of shorebirds roosted at "Pony Club" and foraged in Cobaki Broadwater (Martindale 1987). Whilst the demise of the Pony Club roost has been detrimental to the estuaries shorebird population the location of the roost beneath the flight path of the Gold Coast Airport means that it is not ideally situated.

Two large-scale developments, the Tugun Bypass and the Gold Coast Airport runway extension, have recently been completed immediately north of the roost. These projects could affect the site in two ways, increased disturbance from vehicles and jets and altered site hydrology. Disturbance effects are considered unlikely based on previous observation of the response of roosting birds to jets (see Lewis Ecological Surveys 2003) and the fact that the highway extends through a tunnel as it passes the roost. The effect of altered hydrology, should such an impact occur, is difficult to predict, although it could affect the floristic and physical structure of the roost. Ideally empirical data gathered over several years would be required to make judgements on how the developments have affected the roost. Problems associated with determining the effect of these activities is compounded by the recent increase in woody vegetation.

Summary

The demise of Tony's Bar and Pony Club has contributed to the steady cumulative decrease in the distribution and quality of shorebird roosting habitat in the Tweed River Estuary. This decline has been particularly noticeable in the main river where Dreamtime Beach, South Head Beach and Tony's Bar, three important roosts in the 1990's, are now of limited value. The decrease in the availability of roosts is attributed to coastal development, mangrove encroachment, increased levels of recreational disturbance and erosion of South Head Beach[2]. Historically,

[2] South Head Beach may become more suitable to shorebirds as the erosion rate stabilises.

alternative roosts would have been created by disturbance to brackish and estuarine wetlands. However, increased protection of these habitats, whilst having a valuable benefit to estuarine ecosystems, has reduced the availability of roosting habitat.

5.4 Shorebirds in the Cobaki and Terranora Broadwaters

5.4.1 Population

The broadwaters are not used by an isolated population of shorebirds and individuals move regularly between the main river channel and the broadwaters to roost and forage. Some species undertake daily movements between roost and foraging areas, whilst movement of others may be influenced by the lunar phase (i.e. spring & neap tide cycle) or the migration cycle. Changes in habitat use at night may also influence movement.

Monitoring data collected between 1997 and 2002 shows that at high tide the proportion of the estuaries shorebird population roosting in the broadwaters ranged from 22.2% to 69% with an average of 45.3% (sd^{-1} 14.6) (Table 5.6). At low tide the proportion ranged from 46% to 72.1% with an average of 57.8% (sd^{-1} 8.21). These data show that roosting and foraging habitat within the broadwaters is critical for the shorebird population in the Tweed River Estuary. The broadwaters are predicted to be more important than the data suggest. Many individuals are predicted to move into the broadwaters in the latter stages of the low tide cycle after sampling has been completed.

The maximum number of shorebirds recorded roosting in the broadwaters between 1997 and 2002 was 576 in Summer 1998 with 509 individuals recorded foraging in the broadwaters in spring 1997. Comparison of bird numbers between high and low tide during the same sample (e.g. spring 1998) provides some indication of the extent to which birds move to and from the broadwaters. Movement is particularly noticeable during the spring tide cycle when birds move to roosts in the Tweed River at high tide and return to the broadwaters to forage at low tide.

Table 5.6. Number of individuals and percentage of the total Tweed Estuary shorebird population recorded in the Cobaki and Terranora Broadwaters during spring and summer surveys between 1997 and 2002. *Early autumn survey which was the first in the monitoring program. A = autumn, Sp = spring, Su = summer.

Tide	A97*	Sp97	Su98	Sp98	Su99	Sp99	Su00	Sp00	Su01	Sp01	Su02
High	230	312	576	126	316	318	246	211	175	366	349
	49.7%	40.2%	69.0%	22.2%	48.5%	51.5%	38.9%	33.8%	26.0%	59.6%	59.3%
Low	301	509	464	409	306	361	322	338	382	391	270
	65.0%	65.6%	55.6%	72.1%	47.0%	58.5%	51.0%	54.1%	56.8%	63.7%	46.0%

5.4.2 Shorebird Habitat

Roosts

Since 1987 shorebirds have been recorded roosting at 28 sites in the broadwaters, although only 10-14 sites are used regularly (Figure 5.1). A variety of roost types are represented, including saltmarsh, sand bars, mangroves, shoreline and rock groin. Both spring and neap tide roosts occur in the broadwaters. Spring tide roosts are limited to saltmarsh and mangrove types, whilst neap tide roosts include all the above-mentioned types. Use of roosts has varied over time, some of the major changes include:

1. Spring tide roost near Trutes Bay (Trutes Marshland) has been developed for houses.

2. Spring tide roost (Cobaki Broadwater) identified by Martindale (1987) has been overgrown by vegetation.
3. Mangrove fringe in Cobaki Broadwater has been overgrown by vegetation
4. Sewage drain roost identified by Martindale (1987) has become overgrown with vegetation.
5. Spring tide roost at Pony Club has been affected by vegetation encroachment.
6. Spring tide roost adjacent to Duroby Creek (Duroby Marsh) has been affected by vegetation encroachment.
7. Rock groin roost in Cobaki Creek has been affected by vegetation encroachment.

Apart from mangrove roosts in Cobaki Broadwater and at Womgin and Big Islands the only remaining spring tide roosts in the broadwaters are Duroby Marsh and Pony Club, both of which have been affected by vegetation encroachment.

Sandpiper Ecological Surveys (2003) prioritised roosts for estuarine birds using data gathered between 1997 and 2002. Although the site prioritisation considered all estuarine birds the results are relevant to shorebirds. That study identified Kerosene Inlet, Tony's Bar, Trutes Marshland, Womgin Island and Duroby Marsh as the five most important shorebird roost sites. The latter three sites are situated within or near Terranora Broadwater, although Trutes Marshland was partially destroyed by residential development and is no longer used by shorebirds. Roosts in Cobaki Broadwater, that is, Cobaki Creek, Pony Club and Cobaki Broadwater, were rated 15 (20.1), 18 (15.06) and 13 (21.59) respectively. The primary limitations of roosts in the broadwaters is that most are neap tide roosts only, are small in size, provide habitat for single species or are effected by vegetation encroachment. Collectively the available roosts are unsuitable to satisfy the requirements of shorebirds foraging in the broadwaters.

Foraging Areas

Extensive areas of intertidal foraging habitat occur in the Terranora and Cobaki Broadwaters. These foraging areas include a variety of habitat types and are of critical importance to the shorebird population in the Tweed Estuary. Of particular importance are the extensive intertidal mudflats in Trutes Bay, Trutes Bay west and Cobaki Broadwater, and seagrass beds and sandflats at Womgin Island (Sandpiper Ecological Surveys 2003). These areas regularly support 40-60% of the estuaries shorebird population at low tide. A low tide site prioritisation ranked Womgin Island, Trutes Bay and Cobaki Broadwater as the second, fourth and fifth most important sites in the estuary (Sandpiper Ecological Surveys 2003). Based on area alone the intertidal habitat in the broadwaters could support substantial numbers and a high diversity of shorebirds. However, it is strongly suspected that use of foraging habitat is constrained by the absence of good quality spring tide roosts nearby.

Important Habitat Features

The habitat prioritisation undertaken by Sandpiper Ecological Surveys (2003) showed that the highest priority roosts (i.e. Kerosene Inlet and Tony's Bar) are remote to high quality foraging habitat which occurs in the broadwaters. One of the most important features of shorebird habitat is that good quality spring tide roosts occur near important foraging areas (Table 5.1). Shorebirds expend less energy moving between roost and foraging sites when these critical habitat features are close together. The distance between roost and foraging areas is thought to be a major reason for the decline in the number of migratory shorebirds and the absence of small species (Rohweder 2007). Historically, important spring tide roosts were situated within or close to important foraging habitat in the broadwaters (Martindale 1987; WBM 1996; Sandpiper

Ecological Surveys 1999). Over time these roosts have deteriorated (i.e. Trutes Marshland and Pony Club) and the only remaining spring tide roost at Duroby Marsh is deteriorating.

Other important habitat features that require protection include:

- Expansive mudflats in Trutes Bay, Trutes Bay west and Cobaki Broadwater.
- Expansive intertidal sandflats at Womgin Island and at the entrance to Cobaki Broadwater (i.e. upper limit of Cobaki Creek)
- Seagrass beds at Womgin Island and around the islands at the entrance to Terranora Broadwater.
- Healthy benthic macro-invertebrate community.
- Low levels of human recreation.
- Saltmarsh habitat adjacent to Duroby Creek (i.e. Duroby Marsh).
- Established mangrove forests.

Management of important habitat features extends beyond the protection of individual sites. It includes the need to manage stormwater inputs, sediment deposition, water quality and recreational use of the broadwaters.

How are Shorebirds affected by Threatening Processes?

Threatening processes have both immediate and long-term impacts on shorebirds and together the various threatening process and impacts have a cumulative effect on shorebird populations. The immediate effect of a threatening process is often obvious. For example, removal of a roost means that birds can no longer use that site. Likewise recreational disturbance has an immediate effect – it typically causes birds to fly away from the disturbance source, and predation of nests means that eggs are consumed. Long-term impacts are often less obvious but still reduce the suitability of sites. For example, growth of mangroves on sandbars and in saltmarsh takes many years to have a detrimental effect on shorebirds. In the early stages of mangrove invasion shorebirds can roost within seedlings, however, this changes as the mangroves grow, reducing visibility and space. The impact of predation can also be long-term as it can take many years before the effect of reduced juvenile recruitment becomes obvious.

To fully understand the cumulative effect of threatening processes it is essential to have a basic understanding of shorebird biology, particularly migratory shorebirds. Migratory shorebirds have a rigorous annual cycle which involves reproduction, southward migration, two moults (i.e. into and out of breeding plumage) and northward migration. Each component of the annual cycle requires energy. In the weeks prior to migration shorebirds accumulate large fat reserves, up to 50% of body mass in some species, often doubling their arrival (post migration) weight. Reserves of body fat are converted to energy to fuel migration. To accumulate the fat reserves required for migration (and moult) shorebirds must adhere to a strict energy budget and it is essential that energy income exceeds energy expenditure. This means that on a day-day basis shorebirds must reduce energy expenditure and maximise energy income. Birds that are unable to accumulate sufficient fat reserves (or energy income) for migration will most likely perish. The high degree of site fidelity shown by shorebirds means that high mortality and reduced breeding success ultimately leads to population decreases at non-breeding sites like the Tweed River Estuary.

Non-breeding habitat plays a critical role in the annual cycle as it is at these sites that birds must gain sufficient energy reserves to return to the breeding grounds. The distribution and use of roost and foraging areas is of fundamental importance in ensuring that energy income exceeds expenditure. Ideally roosts should be situated close to preferred foraging areas and experience minimal disturbance. Shorebirds are more likely to experience an energy deficit when they are disturbed at high tide when they are often forced to fly in response to disturbance. Flight costs a bird 2-3 times more energy than walking or foraging (Van de Kam 2004). The effect of disturbance is compounded when roosts are widely separated or limited in number. The energy expended at high tide must be accounted for by foraging at low tide. The worst-case-scenario occurs when birds spend most of the high tide period flying and an energy deficit occurs when birds are unable to account for lost energy. Successive days of an energy deficit means that birds become energetically bankrupt and are unable to successfully complete their annual cycle.

The pattern of habitat loss, modification and disturbance of roosts in the Tweed Estuary provides an excellent scenario for population decrease. For example:

- Roosts close to major foraging areas (in the broadwaters) have declined in quality forcing birds to fly longer distances between roosts and foraging areas.
- The matrix of roosts in the Tweed River, which provided alternative sites during periods of disturbance, have declined in suitability leaving only one viable site at high tide.
- The frequency of human disturbance has increased causing birds to be disturbed more frequently.
- The lack of roost options means that birds are forced to fly more frequently and for longer periods of time.
- Whilst the frequency and duration of disturbance have increased the amount of time that birds need to forage (to balance the energy budget) and the quality of foraging habitat has not increased.

The end result of the above situation is an energy deficit for shorebirds residing in the Tweed River Estuary and poor migration and breeding prospects.

5.5 Management of Shorebirds in Terranora and Cobaki Broadwaters

Management of shorebird habitat in the broadwaters is critical to ensure that the Tweed River Estuary shorebird population remains viable. Without immediate action it is predicted that the migratory shorebird population will decrease to less than 100 individuals within 5-10 years, or approximately 10% of the population recorded in the 1980’s (Martindale 1987; DPWS 1991). In developing and implementing management strategies it is important to realise that the broadwaters are not used by a unique population of shorebirds that is isolated from the rest of the Tweed Estuary and that the population within the broadwaters is influenced by factors operating at the estuarine scale and, in the case of migratory species, the flyway scale.

Sandpiper Ecological Surveys (2003) recommended a five tiered approach to managing estuarine birds in the Tweed River Estuary, including:

1. Protection of important sites.
2. Restoration of important sites that have been degraded by threatening processes.
3. Creation of new habitat in areas where habitat has declined in suitability.
4. Monitoring and research.
5. Ongoing management of estuarine bird habitat.

Each of the above components remains relevant to managing shorebirds. However, given the failure of recent proposals to restore habitat at Kerosene Inlet, Tony’s Bar and Rocky Point by selectively removing mangroves, and manage recreational activity at Kerosene Inlet through signage it is necessary to adopt an alternative approach. The recommended approach focuses most effort on the broadwaters as these contain extensive areas of foraging habitat and experience minimal human disturbance. Nonetheless, ongoing management at Kerosene Inlet is also critical to the shorebird population in the Tweed Estuary. Kerosene Inlet includes known breeding and roosting habitat for threatened and migratory shorebirds and will remain a major roost.

Management strategies have been provided in Section 14.

6 Aboriginal Cultural Heritage Values

Aboriginal people along the North Arm of the Tweed River are known as the Tul-gi-gin tribe. The Tul-gi-gin people were one of three groups of the Tweed Valley. Their country probably included the Cobaki and Terranora Broadwaters and connected sub-catchments. The two other groups of the Tweed Valley were the Cooginburra people, who occupied the coastal strip south from the Tweed River to around Pottsville and inland to the Condong Range, and the Moorung-Moobar who occupied the balance of the valley around Wollumbin (Mt Warning) (Fox, 2006).

The Cultural Heritage Management Strategy 2003 – 2007 (DEC – NPWS) requires that Aboriginal heritage must be considered as part of land management. The region has a rich and continuing Aboriginal heritage. Historic records demonstrate a history of regular large gatherings of traditional Aboriginal people along the Tugun sand plain, Lower Tweed Estuary, and adjacent broadwater shorelines. The significant number of remaining middens and campsites within the area support the historic record (Fox, 2006).

Site types include: open campsites, isolated artefacts, occupational deposits in rock shelters and caves, middens, quarries, grinding grooves, scarred trees, fish traps, burial sites, rock art, ceremonial sites, and natural sacred sites. There are many locations throughout the creeks' catchments with a high probability for containing sites of cultural significance. The location of these sites is mapped in the Cobaki and Terranora Broadwater Aboriginal Cultural Heritage Management Plan (Fox, 2006). There are extensive areas of the catchment that have a higher probably for containing sites of Cultural Significance. Areas of cultural significance which contain registered sites are primarily along the foreshores of the broadwaters and include:

- The eastern and north-eastern foreshore of Terranora Broadwater;
- The southern bank of Terranora Creek;
- Areas near the confluence of Cobaki Creek and Terranora Creek;
- The area to the east of the Cobaki Broadwater in the vicinity of the alignment of the Tugun Bypass.

It is likely that important sites in the vicinity of the Tugun Bypass have been lost (Ecograph, 2004). Measures are required to protect the remaining sites of the Terranora Broadwater (Tweed Shire Council 1994 – Terranora Broadwater Management Plan). Threats to cultural heritage sites include agricultural development, housing / urban development, deliberate vandalism, mining, recreational interest, natural causes and road making have contributed to the destruction of Aboriginal sites. It is therefore important to recognise the Aboriginal cultural sites that remain (Fox, 2006).

The Cobaki and Terranora Broadwater Aboriginal Cultural Heritage Management Plan (Fox, 2006) is a component plan and is to be read in conjunction with the CZMP. The Aboriginal Cultural Heritage Management Plan prepared for Cobaki and Terranora in 2006 will be updated in 2010 to ensure that significant new information derived from excavation studies undertaken in association with developments in the area can be incorporated.

7 Socio-economic Values

7.1 Recreation

The foreshores of the Terranora and Cobaki Broadwaters have been assessed as being of high, or the highest visual quality and are important recreation areas for locals and tourists. Existing recreation facilities include: boat ramps, jetties / public wharves, boat mooring areas, parks and public reserves, estuarine swimming areas, exercise trails, walking tracks / boardwalks, cycle paths.

7.1.1 Boating and Fishing

Popular boating activities in the Tweed Estuary include: cruising/pleasure boating, water skiing, rowing, canoeing, sailing and kayaking (NSW Maritime, 2006, Boating plan). Tweed Estuary is one of the busiest waterways in the state with the number of vessels increasing each year (NSW Maritime, 2006). The Lower Tweed is used by large numbers of recreational fishers and has the reputation of being an excellent fishing area. The river banks are generally easily accessible, attracting many anglers to fish from shore. In contrast, most recreational fishing in the upper Tweed Estuary is vessel based, as bank access is more limited (NSW Maritime, 2006).

The broadwaters are valued as areas to enjoy passive recreational activities such as fishing, canoeing and kayaking. Cobaki Broadwater contains several popular fishing spots including bridges and rocky outcrops, particularly within the reaches between Piggabeen Bridge to West Tweed Heads. The Cobaki and Terranora Broadwaters are a significant component of the Tweed system and directly contribute to the recreational catch from the Tweed (FRC, 2001 Tugun Bypass EIS - Technical Paper 12)). Recreational anglers are mostly local with tourist numbers peaking over the summer months. Fish commonly caught by recreational anglers within the broadwaters include: whiting, flathead, bream, mangrove jack, garfish, trevally, herring and mullet.

The broadwaters are shallow and sheltered, and a natural navigational hazard for all but small boats. The Tweed Estuary Boating Plan (2006 – 2010) recognises the need to reduce potential boating impacts on the broadwaters while maintaining the recreational amenity by encouraging only sensitive low impact activity. The current strategy is to discourage any improvements in boating access that would increase boating activity to promote habitat protection.

7.1.2 Walking Tracks

There are existing paths and cycleways that are promoted by Council as part of the Tweed Cycleways network. Mapping is provided below, showing the pathways in yellow (Figure 7.1) which are a combination of off road and on road cycleways, footpaths and boardwalks.

Opportunities for improvement or extension to the current network have been considered with Council as part of this study. Opportunities existing in the Cobaki Broadwater catchment for the establishment of walking trails or utilisation of existing fire trails around the Cobaki Broadwater foreshore. These may become a higher priority as the demand for recreational facilities increases with the development of Cobaki Lakes.

In the Terranora Broadwater Catchment a walking track is present along the north-western foreshore of Terranora Broadwater. Interpretive signage was installed along this track but was destroyed. A walkway/boardwalk was proposed in the previous management plan for the 'tall timbers' and mangrove forests of the eastern foreshore to blend habitat conservation and educational experience. One section of this walkway and board walk has been constructed at Philp Parade.

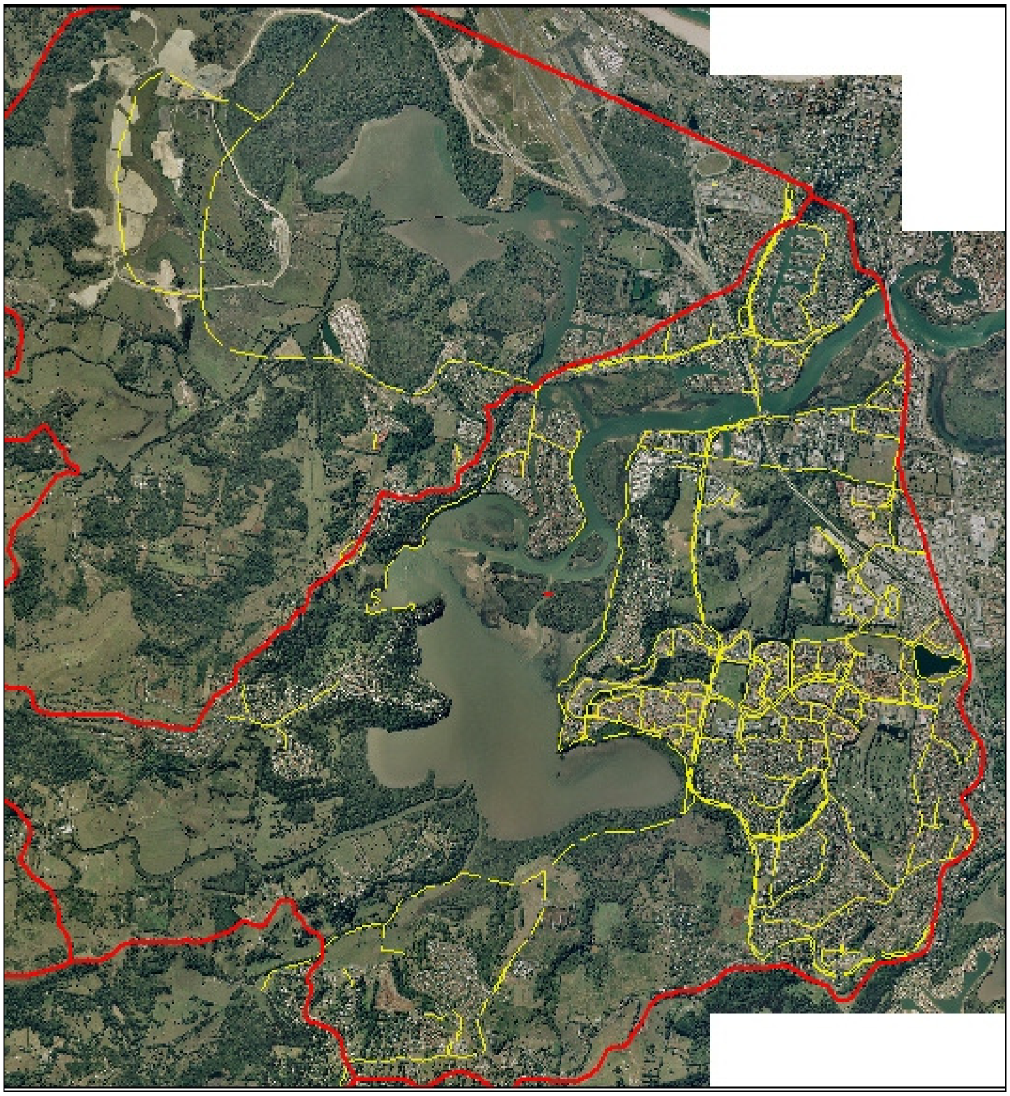


Figure 7.1. Existing/planned paths and cycleways

7.2 Commercial

7.2.1 Commercial Fishing

The Tweed River Estuary comprises one of the most productive estuaries for finfish and crustacean in northern NSW. The estuary supports an extensive commercial fishery. The

Terranora Creek system hosts a number of fish species of commercial and recreational importance (GHD, 2005).

Major commercial species include *Girella tricuspidate* (luderick), *Silago ciliata* (sand whiting), *Mugil cephalus* (sea mullet), and *M. georgii* (fantail mullet). Commercially important crustacean include *Metapenaeus macleayi* (school prawn) and *Scylla serrata* (mud crab).There are approximately 30 commercial fishers licensed to fish the Cobaki Broadwater. Net (haul and mesh) fishing, crab fishing, prawn netting (Tugun Bypass EIS – Technical Paper 12)

Commercial fishing is regulated under the Fisheries Management Act, 1994. Commercial fisheries within NSW have been undergoing structural adjustment since the early 1980's when a freeze was placed on the issuing of licences.

Commercial fishing that is undertaken in the Tweed River estuary is undertaken by licensed fishers endorsed in the Estuary General commercial fishery. The Tweed estuary is located in Region 1 which extends to Jerusalem Creek half way between Evans Head and Iluka. Estuary General fishers within Region 1 can, subject to various closures and other restrictions fish in either the Tweed or Richmond estuaries. Estuary General fishing is managed with a suite of controls, including limiting the number of participants within the estuary. Regulations govern the location, time, method, number of persons undertaking fishing operations and the gear used (mesh sizes and net lengths). Commercial fishers are also governed by minimum size limits. The Estuary General Fishery Management Strategy details the controls on the fishery in considerably more detail and is available at: www.dpi.nsw.gov.au/_data/assets/pdf_file/0003/224274/EG-FMS.pdf.

The stocks of fish species caught by Estuary General Fisheries are also caught by other commercial fishers in other fisheries, i.e. in the Ocean Haul Fishery and by recreational fishers within the Tweed estuary and also within other estuaries in NSW. Managing sustainable fisheries needs to be about managing the sustainable harvest of the stock by all stakeholders over a wide area. Management of the key fish habitats required by the stock is another important aspect of fisheries management.

Within Region 1 several parts of the Tweed estuary were identified as Rec havens and 18 commercial fishing businesses were bought out. Today approximately 50 fishing businesses with endorsements in the Estuary General Fishery remain in Region 1. It should be noted that an individual can have more than one fishing business. Only a small number of these fishing businesses, perhaps as few as 10 derive the majority of their income from estuary fishing in the Tweed.

7.2.2 Oyster Farming

Oyster aquaculture is the state's most valuable fishery (NSW DPI, 2006). In accordance with the recommendations of the Healthy Rivers Commission, 'priority' areas for edible oyster aquaculture have been identified based on criteria including location, environmental and socio-economic suitability. The priority areas are considered areas where commercial oyster aquaculture is a priority intended outcome from a state perspective. There are currently between ten to twelve commercial oyster leases in the Terranora Broadwater at present all of which are located within the areas designated as priority commercial aquaculture areas (Figure 7.3).

Figure 7.2. Oyster leases in Bingham Bay, Terranora Broadwater, viewed from Bilambil Heights

Source: ABER

There are currently four active oyster farms, all operating in Bingham Bay in Terranora Broadwater. There have been short term closures of the oyster industry in Terranora Broadwater due to concerns about sewage discharge in the past.

Farmed oysters are considered a sentinel species, in that oysters healthy and suitable for human consumption are likely to be correlated with a healthy estuary (NSW DPI, 2006). By filtering estuarine water, oysters can remove large quantities of suspended material such as nutrients bound in phytoplankton. However estuaries with poor water quality are therefore likely to have a large impact on the health of oysters.

To provide for the healthy growth of oysters that are safe for human consumption, a set of water quality and flow objectives for oyster aquaculture areas has been established in the NSW Oyster Industry Sustainable Aquaculture Strategy (NSW DPI, 2006). The Tweed Shellfish Quality Assurance Program requires that water quality and oyster meat testing is undertaken regularly, especially in response to rainfall. The Shellfish Program is administered by the NSW Food Authority under the Food Act, 2003. Oyster farmers are required to undertake water quality and meat testing every two weeks. Where rainfall exceeds 30mm the industry is closed until testing undertaken on water quality and meat indicates compliance with standards.

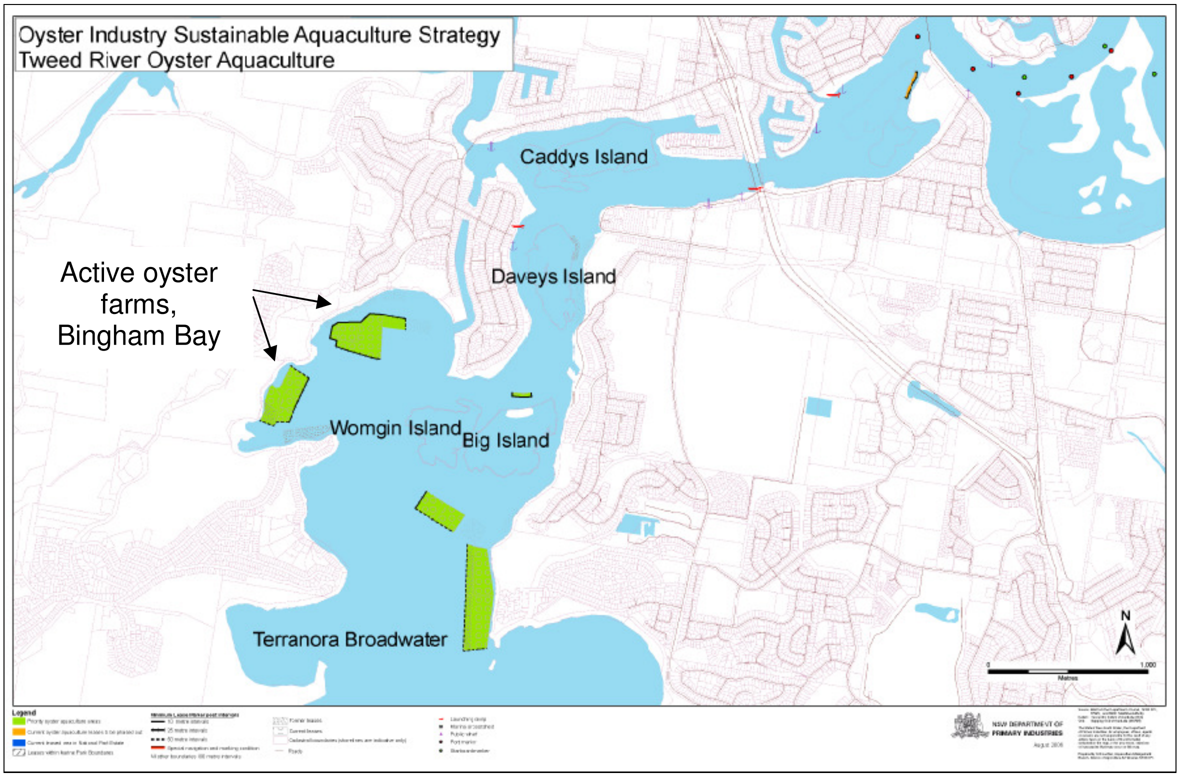


Figure 7.3. Aquaculture in Terranora Broadwater, indicating priority oyster aquaculture areas in green.

Source: NSW Oyster Industry Sustainable Aquaculture Strategy, 2006

7.2.3 Tourism

Tourism is another important commercial value of the broadwaters, with two commercial operators: Catch a Crab and Tweed Endeavour Cruises currently operating in Terranora Broadwater. These operators take shallow vessels into the Broadwater on average three – four days per week all year round, with an estimated 15,000 tourists per year, the majority being international visitors. Cruises focus on recreational fishing, bird feeding and general nature appreciation/sight seeing, providing visitors with local historical information as well as educational information relating to the native local flora and fauna. These cruises are valued due to the serenity and natural beauty of the broadwaters, the lack of houses in many areas of the broadwater and the opportunity to catch crabs.

8 Riparian and Geomorphic Assessment

A riparian and geomorphic assessment of the four main creeks (Piggabeen Creek, Cobaki Creek, Bilambil Creek and Duroby Creek) was undertaken by Australian Wetlands and Riparian Engineering to assist with the identification of priority rehabilitation areas throughout the catchment that are both highly likely to be pollutant sources and suitable for rehabilitation. The assessment of creek bank soils, structural stability and vegetation was undertaken in two stages to assist selection and prioritisation of suitable rehabilitation sites. The aim of the assessment was to select sites, which once rehabilitated, will provide the greatest enhancement to the sustainability of the broadwaters. The two stages included:

1. Aerial photograph interpretation and vegetation mapping interrogation to determine the location of suitable ground-truthing sites.
2. Field investigation of sites identified in Stage 1 including riparian and geomorphic assessment.

The methods and results are described in further detail below.

A rapid assessment of broadwater riparian vegetation was undertaken in collaboration with Tweed Shire Council based on their on-ground knowledge and Council's GIS vegetation mapping layers. The results of this assessment informed the rehabilitation prioritisation and management recommendations provided in Section 14.

8.1 Stage 1- Methodology

Stage 1 involved the selection of potential riparian rehabilitation sites (to be investigated during field assessment) via aerial photograph interpretation based on the parameters in Table 1 below. The assessment methodology for Stage 1 is based on selecting sites that are likely to be consistent with areas classed as high priority within the Tweed Vegetation Strategy, which contain, or are in the vicinity of, areas of HCV. Stage 1 also incorporated priority sites identified by the project team and TSC. These sites include potential 'hot spot' sites as determined by MUSIC modelling and sites located within certain 'functional zones' within the sub-catchments deemed likely to contribute a high pollutant load.

Table 8.1. Score sheet for Stage 1 riparian vegetation aerial mapping evaluation

RIPARIAN SITE PRIORITISATION/ CLASSIFICATION SCORE (reach based 250m approx)	**SCORE**
SEPP 14 /other – score 10 for protection / 7.5 for adjacent to protected area/ 5 for across river, 0 for no protection.	**/ 10**
Known ecological significance/ HCV – score 10 for ecological significance or for a site adjacent to an area of significance, 0 for no significance	**/ 10**
Threatened flora or fauna species – score 5 for threatened species/ 0 for no threatened species recorded at sites	**/ 5**
Location tenure - 1 = all private, 3 = public and private landholders, 5 = all public	**/ 5**
Land management /community opportunities – 0 = none, not explored, 3 = some potential, 5 = high potential	**/ 5**
Proximity to riparian zone/existing wetlands/forest - 0 = none, 1= >5km, 2 = 1-5 km, 3 = < 1 km , 4 = < 500m, 5 =adjacent/connected to existing riparian zone or existing wetlands.	**/ 5**
RIPARIAN WIDTH (aerial) : 0 = >20 m, 3 = 5- 20m, 5 = <5 m	**/ 5**
TSC PRIORITY SITE score 5	**/ 5**
OTHER FACTORS : POSSIBLE POTENTIAL FOR HIGH WQ IMPROVEMENT – MEDIUM	
SITE ASSESSMENT SCORE – HIGHEST SCORES WILL BE PRIORITISED FOR RIPARIAN ASSESSMENT	**/ 50**

The previously identified functional zones (Figure 8.1) considered likely to contribute the greatest pollutant load to the broadwaters were considered to be the mid freshwater – transition zones. As such, sites located within these zones were often given a higher 'hot spot' score. The outcomes of a preliminary Stage 1 assessment of the catchment based on API and functional zone hot spots is summarised in Table 8.2. Amongst the highest ranked sites were sites associated with Area E and Cobaki Lakes developments which are to be addressed as part of the planning and design phase of these developments and included in recommendations for Broadwater Riparian Vegetation. As such these sites were not investigated further as part of this investigation. All remaining vegetation surrounding the broadwaters is considered valuable and as such is prioritised separately. The remaining areas of the catchment ranked highest priority for further investigation in Stage 2 were:

- Bilambil Creek: mid freshwater – transition
- Piggabeen Creek: mid freshwater – transition

Results of Stage 1 field assessment are provided in Appendix B.

8.2 Main Tributaries: Stage 1 Results

Table 8.2. Stage 1 assessment scores

Subcatchment	Zone	Score	Notes
Trutes Bay/Area E Terranora Broadwater	Lower	48	To be addressed as part of Area E development.
Cobaki Lakes/Lower Piggabeen	Lower	48	To be addressed as part of Cobaki Lakes development (refer to proposed Saltmarsh rehabilitation area).
Cobaki Creek	Lower	47	High priority for further investigation
Bilambil Creek	Lower	46	High priority for further investigation
Duroby Creek	Confluence	46	To be addressed in association with Area E development.
Charles Bay / Terranora Broadwater	Lower	46	To be addressed in Terranora Broadwater foreshore rehabilitation plan.
Piggabeen/Cobaki Creek Confluence	Transition	36.5	High priority for further investigation
Bilambil Creek	Mid	33	High priority for further investigation
Bilambil Creek	Upper	27	
Piggabeen Creek	Mid	26	
Piggabeen Creek	Lower	26	
Piggabeen Creek	Upper	23	
Duroby Creek	Upper	16	
Duroby Creek	Mid	16	
Duroby Creek	Mid/Lower	13	
Cobaki Creek	Mid	11	
Cobaki Creek	Upper	7	

8.3 Stage 2 – Methodology

Stage 2 involved ground-truthing the sites selected in Stage 1. An assessment of site parameters including vegetation, habitat values, connectivity, bed/bank stability and threatening processes was undertaken. In recognition of the importance of geomorphic processes on the water quality and ecology of the broadwaters, a rapid geomorphic assessment of the four creeks was undertaken by Riparian Engineering. The scores from this assessment were incorporated with riparian vegetation assessment scores to produce a total score for each site.

The location of the sites assessed are shown in Figure 8.1 and Appendix C (GPS coordinates). The same sites were assessed for both riparian and geomorphic condition, with additional sites added as deemed appropriate to most accurately reflect the geomorphic attributes of each subcatchment.

Stage 1 identified high value zones suitable for rehabilitation using API and discussion with TSC. The field assessment then investigated the condition of these identified zones and sites, generating a score reflective of their condition and severity of threatening processes. Those in the poorest condition, contributing to declining water quality, could then be prioritised for rehabilitation based on the aim of rehabilitating sites where the biggest improvement to ecosystem health could be made.

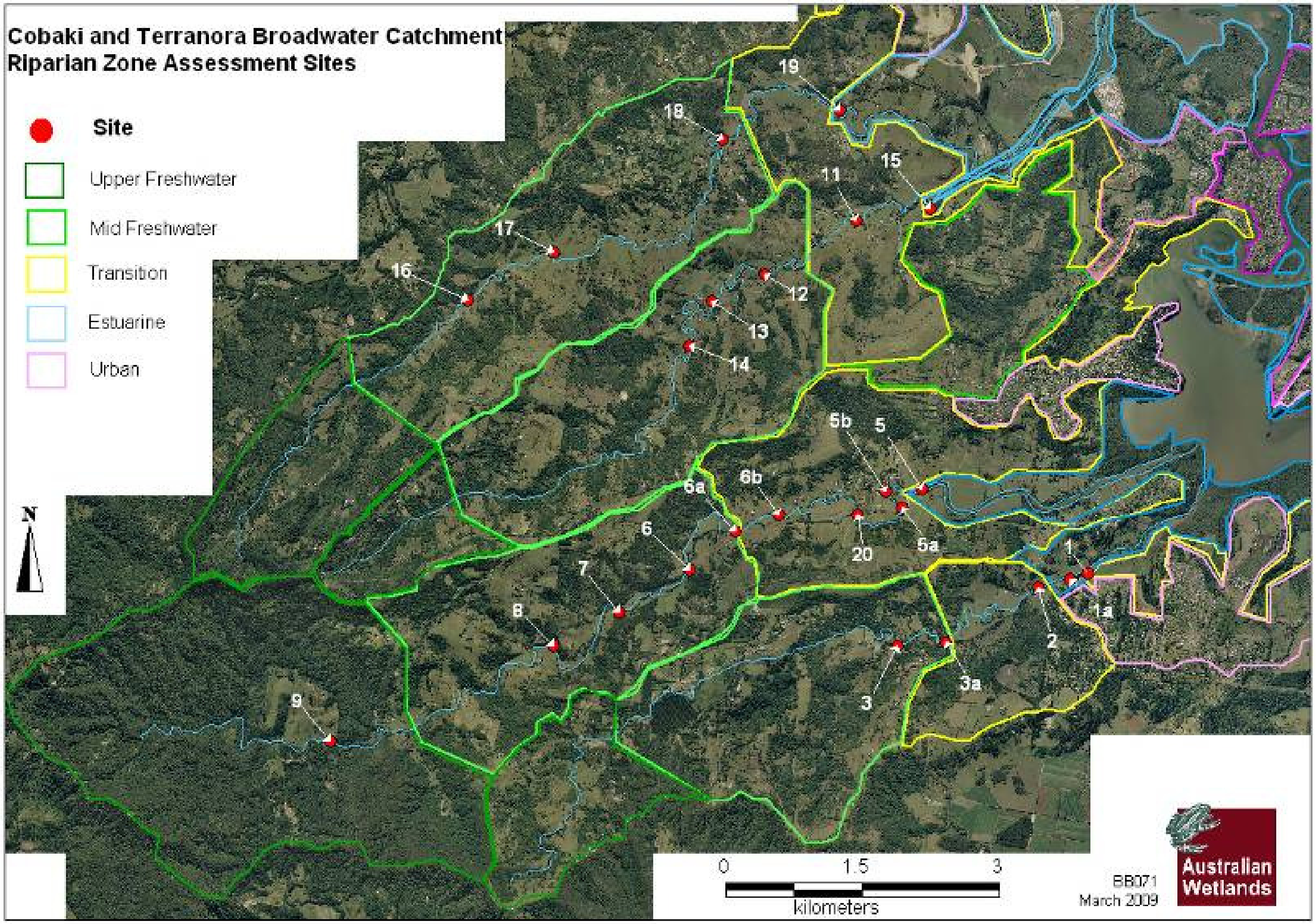


Figure 8.1. Cobaki and Terranora Broadwater catchment riparian zone assessment sites and function zone

8.3.1 Geomorphic Assessment Methodology

The rapid geomorphic assessment was undertaken by Riparian Engineering (Dilworth, 2008). Additional sites were selected in the field and targeted *alluvial meandering, tidal, and confined valley with bedrock controlled discontinuous floodplain* Rivers Styles as classified by Lambert *et al* (1999), as these were considered the most sensitive to anthropogenic disturbances. An assessment table was completed describing the creek geomorphic characteristics, behaviour, processes, stability, condition, and recovery potential. Creek target conditions were also assessed. The following geomorphic assessments were undertaken:

- Geomorphic Stability assessment;
- Geomorphic Condition (creek bed and banks); and,
- Recovery Potential.

Geomorphic Stability Assessment

Geomorphic stability was assessed at each site using a developed methodology by Rosgen (1996). The assessment was scored using Table 8.3.

Table 8.3. Geomorphic stability assessment

Geomorphic Stability	Characteristics	Score
Stable	Geomorphic structure of the channel unaltered or largely unchanged from pre-European disturbance state, and geomorphic form processes (sediment transport) are in equilibrium with existing channel geometry. High sediment transport competence. These stream sections were bedrock controlled and hence have not been subject or will be subject to bed level adjustments.	**100 – 80**
Moderately Unstable	Stable convex stream banks with intact bank toes stable. Isolated incidences of bed and bank erosion may be observed but can easily be addressed by restoring riparian vegetation, strategic reintroducing LWD, and protecting bank toes with bolders.	**80 – 50**
Unstable	Both bed level and and/or lateral adjustments are active in the stream. Vertical stream banks indicate major bank erosion, which is associated with active bed level adjustments in the creek. Vertical stream banks and bed level adjustments (minor head cuts) are observed frequently	**50 – 35**
Highly unstable	The channel is entrenched and highly unstable with ongoing vertical and/or lateral bed and bank erosion observed. Stream banks are vertical to concave and there numerous bed level adjustments found in the creek section.	**35 – 0**

Geomorphic Condition

Geomorphic condition was assessed at each site based on the geomorphic condition assessment developed by Lambert *et al.* (1999). Table 8.4 outlines this assessment and how each site was scored.

Table 8.4. Geomorphic Condition (creek bed and banks)

Geomorphic Condition	Characteristics	Score
Near Intact	Geomorphic structure is largely unchanged from the pre-disturbance state. Riparian vegetations often largely unchanged. Geomorphic form characteristics, and processes in equilibrium. The creek still provides critical aquatic habitat refuge.	100 – 80
Good	Geomorphic structure is largely unchanged from the pre-disturbance state, but vegetation cover and compositions may be significantly altered. Geomorphic form characteristics, and processes in equilibrium. The creek still provides critical aquatic habitat refuge.	80 – 65
Moderately Impacted	Geomorphic form characteristics and processes have been disturbed in the past and remain out of equilibrium. The creek has not adjusted to prevailing conditions and is experiencing ongoing changes. However, the creek still provides critical aquatic habitat refuge, although in a some what degraded condition.	65 – 45
Degraded	The channel has become entrenched, laterally and vertically expanded to its most degraded condition, and the channel is disconnect form the floodplain. Geomorphic form characteristics and processes are degraded. The creek provides limited aquatic habitat refuge.	45 – 0

Recovery Potential

Recovery potential was assessed at each site based on the recovery potential assessment developed by Lambert *et al*. (1999). Table 8.5 outlines this assessment and how each site was scored.

Table 8.5. Recovery Potential

Recovery Potential	Characteristics	Score
Strategic	Are sites or reaches which are sensitive to disturbance triggering: upstream geomorphic degradation; lateral and vertical expansion of the channel; and, deliver an oversupply of sediment to downstream reaches. Proactive management strategies are the most effective means of creek conservations. Particular emphasis on bed level adjustments (nick points/head cuts).	100 – 0 Recovery potential variable
Conservation	River structure and vegetation associations are relatively intact. Management strategies should aim to maintain, or improve, the current River Style.	100 – 80
High recovery	These reaches have high inherent natural recovery potential and will respond well to improved land management and assisted regeneration.	80 – 60
Moderate recovery	These moderately degraded sites/reaches have reasonable potential to recover and can be rehabilitated at reasonable cost. River structure and vegetation associations require improvement. Creek bed and bank rehabilitation strategies may need to employed to stabilise the creek.	60 – 40
Degraded reaches	These highly degraded sites/reaches have little natural recovery potential (i.e. the creek shows signs of continued geomorphic degradation). Extensive creek bed and bank stabilisation works are required at considerable cost over a long period of time.	40 – 0

8.3.2 Riparian Vegetation Assessment Methodology

Priority areas already selected during Stage 1 and catchment visits with TSC staff were ground-truthed during Stage 2. The methodology for Stage 2 was based on the assumption that prioritisation of sites identified in Stage 1 for rehabilitation was to be undertaken in order from the most to least degraded sites (i.e. the most degraded sites within the priority areas identified in Stage 1 would be given the highest rehabilitation priority).

The higher the score, the better condition the site was in, so the lower it scored as a priority rehabilitation site. Scoring has been weighted to emphasise the severity of threatening processes. Specific information can be selected e.g. the sites with the best habitat potential or the highest level of canopy weeds.

An example of the score sheet used for the Stage 2 assessment is provided in Appendix D. Site assessments included measures of the level of works required for rehabilitation, including identification of sites where structural works are necessary. The results of Stage 2 riparian field assessments are provided in the following sections.

8.4 Stage 2 Riparian and Geomorphic Assessment Results

The full set of riparian and geomorphic assessment scores is provided in Appendix E which includes a table of scores for all parameters. A summary of the scores given for each category of parameters is provided in Table 8.6. Several sites in the mid – transition zones of Piggabeen and Cobaki Creeks were prioritised for geomorphic rehabilitation. Given the site selection undertaken in Stage 1, which highlighted much of the degraded areas of the riparian zone, the majority of the sites received a high priority rehabilitation score of Level 1.

Table 8.6. Summary of Stage 2 riparian and geomorphic assessment scores

	PARAMETER	Longitudinal Connectivity	Width Riparian Vegetation	Native Vegetation Cover	Habitat Quality	Severity of Threatening Processes	Site Weed Control Issues /Maintenance	Rehabilitation/WQ Remediation Pot.	Bank /Bed Stability	TOTAL SITE SCORE	RIPARIAN REHABILITAITON PRIORITY	GEOMORPHIC CONDITION PRIORITY
Site	**18PM**	0	0	9	25	10	0	5	16	**65**	**1**	**1**
	12CM	0	0	8	16	20	0	8	15	**67**	**1**	**1**
	11CT	0	0	8	16	40	0	0	11	**75**	**1**	**1**
	7BM	0	0	14	5	10	10	7	31	**77**	**1**	3
	8BM	0	0	7	14	30	10	11	34	**106**	**1**	4
	3ADM	0	0	4	26	40	15	0	23	**108**	**1**	2
	13CM	0	0	12	19	50	10	0	21	**112**	**1**	**1**
	17PM	0	0	8	10	20	10	35	32	**115**	**1**	3
	6BM	5	2	10	17	30	10	7	34	**115**	**1**	3
	2DT	0	0	5	18	60	0	5	30	**118**	**1**	3
	5BL	5	0	8	34	40	5	8	38	**138**	**1**	4
	14CM	0	0	8	16	80	0	8	30	**142**	**1**	3
	16PU	5	0	9	26	40	20	40	31	**171**	**2**	3
	19PT/L	10	0	17	41	70	0	10	25	**173**	**2**	**1**
	20BT	0	2	12	29	60	5	40	30	**178**	**2**	3
	9BU	0	0	11	32	80	5	35	39	**202**	**2**	4
	3DM	0	0	10	44	100	15	3	33	**205**	**2**	3
	1DL	0	0	10	33	90	5	38	38	**214**	**2**	4
	15CL	5	0	15	49	80	25	46	40	**260**	**3**	4
ADDITIONAL GEOMORPHIC SITES	**1aDL**	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	**1**
	3aDM	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2
	5aBT	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	4
	5bBT	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2
	6a	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2
	6bBT	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	3

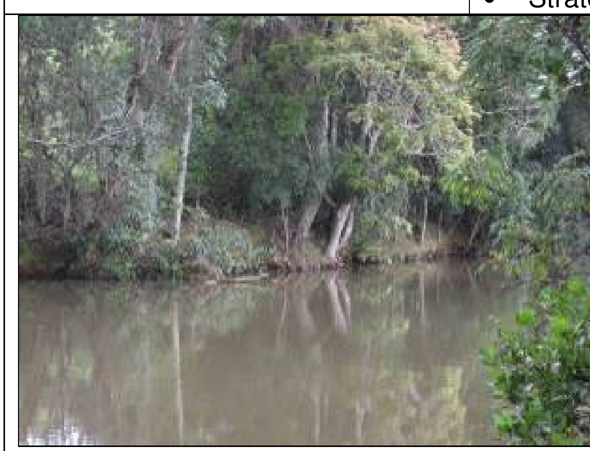
Note:
D = Duroby Creek
B = Bilambil Creek
C = Cobaki Creek
P = Piggabeen Creek
L = Lower functional zone
T = Transition functional zone
M = Mid functional zone
U = Upper functional zone

The following section provides the results of the riparian and geomorphic assessment for each site. These tables will be useful as a reference when planning riparian and geomorphic rehabilitation and are to be used in conjunction with the score sheets (Appendix) to inform the extent and type of rehabilitation necessary.

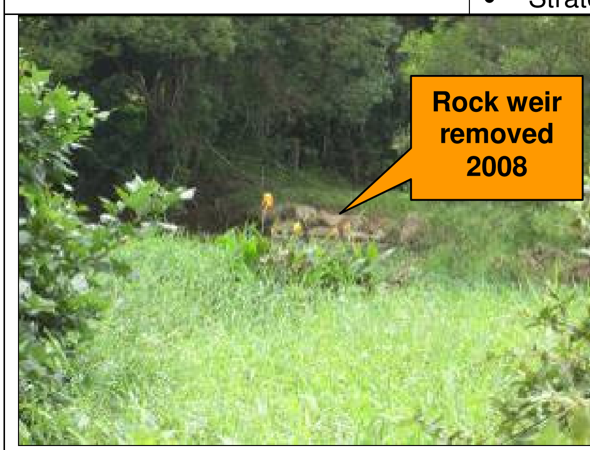
8.4.1 Duroby Creek – Lower Functional Zone

Geomorphic Assessment
(Sites 1, 1a)

Site No:	**Site 1**	
River Style Classification:	***Tidal***	
Channel Morphology:	• Symmetrical convex stream banks (max. height 2m) Bank heights range from 1m to 2m • Channel slightly entrenched • Pool dominated stream bed	
Sediment Supply/Transport	• Fines/gravels • High sediment conveyance maintains pool dominated bedform	
	Description	**Score (1..100)**
Geomorphic Stability (Description & Score):	***Moderately unstable.*** Only minor bank slumping.	75
Creek Bed and Bank Indicative Condition (Description & Score):	***Good.*** Pool dominated stream provides good aquatic habitat.	75
Recovery Potential (Description & Score):	***High.***	75
Target Condition & Regeneration Objectives:	Tidal (Existing Condition) • Remove camphor from stream banks and use as LWD in channel • Riparian vegetation buffer width (minimum 10-15m) • Strategic habitat placement of LWD	



Site No:	Site 1a	
River Style Classification:	***(Weir) Tidal***	
Channel Morphology:	• Asymmetrical convex stream banks (max. height 4m). Bank heights range from 3m to 4m • South bank 3m with rock revetment • Channel Entrenched • Pool dominated stream bed downstream • Weir will obstruct fish passage in low flows	
Sediment Supply/Transport	• Fines/gravels • Discontinuity in sediment conveyance at weir	
	Description	**Score (1..100)**
Geomorphic Stability (Description & Score):	***Moderately Unstable***. Rock revetment works prevent channel instability at weir.	65
Creek Bed and Bank Indicative Condition (Description & Score):	***Moderately Impacted.***	55
Recovery Potential (Description & Score):	***Moderate.*** Removing the weir may potentially lead to upstream channel re-adjustments.	55
Target Condition & Regeneration Objectives:	• Replace weir outlet with a series of smaller step weirs that will allow fish passage in low flows • Removal of weir will release up to 5000m^3 of sediment into the estuary • Resurvey channel following weir removal to monitor any sediment movement. • Riparian vegetation buffer width (minimum 5-10m) • Strategic habitat placement of LWD	



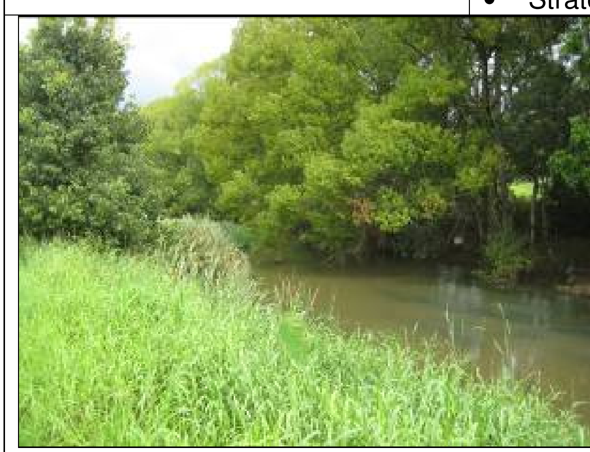
Riparian Vegetation Assessment

Site 1	Vegetation Description	Weed Species and Management
	Canopy dominated by Grey Mangrove, with mature Forest Red Gum, Brushbox and Black Walnut. The mid storey is dominated by River Mangrove and rainforest species such as Tuckeroo, Foambark, Sweet Pittosporum and Red Kamala. The understorey is dominated by Basket Grass, Native Trad and ferns.	Canopy weeds include Camphor Laurel, Hybrid Coral Tree and exotic planted trees such as African Tulip Trees. The major midstorey weed is Lantana with Para Grass, Setaria, and Broad-leaved Paspalum in the understorey. >30% weeds in canopy – mid storey 10-30% understorey up to 100%.
SITE RECOMMENDATIONS Lower Duroby Creek	Allow natural regeneration of native species near existing remnant vegetation. Use supplementary planting of lower catchment species in open areas. Encourage mangrove and saltmarsh regeneration in adjoining zones.	Fence and exclude stock from banks. Remove and control weeds Extend buffer vegetation to maximum achievable width (minimum 10m).

8.4.2 Duroby Creek – Transition Zone

Geomorphic Assessment
(Site 2)

Site No:	**Site 2**	
River Style Classification:	***Alluvial meandering***	
Channel Morphology:	• Asymmetrical convex/concave stream banks (max. height 2.5m). Bank heights range from 1 to 2m • Channel not entrenched • Pool dominated stream bed	
Sediment Supply/Transport	• Fines/gravels • Low sediment conveyance accreting in the creek due to low boundary roughness, which is caused by lack of riparian vegetation	
	Description	**Score (1..100)**
Geomorphic Stability (Description & Score):	***Moderately Unstable.***	65
Creek Bed and Bank Indicative Condition (Description & Score):	***Moderately Impacted.***	55
Recovery Potential (Description & Score):	***Strategic/Moderate.*** There is evidence that a major bed level adjustment could be active downstream of the site towards site 1a.	55
Target Condition & Regeneration Objectives:	• Investigate potential for a downstream bed level adjustment to become activated causing future geomorphic degradation • Riparian vegetation buffer width (minimum 10-15m) • Strategic habitat placement of LWD	



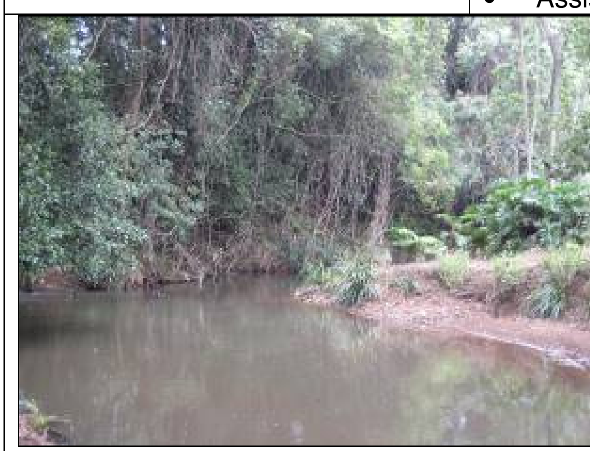
Riparian Vegetation Assessment (Site 2)

Site 2	Vegetation Description	Weed Species and Management
	Canopy is dominated by woody weeds predominantly Camphor laurel or Coral Trees. Few to no native species. The midstorey and understorey is dominated by grasses and weeds including Lantana.	Canopy weeds include Camphor Laurel, Hybrid Coral Tree. Midstorey weeds are Barner Grass and Tobaccos Bush. Understorey weeds Parra Grass 10-30% weed cover in canopy, midstorey – 31-100% weeds, understorey >10% weed cover
SITE RECOMMENDATIONS Transition Duroby Creek	Identify and encourage natural regeneration of native species near existing Camphor Laurel Use supplementary planting in open areas of lower and transition zone species. Possible demonstration site for riparian restoration	Remove Camphor Laurel using a staged approach. Control successional weeds. Extend buffer vegetation to maximum achievable width (minimum 10m).

8.4.3 Duroby Creek – Mid Zone

Geomorphic Assessment

Site No:	**Site 3**	
River Style Classification:	***Confined valley with bedrock controlled discontinuous floodplain***	
Channel Morphology:	• Asymmetrical convex stream banks (max. height 4m). Average bank height 2m • Channel moderately Entrenched • Pool/riffle dominated stream bed	
Sediment Supply/Transport	• Fines/gravels/cobbles • High sediment conveyance maintains pool/riffle dominated bedform	
	Description	**Score (1..100)**
Geomorphic Stability (Description & Score):	***Moderately Unstable***. Minor lateral and vertical adjustments observed.	65
Creek Bed and Bank Indicative Condition (Description & Score):	***Good.*** Riffle dominated stream provides good aquatic habitat.	65
Recovery Potential (Description & Score):	***High.*** Will respond well to assisted regeneration, and minor bank toe protection works.	65
Target Condition & Regeneration Objectives:	• Remove barrier to fish passage at causeway with 0.75m deeper box culvert • Assisted regeneration • Riparian vegetation buffer width (minimum 10-15m) • Assisted regeneration	



Site No:	Site 3a	
River Style Classification:	***Alluvial meandering***	
Channel Morphology:	• Symmetrical convex stream banks (max. height 2m) Bank heights range from 0.5 to 2m • Chain of ponds intersected by short riffles • Channel not entrenched (and floodplain is active	
Sediment Supply/Transport	• Fines/gravels • Moderate sediment conveyance maintains pool/riffle dominated bedform	
	Description	**Score (1..100)**
Geomorphic Stability (Description & Score):	***Unstable.*** Laterally and vertically unstable.	40
Creek Bed and Bank Indicative Condition (Description & Score):	***Moderately Impacted.*** Despite actively degrading stream provided aquatic habitat.	50
Recovery Potential (Description & Score):	***Moderate.***	50
Target Condition & Regeneration Objectives:	• Riparian vegetation buffer width should cover all lower floodplain benches and extent at least 5m outwards from top of bank • Strategic placement of LWD • Bank toe protection with boulders	

Riparian Vegetation Assessment

Site 3	Vegetation Description	Weed Species and Management
	The canopy is dominated by Blue Quandong, Bangalow Palm and White Fig. Common species in the midstorey are by Sandpaper Fig and Foambark. Creek Mat Rush (*Lomandra hystrix*) is a common native species along the toe of the bank. Native species cover is high in some places.	Canopy weeds – Camphor Laurel. Midstorey weeds Guava, Barner Grass, Cannas and pasture grasses.
SITE RECOMMENDATIONS Middle to Upper Duroby Creek	Allow natural regeneration of native species near existing remnant vegetation. Replant *Lomandra hystrix* along bank toes. Use supplementary planting of middle and upper catchment species in open areas.	Fence and exclude stock from banks. Remove and control weeds Extend buffer vegetation to maximum achievable width (minimum 10m).

8.4.4 Bilambil Creek – Lower Functional Zone

Geomorphic Assessment

Site No:	**Site 5**	
River Style Classification:	***Tidal***	
Channel Morphology:	• Symmetrical convex stream banks (max. height 2m). Bank heights range from 1 to 2m • Channel moderately entrenched and floodplains are active in larger flood events • Pool dominated stream bed	
Sediment Supply/Transport	• Fines/gravels • High sediment conveyance maintains pool dominated bedform	
	Description	**Score (1..100)**
Geomorphic Stability (Description & Score):	***Moderately Unstable.*** Minor bank slumping.	75
Creek Bed and Bank Indicative Condition (Description & Score):	***Good.*** Pool dominated stream provides good aquatic habitat.	75
Recovery Potential (Description & Score):	***High.*** Will respond well to regeneration objectives already in place. LWD inputs could be artificially increased and bank vegetation could be improved on the north bank.	75
Target Condition & Regeneration Objectives:	• Remove camphor from stream banks and use as LWD in channel • Riparian vegetation buffer width planting (minimum 10-15m out form bank) • Strategic habitat placement of LWD	

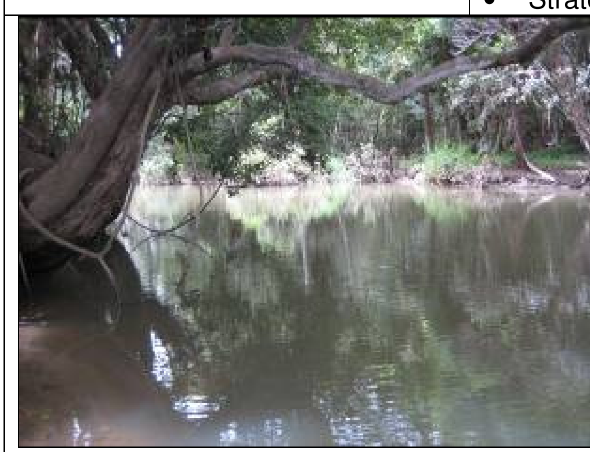
Riparian Vegetation Assessment

Site 5	Vegetation Description	Weed Species and Management
	Dominated by regenerating rainforest in the canopy and mangroves near the waterline. The major species are Hard Quandong, Foambark and Guioa with Swamp Oak, Tuckeroos and Black Wattle. The understorey is dominated with native and exotic grasses. Good regeneration on one side.	Camphor Laurel dominates the canopy weeds >30% - 100%. Midstorey weed cover 10-30% , Understorey weed cover >80%
SITE RECOMMENDATIONS Lower Bilambil Creek	Allow natural regeneration of native species near existing remnant vegetation. Use supplementary planting of lower catchment species in open areas. Encourage mangrove community regeneration. Excellent Demonstration site at the sportsground.	Remove and control weeds Extend buffer vegetation to maximum achievable width (minimum 10m). Banks stabilization works required

8.4.5 Bilambil Creek – Transition Zone

Geomorphic Assessment

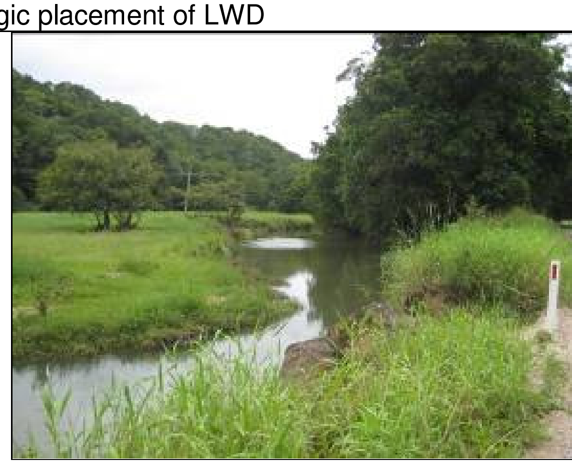
Site No:	**Site 5a**	
River Style Classification:	***Tidal***	
Channel Morphology:	• Asymmetrical convex stream banks (max. height 3m). Bank heights range from 1 to 2m • Channel moderately entrenched and floodplains are active in larger flood events • Pool dominated stream bed	
Sediment Supply/Transport	• Fines/gravels • High sediment conveyance maintains pool dominated bedform	
	Description	**Score (1..100)**
Geomorphic Stability (Description & Score):	***Moderately Unstable***. Minor bank slumping.	70
Creek Bed and Bank Indicative Condition (Description & Score):	***Good.*** Pool dominated stream provides good aquatic habitat.	75
Recovery Potential (Description & Score):	***High.*** Will respond well to regeneration objectives already in place. LWD inputs could be artificially increased and bank vegetation could be improved on the north bank.	75
Target Condition & Regeneration Objectives:	• Assisted riparian vegetation regeneration • Remove camphor from stream banks and use as LWD in channel • Riparian vegetation buffer width planting (minimum 10-15m out form bank) • Strategic habitat placement of LWD	



Site No:	Site 5b	
River Style Classification:	***Tidal***	
Channel Morphology:	• Symmetrical convex/concave stream banks (max. height 2m). Bank heights range from 1 to 2m • Pool dominated stream bed • Channel moderately entrenched and floodplains are active in larger flood events	
Sediment Supply/Transport	• Fines/gravels • Poor sediment transport conveyance, deposition of coarse sediment causing cut bank erosion and channel widening	
	Description	**Score (1..100)**
Geomorphic Stability (Description & Score):	***Unstable.*** Extensive bank erosion observed. The channel has significantly widened and a new point bar is depositing on the inside of the bend.	40
Creek Bed and Bank Indicative Condition (Description & Score):	***Moderately Impacted.***	50
Recovery Potential (Description & Score):	***Moderate.*** Recovery can occur if accreting bar can be stabilised.	50
Target Condition & Regeneration Objectives:	• Encourage bar accretion on the inside bend • Re-establish channel roughness on north bank • Protect bank toes with boulders, encourage recruitment of mangroves and salt tolerant species on bank toes. Existing bank toe protection works are not satisfactory. Flow structures can be used to improve sediment transport and geomorphic structure	

Site No:	**Site 20**	
River Style Classification:	***Alluvial Meandering***	
Channel Morphology:	• Symmetrical convex stream banks (max. height 3m). Bank heights range from 2 to 3m • Channel moderately entrenched and floodplain is active in large flood events	
Sediment Supply/Transport	• Fines/gravels • Good sediment transport conveyance	
	Description	**Score (1..100)**
Geomorphic Stability (Description & Score):	***Moderately Unstable.***	55
Creek Bed and Bank Indicative Condition (Description & Score):	***Good/Moderately Impacted.***	60
Recovery Potential (Description & Score):	***High.***	70
Target Condition & Regeneration Objectives:		

Site No:	Site 6 b	
River Style Classification:	***Confined valley with bedrock controlled discontinuous floodplain***	
Channel Morphology:	• Asymmetrical convex stream banks (max. height 1.75m). Average bank height 1m • Channel not entrenched and floodplain is active • Riffle/glide dominated stream bed	
Sediment Supply/Transport	• Fines/gravels/cobbles • Moderate to poor sediment conveyance maintains glide dominated bedform	
	Description	**Score (1..100)**
Geomorphic Stability (Description & Score):	***Moderately Unstable.*** Minor lateral adjustment to channel location.	65
Creek Bed and Bank Indicative Condition (Description & Score):	***Moderately Impacted.*** Glide dominated stream provides average to poor aquatic habitat.	50
Recovery Potential (Description & Score):	***Moderate.***	60
Target Condition & Regeneration Objectives:	• Riparian vegetation buffer width (minimum 10-15m offset form top of bank). Restrict grazing adjacent revegetation sites • Some bank toe boulder protection may be required at cut bank sites • Strategic placement of LWD	



Riparian Vegetation Assessment

Site 20	Vegetation Description	Weed Species and Management
	Canopy vegetation dominated by Creek Weeping Lilly Pilly (*Waterhousia floribunda),* with Sandpaper Fig in the midstorey and Creek Mat Rush (*Lomandra hystrix*) in the understorey. Approximately 30% native cover in the canopy, with 10% native in the understorey	The major canopy weed is Camphor Laurel with Guava in the midstorey. Understorey weeds were Para Grass, Hairy commelina and Mist Flower. Up to 70% weed cover in canopy, midstorey – 31-100% weeds, understorey >10% weed cover.
SITE RECOMMENDATIONS Bilambil Transition	Identify and encourage natural regeneration of native species near existing Camphor Laurel Use supplementary planting in open areas of transition zone species.	Ensure stock is excluded from banks by fencing. Remove Camphor Laurel and non natives using a staged approach. Control successional weeds. Extend buffer vegetation to maximum achievable width (minimum 10m).

8.4.6 Bilambil Creek – Mid Zone

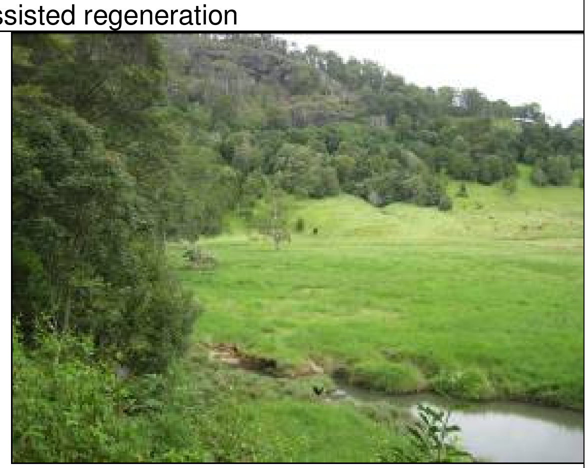
Geomorphic Assessment

Site No:	**Site 6 a**	
River Style Classification:	***Confined valley with bedrock controlled discontinuous floodplain***	
Channel Morphology:	• Asymmetrical convex stream banks (max. height 1.75m). Average bank height 1m • Channel width (W) 60m to depth (D) 2m • Channel not entrenched (W/D=30) and floodplain is active • Riffle/glide dominated stream bed	
Sediment Supply/Transport	• Fines/gravels/cobbles • Moderate to poor sediment conveyance maintains glide dominated bedform.	
	Description	**Score (1..100)**
Geomorphic Stability (Description & Score):	***Moderately Unstable***. Minor lateral adjustment to channel location.	55
Creek Bed and Bank Indicative Condition (Description & Score):	***Moderately Impacted.*** Glide dominated stream provides average to poor aquatic habitat.	45
Recovery Potential (Description & Score):	***Moderate.***	55
Target Condition & Regeneration Objectives:	• Riparian vegetation buffer width (minimum 10-15m offset form top of bank). Restrict grazing adjacent revegetation sites • Some bank toe boulder protection may be required at cut bank sites • Strategic placement of LWD	

Site No:	**Site 6**	
River Style Classification:	***Confined valley with bedrock controlled discontinuous floodplain***	
Channel Morphology:	• Asymmetrical convex stream banks (max. height 2.25m). Average bank height 1-1.5m • Channel not entrenched and floodplain is active • Riffle/glide dominated stream bed	
Sediment Supply/Transport	• Fines/gravels/cobbles • Moderate to poor sediment conveyance maintains glide dominated bedform	
	Description	**Score (1..100)**
Geomorphic Stability (Description & Score):	***Moderately Unstable.***	65
Creek Bed and Bank Indicative Condition (Description & Score):	***Good.***	65
Recovery Potential (Description & Score):	***High.*** Will respond well to revegetation and assisted regeneration.	75
Target Condition & Regeneration Objectives:	• Riparian vegetation buffer width (minimum 10-15m offset form top of bank). Restrict grazing adjacent revegetation sites • Some bank toe boulder protection may be required at cut bank sites • Strategic placement of LWD	
		

Site No:	Site 7	
River Style Classification:	***Confined valley with bedrock controlled discontinuous floodplain***	
Channel Morphology:	• Asymmetrical convex stream banks (max. height 1.75m). Average bank height 0.75m • Channel not entrenched and floodplain is active • Riffle dominated stream bed	
Sediment Supply/Transport	• Fines/gravels/cobbles • Moderate sediment conveyance maintains riffle/glide dominated bedform	
	Description	**Score (1..100)**
Geomorphic Stability (Description & Score):	***Moderately Unstable.***	65
Creek Bed and Bank Indicative Condition (Description & Score):	***Moderately Impacted.*** Riffle/ glide dominated stream provides average aquatic habitat.	55
Recovery Potential (Description & Score):	***Moderate.*** Will respond well to regeneration/revegetation.	65
Target Condition & Regeneration Objectives:	• Riparian vegetation buffer width (minimum 10-15m) • Some bank toe boulder protection may be required at cut bank sites • Strategic placement of LWD	

Site No:	**Site 8**	
River Style Classification:	***Confined valley with bedrock controlled discontinuous floodplain***	
Channel Morphology:	• Asymmetrical convex stream banks (max. height 2m). Average bank height 1m • Channel not entrenched floodplain active • Riffle dominated stream bed	
Sediment Supply/Transport	• Fines/gravels/cobbles • High sediment conveyance maintains pool/riffle dominated bedform	
	Description	**Score (1..100)**
Geomorphic Stability (Description & Score):	***Moderately Unstable.***	75
Creek Bed and Bank Indicative Condition (Description & Score):	***Good.*** Riffle dominated stream provides good aquatic habitat.	70
Recovery Potential (Description & Score):	***High.***	75
Target Condition & Regeneration Objectives:	• Strategic placement of LWD • Riparian vegetation buffer width (minimum 10-10m) and assisted regeneration	



Site 6	**Vegetation Description**	**Weed Species and Management**
	Canopy dominated by Camphor Laurel with around 30% native trees including Hoop Pine, Weeping Lilly Pilly and Hard Quandong. The midstorey is underdeveloped. The understorey is mainly grasses with some native Carex.	Canopy and midstorey weed cover is 10-30%, The midstorey is underdeveloped and where present is dominated by Lantana and Cestrum. Understorey weed cover is up to 100% The understorey is mainly exotic grasses including Broad-leaved Paspalum and Para Grass.
Sites 7 & 8		
	Native canopy species were sparse but included Blue Quandong, Blackbean and various figs. Midstorey and understorey natives rare.	Canopy weeds are predominantly Camphor Laurel, with Lantana and pasture grasses in the mid and understorey. Canopy cover is less than 10%
SITE RECOMMENDATIONS Bilambil middle	Allow natural regeneration of native species near existing remnant vegetation. Replant *Lomandra hystrix* along bank toes. Use supplementary planting of middle catchment species in open areas.	Fence and exclude stock from banks. Remove and control weeds Extend buffer vegetation to maximum achievable width (minimum 10m).

8.4.7 Bilambil Creek – Upper Zone

Geomorphic Assessment

Site No:	**Site 9**	
River Style Classification:	***Bedrock controlled headwater***	
Channel Morphology:	• Symmetrical convex stream banks (max. height 2m). Average bank height 2m • Channel naturally entrenched • Riffle dominated stream bed	
Sediment Supply/Transport	• Fines/gravels/cobbles • High sediment conveyance maintains riffle dominated bedform	
	Description	**Score (1..100)**
Geomorphic Stability (Description & Score):	***Moderately Unstable.***	80
Creek Bed and Bank Indicative Condition (Description & Score):	***Good.*** Riffle dominated stream with average to good riparian vegetation association provides good aquatic habitat.	75
Recovery Potential (Description & Score):	***Near Intact.*** Will respond well to regeneration and conservation strategies.	85
Target Condition & Regeneration Objectives:	• Remove barrier to fish passage at causeway with 1m deeper box culvert • Assisted regeneration • Riparian vegetation buffer width (minimum 10-10m) and assisted regeneration	
		

Riparian Vegetation Assessment

Site 9	Vegetation Description	Weed Species and Management
	Canopy species included Blue Quandong, Bangalow Palm and Water Gum. Dominant midstorey species were White Bolly Gum and seedlings of various rainforest species. Creek Mat Rush was the dominant understorey native species. Understorey cover was sparse <10%	Canopy weed cover is approximately 50%, dominated by Camphor Laurel. Lantana and Broad-leaved Paspalum are the major weeds in the mid and understorey.
SITE RECOMMENDATIONS Bilambil Upper	Allow natural regeneration of native species near existing remnant vegetation. Use supplementary planting of upper catchment species in open areas.	Fence and exclude stock from banks. Remove and control weeds Extend buffer vegetation to maximum achievable width (minimum 10m).

8.4.8 Cobaki Creek – Lower Zone

Geomorphic Assessment

Site No:	**Site 15**	
River Style Classification:	***Tidal***	
Channel Morphology:	• Symmetrical convex stream banks (max. height 2 m). Bank heights range from 1 to 2m • Channel width (W) 40m to depth (D) 3m • Channel moderately entrenched and floodplains are active in large flood events	
Sediment Supply/Transport	• Fines/gravels • High sediment transport conveyance to estuary	
	Description	**Score (1..100)**
Geomorphic Stability (Description & Score):	***Moderately Unstable.*** Isolated bank erosion.	75
Creek Bed and Bank Indicative Condition (Description & Score):	***Near Intact.***	85
Recovery Potential (Description & Score):	***Conservation.***	90
Target Condition & Regeneration Objectives:	• Protect existing channel dimensions • Retain and protect LWD • Protect riparian vegetation	

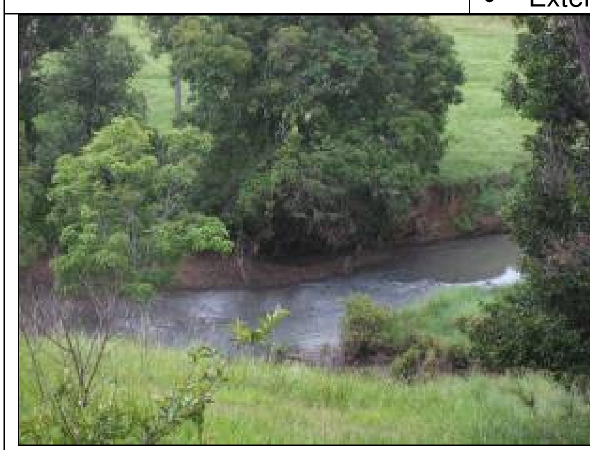
Riparian Vegetation Assessment

Site 15	Vegetation Description	Weed Species and Management
	Diverse native canopy present with good grey and river mangrove cover. Dominant species in canopy are Brushbox, Tuckeroo, Foambark and Guioa. Understorey and midstorey cover of mangroves 60-100%. Seedlings of rainforest trees and native groundcover present in the understorey.	The major canopy weed is Camphor Laurel but is present in low cover (10-30%). Understorey weeds include Silver-leaf Desmodium and pasture grass. Pasture grasses dominate in the grazed sites.
SITE RECOMMENDATIONS Lower Cobaki Creek	Allow natural regeneration of native species near existing remnant vegetation. Use supplementary planting of lower catchment species in open areas. Encourage mangrove colonization at the bank toe	Fence and exclude stock from banks. Remove and control weeds Extend buffer vegetation to maximum achievable width (minimum 10m).

8.4.9 Cobaki Creek – Transition Zone

Geomorphic Assessment

Site No:	**Site 11**	
River Style Classification:	***Alluvial meandering***	
Channel Morphology:	• Eroding concave banks stream banks (max. height 3.5 m). Bank heights range from 2m to 3.5m • Channel width (W) 40m to depth (D) 3m • Channel entrenched downstream and entrenching (eroding) upstream	
Sediment Supply/Transport	• Fines/gravel • Large quantities of sediment stored within the channel that is currently subject to active geomorphic instability. Potentially catastrophic sediment delivery to Cobaki Estuary.	
	Description	**Score (1..100)**
Geomorphic Stability (Description & Score):	***Highly Unstable.***	5
Creek Bed and Bank Indicative Condition (Description & Score):	***Degraded.***	30
Recovery Potential (Description & Score):	***Strategic/Low.***	40
Target Condition & Regeneration Objectives:	• Strategic stream management site • SSSM needs to be addressed with suitable bed and bank control works • Stream bed erosion control works required • Boulder revetment required to stabilise eroding stream banks • Extensive revegetation required	



Riparian Vegetation Assessment

Site 11	Vegetation Description	Weed Species and Management
	Canopy natives sparse <10% canopy cover. The dominant native tree is *Waterhousia floribunda.* Little to no remnant vegetation. Stabilisation of banks required.	Site dominated by pasture grasses up to 100% cover, Para grass on stream banks. Other weed species are Camphor Laurel, Willow in the canopy, >80% of the canopy is non native. Tobacco in the midstorey and Hairy Commelina in the understorey.
SITE RECOMMENDATIONS Transition Cobaki Creek	Extensive revegetation required. Use supplementary planting of middle catchment species in open areas. Replant *Lomandra hystrix* along bank toes. Rebattering and toe stablisation required.	Fence and exclude stock from banks. Remove and control weeds. Extend buffer vegetation to maximum achievable width (minimum 10m).

8.4.10 Cobaki Creek – Mid Zone

Geomorphic Assessment

Site No:	**Site 12**	
River Style Classification:	***Alluvial meandering***	
Channel Morphology:	• Eroding concave banks stream banks (max. height 5 m. Bank heights range from 2.5m to 5 m • Channel entrenched downstream and entrenching (eroding) upstream	
Sediment Supply/Transport	• Fines/gravel • Large quantities of sediment stored within the channel that is currently subject to active geomorphic instability	
	Description	**Score (1..100)**
Geomorphic Stability (Description & Score):	***Unstable.*** Laterally and vertically unstable and likely to degrade further.	25
Creek Bed and Bank Indicative Condition (Description & Score):	***Degraded.***	30
Recovery Potential (Description & Score):	***Strategic/Low.***	40
Target Condition & Regeneration Objectives:	• Strategic stream management site. Bed level adjustment need to be investigated further and rehabilitated • Boulder revetment required to stabilise eroding banks • Extensive revegetation required	

Site No:	Site 13	
River Style Classification:	***Alluvial meandering***	
Channel Morphology:	• Eroding concave/convex banks stream banks (max. height 4 m). Bank heights range from 2m to 4 m. • Channel moderately entrenched	
Sediment Supply/Transport	• Fines/gravel • Large quantities of sediment stored within the channel that is currently subject to active geomorphic instability. High sediment delivery to downstream reaches.	
	Description	**Score (1..100)**
Geomorphic Stability (Description & Score):	***Unstable.*** Laterally and vertically unstable and likely to degrade further	40
0Creek Bed and Bank Indicative Condition (Description & Score):	***Degraded/Moderately impacted.*** Pools still provide aquatic habitat refuge.	40
Recovery Potential (Description & Score):	***Strategic/Moderate.***	50
Target Condition & Regeneration Objectives:	• Strategic stream management site. Large bed level adjustment (0.75m) at culvert needs to be stabilised • Riparian vegetation buffer width (extending a minimum 10-15m offset form top of bank). Restrict grazing adjacent revegetation sites • Some bank toe boulder protection may be required at cut bank erosion sites • Strategic placement of LWD	

Site No:	**Site 14**	
River Style Classification:	***Alluvial meandering***	
Channel Morphology:	• Symmetrical convex banks stream banks (max. height 1.5 m). Bank heights range from 1m to 2 m. • Channel not entrenched.	
Sediment Supply/Transport	• Fines/gravel • High sediment transport competence	
	Description	**Score (1..100)**
Geomorphic Stability (Description & Score):	***Moderately Unstable.*** Minor and vertically instability.	60
0Creek Bed and Bank Indicative Condition (Description & Score):	***Moderately Impacted***	50
Recovery Potential (Description & Score):	***Moderate.***	65
Target Condition & Regeneration Objectives:	• Riparian vegetation buffer width (extending a minimum 10m to 15m offset from top of bank) • Restrict grazing adjacent revegetation sites • Strategic placement of LWD	

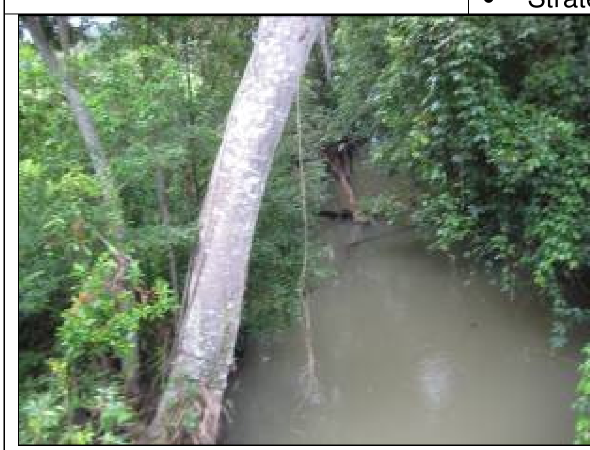
Riparian Vegetation Assessment

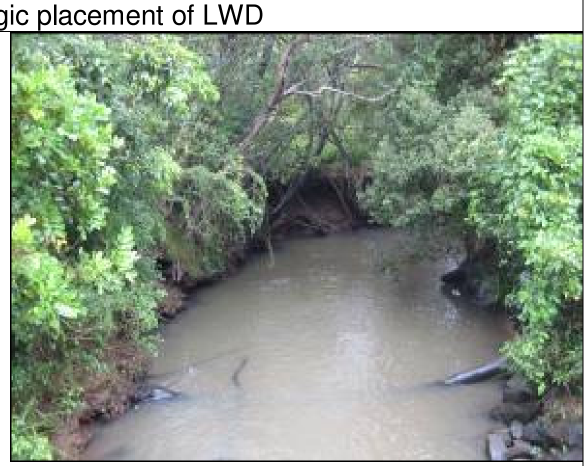
Site 12	Vegetation Description	Weed Species and Management
	Canopy natives sparse <10% canopy cover. Major native species present Weeping Lilly Pilly, Cudgerie, Few plants of Mat Rush in understorey.	Site dominated by pasture grasses up to 100% cover, Hairy Commelina also present in the understorey. No developed mid storey or canopy. Major shrub and tree weeds were Camphor Laurel, Barner Grass.
Site 13		
	Canopy natives sparse <30% canopy cover. Major native species present Blue Quandong, Weeping Myrtle, Macaranga. No developed mid or understorey cover.	Site dominated by pasture grasses up to 100% cover, No developed mid storey or canopy. Major shrub and tree weeds were Camphor Laurel, Barner Grass
Site 14		
	Native canopy sparse < 10%. Native trees present include Rough-leaved Elm, Blue Quandong. Seedling regeneration of Macaranga in understorey. No developed mid or understorey cover.	Site dominated by pasture grasses up to 100% cover. No developed mid storey or canopy. Major shrub and tree weeds were Camphor Laurel, Barner Grass
SITE RECOMMENDATIONS Cobaki Creek Middle	Allow natural regeneration of native species near existing remnant vegetation and encourage a natural zonation of native species. Replant *Lomandra hystrix* along bank toes. Use supplementary planting of middle catchment species in open areas.	Fence and exclude stock from banks. Remove and control weeds Extend buffer vegetation to maximum achievable width (minimum 10m).

8.4.11 Piggabeen Creek – Lower Zone

Geomorphic Assessment

Site No:	**Site 19**	
River Style Classification:	***Alluvial meandering***	
Channel Morphology:	Steep concave stream banks (max. height 4.5 m). Average bank heights range 3m – 4m. • Entrenched channel.	
Sediment Supply/Transport	• Fines/gravel • High sediment transport competence • Eroding stream banks contributing significant amounts of sediment to the estuary	
	Description	**Score (1..100)**
Geomorphic Stability (Description & Score):	***Unstable.*** Stream banks subject to erosion.	35
Creek Bed and Bank Indicative Condition (Description & Score):	***Moderately Impacted / Good.*** Pool dominated stream bed provided good habitat	60
Recovery Potential (Description & Score):	***Strategic / Moderate.*** Geomorphic degradation needs to be prevented.	60
Target Condition & Regeneration Objectives:	• Strategic stream management was observed downstream of the bridge, where vertical bed degradation may lead significant channel expansion • Boulder revetment may be required at major bank and bed erosion points located upstream and downstream of the survey site • Riparian vegetation buffer width (extending a minimum 10 to 15m offset form top of bank). • Restrict grazing adjacent revegetation sites • Strategic placement of LWD	





Riparian Vegetation Assessment

Site 19	Vegetation Description	Weed Species and Management
	Canopy dominated by Tuckeroo *(Cupaniopsis anacardioides)*, Bangalow Palm and other rainforest species with less than 30 % weed species in the canopy. Understorey with rainforest regeneration and Lomandra (*Lomandra hystrix*) on banks. Structural riparian vegetation present.	This reach has strong potential for regeneration of native species with removal of dominating canopy (Camphor Laurel, Large-leaved Privet and Umbrella Tree) and midstorey weeds. Understorey weeds up to 30 %. Canopy weeds less than 30%.
SITE RECOMMENDATIONS Lower Piggabeen Creek	Allow natural regeneration of native species near existing remnant vegetation. Use supplementary planting of lower catchment species in open areas. Encourage mangrove colonization at the bank toe.	Fence and exclude stock from banks. Remove and control weeds Extend buffer vegetation to maximum achievable (minimum 10m).

8.4.12 Piggabeen Creek – Mid Zone

Geomorphic Assessment

Site No:	**Site 18**	
River Style Classification:	***Alluvial meandering***	
Channel Morphology:	Steep concave / concave stream banks (max. height 3.5 m). Average bank heights range 2 – 3m. • Entrenching channel.	
Sediment Supply/Transport	• Fines/gravel • High sediment transport competence. • Eroding stream banks contributing significant amounts of sediment to the estuary.	
	Description	**Score (1..100)**
Geomorphic Stability (Description & Score):	***Highly Unstable.*** Laterally and vertically unstable and likely to degrade further if bed level adjustment is not addressed.	15
Creek Bed and Bank Indicative Condition (Description & Score):	**Moderately Impacted.**	40
Recovery Potential (Description & Score):	**Strategic/ *Moderate.***	50
Target Condition & Regeneration Objectives:	• Strategic stream management site. Large bed level adjustment (1m) found at the base of the bridge/culvert needs to be stabilised. Upstream migrations of this bed level adjustment will lead to catastrophic bed and bank erosion. • Boulder revetment required at bank erosion points. • Riparian vegetation buffer width (extending a minimum 10 to 15m offset from top of bank). • Restrict grazing adjacent revegetation sites. • Strategic placement of LWD.	

Site No:	Site 17	
River Style Classification:	***Alluvial meandering***	
Channel Morphology:	• Convex stream banks (max. height 3.5 m). Average bank heights range 1m – 3m • Channel is not entrenched and floods regularly	
Sediment Supply/Transport	• Fines/gravel/cobbles • Moderate sediment transport competence	
	Description	**Score (1..100)**
Geomorphic Stability (Description & Score):	***Moderately Unstable.***	75
Creek Bed and Bank Indicative Condition (Description & Score):	***Moderately Impacted.*** The removal of LWD and Vegetation has impacted on condition of the stream.	50
Recovery Potential (Description & Score):	***Moderate.***	65
Target Condition & Regeneration Objectives:	• Riparian vegetation buffer width (extending a minimum 10 to 15m offset form top of bank) • Restrict grazing adjacent revegetation sites • Strategic placement of LWD	

Site No:	Site 16	
River Style Classification:	***Confined valley with bedrock controlled discontinuous floodplain.***	
Channel Morphology:	• Asymmetrical concave / convex stream banks (max. height 3m). Average bank heights range 2 – 3m. • Stream bank adjoins valley margin 10 – 50 % of the time • Entrenching channel	
Sediment Supply/Transport	• gravel/cobbles/large cobbles • High sediment transport competence	
	Description	**Score (1..100)**
Geomorphic Stability (Description & Score):	***Unstable.*** Lateral and vertically adjustments have occurred in the past and are still active.	50
Creek Bed and Bank Indicative Condition (Description & Score):	***Moderately Impacted/Good.***	65
Recovery Potential (Description & Score):	***High.***	75
Target Condition & Regeneration Objectives:	• Boulder revetment required at bank erosion points • Riparian vegetation buffer width (extending a minimum 10m to 15m offset form top of bank) • Restrict grazing adjacent revegetation sites • Strategic placement of LWD	

Riparian Vegetation Assessment

Site 18	Vegetation Description	Weed Species and Management
	Canopy dominant was Brush box but very little remaining native vegetation. Structural riparian vegetation non existent	Camphor Laurel dominated with Senna and Para grass in the mid and understorey vegetation. Understorey weed cover was 100%.
Site 17		
	Canopy natives sparse <5% canopy cover. Major canopy dominants, Blue Quandong (*Elaeocarpus grandis)*, Ficus sp. And *Acacia melanoxylon* with regrowth species such as *Guioa* semiglauca.	Site dominated by pasture grasses up to 100% cover, No developed mid storey or canopy. Major shrub and tree weeds were Camphor Laurel and Guava.
SITE RECOMMENDATIONS Middle Piggabeen Creek	Use supplementary planting of middle catchment species in open areas. Design planting to allow for high velocity flows.	Fence on higher ground and exclude stock from banks. Mosaic fencing may be an option. Remove and control weeds Extend buffer vegetation to maximum achievable width (minimum 10m).
Site 16		
	Canopy species included Blue Quandong, Cudgeri and Teak but canopy cover was not dense <10%. Dominant midstorey species were Bleeding Heart with little or no seedlings of rainforest species. Ferns were the dominant native understorey species. Understorey native cover was sparse <10%.	Canopy weed cover low <1%. Guava and various pasture grasses are the major weeds in the mid and understorey. No seedling regeneration due to cattle grazing on banks
SITE RECOMMENDATIONS Piggabeen Creek Upper	Allow natural regeneration of native species near existing remnant vegetation. Use supplementary planting of upper catchment species in open areas.	Fence on higher ground and exclude stock from banks. Mosaic fencing may be an option. Remove and control weeds. Extend buffer vegetation to maximum achievable width (minimum 10m).

8.5 Riparian Rehabilitation Prioritisation

The lowest scoring sites were in the middle and transition zones of the catchment, indicating sites in the poorest condition. Site scores are graphed in Figure 8.2. The sites were grouped into three rehabilitation priority categories based on their condition and the management response required. Rehabilitation options are described further in the action plan and implementation plan in Section 14.

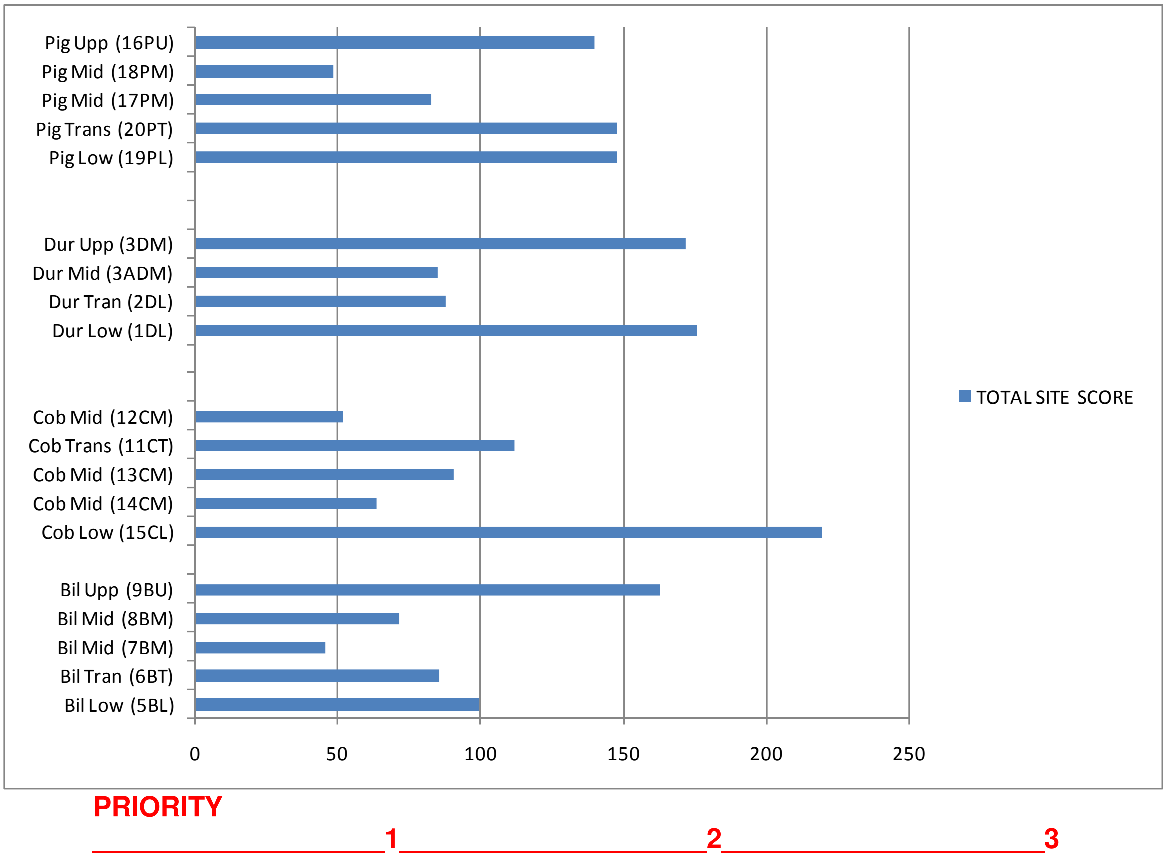


Figure 8.2. Assigned riparian rehabilitation priority based on Stage 2 vegetation and geomorphic assessment

8.6 Development of Management Targets

To facilitate the development of riparian vegetation rehabilitation management targets, the current riparian vegetation cover was assessed to determine the baseline vegetation cover. The assessment involved aerial photograph interpretation of 2008 (Google) images. From a height of approximately 200 metres above land, a rapid assessment of percentage cover and width of buffer was undertaken for the main channel of Duroby, Bilambil, Cobaki and Piggabeen Creeks. A riparian vegetation cover ranking score was assigned based on a category that combined riparian width and percentage canopy cover (Table 8.7). For example, the lowest ranking score of 1 represents riparian width of less than 10m and less than 25% canopy cover, and the highest ranking score of 12 represents riparian width greater than 20m and greater than 75% canopy cover.

Table 8.7. Ranking scores for existing riparian vegetation cover

Riparian With (m)	Canopy Cover (%)			
	<25%	25-50%	50-75%	>75%
<10m	1	2	3	4
10-20m	5	6	7	8
>20m	9	10	11	12

Both banks of the creek were assessed with a ranking score throughout the estuarine and transition zones. When the creek channel narrowed in the mid zone, a single ranking score was given for both banks (mid – upper freshwater zone) where delineation between banks was not possible. For example, the north bank of Bilambil Creek from the mouth where it discharges into Terranora Broadwater upstream 1.2 km was given a ranking score of 12 indicating > 20m width and >75% canopy cover (this area incorporates Charles Bay Reserve). Appendix F contains lists of the ranking scores allocated progressively upstream of each creek.

Ranking scores indicate that Piggabeen Creek has the poorest riparian vegetation cover with the largest percentage of riparian vegetation (74%) ranked in the lowest category of < 10m width and < 50 % canopy cover (Table 8.8). In terms of the percentage of riparian vegetation cover in the poorest category, the creeks were ranked from north (worst condition) to south (best condition), with Duroby Creek containing 38% of riparian vegetation in the lowest category.

Table 8.8. Ranking scores indicating width of riparian zone and percentage canopy cover for each creek

Score	**1 + 2**		**3 + 4**		**5 + 6**		**7 + 8**		**9 + 10**		**11 + 12**	
Width	**Bare - <10m**		**< 10m**		**10 – 20m**		**10 – 20m**		**> 20m**		**> 20m**	
Cover	**< 50%**		**> 50%**		**< 50%**		**> 50%**		**< 50%**		**> 50%**	
Subcatchment	**length (km)**	**% of total**	**length (km)**	**% of total**	**length (km)**	**% of total**	**length (km)**	**% of total**	**length (km)**	**% of total**	**length (km)**	**% of total**
Duroby Ck	5.7	**38**	0.6	4	0.7	5	3.6	**24**	0	0	4.3	**29**
Bilambil Ck	10.9	**60**	0.7	4	1.3	7	1.6	9	0	0	3.8	**21**
Cobaki Ck	8.8	**62**	1.1	8	0	0	2.6	18	0.2	2	1.5	10
Piggabeen Ck	10	**74**	1.4	11	0	0	0.4	3	0.2	2	1.5	11

All creeks have some good riparian vegetation cover near the confluence with the broadwater foreshore, however the transition and mid zones are typically the areas that have experienced the majority of vegetation clearing throughout the catchment. This snapshot of the current riparian vegetation cover was intended to assist with the future quantification of rehabilitation success based on the total width and % cover of riparian vegetation cover on a sub - catchment scale. The use of these targets is discussed in Section 14.3.7 of the Action Plan.

The above rapid API is useful when determining priority areas for rehabilitation on a subcatchment scale and may be useful when monitoring the progress of works as well as evaluating the success of rehabilitation works over time on the medium scale. The API does not attempt to recognise the composition of the vegetation in terms of the percentage of exotic and native species present in the riparian zone, providing an inclusive score for all vegetation cover which will include weeds.

9 Water Quality Assessment

This water quality review provides an overview of the limited data available for the Cobaki and Terranora Broadwater catchments through the recent EHMP carried out by IWC. The aim is to provide some background insight into water quality processes. Data were collected during a single sample effort between 26th and 30th October 2007 at four sites along each of the main creeks draining into the broadwaters. The sites do not cover all of the functional zones used within this study, however they have been assigned to the relevant zone where possible.

9.1 Water Quality in the Cobaki and Terranora Broadwater Catchments

9.1.1 Conditions During Sampling

Approximately 78mm of rain was recorded at Elanora during the EHMP freshwater creek sampling period, and over 60mm during the 4 weeks prior to sampling. No rainfall data for other stations across the catchment were obtained for this study. The rainfall recorded at Elanora suggests that sampling may have occurred during a moderate runoff event, however salinities at the estuarine reach sites of Cobaki and Bilambil Creeks less than three weeks later (on the 19/11/07) were reasonably high (10 and 23 respectively), suggesting that rainfall in the upper catchments may not have been as great as on the coast. The exception was the estuarine reach site in Duroby Creek which was considerably fresher (~3) on the 19/11/07 suggesting higher flow was possible in this subcatchment during sampling.

9.1.2 System comparison

Overall, nutrient concentrations (in particular nitrate and ammonium) in the study creeks were generally low in comparison to median concentrations in other nearby sub-tropical catchments (see Table 9.1). The exception was Duroby Creek, which displayed high total nitrogen concentrations in excess of the Qld EPA guidelines along the entire length, potentially reflecting higher flow in this system at the time of sampling. High concentrations of nitrate at the middle Duroby Creek site may reflect either a localised point source, or the influence of the tributary stream entering at this site.

It is possible that the generally low nutrient concentrations reflect removal of inorganic nutrients by biological processes during a low to moderate flow period (e.g. algal growth) and the deposition of organic material in the sediments. This is supported by the low concentrations of nitrate and ammonium at the majority of sites.

9.1.3 Diel Dissolved Oxygen Variation – High Rates of Instream Processing

High rates of instream processing are supported by large diel variations in dissolved oxygen (Figure 9.1). This measure indicates the rate of biological activity within the stream reach (oxygen is produced by photosysnthesis during the day and consumed by bacterial breakdown of organic matter at night). There was a general trend towards hypoxia (under saturation of dissolved oxygen indicating a predominance of organic matter breakdown) moving downstream towards the transition zones.

The diel range tended to be greatest in the middle zones, indicating more vigorous recycling of nutrients between autotrophic and heterotrophic organisms (i.e. photosynthetic growth and bacterial decay). The greater diel range was related to the availability of ammonium, and may indicate chronic nutrient inputs along these reaches (e.g. due to stock access) coupled with good light availability (due to lack of riparian vegetation). While freshwater streams may naturally be expected to be dominated by heterotrophic processes (due to light limitation and a predominance of organic inputs from leaf litter fall), the combination of hypoxia and large diel variations in dissolved oxygen suggest that these streams are moderately to highly stressed.

9.1.4 High Flow – Export of Nutrients and Organic Matter to the Broadwaters

The better temporal dataset collected in the estuarine reaches of the main creeks (EHMP sites 12-14) indicate that high flow periods are characterised by much higher nutrient concentrations, and confirm that the freshwater survey captured the lower end of the nutrient concentration range for these systems. Figure 9.2 clearly shows generally higher total nitrogen and phosphorus and nitrate concentrations as salinity approaches zero at the estuarine sites. The implied concentrations for total nitrogen (<1000$\mu g.L^{-1}$) in freshwater runoff from all of the subcatchments tends to be at the low end of the range for runoff in the comparison systems (see 95%ile and max values in Table 9.1). In contrast, DIN (nitrate + ammonium) concentrations (>250 $\mu g.L^{-1}$) in the Cobaki-Terranora subcatchments tend to be among the high end of the range.

Total suspended solids (TSS) concentrations tend to be fairly low at all estuarine sites, and are in part driven by phytoplankton concentrations (chlorophyll-*a*). It is likely that the routine sampling strategy has not captured peak flows during any runoff event over the monitoring period when TSS concentrations are likely to be highest. The lack of any correlation between TSS and salinity suggests that TSS settles out quickly after a runoff event.

9.1.5 Nitrogen Limitation

Data from sites 12-14 indicate that freshwater inputs to the estuarine reaches and broadwaters during runoff events area characterised by total nitrogen and phosphorus concentrations of ~1000$\mu g.L^{-1}$ and ~80 $\mu g.L^{-1}$ respectively. The resultant N:P ratio of approximately 6 indicates that the system is generally nitrogen limited (aquatic algae uptake N and P at a ratio of 16:1). This is supported by the stronger relationship between nitrogen and chlorophyll-*a* throughout the broadwaters and Terranora Creek (see later sections). Similar to total nitrogen, nitrate concentrations are generally greatest as salinity approaches zero indicating that catchment runoff is generally nitrate-rich (up to 300 $\mu g.L^{-1}$). The highest nitrate concentrations occur in Duroby Creek. In contrast, ammonium concentrations tend to be greatest as salinity increases most likely reflecting the increased importance of internal recycling processes (e.g. breakdown of organic matter in the sediments) as residence times increase.

9.1.6 Insream Processing of Nutrients and Organic Matter in the Estuarine Reaches

The estuarine reaches of the creeks act to transform and attenuate nutrient and organic matter loads to the broadwaters under low flow conditions. As such, much of the total nutrient load present in these reaches is associated with particulate material (Figure 9.3). The composition of this material includes contribution from phytoplankton (indicated by chlorophyll-*a*) and catchment-derived organic detritus, both of which strongly influence the rate of organic matter decay and therefore hypoxia within these reaches (Figure 9.3, C). The balance between these forms is highly dependent on the time of sampling in relation to runoff events. Modelling has shown that the response of phytoplankton growth to nutrient inputs from a runoff event is rapid and that algal blooms can be fairly transient due to the depletion of nutrients. As such, routine sampling is unlikely to capture the peak phytoplankton response to nutrient inputs.

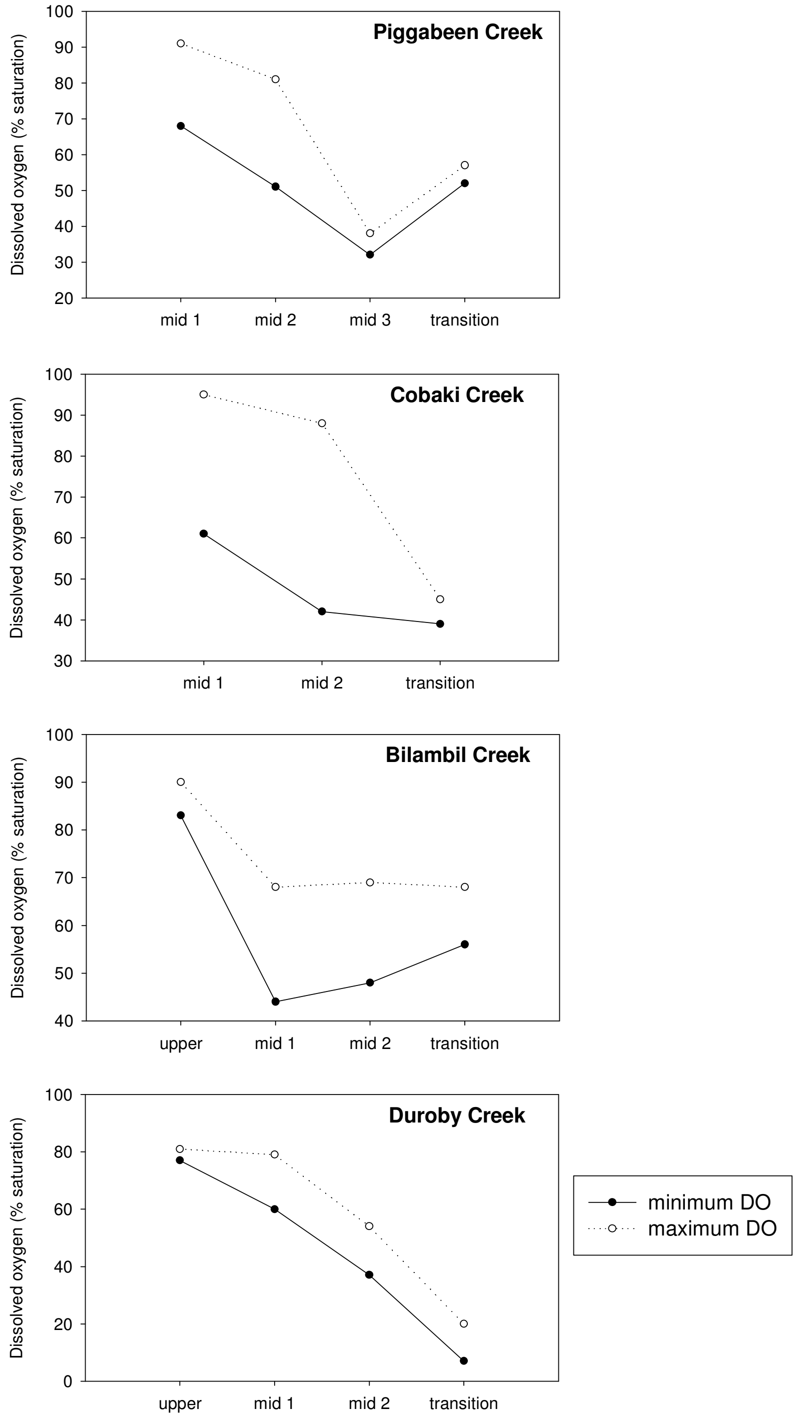


Figure 9.1. Diel variation in dissolved oxygen saturation in the freshwater creeks. There is a general trend towards increasing hypoxia moving downstream to the transition zones. The high diel range (i.e. difference between max and min values) in the middle zones indicates system stress due to nutrient enrichment and lack of riparian vegetation.

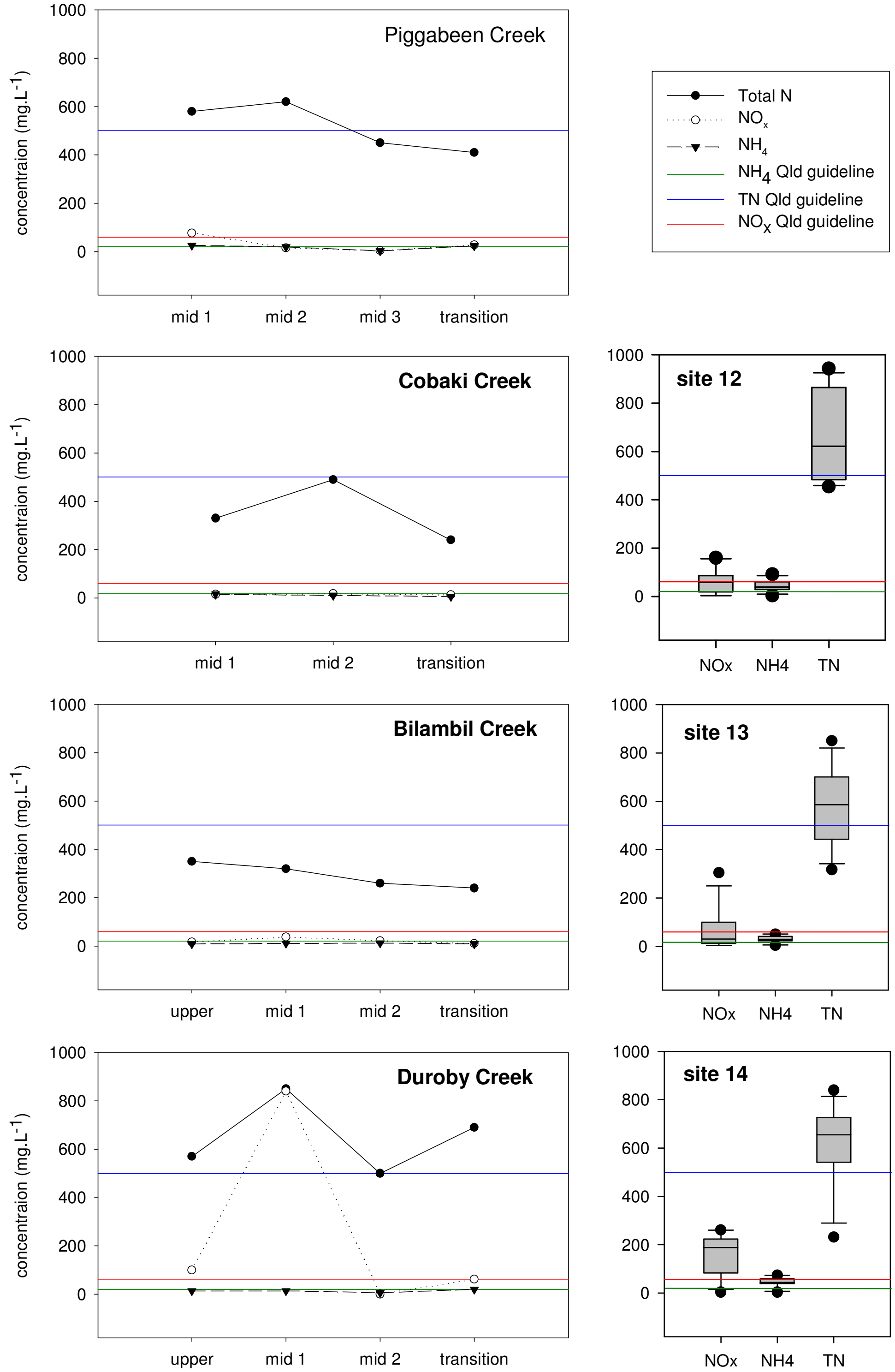


Figure 9.2. Observed total nitrogen, nitrate and ammonium concentrations in the freshwater creeks and their estuarine outlets (EHMP data). Generally low concentrations most likely reflect high rates of internal recycling due to low flow conditions at the time of sampling. Increased concentrations during runoff events are indicated by the boxplots for the estuarine sites

Table 9.1. Comparison of freshwater inputs to northern NSW estuaries

River system	Subcatchment	Statistic	NO_x	NH_4	DON	TPN	TN
Cobaki-Terranora	Piggabeen	mean	31	18			515
	Cobaki	mean	15	11			353
	Bilambil	mean	22	10			293
	Duroby	mean	251	14			653
Nambucca	main	median	32	12	22	18	121
		95%ile	138	21	504	530	1064
		max	495	31	514	577	1660
Bellinger	main	median	49	3	176	34	263
		95%ile	152	37	536	431	744
		max	252	78	1251	891	1437
Brunswick	main	median	90	22			351
		95%ile	339	76			1427
		max	962	578			1916
Richmond	Bungawalbin	Wet mean	49	70	1188	381	1688
		Dry mean	30	65	811	316	
	Richmond	Wet mean	89	39	556	265	949
		Dry mean	39	56	817	296	1208
	Leycester	Wet mean	108	23	465	285	881
		Dry mean	22	47	743	373	1185
	Wilsons	Wet mean	63	23	297	314	697
		Dry mean	15	60	573	193	841
	Coastal	Wet mean	232	42	438	340	1052
		Dry mean	125	4	385	358	872

References:
1 (Moffatt 2008)
2 (Eyre and Pont 2003)
3 (Ferguson, Eyre et al. 2004)
4 (McKee, Eyre et al. 2000)

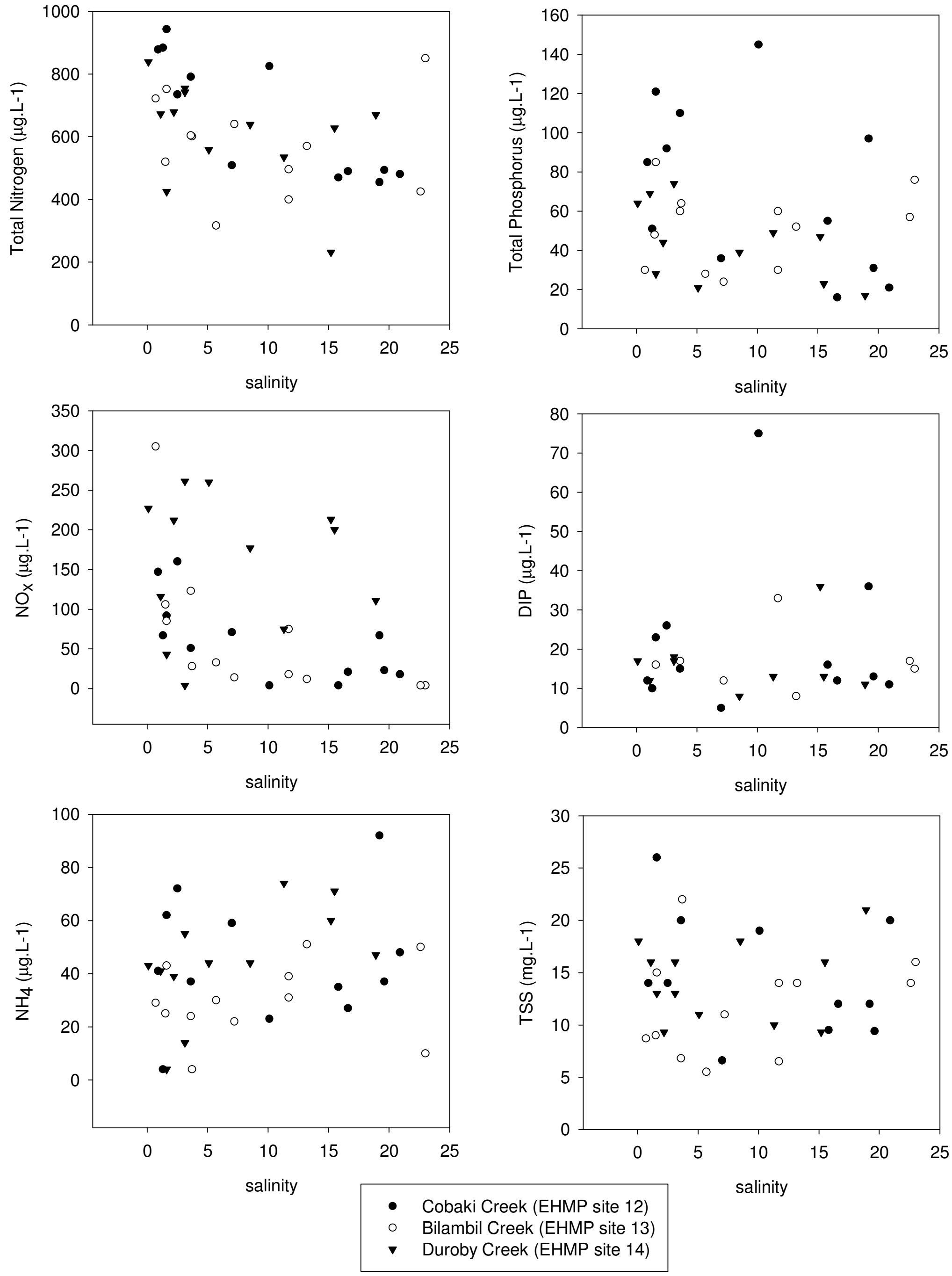


Figure 9.3. Water quality at the estuarine sites of Cobaki, Bilambil, and Duroby Creeks. Concentrations have been plotted as a function salinity to give an indication of the influence of high flow (i.e. fresh) and low flow (i.e. saline) conditions. Total nitrogen and nitrate are highest at the fresh end of the scale due to increased concentrations in catchment runoff. In contrast, ammonium tends to be greater as salinity (and residence times) increase, reflecting greater rates of internal recycling. TSS exhibits no clear relationship with salinity due to 1) the rapid deposition of sediments post high flow and 2) the increasing influence of phytoplankton on TSS as residence times (salinity) increase.

9.2 Water Quality in the Broadwaters and Terranora Creek

Water quality in the estuarine creeks, broadwaters, nexus channels and Terranora Creek over the 2007 – 2008 period is summarised in Figure 9.4.

9.2.1 Salinity

The salinity regime of the estuarine creeks is significantly fresher than the adjoining broadwaters indicating a marked drop in the efficiency of tidal flushing and a likely increase in residence times in these reaches. The broadwaters are episodically affected by freshwater inputs, but only briefly flush completely fresh during large floods. The tidal flushing of the broadwaters is relatively efficient (see modelling results), resulting in a rapid recovery of estuarine conditions (i.e. increase in salinity) following runoff events. Likewise, the nexus channels and Terranora Creek are well flushed by tides and as such are dominated by high salinity throughout the year.

9.2.2 Dissolved Oxygen

Dissolved oxygen was consistently undersaturated across the system indicating moderate organic enrichment arising from high point and diffuse nutrient loadings. The most severe undersaturation occurs in the estuarine creeks most likely reflecting the longer residence times in these reaches.

9.2.3 Total Suspended Solids (TSS)

As noted above, TSS concentrations in the estuarine creeks were relatively low which may reflect 1) the absence of any event sampling, and 2) the rapid settling of TSS following a runoff event. The highest TSS concentrations were recorded in the broadwaters, and in particular Trutes Bay where concentrations exceeded $500mg.L^{-1}$ on one occasion. The reasons for this include: 1) the broadwaters represent depositional basins for catchment-derived TSS due to the rapid drop in velocities as floodwaters pass from the narrow creek channels to the broadwater; 2) wind driven resuspension in the broadwaters is likely to be high due to their shallow nature; 3) in extremely shallow intertidal areas (e.g. Trutes Bay), resuspension is accentuated due to waves at the receding/advancing waters edge. High TSS concentrations in Trutes Bay indicate that resuspension events tend to be greatest during the spring-summer season when the incidence of north-easterly winds is highest.

9.2.4 Chlorophyll-a

Chlorophyll-*a* concentrations (indicating phytoplankton biomass) were generally high throughout the system, reflecting the relatively high nutrient loading from catchment / urban runoff and STP effluent inputs (see Section 10 for modelling results). Both broadwaters are prone to large phytoplankton blooms due to the absence of light limitation in the well mixed shallow water column. Modelling indicated that phytoplankton biomass was most likely highly variable over time, and as such the routine monitoring program is unlikely to have sampled peak concentrations. The current concentrations of chlorophyll-*a* are estimated to be at the threshold of causing major impacts on seagrass habitat due to light limitation (see Section 10 modelling results).

9.2.5 Total Nitrogen

Total nitrogen concentrations throughout the system reflected the mixing of four major water types: 1) catchment runoff, 2) sewage effluent, 3) oceanic water and 4) ebb flows from the Tweed River estuary. An additional source in the broadwaters is due to wind/tide driven resuspension of sediment nitrogen.

9.2.6 Dissolved Inorganic Nitrogen (DIN)

DIN (nitrate + ammonium) concentrations were generally low throughout the system reflecting the rapid rates of internal recycling (see Section 10 modelling). Due to high rates of assimilation by phytoplankton, DIN concentrations rarely reflect the magnitude of inputs. Similar to phytoplankton, the distribution of DIN throughout the system is highly variable over time and as such the routine sampling program is unlikely to have sampled peak concentrations.

9.2.7 Phosphorus

Total and dissolved inorganic phosphorus concentrations throughout the system were high relative to available nitrogen, indicating likely nitrogen limitation of productivity. Similar to total nitrogen there was evidence of elevated phosphorus in association with sediment resuspension in the broadwaters.

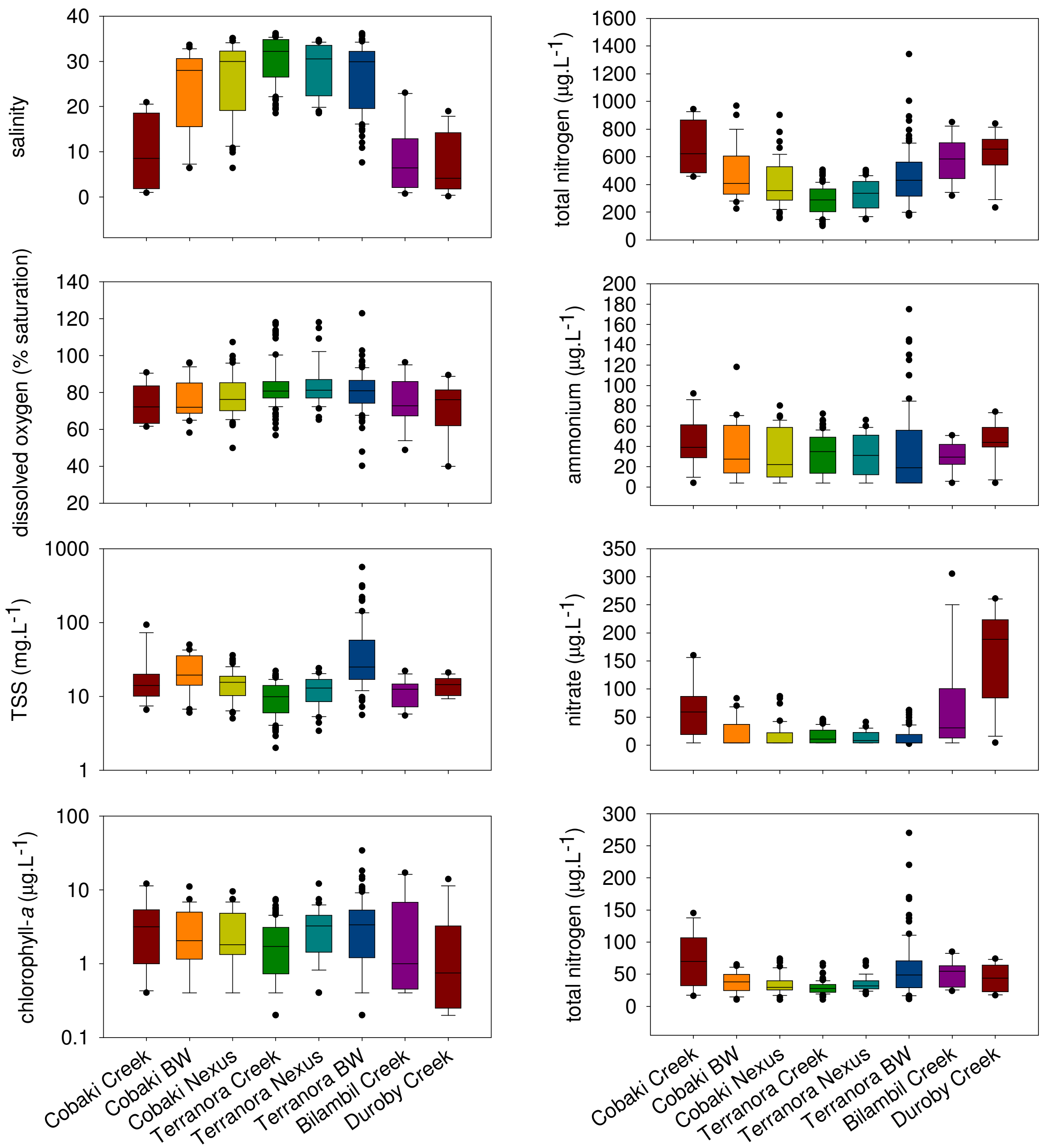


Figure 9.4. Summary statistics of monthly water quality observations in the estuarine creeks, broadwaters, nexus channels and Terranora Creek from October 2007 to October 2008 (EHMP data). Where relevant, data from multiple sites within a zone (e.g. Terranora Broadwater) have been pooled.

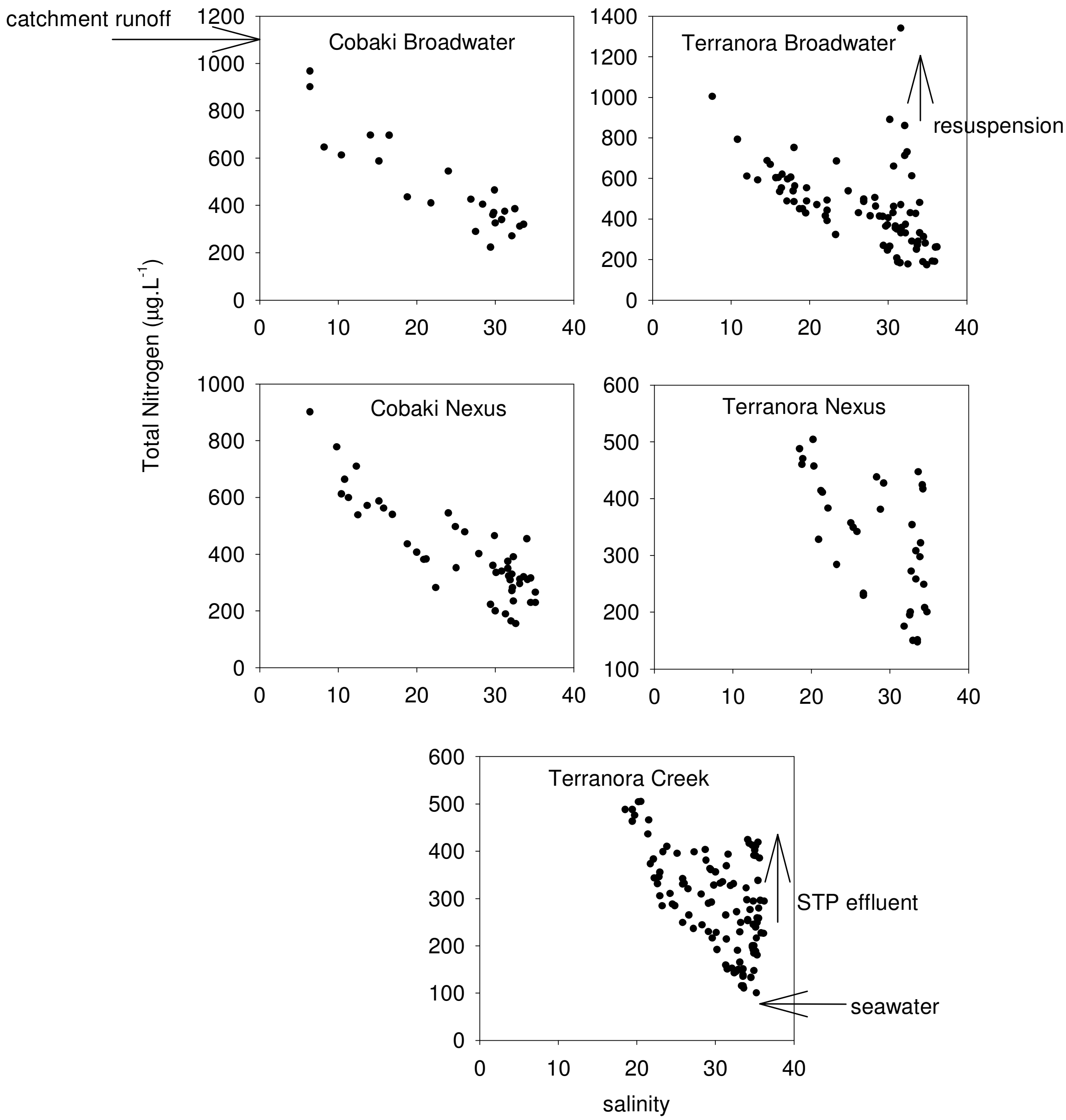


Figure 9.5. Mixing plots of total nitrogen in the five major functional zones of the Cobaki-Terranora Broadwater system. Observed concentrations across the salinity gradient (EHMP data) arise from the mixing of three-four different water types. In general, catchment runoff (TN ~ 1200 $\mu g.L^{-1}$) mixes with oceanic water (TN 30 – 50 $\mu g.L^{-1}$), with increased concentrations observed due to sediment resuspension in the broadwaters, inputs of STP effluent in Terranora Creek, and the influence of ebb tide flows from the Tweed River estuary.

10 Ecosystem Response Modelling of the Cobaki-Terranora Broadwater System

An ecosystem response model (ERM) was developed for the Cobaki-Terranora Broadwater, nexus channel and Terranora Creek continuum to 1) understand the factors controlling ecosystem health, 2) to test the impacts of management scenarios on key processes and habitats, and 3) derive system specific thresholds for critical pollutant loads.

10.1 Model Setup

The model is based on a modified 1D box model approach, comprising 10 boxes from the broadwaters to the confluence with the Tweed River estuary (Figure 10.1). The hypsometry of the system was mapped from a detailed bathymetric survey undertaken in July 2007 (Figure 10.2). The ERM operates on daily time steps, with the transport / mixing sub-model driven by freshwater inputs generated by the MUSIC catchment model (see Appendix H) and tidal prisms (varied according to the spring/neap cycle). Diffuse nutrient and TSS loadings were taken from the MUSIC catchment model, with DIN concentrations assumed to be 30% of total nitrogen for runoff events. A separate model run was undertaken with nutrient loadings from the Banora Point STP included. The STP discharge point was Dry Dock, with effluent discharge set at $15ML.d^{-1}$ with a DIN concentration of $2000\mu g.L^{-1}$. It was not possible to account for ebb tide discharge due to the daily timestep of the model. The transport / mixing sub-model predicts spatial and temporal variation in nutrients (dissolved inorganic nitrogen and phosphorus), TSS, and light attenuation. The biological response sub-model predicts the growth and biomass of phytoplankton and benthic microalgae, as well as rates of bacterial breakdown of organic matter, nutrient fluxes to and from the sediments, and loss of nitrogen via denitrification.

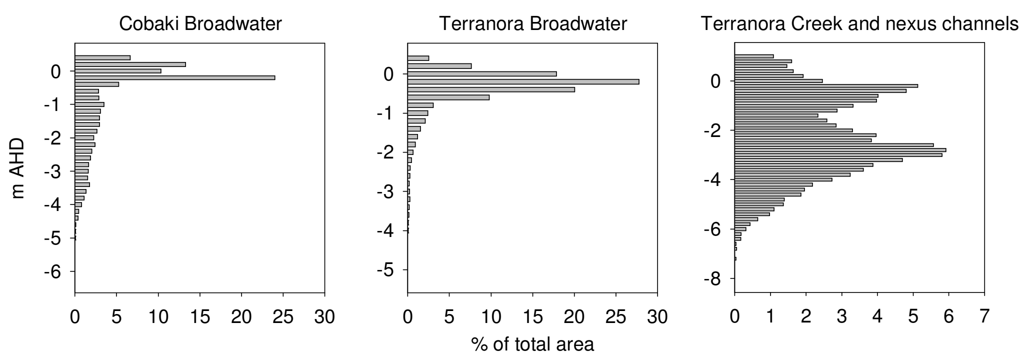


Figure 10.1. The percentages of total sediment area at each depth range for the Cobaki and Terranora Broadwaters and Terranora Creek and nexus channels. Note that hypsometry for Terranora Creek and nexus channels was applied to boxes 1-5 and box 7 in the model.

Figure 10.2. The layout of the Cobaki-Terranora ERM showing box boundaries and locations of catchment inputs (blue arrows) and STP inputs (orange arrows).

Source: ABER

Figure 10.3. The locations of the EHMP sample sites used for model calibration/verification.

Source: ABER

10.2 Model Calibration / Verification

The transport / mixing sub-model was calibrated by comparing salinity outputs for the 2007-2008 period with measured data from within each of the boxes (Figure 10.4). The percentage of the tidal prism exchanged at each tidal was adjusted to provide the best fit for estimated salinity throughout the system.

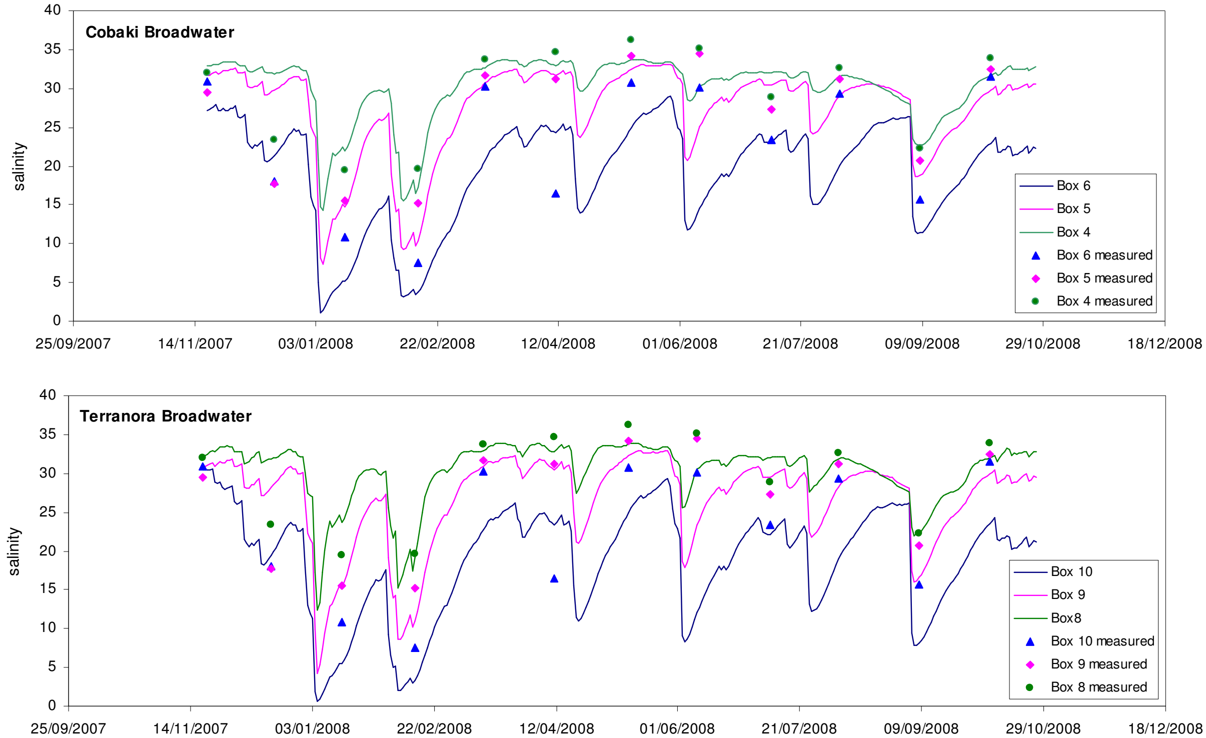


Figure 10.4. Measured (dots; EHMP data) and modelled (solid lines) salinity in the Cobaki and Terranora Broadwaters from Nov 2007 to Oct 2008.

Predictions of chlorophyll-*a* within each box were checked against measured data for the same period to verify that the model was reasonably estimating chlorophyll-a under existing conditions (Figure 10.5). The results show a reasonable fit with the measured data, given the limitations of the current model setup: the range of estimated chlorophyll was similar to measured values and displayed similar seasonal trends. The exception was for the Cobaki nexus and Terranora Creek boxes during the latter part of the model period where chlorophyll as consistently underestimated. This is most likely a combination of poor representation of base flow inputs from the MUSIC model (see below) and the omission of STP inputs. Chlorophyll was also consistently underestimated in box 10 (Trutes Bay) using the raw outputs from the MUSIC model. After more in depth consideration of this box (see Section 10.3 below), the concentration of total nitrogen in runoff from the Banora Point western drainage scheme was significantly increased, giving a better fit between measured and modelled chlorophyll in this box and throughout the broadwater. However a flat increase in runoff concentrations over the entire model period is likely to be unrealistic due to seasonal variations in the accumulation of nutrient-rich sediments in the drainage scheme.

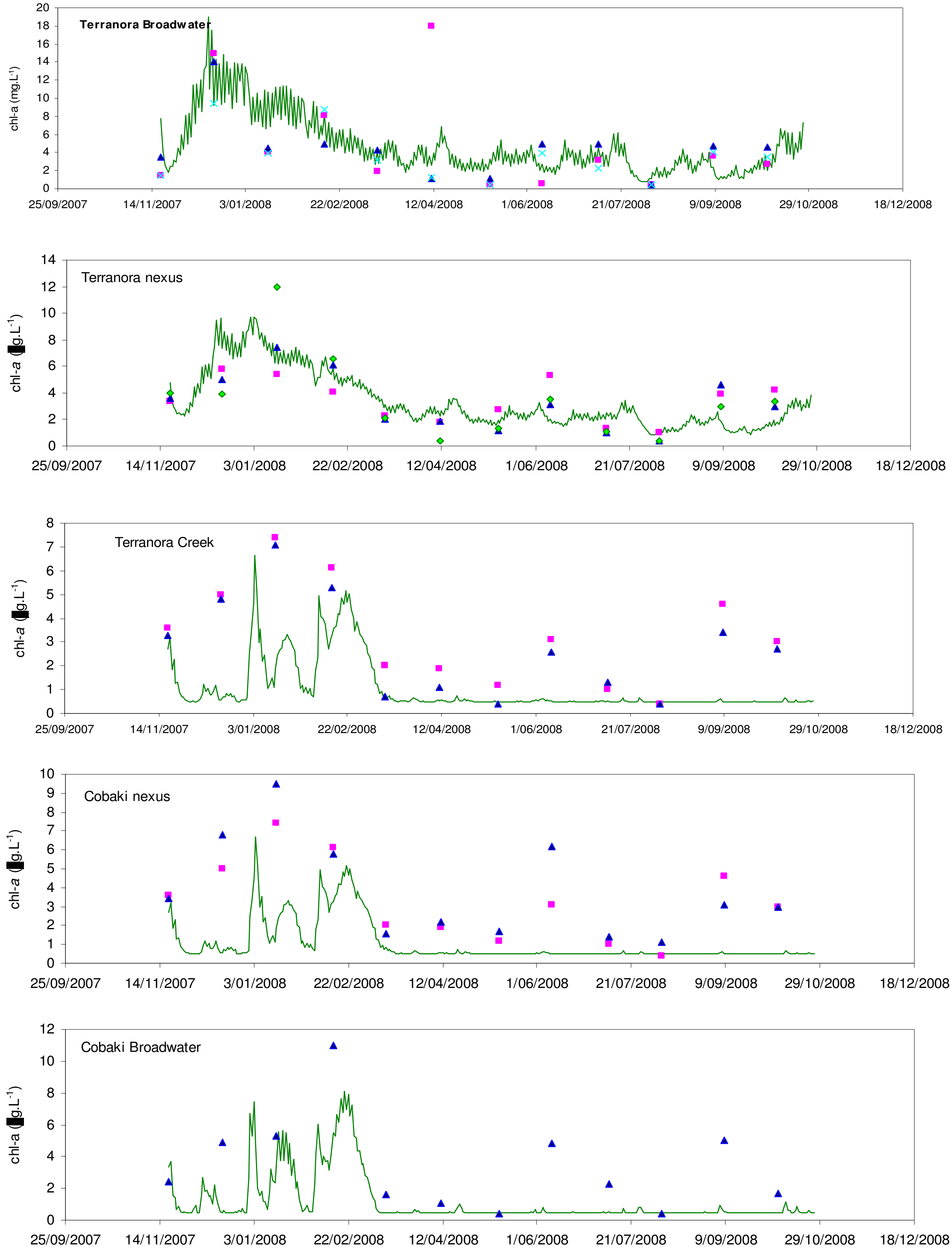


Figure 10.5. Measured (dots) and modelled (solid lines) chlorophyll-*a* in the Cobaki and Terranora Broadwaters and nexus channels from Nov 2007 to Oct 2008. Measured data are from the EHMP.

10.3 ERM Limitations

10.3.1 MUSIC Freshwater Flows

The ERM outputs are highly sensitive to the transport / mixing sub-model, which is in turn highly sensitive to the freshwater flow outputs from the MUSIC catchment model. The MUSIC model used in these simulations was configured using the same parameters used in previous studies (GHD 2005) in order to provide consistency between the results of both studies. Inspection of the hydrograph revealed artificially high peak flows and inadequate representation of post-peak flows and baseflows. The effect of this on ERM outputs was a more accentuated bloom-bust cycle for phytoplankton response (i.e. chlorophyll-*a* time series are characterised by large peaks followed by dramatic crashes). In reality, freshwater hydrographs would display a longer tail following a runoff event due to contributions from higher baseflows after surface flows diminish. This would have the effect of sustaining phytoplankton populations for longer periods of time. In order to correct for this artefact on the MUSIC hydrograph, model simulations for the urban development scenarios were amended by reducing the peak flows by 30% and distributing this across subsequent days (Figure 10.6). The result was an identical volume of runoff for a given rainfall event.

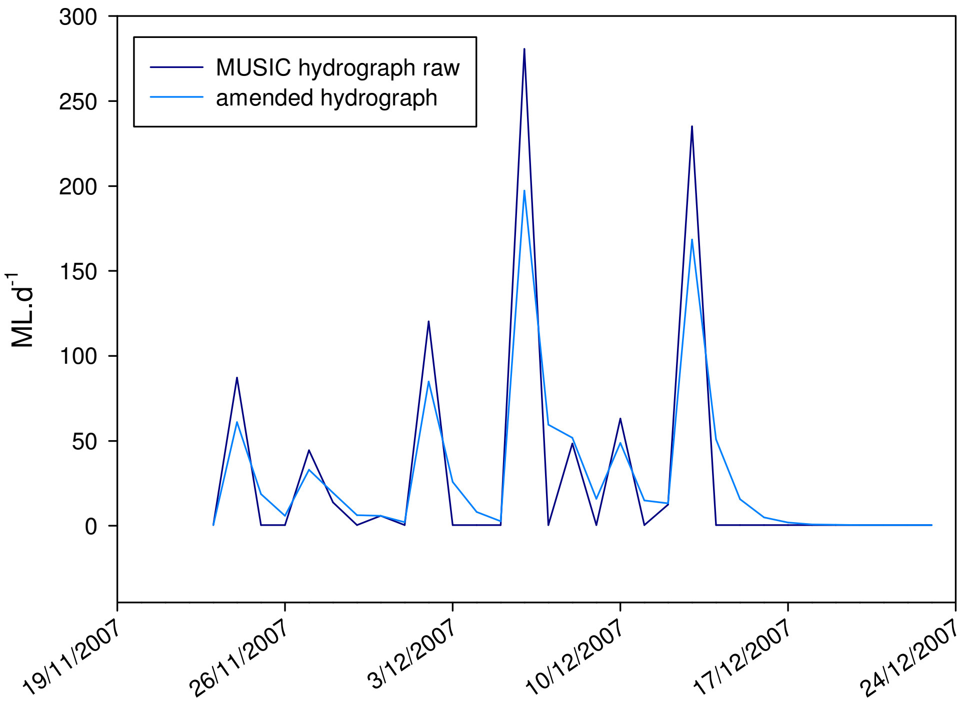


Figure 10.6. Example of an amended hydrograph used for urban development scenarios.

10.3.2 MUSIC Catchment Nutrient Loads

The MUSIC model outputs only total nitrogen, while the ERM uses DIN as its nutrient currency. As such, the current study has applied a flat ratio of 0.30*TN to the MUSIC outputs from all subcatchments to estimate DIN inputs to the ERM. This resulted in median modelled DIN concentrations within the observed range for samples taken from EHMP sites DC14, BC13 and CC12 corresponding to high freshwater flows and low salinity (see Figure 9.2, water quality review section).

10.4 Definition of Indicators and Ecosystem Targets

10.4.1 Introduction

The aim of the ecosystem response modelling was to provide measures of indicators which are 1) sensitive to catchment stressors (e.g. nutrient and TSS inputs), and 2) relate directly to ecosystem function and the provision of ecosystem services. Chlorophyll-*a* concentration (a proxy for phytoplankton biomass) was chosen as a primary indicator due to phytoplankton production being directly coupled with nutrient inputs, and water clarity, and the direct linkage between phytoplankton production and a number of key ecosystem processes (Figure 10.7).

Phytoplankton are a major source of labile (readily mineralised) organic matter in many estuarine systems, driving both pelagic foodchains and detrital foodchains in the sediments. In shallow systems however, there is competition for nutrient resources by benthic microalgae resulting in more balanced production between the pelagic and benthic compartments. Maintenance of moderate phytoplankton biomass is important due to its controls over 1) light climate, and 2) rates and nature of organic matter breakdown in sediments. These are dealt with separately below.

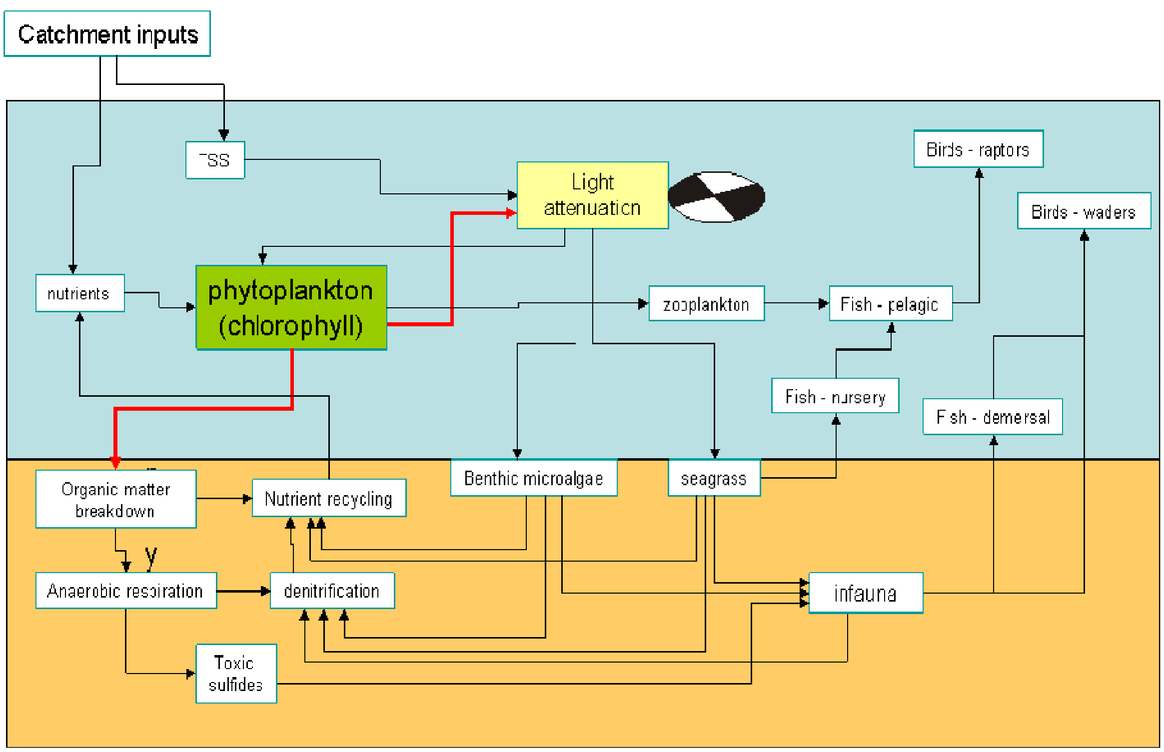


Figure 10.7. Important linkages between catchment inputs, phytoplankton production, and key ecosystem processes / services.

10.4.2 Light Climate

Phytoplankton biomass is a major contributor to the attenuation of light in aquatic systems. High chlorophyll concentrations can result in significant light limitation of sediments thereby retarding benthic microalgae and seagrass production. This results in disruption to foodchains dependent on these benthic producers, and persistent phytoplankton blooms may result in the permanent loss of seagrass habitat. A reduction in benthic production also has important implications for benthic biogeochemical cycles: sediments become more “heterotrophic” (consumers of organic matter), resulting in higher oxygen consumption, greater recycling of bio-available nutrients, and build-up of toxic chemical species (e.g. iron monosulfides).

10.4.3 Organic Matter Breakdown

Phytoplankton biomass is a major contributor to the organic matter content of the sediments. The rate of organic matter breakdown in estuarine sediments is directly related to the magnitude and persistence of phytoplankton blooms in the water column (Figure 10.8). Oxygen consumption due to organic matter breakdown in the sediments is the major contributor to deoxygenation of the water column. Organic matter breakdown in the sediments is the major pathway of nutrient recycling in estuaries, in some cases significantly prolonging phytoplankton blooms. In the absence of benthic primary production, nutrients liberated by the bacterial breakdown of organic matter are either fluxed back to the water column, or in the case of nitrogen, may be lost via denitrification.

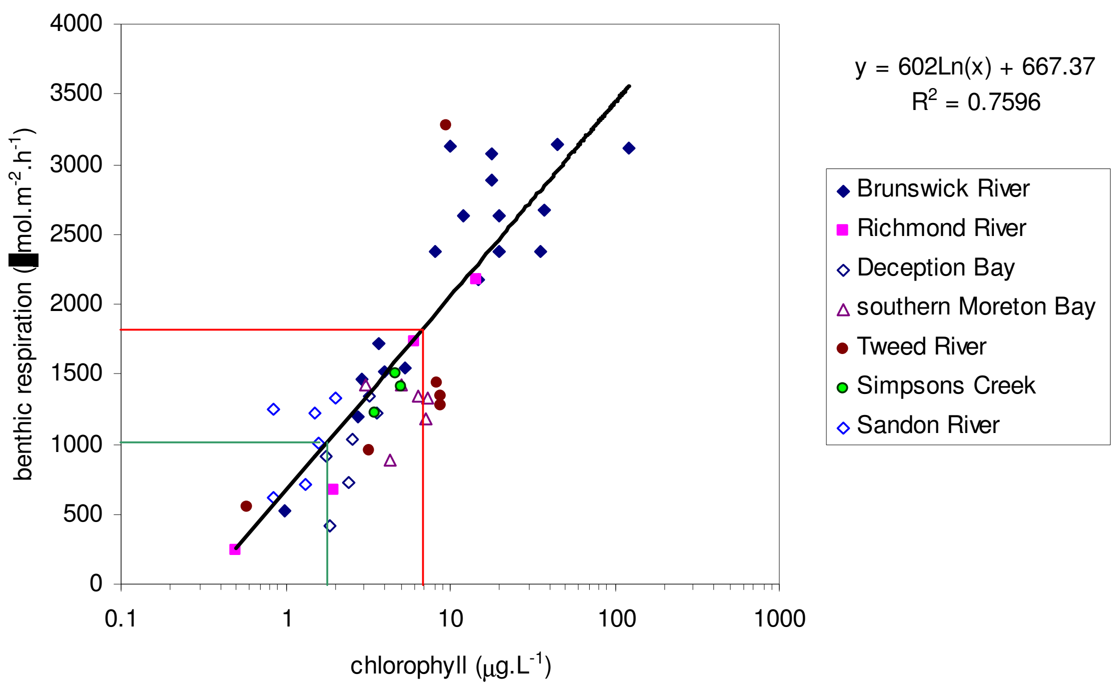


Figure 10.8. The relationship between chlorophyll concentrations in the water column and rates of benthic respiration (organic matter breakdown, measured as oxygen consumption by sediments. (Note : Brunswick Estuary represents a highly impacted system). The green reference line relates to the threshold shown in Figure 10.9, and identifies the median target for chlorophyll at approximately 2 $\mu g.L^{-1}$. The red line encompasses most of the un-impacted systems and represents the desired upper limit to chlorophyll/benthic relationship (80th percentile).

10.4.4 Critical Thresholds in Sediment Processes

Research from numerous sub-tropical estuaries has shown that when benthic respiration exceeds a certain threshold, there are fundamental shifts in benthic processes and ecology which have far reaching ramifications for ecosystem health (Figure 10.9). When benthic respiration exceeds 1000 µmol.m^{-2}.h^{-1}, the relative percentage of anaerobic respiration increases to greater than 95%, leading to a number of impacts including: 1) build-up of toxic sulfides, 2) severe limitation of denitrification, 3) a sharp increase in the recycling of bio-available nitrogen to the water column, and 4) a reduction of the diversity and abundance of benthic infauna. Due to the dynamic nature of estuarine environments (i.e. episodic high flow events interspersed with low flow periods), benthic respiration naturally exceeds this threshold for short periods of time, however sufficient recovery periods allow the reestablishment of optimal sediment conditions.

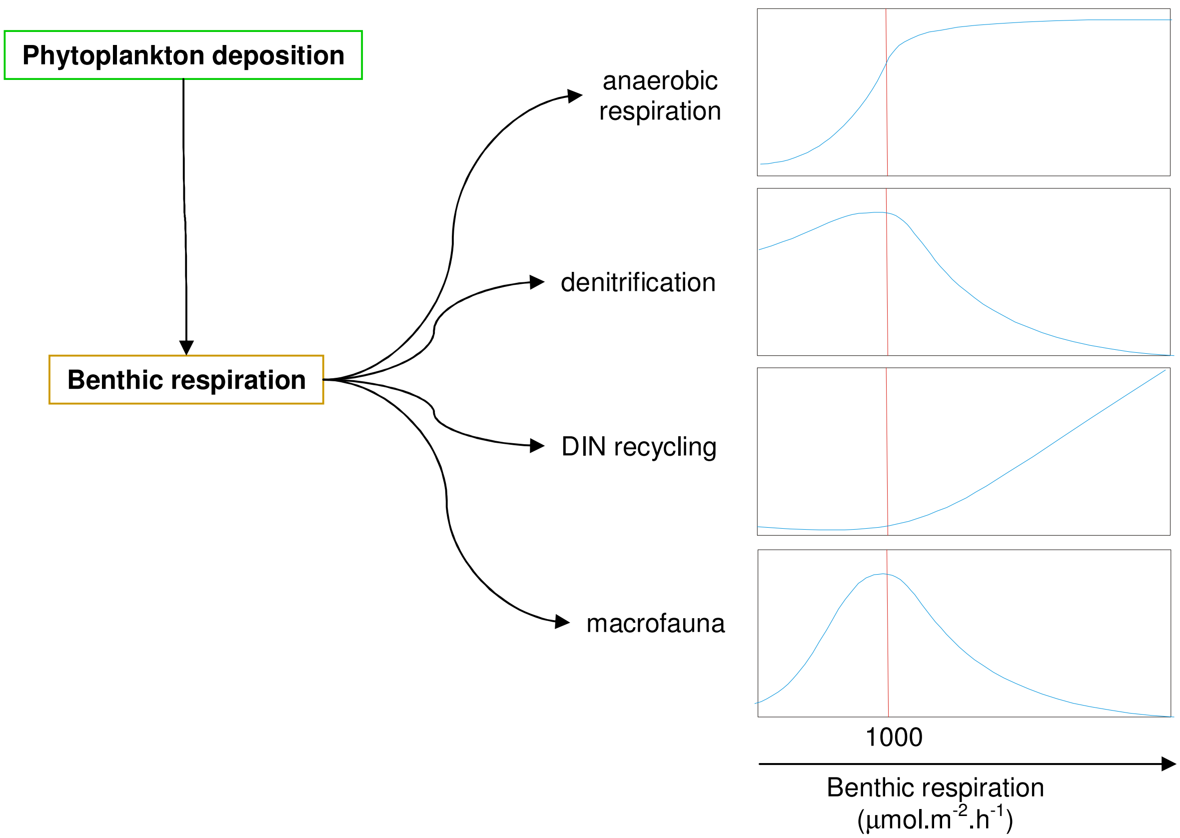


Figure 10.9. Conceptual diagram showing key biogeochemical and ecological responses to increased benthic respiration (organic matter breakdown). Variation in benthic respiration is primarily driven by the deposition phytoplankton to the sediments. Multiple system comparisons have shown that a common threshold in benthic respiration exists (represented by the red vertical lines) beyond which processes fundamentally change. These changes relate primarily to reduced oxygen supply in the sediments.

10.4.5 Chlorophyll Targets

For the purposes of this report, we have adopted the threshold relationship between chlorophyll and benthic respiration (green line; Figure 10.8) as the median target for the broadwaters. The 80th percentile target (red line; Figure 10.8) encompasses the upper limit of all the un-impacted systems used in Figure 10.8 and accounts for the natural tendency for episodic blooms to occur. Modelling indicated that the broadwaters (especially Cobaki) are susceptible to seasonally high chlorophyll concentrations due to their shallow nature and relatively long water residence times. This tendency is illustrated in the relationship between median and 80th percentile chlorophyll concentrations across a range of loading scenarios (Figure 10.10). Figure 10.10 indicates that simultaneous achievement of the median and 80th percentile targets for chlorophyll is possible.

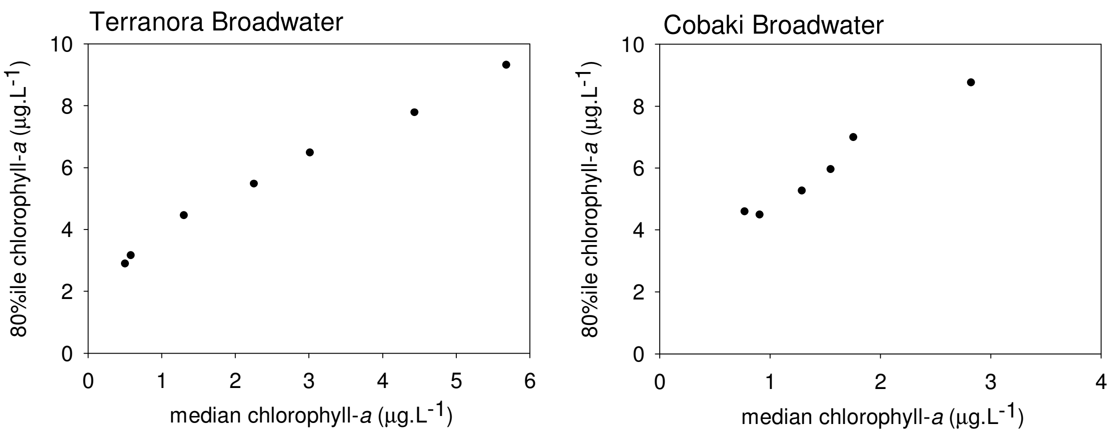


Figure 10.10. The relationship between median and 80th percentile chlorophyll concentrations for a range of loading scenarios (existing conditions down to estimated pristine). These plots illustrate the tendency for blooms to still occur even under potentially pristine conditions.

10.4.6 Dissolved Oxygen

The dissolved oxygen (DO) concentration of the water is a major control over habitat quality for many estuarine species. Generally, DO saturation varies according to the balance between biological processes that consume oxygen (e.g. breakdown of organic matter) and produce oxygen (e.g. photosynthesis), and physical processes that reoxygnenate the water (e.g. exchange at the water-air interface). Estuarine biota have generally evolved to tolerate some variation in DO saturation, however general ecosystem stress is thought to occur at DO saturations less than 40%. Some smaller, tannin dominated systems have natural seasonal DO sags to less than 40% due to photo-oxidation of tannins, however the ecology of these systems is restricted to a more limited suite of hypoxia-tolerant species.

Lower estuarine-broadwater environments such as the Cobaki-Terranora system are generally characterised by good DO saturation (>90%) due to a combination of low phytoplankton biomass, good water clarity, high benthic productivity and short residence times. There is no quantitative evidence to allow the setting of appropriate DO saturation thresholds to maintain optimum ecosystem services in these environments. However, the ecology of these systems is likely to be adapted to good DO saturation for the bulk of the time, with tolerance to brief episodic periods of hypoxia following high flow events. For the purposes of this report therefore, it will be assumed that ecosystem services will be maintained if DO saturation is greater than 80% for more than 80% of the time.

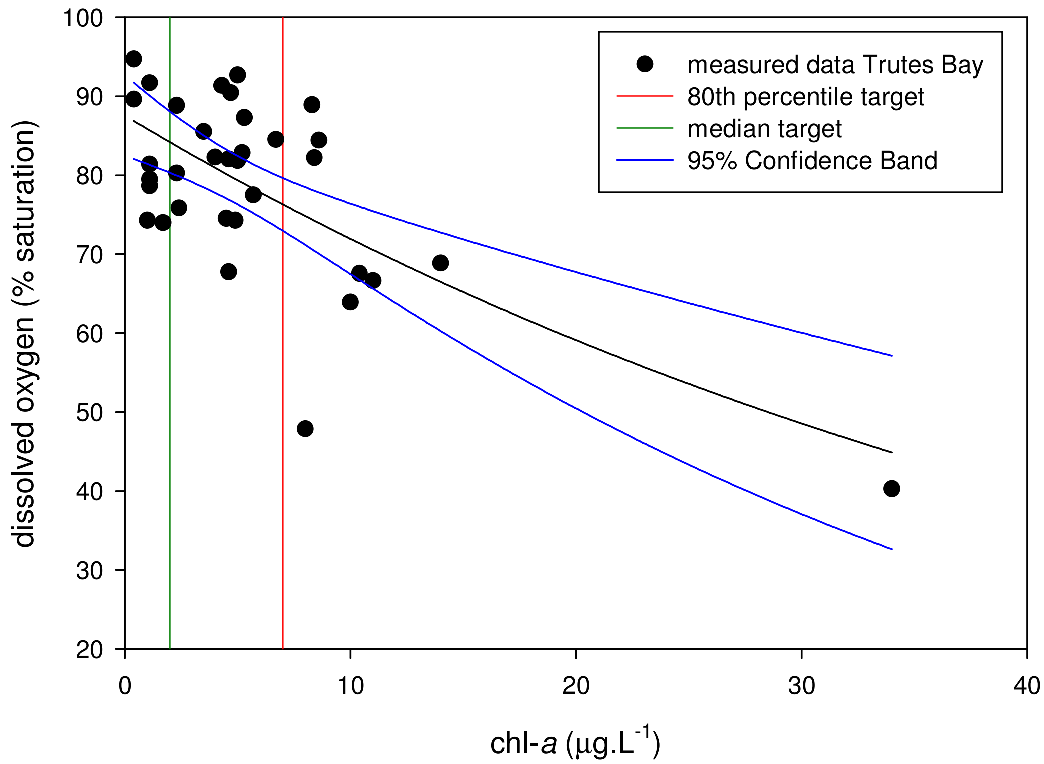


Figure 10.11. The relationship between chlorophyll-*a* and dissolved oxygen saturation in Trutes Bay (EHMP data site 11). Dissolved oxygen saturation is reduced to around 40% in association with large phytoplankton blooms. The ultimate target for the broadwater is the maintenance of dissolved oxygen at 80% saturation or greater for more than 80% of the time. The measured data indicate that adoption of the proposed median and 80th percentile targets for chlorophyll would achieve this target for dissolved oxygen.

A summary of indicators and target values is provided below in Table 10.1. The median and 80th percentile targets are intended to give a dynamic guide for assessing the results of monitoring. For example, the median of chlorophyll-a concentrations over a year should be equal to or lower than the median target of 2 ug/L.

Table 10.1. Summary of indicators and target values

	Chlorophyll *a* (ug/L)	**DO (% saturation)**
Median value	2	>80
80th percentile value	7	70 - 85

10.5 Impacts of Urban Runoff on Trutes Bay, Terranora Broadwater

10.5.1 Introduction

This section investigates the potential impacts of runoff from 1) the Banora Point western drainage scheme and 2) the proposed development of Area E on Trutes Bay, Terranora Broadwater.

10.5.2 Methodology

In order to isolate the impacts of runoff from the western drainage scheme on the broadwater, a sub-model was constructed of Trutes Bay (equivalent to Box 10 in the Cobaki-Terranora ERM). Only inputs from the immediate surrounding catchments were considered in model simulations, including the western drainage scheme, Area E, Bilambil estuarine, and Duroby Creek.

The hydrograph arising from a series of rainfall events occurring during late November-early December 2007 used for the simulation was generated by MUSIC (Figure 10.12). The average discharge during this period was equal to the median event discharge from the drainage scheme (~15ML.d^{-1}), while peak discharges were approximately equal to the 90%ile event discharge (~85ML.d^{-1}). The Duroby, Bilambil estuarine, Area E and western drainage scheme catchments accounts for 46%, 29%, 12% and 13% of the total discharge to Trutes Bay respectively.

The concentrations of DIN were held constant for each of the subcatchments over the entire simulation in order to clearly compare the relative impacts. Concentrations for Duroby Creek, Bilambil estuarine, and undeveloped Area E catchments were set at 300µg.L^{-1} based on measured data from Duroby Creek (see Figure 10.13). This is likely to underestimate concentrations in runoff from the urbanised part of the Bilambil estuarine catchment, however no data for this area exists. Whole system model simulations indicated that total nitrogen concentrations from the western drainage scheme were most likely underestimated by up to 4 times by the MUSIC catchment model at certain times of the year. As such, DIN concentrations were iterated up to 6000µg.L^{-1} in separate model simulations to show the impacts across the likely range.

Chlorophyll-*a* data from the EHMP (IWC, 2009) were used for model verification.

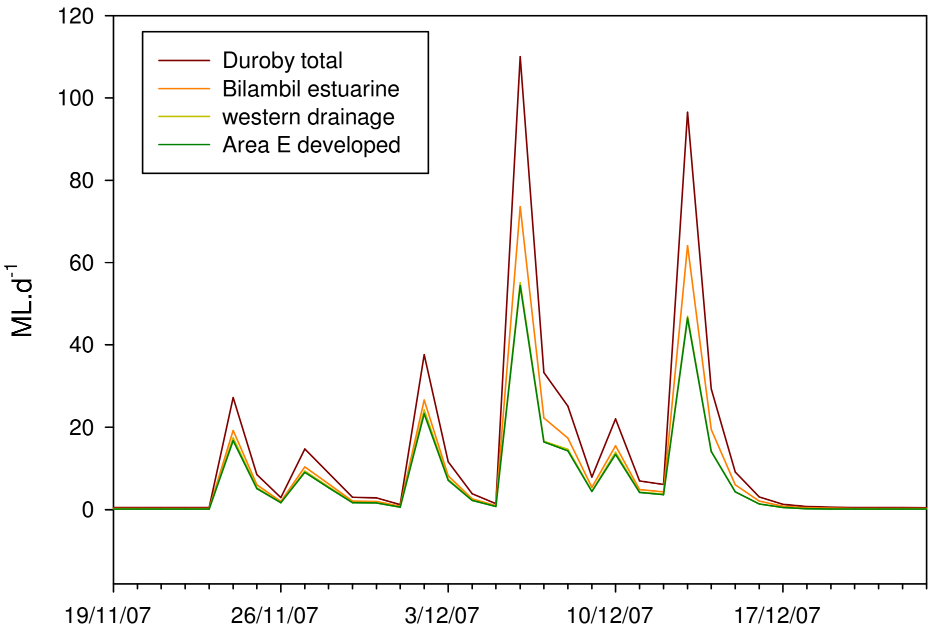


Figure 10.12. The hydrograph for the extended rainfall event in late November-early December 2007 used for model simulations.

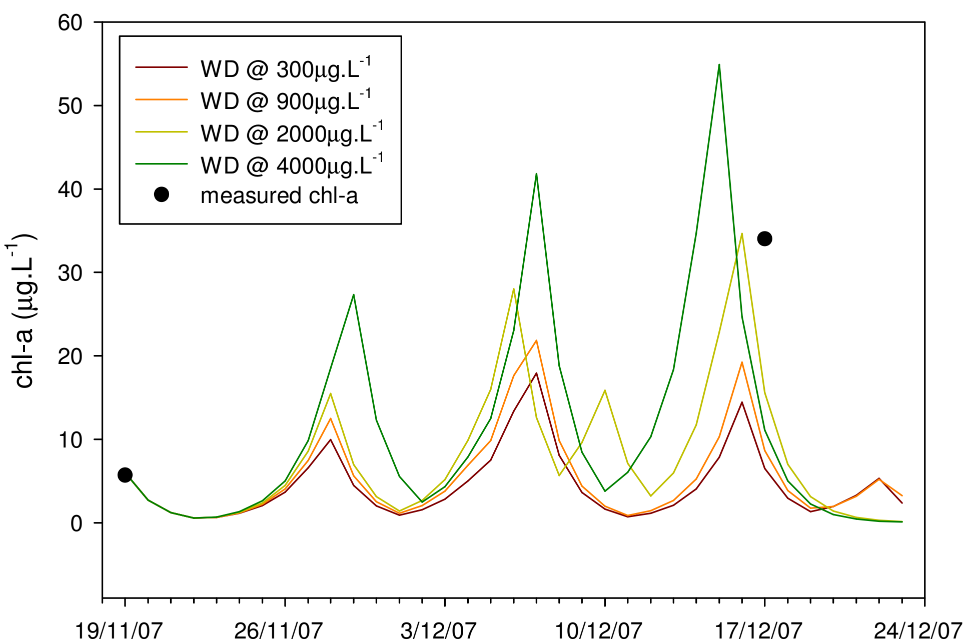


Figure 10.13. Modelled chlorophyll-*a* (lines) and measured chlorophyll-*a* (black dots) for the simulation period. Model simulations used various concentrations for DIN in runoff from the western drainage scheme while holding inputs from the other catchments at 300µg.L^{-1}.

10.5.3 Nutrient Concentrations in Urban Runoff

The concentration of dissolved inorganic nitrogen (DIN) in urban runoff from the western drainage scheme is unknown. A single sample effort was undertaken during June 2001 (TSC 2001) across eight sites throughout the drainage network, with DIN concentrations not exceeding 1.0 $mg.L^{-1}$ at any site. However this survey was undertaken during low flow conditions and it is likely that DIN concentrations were greatly reduced due to internal recycling processes. First flush concentrations during a runoff event are likely to be much greater due to the mobilisation of accumulated pollutants in the catchment and the disturbance of nutrient rich porewaters in drain sediments. Studies in Ballina have shown that peak concentrations of DIN may exceed 30$mg.L^{-1}$, with average concentrations for an event at around 3.4 $mg.L^{-1}$ (Eyre and Morrisey, 1994).

10.5.4 Western Drainage Scheme Runoff

Model simulations using relatively high DIN concentrations for runoff from the western drainage scheme (2000$\mu g.L^{-1}$) provided the best fit with the measured chlorophyll-*a* concentrations in Trutes Bay during the November 2007 rainfall event. It is stressed that this represents the likely worst case scenario, occurring when drain sediments and pollutants in the catchment have accumulated, and light / temperature are at a seasonal optimum to promote a rapid phytoplankton response in the receiving waters.

While the model simulation used a flat runoff DIN concentration (representing the average concentration of runoff from the western drainage scheme over the modelled period), it is likely that concentrations vary significantly over the course of a runoff event, with peak concentrations in the first flush dropping to lower concentrations in the falling phase of the hydrograph. The high average DIN concentration used to provide best fit with measured data indicates that the disturbance of drain sediments may be a significant factor in determining the water quality of runoff from this area. It is likely that the DIN concentrations of runoff will very significantly according to other factors such as antecedent rainfall, and season.

10.5.5 Area E Runoff

The MUSIC model predicted very similar impacts for the development of Area E due to the similarity in the estimated volume of runoff from this catchment and the western drainage scheme. The results showed that even a tripling of DIN loads from this catchment would have a relatively large impact on chlorophyll concentrations in Trutes Bay due to the existing high background inputs from the western drainage scheme (e.g. see the lower end of the DIN concentration scale on the x axis in Figure 10.9). At the higher end of the DIN concentration scale impacts from Area E become relatively insignificant due to the vastly overriding effects of nutrient-rich runoff from the western drainage scheme.

10.5.6 Relative Impacts of the Western Drainage Scheme on Trutes Bay

The model simulations highlight a potentially large impact on Trutes Bay and the Terranora Broadwater due to runoff from the western drainage scheme and Area E developments. The primary reasons for this are the shallow nature of the bay (providing optimal light climate for phytoplankton growth) and the relatively long residence times of this bay (in excess of 10 days during neap tides). The impacts of urban runoff are somewhat localised within Trutes Bay due to incomplete mixing, and it is likely that the model may underestimate impacts due to the assumption of uniform mixing of runoff from Duroby Creek.

The stimulation of large algal blooms within Trutes Bay has significant implications for the ecology of Terranora Broadwater. The model simulations indicated that the breakdown of algal material in the sediments was capable of significantly lowering dissolved oxygen (by up to 0.7mg.L^{-1}.d^{-1}). This is confirmed by the EHMP data which show oxygen saturation was lowered to ~40% during the peak chlorophyll-*a* concentrations within the model period. This is despite the high degree of mixing and atmospheric exchange likely in this shallow bay. The tidal and wind-driven resuspension of sediments within Trutes Bay most likely exacerbate the deoxygenation of the water column by exposing reduced sulfides (created by the breakdown of algal material) to oxidation in the water column.

10.5.7 Monitoring Recommendations

It is recommended to carry out a flow-weighted sampling effort at major outlets within the drainage network to ascertain the major sources of nutrients in urban runoff. In particular, this would enable the separation of contributions from the first flush of accumulated pollutants within the catchment and the mobilisation of drain sediments. It is likely that the pollutant concentrations in runoff from the scheme will vary significantly depending on factors such as antecedent rainfall and season. As such, it is recommended that a minimum of four runoff events be sampled over the course of a year. In addition, the properties of sediments (organic carbon, nutrients) within the drainage scheme should be sampled to better understand internal recycling processes.

10.5.8 Targets

Model simulations were undertaken using a range of DIN concentrations for urban runoff to estimate the improvements necessary to maintain acceptable chlorophyll-*a* concentrations in Trutes Bay. The results indicate that even with a dramatic reduction in DIN concentrations in western drainage scheme runoff to less than 300 μg.L^{-1} median chlorophyll concentrations are still likely to exceed targets for the Terranora Broadwater. The achievement of this target is therefore going to require major reductions in the DIN concentrations of existing urban runoff to 250 μg.L^{-1}, coupled with no future increases in DIN loads from Area E and a reduction in the DIN concentrations of runoff from the Duroby Creek catchment to 250 μg.L^{-1}.

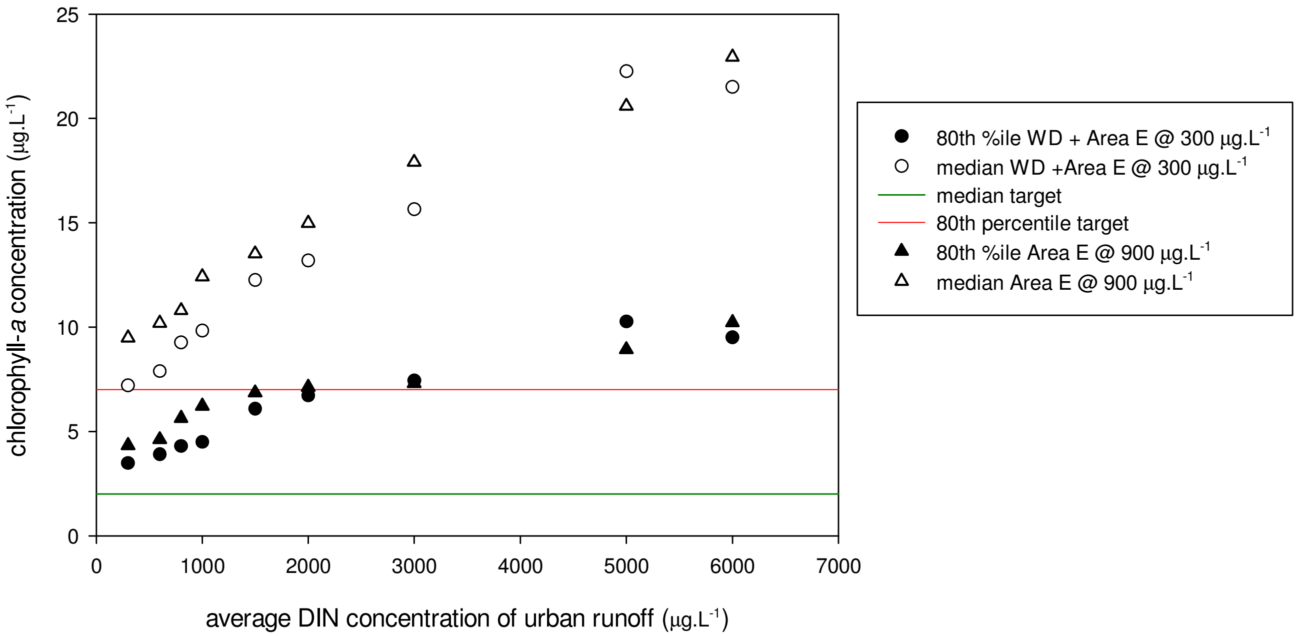


Figure 10.14. Median and 80th percentile chlorophyll concentrations associated with a range of DIN concentrations for urban runoff from the Banora Point Western Drainage Scheme. Due to the closeness of the estimated runoff volumes from the Western Drainage Scheme and the developed Area E catchment, this chlorophyll curve applies to both catchments.

10.6 Impacts of the Proposed Cobaki Lakes and Bilambil Heights Urban Developments on Cobaki Broadwater

10.6.1 Methodology

The combined impacts of the proposed development of Cobaki Lakes and Bilambil Heights on Cobaki Broadwater were tested on a sub-model of the broadwater (equivalent to Box 6 of the Cobaki-Terranora ERM). The estimations were based on runoff from the entire Cobaki transition and Bilambil Heights zones, assuming that urbanisation would broadly affect runoff from these areas. This was done in order to capture disturbances outside the boundaries of the actual urban footprint (e.g. roads).

The model simulations were restricted to a series of rainfall events occurring during late November-early December 2007. The hydrograph arising from these rainfall events was generated by MUSIC (Figure 10.15). The average discharge during this period was equal to the median event discharge from the drainage scheme (~15ML.d^{-1}), while peak discharges were approximately equal to the 90%ile event discharge (~85ML.d^{-1}). This rainfall event was chosen for model simulations because: 1) it occurred during summer when the ecosystem response to pollutant loadings is highest, and 2) the period is covered by the EHMP dataset allowing model verification.

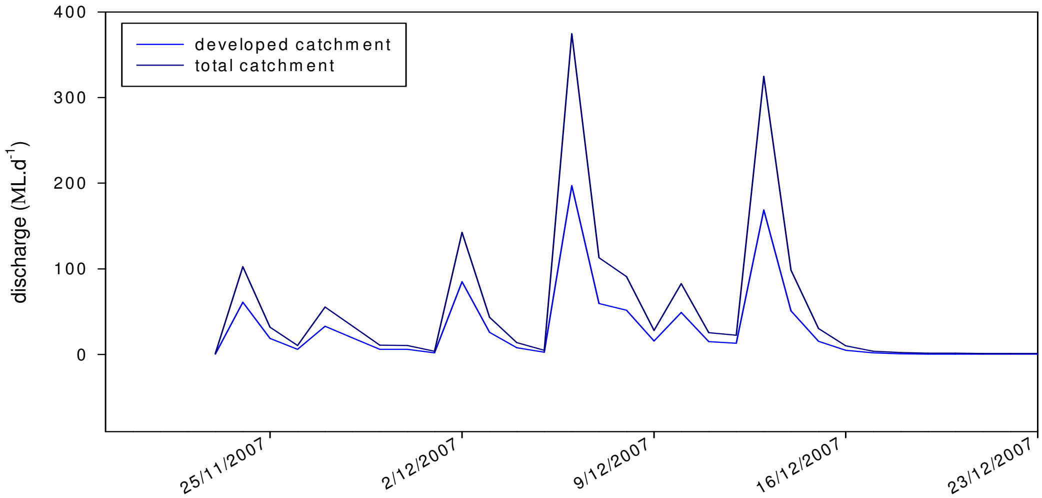


Figure 10.15. Discharge hydrograph used for model simulations, showing the total catchment discharge and the developed catchment discharge.

The dissolved inorganic nitrogen (DIN) concentrations of freshwater runoff from the undeveloped catchment were set at 250 µg.L^{-1} based on the observed maximum concentrations in Cobaki Creek during the EHMP monitoring period (Figure 10.16). The impacts of urban runoff were assessed by running model iterations with average event concentrations varying between 400 and 6000 µg.L^{-1}.

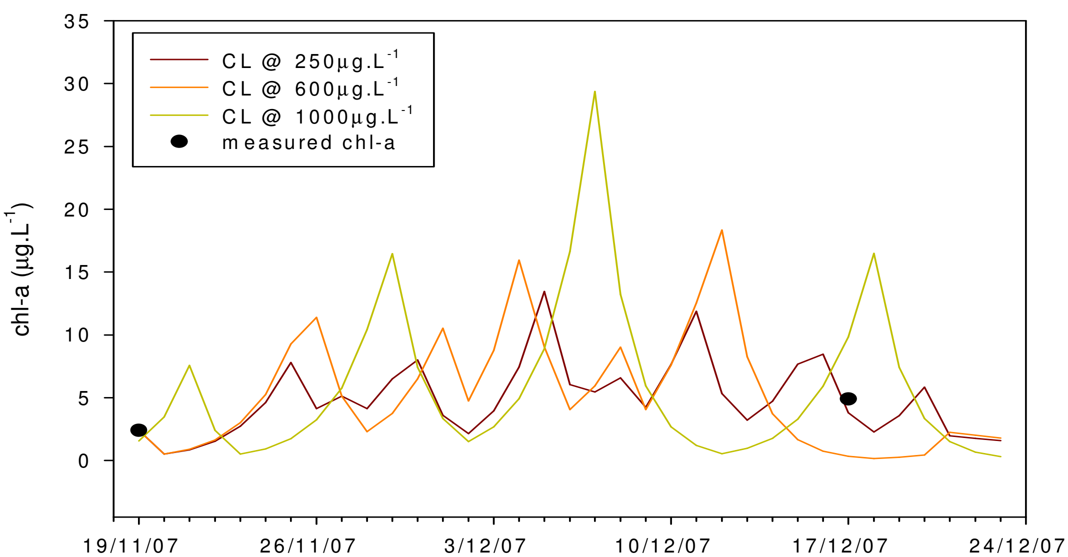


Figure 10.16. Modelled chlorophyll-*a* in the Cobaki Broadwater for different developed and undeveloped (dark brown line) scenarios. The results show that the Cobaki broadwater is particularly sensitive to any increased DIN concentrations in runoff from the developed area. This sensitivity arises from: 1) the relatively large contribution of the development catchments to overall discharge, 2) the long residence times of receiving waters, and 3) the shallow morphology of the broadwater.

10.6.2 Impacts within Cobaki Broadwater

The model simulations shown here used coarse estimations of runoff from the proposed development areas and as such are intended to show the sensitivity of the broadwater to the scales of development proposed in the catchment. It is likely that biological response (and therefore impacts) will vary according to many factors including:

- The time of year
- Cloudiness
- Distribution of rainfall across the catchment
- The spring/neap tidal cycle

The impacts of the developments are likely to be heightened due to a combination of a significant increase in runoff coefficients due to urbanisation and the proximity of the catchments to the broadwater. This may result in a disproportionately large contribution of runoff from the developed catchments during smaller coastal storms, which would result in a larger impact on the broadwater than indicated by the model results. Biological response to pollutant loadings will be greatest during summer when incident light and temperature is highest.

The Cobaki Broadwater is particularly sensitive to an increase in nutrient (nitrogen) loadings during median flow events arising from smaller storms due to the relatively long residence times for freshwater runoff. The shallow morphology means that light penetration will not limit phytoplankton production, resulting in the rapid development of relatively large blooms.

10.6.3 Downstream Impacts

The EHMP data and Cobaki-Terranora ERM results show a close coupling between biological response in the Cobaki Broadwater and the downstream nexus. There is some attenuation of chlorophyll-*a* concentrations downstream due to settling of phyto-detritus, however this is masked by internal production within the nexus which is fuelled by recycling of nutrients from the sediments (and potentially inputs of nutrients advected upstream by tidal mixing of STP effluent). As such, the nexus environment is also sensitive to an increase in pollutant loads due to upstream urbanisation. Of particular concern are the remaining seagrass beds within the nexus which will be exposed to higher ambient nutrient concentrations (and hence epiphytic algae growth), and a reduction in light climate due to higher phytoplankton concentrations (see seagrass risk assessment, Section 10.6).

10.6.4 Targets

Model simulations were undertaken to estimate the DIN concentrations for urban runoff necessary to maintain acceptable chlorophyll-*a* concentrations in Cobaki Broadwater. The results indicate that there is no detectable impact with DIN concentrations less than 250 $\mu g.L^{-1}$ for runoff from the developed areas (i.e. Cobaki Lakes and Bilambil Heights Figure 10.17).

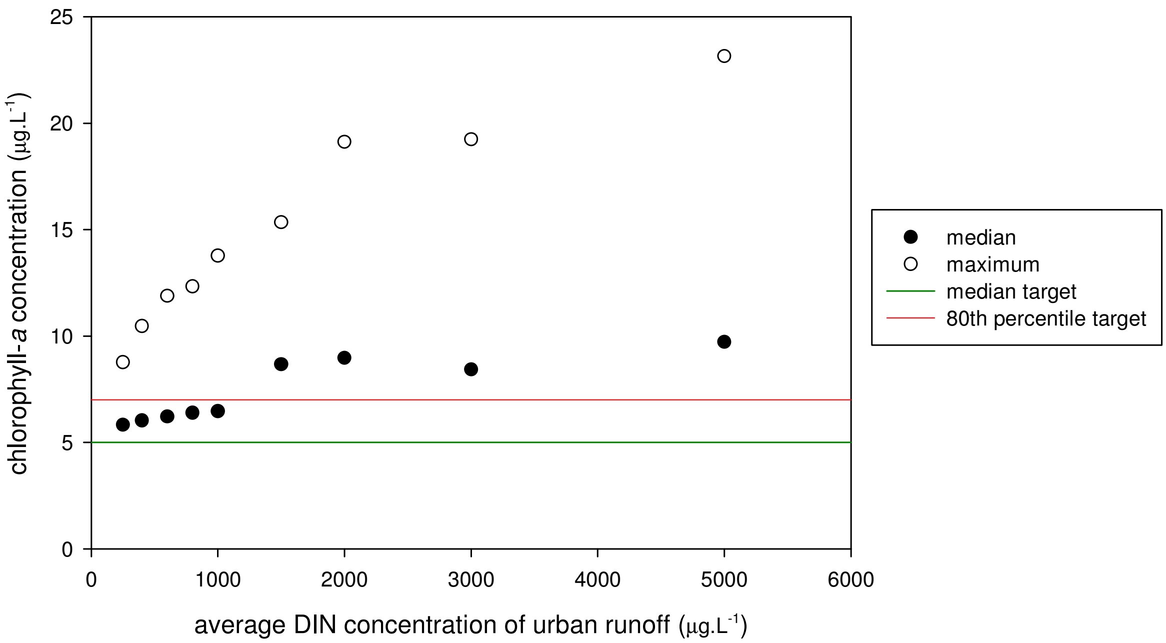


Figure 10.17. Median and 80th percentile chlorophyll concentrations associated with a range of DIN concentrations for urban runoff from the ongoing and proposed developments in the Cobaki Broadwater catchment.

10.7 Seagrass Risk Assessment

10.7.1 Background

Seagrasses represent a major ecosystem component of the Cobaki-Terranora system, providing a range of ecosystem services. They provide significant inputs of organic matter to detrital and pelagic foodchains, and are habitat / refuge for a wide diversity of crustacean and fish species.

In general, seagrass distribution is determined by light availability and substrate stability. Seagrasses require a minimum amount of light in order to survive, which is generally accepted to be approximately 100-120 μEinsteins. The depth below which light falls below this value is termed the seagrass compensation depth. The ecosystem response model can be used to estimate the percentage of sediments above the seagrass compensation depth (termed 'viable seagrass habitat') for different concentrations of chlorophyll in the water column (Figure 10.18). These results are then plotted to provide a system-specific estimation of seagrass sensitivity to phytoplankton biomass (chlorophyll). It should be noted that not all shoals identified as viable seagrass habitat according to light criteria will support seagrass due to excessive current speeds and unstable substrate (e.g. shifting marine deltas).

10.7.2 Current Risks

Seagrass beds in the Cobaki and Terranora Broadwaters and Terranora Creek systems are at risk from two primary influences: 1) light limitation due to excessive turbidity, and 2) growth of epiphytic algae due to high ambient nutrient concentrations. The risk due to light limitation has been included in the current ERM, however no data exist on the thresholds for epiphytic algal growth, therefore it is only possible to make an assessment of risk in terms of potential habitat based on literature values for seagrass compensation depths.

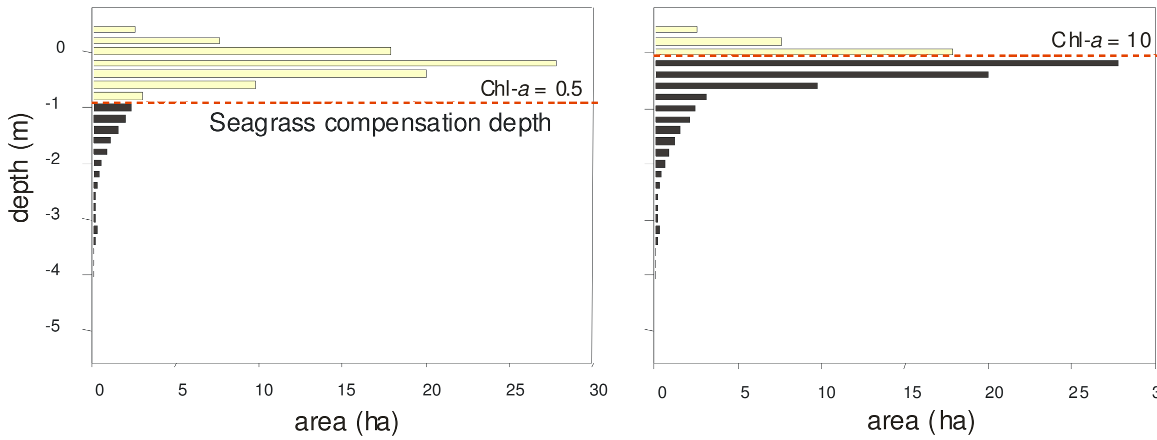


Figure 10.18. The ERM can be used to estimate the percentage of sediments which receive adequate light to support seagrass under different concentrations of chlorophyll in the water. Under relatively low chlorophyll concentrations the bulk of sediments are above the seagrass compensation point, while under moderately high concentrations the relative area of viable seagrass habitat is reduced dramatically.

10.7.3 Methodology

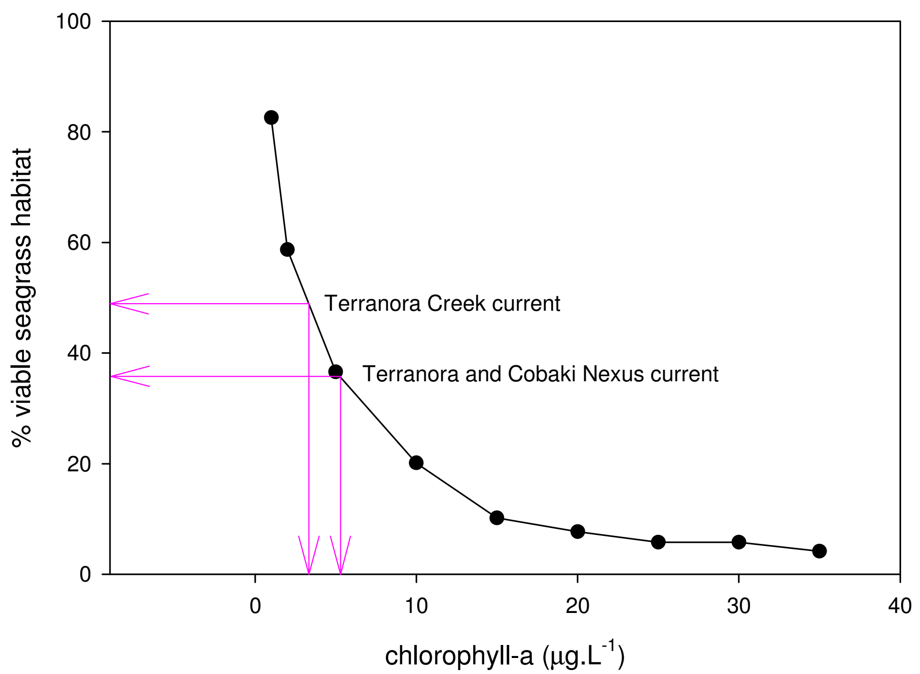
The ERM estimates light attenuation (Kd) as a function of chlorophyll, colour and TSS concentrations. The average light climate at any depth can then be estimated throughout the system. In order to be viable, seagrass requires the minimum light climate to be above the compensation depth of approximately 100 µEinsteins during the growing season. Sediments receiving light above this level are considered to be ‘euphotic’, and able to support seagrass beds. The impacts of different chlorophyll concentrations on the area of euphotic sediments within the system was assessed by holding colour and TSS at values of 50 and 20 respectively (which approximate average background concentrations of these constituents). An extra simulation was run to account for the impacts of resuspension on light climate in the broadwater. TSS for this run was set at $200mg.L^{-1}$ which is equal to the 80%ile value for the whole broadwater based on EHMP data. Incident light used for the simulations was 1000 µEinsteins, which is estimated to equal the average daily light intensity (taking into account cloudy days) during the growing season.

10.7.4 Results

The risk curves for viable seagrass habitat reduction due to increases in water column chlorophyll for the nexus and Terranora Creek channels and the Terranora Broadwater are presented in Figure 10.19. The distinctly different curves for the two environments arise from differences in hypsometry: shallow shoals are more restricted in area in the Terranora Creek and nexus channels (resulting in greater risk of seagrass habitat loss) compared to the broadwater which is dominated by shallow shoals. The high turbidity simulation for the broadwater yielded a much greater sensitivity of seagrass habitat.

The current condition of each environment is indicated by plotting the 80%ile chlorophyll value (based on EHMP data). Seagrass in both Terranora Creek and the nexus channels is highly sensitive to any increase in ambient chlorophyll concentrations. Despite the apparent resilience of seagrass habitat in the broadwater to light limitation implied by Figure 10.14, field inspections during this study revealed that seagrass condition in Terranora Broadwater was poor due to epiphytic algae growth. Given the current nutrient loadings from the Banora Point western drainage scheme, seagrass in this area should be regarded as highly stressed. In addition, high turbidity caused by resuspension significantly impacts on the area of viable habitat.

It should be noted that modelling has indicated that routine monitoring may have significantly underestimated chlorophyll concentrations in some areas due to the high temporal variability in phytoplankton. As such, the assessment of current status should viewed as conservative. For example, chlorophyll concentrations in excess of 10µg.L^{-1} were observed more than 40% of the time, which significantly reduces the estimated viable seagrass habitat area even in the absence of resuspension events.



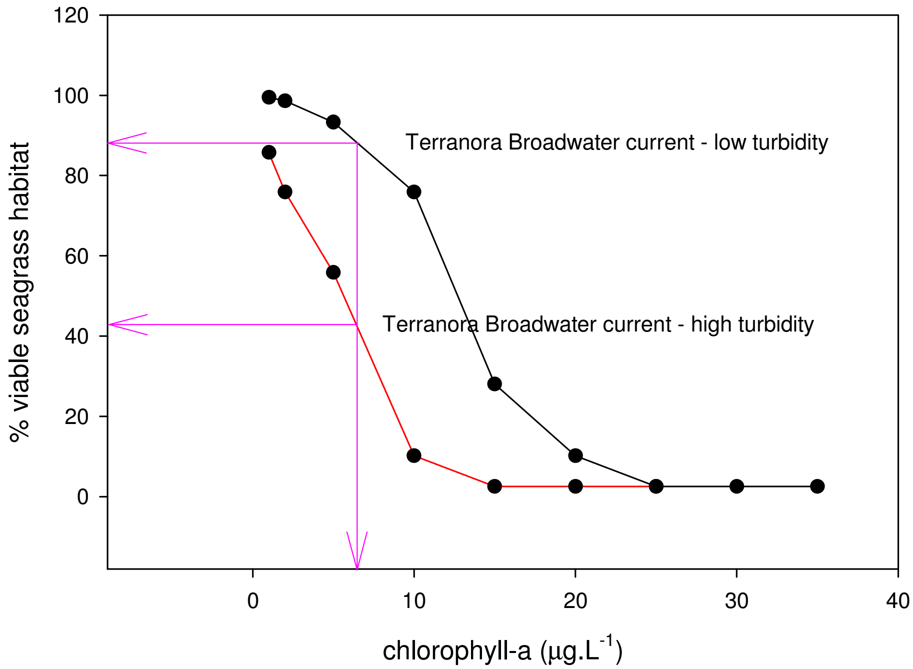


Figure 10.19. The percentage of shoals receiving sufficient light to support seagrass under different concentrations of chlorophyll in the water column. The pink arrows indicate the current 80th percentile chlorophyll concentrations (EHMP data). The results for Terranora Creek / nexus environments show that viable seagrass habitat is highly sensitive to small increases in chlorophyll concentrations.

10.7.5 Targets

Adoption of the median and 80th percentile targets for chlorophyll result in maximum potential seagrass habitat in the Terranora Broadwater / nexus and Terranora Creek systems. These targets are presented in Table 10.1.

10.8 Catchment Load Reduction Scenarios

The ERM was used to assess various catchment load reduction scenarios on chlorophyll concentrations. The aim was to help set targets for catchment rehabilitation in order to offset the discharge of effluent from the Banora Point STP

10.8.1 Methodology

The concentration of total nitrogen was iteratively decreased by 20% from all rural subcatchments while holding the STP and urban loads constant. At 40% of the existing catchment load, urban loads were then reduced iteratively by 25%. Peak chlorophyll-*a* concentrations in each box of the ERM were recorded for each scenario.

10.8.2 Results

The median chlorophyll-*a* concentrations for each of the scenario runs are presented in Figure 10.20. The reduction of rural catchment loads in the Cobaki subcatchments significantly reduced the occurrence of major phytoplankton blooms, with a 30% reduction resulting in acceptable median chlorophyll concentrations of approximately 2µg.L^{-1}. In contrast, the reduction of rural catchment loads in the Terranora Broadwater catchments had minimal impact, due to the overriding influence of urban runoff with high nutrient concentrations. The reduction of DIN concentrations in runoff from the western drainage scheme by 75% resulted in acceptable median chlorophyll concentrations of approximately 2μg.L^{-1} (Figure 10.21).

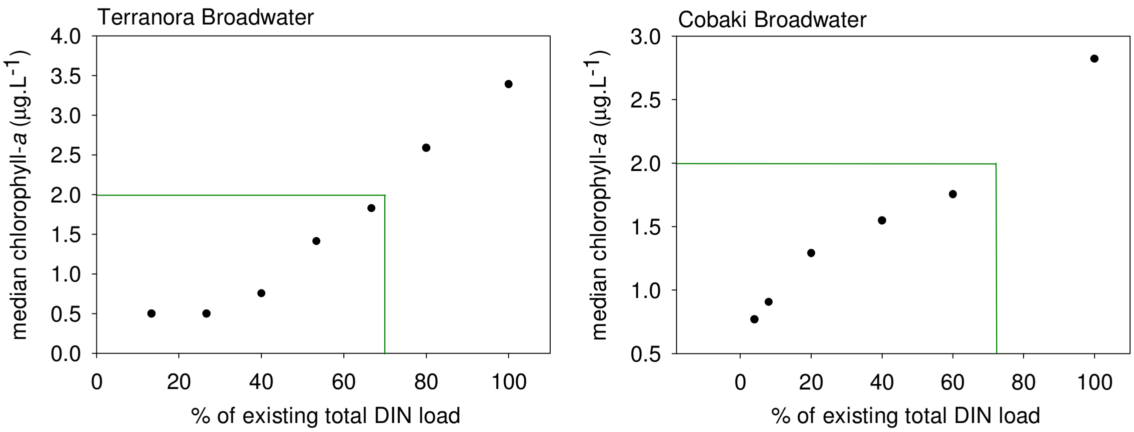


Figure 10.20. Reductions in median chlorophyll-a concentrations due to incremental reductions in catchment nitrogen loads (expressed here as percentage of existing load). In order to achieve the median target for chlorophyll it is necessary to reduce total catchment loads by approximately 30% in both the Terranora and Cobaki Broadwater catchments.

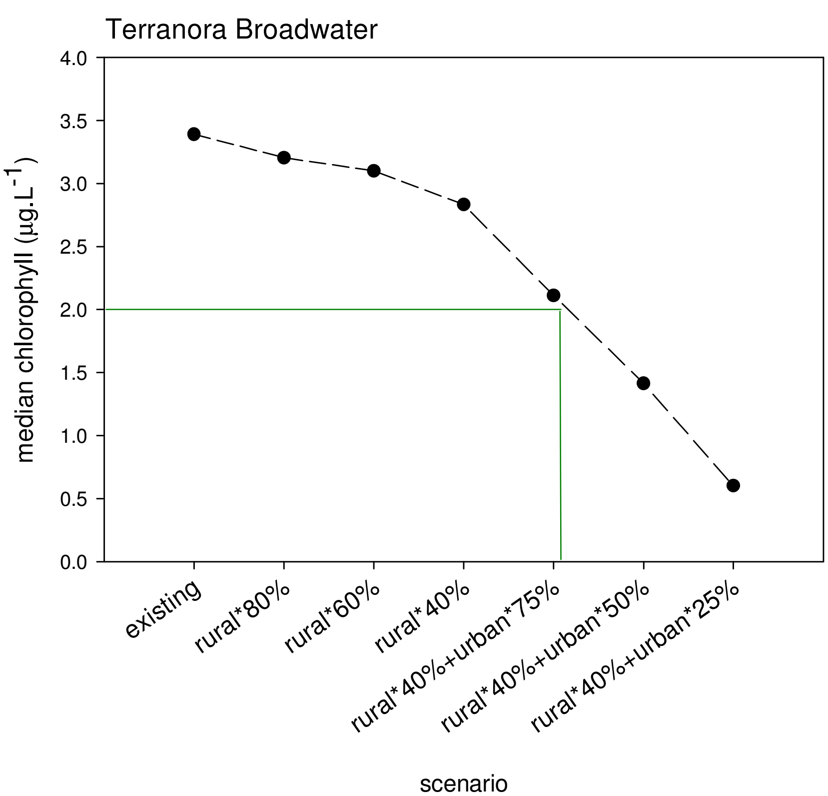


Figure 10.21. Impacts on median chlorophyll of incremental reductions in rural total nitrogen loadings (holding urban loadings at existing), followed by incremental reductions in urban loadings. In order to achieve the median target for chlorophyll (i.e. reducing total catchment loads

by approximately 30%, refer to Figure 10.20 above) it is necessary to reduce catchment loads by 60% and urban loads by 25%. This figure illustrates the significantly greater impact of the urban catchments on broadwater health.

10.9 Impacts of Effluent from Banora Point Wastewater Treatment Plant

It was beyond the brief of this study to undertake a complete investigation into the impact of the Banora Point Wastewater Treatment Plant discharge into the system. This has been undertaken in the EIS for the upgrade of the Banora Point plant and its discharge. The WWTP input has however been considered in the context of the catchment and relative to all other catchment runoff inputs.

Nutrient discharge from the Banora Point plant has been included in the pollutant export and ERM model formulation. A constraint in this approach is that due to the daily time step resolution of the ERM model, the practice of ebb tide discharge could not be accurately assimilated. As such, the WWTP inputs were treated as catchment inputs (i.e. daily discharges). The effluent discharge was set at 15 ML.d, with an effluent DIN concentration at 2000 ug.L.

Results from model runs including STP effluent inputs show increased chlorophyll concentrations in the nexus channels and Terranora Creek. Impacts are moderated due to phytoplankton biomass being limited in these reaches by greater tidal flushing and significantly shorter residence times. Reducing the concentration of effluent (equivalent to reducing the total load) in the model simulations showed a reduction in chlorophyll concentrations (Figure 10.22).
Treated effluent from the Banora Point WWTP is discharged on an ebb tide so that tidal flows take the bulk of treated effluent out of Terranora Creek. However, unless discharge ends well before the bottom of the ebb tide, a significant amount of effluent will remain in Terranora Creek and the lower Tweed Estuary. Due to the large tidal prism of the Cobaki-Terranora Broadwater system, the following flood tide will subsequently transport effluent remaining in the lower reaches of the creek, back upstream of the WWTP discharge point into the nexus channels. This is evidenced by the results of processed nitrogen tracking undertaken in the EHMP project, which show that there is a strong processed nitrogen signal immediately upstream of the WWTP discharge point.

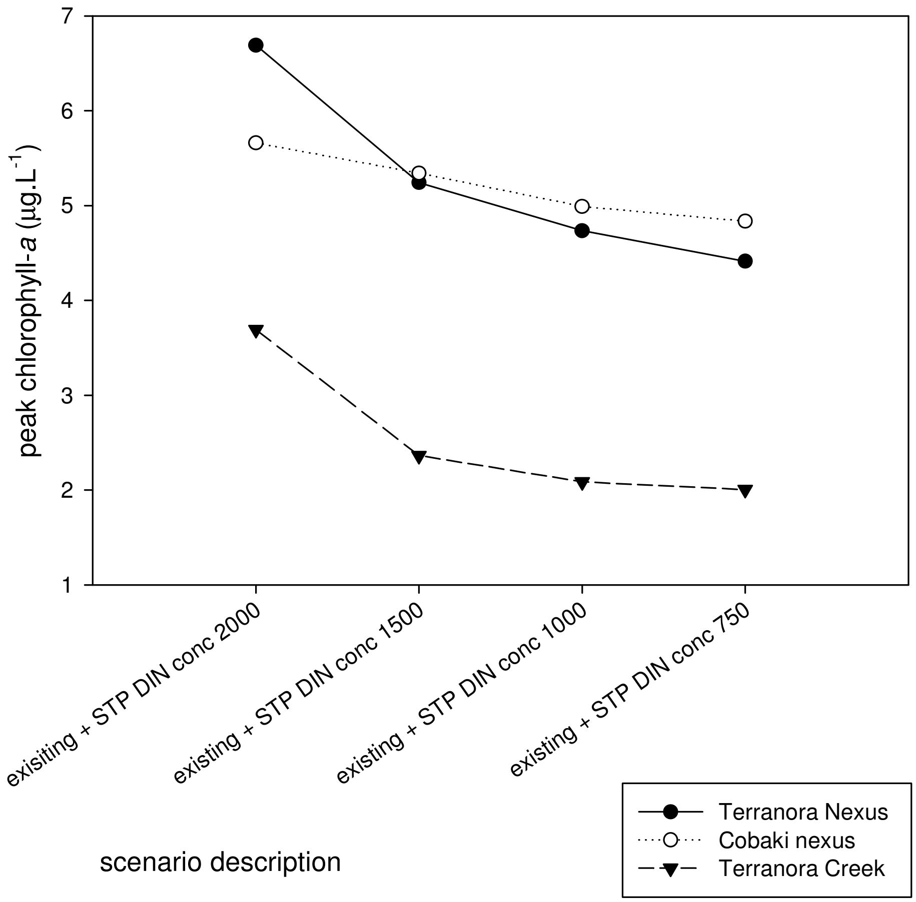


Figure 10.22. Reductions in peak chlorophyll-*a* concentrations in the nexus channels and Terranora Creek due to incremental reductions in catchment nitrogen loads from the Banora Point Wastewater Treatment Plant.

10.10 Reduction of Nitrogen Concentrations in Catchment Runoff

The highest priority for minimising impacts on the broadwaters and downstream environments is the reduction of dissolved inorganic nitrogen (DIN) concentrations in freshwater discharges during runoff events. This can be achieved by either reducing the total nitrogen load, or by reducing the DIN fraction of the total nitrogen load. Different functional zones and subcatchments will have their own optimal actions for achieving this. To further understand the nitrogen speciation of catchment runoff in the system a well targeted, flow-weighted water quality monitoring program would assist with locating sources of DIN throughout the catchment. The results of such a study would be useful in the development of targeted works programs. However, strategies to reduce catchment DIN loads, such as rehabilitation projects should commence immediately. The long term effectiveness of rehabilitation projects can be assessed as part of an ongoing process of prioritising rehabilitation efforts.

10.10.1 Cobaki Broadwater

To achieve the desirable reductions in DIN loads to the Cobaki Broadwater rehabilitation should target the transition and estuarine zones of Cobaki Creek, the whole of the Bilambil Heights zone, and the middle zone of Piggabeen Creek (Table 10.1).

It is noted that urban development in currently underway or planned for two of these zones, and that additional modelling has indicated a potentially major impact due to poor water quality in urban runoff from these developments. It would be extremely hard to offset the impacts of these developments with any rehabilitation actions in the rural catchment. As such, the implementation of best practice WSUD in these developments is of paramount importance to maintaining the current status of the broadwater .

10.10.2 Terranora Broadwater

The priority for DIN load reduction in the Terranora Broadwater is the improvement of water quality in urban runoff from the Banora Point western drainage scheme. This is due to the relative size of this input, its direct discharge to the most poorly flushed part of the broadwater, and the high runoff coefficients in the catchment.

Reductions of DIN loads from the rural catchment are considered a secondary priority, however the middle zone of Bilambil Creek should be targeted due to the relative size of its contribution. Duroby Creek should also be targeted due to its relatively high nitrate concentrations (Tables 10.2 and 10.2).

Table 10.2. Total nitrogen export from functional zones. The median loads represent normal low flow conditions, 90th percentile loads represent an average runoff event and maximum loads represent a major flood event. Highest priority zones are indicated by orange highlight and secondary priority zones are indicated by yellow highlight.

Subcatchment	Functional Zone	Total nitrogen load ($kg.d^{-1}$)		
		median	90%ile	max
Piggabeen Creek	upper	0.2	5.5	68.5
	middle	0.4	10.3	131.2
	Bilambil Heights	0.3	21.4	173.4
Cobaki Creek	upper	0.3	5.2	284.0
	middle	0.4	6.8	441.1
	transition	0.6	38.0	782.3
	estuarine	0.5	25.5	443.7
Bilambil Creek	upper	0.7	17.4	153.5
	middle	0.8	17.2	283.0
	transition	0.1	3.3	37.9
Terranora BW	estuarine	0.9	57.5	508.5
Duroby Creek	upper	0.4	9.1	128.4
	middle	0.3	6.2	93.8
	transition	0.0	8.0	58.8

Table 10.3. Total nitrogen concentration of functional zones.

Subcatchment	Functional zone	Total nitrogen concentration ($\mu g.L^{-1}$)		
		median	90%ile	max
Piggabeen Creek	upper	649	1707	4722
	middle	737	1713	3934
	Bilambil Heights	958	1468	3026
Cobaki Creek	upper	678	2115	7689
	middle	757	1654	4376
	transition	1014	1301	2251
	estuarine	936	1369	2504
	upper	833	1455	1848
Bilambil Creek	middle	725	1711	3395
	transition	789	2154	5228
Terranora BW	estuarine	1022	1363	2208
Duroby Creek	upper	673	1982	5303
	middle	661	2301	5594
	transition	856	1573	1858

10.11 Potential Strategies to Reduce DIN Loads

10.11.1 Identify DIN Sources

A spatially intensive water quality monitoring strategy should be carried out to help pin point the most likely hotspots for DIN entering the streams. Sites should be chosen to provide good resolution of reach-scale variations in water quality associated with distinct land use and geomorphologic units. A minimum of two sample efforts should be made during median and high flow conditions.

10.11.2 Improvement of Instream Health

Despite relatively low ambient nutrient concentrations along much of the freshwater reaches during low flow conditions, there evidence that stream habitats are stressed due to a likely combination of poor riparian zone condition and chronic nutrient enrichment due to stock access. While this condition does not directly impact on the broadwaters during low flow, the build up of organic-rich sediments and faeces can result in the delivery of higher nutrient loads during runoff events due to the mobilisation of these sediments. Actions include but are not limited to:

- Increase riparian vegetation cover in the middle and transition zones
- Identify and control stream bank erosion hotspots
- Restrict stock access to streams
- Provide off stream water points

10.11.3 Audit and Improve Onsite Sewage Systems in the Catchment

Problematic onsite sewerage systems throughout the catchment should be identified through a combination of auditing and the results of the spatially intensive water quality survey (see above).

10.11.4 Improve Existing Urban Runoff Water Quality

The Banora Point western drainage scheme has been identified as a potentially major contributor to ecosystem stress in the Terranora Broadwater. In particular, it is suspected that the mobilisation of accumulated drain sludge major during high flow events is of concern. Ideally drainage canals should be significantly shallowed or converted to dry drains. However, it is recognised that this would require costly engineering solutions and may meet significant opposition in the community. Source reduction through community education should also be implemented.

10.11.5 Ensure Best Practice WSUD for all Future Urban Developments

Given the existing stress and extreme sensitivity of both broadwaters to increases in DIN loading, it is vital that future urban development strives to minimise DIN loads to the system. The relatively large scale of all proposed and current developments and their proximity to the most poorly flushed reaches of the system combine to pose a major threat to the ecological sustainability of the Cobaki-Terranora Broadwater system.

11 Management Issues

A review of historical literature, research and recent investigations reveal several management issues in the Cobaki and Terranora Broadwater catchment. Management issues are those processes or actions that are occurring throughout the catchment that are likely to threaten the values of the catchment either now or in the future, whether they be ecological, recreational, commercial, socioeconomic or cultural. The issues are summarised in this section and are addressed where appropriate in the management plan.

A key management issue is the potential for algal blooms in the broadwaters due to nutrient inputs from catchment stormwater following large rain events. The broadwaters' shallow conditions and reduced flushing mean they act like a retention pond to the surrounding catchment, and by nature absorb the stormwater runoff impact. Given the highly impacted nature of the catchment, it is safe to assume there will have been a corresponding loss of ecosystem health. Ecosystem response modelling indicates one of the key threats to the health and sustainability of the broadwaters is the elevated DIN component of catchment stormwater. Reduction of DIN concentration from both the rural and urban catchment has been identified as a key objective in the ecosystem response modelling (Section 10).

The broadwaters' shallow conditions and reduced flushing mean they act like a retention pond to the surrounding catchment, and by nature absorb the stormwater runoff impact. Given the highly impacted nature of the catchment, it is safe to assume there will have been a corresponding loss of ecosystem health.

11.1 Major Urban Development

11.1.1 Pacific Highway Tugun Bypass / Gold Coast Airport Runway Extension / Gold Coast Desalination Plant Construction

There are ongoing concerns about the potential impacts on Cobaki Broadwater associated with the Tugun Bypass, Gold Coast Airport runway extension and Gold Coast Desalination Plant, relevant to both construction and operation. Some of the recent concerns are summarised below.

The potential for long term impact on the health of Cobaki Broadwater due to disturbed ASS, such as acidic drainage during construction of the tunnel under the airport runway was described as high (Pacific Link Alliance, 2004). One recent visible impact is the formation of a delta of sediment/iron floc at the point of discharge of one of the surface water drains from the Tugun Bypass. The delta is thought to be a result of the dewatering process during tunnel construction which led to changes in groundwater chemistry, the acidification of soils and iron mobilisation, leaving an iron-rich sediment delta in Cobaki Broadwater.

There is concern for potential long term impacts of the altered hydrological regime created by the Tugun Bypass and tunnel on wetland communities surrounding the Tugun Bypass and Cobaki Broadwater. There are also concerns about the long term impacts of airport stormwater runoff discharging to Cobaki Broadwater.

The construction of the bypass and the Desalination Plant involved some excavation of the Tugun Landfill site. Preliminary tests undertaken as part of the Tugun Bypass EIS (Pacific Link

Alliance, 2004) indicated potential impacts including: increased volume of leachate containing elevated levels of N and P, raised levels of heavy metals (cadmium and iron) and dissolved organic matter such as phenolics. Groundwater flows in the direction of the Cobaki Broadwater, so there is a possibility that migration of contaminants from the landfill is occurring.

Issues such as these have been discussed at meetings with the parties associated with the MoU for the cooperative management of the Cobaki Broadwater and its catchment. Evidence of other impacts generated during construction and/or operation phase of these works may become apparent over time. To ensure timely and appropriate responses, ongoing monitoring reports and results of investigations should be provided to the TSC to be discussed with the Tweed River Committee and the relevant parties of the MoU for Cobaki Broadwater.

11.1.2 Cobaki Lakes / Area E / Bilambil Heights

There are three major urban subdivisions planned, covering extensive areas of the catchment, two in the Cobaki Broadwater catchment (Cobaki Lakes and Bilambil Heights) and one in Terranora Broadwater catchment (Area E) (Figures 3.3 and 3.5, Section 3). Cobaki Lakes will be a residential area catering for a population of approximately 14,000 people, Bilambil Heights for 8,000 people, and Area E has another 3,000. Associated with large scale developments are issues concerning the design, construction and post-development phases.

There are many difficult environmental issues to be suitably dealt with if the health of the broadwaters is not to be affected, or improved from the current condition. Some of the issues include:

- Managing ASS within the development area to ensure water quality and aquatic fauna, shorebirds are not impacted
- Erosion and sediment control issues are exacerbated due to the mixture of high nutrient soils, silty clays and sandy clays on steep topography. Potential impacts on sedimentation, water quality, aquatic fauna, recreation, tourism, commercial fishery.
- The protection of SEPP 14 wetlands that surround the broadwaters including important saltmarsh remnants
- Maintenance and enhancement of remaining wildlife corridors
- Stormwater treatment and management
- Changes to hydrology

11.2 Existing Urban Areas – Stormwater Management

Challenges to water quality are created by stormwater generated within urban areas resulting in the export of various pollutants including nutrients, heavy metals, faecal coliforms, pathogens and hydrocarbons. Pollutants deteriorate water quality, aquatic habitat, and lead to eutrophic conditions. Such conditions are unsafe for the community and compromise the health of aquatic ecosystems.

This urban catchment is an area of intense residential development, industrial and commercial areas including Banora Point Golf Course. The Western Drainage Scheme contains large open channels that currently require maintenance to control aquatic weed infestations and sedimentation. The drains also provide conditions conducive to the accumulation of sludge rich in DIN that is easily mobilised in any flow event and discharged to the most poorly flushed area of Terranora Broadwater. Water quality has been characterised by low dissolved oxygen, high BOD, high TP and TN and algal blooms (Banora Point/South Tweed Stormwater Management

Plan, 1999). As such, drain management is hugely important to the water quality of the broadwaters. The impacts of this pollution are likely to extend to oyster leases and shorebird habitat.

Other urban areas generally require retrofitting with suitable SQIDs, targeted in priority areas in addition to education about household and general residential pollutant sources and practices.

11.3 Sedimentation of Broadwaters

Sedimentation of the broadwaters is considered a priority issue. This includes sediment from stormwater drains such as the Banora Point Western Drainage Scheme, from the construction phase of future development, and from the existing rural catchment. Any catchment runoff has the potential to contribute to the silting of the mud basin in Terranora Broadwater (Parsons Brinckerhoff, 2003). Historically, the ability of the construction and building industry to control sedimentation, and the ability of TSC to regulate it has been poor. Furthermore, the climate and geography of the area makes erosion and sediment control very difficult, and at times, impossible.

The recent EHMP study (IWC, 2009) noted higher than expected (compared to natural systems) in-stream silt loads in the study area. There are several impacts resulting from high sediment loads on the creek and broadwater system. High sediment loads increase the rate at which the broadwaters fill, thus affecting visual amenity, recreation, tourism and commercial operations that all rely on the current aquatic environment. Additionally, there are several likely impacts on the ecosystem including the acceleration of mangrove encroachment, localised smothering of benthic habitat and seagrass and increasing turbidity all of which will impact on aquatic fauna such as important recreation and commercial fish species, macroinvertebrates and the local and migratory shorebird population. Ecosystem health scores from the recent EHMP study (IWC, 2009) were low for aquatic macroinvertebrates and fish, particularly in Duroby Creek.

11.4 Riparian Zones

11.4.1 Lack of Native Riparian Vegetation - Clearing

Extensive clearing of the native riparian vegetation of all creeks within the broadwaters' catchment has occurred. Clearing of riparian vegetation was the most visually noticeable process influencing the condition of creeks during the collection of field data during the EHMP study in 2007 - 2008 (IWC, 2009). There are current concerns in the community regarding the illegal clearing of riparian vegetation on creek banks e.g. reports of a local nursery clearing once dense riparian rainforest to the creek bank, and bank erosion in Duroby Creek reported by residents who have noted erosion on 15ft banks due to riparian vegetation clearing conducted by private landowners.

11.4.2 Grazing and Cattle Access to Waterways

A major issue is rural runoff from poor agricultural practices (TSQMP, 2000). Uncontrolled access by domestic stock can impact riparian land in several ways. It can lead to increased runoff, bank erosion, loss of native vegetation, weed invasion, loss of productive land, decline in habitat, reduced water quality and damage to aquatic ecosystems (Land and Water, 2002). Some impacts that are particularly relevant to this catchment include:

- *Water Quality*. Livestock can contaminate streams with manure. This increases nitrogen and phosphorus levels which, under the right conditions, can lead to excessive growth of nuisance water plants and algae. Manure can also contaminate streams with disease-causing bacteria and viruses. This can impact on the health of humans and animals drinking downstream. Stock associated erosion can also contribute large amounts of soil and nutrients to the stream during heavy rainfall.

- *Erosion*. Over- grazing by livestock can lead to exposed soil along banks creating rapid erosion during subsequent rain events as discussed above.
- *Loss of native plant species and weed invasion*. Livestock that graze the seedlings of native species prevent the establishment of native plants and may result in a loss of species and a decrease of structural diversity. A combination of a loss of native species, disturbance, increased bare ground and increased nutrients creates an environment very conducive to weed establishment.
- *Soil compaction*. Prolonged access by livestock causing soil compaction can affect the ability of seeds to germinate and reduces the infiltration rate of rainfall and runoff.

However, if managed well, cattle can limit weed invasion where there is no scope to implement a full rehabilitation strategy. A balanced approach is required to manage stock in the riparian zone.

11.4.3 Weed Invasion

Weeds grow in all plant communities, most commonly in areas where there is bare, soft soil, high nutrient availability, moist conditions and high light intensity. In urban areas, one of the most common places to find these conditions is along creeks. Weeds are highly tolerant of climatic and soil variation, have rapid seedling growth, the ability compete by special means and can readily reproduce. Many creek lines are weed-infested due to clearing of natural vegetation.

Weeds compete with native plants for space and light and as they often don’t suffer from pests, diseases or predators, they can spread easily. Weeds can overtake native riparian vegetation, reducing the diversity of native species and the value of the riparian habitat. Common in riparian zones are introduced vines which can rapidly kill a community of plants by smothering the natives and preventing photosynthesis.

The clearance of native riparian vegetation has lead to extensive areas of Camphor Laurel (*Cinnamomum camphora*), as mapped in TSC GIS vegetation mapping. In riparian areas Camphor Laurel has a shallow root system which doesn’t grow into the water so has been labelled “water shy”. This shallow root system is usually undercut by water flows. The soil that is washed away causes sedimentation downstream and localised bank erosion. Camphor Laurel is a dominant species often forming monocultures on creek banks. Where no other species are assisting in bank stabilisation and the vegetation zone is narrow, the bank can eventually become unstable from deep undercutting and the tree falls into the water. Although serious degradation is caused by Camphor Laurel, the trees still provide riparian function which needs to be considered in weed control programs. Camphor Laurel provides shade on the waterway, reducing water temperature and provides limited canopy habitat for fauna.

In addition to destabilising creek banks, the replacement of native riparian vegetation with Camphor Laurel has several possible implications for the ecological processes of the system including (IWC, 2009):

- changing the creek shading
- altering the type and quantity of in-stream leaf litter and woody debris
- direct toxic effects upon aquatic organisms

The Tweed Estuary Nature Reserve Draft Plan of Management (DECC, 2006) lists introduced species as a threat to this reserve due to its close proximity to urban areas. Weed species known to occur include lantana (*Lantana camara*), asparagus fern (*Asparagus aethiopicus*), groundsel bush (*Baccharis halimifolia*), coastal morning glory (*Ipomoea cairica*) and bitou bush (*Chrysanthemoides monilifera*). Other common weeds found during site assessments conducted in the current study include: para grass , setaria, barner grass, hairy commelina and mist flower.

In a report on the impacts on native vegetation adjacent to the Tugun Bypass, weed invasion into surrounding protected areas was listed as a potential threat due to insufficient measures within the Vegetation Management Plan (Ecograph/TSC, 2004). Importation of new weeds from construction activities is also listed as a potential threat in the Draft Airport Environmental Strategy (GCAL, 2004).

11.4.4 Minimum Riparian Buffer Distances

Based on the findings of water quality, geomorphic and vegetation investigations undertaken during the preparation of this plan, a suite of minimum riparian buffer distances has been developed for the Cobaki and Terranora Broadwater catchments and tributaries. The recommended minimum buffer distance to any waterway or wetland vegetation in the catchment is 10m. This will provide for filtering of runoff, increased bank stability and improved water quality. On agricultural land, increasing riparian buffers to a width of 30m will provide for effective filtering of runoff and accommodate bed and bank morphological change, as well as provide value as a wildlife habitat and corridors. It is recognised that buffers of this width will not be practical in all cases, and that buffers will generally not be a uniform width along a stream reach. Wherever practically achievable, livestock should be prevented from entering natural waterways.

In areas where development is proposed anywhere adjacent to the broadwater foreshores, Terranora Creek or Bilambil, Durroby, Cobaki and Piggabeen Creeks, a minimum 50m buffer is recommended. The recommended buffer distance to rural landuse in non-tidal sections of Bilambil, Durroby, Cobaki and Piggabeen Creeks is 30m. Generally, buffers should be fully vegetated with appropriate local native riparian species.

11.5 Impacts on Fauna

11.5.1 Birds

There is no published information on which threatening processes affect shorebirds in northern NSW estuaries; however, there has been considerable research elsewhere and there is general consensus on the type of activities that affect shorebirds. The impact of human recreation is one issue that has gained considerable attention. Threats of particular relevance to the broadwaters are:

1. Habitat Loss – removal of habitat through land reclamation or severe erosion.
2. Habitat Modification – changes in the characteristics of habitat that reduce its suitability for shorebirds. This may occur through vegetation growth or erosion.
3. Habitat Disturbance – activities that result in disturbance to roosting and foraging shorebirds causing birds to take flight and expend energy.

There is direct evidence of how these threats have affected shorebirds in the Tweed Estuary. Examples include:

- Residential development east of Trutes Bay removed a known roost (Trutes Marshland).

- The Tweed River Sand Bypass has caused severe erosion of South Head Beach reducing its suitability as a roost site for shorebirds.
- Growth of mangroves on Tony's Bar, at Kerosene Inlet, Pony Club and Duroby Marsh has reduced the suitability of these roosts.
- High levels of human visitation to Kerosene Inlet, South Head Beach, Dreamtime Beach and Tony's Bar disturbs birds causing them to fly between sites and expend energy that should be used for moult and migration.

Most of the documented threatening processes in the Tweed affect known roosts, although foraging habitat is also affected by activities that reduce the health of benthic invertebrate communities such as water pollution.

Management of shorebird roosting habitat creates conflicting management issues particularly between managing disturbance but allowing for sufficient human recreation and managing mangrove encroachment but allowing for the restoration of aquatic habitat. The conflict between shorebird habitat management and recreation is easy to comprehend as coastal towns such as Tweed Heads are promoted as aquatic recreational havens for tourists. It is contradictory to promote the Tweed Estuary as an area for water-based recreation and then stop people from mooring boats on a sandspit, such as Kerosene Inlet.

The conflict between shorebird habitat management and mangroves is more difficult to comprehend as both are natural components of the estuarine ecosystem. The reasons for the conflict between shorebirds and mangroves are complex; however, a major contributing factor is the manner in which estuarine hydrology and habitat has been altered due to the construction of training walls. Prior to the construction of training walls estuary mouths were dynamic areas that consisted of mobile sand bars and spits, whilst more sheltered (upstream) areas would have included a mix of saltmarsh, sandbars and mangrove forest. Collectively these areas would have provided ample roosting habitat for shorebirds. Training walls have stabilised estuary mouths enabling urban development and vegetation growth on previous roost sites and changes to tidal amplitude. In recent decades the short-fall in roosting habitat caused by training walls was supplemented by disturbance to estuarine habitat elsewhere. However, previously disturbed areas have regenerated and new areas have not been created due to improved protection of estuarine habitat. Altered hydrology and increased sediment deposition and nutrients has provided suitable conditions for mangroves, which have colonised saltmarsh and sandbars (refer to Saintilan & Williams 1999) further reducing the availability of roost sites. Whilst the protection of mangroves is important for estuary health a balanced "ecosystem approach" to estuary management is warranted to ensure that the needs of shorebirds are considered.

11.5.2 Fish and Crustaceans

There are varying views on the status of fish populations throughout the system. Recent investigations completed as part of the EHMP study (IWC, 2009) indicated low scores for biological indicators such as aquatic macroinvertebrates and fish in freshwater reaches. This implies evidence to support observations made by some community members who have expressed concern about changes in aquatic fauna abundance, reporting a reduction in sightings and fishing catch in Terranora Inlet and a noticeable absence of fish in the Inlet compared to the Tweed River and a reduction of crabs on Davey's Island. Water quality and fish passage obstruction are factors that may be impacting on fish populations. Conversely, comments made by other community members and a representative of the NSW DPI imply healthy fish populations showing no signs of decline and a reduction in the amount of commercial fishing in the system.

There are general community concerns regarding the impact of discarded fishing materials (e.g. hooks and fishing line) and general litter including plastics, on fauna.

The issue of destruction of Yabbie (Ghost Shrimp) habitat by excessive pumping and trampling of intertidal banks has been reported by local fishermen with a long association with Terranora Creek. The impact of trampling, as a habitat degrading activity, additional to the impact of bait removal, has been documented in literature (Contessa and Bird (2004) and Wynberg and Branch (1997)). It has been found that trampling and the resulting loss of porosity and compaction of the sensitive mud-sand habitat can result in a significant decline in the Yabbie population. This can have flow on effects on sediment chemistry and therefore water quality.

It is recommended that the impact of bait collection and related trampling on the Yabbie populations of frequently used intertidal banks in Terranora Creek be investigated and monitored. It is recommended that NSW Fisheries work with Southern Cross University to establish a program of monitoring the abundance of yabbies in Terranora Inlet and consider the establishment of 'sanctuary' zones to ensure that sediments and Yabbie populations are not unsustainably impacted.

11.5.3 Oysters

Suspended solids affect the healthy growth of oysters as silt affects the sensitive feeding apparatus of oysters which can lead to infestations of mudworm. and reduce primary production. Oysters feed more efficiently in relatively clear waters (White, 2001 as cited in NSW DPI, 2006). Oysters can survive in low pH waters for short durations but eventually the shell dissolves with prolonged exposure. Elevations of iron and aluminium at low pH could cause significant mortality in oysters. Suspended iron compounds (flocs) associated with acid drainage can also smother growing oysters and clog gill structures (Dove *et al.*, 1999 as cited in NSW DPI, 2006).

Local oyster farmers indicate that water and meat quality is excellent during dry times, and only fails to meet standards in response to rainfall events. The main threats to the oyster industry are described by local farmers as:

- sewage overflows/discharge – causing contaminated oyster meat,
- urban runoff – causing contaminated oyster meat,
- heavy metals (specifically concerns regarding the transmission of heavy metals from the Tugun Landfill site through groundwater to the broadwater) – causing contaminated oyster meat,
- acid sulfate soils (specifically an increase in metals that promote the QX virus in oysters) – causing mortality to oysters and possible collapse of the local oyster industry.

11.6 Wastewater Management

11.6.1 STP

The Tweed Heads West Water Reclamation Plant (WRP) and the Banora Point WRP were constructed in the 1960's and 1970's respectively and have since been upgraded to increase the capacity. To meet the effluent treatment needs of the increasing population and proposed large-scale developments, the Banora Point Waste Water Treatment Plant is to be upgraded again. While the quality of effluent discharged will be improved, the quantity discharged will increase (GHD, 2005).

Previous studies have concluded that while nutrient concentrations in the vicinity of the discharge point are more elevated than at other sites (GHD, 2005 and IWC, 2009), the principal driver of nitrogen and phosphorus concentrations in the system is stormwater runoff given effluent is only discharged into Terranora Creek on the ebb tide and is flushed from the system. These findings were supported by other water quality investigations (KEC Science, 1998).

Current threats to ecosystem health posed by the Banora Point Waste Water Treatment Plant include pumpstation overflows and recycling of nutrients from sediments and nutrients from STP effluent tidally moving upstream to the broadwaters (IWC, 2009).

11.6.2 On Site Sewage Facilities

On-site sewage disposal in the Terranora sub-catchment has been listed as a priority management issue in the Tweed Urban Stormwater Quality Management Plan (2000). The recent EHMP results (IWC, 2009) indicated elevated nutrients in all creeks draining to the broadwaters, including high levels of sewage related nitrogen and as such recommends investigations into the potential influence of household septic systems.

11.7 Dredging

Dredging has historically occurred within the airport boundary of Cobaki Broadwater, in the main navigation channel through the centre of the entrance delta, the perimeter of Birds Bay and across Bingham Bay to provide general boating access and re-establish scenic charter boat tours.

The previous recommendation to investigate further dredging for environmental benefit and improved Cobaki Broadwater entrance access was considered and rejected by Council as no real environmental benefits were determined and low economic reward for such high capital expenditure. Consensus was reached between Council, NSW Maritime and the project team that there were no gains to be had from dredging as the existing use of the broadwaters and estuary is not impeded for small boats. Dredging would increase larger boat traffic which is contradictory to the objectives of the Boating Management Plan and ecological health.

However, it is acknowledged that on occasion, minimal maintenance of navigational channels such as the entrance to Seagulls canal estate may be required. This would involve the removal of sand slugs with a small dredge to maintain navigation for small boats only.
Some of the potential impacts of dredging are considered below.

11.7.1 Operational Impacts

Increased turbidity during dredging operations will have a relatively large impact in such a confined area. Impacts include smothering of nearby seagrass and subtidal shoals and increased nutrient concentrations due to the resuspension of sediment porewaters.

11.7.2 Flushing and Salinity Regimes

Increasing the channel size at the entrance will increase the tidal range and flushing potential of the Terranora Broadwater. This may marginally reduce the peak chlorophyll concentrations in spring tide periods, however this is likely to be offset by increases in the upstream transport of nutrient-rich sewage effluent from the Banora Point STP.

11.7.3 Turbidity

Increased tidal ranges within the broadwater are likely to increase the occurrence of tidally-driven resuspension in Trutes Bay causing an increase in turbidity and reducing the extent of potential seagrass habitat.

11.7.4 Increased Sediment Water Nutrient Fluxes

Dredged channel areas are likely to be light limited and will therefore tend to shift from being nutrient sinks to sources. In addition, anomalously deep holes may tend to trap high salinity water which will tend to become hypoxic or periodically anoxic, thereby increasing the flux of nutrients (in particular DIN) to the water column. Given the proximity of the proposed dredge areas to existing seagrass areas in the broadwater, these processes present a reasonably significant ecological risk.

11.7.5 Increased Access for Large Water Craft

Improved access to the broadwater will increase boat traffic with attendant impacts on turbidity and disturbance of stressed seagrass areas. It is recommended that boat access be restricted to shallow draft vessels which are less likely to disturb sensitive shallow water habitats.

11.8 Provision of Recreational Facilities

There is a need for expansion of integrated low-impact foreshore and waterway recreation facilities in the vicinity of developed foreshores of the north, east and west Terranora Broadwater.

Recreation must be managed in association with the protection of the ecological values of the broadwaters, such as protection of shorebird habitat. Inappropriate visitor use such as unauthorised camp fires, cutting of vegetation for makeshift shelters, rubbish, weeds has been noted as a threat to the Tweed Estuary Nature Reserve values (Tweed Estuary Nature Reserve Draft Plan of Management, NPWS, 2007)

11.9 Mosquito and Biting Midge Management

Mosquitoes and biting midges are abundant in the Tweed Shire, breeding in local wetland and inter-tidal areas. Some species of saltmarsh mosquitoes are known to carry diseases affecting human health. The major mosquito nuisance in the Shire is caused by several species of saltmarsh breeding mosquitoes that breed in salty to slightly brackish water. Following heavy rainfall these mosquitoes may also be found in fresh water ground pools (Tweed Shire Council, 2005). The following is extracted from the Tweed Shire Council website, for more information, refer to: www.tweed.nsw.gov.au/YourEnvironment/Mosquitos.aspx.

11.9.1 Mosquito Management

Mosquito species relevant to the Cobaki and Terranora Broadwater catchment include:

- ***Ochlerotatus vigilax***

This species favours hill and ridge tops overlooking tidal flats whose range includes Cobaki Inlet, Piggabeen, Bilambil Heights, Terranora and parts of West Tweed Heads.

- ***Verrallina funerea***

This species has been identified as a possible carrier of Ross River virus. It breeds in more elevated sites, including surrounding parts of Cobaki Broadwater and Terranora Broadwater.

- ***Culex sitiens***

This species breeds in fresh to brackish ponds in tidal saltmarsh pools and flooded low-land agricultural flats. This mosquito is a night feeder and may affect Cobaki Inlet and Terranora.

TSC has been undertaking mosquito abatement since 1983 and is currently carried out by Council's Environment and Community Services Division. Council monitors the following:

- Weekly monitoring of mosquito species present, seasonal abundance and viral incidence to enable early waning of potential viral disease presence
- Habitat reduction to reduce the breeding potential in semi-tidal saltmarshes
- Aerial larviciding after extensive areas hatch mosquito larvae following heavy rain or abnormally high spring tides
- Biological larviciding when warranted.

11.9.2 Biting Midge Management

Biting midges are not known to carry any diseases that affect human health in Australia, however they can directly impact human health due to allergens in midge saliva reacting on people of varying degrees of sensitivity and immunity, which can lead to scratching and infected sores (Tweed Shire Council, 2005).

Biting midge species relevant to the Cobaki and Terranora Broadwater catchment include:

- ***Culicoides molestus***

This species breeds in clean flocculated sand in the open or under light mangrove cover between mean tide level and mean high water spring tide level. They are found at the sandbar off Tony's Island at Banora Point.

- ***Culicoides subimmaculatus***

This species breeds in clean to muddy san din the open or under light mangrove cover between mean high water neap tide level and mean high water spring tide level. Within the catchment, they are found on the upper Terranora passage islands.

- ***Culicoides longior***

This species breeds under tree cover amongst heavy fibrous muds, between mean high water neap and mean high water spring tide zone. They are found on Womgin Island, West Tweed Heads and parts of South Tweed Heads.

TSC has been researching and controlling biting midges since 1981 and is currently carried out by Council's Environment and Community Services Division. Council undertakes the following:

- Monthly midge monitoring along canal estate beaches
- Midge larval control with larvicide several times per year along artificial beaches of canal developments
- Potential biological control
- Habitat control via removal of the midge breeding layer from a large river sandbar off Banora Point was investigated for over 10 years, but rejected

There is concern that poorly managed agricultural or development areas may contribute to mosquitoes and biting midges. This includes the design of stormwater treatment systems that do not exacerbate mosquito or biting midge breeding.

11.10 Cultural Heritage

The protection of highly significant archaeological sites is an extremely important issue in recent and future developments occurring throughout the catchment.

Agricultural development, housing / urban development, deliberate vandalism, mining, recreational interest, natural causes and road making have contributed to the destruction of Aboriginal sites. It is therefore important to recognise the Aboriginal cultural sites that remain (Fox, 2006). Further cultural heritage investigations are underway in association with the Tugun Bypass.

11.11 Climate Change

Climate change has the potential to play a large role in the management of coastal ecosystems. The potential for inundation of low-lying coastal areas, in response to climate change, is being considered by TSC. Council is in the process of preparing a Floodplain Risk Management plan for the Tweed Valley. A draft plan is scheduled for late 2010-early 2011 and is founded on the Tweed Valley Flood Study (BMT WBM, 2009) and a study update that incorporates climate change scenarios based on DECC guidelines and the draft Sea Level Rise Policy Statement parameters.
This sections provides a largely qualitative review of the likely impacts of climate change on the Cobaki Terranora Broadwater system based on predictions found in CSIRO and BOM (2007) and CSIRO (2002). These changes are represented diagrammatically in Figure 11.1.

11.11.1 Warming

Global warming due to increased greenhouse gas emissions is now recognised as a major environmental problem. Observed changes in Australia show increased continental annual average temperature by 0.76^{o}C from 1910 to 2000 with most of this increase occurring since 1950. The NSW and southern Qld coast have experienced relatively high increases in temperature. Estimates of annual warming over Australia range from 0.8 to 1.8^{0}C by 2050 and 1.0 to 5.0^{0}C by 2070, with increases tending to be greatest in the inland areas.

Impacts of warming in the Cobaki-Terranora
The impacts of temperature rises in the Cobaki-Terranora system are likely to result primarily from an interaction with increases in summer rainfall (see below). Likely impacts include, but are not limited to:

- Increased rates of primary productivity in the water and sediments
- Increased rates of organic matter breakdown
- Greater risk of hypoxia (low dissolved oxygen) in the broadwaters

11.11.2 Rainfall

Projections for NSW and southeast Qld indicate a tendency for decreased rainfall in winter/spring and increased rainfall during summer/autumn. Extreme rain events are projected to increase north of Cape Byron. The intensity and frequency of tropical cyclones will most likely increase. The occurrence of East Coast Lows is expected to increase.

Impacts of changes in rainfall patterns in the Cobaki-Terranora
Projections for changes in rainfall patterns in the region are likely to result in significant impacts in ecosystem function including but not limited to:

- Increases in the occurrence of extreme rainfall events during summer coupled with increased temperatures will result in a higher risk of large phytoplankton blooms in the broadwaters
- Lower rainfall during winter will result in the accumulation of pollutants in the urban catchments
- Increases in the occurrence of extreme rainfall events may increase the risk of erosion in the transition and middle catchment zones resulting in greater sediment delivery to the broadwaters.
- Increased turbidity in the broadwaters coupled with increased water depths due to sea level rises will decrease the potential euphotic habitat for seagrasses.
- Extended periods of drought/low rainfall may result in the stress of littoral wetland communities
- Lowering of floodplain groundwater levels during extended drought periods may increase the risk of acid sulfate soil oxidation in areas adjacent to the Cobaki Broadwater.

11.11.3 Sea Level Rise

Sea level rise is anticipated to be a major impact of global warming. Global sea levels have been generally rising since accurate records began, with an average recorded rise of 0.94 mm per annum at Fort Denison in Sydney Harbour. Sea level around Australia is projected to rise between 100 and 400 mm by 2050, depending on scenarios. The frequency of extreme sea-level events reaching 2.1m has doubled and those reaching 2.2m has tripled since 1950.

The NSW Government has prepared a Sea Level Rise Policy Statement (2009) which includes sea level planning benchmarks developed to support consideration of sea level rise in land-use planning and decision-making. The adopted planning benchmarks are for a rise relative to 1990 mean sea levels of 40cm by 2050 and 90cm by 2100.

Impacts of sea level rise in the Cobaki-Terranora
Sea level rise adjacent to the Tweed River estuary would cause a rise in estuary water levels resulting in impacts including, but not limited to:

- Shoreline recession
- Inundation of low lying ecosystems
- Implications for drainage in urban and agricultural areas
- Implications for flooding in urban and agricultural areas
- Increased salt penetration into the broadwaters and associated wetland systems

11.11.4 Landward Migration of Ecological Communities

Some riparian communities may face local extinction if the altered sea level regime does not simply translocate their habitat requirements upward and landward, for example wetland communities may become constrained by elevation or development on their landward edge. Mangrove transgression will be at the expense of threatened saltmarsh communities. There may be a loss of intertidal emergent mud flats and other valuable habitats.

11.11.5 Other Ecosystem Responses

Increased summer rainfall may cause changes to ecosystem functioning due to increased organic matter deposition and lower light penetration throughout the estuary. This may result in negative impacts on key habitats such as marine delta shoals and seagrasses. Changes in salinity and organic matter supply to intertidal wetlands may have ramifications up the foodchain, with predicted initial increases in secondary production followed by subsequent collapses in fauna biomass.

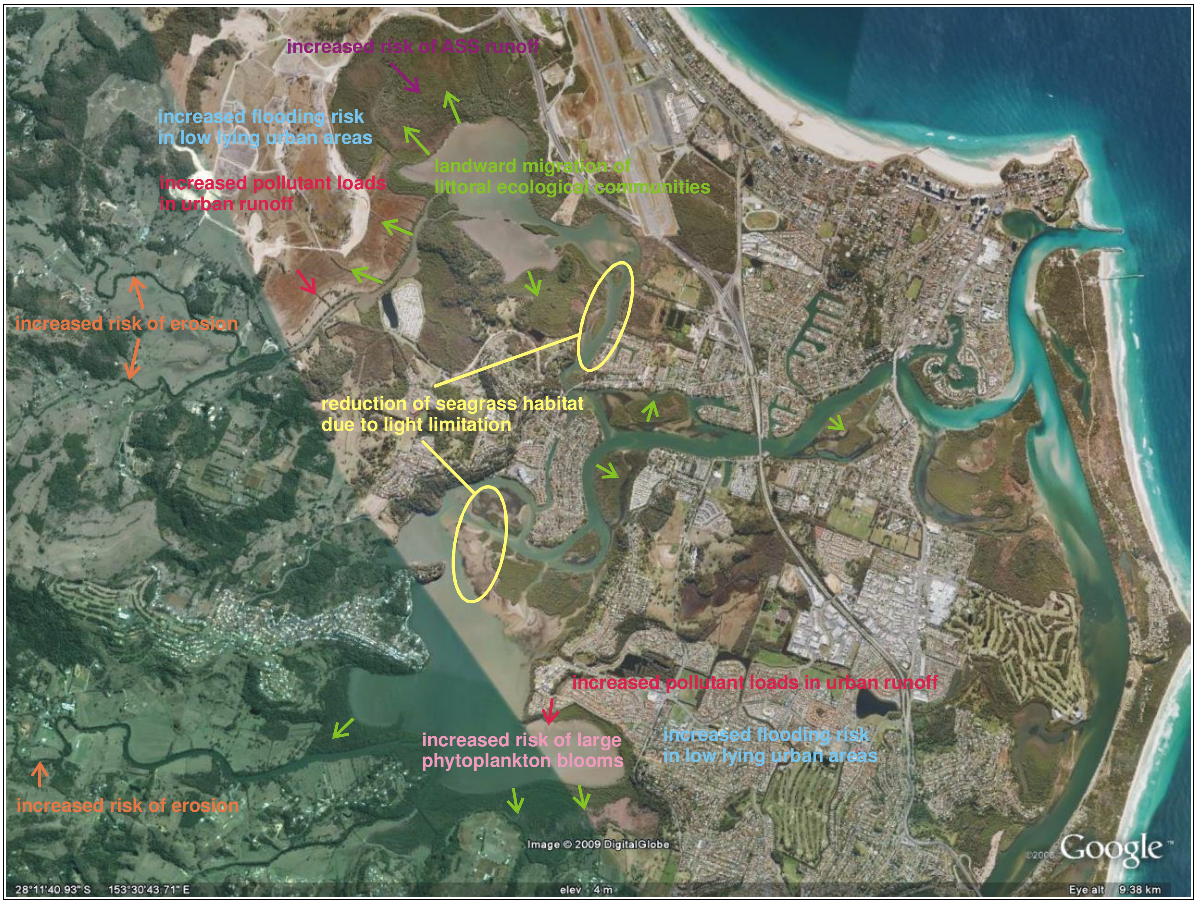


Figure 11.1. Diagrammatic representation of likely impacts of climate change on the Broadwaters

Source: ABER

12 Action Plan

The development of the CZMP was informed by existing studies, recent investigations undertaken in association with recent development, the EHMP report (IWC, 2009), current field work, stakeholder consultation and catchment modelling. In addition, an audit of the existing management plans was undertaken to incorporate any outstanding actions in the updated plan.

The primary outcome for the Cobaki and Terranora Broadwaters, as listed in the NSW Coastal Lakes Strategy (2002) is that *'key natural and/or highly valued modified ecosystem processes are rehabilitated and retained'*. This plan aims to achieve this outcome by taking a whole of catchment approach and in recognising the Cobaki-Terranora Broadwater ecosystem as a continuum of interconnected aquatic, riparian and catchment zones. The plan aims to provide workable recommendations to address the identified management issues and incorporate the varied, and sometimes competing, uses each group of stakeholders have, to achieve the common outcome of ecosystem health.

Strategy development was based on a combination of catchment-wide and site-based issues. Actions have been prioritised based on the implementation timeframe of five years (Table 12.1). Section 14 provides more detail on action description, rationale and implementation wherever necessary.

Table 12.1. Implementation timeframe

Priority	**Recommended timeframe for implementation**
Immediate / High	Within 1 -2 years
Medium	Within 2 – 3 years
Long term / Low	Within 3 - 5 years

The actions within this Plan are consistent with relevant federal, state, regional and local environmental planning legislation, policy and strategic documents.

Costings for the implementation of High Priority actions only are provided in Appendix I.

COASTAL ZONE MANAGEMENT PLAN FOR COBAKI BROADWATER AND TERRANORA BROADWATER

Strategy	Action		Measurable Target	Priority	Responsible Authority	Cost
1. Geomorphic Structural Works						
Riparian zone of major creeks.	1.1	Undertake detailed geomorphic investigation of the seven Level 1 priority sites of the catchment identified within this study. (a) Survey section (b) Undertake hydraulic analysis, evaluate potential flood hazards (c) Develop concept design and evaluate (d) Develop detailed design.	Detailed geomorphic assessments completed for all Level 1 priority areas by 2010.	**High**	TSC - Engineering & Operations / Natural Resource Management	$30,000 / site x 7 Level 1 sites
2. Broadwater Foreshore Rehabilitation						
Terranora Broadwater	2.1	Site T1 T3, T4 and T7 (HCV remnants) – Level 1: Undertake ecological restoration such as assisted natural regeneration. Protect, maintain and expand remaining remnant. (a) Develop urban remnant action plans to address key threatening processes (b) Undertake bushland regeneration and maintenance in accordance with plans	Urban remnant action plans completed by 2010. Improve/maintain EHMP broadwater riparian grade to 4/5	**High**	TSC – Natural Resource Management	(a) $3,000 - $5,000 per remnant (b) Bushland regeneration rates variable.
	2.2	T1a, T2 (Narrow, discontinuous/fragmented vegetation, between urban area and broadwater) – Level 2: Investigate options and community interest for neighbourhood bush regeneration.	Neighbourhood bush regeneration programs underway by 2010, subject to appropriate interest.	Low	TSC – Natural Resource Management	Outreach officer
	2.3	T5 (HCV remnant) – Level 1: All remnant vegetation, including saltmarsh community at confluence of Duroby Creek, to be rehabilitated in association with development of Area E.	Improve/maintain EHMP broadwater riparian grade to 4/5.	High	TSC – Development Assessment / Major Subdivisions / Natural Resource Management	To be negotiated with developer.
	2.4	T6 (HCV remnant) – Level 1: Investigate the area between the foreshore and houses and consider rezoning for conservation.	Investigation completed by 2010.	High	TSC – Natural Resource Management / Planning	N/A
	2.5	T8 (HCV remnants/ Degraded bushland) – Level 1: (a) Develop site-based action plans (b) Fence and restore the road reserve along both banks of Bilambil Creek estuarine riparian corridor. (c) Maintenance.	Increase riparian vegetation width (> 10m) and cover (FPC) (> 50%) of the most degraded areas of each subcatchment.	**High**	TSC – Natural Resource Management	(a) $3,000 (b) Fencing: $2,500 - $9,000/ km Planting: $3 - $6/ m^2 Weed removal: $0.40/ m^2 Initial watering: $0.50/ m^2 Off creek stock watering: $800 - $1,500 (c) $10,000/km/year

Strategy	Action		Measurable Target	Priority	Responsible Authority	Cost
	2.6	T8a (HCV remnant) – Level 1: Investigate saltmarsh rehabilitation in collaboration with landowner.	Investigation completed by 2010.	High	TSC – Natural Resource Management	Outreach officer.
	2.7	T9 (HCV remnant) – Level 1: (a) Develop urban remnant action plans to address key threatening processes (including residual rainforest on edge of Birds Bay). (b) Undertake bushland regeneration and maintenance in accordance with plans (c) Investigate potential expansion of remnant into adjacent private land to the north.	Investigation and action plans completed by 2010. Riparian remnant area increased.	**High**	TSC – Natural Resource Management	(a) $3,000 - $5,000 (b) Bushland regeneration rates variable. (c) Outreach officer.
	2.8	T10 (mostly cleared, mown grassy areas) – Level 2: Consider use of enhancement plantings to buffer against wave erosion and improve local habitat.	Wave erosion of bank reduced.	Low	TSC – Natural Resource Management	$8.40 / lineal metre for macrophytes (plants only)
	2.9	T11, T12, T13 (mostly cleared, narrow, mown grass) – Level 2: Investigate community interest in neighbourhood bush regeneration at sites in this area.	Neighbourhood bush regeneration programs underway by 2010, subject to appropriate interest.	Low	TSC – Natural Resource Management	Outreach officer
	2.10	This action was deleted in June 2012 at the request of NSW DPI Crown Lands.				
Cobaki Broadwater	2.11	C1 (Garbino Pty Ltd): Encourage remnant riparian buffer rehabilitation in association with any development.	Width of riparian vegetation increased. Improve/maintain EHMP broadwater riparian grade to 4/5	High	TSC – Natural Resource Management / Development Assessment	N.A.
	2.12	C2 (Department of Lands): Encourage management of remnants for conservation, with low impact recreation only.	Width of riparian vegetation increased. Improve/maintain EHMP broadwater riparian grade to 4/5	High	TSC – Natural Resource Management Department of Lands	N.A.
	2.13	C3 (Gold Coast Airport Ltd): Review Gold Coast Airport plan of management for foreshore reserve as an action associated with MoU for management of Cobaki Foreshore to ensure consistency with the overarching principles of the MoU.	Gold Coast Airport plan of management for foreshore reserve reviewed by 2010.	High	TSC – Natural Resource Management Cobaki Foreshore MoU parties	N.A.
	2.14	C4, C5 (TBLALC), C7, C8, C9, C10 (State Crown, TSC): Review foreshore management plans to ensure consistency with the overarching principles of the MoU.	All foreshore management plans reviewed by 2010.	High	TSC – Natural Resource Management/ Cobaki Foreshore MoU parties	N.A.
	2.15	C6 (Leda Developments): All foreshore vegetation to be restored in association with the development of Cobaki Lakes, including saltmarsh restoration, consistent with the overarching principles of the MoU.	Foreshore vegetation restoration plans are reviewed in 2009.	High	TSC – Natural Resource Management/ Cobaki Foreshore MoU parties	N.A.
3. Rural Riparian Rehabilitation						
	3.1	Site-based action plans for Level 1 rehabilitation zones (mid and transition	1. Increase riparian vegetation	**High**	TSC – Natural	(a) – (c) Outreach

Strategy	Action		Measurable Target	Priority	Responsible Authority	Cost
Transition / Mid Zone of Rural Catchment		of all creeks, including ephemeral drainage lines). (a) Develop and implement an effective landowner engagement program targeting all landowners with riparian frontage to the main channel or tributaries of Piggabeen, Cobaki, Bilambil and Duroby Creeks (b) Develop and promote existing landowner incentive and assistance packages, such as the *TSC River Health Grants Support for Farmers and Rural Land Owners* (c) Develop action plans to address key threatening processes and have them adopted by Council. Areas of priority include the mid-transition riparian zone and ephemeral drainage lines. (d) Undertake restoration works, encourage private landholders to undertake with support from TSC outreach officers. (e) Maintain restoration sites for a minimum of three years.	width and cover (FPC) of most degraded areas of each subcatchment to meet targets in Table 14.7. 2. Improve EHMP subcatchment grades to B. 3. 30% of all farms with off-creek stock watering by 2012. 4. Long term compliance with Tweed River Water Quality Objectives for freshwater creeks and estuaries.		Resource Management	officer position (d) Fencing: $2,500 - $9,000/ km Planting: $3 - $6/ m^2 Weed removal: $0.40/ m^2 Initial watering: $0.50/ m^2 Off creek stock watering: $800 - $1,500 (e) $10,000/km/year
	3.2	Employ a permanent extension officer to facilitate the development of site-based action plans with landowners.	Officer in place by 2010.	**High**	TSC – Natural Resource Management	$70,000
Upper Zone of Rural Catchment	3.3	Continue to protect and manage HCV vegetation in the upper riparian zone of all catchments consistent with the Tweed Vegetation Management Strategy (2004) and existing programs such as NRCMA Biodiversity Program.	No reduction in area of mapped HCV.	Medium	TSC – Natural Resource Management	Bushland regeneration rates variable.
	3.4	Considerations for the Draft LEP 2010: (a) Zoning Cobaki and Terranora Broadwaters W1 Natural Waterway (b) Protect riparian lands by including in zoning and a supporting clause or map overlay clause with clear policy statements relating to buffer zones.	Draft LEP is updated.	High	TSC – Natural Resource Management / Planning and Regulation	Staff
4. Industry Management						
Catchment -wide	4.1	(a) Audit existing industry management plans and compliance requirements throughout the catchment. Include: golf courses, nurseries, banana farms, other industry. (b) Develop a management strategy involving education, monitoring, auditing and industry participation. (c) Consider development of a proforma for an Industry Environmental Management Plan including routine monitoring and checklist sheets.	Management plans for key landusers completed by early 2011.	Medium	TSC – Planning and Regulation / Natural Resource Management	(a) Staff (b) Staff (c) $5,000
5. Urban Stormwater						
Western Drainage Scheme	5.1	Undertake flow-weighted water quality sampling at major outlets of Western Drainage Scheme network (including outlet from Vintage Lakes) to ascertain major sources of nutrients in urban runoff. Minimum of four runoff events to be sampled over one year. (Target works in priority areas).	Stormwater quality study completed by end 2010.	**High**	TSC – Natural Resource Management	Field work and laboratory analysis: $10,000 Report: $20,000 Total: $30,000
	5.2	Undertake sediment analysis (organic carbon, nutrients) within Western Drainage Scheme network to enhance understanding of internal recycling processes e.g. four sediment sampling events in one year – Summer (wet and dry), Autumn, Spring.	Sediment analysis completed by mid 2010.	**High**	TSC – Natural Resource Management	Field work and laboratory analysis: $15,000 Report: $20,000

Strategy	Action		Measurable Target	Priority	Responsible Authority	Cost
						Total: $35,000
	5.3	Conduct a workshop with key staff to discuss feasibility of all options for retrofitting and redesign of Western Drainage Scheme, to be informed by the results of water and sediment analyses.	Workshop completed by end 2010.	**High**	TSC – Natural Resource Management	$15,000
	5.4	Address ongoing maintenance issues of Vintage Lakes in accordance with the Banora Point Western Drainage Operational Management Plan (Periott, 2001) and investigate a trial of rafted reed beds to improve water quality.	Investigation of rafted reed beds completed. Improvement in water quality throughout the system	**High**	TSC – Natural Resource Management	Condition - dependent
	5.5	Conduct an audit of the existing SQIDs throughout the existing urban priority sub-catchments including Tweed Heads, Tweed Heads South, Bilambil Heights, and Seagulls Estate so recommendations can be made for either their repair, upgrade, correct maintenance or decommission.	Audit completed by early 2011.	Medium	TSC – Natural Resource Management / Water / Engineering & Operations	$15,000
	5.6	(a) Undertake a feasibility study for retrofitting SQIDs into existing stormwater system throughout priority areas of Tweed Heads, Tweed Heads South, Bilambil Heights, Seagulls Estate and surrounding urban subcatchments. (b) Undertake detailed designs (c) Implementation of SQID retrofitting throughout priority subcatchments.	(a) Study completed by late 2011. (b) Early 2012. (c) Begin implementation by late 2012.	Medium	TSC – Natural Resource Management / Water / Engineering & Operations	(a) $10,000 (b) $ 10,000 + $3,000/ha (c) $300/m2 @ 1% - 2% of catchment – or $60,000 per contributing catchment.
New Development	5.7	Allocate additional resources to appoint a specialist environmental compliance officer to Council's regulation staff. Duties to include monitoring compliance with erosion and sediment control, stormwater quality, vegetation clearing, vegetation rehabilitation and other relevant conditions of development approval.	Best practice sediment and erosion control maintained on 100% of construction activities.	High	TSC – Building and Environmental Health	N.A.
	5.8	Amend DCP D7 and update TSC's Urban Stormwater Quality Management Plan. Include pollutant removal efficiency/load based reduction targets consistent with industry best practice. Work towards developing catchment - specific stormwater discharge targets for Cobaki and Terranora Broadwater catchment.	Amendment of DCP D7 and Urban Stormwater Quality Management Plan.	Immediate	TSC – Planning and Regulation	N.A.
	5.9	(a) Develop site specific Stormwater Management Plans for all new developments which comply with TSC's updated guidelines. (b) Stormwater management plans should include contingencies for scenarios where it appears treatment measures are ineffective in meeting pollutant discharge targets.	Site specific Stormwater Management Plans developed for all new developments.	Immediate	Developers	N.A.
	5.10	Investigate the impacts of soil acidification and potentially contaminated runoff discharged from surface drains at Tugun Bypass site.	Investigation complete by late 2009.	**High**	TSC QLD DMR NSW RTA NSW DECC	$20,000
	5.11	Consider sealing gravel roads throughout the catchment to reduce the	Feasibility of gravel road	Medium	TSC	Staff

Strategy	Action		Measurable Target	Priority	Responsible Authority	Cost
		export of sediment to waterways. Roadside drainage must be appropriately managed to reduce the export of sediment to waterways by preventing the erosion of table drains.	sealing completed by late 2011.			
6. Wastewater Management						
Rural Catchment	6.1	Continue to investigate pre-2002 septic systems still requiring upgrades to help eliminate this potential source of pollutants. Where possible, incorporate with results of any intensive water sampling to prioritise 'hotspot' areas to upgrade.	All pre-2002 septic systems audited by late 2010/	High	TSC – Water / Waste Management	Staff
Urban Catchment	6.2	Ensure continued monitoring of impacts of Banora Point Water Reclamation Plan on water quality and ecosystem health in Terranora Creek and Broadwater.	Water quality and ecosystem health monitoring programs are underway in 2010.	High	TSC – Water/Waste Management / Natural Resources	N.A.
7. Ecology						
Rural Catchment	7.1	Incorporate Draft LEP Guidelines for Riparian Protection Area for all streams in the catchment that are not zoned E2 Environmental Conservation or E3 Environmental Management	Zoning approved and incorporated into LEP by 2010.	High	TSC – Planning	N.A.
Fish passage	7.2	Install fish/other fauna friendly culverts throughout the catchment: (a) Audit current crossings, culverts and structures mapped as fish passage barriers (b) Prioritise the retro-fitting of structures from downstream to upstream and/or those that are having any negative hydrological impact in high flow events (c) Engage with landholders, RTA, DPI on fish and fauna passage strategies (d) Ensure that fish and fauna friendly culverts are conditioned as part of any proposed construction of waterway crossings via the planning and development approval process.	All crossings audited and prioritised for retro-fitting by late 2010.	Medium	TSC – Engineering and Natural Resources DPI Fisheries	(a) Audit: $30,000 (b) Prioritisation: $5,000 (c) Engagement: $10,000 (d) N.A.
Bird Habitat	7.3	Assess the feasibility of constructing a spring tide shorebird roost at Tommy's Island in Terranora Broadwater. (a) Discuss feasibility with state agencies and engineers. (b) Undertake Environmental Impact Assessment (c) Construction of roost (d) Prohibit boat access to roost site – install a sign 50m west of site identifying site as a shorebird roost and enforce 50m exclusion zone.	Bird roost in place by early 2010.	**High**	TSC – Natural Resources DECC	(a) N.A. (b) $10,000 (c)To be confirmed (d) $1,000 (e) N.A.
	7.4	If Tommy's Island is unviable for a spring tide shorebird roost, assess the feasibility of constructing a sand island roost on the existing neap tide roost at Womgin Island.	Investigation complete by early 2010.	High	TSC – Natural Resources DECC	$5,000
	7.5	Assess the feasibility of constructing a spring tide roost around the small mangrove island in the southern part of Cobaki Broadwater or on the existing neap tide roost. Discuss feasibility with state agencies and engineers.	Investigation complete by 2010	Medium	TSC – Natural Resources DECC	$5,000
	7.6	Bird roost maintenance:	(a) Permit obtained by early	High	TSC – Natural	(a) N.A.

Strategy		Action	Measurable Target	Priority	Responsible Authority	Cost
		(a) Obtain a permit from DPI Fisheries for the ongoing control of mangroves on constructed roosts. (b) Annually remove all woody vegetation from roosts including mangrove seedlings along the foreshore. Inspect any retained patches of mangroves to determine if pruning is required. Maintenance should be undertaken in July/August each year prior to the arrival of migratory shorebirds.	2010. (b) Maintenance program in place in 2010		Resources	(b) $2,500
	7.7	Ensure constructed roosts are given appropriate protection in the Local Environment Plan.	Zoning approved and incorporated into LEP by 2010.	Medium	TSC – Planning	N.A.
	7.8	Implement a study to determine the type, frequency and distribution of human recreation on and near shorebird foraging areas in the broadwaters and determine if these activities have a detrimental impact on shorebirds. Depending on the findings, consider options to reduce the impact of recreation on shorebirds.	Study commenced by early 2011	Medium	TSC – Natural Resources	$20,000
	7.9	(a) Develop a policy on the management of dynamic estuarine areas for which there are often conflicting management issues involving recreation, shorebird habitat protection, mangrove and saltmarsh preservation, with consideration of likely impacts of climate change. (b) Undertake workshop with stakeholders.	(a) Policy development underway by mid 2010. (b) Workshop with stakeholders complete by late 2010.	**High**	TSC – Natural Resources	Staff
8. Cultural Heritage						
	8.1	Compile a heritage schedule of Aboriginal sites and places which are to be listed on the Tweed LEP and managed in accordance with stated conservation provisions to be listed in the LEP (as per Implementation Strategies listed in Cobaki and Terranora Aboriginal Cultural Heritage Management Plan, 2006).	To be finalised within the Draft LEP.	High	TSC – Planning, Natural Resources	Staff
	8.2	Ensure that an appropriate Aboriginal cultural heritage study and assessment are conducted for all developments that will cause land surface disturbance within culturally sensitive landforms as mapped in Cobaki and Terranora Broadwater Aboriginal Cultural Heritage Management Plan (2006).	Studies are assessed as part of all applicable developments.	High	Developers	N.A.
	8.3	Establish a formal policy of appropriate consultation protocols with the local Aboriginal community (as per Implementation Strategies listed in Cobaki and Terranora Aboriginal Cultural Heritage Management Plan, 2006).	Policy finalised by end 2011.	**High**	TSC – Natural Resources	$50,000
	8.4	Update the Cobaki and Terranora Broadwater Cultural Heritage Management Plan to incorporate new information gained through recent site assessments.	Plan updated by end 2011.	**High**	TSC – Natural Resources	N.A.
9. Recreation						
	9.1	Investigate opportunities for canoe discovery trail in Terranora and Cobaki Broadwaters with guide brochure and interpretive signage (recreation and education). Include launch site at Boyd Family Park.	Feasibility study complete by late 2010.	Medium	TSC – Natural Resources, Recreation Services.	$5,000
	9.2	Investigate feasibility of extending walkway along eastern foreshore of Terranora Broadwater from approximately Ridgeview Street (south of Tweed Broadwater Village) to Daintree Close (north-west corner of Trutes Bay).	Feasibility study complete by late 2010.	Medium	TSC – Natural Resources, Recreation Services.	$10,000
	9.3	Investigate the feasibility of creating a walkway along Bilambil Creek from Bilambil Village, around the western foreshore of Terranora Broadwater to Seagulls Estate.	Feasibility assessment complete by late 2010.	Medium	TSC – Natural Resources, Recreation Services	$10,000

Strategy	Action		Measurable Target	Priority	Responsible Authority	Cost
	9.4	Complete final design and obtain approvals for construction of foreshore walkway in Dog Bay, Terranora Broadwater. Walkway to extend approximately from Peninsula Drive to Broadwater Esplanade.	Walkway approved and constructed by early 2011.	**High**	TSC – Natural Resources, Engineering, Recreation Services.	$100,000
	9.5	Relace destroyed interpretive signage along foreshore in Bingham Bay.	Signage replaced by early 2010.	**High**	TSC – Natural Resources, Recreation Services.	$10,000
	9.6	Consider practicality of walking trails on existing fire trails around Cobaki Broadwater area once developed as Cobaki Lakes (e.g. Leda land to National Estate and Boyd Family Park to the eastern side of Cobaki Creek entrance).	A possible feature of joint management of foreshore lands (MOU)	Low – undertake when area is being developed	TSC – Natural Resources, Recreation Services, Leda Developments	N.A.
	9.7	If monitoring of the shorebird roost site in Terranora Broadwater indicates success based on observable bird roosting behaviour, undertake feasibility study on construction of a bird hide on the promontory on the adjacent mainland to enable local bird watchers to observe the roost.	Decision on suitability of a bird hide complete by early 2012.	Low – undertake following determination of successful roost site construction and use.	TSC – Natural Resources, Recreation Services, Engineering.	$20,000
	9.8	Consider recreation and interpretive wetland signage opportunities in The Western Drainage Scheme waterway system. This action should be delayed until all stormwater quality and SQID investigations are completed so subsequent retrofitting designs can incorporate relevant aspects of recreation.	Investigation completed by late 2012.	Low	TSC – Natural Resources, Recreation Services.	N.A.
10. Mosquito and Biting Midge Management						
	10.1	Design considerations for stormwater treatment waterbodies may conflict with the guidelines in DCP A6 *Biting Midge and Mosquito Control,* however current best practice in wetland design should be adhered to, i.e. water bodies should not be designed to be deeper than 2m.	Assessment of wetland and lake designs with consideration of DCP A6 to be undertaken as part of all development applications.	High	TSC – Planning	N.A.
	10.2	Restoration of the bund in Area E to prevent salt water intrusion into the freshwater wetland area to reduce mosquito breeding habitat.	Bund is restored by early 2010	Medium	TSC – Engineering	To be confirmed
11. Education						
	11.1	Consider the development of riparian restoration demonstration sites on public land to provide 'reference' sites in the catchment, e.g. Site 5, sportsground in Lower Bilambil Creek	Demonstration site establishment underway by 2011.	Medium	TSC – Natural Resources	Staff
	11.2	Manufacture and install interpretive signage regarding the significant archaeological sites along the eastern foreshore of Terranora Broadwater.	Signage installed by end 2010.	Medium	TSC – Natural Resources	$2,000
	11.3	Promote an education program aimed specifically at reduction of stormwater pollution at the source to improve the stormwater quality of the rural and urban catchment.	Program underway in 2010.	High	TSC – Community and Natural Resources.	Staff
	11.4	Publicise EHMP scorecard results to educate and increase awareness of water quality issues throughout the catchment.	A successful public awareness program that increases the profile of estuary management.	High	TSC – Community and Natural Resources	Staff
	11.5	Undertake an education program targeting the impacts of discarded fishing materials (e.g. hooks and fishing line) and general litter including plastics on sea birds and marine life generally.	Program underway in 2010.	High	TSC – Community and Natural Resources.	Staff

Strategy	Action		Measurable Target	Priority	Responsible Authority	Cost
	11.6	Make accessible to the public the detailed flora and fauna surveys undertaken including: - native vegetation, threatened/significant flora - habitat values of native vegetation for fauna and threatened/significant species - Aboriginal heritage values	Information is available to the public in 2009.	Medium	TSC – Community and Natural Resources.	Staff
	11.7	Promote the importance of roost sites, including those constructed. Educate importance of not disturbing sites.	Program underway in 2010.	High	TSC – Community and Natural Resources.	Staff
12. Monitoring						
	12.1	Identify DIN sources in the catchment. Undertake spatially intensive water quality monitoring strategy to pin point most likely hotspots for DIN entering streams. Minimum of two sample events during median and high flow conditions. Results will reflect effectiveness of catchment rehabilitation.	Targeted water quality strategy in place by early 2011.	Medium	TSC – Natural Resources.	$15,000
	12.2	Monitor the use of constructed roost sites by shorebirds to determine success based on observable bird roosting behaviour. Monitor in spring/summer during years 1, 2, 5 and 10 post construction.	Monitoring program established on completion of roost sites.	High	TSC – Natural Resources.	$2,000
	12.3	Monitor the use of restored bird roost sites by shorebirds during the first spring/summer period following the completion of remediation work.	Monitoring program established on completion of roost sites restoration.	High	TSC – Natural Resources.	$2,000
	12.4	Aerial photo interpretation assessment of riparian width and % canopy cover in updated photos after 5 years to measure improvement.	API assessment updated to allow assessment of improvement in riparian width and cover following implementation of this CZMP.	At completion of Plan	TSC	$3,000
13. Climate Change						
	13.1	Undertake land and habitat vulnerability assessments.	Assessments underway 2010.	High	TSC – Natural Resources.	Staff
	13.2	Develop climate change adaptation strategies.	Strategies developed in 2011.	Medium	TSC – Natural Resources.	Staff
	13.3	Incorporate climate change impact actions into planning instruments, development controls and environmental assessments	Actions incorporated once finalised.	Medium	TSC – Planning	Staff

13 Implementation Plan

The following section includes a description of the proposed actions, prioritisation and costings where relevant.

13.1 Geomorphic Investigations

The Tweed Vegetation Management Strategy, 2004 identifies areas subject to land degradation and threatening processes as priority restoration areas. These areas include the riparian zone where only cleared and fragmented native vegetation remains and where processes are actively leading to the likely sedimentation and eutrophication of waterways.

Strategic sites have been identified throughout the catchment that require direct intervention to prevent severe geomorphic degradation that could potentially undermine upstream reaches and lead to excessive quantities of sediment delivered to downstream reaches, particularly the estuary (Figure 13.1). Seven sites have been prioritised 'Level 1' for detailed geomorphic investigations (Figure 13.1). Investigations should be informed by the assessment at each site already completed as part of this study and consider the target condition and regeneration objectives noted for each site (refer to site assessment, Section 8). This is consistent with management option NS13 of the Tweed Urban Stormwater Quality Management Plan which recommends stabilising eroding river banks and drainage channels.

Sites were prioritised based on the field assessment scores (provided in Section 8). A geomorphic stability/condition priority ranking was also assigned based on the need to prioritise/identify sites that were experiencing active geomorphic degradation. The priority ranking system consisted of four levels, summarised below (Table 13.1).

Table 13.1. Geomorphic condition/stability priority categories and description

Priority	Geomorphic Condition Description
Level 1	Strategic sites that require direct intervention to prevent severe geomorphic degradation that could potentially undermine upstream reaches and lead to excessive quantities of sediment delivery to downstream reaches, particularly the estuary.
Level 2	Sites that are subject to active geomorphic degradation.
Level 3	Sites that are in good to moderate condition experiencing moderate geomorphic instability.
Level 4	Sites that were in good to near intact condition and were stable or moderately unstable.

Detailed geomorphic investigations are likely to include the following set of actions at each site (Dilworth, 2008):

The following set of actions is likely to be required for each priority site.

- *Survey section, develop channel cross section and plan view of the section using conventional surveying techniques. Survey cross sections should be taken at least every 10-20m.*
- *Undertake 1D hydraulic analysis, calculate shear stress at the base of bed level adjustment and other hydraulic parameters needed to determine design constraints.*
- *Undertake a detailed geomorphic/hydraulic assessment of the section and prepare concept designs to address processes responsible for geomorphic degradation.*
- *Evaluate concept design and determine if the proposed stream restoration structure would obstruct natural sediment transport, is consistent with the geomorphic structure of the creek, and presents a barrier to aquatic biota.*
- *Prepare detailed designs that address creek bed and bank stability. Stream restoration designs should be based on stream restoration targets.*
- *Evaluate potential flood hazards due to the construction of structures.*
- *Ensure civil contractors are well supervised and are well informed about the design and the potential hazards about excavating into the creek bed. Preferably employ an environmental engineer or geomorphology specialist to oversee the works.*
- *Evaluate works and identify if improvements in stream restoration works need to be undertaken at new sections.*

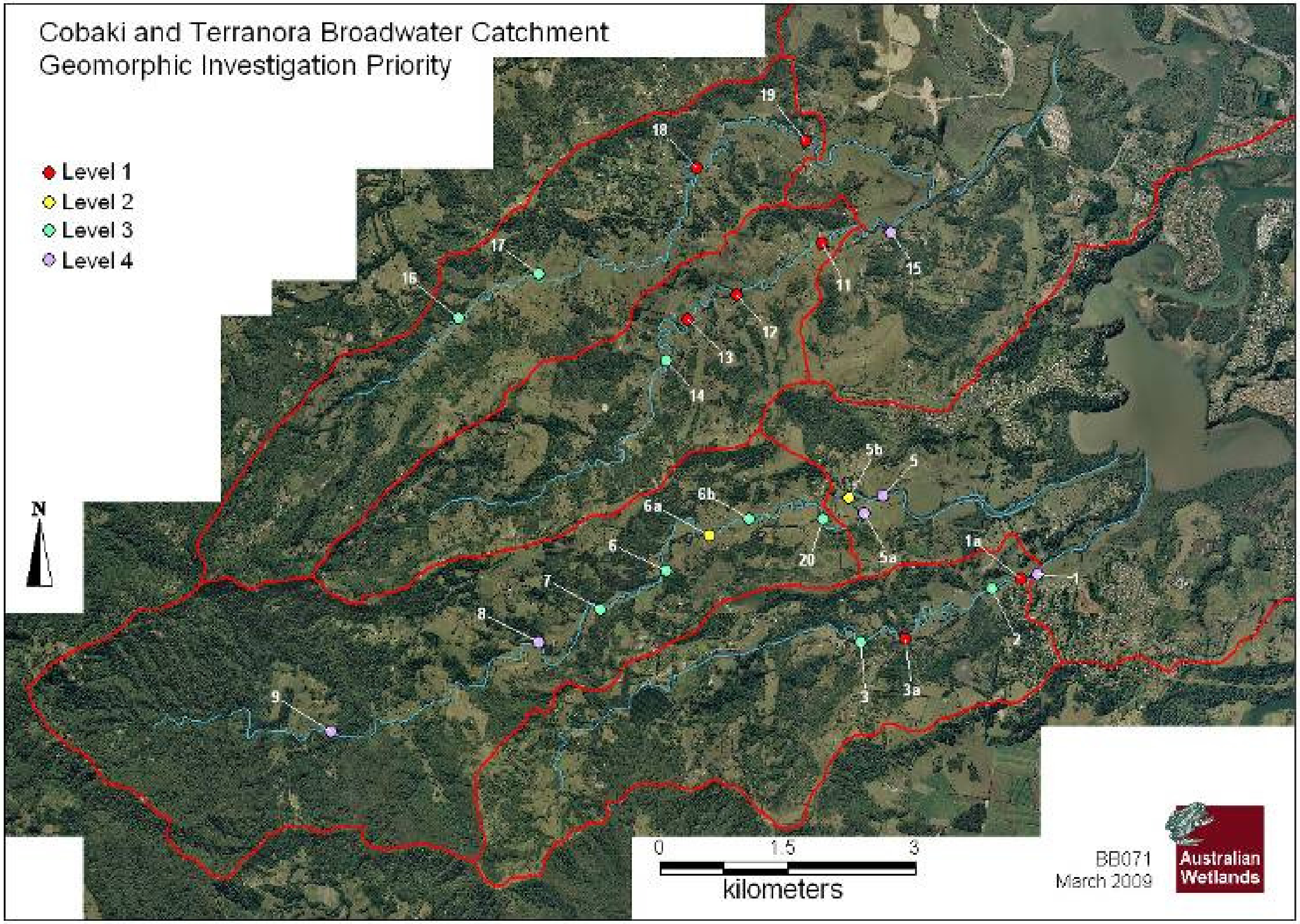


Figure 13.1. Cobaki and Terranora Broadwater geomorphic investigation prioritisation.

13.2 Broadwater Foreshore Rehabilitation

On-going rehabilitation and expansion of broadwater riparian vegetation remnants is vital to the health of the broadwaters. All remaining foreshore remnants of both broadwaters are mapped as High Conservation Vegetation in the Tweed Vegetation Management Strategy (2004) and as such include the most valuable ecological assets in the Shire. The maintenance and improvement of their value must therefore be considered a high priority management action. In accordance with Item 8.3.1 of the Tweed Vegetation Management Strategy, 2004.

Tweed Shire Council owns most of the remnants surrounding Terranora Broadwater, most of which have been classified as Level 1, high priority for rehabilitation. Any opportunities for expansion of these remnants should be investigated to enhance the ecological value of the existing remnants and to improve key habitat linkages provided by regional corridors. The isolation and fragmentation of coastal lowland vegetation is noted in the Tweed Estuary Nature Reserve Draft Plan of Management (NPWS, 2007) as a threat to the reserve values and recommends conservation of remnant native vegetation in the vicinity of the reserve and inclusion of other wetlands in the reserve, particularly Meebun Island.

There are multiple landowners of the Cobaki Broadwater foreshore including DECC, Department of Lands, TBLALC, Gold Coast Airport, Tweed Shire Council and two private landowners who have agreed to a form a Memorandum of Understanding (MoU) to facilitate a coordinated approach to the management of the foreshore. The Details of MoU are provided in Appendix G.

Rehabilitation priority levels are described in Table 13.2. Tables 13.3 and 13.4 and Figures 13.2 and 13.3 provide a summary of the management recommendations and rehabilitation prioritisation of the remnants of Cobaki and Terranora Broadwater foreshores. The recommendations are consistent with the water quality objectives for estuaries/broadwaters of the Tweed River, which includes an objective to *maintain or rehabilitate estuarine processes and habitats*.

Table 13.2. Broadwater foreshore vegetation rehabilitation priority levels

Priority	Description	Management Response
Level 1	Excellent rehabilitation potential, high ecological value, good ecological return for management investment.	Undertake ecological restoration such as assisted natural regeneration. Protect, maintain and expand remaining remnant. E.g. plant buffer zones wherever possible. Aim to restore the vegetation to as near as is practical to the previous naturally occurring native vegetation on that site. All weed removal to be in accordance with the Tweed Vegetation Management Strategy, 2004.
Level 2	Narrow, discontinuous/fragmented vegetation, between urban area and broadwater, some areas mown by Council, low ecological return for high management investment.	Investigate options and community interest for neighbourhood bush regeneration.

13.2.1 Costing

Costs for HCV vegetation remnants more variable depending on the actions required, and are likely to include more labour-intensive bushland regeneration techniques than cost estimates for poorer quality sites. As such an estimate has not been provided. Costs will need to be determined on a site specific basis.

Table 13.3. Summary of the remnant vegetation of Terranora Broadwater foreshore and rehabilitation priority.

Terranora Broadwater						
Site	**Description**	**SEPP14**	**Tweed Vegetation Management Strategy**	**LEP 2000 zoning**	**Land Tenure**	**Rehabilitation Priority / Recommendation**
T1	602 Mangrove Open Forest to Woodland 601 Swamp She-oak Closed Forest to Woodland	Yes	HCV	7a (Environmental Protection)	TSC Crown Reserve	Level 1
T1a	Discontinuous and fragmented vegetation. Limited ecological value. Steep unnatural bank that has been eroded.	No	No vegetation conservation priority	6b (Recreation)	Not mapped	Level 2
T2	601 Swamp She-oak Closed Forest to Woodland Narrow remnant adjacent to relocatable home park. Not core habitat, management issues concern social usage and visual amenity.	No	HCV	2c (Urban Expansion)	Not mapped	Level 2
T3	207 Brush box Open Forest. Good condition with gentle bank slope and natural vegetated substrate.	Yes	HCV	6a (Recreation) 7a (Environmental Protection)	Community Land	Level 1 Rehabilitation can be linked with recreation and interpretive signage recommendations.
T4	602 Mangrove Open Forest to Woodland 601 Swamp She-oak Closed Forest to Woodland	Yes	HCV	2c (Urban Expansion)	Community Land / State Crown Land	Level 1 Ensure remnant is not encroached upon by any urban expansion in this

Terranora Broadwater						
Site	**Description**	**SEPP14**	**Tweed Vegetation Management Strategy**	**LEP 2000 zoning**	**Land Tenure**	**Rehabilitation Priority / Recommendation**
	304 very small remnant Coastal Red Gum Open Forest to Woodland. Good condition with gentle bank slope with natural vegetated substrate.					region.
T5	602 Mangrove Open Forest to Woodland 402 Broad-leaved Paperbark/Swamp She-oak Closed Forest to Woodland 701 Sedgeland/Rushland 603 Large Saltmarsh community west of Area E.	Yes	HCV	7a (Environmental Protection)	Private: Area E	Level 1 All remnant vegetation, including saltmarsh community to west of site should be rehabilitated in association with Area E development.
T6	602 Mangrove Open Forest to Woodland.	Yes	HCV	6a (Recreation)	TSC Crown Reserve	Level 1 Investigate the area between foreshore and houses for conservation.
T7	Charles Bay Reserve. 602 Mangrove Open Forest to Woodland 601 Swamp She-oak Closed Forest to Woodland 304 Coastal Red Gum Open Forest to Woodland 402 Broad-leaved Paperbark/Swamp She-oak Closed	Yes	HCV	7a (Environmental Protection)	TSC Crown Reserve	Level 1

Terranora Broadwater						
Site	**Description**	**SEPP14**	**Tweed Vegetation Management Strategy**	**LEP 2000 zoning**	**Land Tenure**	**Rehabilitation Priority / Recommendation**
	Forest to Woodland 401 Broad-leaved Paperbark losed Forest to Woodland 104 Lowland Rainforest on Floodplain 303 very small remnant Coastal Brush Box Open Forest to Woodland. Good quality, weed removal currently underway.					
T8	602 Mangrove Open Forest to Woodland 1004 scattered Camphor Laurel Dominant Closed to Open Forest 1002 one remnant Early Regrowth Rainforest 304 one remnant Coastal Forest Red Gum Open Forest to Woodland 601 Swamp She-oak Closed Forest to Woodland 603 small remnants of Saltmarsh Communities	602 – yes	HCV / Degraded bushland	6a (Recreation)	Private and TSC Crown Reserve	Level 1 The road reserve along both banks of the estuary riparian corridor requires fencing and planting.
T8a	401 Broad-leaved Paperbark Closed Forest to Woodland 603 Saltmarsh Community	Yes	HCV	7a (Environmental Protection)	Private	Level 1 High saltmarsh rehabilitation potential.
T9	202 Grey Ironbark/White Mahogany/ Grey Gum Open Forest Complex	Yes – western	HCV	6a 7a	TSC Crown Reserve	Level 1 Potential for expansion of

Terranora Broadwater						
Site	**Description**	**SEPP14**	**Tweed Vegetation Management Strategy**	**LEP 2000 zoning**	**Land Tenure**	**Rehabilitation Priority / Recommendation**
	602 Mangrove Open Forest to Woodland 207 Brushbox Open Forest 208 Tallowwood Open Forest 1004 small Camphor Laurel Dominant Closed to Open Forest.	corner Bingham Bay		(Environmental Protection)		remnant into adjacent private land to north.
T10	Very narrow strip of remnant 602 and 601 but substantially cleared of native vegetation and mown grassy areas.	No	HCV / no vegetation conservation priority	6a (Recreation)	Community Land / State Crown	Level 2 Possible area for enhancement plantings to buffer against wave erosion and improve local habitat. Low ecological value.
T11	Substantially cleared of native vegetation with small 602 remnant. Weedy interface with parkland and a long narrow interface with houses of mown grass. Low ecological value.	Remnant 602	Majority no vegetation conservation priority	6a (Recreation)	TSC Crown Reserve / State Crown	Level 2 Investigate community interest in neighbourhood bush regeneration at sites in this area.
T12 / T13	Substantially cleared of native vegetation, mown grass areas between houses and water. Low ecological value.	No	No vegetation conservation priority	6a (Recreation)	Community Land / TSC Crown Reserve	Level 2 Investigate community interest in neighbourhood bush regeneration at sites in this area.

Cobaki Broadwater

Site	Description	SEPP14	Tweed Vegetation Management Strategy	LEP 2000 zoning	Land Tenure	Recommendation
C1	Substantially cleared of native vegetation 403 Melaleuca and Swamp She-oak Forest	No	HCV	4a (Industrial)	Private: Garbino Pty Ltd	Remnant riparian buffer vegetation rehabilitation to be undertaken in association with any development onsite.
C2	Substantially cleared of native vegetation 603 Saltmarsh community 601 Melaleuca and Swamp She-oak Forest	Yes	HCV	6a (Recreation) 7a (Environmental Protection)	State Crown – Department of Lands	Manage for conservation with low impact recreation only.
C3	Substantially cleared 502 Wet Heathland 305 Coastal Swamp Mahogany 601/401 Melaleuca and Swamp She-oak Forest 701 Sedgeland / Rushland 104 Lowland Rainforest on Floodplain 304 Coastal Forest Red Gum 311 Coastal Acacia Community 306 Coastal Scribbly Gum Open Forest	Yes	HCV	5a (Airport) 7a (Environmental Protection)	Federal Government	Review Gold Coast Airport plan of management for foreshore reserve.
C4	502 Wet Heathland to Shrubland 306 Coastal Scribbly	Yes	HCV	7a (Environmental Protection)	State Crown –Tweed-Byron Local Aboriginal Lands	Manage for conservation.

Cobaki Broadwater						
Site	**Description**	**SEPP14**	**Tweed Vegetation Management Strategy**	**LEP 2000 zoning**	**Land Tenure**	**Recommendation**
	Gum Open Forest 403 Melaleuca and Swamp She-oak Forest 301 Coastal Pink Bloodwood Open Forest 401 Broad-leaved Paperbark Closed Forest 402 Broad-leaved Paperbark/Swamp She-oak Closed Forest 601 Swamp She-oak Closed Forest				Council	
C5	401 Broad-leaved Paperbark Closed Forest 306 Coastal Scribbly Gum Open Forest 502 Wet Heathland to Shrubland 305 Coastal Swamp Mahogany 402 Broad-leaved Paperbark/Swamp She-oak Closed Forest 601 Swamp She-oak Closed Forest 602 Mangrove Low Closed Forest	Yes	HCV	7a (Environmental Protection)	Tweed-Byron Local Aboriginal Lands Council	Manage for conservation.

Cobaki Broadwater						
Site	**Description**	**SEPP14**	**Tweed Vegetation Management Strategy**	**LEP 2000 zoning**	**Land Tenure**	**Recommendation**
C6	Substantially cleared of native vegetation 502 Wet Heathland to Shrubland 306 Coastal Scribbly Gum Open Forest 602 Mangrove Low Closed Forest 201 Blackbutt Open Forest Complex	Yes	HCV	2c (Urban Expansion) 7l (Environmental Protection) 6b (Recreation) 7a (Environmental Protection)	Private: Leda Developments	All foreshore vegetation to be restored in association with development.
C7	602 Mangrove Low Closed Forest 601 Swamp She-oak Closed Forest	Yes	HCV	7a (Environmental Protection)	State Crown	Manage for conservation.
C8	602 Mangrove Low Closed Forest 601 Swamp She-oak Closed Forest	Yes	HCV	7a (Environmental Protection)	Tweed Shire Council Crown	Manage for conservation.
C9	201 Blackbutt Open Forest Complex 601 Swamp She-oak Closed Forest 402 Broad-leaved Paperbark/Swamp She-oak Closed Forest 401 Broad-leaved Paperbark Closed Forest	Yes	HCV	1a (Rural)	State Crown – DECC: Tugun Bypass Compensatory Habitat	Manage for conservation.

Cobaki Broadwater						
Site	**Description**	**SEPP14**	**Tweed Vegetation Management Strategy**	**LEP 2000 zoning**	**Land Tenure**	**Recommendation**
	602 Mangrove Low Closed Forest					
C10	602 Mangrove Low Closed Forest 603 Saltmarsh 601 Swamp She-oak Closed Forest 101 Littoral Rainforest 102 Sub-tropical / Warm Temperate Rainforest	Yes	HCV	7a (Environmental Protection)	State Crown – Department of Lands	Manage for conservation.

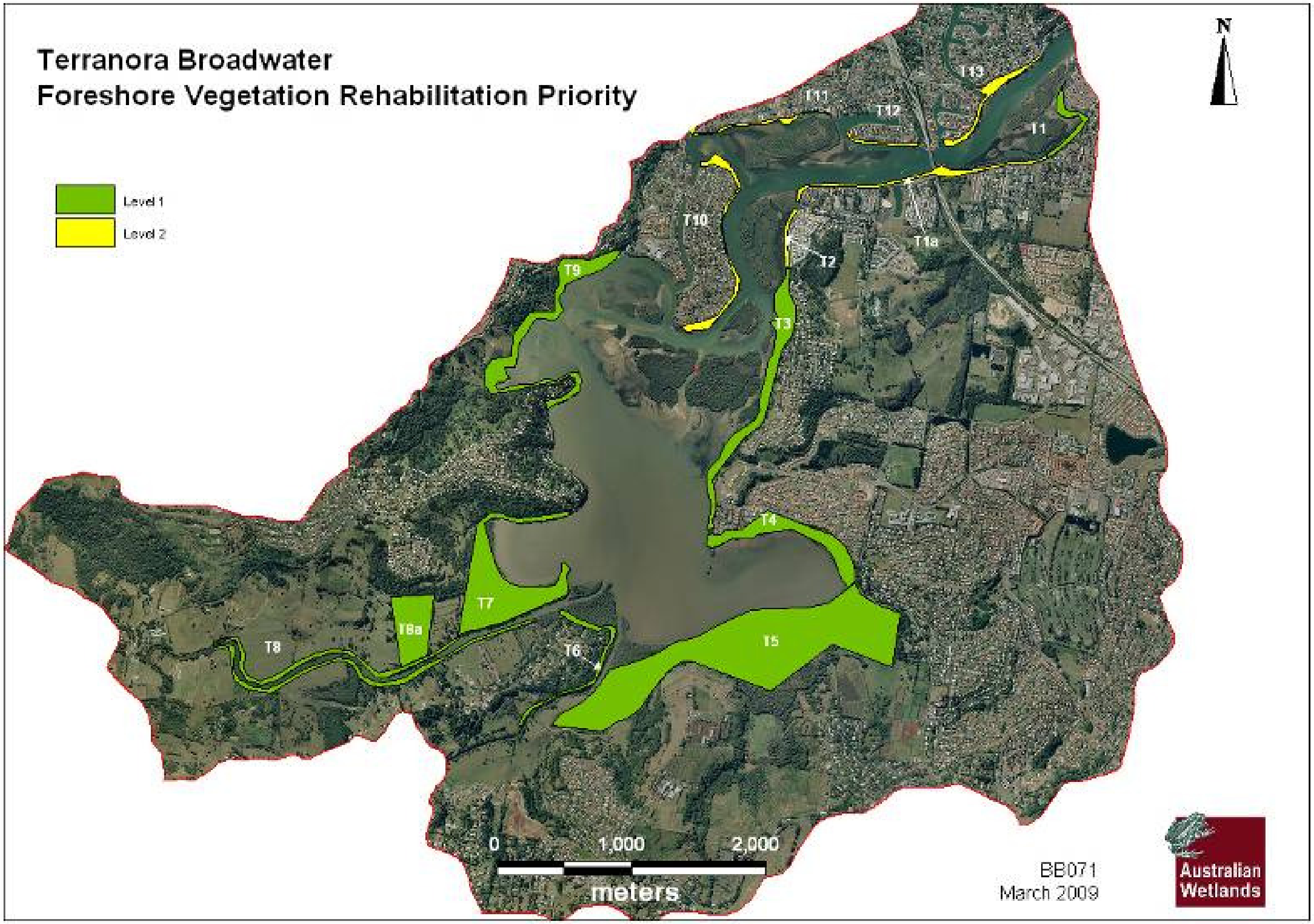


Figure 13.2. Terranora Broadwater foreshore vegetation rehabilitation priority

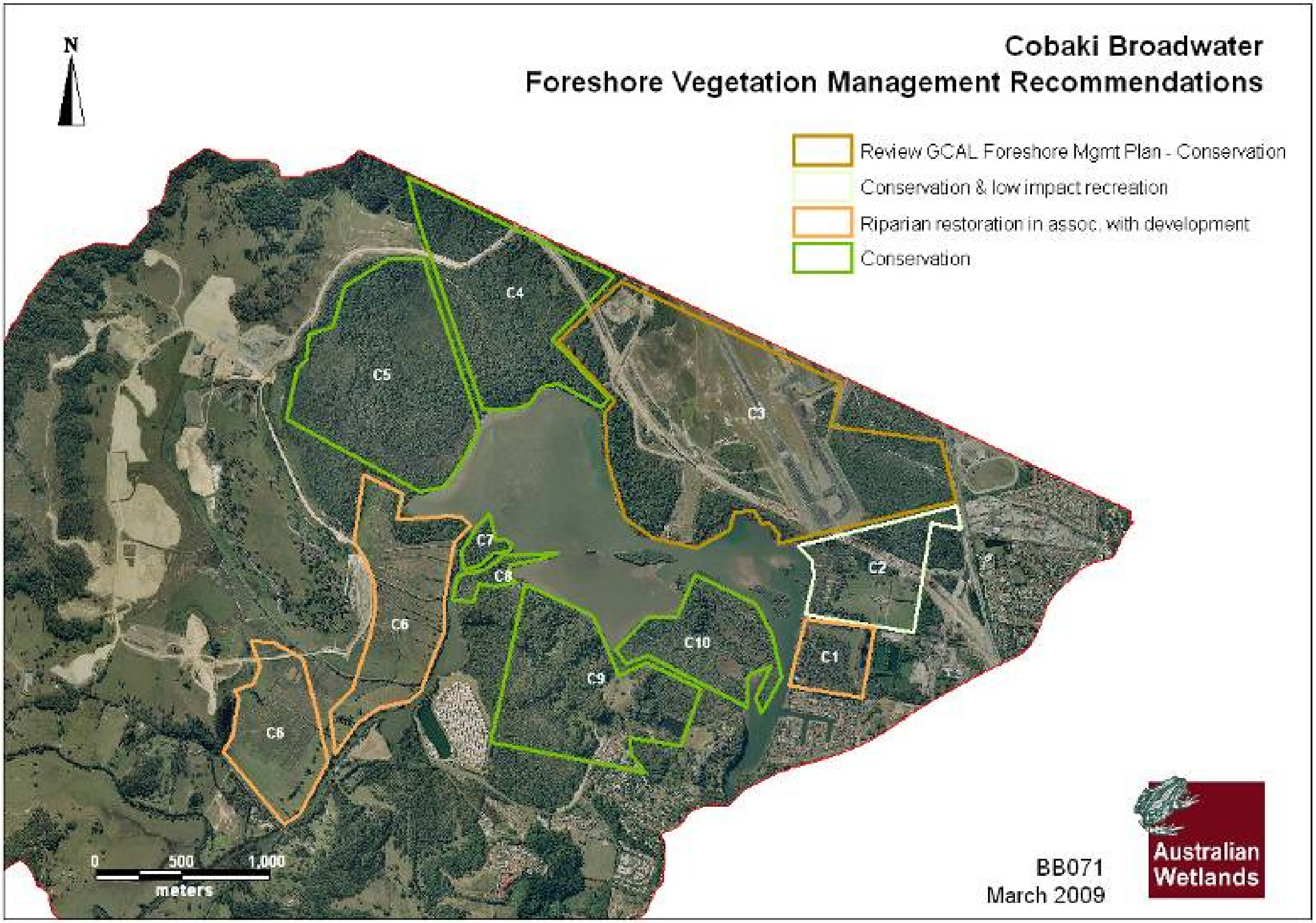


Figure 13.3. Cobaki Broadwater foreshore vegetation management recommendations

13.3 Rural Riparian Rehabilitation

Riparian corridors are integral components of the catchment framework, providing a host of values and functions that maintain and support the health of our natural environment (NSW Department of Water and Energy, 2008). There is evidence to suggest that stream habitats are stressed due to a likely combination of poor riparian zone condition and chronic nutrient enrichment due to stock access. While this condition does not directly impact on the broadwaters during low flow, the build up of organic-rich sediments and faeces can result in the delivery of higher nutrient loads during runoff events due to the mobilisation of these sediments.

In recognition of the role of the riparian zone in improving catchment stormwater quality, Council has committed to undertake catchment rehabilitation as part of offsetting the impacts of increasing WRP effluent discharges into Terranora Creek. Catchment rehabilitation should be viewed as a strategy to improve rural stormwater runoff quality, however alone, it is not sufficient to offset the pollutants discharged to the entire system from urban stormwater, the WRP and large-scale development. Strategies addressing pollutant reduction from urban areas must be implemented as a priority in association with rural riparian rehabilitation.

Consistent with the water quality objectives for the Tweed River system, reduction of diffuse pollutant loads during rainfall and runoff periods is a key focus for improving water quality (DECC, 1999).This was emphasised in the ecosystem response modelling which recommended a reduction of catchment TN loads by 30% (Chapter 10). Rehabilitation of the riparian zone is seen as an important component of reducing diffuse pollutants loads but also in changing the composition of the discharge. For example, rehabilitating the riparian zone via revegetation, removal of stock and stabilisation of the creek bank is likely to reduce TN loads by decreasing the DIN and increasing the organic nitrogen components of TN, thus enhancing nutrient cycling, instream ecological processing, downstream water quality and aquatic fauna health. Results of the EHMP study (IWC, 2009) indicated the lowest scoring ecosystem health indicator to be that of nutrient cycling. Generally the low scores for this indicator demonstrated a breakdown of natural nitrogen cycling processes and concentrations of TN and TP in excess of water quality guidelines.

The rural riparian rehabilitation strategy targets the areas of the catchment most likely contributing to the degradation of water quality in the broadwaters. This is the mid – transition zones of each creek where land clearing, bank erosion and land management practices are the key threatening processes. Processes such as bank erosion are likely to be exacerbated with the predicted increase in extreme rainfall events associated with climate change. Prioritisation of such degraded riparian lands for rehabilitation and water quality improvement is consistent with the NRCMA Catchment Action Plan (CAP). The Catchment Resource Condition Targets for each theme within the CAP have been developed with the underlying intent of sustainably managing natural resources that are currently in good condition and improving those that are degraded while maintaining or improving socio-economic outcomes (NRCMA, 2005).

The rural riparian zone is highlighted for priority rehabilitation in the Tweed Vegetation Management Strategy, 2004. For the rehabilitation of non-bushland areas (as mapped in the Tweed Vegetation Management Strategy, 2004) it is suggested that habitat rehabilitation be directed toward areas subject to land degradation processes. One of the major areas where restoration is likely to have relatively tangible benefits in the short term is the riparian zone (demarcated on the drainage map, Figure 13.16). The riparian zone is also to be prioritised in the management of threatening processes, such as areas that have cleared and fragmented native vegetation and in managing processes leading to the sedimentation and eutrophication of waterways.

The successful implementation of similar riparian rehabilitation projects within the catchment has shown both improvement of degraded riparian vegetation and in the socio-economic welfare of local rural landholders.

The rehabilitation of riparian vegetation is a key component of the management plan and comprises the following:

(a) Private landholder participation is critical to the success of this strategy as the majority of rural catchment rehabilitation will be on private land. An effective landholder engagement strategy targeting all landholders with riparian frontage should be developed and implemented. The strategy should consider workshops for new residents informing them of how to best manage their rural residential riparian land.

(b) Council should provide financial assistance with materials and labour requirements and create a stewardship agreement with landholders to secure the protection of rehabilitated sites from development and farming. TSC needs to invest resources in extension officers to meet with landowners to facilitate and advise on appropriate farm planning, funding options and grant applications.

(c) Site based action plans need to be developed and adopted by Council and landholders who should collaborate to achieve successful implementation. It is imperative that the process of site-based action planning consider the location of areas that have been flagged for further geomorphic investigation to ensure riparian restoration works are not later compromised by in-stream structural works and associated access. This includes areas upstream and downstream of the restoration site. If there is the potential for in-stream works in the vicinity of the riparian restoration site, coordination is required to ensure one does not undermine the integrity of the other.

(d) An important component of the action plan is the long term maintenance of each site. A minimum of three years should be factored in to works and costs.

13.3.1 Upper Freshwater Zone – Protect HCV Vegetation

The upper freshwater zone is in relatively good condition and is therefore the focus of rehabilitation projects that aim to protect and regenerate High Conservation Value vegetation remnants as mapped in the Tweed Vegetation Management Strategy (TSC, 2004). It is recommended that projects continue to protect and manage HCV vegetation remnants in the upper freshwater riparian zone of all subcatchments via the development of site based action plans based on the approach listed above. The plans will be developed on a property-by-property basis, designed to meet the requirements of each property owner/manager according to their capacity, landuse requirements and expectations. Activities within the action plans will range according to past and current landuse practice from total revegetation and bank stabilisation works, to low level weed control in otherwise natural bushland areas that are already in good condition, fenced and protected.

13.3.2 Mid – Transition Zone – Rehabilitate and Fence Riparian Zone

The mid-transition zone has been identified as the priority riparian rehabilitation region given its degraded condition and influence on the water quality and ecosystem health of the broadwaters. Riparian rehabilitation of any part of this zone is, therefore desirable. Sites identified as Level 1 riparian rehabilitation are identified in Figure 13.4 and Table 13.4 describes the levels of prioritisation and indicative management response required for each category. Subject to landowner willingness, the following Level 1 rehabilitation sites: 2, 3a, 5, 11, 13, 18 have been selected for priority consideration and are represented in Figure 13.4 with a red star. These sites were selected, based on the field assessments and the following key attributes:

- Good access
- Severe threatening processes (to water quality) such as nutrient export and sedimentation
- High potential for water quality improvement
- Two sites are owned by TSC
- One site is a large area of the transition zone.

The key recommendation is the development of site-based action plans for Level 1 priority rehabilitation zones (mid and transition zones of all creeks) via the process outlined above. Priority rehabilitation sites are to be considered in this process.

The location of riparian rehabilitation sites is also to consider parallel rehabilitation projects to promote a coordinated approach wherever possible. Projects include those that are part of the NRCMA Biodiversity Program and the NSW Threatened Species Priorities Action Statement (PAS). Priority Implementation Areas (PIA) have been identified for rehabilitation to meet the needs of threatened species and abate key threatening processes. Duroby Creek and Bilambil Creek subcatchments have been incorporated in a PIA, while Cobaki Broadwater, Cobaki Creek and upper Piggabeen Creek have been mapped as a Climate Change Corridor (Tweed/Border Ranges to Mount Clunie Corridor).

The Key Corridor Connections and PAS Implementation Pilot Projects aim to improve connectivity in these identified habitat corridors via revegetation, to infill gaps and rehabilitate existing native vegetation to improve condition and habitat quality. There is likely to be overlap between sites identified for revegetation as part of these projects and the degraded areas prioritised as part of the current study. Funding opportunities should be considered concurrently. For example, Sites 11 – 13 are within the Climate Change Corridor at Cobaki Creek and Sites 2 and 3a are within the PIA of Duroby Creek.

Table 13.4. Riparian rehabilitation priority categories and associated required management response

Priority	Description	Management Response Required
Level 1	Riparian zone in poor condition	High management intervention required. These riparian sites require fencing from stock, and /or structural works, native vegetation may be non-existent and more extensive planting of a riparian buffer will be required. Some bank erosion may be present. These sites often have no canopy vegetation or riparian structural vegetation including woody species such as Camphor Laurel. Sites which were classified in poor condition were predominantly in the middle and transition zones of all sub catchments. Goals: - Extend riparian vegetation cover to at least 10m. The type of restoration to be negotiated with landowners on a site-specific basis. Options range from full reconstruction to fencing and weed management (refer to Section 13.3.4) - Fence riparian area from adjacent landuse (consider fauna-friendly fencing design, refer to Section 13.3.4) - Remove stock from riparian zone and provide off stream water points wherever possible
Level 2	Riparian zone in medium condition	Medium management intervention required. These sites will typically be dominated by a woody weed canopy and may require major weed control work or fencing. Structural works such as culvert replacement may be required. These sites have some regeneration potential as native seedlings or some fauna habitat is present. Supplementary planting may be required. Goals: - Assisted natural regeneration to achieve a riparian vegetation cover of at least 10m
Level 3	Riparian zone in good condition	Little management intervention required (minor works). These sites were the highest scoring sites from the assessment and consequently will be a lesser priority for rehabilitation as these sites are in better condition. These sites have a good canopy cover of native species with only small weed control works required to achieve a highly functioning riparian zone and good water quality for the broadwaters. - Assisted natural regeneration and possible expansion of riparian vegetation to enhance wildlife habitat corridors.

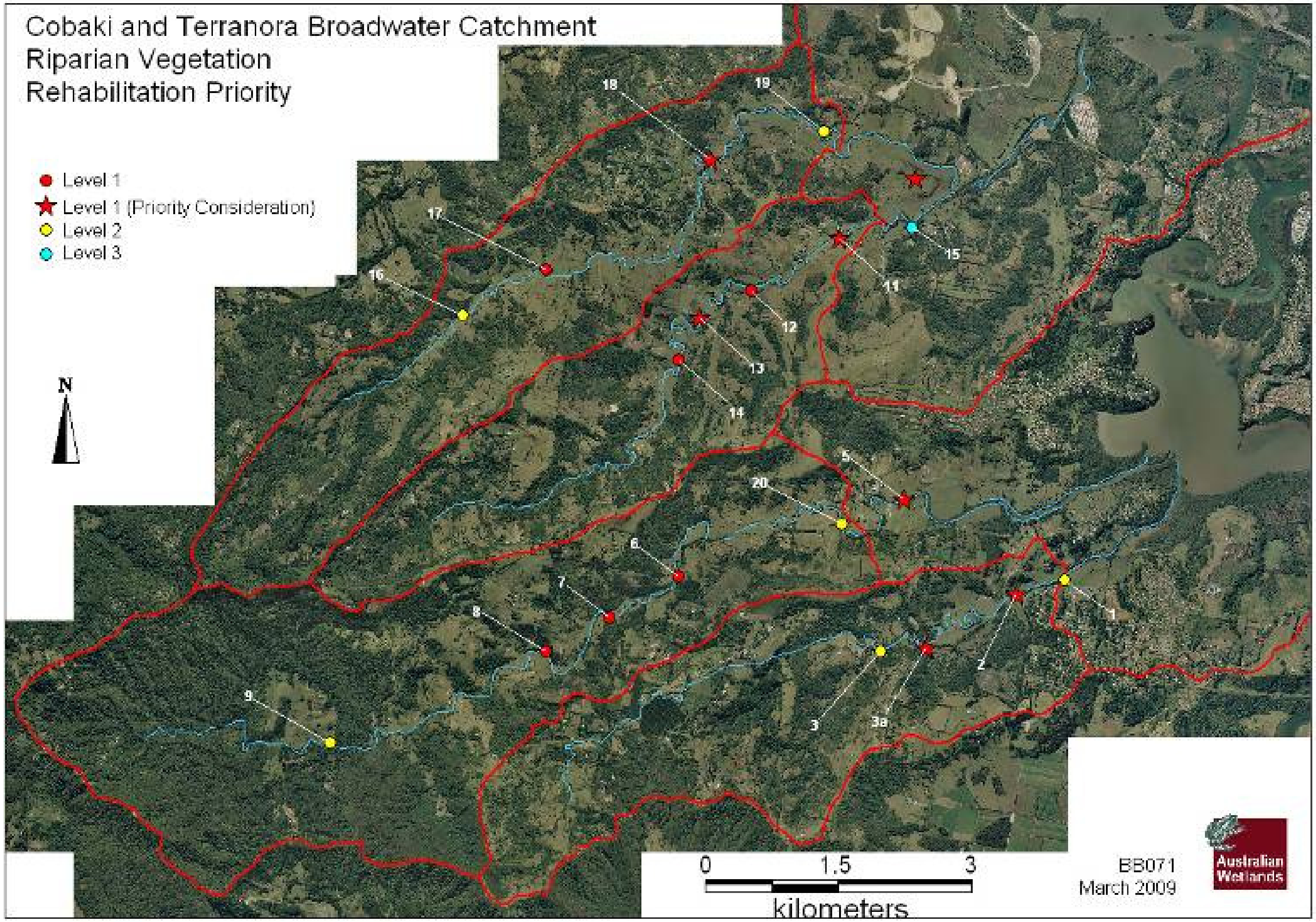


Figure 13.4. Cobaki and Terranora Broadwater catchment riparian vegetation rehabilitation priority

13.3.3 All Zones – Rehabilitate and Fence Ephemeral Drainage Lines

A large proportion of the creek network is made of small gullies, which is emphasised in Figure 13.5. For much of the time, these are dry and not easily identifiable as important parts of the broadwater catchments. However, after rain, they become the drainage lines into which rainfall runoff collects and flows, forming a vast branching network that eventually comes together to discharge into the main channels. In South East Queensland these gullies, or 'first order streams' make up a very large proportion of the total length of waterways (approximately 47% of the stream network in SEQ) (South East Queensland Healthy Waterway Strategy (SEQHWS), 2007).

Many of these smaller gully networks have been poorly managed in the past and have lost their native vegetation cover and the important role it plays as a water quality buffer. The more protective vegetation cover these gullies have, the greater the chance there is of a healthy ecosystem downstream in the estuary and broadwaters. Failure to recognise these small streams and gullies as important components of our local waterways has led to major problems downstream (SEQHWS, 2007).

Water Quality Buffers are a cost effective solution for low priority ecological zones where poor water quality associated with landuse is a significant challenge.

The vegetation structure required to deliver water quality outcomes is much simpler than that required for full ecological restoration.

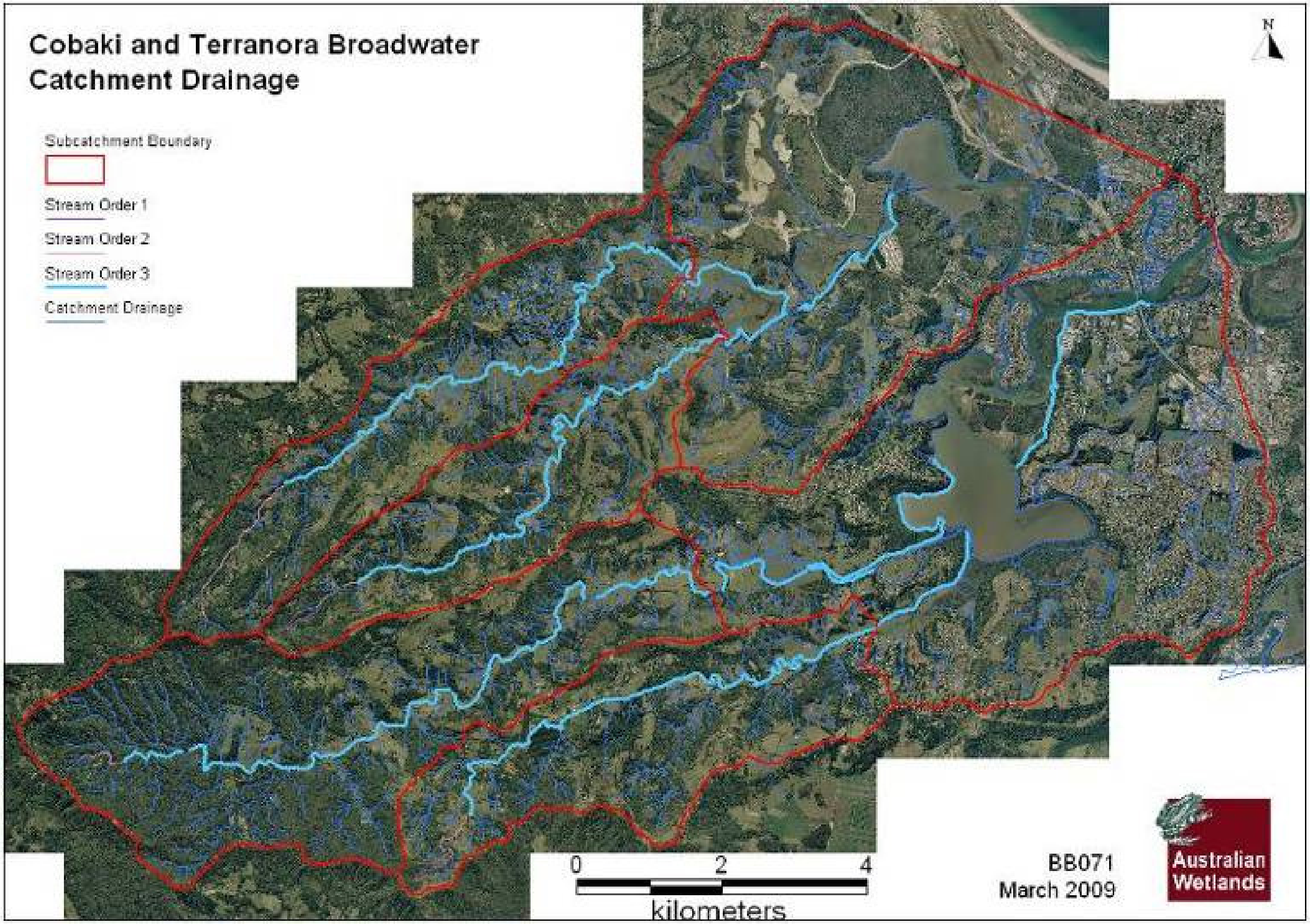
Ephemeral drainage line rehabilitation attempts to improve the condition of land that may otherwise not be prioritised for any form of restoration.

Studies have shown that under favourable conditions, natural vegetation and grassy filter strips can trap approximately 90% of the sediment moving from upslope and trap or absorb nutrients. Vegetation (including most grasses) can quickly grow over and through the trapped sediment, protecting the creek from future storms (Price and Lovett, 2002). Stock management is an important component to be addressed in conjunction with Water Quality Buffers. This concept is illustrated in Figure 13.6.

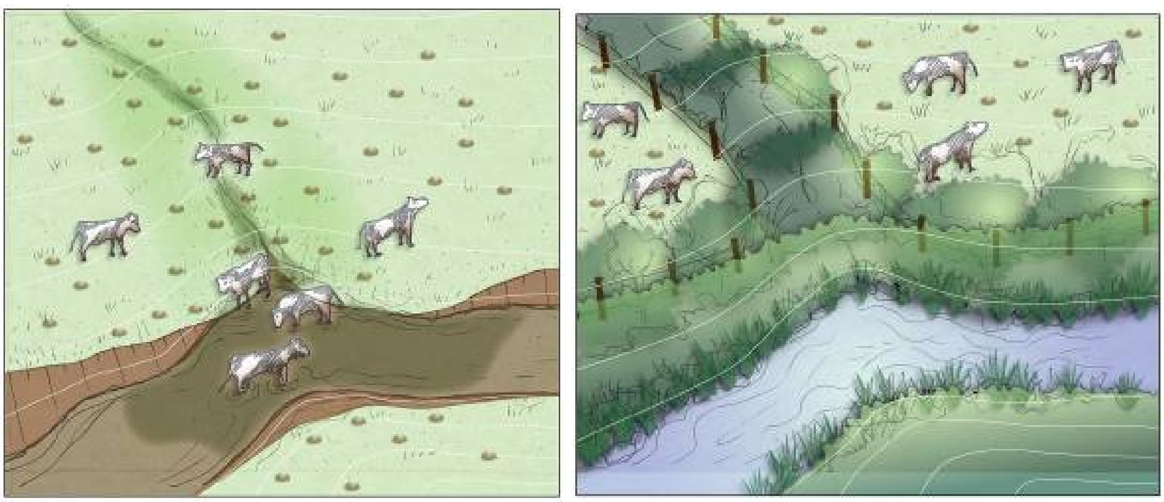
Potential benefits of ephemeral lateral gully rehabilitation include:

- improvement to water quality
- rehabilitation of habitat
- decreased mosquito breeding
- improvement to ASS discharge
- low cost
- broader scope for funding opportunities

The type of rehabilitation should be determined on a site-specific basis and will be informed by the landuse and landowner. Ephemeral drainage line rehabilitation could also be viewed as the first step in restoring the site back to its original condition, subject to future funding availability and landowner willingness. This strategy for rehabilitation is potentially not as threatening to landholders as fencing off the entire riparian zone of the main channel but can still produce water quality improvements.



13.5. Cobaki and Terranora Broadwater catchment drainage network



13.6. Conceptual image of Riparian Water Quality Buffer indicating existing degraded condition (left) and revegetated riparian water quality buffer (right). (Australian Wetlands, 2008).

13.3.4 Rehabilitation Options:

Riparian rehabilitation options could include one or a combination of many treatments ranging from fencing an ephemeral lateral gully and undertaking seasonal weed control to a possible end goal of full ecological restoration. Options include:

- fencing + weed management
- fencing + grass buffer strip + weed management
- fencing + pioneer planting + weed management
- fencing + eventual ecological restoration
- natural assisted regeneration

The initial fencing and planting of a site could be seen as the first stage of improving riparian vegetation throughout the catchment. A progressive goal could be full ecological restoration should landowner interest be forthcoming in subsequent years.

Note: any regeneration process that might add to DIN loading in a waterway must be done progressively and systematically to lesson and/or prevent the impact e.g. use of fertilisers. Ideally any activities that could contribute to DIN loading in a waterway would be avoided.

Fencing

Uncontrolled use of riparian lands around the main channels and ephemeral lateral gullies by stock can contribute greatly to the amount of sediment, nutrients and animal wastes moving into the creek. In addition, uncontrolled access can lead to excessive run-off, bank erosion, loss of productive land, decline in important wildlife habitat and damage to in-stream ecosystems. As domestic stock favour riparian frontages and low-lying gullies, these areas can become over-grazed, eroding the bank soils allowing weed invasion and eroding stock tracks which result in increased sediment, nutrients and animal wastes being washed into the main creek channel.

The simplest way of regulating stock access to riparian land is to fence the area between the lateral gully and/or the creek and the rest of the property. Fencing along but not across any vegetation corridor is desirable (Tweed Vegetation Management Strategy, 2004). Riparian fencing requires careful planning as flooding is a potential threat to conventional fencelines. There are several alternative fence options including hanging fences, electric fences and drop fences. Fauna friendly fencing should be investigated.

Fencing is an integral component of the riparian vegetation restoration and water quality buffer design. However, fences can be a major obstacle to fauna movement. Inappropriately designed fences can injure native animals (Figure 13.7), create physical barriers to fauna movement and therefore can disrupt the feeding, migration, breeding and social patterns of local fauna. Barbed wire fences and electric fences are generally not wildlife friendly and can seriously impact local wildlife, especially bats, birds and gliders. The top strand of barbed wire is most often involved in entanglements. Barbed wire is both an animal welfare and conservation issue, as it is now being recognised as a threatening process in several draft/recovery plans for a number of species of gliders and flying foxes including:

- Yellow-bellied glider (*Petaurus australis*)
- Mahogany glider (*Petaurus gracilis*)
- Spectacles flying fox (*Pteropus conspicillatus*)
- Grey-headed flying fox (*Pteropus poliocephalis*)

A fauna-friendly fence is one that does not inhibit the movement of native fauna between properties (Redland City Council, 2007). Given the variety of animals inhabiting the catchment, it is recommended that suitable fauna-friendly fencing be defined wherever possible relative to the local fauna. Examples of fauna-friendly fence guidelines obtained from Redland City Council are provided below:

- a 50cm gap between ground level and the first rail or strand. Spacing above this level is at the owner's discretion
- a series of 30cm gaps between the rails or strands (the first gap should be no higher than 30cm above ground level)
- a 30cm gap between ground level and the first rail or strand followed by a series of 30cm gaps
- box wire mesh (squares of no less than 15cm) may be used provided that there is a 30cm gap between the ground level and the mesh, and provided the fence is not more than 1.2m in height. A capping rail along the top allows for easy movement.

Figure 13.7. Flying foxes caught in a barbed wire fence in the riparian zone

Source: J. Maclean http://wildlifefriendlyfencing.com/about_Fform.htm

Weed Management

Once an area is fenced off, it will require maintenance to prevent weed invasion. The maintenance of fenced areas will be required several times each year, however where water quality as a primary objective, it is seen as acceptable that these buffers may receive a reduced level of maintenance without compromising their key function. Weed control may range from slashing periodically or allowing seasonal grazing within a grass buffer, through to routine assisted regeneration of reconstructed areas such as spot spraying and hand weeding. Although some of these options are not consistent with best practice management bushland regeneration, we recommend this as a compromise, if necessary, that upholds the principle that some vegetation cover is more beneficial to the health of the creek than none, particularly as this rehabilitation could be viewed as Stage 1 of further ecological restoration.

While undertaking weed control, erosion needs to be managed by maintaining some vegetation cover to avoid exposed soils along ephemeral drainage lines and on the banks of the creek. Retaining some vegetation cover should also prevent an increase in weed species. Follow up maintenance is an integral part of regeneration and needs to be funded as part of the initial planning for each site. Any follow up works requiring more highly skilled regenerators will require funding for professional contractors or trained TSC staff.

As an incentive for landowners, investigations into a source of funding for maintenance should be undertaken. For example, the ongoing maintenance could be funded by Landcare CarbonSMART for planted or naturally regenerating vegetation of at least five hectares.

Grass Buffer Strip

Grass buffer strips should to be established and maintained along landscape depressions where overland flow concentrates and enters small channels or gullies to reduce sediment and nutrients entering the creek (Figure 13.8). The aim is for a broad, well-grassed strip covering the entire area of flow concentration if possible, to protect against times of heavier rainfall.

It is important to keep livestock out and to maintain the buffer to ensure there is almost complete ground cover and a good height of vegetation (grasses should be at least 10-15 cm) to maximise the capacity for sediment and nutrient entrapment. The ideal width and management practice for grass buffer strips depends on the volumes of water and sediment being transported and the nature of the adjacent landscape, however it is generally accepted that a combination of 10m of grass buffer and 10m of natural vegetation adjacent to a stream will be effective in most situations (Prosser and Karssies, 2001).

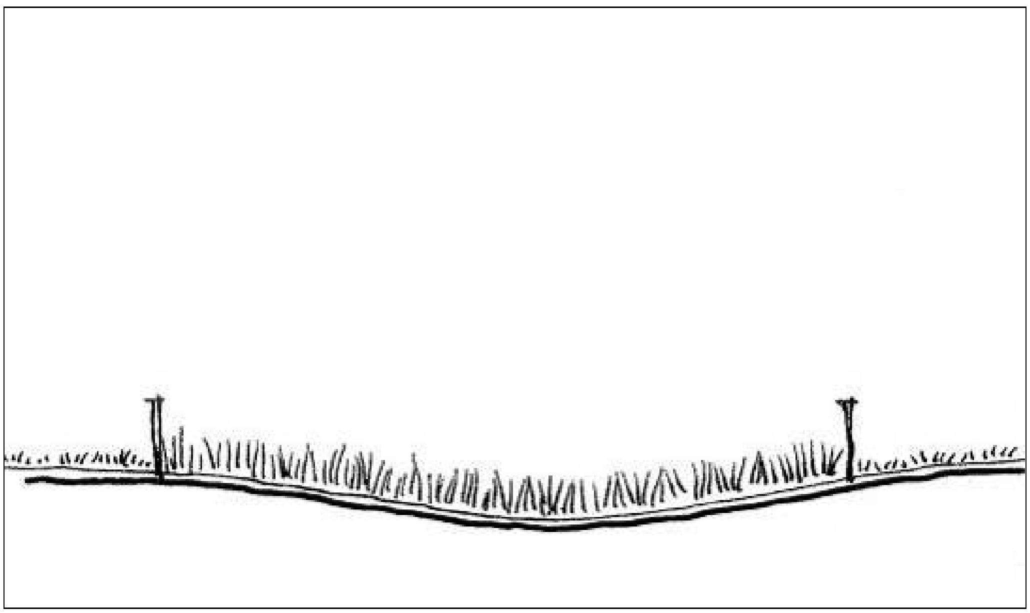


Figure 13.8. Grass buffer strips trap sediment and protect the ephemeral gully and main creek channel from sediment, nutrients and animal wastes (Australian Wetlands, 2008)

Pioneer Planting

Pioneer planting is a thick density of fast-establishing pioneer riparian species that will quickly encourage soil binding and canopy shade to deter weed infestation. This is likely to include species such as Acacias, Eucalypts, Macaranga, Casuarina, and Brown Kurrajong, but will not be particularly structurally complex or have high species richness (conceptual image, Figure 13.9).

The primary aim of the planting is to improve water quality, however this style of planting has potential additional value a woodlot or carbon sink without its water quality function being compromised. Similar to grass buffers, it is recommended that this planting type be at least 5m wide and be situated to ensure that ephemeral and overland flow paths are intercepted.

Establishment of this buffer would involve fencing to exclude livestock, slashing and spraying of pasture grass, planting of appropriate native species at a density of between one and two tubestock per square metre, initial watering and periodic follow up weeding until the native plants are sufficiently established.

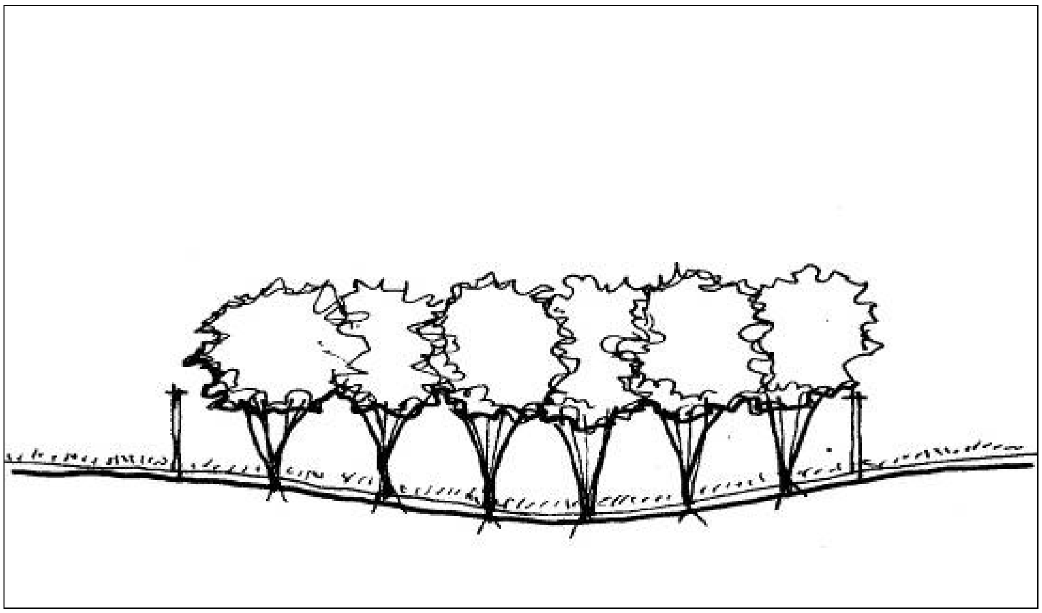


Figure 13.9. Conceptual image of pioneer planting (Australian Wetlands, 2008).

Structural Planting / Reconstruction

Consistent with the definition of reconstruction, this option involves a wholesale reinstatement of the original vegetation community. The aim of reconstruction will be to recreate the system that would occur naturally onsite by planting a range of species such as native grasses, reeds, and to mimic a natural vegetation community (Figure 13.10). Local native plant species, i.e. plants that are indigenous or commonly found, occurring naturally within Tweed Shire region (including trees, shrubs, herbs and grasses) should be used.

This type of reconstruction could be seen as a progressive goal on suitable riparian land. The initial fencing and planting of a grass buffer strip could be seen as the first stage of improving water quality buffers throughout the catchment should landowner interest be forthcoming in subsequent years.

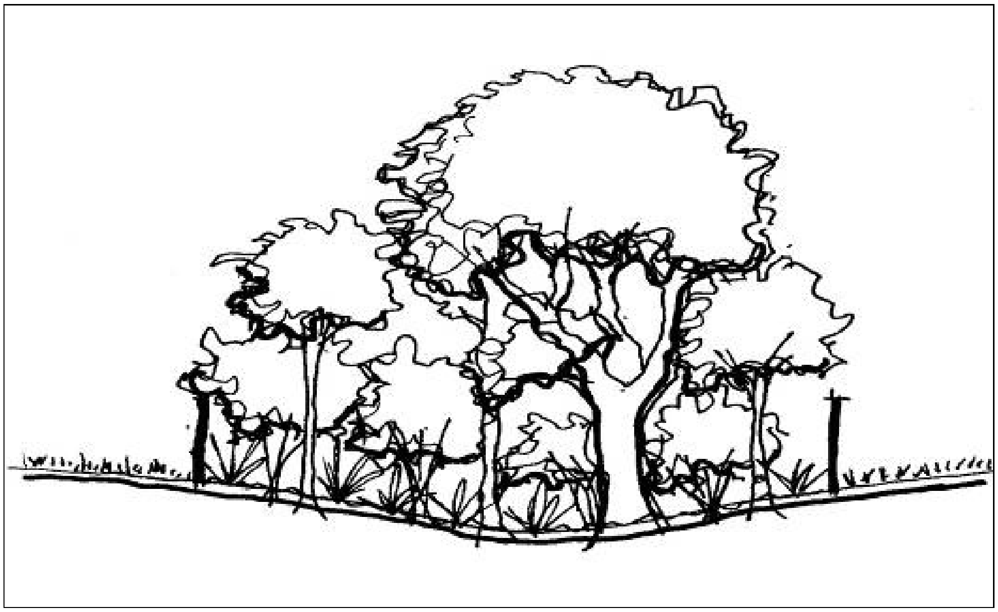


Figure 13.10. Conceptual image of structural vegetation (Australian Wetlands, 2008)

13.3.5 Costing

The following are indicative costings only to assist with funding and budgeting (Table 13.5). Completion of the site-based plan will inform actual costs.

Costing Rationale
It is proposed that buffers aimed simply at water quality improvement could take a number of forms and need not necessarily comprise riparian vegetation to fulfil their role of intercepting mobilised pollutants from rural land uses. The different forms of buffer could include a fenced grass zone, a fenced pioneer species planting, or full reconstruction of riparian vegetation with fencing. Cost estimates for each of these options are detailed below.

Grass Buffer
- Assumes the requirement for fencing is only to exclude cattle.
- Supply and install electric fencing or post and wire fence with 3 strands of wire and posts - $2,500 to $9,000/km.

Pioneer/Woodlot Planting
Assumes one to two trees per square meter using fast growing native species to provide quick cover and weed suppression. Costs include:

- broad acre spraying - $0.40/m^2
- planting 1-2 plants/m^2 - $3.00/m^2 to $6.00/m^2
- initial watering - $0.50/m^2
- follow up weed spray - $0.40/m^2

Total cost: $4.10/m^2 to $7.10/m^2

Structural Planting
Assumes full recreation of a riparian vegetation community with costs including:

- broad acre spraying - $\$0.40/m^2$
- planting 1-2 plants/m^2 - $\$3.00/m^2$ to $\$6.00/m^2$
- initial watering - $\$0.50/m^2$
- maintenance for two years at a rate of \$1 to $\$2/m^2$ per year - $\$4/m^2$

Total cost: $\$6.10/m^2$ to $\$11.10/m^2$.

Table 13.5. Summary of rehabilitation treatments and associated costs

Treatment	Description	Cost
Fencing	Electric fencing can be used to upgrade existing older fences or to strengthen plain wire fencing in riparian areas especially for cattle. The cost can be as little as \$2.50/m including two strands of heavy duty electric wire, insulators and a solar energiser, while traditional post and wire fencing is considerably more expensive \$7 to \$9 per lineal metre. We recommend consideration of fauna friendly fencing.	\$2500 - \$9000/km
Weed Management	Cost is dependant on the type of buffer ultimately created with weed management ranging from herbicide spraying to more labour intensive bushland regeneration techniques.	$\$0.20/m^2$ - $\$1.50/m^2$
Off-Stream Stock Watering	Solar powered pump and trough with float valve and 50m of 2" poly pipe, fittings and taps	\$800 – \$1500
Grass Buffer Strip	Minimum 5m wide grass buffer from which cattle are excluded	Refer to fencing costs
Pioneer Planting	Thick density of fast-establishing pioneer riparian species that will quickly encourage soil binding and canopy shade to deter weed infestation. Requires initial weed control and follow up weed control (6-monthly) + planting at 2 plants per m^2 + initial watering.	$\$7.20/m^2$
Assisted Natural Regeneration	Limited intervention such as weed control, erection of fencing to restore the native vegetation through natural regeneration and successional processes.	As per costs for relevant actions
Structural Planting / Reconstruction	Complete reconstruction of a riparian vegetation community including weed control, planting, watering and maintenance for a minimum of 2 years, preferred maintenance is for 5 years.	$\$11.90/m^2$

13.3.6 Long Term Management Targets

The long term management target for the rural catchment riparian zone is to increase the width and cover of riparian vegetation of the most degraded areas, i.e. from areas that are almost bare, to riparian vegetation of at least 10m width and at least 50% canopy cover. The rate of implementation is dependant on the successful development of community engagement and partnerships in this rehabilitation strategy.

The long term management target for the rural catchment riparian zone is to increase the width and cover of riparian vegetation of the most degraded areas, i.e. from areas that are almost bare, to riparian vegetation of at least 10m width and at least 50% canopy cover.

Rehabilitation of the riparian zone incorporates ephemeral drainage line rehabilitation, so ephemeral rehabilitation can be included when assessing performance against this target, however, ephemeral watercourses were not included in the rapid API described in Section 8.6. The capacity for improvement is also gauged by the level of participation from land owners and property managers.

Table 13.6 below describes each Creek catchment in terms of the rapid API for cover, buffer width and length of stream. It gives an overall picture of each creek in terms of riparian vegetation present. The condition of the vegetation in those areas with a positive score can only be truly ascertained on a site-by-site basis. That is, even when there is good cover (>50%) and buffer width (>20m), the quality and condition of the vegetation may be marginal or contain dominant weed species (such as Camphor Laurel or vines).

Using a combination of the above assessment, the results of the EHMP (IWC, 2009) and the Tweed Water Quality Objectives, long term management targets for the rural riparian zone have been developed to assist with the determination of the successful implementation of the action plan. An EHMP ecosystem health grade of B ('good ecosystem health') was used as the target for ecosystem health and is described in the EHMP report as *'Conditions meet all set ecosystem health values in most of the reporting region; most key processes are functional and most critical habitats are intact'.*

A summary of management targets are provided in Table 13.7.

Table 13.6. Results of API assessing current rural catchment riparian vegetation cover

Score	**1 + 2**		**3 + 4**		**5 + 6**		**7 + 8**		**9 + 10**		**11 + 12**	
Width	**Bare - <10m**		**< 10m**		**10 – 20m**		**10 – 20m**		**> 20m**		**> 20m**	
Cover	**< 50%**		**> 50%**		**< 50%**		**> 50%**		**< 50%**		**> 50%**	
Subcatchment	**length (km)**	**% of total**	**length (km)**	**% of total**	**length (km)**	**% of total**	**length (km)**	**% of total**	**length (km)**	**% of total**	**length (km)**	**% of total**
Duroby Ck	5.7	**38**	0.6	4	0.7	5	3.6	**24**	0	0	4.3	**29**
Bilambil Ck	10.9	**60**	0.7	4	1.3	7	1.6	9	0	0	3.8	**21**
Cobaki Ck	8.8	**62**	1.1	8	0	0	2.6	18	0.2	2	1.5	10
Piggabeen Ck	10	**74**	1.4	11	0	0	0.4	3	0.2	2	1.5	11

Table 13.7. Long term management targets for the rural riparian zone

Indicator	Piggabeen Creek	Cobaki Creek	Bilambil Creek	Duroby Creek
Riparian Vegetation Cover	Increase the riparian vegetation width (to >10m) and cover (to > 50% FPC) in the 74% of the riparian zone ranked 1 and 2 to an equivalent ranking of at least 7 or 8. **Equates to approximately 10km of rehabilitation*.**	Increase the riparian vegetation width (to > 10m) and cover (to > 50% FPC) in the 62% of the riparian zone ranked 1 and 2 to an equivalent ranking of least 7 or 8. **Equates to approximately 8.8km of rehabilitation*.**	Increase the riparian vegetation width (to > 10m) and cover (to > 50% FPC) in the 60% of the riparian zone ranked 1 and 2 to an equivalent ranking of least 7 or 8. **Equates to approximately 10.9km of rehabilitation.**	Increase the riparian vegetation width (to > 10m) and cover (to > 50% FPC) in the 38% of the riparian zone ranked 1 and 2 to an equivalent ranking of least 7 or 8. **Equates to approximately 5.7km of rehabilitation.**
Ecosystem Health	Improve EHMP Grade from C- to B.	Improve EHMP Grade from C- to B.	Improve EHMP Grade from C- to B.	Improve EHMP Grade from D to B.
Water Quality	Compliance with Tweed River Water Quality Objectives for freshwater creeks and estuaries.			

* The length of riparian rehabilitation applies to separate banks of the creek throughout the estuarine and transition zones. Where the creek channel narrows in the mid zone, a single km value incorporates both banks (mid – upper freshwater zone) where delineation between banks is not useful or possible for rehabilitation purposes.

13.4 Industry Management Plans / Land Management Practices

An investigation should be undertaken into the current Environmental Management Planning process for industries. This should incorporate an audit of existing management plans and compliance requirements for the following land-uses throughout the catchment:

- Golf courses;
- Nurseries;
- Banana farms;
- Other industrial e.g. petrol stations.

This recommendation is consistent with management option NS42 of the Tweed Urban Stormwater Quality Management Plan (2000) which recommends starting an ‘environmental accreditation program’ with industry groups. To date this recommendation has not been actioned.

13.4.1 Golf Courses

There are three golf courses in the catchment:

- Club Banora Golf Course (Banora Point)
- Tweed Greens Golf Club (Mid Bilambil Creek)
- Woodlands Lakeside Golf Course (Piggabeen)

If not well managed, golf courses can be a source of nutrient and chemical run-off that pollute creeks and lead to the degradation of native flora and fauna habitats. In situations where these creeks are in close proximity to the sea, the negative impacts can extend into estuarine and marine ecosystems. Studies have found that runoff from golf courses can carry considerable levels of nutrients into downstream waterbodies (Milligan and McAlister, 1989). However, if well managed, there is an opportunity not only for the mitigation of potential impacts, but for golf courses to provide many environmental benefits such as removing contaminants and nutrients from urban stormwater and providing/improving wildlife corridors in congested urban environments (Neylan, 2007). Opportunities for restoration of the riparian zone could be investigated including maintenance of 'roughs' as ephemeral wetlands.

In 2000, the Australian Golf Course Superintendents Association (AGSCA) developed a project that addressed the key environmental issues for golf course management such as water management, pesticides and fertiliser management and other related practices. In 2001, a manual was developed by the AGSCA and the Queensland EPA to provide direction to golf course superintendents and their staff for implementation of better environmental management practices. This manual has been adapted for NSW by the NSW DECC (2007).

Some of the key areas this manual refers to include:

- Planning and siting
- Design
- Construction
- Maintenance
- Water use
- Waste management
- Wildlife management and
- Facility operations

A few of the principles particularly relevant to protecting water quality include:

- Implement water reuse (wastewater) strategies wherever economically feasible and environmentally and agronomically acceptable
- Create buffer zones to protect high quality surface waters and environmentally sensitive areas
- Employ integrated pest management strategies
- Store and handle pesticides and fertilisers safely according to environmental regulations
- Use nutrient products (e.g. slow release fertilisers) and practices that reduce the potential for contamination of ground and surface waters
- Test and monitor soil conditions

Existing management plans should be consistent with these principles.

13.4.2 Nurseries and Banana Farms

There are several plant nurseries throughout the catchment that also have the potential to discharge high levels of nutrients into the creek, particularly during periods of low flow. An investigation should be undertaken into the current Environmental Management Plan process and an audit of existing management plans and compliance requirements at the nurseries within the catchment. Management plans should be consistent with Best Practice Management for water, pesticide and fertiliser use and with the NSW Nursery Industry Association. Confirmation that the nurseries are operating under an approved development application and water extraction licence should also be gained.

Banana farming has several potential impacts on the health of the catchment including the discharge of high nutrient wastewater due to fertiliser application. Any opportunities to engage the banana farming industry in this process should be investigated.

13.4.3 Other Industry

The remaining industrial sites found within the catchment e.g. service stations are also potential contributors of pollutants to waterways. If existing management practices are not effective, there is the potential for the entry of industrial materials and wastes into the creeks and broadwaters or soils via stormwater runoff or through leaks and spills.

One of the short term objectives of the Tweed Urban Stormwater Quality Management Plan (2000) is 'a measurable reduction in anthropogenic pollutants from commercial and industrial areas'. One of the existing management options for the Lower Tweed sub-catchment listed in the Tweed Stormwater Quality Management Plan (2000) that has not yet been actioned, is to undertake an environmental audit and education campaign in the Tweed Heads South industrial estate to facilitate change of practices.

Recommendations:
A management strategy for all industries should be developed and implemented involving education, monitoring and industry participation. A pro-forma could be developed for an Environmental Management Plan to be submitted to TSC. The plans could then be followed up with periodic regular auditing for compliance with the submitted plans. The management strategy should consider the following:

- Audit of existing industry management plans and compliance requirements throughout the catchment
- Development of a proforma for an Industry Environmental Management Plan including routine monitoring and checklist sheets
- Development of a web-based process via which completed plans and forms can be returned to Council.
- Development of a management strategy involving education, monitoring, auditing and industry participation.
- Consideration of funding opportunities such as government grants.

13.5 Urban Stormwater

Urban stormwater plays in integral role in determining the health of the broadwaters. Challenges to water quality are created by stormwater generated within urban areas resulting in the export of various pollutants including nutrients, heavy metals, faecal coliforms, pathogens and hydrocarbons. Pollutants deteriorate water quality, aquatic habitat, and lead to eutrophic conditions. Such conditions are unsafe for the community and compromise the health of aquatic ecosystems. The Environmental Values of the broadwaters that require protection include:

- Aquatic ecosystem protection
- Edible Molluscs (Raw)
- Primary Contact Recreation
- Secondary Contact Recreation

To protect the environmental values of the broadwaters, short and long term stormwater management objectives for existing urban areas are provided in the Tweed Stormwater Quality Management Plan, 2000 Some of the short-term objectives include:

- Physico-chemical pollutant loadings from sub-catchments to be reduced
- Nitrogen and phosphorus concentrations reduced in all waterways impacted by urban land use

To plan for and manage the water resource in the Tweed, Council has committed to an Integrated Water Cycle Management (IWCM) process which is the integrated management of water supply, sewerage and stormwater within the catchment strategic framework. One of the key urban stormwater actions contained within the Tweed IWCM Context Study and Strategy (Smith, 2006) is:

- Preparation of a targeted retrofit program of stormwater detention and/or treatment devices for 'hot spot' pre-2000 development areas

The recommendations of this management plan are consistent with the attainment of these objectives. The priority implementation of actions targeting urban stormwater pollution is crucial to the health of the broadwaters given the current health of the broadwaters and the scale of development imminent in the catchment.

13.5.1 Western Drainage Scheme

The Western Drainage Scheme represents the largest current urban 'hot spot' in the catchment of Terranora and Cobaki Broadwaters. This is due to the relative size of the input, its direct discharge to the most poorly flushed part of the broadwater, and the extensive impervious (i.e. paved/urbanised) areas within this catchment. It is a potentially major contributor to ecosystem stress in the Terranora Broadwater and in particular, the potential mobilisation of accumulated drain sludge during high flow events is a major concern.

MUSIC modelling associates pollutant discharge from urban areas based on the area and landuse of each subcatchment. The model indicates that approximately 30% of the urban TN load from all urban subcatchments is discharged from the Western Drainage Scheme. This catchment contains the largest urban subcatchment area (approximately 350 ha). However, it is felt that pollutant loads are likely to be underestimated by the model due to the drainage design of deep channels and lakes. In terms of 'hot spots' the Western Drainage Scheme is a clear priority for further investigation.

To ensure the most cost-effective and well targeted stormwater management solution, it is recommended that a flow-weighted sampling effort be undertaken at major outlets within the drainage network to ascertain the major sources of nutrients from urban areas. Flow-weighted sampling involves sampling over the duration of a rain event including the rising and falling stages of the runoff event to capture variations of pollutant concentrations. This would enable the separation of contributions from the first flush of accumulated pollutants within the catchment and the mobilisation of drain sediments/ accumulated sludge. Accumulated sludge is a potentially large source of nutrients and oxygen-consuming materials. Sludge can act as a pollutant trap and has a very large biochemical oxygen demand. When mobilised it strips the water column of oxygen and releases large amounts of nutrients (re-mobilisation of pollutants from the sediments).

It is likely that the pollutant concentrations in runoff from the scheme will vary significantly depending on factors such as antecedent rainfall and season. As such it is recommended that a minimum of four runoff events be sampled over the course of a year. In addition, the properties of sediments (organic carbon, nutrients) within the drainage scheme should be sampled to better understand internal recycling processes in the lakes and drains which we suspect are a key source of pollutants which are released in pulses during storm events. This monitoring recommendation is consistent with management option NS46 of the Tweed Urban Stormwater Quality Management Plan to investigate pollution types and their sources.

Retrofitting and redesign should be informed by the results of this water and sediment sampling. Options for redesign should consider:

- Drainage canals should be significantly shallowed or converted to dry drains to prevent anoxia, however it is recognised that this would require costly engineering solutions and may meet significant opposition in the community
- Whether smaller wetlands will be more efficient for trapping organic matter and sediment prior to discharge of stormwater to Trutes Bay
- Any lake should have at least 30% plant cover and wetland at least 80% plant cover to enhance pollutant removal capacity
- Bathymetry of lakes and wetlands which can result in dead zones, poor flushing and stratification
- Flooding constraints.

Existing issues
Salvinia molesta is a weed of national significance and declared noxious in NSW. *Salvinia molesta outbreaks* in the Western Drainage network are an indicator of the high nutrient content of the stormwater. Impacts of *Salvinia molesta* include:

- Reduction of dissolved oxygen
- Choking of the waterway
- Prevention of birds and wildlife from using the waterbody
- Reduction of fish
- Restriction of recreational activity.

Other issues include:
- algal blooms
- deoxygenated, stratified water and accumulated sludge that can lead to fish kills
- eutrophic conditions
- residents cutting back fringing vegetation
- lack of instream vegetation

Figure 13.11. Example of parts of the Western Drainage Scheme including a deeper channel with less pollutant removal capacity and higher flood mitigation capacity (left) and shallower, densely vegetated channels providing higher pollutant removal capacity.

Recommendations:
- Undertake a flow-weighted sampling effort at major outlets within the Western Drainage Scheme network (including outlet from Vintage Lakes) to ascertain the major sources of nutrients in urban runoff (four runoff sampling events in one year).
- Undertake sediment analysis (organic carbon, nutrients) within Western Drainage Scheme system to enhance understanding of internal recycling processes e.g. four sediment sampling events in one year - Summer (dry and wet), Autumn, Spring.
- Address ongoing maintenance issues of the Western Drainage Scheme in accordance with the Banora Point Western Drainage Operational Management Plan (Periott, 2001) and investigate a trial of rafted reed beds to improve water quality.
- Following water quality investigations, conduct a workshop with key staff to discuss site-specific solutions.

13.5.2 Other Existing Urban Areas

The established commercial, industrial and urban residential areas are likely to have existing Stormwater Quality Improvement Devices (SQIDs) in need of auditing. It is recommended that the existing SQIDs throughout these priority sub-catchments be investigated and audited so recommendations can be made for either their repair, upgrade, correct maintenance or decommission. This audit process should inform decision-making with respect to implementing Water Sensitive Urban Design measures throughout the catchment. This is consistent with management option NS47 of the Tweed Urban Stormwater Quality Management Plan to measure and report efficacy of stormwater management options including monitoring of pollutant volumes and type trapped by GPT's and other devices.

MUSIC modelling has informed the choice of subcatchments identified as being suitable for retrofitting within this study. The following catchments are likely to be contributing the greatest pollutant loads: the Western Drainage Scheme, future development areas and the Gold Coast Airport. Stormwater treatment in future development areas is discussed further in Section 13.5.3. Gold Coast Airport has a strategy for stormwater treatment and monitoring, making the Western Drainage Scheme the priority area for retro-fitting.

Based on subcatchment area and pollutant contribution, the larger remaining urban areas for consideration include Tweed Heads South and Tweed Heads. In addition, the existing development at Bilambil Heights and Seagulls Estate and surrounding urban area have been added as areas warranting assessment for retrofitting with SQIDs (Figure 13.12).

There exists a range of treatment technology and options available for retr-fitting urban catchments. The appropriateness of these options will be dependant upon site constrints. And pollutants being targeted, but is likely to include bioretention filters, gross pollutant traps, constructed wetlands and sub-surface stormwater filtration. In northern NSW, WSUD typically require a treatment area of between 2% and 5% of the contributing catchment area. Areas nominated in Figure 13.12 are based on 2% of existing catchment.

Working within an established urban area means that any stormwater treatment measure employed must be integrated into the landscape with minimal disturbance to the locality's amenity and social character. It is likely that the final selection and placement of any device will be determined in consultation with the community and various stakeholders. Integrated solutions enable greater response to site constraints (particularly when working within an established urban area), potentially reduce construction costs and reduce the risk of system failure by not relying upon any single device for water quality improvement.

Successful implementation of water sensitive urban design (WSUD) measures requires an appreciation of a variety of issues relating to ecology, engineering, hydrology and landscape architecture. A holistic approach is therefore required to enable a response that will function effectively but also be considered a desirable asset for the community.

Recommendations:

- Audit existing SQIDs in priority existing urban subcatchments including Tweed Heads, Tweed Heads South, Bilambil Heights, and Seagulls Estate so recommendations can be made for their repair, upgrade, maintenance or decommission
- Undertake a Feasibility Study for retrofitting SQIDs in the existing stormwater system throughout, Tweed Heads, Tweed Heads South, Bilambil Heights and Seagulls Estate urban subcatchments.
- Undertake detailed designs and implement retrofitting throughout priority subcatchments

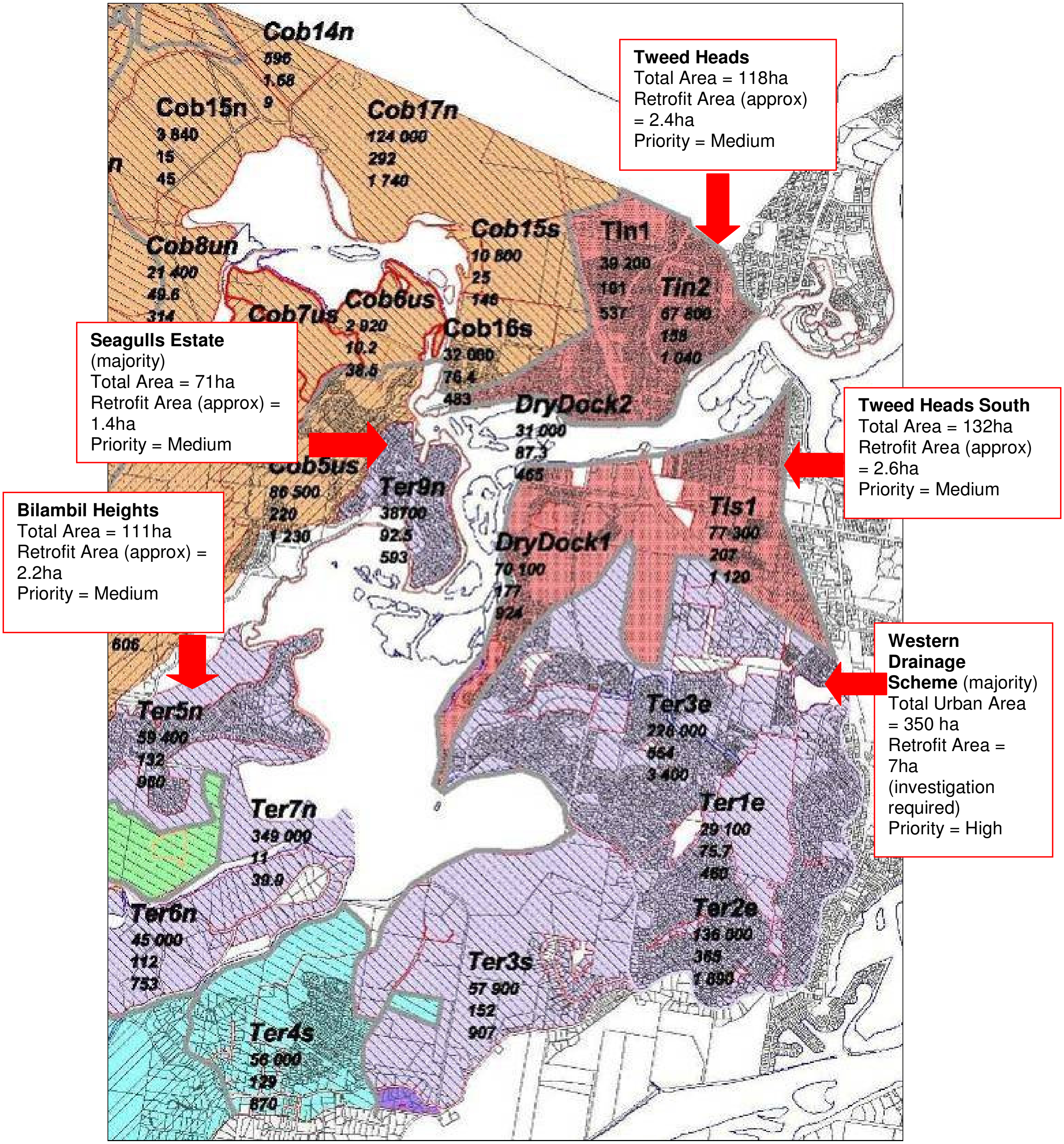


Figure 13.12. Priority areas for SQID retrofitting investigation

13.5.3 Future Urban Development

Stormwater Management Objectives in the Tweed Shire are based on the principles of Ecologically Sustainable Development which is defined as *'development that improves the quality of life both now and forever in a way that maintains the ecological processes on which life depends'* (National Strategy for Ecologically Sustainable Development, 1992, as cited in Tweed Stormwater Management Plan, 2006).

Given the existing stress and extreme sensitivity of both broadwaters, it is vital that future urban development minimises DIN sediment loads to the system to protect ecological processes. The relatively large scale of all proposed and current developments and their proximity to the most poorly flushed reaches of the system combine to create a major threat to the ecological sustainability of the Cobaki-Terranora Broadwater system. The Tweed Urban Stormwater Quality Management Plan has identified erosion and sediment control as a threat to urban water quality and has nominated a management option for new development areas such as Cobaki Lakes including improved inspection and enforcement of sediment and erosion control on building sites (Option NS9). Figure 13.13 shows an example of poorly maintained erosion and sediment control devices within the catchment.

Sediment deposition in the broadwaters affects tidal flushing which can have detrimental effects on water quality and increases mangrove expansion. Pollutants contained within stormwater can also affect benthic invertebrates. Good quality water, a healthy benthic invertebrate community and retention of existing seagrass and intertidal mudflats is also important to ensure no impact on local and migratory shorebirds. In addition to ecological factors, reducing sediment deposition is desirable for retention of scenic amenity, recreation and tourism.

Figure 13.13. Poorly maintained erosion and sediment control devices within the Terranora Broadwater catchment

Tweed Stormwater Quality Management Plan

There are two options for satisfying the criteria for post construction runoff quality:

1. The TSQMP (Section 5.5.3) requires that stormwater runoff post construction or the occupational phase of development, comply with load-based (kg/ha/year) performance criteria by demonstrating compliance using modelling.
2. Alternatively, Section 5.5.5 includes a 'deemed to comply' clause which states that *treatment that is in accordance with the 'deemed to comply' provision of Tweed Shire Council DCP D7 – Stormwater Quality is deemed to comply with the objectives of 5.5.3.* Clause D7.11 sets out the stormwater quality treatment measures that are 'deemed to comply' with the performance criteria in the TSQMP. For large subdivisions (residential > 50 lots or other > 5ha), constructed wetlands are required to remove sediments, pollutants and nutrients. Parameters for the sizing of wetlands are provided and are based around sizing the wetland at 5% of the catchment.

The risk in having a blanket 'deemed to comply' provision is the potential for site specific issues relating to the broadwaters, in this case the removal of DIN, being ignored. It is recommended that DCP D7 and the TSQMP be amended to ultimately include stormwater treatment and discharge performance criteria specifically tailored to problems identified in the Cobaki and Terranora catchments. As an interim measure, the TSQMP should be reviewed and amended with an updated set of water quality objectives and pollutant removal efficiency/load based reduction targets that can be adopted by Council.

Related issues to be considered in the review and update of DCP D7 and TSQP include targeted site-specific pollutant removal. To achieve the level of DIN reductions recommended in this report, Council must specify the implementation SQIDs that remove ammonia and nitrates explicitly. The different removal pathways of these pollutants mean that different treatment measures should be used in series. For example, a combination of bio-retention filters and constructed wetlands will effectively remove DIN and discharge more organic nitrogen rather than dissolved inorganic nitrogen. Such an approach can reduce the total footprint within a sub-division required to achieve the necessary DIN reductions. D7, specifically section D.9 Permanent Water Quality Control Features and Devices should be amended to reflect the need for targeted treatment strategies appropriate for pollutants of concern.

In addition, large future developments or subdivisions should have a site specific stormwater management plan developed which explicitly demonstrates ability to comply with the newly established water quality objectives in the updated TSQMP. This includes the stormwater management plans for Cobaki Lakes, Bilambil Heights and Area E.

A suitable sampling methodology should be developed and included in stormwater management plans that demonstrates stormwater treatment measures meet the newly developed water quality objectives. For example, a median of 15 samples taken from three storm events (5 per storm event). The stormwater management plan should include contingencies in the event that water quality objectives are exceeded.

While these measures are addressing the operational phase of development, one of the major issues in stormwater quality improvement is erosion and sediment control during construction phase. During this time temporary measures must be correctly installed and maintained. It is essential that there be early and regular inspection and enforcement of sediment and erosion controls on construction sites and adjacent areas. Higher penalties such as 'stop work' orders should be considered to achieve 100% compliance.

Recommendations:

- Amend DCP D7 and update TSC's Urban Stormwater Quality Management Plan. Include pollutant removal efficiency/load based reduction targets consistent with industry best practice.
- Work towards developing catchment - specific stormwater discharge targets for Cobaki and Terranora Broadwater catchment that include site-specific pollutant discharge targets.
- Ensure site specific Stormwater Management Plans for all new developments comply with TSC's updated stormwater discharge guidelines.
- Stormwater management plans should include contingencies for scenarios where it appears treatment measures are ineffective in meeting pollutant discharge targets.
- Improve inspection and enforcement of sediment and erosion control on construction sites and adjacent areas through early and regular inspections and higher penalties such as 'stop work' orders to achieve 100% compliance. Allocate additional resources to appoint a specialist environmental compliance officer to Council's regulation staff. Duties to include monitoring compliance with erosion and sediment control, stormwater quality, vegetation clearing, vegetation rehabilitation and other relevant conditions of development approval.

13.6 Wastewater Management

A commitment has been made in the EIS for the Banora Point Water Reclamation Strategy to fund catchment management actions to offset the discharge of nutrients into the Terranora and Cobaki system. This commitment reflects the TSC's acknowledgement that maximum ecological resilience of the whole catchment is required to limit any impact from effluent discharge. This commitment will take the form of ongoing financial investment in catchment rehabilitation, including riparian rehabilitation in rural areas and appropriate retrofitting projects in existing urban areas.

There are community concerns that sewage from the sewage tank located in upper Broadwater Esplanade overflow into a drain leading to Charles Bay area. In response to this concern, Council has recently installed a generator at the sewage pump station at Peninsular Drive. This is a standby and will give protection during extended power outage to prevent any overflow into the waterway.

There are areas of the rural catchment that are unsewered, utilising on-site sewerage facilities (OSSF). Historically, systems in the catchment installed prior to 2002 have been described as being prone to high incidences of failure due to the use of systems not appropriate for the site and lack of maintenance (Smith, 2006). The recent EHMP study (IWC, 2009) included a nitrogen stable isotope parameter that confirmed a high level of sewage related nitrogen in Piggabeen, Cobaki and Duroby Creeks.

Septic systems constructed post 2002 have been subject to licensing and annual inspections. There is an ongoing program of inspections and upgrades to systems built prior to 2002. First round inspections of all systems have been completed, with second round inspections currently underway. Following first round inspections, there has been a substantial improvement in OSSF operation. A report on second round inspections is due in 2010.

If incorrectly sized, not maintained, or located too close to a watercourse, septic systems can lead to:

- Pollution of surface waters via contribution of high levels of nitrogen and phosphorus. Studies have shown that 55-85% of nitrogen entering a septic tank is available to groundwater (Harris, 1995, as cited in GHD, 2002) and a significant percentage of this nitrogen is then eventually discharged to surface water.
- Spread of infectious diseases via groundwater contamination by septic tank leakage – this may result in surface water microbial contamination especially following a rainfall event when effluent may be flushed by the movement of runoff over and through soils into surface water. (This has implications for consumption of aquatic food and primary contact recreation activities).

A performance evaluation of septic tanks in the Gold Coast Region (Goonetilleke *et al.* 2002, as cited in GHD, 2002) was undertaken focussing on blackwater treatment systems to provide an informed overview of the current status of septic tank performance. Key findings of the investigation included:

- In 70% of the sites investigated, there was an immediate need for sludge removal. The build up of sludge can lead to plug flow through the tank with greatly reduced sewage retention time.
- There is limited perception among householders of the adverse public health and environmental consequences of septic tank-soil subsurface effluent disposal system failure.

Given that Primary Contact Recreation is listed as an Environmental Value for all the freshwater creeks, estuaries and the broadwaters, it is recommended (consistent with one of the key actions from the Tweed IWCM Context Study and Strategy, 2006) that resources continue to be allocated to ensure the ongoing inspection of OSSF to help eliminate this potential source of pollutants, particularly DIN and microbial contamination.

Recommendations

- Ensure resources continue to be allocated to the ongoing inspection of OSSF to help eliminate this potential source of pollutants, particularly DIN and microbial contamination.
- Ensure continued monitoring of impacts of Banora Point Water Reclamation Plant on water quality and ecosystem health in Terranora Creek and Broadwater.

13.7 Ecology

Aquatic ecosystem protection is listed as an Environmental Value for all waters of the catchment. This value relates to the protection of water quality and *to ensure that all essential ecological processes can be performed such that the ecological integrity of the system is maintained.* Recent investigations completed as part of the EHMP study (IWC, 2009) indicated low scores for biological indicators such as aquatic macroinvertebrates and fish. There are a number of culverts and creek crossings which are likely to be having a negative effect on fish passage of native fish species within and between creeks.

13.7.1 Fish and Crustaceans

Fish passage is critical to long-term viability of native fish populations. Drainage culverts and creek crossings can represent a significant impediment to the movement of terrestrial and aquatic fauna by creating physical obstructions, increased flow velocities and turbulence (Figure 13.14). These structures can also artificially alter water levels in a locality by sitting higher than a creek invert, having a weir effect. One of the river flow objectives for the Tweed River Catchment is to *minimise effects of weirs and other structures* (DECC, 2009).

Council have mapped the location of fish passage obstructions. There are six culvert bridges in the mid and transition zones of Bilambil Creek and a rock weir obstruction in lower Duroby Creek. The retrofitting of at least the lower four obstructions in Bilambil Creek would enhance a large area of fish habitat. The weir in lower Duroby Creek has been identified as a Level 1 priority site for further geomorphic investigation and another obstruction has been located at Site 9 in Upper Bilambil Creek during geomorphic investigations. It is recommended that investigation into fish/other fauna friendly culverts is conducted at all sites.

Figure 13.14. Culvert bridge fish passage barrier, upper Bilambil Creek (Site 9).

Recommendations:

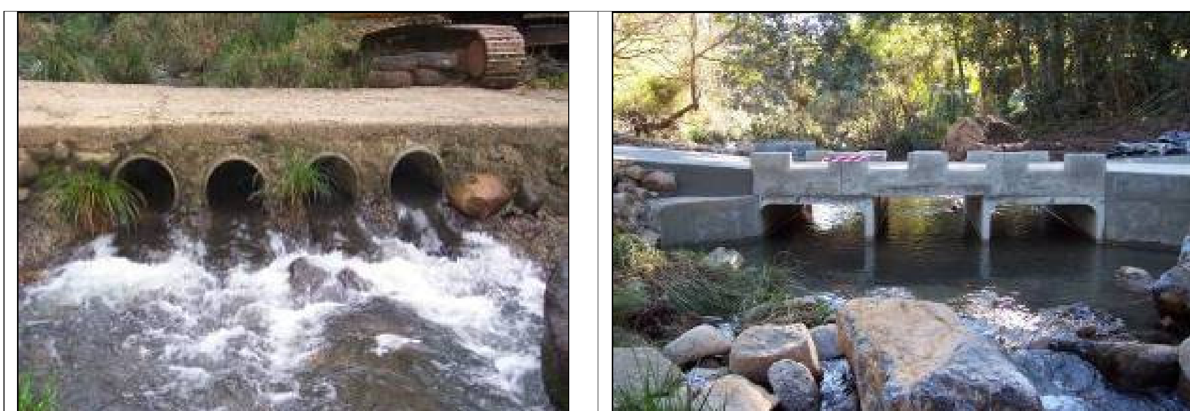
(a) Audit current crossings, culverts and structures mapped as fish passage barriers
(b) Prioritise the retro-fitting of structures from downstream to upstream and those that are having any negative hydrological impact in high flow events
(c) Engage with landholders, RTA, DPI on fish and fauna passage strategies
(d) Ensure that fish and fauna friendly culverts are conditioned as part of any proposed construction of waterway crossings via the planning and development approval process.

It is recommended that the impact of bait collection and related trampling on the Yabbie populations of frequently used intertidal banks in Terranora Creek be investigated and monitored. It is recommended that NSW Fisheries work with Southern Cross University to establish a program of monitoring the abundance of yabbies in Terranora Inlet and consider the establishment of ‘sanctuary’ zones to ensure that sediments and Yabbie populations are not unsustainably impacted.

Examples of road crossings and culverts that have been successfully retro-fitted in New South Wales are provided below (Figure 13.15).

Private landholders crossing, Brunswick River. Causeway replaced with concrete bridge.

Cora Avenue, Mullumbimby, Brunswick River. Pipe causeway replaced with bridge.



Wilsons River. Pipe culvert replaced with box culvert – decreased velocities and increased depth.

Figure 13.15. Examples of fish passage barriers that have been successfully retrofitted in Northern New South Wales,

Source: NSW DPI (Fisheries), M. Gordos.

13.7.2 Shorebird Habitat

Historical and ongoing loss of shorebird habitat creates a need for the creation and long-term management of spring tide roosts close to foraging habitat and managing threats that affect intertidal benthic invertebrates (Table 13.8). The broadwaters provide the ideal opportunity for such an approach as they have low levels of human activity and include large areas of good quality foraging habitat.

Although recreation levels are considered to be low, impacts could occur if the constructed roost is used as a fishing site or the intensity of bait collection and fishing increases on foraging areas. No recreational activity should be allowed on constructed roosts. This could be achieved by applying a 50m watercraft exclusion zone around constructed roosts and imposing fines on watercraft owners that beach their craft on the roost. The exclusion zone should be signposted. At present levels bait collection and/or fishing on foraging areas may have minimal impact on shorebirds, although the intensity of use should be monitored. There are no established benchmarks to identify detrimental disturbance levels, although a precautionary approach is warranted. Appropriate levels of disturbance would need to be established at the time of monitoring. If monitoring identified a detrimental impact then restrictions should be applied. Types of restrictions could include zoning intertidal areas to distinguish between areas of high, moderate and low importance to shorebirds and the imposition of buffer zones. At present, recreational disturbance at low tide is assumed to be low, however, a brief field survey may be warranted to confirm this assumption.

The proposed management strategy for shorebirds in Cobaki and Terranora Broadwaters focuses on the construction of two spring tide roosts, one in each broadwater. The construction of secure roosts is paramount to managing the estuaries shorebird population and is consistent with previous recommendations (Sandpiper Ecological Surveys 1998; 2003). Restoration of existing high tide roosts, such as Pony Club and Duroby Marsh is not recommended. The likelihood of gaining approval for restoration at Pony Club and Duroby Marsh is low because the Pony Club roost is located beneath the flight path of Gold Coast Airport, mangrove growth at Duroby Marsh is well advanced, and regenerating floodplain vegetation at Pony Club satisfies the definition of Swamp Oak Forest on Coastal Floodplain, an Endangered Ecological Community.

The construction of roosts in both broadwaters should be treated as separate proposals (Table 13.8). Tommy's Island roost in Terranora Broadwater is the main priority as it has a high likelihood of success and is less costly than options for Cobaki Broadwater.

The proposed Terranora roost is situated on a small rocky outcrop (Tommy's Island) at the entrance to Trutes Bay (Figure 13.16). The island has an area of approximately 0.14ha and consists of regrowth Swamp Oak with fringing mangroves. The island has been previously used as a storage area for nearby oyster leases and may have been previously cleared. The island is approximately 1-1.5m above Spring High Water and is approximately 80m from the mainland. The cost of constructing a roost at Tommy's Island would be low compared to other options discussed for Terranora Broadwater (Sandpiper Ecological Surveys 1998, 2003). The advantages of Tommy's Island include: low relative cost; separated from the mainland and areas of human recreation; low energy tidal environment; and previous site disturbance. The major disadvantage is that the island is dominated by protected vegetation.

Ongoing maintenance will be a critical component of any proposal to construct a roost. Maintenance would involve annual vegetation control prior to the arrival of migratory shorebirds. It may also be feasible to construct a bird hide on the adjacent mainland to enable local bird watchers to observe the roost (Figure 13.16). A bird hide is regarded as a low priority as it is necessary to firstly ensure that birds use the roost and to determine if roosting birds are observable from the mainland.

There are greater constraints on the construction of a roost in Cobaki Broadwater. As a first step it is recommended that Council seek formal advice from Gold Coast Airport Limited (GCAL) that they do not support a roost at the former dredge spoil site as proposed by Sandpiper Ecological Surveys (2003; 2005). If the dredge spoil site is confirmed as unviable then the feasibility of two alternative roost options should be assessed.

There are several options for roosts in Cobaki Broadwater (Figure 13.17), including:

1. Using dredge spoil to develop a sand island roost on the existing mangrove roost.
2. Using dredge spoil to develop a sand island roost on the existing neap tide roost.
3. Using a combination of fill, minor clearing and rock revetments to create roosts on either the southern or western shores.

Both options 1 and 2 would require protection from wave energy and engineering input will be essential at the onset. Shoreline sites (option 3) are less viable as they abut tall vegetation and would have reduced visibility, although the southern site would be accessible from the mainland and adjoins crown land.

One of the management issues described in Section 13 is how to manage estuarine habitat areas that are changing over time and for which there are competing uses and ecological values. For example, the conflict between providing areas for human recreation and protection of shorebird habitat, the conflict between retaining shorebird habitat and mangrove protection, the trend toward mangrove encroachment and declining saltmarsh, and urban development pressures. In order to adopt a balanced ‘ecosystem approach’ to estuary management, a strategy should be developed to address the often conflicting management issues of recreation, shorebird habitat protection, mangrove and saltmarsh preservation.

Recommendations:

- Assess the feasibility of constructing a spring tide shorebird roost at Tommy’s Island in Terranora Broadwater

  (a) Discuss feasibility with state agencies and engineers.
  (b) Undertake Environmental Impact Assessment
  (c) Construction of roost
  (d) Prohibit boat access to roost site – install a sign 20m west of site identifying site as a shorebird roost, and impose penalties on those using roost for recreation.

- If Tommy’s Island is unviable for a spring tide shorebird roost, assess the feasibility of constructing a sand island roost on the existing neap tide roost at Womgin Island.
- Assess the feasibility of constructing a spring tide roost around the small mangrove island in the southern part of Cobaki Broadwater or on the existing neap tide roost (Figure 13.17). Discuss with state agencies and engineers.
- Develop a strategy for management of dynamic estuarine areas for which there are often conflicting management issues involving recreation, shorebird habitat protection, mangrove and saltmarsh preservation.

Figure 13.16. Location of Tommy's Island, bird hide investigation area and alternative roost site in Terranora Broadwater.

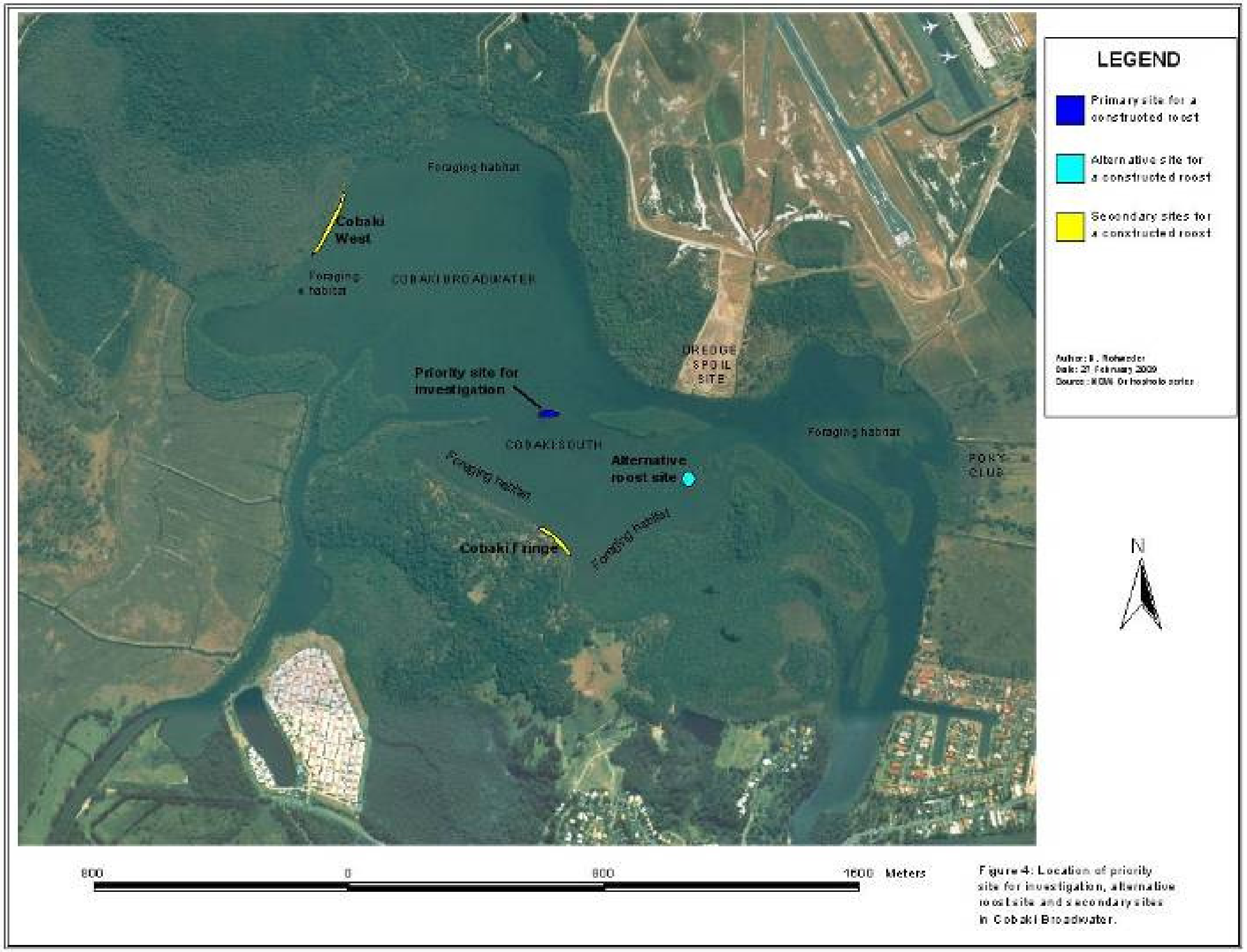


Figure 13.17. Location of priority site for investigation, alternative roost site and secondary sites in Cobaki Broadwater.

Table 13.8. Management strategies for shorebird habitat

Issue and Present Situation	Desired Outcome	Actions and Guidelines	Priority
Spring tide roost in Terranora Broadwater Spring tide roosting habitat in Terranora Broadwater is limited to mangroves and saltmarsh at Duroby Marsh. Mangrove roosts are suitable for Whimbrel and Grey-tailed Tattler only and habitat at Duroby Marsh is declining in quality.	Create a spring-tide roost situated close to important foraging habitat at Trutes Bay, Trutes Bay west and Womgin Island. Such a roost would minimise the movement distances required and be isolated from major areas of human recreation.	Construct a spring tide roost at Tommy's Island. Actions would include: • Initial discussions with state agencies (i.e. DPI Fisheries, DECC, DoP) and engineers to asses feasibility. • Prepare an Environmental Impact Assessment. • If approved seek funding and implement the project. Actions required to create a roost on Tommy's Island are simplified due to the presence of an existing stable base which overcomes, to some extent, problems of erosion. A preliminary list of actions include: remove all vegetation and rubbish (i.e. old oyster-farming infrastructure) from the island (Note: some rubbish such as concrete blocks may be used to assist with stabilising the site); lower the islands elevation to minimise future vegetation growth; depending on the substrate import sand or oyster shell; if required, install a perimeter of small rocks or blocks 10-15m from the shoreline to diffuse wave energy and minimise erosion – the perimeter of blocks or rocks would also inhibit boat access at high tide. There may be opportunity to retain small patches of mangroves on Tommy's Island, although colonising mangroves should be regularly removed. b) Prohibit boat access to the site by: • Installing signs 20m to the west and east of the site that identifies the site as a shorebird roost. • Impose penalties on people using the roost for recreation. c) Assess the feasibility of constructing a bird hide at the nearby point (Figure 13.16). A hide at this location could be used to promote the importance of the site, educate the public and allow for easy monitoring. The hide must be designed to ensure that human activity is not visible from the roost. d) If Tommy's Island is unviable assess the feasibility of constructing a sand island roost on the existing neap tide roost at Womgin Island (Figure 13.16).	High High Low High
Spring tide roost in Cobaki Broadwater Spring tide roosting habitat in Cobaki Broadwater has either degraded to the point where it is suitable for very few individuals and species or consists of mangrove habitat that is suitable for Whimbrel and Grey-tailed Tattler only.	A spring-tide roost situated close to important foraging habitat in Cobaki Broadwater. Such a roost would minimise the movement distances required and be isolated from major areas of human recreation.	a) Assess the feasibility of constructing a spring tide roost around the small mangrove island in the southern part of Cobaki Broadwater or on the existing neap tide roost (Figure 13.17). The feasibility study should include input from engineers and state agency representatives.	Medium

Issue and Present Situation	Desired Outcome	Actions and Guidelines	Priority
Sediment deposition and water quality Sediment deposition in the broadwaters affects tidal flushing which can have detrimental effects on water quality and increases mangrove expansion. Stormwater can carry pollutants into the broadwaters, which may affect water quality and benthic invertebrates.	Good water quality, a healthy benthic invertebrate community and retention of existing seagrass and intertidal mudflats.	a) Ensure that best practice erosion controls are applied to all development within the catchments. b) Educate residents about the effect of depositing waste products into the stormwater network. c) Ensure that mitigation measures proposed in Development Applications are applied during construction.	High
Human recreation on roosts At present human recreation is limited to low intensity activities such as fishing. The intensity of extant recreation does not pose a threat to shorebirds; however, constructed roosts may become favoured sites for recreation and stringent controls will need to be implemented and enforced to ensure that human activity at roosts is discouraged.	No human recreation occurs on constructed roosts in the Terranora and Cobaki Broadwaters.	a) Ensure that constructed roosts are given appropriate protection in Local Environmental Plans. b) Impose a 50m exclusion zone around constructed roosts. c) Encourage residents to report registration details of watercraft beached on roosts to the Waterways Authority or Tweed Shire Council. d) Impose penalties on watercraft owners and operators that utilise constructed roosts for recreation. e) Provide signage to discourage use. Signs should be installed within a 50m radius of the roost. f) Carefully evaluate the impact on shorebirds of any proposals for water-based tourism in Cobaki and Terranora Broadwaters.	High
Human recreation on feeding areas Disturbance of foraging shorebirds can increase energy expenditure and reduce their ability to meet daily and seasonal energy requirements. Human recreation on foraging areas is predicted to be low, however, site specific data are lacking.	Human recreation on or adjacent to foraging areas does not have a detrimental impact on shorebirds.	a) Implement a study to determine the type, frequency and distribution of human recreation on and near shorebird foraging areas in Cobaki and Terranora Broadwaters and determine if these activities have a detrimental impact on shorebirds. b) Depending on the findings of the above study consider options to reduce the impact of recreation on shorebirds.	Medium
Monitoring of constructed and restored roosts Monitoring will be required to ascertain if roost creation and restoration has been successful. Monitoring will also provide useful information on design changes and maintenance requirements.	Obtain information on the use of constructed and restored roosts by shorebirds and any benefits to the estuaries shorebird population.	a) Monitor the use of constructed sites by shorebirds in spring/summer during years 1, 2, 5 and 10 post construction. b) Monitor the use of restored sites by shorebirds during the first spring/summer period following the completion of remediation work.	High
Roost maintenance Constructed roosts will require on-going maintenance to ensure that woody vegetation does not colonise the roost and reduce its suitability for shorebirds.	Spring tide roosts that are free from woody vegetation and suitable for roosting shorebirds.	a) Annually remove all woody vegetation from roosts including mangrove seedlings along the foreshore. Inspect any retained patches of mangroves to determine if pruning is required. b) Maintenance should be undertaken in July/August each year prior to the arrival of migratory shorebirds. c) Obtain a permit from DPI Fisheries for the ongoing control of mangroves on constructed roosts.	High

13.8 Cultural Heritage

The key document for cultural heritage management is the Cobaki and Terranora Broadwater Aboriginal Cultural Heritage Management Plan (Fox, 2006). The following recommendations were taken from the implementation strategies of this plan to assist in the cohesive management of cultural heritage within the catchment.

Recommendations

- Compile a heritage schedule of Aboriginal sites and places which are to be listed on the Tweed LEP and managed in accordance with stated conservation provision to be listed in the LEP
- Ensure that an appropriate Aboriginal cultural heritage study and assessment are conducted for all developments that will cause land surface disturbance within culturally sensitive landforms as mapped in Cobaki and Terranora Broadwater Aboriginal Cultural Heritage Management Plan (Fox, 2006)
- Establish a formal policy of appropriate consultation protocols with the local Aboriginal community (as per the Implementation Strategy of the Cobaki and Terranora Broadwater Aboriginal Cultural Heritage Management Plan (Fox, 2006).
- Update the Cobaki and Terranora Broadwater Cultural Heritage Management Plan to incorporate new information gained through recent site assessments.

13.9 Recreation

There are several formal recreation facilities located along the foreshores areas of the broadwaters including Plover Place/Tringa Street Reserves, Pioneer Park and Boyd Family Park in the vicinity of Kennedy Drive bridge and parks throughout the north-western bays of Terranora Broadwater including a small public jetty in Birds Bay. There is also a network of walkways and cycleways throughout the urban areas. Given the primary goals of improving water quality, protecting and enhancing existing terrestrial and aquatic habitat and the natural sensitivity of the system, recommendations regarding recreation must be low-impact, or passive activities.

13.9.1 Canoe Trail

Both broadwaters are very shallow and represent a significant navigational hazard for all but canoes, kayaks, small ‘tinnies’ and punts (NSW Maritime, 2006). The strategy of the Tweed Estuary Boating Plan (2006 – 2010) is to discourage any improvements in boating access that would increase boating activity. Passive recreational activities such as canoeing and kayaking are consistent with this strategy and also provide an educational opportunity.

The large islands in Terranora Broadwater and the nexus with Terranora Creek are included in the Tweed Estuary Nature Reserve managed by NSW NPWS. The primary emphasis of this plan is the conservation of the natural and cultural values of the reserve, and does not provide provisions for visitor use. Canoe trails around the islands are consistent with the management strategies of Tweed Estuary Nature Reserve Draft Plan of Management (DECC, 2007) which promote only nature-based visitor use of the reserve, such as bird watching and nature study. Facilities should not be provided on the islands to discourage visitor use of the islands.

It is recommended that opportunities are investigated for a canoe discovery trail in Terranora and Cobaki Broadwaters with guide brochure and interpretive signage to include Aboriginal cultural heritage signage along the eastern foreshore of Terranora Broadwater. An outcome of the project is to improve public acceptance and recognition of responsible behaviour towards Aboriginal heritage sites, as recommended in the Cobaki and Terranora Broadwater Aboriginal Cultural Heritage Management Plan (Fox, 2006).

The trail could incorporate information about shorebird habitat (natural and constructed) and signage identifying roost sites and advice on distance recreational users need to be from roost sites. It is important that no recreation occurs on constructed roosts or on or adjacent to foraging areas in the broadwaters. Existing launch sites could be utilised. A map showing an indicative canoe trail proposed as part of the previous management plan for Terranora Broadwater is provided below (Figure 13.18).

Recommendation:
- Investigate opportunities for canoe discovery trail in Terranora and Cobaki Broadwaters with guide brochure and interpretive signage, incorporating Aboriginal cultural heritage signage
- Create a canoe launch point at Boyd Family Park.

13.9.2 Boardwalks and Walkways

Increasing public access to foreshores when feasible and environmentally sustainable options are available is an objective of the NSW Coastal Policy (1997). There are several options for extending access to the foreshore and enhancing walkways along foreshore areas. Options to extend the eastern foreshore walkway of Terranora Broadwater should be investigated to provide a link from the Tweed Broadwater Village to the north-west corner of Trutes Bay. At this point a bird hide has been proposed to allow viewing of the proposed constructed roost site on Tommy's Island (shown in Figure 13.18 as a green circle). Consistent with the Terranora Broadwater Aboriginal Cultural Heritage Management Plan (Fox, 2006), the walking track along the eastern foreshore would incorporate cultural educational interpretive signage as this area contains eight highly significant shell midden sites. Based on detailed recommendations for signage developed during consultation with AAC, the design of signage is complete and awaiting installation.

Final designs for the construction of the foreshore walkway at Dog Bay, Terranora Broadwater should be completed. The location of the walkway, as indicated in Figure 13.18 is from Peninsula Drive to Broadwater Esplanade along the northern end of Dog Bay. Also to be considered is the feasibility of creating a walkway along Bilambil Creek from Bilambil Village, around the western foreshore of Terranora Broadwater to Seagulls Estate.

There are existing fire trails that run through the bushland surrounding Cobaki Broadwater that may be suitable for walking trails. For example, walkways could be created from the Leda-owned land on the north-west foreshore to the National Estate and from Boyd Family Park along the southern foreshore to the eastern side of the Cobaki Creek entrance. This is considered a lower priority action that could be investigated following development at Cobaki Lakes.

The Western Drainage Scheme waterway system may provide an opportunity for recreation areas by including a cycle and pedestrian pathway system linking other residential areas, sports fields and schools (Banora Point/South Tweed Stormwater Management Plan, 1999). An interpretive wetland boardwalk system could be investigated, however any recreation or rehabilitation considerations should be delayed until all stormwater investigations and SQID investigations and subsequent retrofitting designs have been implemented. As such, this is a low priority recommendation.

Recommendations

- Investigate feasibility of extending walkway along eastern foreshore of Terranora Broadwater from approximately Ridgeview Street (south of Tweed Broadwater Village) to Daintree Close (north-west corner of Trutes Bay).
- Complete final design and obtain approvals for construction of foreshore walkway in Dog Bay, Terranora Broadwater. Walkway to extend approximately from Peninsula Drive to Broadwater Esplanade.
- Investigate feasibility of creating a walkway along Bilambil Creek from Bilambil Village, around the western foreshore of Terranora Broadwater to Seagulls Estate.
- Relace destroyed interpretive signage along foreshore in Bingham Bay.
- Consider practicality of walking trails on existing fire trails around Cobaki Broadwater area once developed as Cobaki Lakes (e.g. Leda land to National Estate and Boyd Family Park to the eastern side of Cobaki Creek entrance).
- If monitoring of the proposed bird roost site in Terranora Broadwater indicates success based on observable bird roosting behaviour, undertake feasibility study on construction of a bird hide on the promontory on the adjacent mainland to enable local bird watchers to observe the roost.
- Consider recreation and interpretive wetland opportunities in The Western Drainage Scheme waterway system. This action should be delayed until all stormwater quality and SQID investigations are completed so subsequent retrofitting designs can incorporate relevant aspects of recreation.

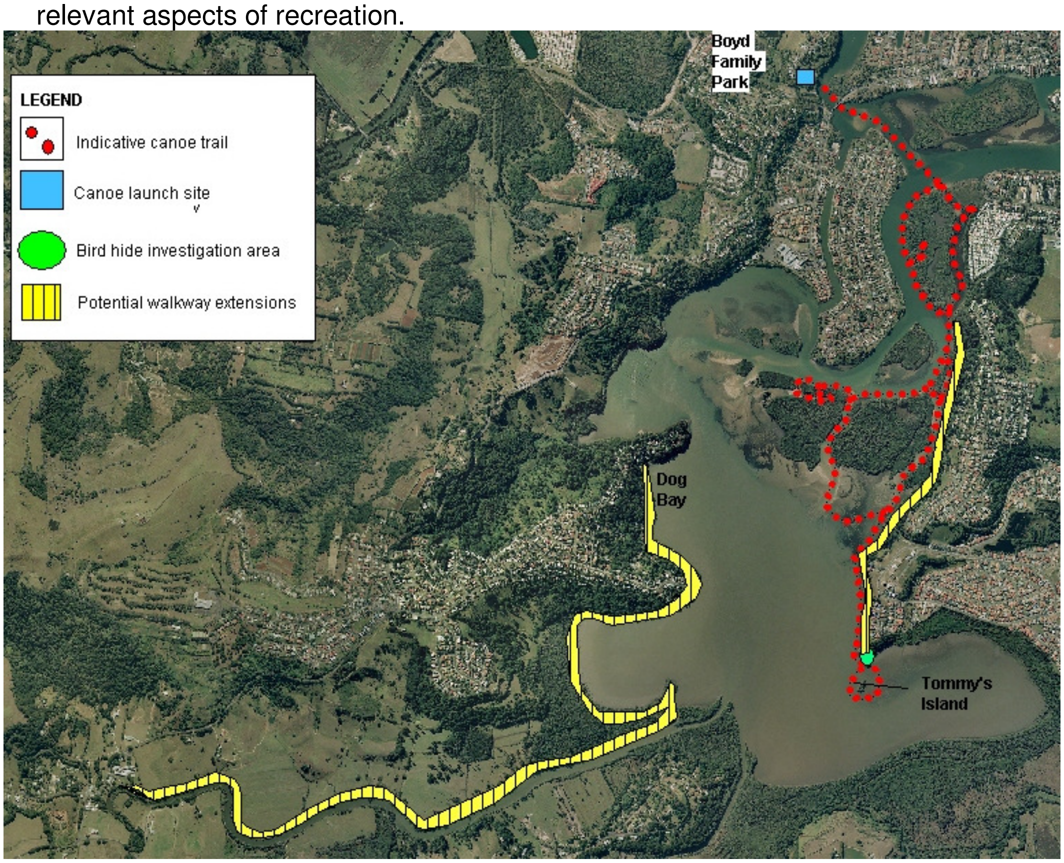


Figure 13.18. Indicative location of proposed boardwalks, walkways, canoe trail and bird hide.
Note: The shaded area of walkways is not to scale, but indicative of the proposed location only.

13.10 Mosquito and Biting Midge Management

There is a bund at Area E that requires restoration to prevent salt water intrusion into a freshwater wetland area. Restoration of the bund will assist with the reduction of mosquito breeding habitat.

13.10.1 DCP A6 – Biting Midge and Mosquito Control

Development Control Plan A6 relates to biting midge and mosquito control by providing guidelines for proposed and existing residential and tourist developments to minimise and control the problem. The provisions of this DCP must be taken into consideration by the Council in the determination of development applications.

The provisions of this DCP are particularly relevant to the catchment given the level of proposed development and the proximity of this proposed development to breeding areas around the broadwaters. Relevant guidelines relating to stormwater treatment design include:

- *Waterway design to avoid the potential for extensive emergent aquatic plant growth. Generally this will require the majority of the water body to be deeper than 2m.*

This contradicts the requirements of a healthy treatment wetland and will need to be considered in stormwater treatment designs for relevant developments such as Cobaki Lakes. Studies have shown that healthy treatment wetlands with a high cover of emergent aquatic plants are not associated with mosquito-related issues (Greenway *et. al.,* 2003). Well balanced and maintained wetlands deter mosquito breeding by providing healthy habitat for macroinvertebrate predators that feed on mosquito larvae, acting as a biological control. In Australian Wetlands' experience, no occasion has arisen where a healthy wetland system has provided significant breeding opportunities for mosquitos.

Recommendations

- Design considerations for stormwater treatment waterbodies may conflict with the guidelines in DCP A6, however current best practice in wetland design should be adhered to, i.e. water bodies should not be designed to be deeper than 2m.
- Restoration of the bund in Area E to prevent salt water intrusion into the freshwater wetland area to reduce mosquito breeding habitat.

13.11 Education

Target W3 of the NRCAP is *Increased community awareness and understanding of how catchments work and how human activities impact upon them via environmental education*.

One of the major issues identified by the community in the process of developing water quality objectives for the Tweed River system, was the provision of more information to the community on managing aquatic environments and water resources. In particular, the community wanted water quality, flow monitoring and biological health information to be further developed and communicated. In response to this, the EHMP was undertaken in 2008 to provide an accessible snapshot of the ecosystem health of the broadwater and major tributaries.

13.11.1 Riparian Restoration Demonstration Sites

To provide examples of good riparian management for each major riparian region of the catchment, demonstration sites could be developed on public land to provide 'reference' sites in the catchment for landowners within that region. Reference sites provide details of the kind of vegetation, the species components and the percentages of each species that occur in that reach of the catchment and how landowners' creek frontage could look. Included could be a description of the key functions provided by a healthy riparian zone. This information can be provided by suitably located interpretive signage and be incorporated into other educational programs such as restoration workshops.

There is also an opportunity to demonstrate before and after restoration at sites currently degraded and/or under restoration. Images of the current degraded condition could be contrasted with the design outcome. As part of the education process, the community could watch the progress of the rehabilitation from the degraded state to the design outcome. An example of an excellent demonstration site is Site 5, near the sportsground in Lower Bilambil Creek (Section 8).

13.11.2 Water Quality

Education programs aimed specifically at reducing stormwater pollution at the source are required to address the ecosystem health issues highlighted in the current study and the EHMP results. The residents of the Western Drainage Scheme catchment should be targeted as a priority. To target water quality issues such as elevated nutrients, turbidity and potential bacterial contamination, the following should be included in a stormwater pollution education strategy:

- Excess fertiliser application in residential areas
- Washing of cars in streets
- Sewer overflows
- Faecal contamination from domestic animals and stock
- Litter - including the impacts of discarded fishing materials (e.g. hooks and fishing line) and general litter including plastics on sea birds and marine life generally.

Recommendations

- Consider the development of riparian restoration demonstration sites on public land to provide 'reference' sites in the catchment, e.g. Site 5, sportsground in Lower Bilambil Creek
- Publicity and education of EHMP scorecard results to increase awareness of water quality issues throughout the catchment
- Education program aimed specifically at reduction of stormwater pollution at the source to improve the stormwater quality of the rural and urban catchment
- Undertake an education program targeting the impacts of discarded fishing materials (e.g. hooks and fishing line) and general litter including plastics on sea birds and marine life generally.
- Install interpretive signage regarding the significant archaeological sites along the eastern foreshore of Terranora Broadwater. Manufacture and installation pending resource allocation
- Make accessible to the public the detailed flora and fauna surveys undertaken including:
  - native vegetation, threatened/significant flora
  - habitat values of native vegetation for fauna and threatened/significant species
  - Aboriginal heritage values
- Promote the importance of roost sites, including those constructed. Educate importance of not disturbing sites.

13.12 Monitoring

13.12.1 Water Quality

To assist with prioritisation of future catchment rehabilitation areas, cost-effective, targeted stormwater quality improvement and problematic onsite sewerage systems, monitoring to identify DIN sources in the catchment should be undertaken. A spatially intensive water quality monitoring strategy should be carried out to help pin point the most likely hotspots for DIN entering the streams. Sites should be chosen to provide good resolution of reach-scale variations in water quality associated with distinct land use and geomorphologic units. A minimum of two sample efforts should be made during median and high flow conditions. This will promote understanding of nitrogen speciation between the different functional zones and sources of DIN. This information can assist with the generation of optimal actions for each zone and is consistent with the recommendations made in the EHMP study (IWC, 2009). As a medium term action, the results of this investigation will provide information on the effectiveness of catchment rehabilitation.

Recommendation

- Identify DIN sources in the catchment. Undertake spatially intensive water quality monitoring strategy to pin point most likely hotspots for DIN entering streams. Minimum of two sample events during median and high flow conditions.

13.12.2 Shorebird Roosts

Monitoring of both constructed and restored roosts will be required to ascertain if roost creation and restoration has been successful and to determine any benefits to the estuary's shorebird population. Monitoring will also provide useful information on design changes and maintenance requirements.

Recommendation

- Monitor the use of constructed roost sites by shorebirds to determine success based on observable bird roosting behaviour. Monitor in spring/summer during years 1, 2, 5 and 10 post construction
- Monitor the use of restored bird roost sites by shorebirds during the first spring/summer period following the completion of remediation work

13.12.3 Riparian Vegetation

To assist with evaluating the long term rehabilitation of riparian vegetation througnout the catchment, and the achievement of long term management targets, the rapid API can be repeated prior to the updating of this plan as per the methodology used in this study, described in Section 8.6. Riparian cover and riparian width can be estimated and categorised for each creek using the most recent aerial images available and compared against the 'baseline' results in Section 8.6. This process may also be useful for identifying areas that have been illegally cleared.

For a medium term evaluation of management target achievement, a database should be kept of all riparian revegetation throughout the catchment, incorporating ephemeral drainage channels. Records should include rehabilitated width, percentage weed cover and FPC when more established. This will provide a clear indication of progress in working towards the target areas (Section 8.6).

Recommendations

- Aerial photo interpretation assessment of riparian width and % canopy cover in updated photos after 5 years to measure improvement.

13.13 Climate Change

The estuarine environment has evolved in response to anthropogenic modifications to the catchment and estuary mouth (e.g. construction of training wall at estuary mouth) and is likely to continue to change in response to climate change. Planning for climate change is an important part of the management of the catchment.

Recommendations

- Undertake land and habitat vulnerability assessments.
- Develop climate change adaptation strategies.
- Incorporate climate change impact actions into planning instruments, development controls and environmental assessments.

14 Summary and Conclusion

The common goal for all stakeholders and managers is to ensure a healthy, functional ecosystem that maintains the capacity to assimilate pollutants so that its values can be enjoyed into the future. The broadwaters' shallow conditions and reduced flushing mean they act like a retention pond to the surrounding rural and urban catchment, and by nature absorb the stormwater runoff impact by assimilating catchment-derived pollutants. The question is: how much longer can the broadwaters assimilate these pollutants and support ecosystem health?

The quality of material delivered to the broadwaters can impact upon the internal recycling and assimilative ability of the system. Once the assimilative capacity is exceeded, internal recycling will be inefficient (as suggested by nutrient cycling data from the EHMP study (IWC, 2009), impacting upon the foodchain including macrofauna such as the local bird populations.

Examples of conditions/scenarios that promote the delivery of poor quality material to the broadwater system include:

- Areas of the catchment that have been cleared (in particular the riparian zone)
- Tweed Shire Council's Banora Point Wastewater Treatment plant discharge
- Bank erosion
- Stock accessing waterways
- Instances of construction erosion and sediment control failure
- Insufficient treatment of urban stormwater.

The aim of recent investigations was to understand the current condition of ecosystem health and run an assimilative model to determine whether the Broadwaters can continue to act as a sink for nutrients under existing and future anticipated loadings, or if the assimilative capacity is likely to be exceeded.

CURRENT SCENARIO

The current condition of ecosystem health has been described as Fair – Poor (IWC, 2009), with data suggesting the streams are moderately to highly stressed and the system is on the threshold of major impacts. Chlorophyll *a* targets are already being exceeded on occasion. If no action is taken, there are likely to be detrimental impacts on the ecology of the broadwaters such as compromised health and loss of seagrass, and subsequent impacts on aquatic fauna and higher order fauna including bird populations (Figure 0.1).

The health of the system is currently impacted by:

- Recycling of nutrients from sediments and nutrients from STP effluent tidally moving upstream to the broadwaters
- Urban stormwater, particularly from the Western Drainage Scheme
- Rural catchment runoff.

Significant work needs to be undertaken if the current health of the system is to be improved. The pollutant of greatest concern to ecosystem health is dissolved inorganic nitrogen (DIN) loading as it is the primary driver of phytoplankton biomass (chlorophyll-*a*, an indicator of algal blooms). To keep the chlorophyll-a concentration low enough to ensure a healthy functioning ecosystem, it is necessary to reduce total catchment DIN loads by approximately 30% in both the Terranora and Cobaki Broadwater catchments.

FUTURE SCENARIO WITH ADDITIONAL PLANNED DEVELOPMENT

The relatively large scale of all proposed developments and their proximity to the most poorly flushed reaches of the system combine to pose a major threat to the ecological sustainability of the Cobaki - Terranora Broadwater system. Given the existing stress caused by urban and agricultural runoff and sewage discharge and the extreme sensitivity of both broadwaters to increases in DIN loading, it is vital that future urban development strives to minimise DIN loads to the system.

The impact of development is likely to be heightened due to proximity to the broadwaters and the relatively long residence times of freshwater runoff. The shallowness of Cobaki Broadwater means light penetration will not limit phytoplankton production, thus enhancing the likelihood of rapid development of large algal blooms which are likely to have a major impact on the ecology of the system (Figure 0.1).

Impending large scale development increases the urgency to implement measures now that will reduce current DIN concentrations. Rural catchment rehabilitation alone, while important, is not sufficient to offset the impacts of the large scale development planned. The implementation of best practice site-specific Water Sensitive Urban Design is of paramount importance to maintaining at least the current status of the broadwaters.

Future sustainability of the broadwaters will depend largely on community and government commitment to the immediate implementation of priority CZMP recommendations. A collaborative effort is required now to improve urban stormwater quality + rehabilitate the rural riparian zone + minimise as far as possible any impact from development, to maintain a healthy, functional ecosystem for future generations.

The CZMP has drawn together existing legislation, planning and policy in the context of the location within the constraints of localised and regional human population requirements, to form an achievable set of management actions that can provide a measurable improvement in the health of the Broadwaters. This document is intended for review at appropriate intervals in the future.

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Appendix A: Stakeholder Consultation

Workshops

An innovative methodology has been applied to the task of documenting the CZMP. A workshop based approach was used to guide and inform the design process. An expert panel was established, incorporating the disciplines of catchment management, aquatic and terrestrial ecology, aquatic biogeochemistry, pollutant modelling, ecological design and restoration and stormwater management. There were three workshops undertaken.

The workshop panel consisted of:

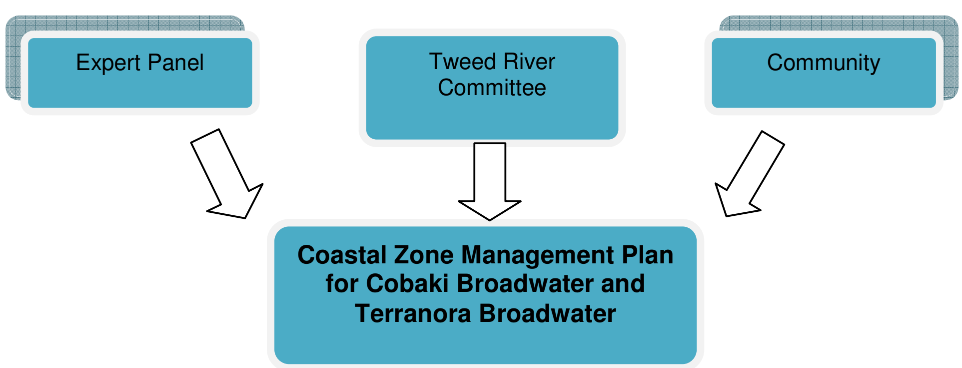
- Tom Alletson (Tweed Shire Council)
- Jane Lofthouse (Tweed Shire Council)
- Marty Hancock (Tweed Shire Council)
- Richard Hagley (Department of Environmental and Climate Change)
- Dr Angus Ferguson (ABER)
- Sarah Holloway (Australian Wetlands)
- Damian McCann (Australian Wetlands)
- Peter Adcock (Australian Wetlands)

In addition to the workshops, the team consulted the Tweed River Committee on two occasions, Council engaged David Rohweder of Sandpiper Ecological for an updated report on Shorebirds and their habitat.

Stakeholder Consultation

Several members of the community were consulted in the initial phases of the project to identify new or emerging management issues and to identify community objectives for catchment water quality and ecological health. The community were advised of the management plan process in the Tweed Link newspaper and several members of the community contacted the team with comments and concerns relating to catchment management and ecosystem health which have been incorporated into the Plan.

The EHMP was undertaken concurrently with this project, the results of which were incorporated into the management plan by providing the most recent ecosystem health assessment data. Following the assimilation of this data, the community were presented with the Draft Management Plan and invited to comment and make submissions. A community meeting was held on 25th November 2009, attended by 21 community members, Council staff and Councillors. Feedback from the community and the Tweed River Committee was considered and incorporated into the final document.



Appendix B. Stage 1 Riparian and Geomorphic Assessment

STAGE 1: Desktop/aerial Mapping Evaluation

DATE : 13/1/08 LOCATION: Upper Bilambil Creek 1

Notes: Limited potential for water quality improvement as regrowth appears to be occurring. Private landholders could be encouraged to carry out extension of riparian zone and weed control. Strong connectivity to existing forest

RIPARIAN SITE PRIORITISATION/ CLASSIFICATION SCORE (reach based 250m approx)	SCORE
SEPP 14 /other – score 10 for protection / 7.5 for adjacent to protected area/ 5 for across river, 0 for no protection.	**0 / 10**
Known ecological significance/ HCV – score 10 for ecological significance or for a site adjacent to an area of significance, 0 for no significance **note type:** potential HCV rainforest adjoining (102, 1099), significant forested area adjoining. Other forested communities Brushbox (207), Grey ironbark/ White mahogany (202). Flooded Gum open forest (206).	**10 / 10**
Threatened flora or fauna species – score 5 for threatened species/ 0 for no threatened species recorded at sites **rainforest spp. potential Koala habitat**	**5 / 5**
Location tenure - 1 = all private, 3 = public and private landholders, 5 = all public	**1/ 5**
Land management /community opportunities – 0 = none, not explored, 3 = some potential, 5 = high potential	**3/ 5**
Proximity to riparian zone/existing wetlands/forest - 0 = none, 1= >5km, 2 = 1-5 km, 3 = < 1 km , 4 = < 500m, 5 =adjacent/connected to existing riparian zone or existing wetlands.	**3 / 5**
RIPARIAN WIDTH (aerial) : 0 = >20 m, 3 = 5- 20m, 5 = <5 m	**5 /5**
TSC PRIORITY SITE score 5	**0 /5**
OTHER FACTORS : POSSIBLE POTENTIAL FOR HIGH WQ IMPROVEMENT – MEDIUM	
SITE ASSESSMENT SCORE – HIGHEST SCORES WILL BE PRIORITISED FOR RIPARIAN ASSESSMENT	**27 /50**

DATE : 14/1/08 LOCATION: Middle Bilambil Creek 2

Notes: Private landholders could be encouraged to carry out extension of riparian zone and weed control.

RIPARIAN SITE PRIORITISATION/ CLASSIFICATION SCORE (reach based 250m approx)	SCORE
SEPP 14 /other – score 10 for protection / 7.5 for adjacent to protected area/ 5 for across river, 0 for no protection.	**0 / 10**
Known ecological significance/ HCV – score 10 for ecological significance or for a site adjacent to an area of significance, 0 for no significance **note type:** potential HCV rainforest adjoining (102,subtropical WT Rf (some 1099 cleared, substantial area - 998 not assessed), significant forested area adjoining. Other forested communities 208 – (tallowwood), 207 (brushbox) Large area of 1002 Early regrowth rainforest, some areas 1004 camphor Laurel	**10 / 10**
Threatened flora or fauna species – score 5 for threatened species/ 0 for no threatened species recorded at sites **potential rainforest spp.**	**5 / 5**
Location tenure - 1 = all private, 3 = public and private landholders, 5 = all public	**1/ 5**
Land management /community opportunities – 0 = none, not explored, 3 = some potential, 5 = high potential (TSC works in the area)	**5/ 5**
Proximity to riparian zone/existing wetlands/forest - 0 = none, 1= >5km, 2 = 1-5 km, 3 = < 1 km , 4 = < 500m, 5 =adjacent/connected to existing riparian zone or existing wetlands.	**2 / 5**
RIPARIAN WIDTH (aerial) : 0 = >20 m, 3 = 5- 20m, 5 = <5 m	**5 /5**
TSC PRIORITY SITE score 5	**5 /5**
OTHER FACTORS : POSSIBLE POTENTIAL FOR HIGH WQ IMPROVEMENT - MEDIUM	
SITE ASSESSMENT SCORE – HIGHEST SCORES WILL BE PRIORITISED FOR RIPARIAN ASSESSMENT	**33 /50**

DATE : 13/1/08 LOCATION: Lower Bilambil Creek 3

Notes: Private landholders could be encouraged to carry out extension of riparian zone and weed control.

RIPARIAN SITE PRIORITISATION/ CLASSIFICATION SCORE (reach based 250m approx)	SCORE
SEPP 14 /other – score 10 for protection / 7.5 for adjacent to protected area/ 5 for across river, 0 for no protection. EEC 601 Swamp oak, 603 Saltmarsh.	**10 / 10**
Known ecological significance/ HCV – score 10 for ecological significance or for a site adjacent to an area of significance, 0 for no significance **note type: adjacent to 102 subtropical rainforest, EEC 601 Swamp Oak, 603 saltmarsh.**	**10 / 10**
Threatened flora or fauna species – score 5 for threatened species/ 0 for no threatened species recorded at sites **potential rainforest spp.**	**5 / 5**
Location tenure - 1 = all private, 3 = public and private landholders, 5 = all public	**3/ 5**
Land management /community opportunities – 0 = none, not explored, 3 = some potential, 5 = high potential (TSC works in the area)	**5/ 5**
Proximity to riparian zone/existing wetlands/forest - 0 = none, 1= >5km, 2 = 1-5 km, 3 = < 1 km , 4 = < 500m, 5 =adjacent/connected to existing riparian zone or existing wetlands.	**3 / 5**
RIPARIAN WIDTH (aerial) : 0 = >20 m, 3 = 5- 20m, 5 = <5 m	**5 /5**
TSC PRIORITY SITE score 5	**5 /5**
OTHER FACTORS : POSSIBLE POTENTIAL FOR HIGH WQ IMPROVEMENT - HIGH	
SITE ASSESSMENT SCORE – HIGHEST SCORES WILL BE PRIORITISED FOR RIPARIAN ASSESSMENT	**46 /50**

DATE : 13/1/08 LOCATION: Upper Duroby Creek 4

Notes: Private landholders could be encouraged to carry out extension of riparian zone and weed control.

RIPARIAN SITE PRIORITISATION/ CLASSIFICATION SCORE (reach based 250m approx)	SCORE
SEPP 14 /other – score 10 for protection / 7.5 for adjacent to protected area/ 5 for across river, 0 for no protection. Check adjoining reserve site?	**0 / 10**
Known ecological significance/ HCV – score 10 for ecological significance or for a site adjacent to an area of significance, 0 for no significance **note type: substantially cleared (1099) or not assessed (998), small pockets of Grey Ironbark /white mahogany (202), small area regrowth rf (1022) close to large area of 202 and 207 (Brushbox)**	**0 / 10**
Threatened flora or fauna species – score 5 for threatened species/ 0 for no threatened species recorded at sites **potential rainforest spp. connects to large area of exisiting forest on southern side, may contain Koala habitat.**	**5 / 5**
Location tenure - 1 = all private, 3 = public and private landholders, 5 = all public	**1/ 5**
Land management /community opportunities – 0 = none, not explored, 3 = some potential, 5 = high potential Exisitng Landcare group	**3/ 5**
Proximity to riparian zone/existing wetlands/forest - 0 = none, 1= >5km, 2 = 1-5 km, 3 = < 1 km , 4 = < 500m, 5 =adjacent/connected to existing riparian zone or existing wetlands.	**2/ 5**
RIPARIAN WIDTH (aerial) : 0 = >20 m, 3 = 5- 20m, 5 = <5 m	**5 /5**
TSC PRIORITY SITE score 5	**0 /5**
OTHER FACTORS : POSSIBLE POTENTIAL FOR HIGH WQ IMPROVEMENT - LOW	
SITE ASSESSMENT SCORE – HIGHEST SCORES WILL BE PRIORITISED FOR RIPARIAN ASSESSMENT	**16 /50**

DATE : 13/1/08 LOCATION: Mid Duroby Creek 5

Notes: Private landholders could be encouraged to carry out extension of riparian zone and weed control

RIPARIAN SITE PRIORITISATION/ CLASSIFICATION SCORE (reach based 250m approx)	SCORE
SEPP 14 /other – score 10 for protection / 7.5 for adjacent to protected area/ 5 for across river, 0 for no protection. Check adjoining reserve site?	**0 / 10**
Known ecological significance/ HCV – score 10 for ecological significance or for a site adjacent to an area of significance, 0 for no significance **note type: substantially cleared (1099) or not assessed (998), small pockets of Grey Ironbark /white mahogany (202), small area regrowth rf (1022) Pockets of 207 (Brushbox)**	**0 / 10**
Threatened flora or fauna species – score 5 for threatened species/ 0 for no threatened species recorded at sites **potential rainforest spp. connects to large area of existing forest on southern side, pot. Koala habitat.**	**5 / 5**
Location tenure - 1 = all private, 3 = public and private landholders, 5 = all public	**1/ 5**
Land management /community opportunities – 0 = none, not explored, 3 = some potential, 5 = high potential Exisitng Landcare group	**3/ 5**
Proximity to riparian zone/existing wetlands/forest - 0 = none, 1= >5km, 2 = 1-5 km, 3 = < 1 km , 4 = < 500m, 5 =adjacent/connected to existing riparian zone or existing wetlands.	**2/ 5**
RIPARIAN WIDTH (aerial) : 0 = >20 m, 3 = 5- 20m, 5 = <5 m	**5 /5**
TSC PRIORITY SITE score 5	**0 /5**
OTHER FACTORS : POSSIBLE POTENTIAL FOR HIGH WQ IMPROVEMENT - LOW	
SITE ASSESSMENT SCORE – HIGHEST SCORES WILL BE PRIORITISED FOR RIPARIAN ASSESSMENT	**16 /50**

DATE : 13/1/08 **LOCATION: Mid/lower Duroby Creek 6**

Notes: Private landholders could be encouraged to carry out extension of riparian zone and weed control.

RIPARIAN SITE PRIORITISATION/ CLASSIFICATION SCORE (reach based 250m approx)	SCORE
SEPP 14 /other – score 10 for protection / 7.5 for adjacent to protected area/ 5 for across river, 0 for no protection.	**0 / 10**
Known ecological significance/ HCV – score 10 for ecological significance or for a site adjacent to an area of significance, 0 for no significance **note type: substantially cleared (1099) or not assessed (998), adjoins areas of camphor laurel regrowth (1004) some early regrowth rainforest (1002). Start of Sclerophyll regrowth(1003)**	**0 / 10**
Threatened flora or fauna species – score 5 for threatened species/ 0 for no threatened species recorded at sites **potential rainforest in regrowth areas. Potential fauna habitat.**	**5 / 5**
Location tenure - 1 = all private, 3 = public and private landholders, 5 = all public	**1/ 5**
Land management /community opportunities – 0 = none, not explored, 3 = some potential, 5 = high potential	**0/ 5**
Proximity to riparian zone/existing wetlands/forest - 0 = none, 1= >5km, 2 = 1-5 km, 3 = < 1 km , 4 = < 500m, 5 =adjacent/connected to existing riparian zone or existing wetlands.	**2/ 5**
RIPARIAN WIDTH (aerial) : 0 = >20 m, 3 = 5- 20m, 5 = <5 m	**5 /5**
TSC PRIORITY SITE score 5	**0 /5**
OTHER FACTORS : POSSIBLE POTENTIAL FOR HIGH WQ IMPROVEMENT - MEDIUM	
SITE ASSESSMENT SCORE – HIGHEST SCORES WILL BE PRIORITISED FOR RIPARIAN ASSESSMENT	**13 /50**

DATE : 14/1/08 **LOCATION: Duroby Creek confluence 7**

Notes: Notes from meeting identified this site as a good opportunity for saltmarsh rehabilitation. Only major area suitable for saltmarsh rehabilitation in the vicinity of the Terranora Broadwater. Needs close inspection. Potentially five EECs adjoining.
Strong connectivity potential.

RIPARIAN SITE PRIORITISATION/ CLASSIFICATION SCORE (reach based 250m approx)	**SCORE**
SEPP 14 /other – score 10 for protection / 7.5 for adjacent to protected area/ 5 for across river, 0 for no protection.	**10 / 10**
Known ecological significance/ HCV – score 10 for ecological significance or for a site adjacent to an area of significance, 0 for no significance **note type: mangroves (602) saltmarsh (603) EEC, Swamp oak (601) EEC, Coastal Forest Red Gum (304) EEC, Some early regrowth rainforest (1002), Sclerophyll regrowth (1003), Camphor laurel (1004) Native grasslands (902) adjacent to EEC, Paper bark forest (401) EEC, Sedgeland (701) EEC freshwater wetlands.**	**10 / 10**
Threatened flora or fauna species – score 5 for threatened species/ 0 for no threatened species recorded at sites **Strong potential**	**5 / 5**
Location tenure - 1 = all private, 3 = public and private landholders, 5 = all public	**3/ 5**
Land management /community opportunities – 0 = none, not explored, 3 = some potential, 5 = high potential	**5/ 5**
Proximity to riparian zone/existing wetlands/forest - 0 = none, 1= >5km, 2 = 1-5 km, 3 = < 1 km , 4 = < 500m, 5 =adjacent/connected to existing riparian zone or existing wetlands.	**5/ 5**
RIPARIAN WIDTH (aerial) : 0 = >20 m, 3 = 5- 20m, 5 = <5 m	**3 /5**
TSC PRIORITY SITE score 5	**5 /5**
OTHER FACTORS : POSSIBLE POTENTIAL FOR HIGH WQ IMPROVEMENT - HIGH	
SITE ASSESSMENT SCORE – HIGHEST SCORES WILL BE PRIORITISED FOR RIPARIAN ASSESSMENT	**46 /50**

DATE : 14/1/08 LOCATION: Trutes Bay 8 (inc Area E)

Notes: This area contains freshwater wetlands, is a flood gated system with nearby rainforest (not mapped). Notes from meeting identified this site to remain freshwater/brackish. Needs close inspection. Potentially four EECs adjoining. Strong connectivity potential.

RIPARIAN SITE PRIORITISATION/ CLASSIFICATION SCORE (reach based 250m approx)	SCORE
SEPP 14 /other – score 10 for protection / 7.5 for adjacent to protected area/ 5 for across river, 0 for no protection. (Mangroves)	**10 / 10**
Known ecological significance/ HCV – score 10 for ecological significance or for a site adjacent to an area of significance, 0 for no significance **note type: mangroves (602), Swamp oak (601) EEC, Coastal Forest Red Gum (304) coastal floodplain forest EEC, Camphor laurel (1004), Open water (903) but may be sedgeland EEC, Paper bark forest (401) EEC, Sedgeland (701) EEC freshwater wetlands, Brushbox forest (207) also coastal floodplain forest EEC. (104)**	**10 / 10**
Threatened flora or fauna species – score 5 for threatened species/ 0 for no threatened species recorded at sites **Strong potential**	**5 / 5**
Location tenure - 1 = all private, 3 = public and private landholders, 5 = all public	**3/ 5**
Land management /community opportunities – 0 = none, not explored, 3 = some potential, 5 = high potential	**5/ 5**
Proximity to riparian zone/existing wetlands/forest - 0 = none, 1= >5km, 2 = 1-5 km, 3 = < 1 km , 4 = < 500m, 5 =adjacent/connected to existing riparian zone or existing wetlands.	**5/ 5**
RIPARIAN WIDTH (aerial) : 0 = >20 m, 3 = 5- 20m, 5 = <5 m	**5 /5**
TSC PRIORITY SITE score 5	**5 /5**
OTHER FACTORS : POSSIBLE POTENTIAL FOR HIGH WQ IMPROVEMENT - HIGH	
SITE ASSESSMENT SCORE – HIGHEST SCORES WILL BE PRIORITISED FOR RIPARIAN ASSESSMENT	**48 /50**

DATE : 14/1/08 LOCATION: Upper Cobaki Creek 9

Notes: Substantially cleared with regrowth. Strong potential for bush regeneration but need to encourage private landholders to manage works.

RIPARIAN SITE PRIORITISATION/ CLASSIFICATION SCORE (reach based 250m approx)	SCORE
SEPP 14 /other – score 10 for protection / 7.5 for adjacent to protected area/ 5 for across river, 0 for no protection.	**0 / 10**
Known ecological significance/ HCV – score 10 for ecological significance or for a site adjacent to an area of significance, 0 for no significance **note type: Substantially cleared (1099), but between camphor regrowth (1004) and rainforest regrowth (1002).**	**0 / 10**
Threatened flora or fauna species – score 5 for threatened species/ 0 for no threatened species recorded at sites**. Need onground assessment, low potential, check data base**	**0 / 5**
Location tenure - 1 = all private, 3 = public and private landholders, 5 = all public	**1/ 5**
Land management /community opportunities – 0 = none, not explored, 3 = some potential, 5 = high potential	**0/ 5**
Proximity to riparian zone/existing wetlands/forest - 0 = none, 1= >5km, 2 = 1-5 km, 3 = < 1 km , 4 = < 500m, 5 =adjacent/connected to existing riparian zone or existing wetlands.	**1/ 5**
RIPARIAN WIDTH (aerial) : 0 = >20 m, 3 = 5- 20m, 5 = <5 m	**5 /5**
TSC PRIORITY SITE score 5	**0 /5**
OTHER FACTORS : POSSIBLE POTENTIAL FOR HIGH WQ IMPROVEMENT - LOW	
SITE ASSESSMENT SCORE – HIGHEST SCORES WILL BE PRIORITISED FOR RIPARIAN ASSESSMENT	**7 /50**

DATE : 14/1/08 LOCATION: Middle Cobaki Creek 10

Notes: Private landholders could be encouraged to carry out extension of riparian zone and weed control.

RIPARIAN SITE PRIORITISATION/ CLASSIFICATION SCORE (reach based 250m approx)	**SCORE**
SEPP 14 /other – score 10 for protection / 7.5 for adjacent to protected area/ 5 for across river, 0 for no protection.	**0 / 10**
Known ecological significance/ HCV – score 10 for ecological significance or for a site adjacent to an area of significance, 0 for no significance **note type:** extremely cleared main classification substantially cleared (1099), substantial area - 998 not assessed Small pockets of vegetated areas, Brushbox (207), Small area (1002) early regrowth rainforest, some areas (1004) Camphor Laurel and Sclerophyll regrowth(1003)	**0 / 10**
Threatened flora or fauna species – score 5 for threatened species/ 0 for no threatened species recorded at sites **low potential for threatened spp.**	**0 / 5**
Location tenure - 1 = all private, 3 = public and private landholders, 5 = all public	**1/ 5**
Land management /community opportunities – 0 = none, not explored, 3 = some potential, 5 = high potential	**3/ 5**
Proximity to riparian zone/existing wetlands/forest - 0 = none, 1= >5km, 2 = 1-5 km, 3 = < 1 km , 4 = < 500m, 5 =adjacent/connected to existing riparian zone or existing wetlands.	**2 / 5**
RIPARIAN WIDTH (aerial) : 0 = >20 m, 3 = 5- 20m, 5 = <5 m	**5 /5**
TSC PRIORITY SITE score 5	**0 /5**
OTHER FACTORS : POSSIBLE POTENTIAL FOR HIGH WQ IMPROVEMENT - MEDIUM	
SITE ASSESSMENT SCORE – HIGHEST SCORES WILL BE PRIORITISED FOR RIPARIAN ASSESSMENT	**11 /50**

DATE : 14/1/08 LOCATION: Lower Cobaki Creek 11

Notes: Notes from meeting identified potential for floodgate work, changes to the Western Drainage Scheme. Includes Vintage Lakes Needs close inspection. Some connectivity potential. Degraded.

RIPARIAN SITE PRIORITISATION/ CLASSIFICATION SCORE (reach based 250m approx)	**SCORE**
SEPP 14 /other – score 10 for protection / 7.5 for adjacent to protected area/ 5 for across river, 0 for no protection.	**10 / 10**
Known ecological significance/ HCV – score 10 for ecological significance or for a site adjacent to an area of significance, 0 for no significance **note type: Substantially cleared (1099) mangroves (602) Large areas mapped as open water (903) which may be sedgeland or freshwater wetlands EEC Tallowood open forest (208), Scribbly gum forest (306). Some early regrowth rainforest (1002), Sclerophyll regrowth (1003), Camphor laurel (1004).**	**10 / 10**
Threatened flora or fauna species – score 5 for threatened species/ 0 for no threatened species recorded at sites **Strong potential koala habitat.**	**5 / 5**
Location tenure - 1 = all private, 3 = public and private landholders, 5 = all public	**3/ 5**
Land management /community opportunities – 0 = none, not explored, 3 = some potential, 5 = high potential	**5/ 5**
Proximity to riparian zone/existing wetlands/forest - 0 = none, 1= >5km, 2 = 1-5 km, 3 = < 1 km , 4 = < 500m, 5 =adjacent/connected to existing riparian zone or existing wetlands.	**4/ 5**
RIPARIAN WIDTH (aerial) : 0 = >20 m, 3 = 5- 20m, 5 = <5 m	**5 /5**
TSC PRIORITY SITE score 5	**5 /5**
OTHER FACTORS : POSSIBLE POTENTIAL FOR HIGH WQ IMPROVEMENT - HIGH	
SITE ASSESSMENT SCORE – HIGHEST SCORES WILL BE PRIORITISED FOR RIPARIAN ASSESSMENT	**47 /50**

DATE : 13/1/08 LOCATION: Upper Piggabeen Creek 12

Notes: Limited potential for water quality improvement in as some regrowth appears to be occurring. Private landholders could be encouraged to carry out extension of riparian zone and wee control.

RIPARIAN SITE PRIORITISATION/ CLASSIFICATION SCORE (reach based 250m approx)	SCORE
SEPP 14 /other – score 10 for protection / 7.5 for adjacent to protected area/ 5 for across river, 0 for no protection.	**0 / 10**
Known ecological significance/ HCV – score 10 for ecological significance or for a site adjacent to an area of significance, 0 for no significance **note type:** potential HCV rainforest adjoining (102, 1099), significant forested area adjoining. Other forested communities Brushbox (207), Grey ironbark/ White mahogany (202).	**10 / 10**
Threatened flora or fauna species – score 5 for threatened species/ 0 for no threatened species recorded at sites **rainforest spp.**	**5 / 5**
Location tenure - 1 = all private, 3 = public and private landholders, 5 = all public	**1/ 5**
Land management /community opportunities – 0 = none, not explored, 3 = some potential, 5 = high potential	**0/ 5**
Proximity to riparian zone/existing wetlands/forest - 0 = none, 1= >5km, 2 = 1-5 km, 3 = < 1 km , 4 = < 500m, 5 =adjacent/connected to existing riparian zone or existing wetlands.	**2 / 5**
RIPARIAN WIDTH (aerial) : 0 = >20 m, 3 = 5- 20m, 5 = <5 m	**5 /5**
TSC PRIORITY SITE score 5	**0 /5**
OTHER FACTORS : POSSIBLE POTENTIAL FOR HIGH WQ IMPROVEMENT – MEDIUM	
SITE ASSESSMENT SCORE – HIGHEST SCORES WILL BE PRIORITISED FOR RIPARIAN ASSESSMENT	**23 /50**

DATE : 14/1/08 LOCATION: Middle Piggabeen Creek 13

Notes: Private landholders could be encouraged to carry out extension of riparian zone and weed control.

RIPARIAN SITE PRIORITISATION/ CLASSIFICATION SCORE (reach based 250m approx)	SCORE
SEPP 14 /other – score 10 for protection / 7.5 for adjacent to protected area/ 5 for across river, 0 for no protection.	**0 / 10**
Known ecological significance/ HCV – score 10 for ecological significance or for a site adjacent to an area of significance, 0 for no significance **note type:** some 1099 cleared, substantial area – (998) not assessed, significant forested area adjoining. Other forested communities 208 – (tallowwood) Major community Grey Iron bark /White mahogany (202) Large area of Early regrowth rainforest (1002), limited areas 1004 camphor Laurel	**10 / 10**
Threatened flora or fauna species – score 5 for threatened species/ 0 for no threatened species recorded at sites **potential rainforest spp. and Koala habitat**	**5 / 5**
Location tenure - 1 = all private, 3 = public and private landholders, 5 = all public	**1/ 5**
Land management /community opportunities – 0 = none, not explored, 3 = some potential, 5 = high potential (TSC works in the area)	**3/ 5**
Proximity to riparian zone/existing wetlands/forest - 0 = none, 1= >5km, 2 = 1-5 km, 3 = < 1 km , 4 = < 500m, 5 =adjacent/connected to existing riparian zone or existing wetlands.	**2 / 5**
RIPARIAN WIDTH (aerial) : 0 = >20 m, 3 = 5- 20m, 5 = <5 m	**5 /5**
TSC PRIORITY SITE score 5	**0 /5**
OTHER FACTORS : POSSIBLE POTENTIAL FOR HIGH WQ IMPROVEMENT - MEDIUM	
SITE ASSESSMENT SCORE – HIGHEST SCORES WILL BE PRIORITISED FOR RIPARIAN ASSESSMENT	**26 /50**

DATE : 15/1/08 LOCATION: Lower Piggabeen Creek 14

Notes: Piggabeen Rd - loss of koalas, ASS, compensatory wetland issues.

RIPARIAN SITE PRIORITISATION/ CLASSIFICATION SCORE (reach based 250m approx)	**SCORE**
SEPP 14 /other – score 10 for protection / 7.5 for adjacent to protected area/ 5 for across river, 0 for no protection.	**0 / 10**
Known ecological significance/ HCV – score 10 for ecological significance or for a site adjacent to an area of significance, 0 for no significance **note type:** Predominantly Blackbutt Open Forest complex (201), Brushbox Open Forest (207), and some lowland rainforest on floodplain (104) EEC	**10 / 10**
Threatened flora or fauna species – score 5 for threatened species/ 0 for no threatened species recorded at sites **potential rainforest spp. and Koala habitat**	**5 / 5**
Location tenure - 1 = all private, 3 = public and private landholders, 5 = all public	**1/ 5**
Land management /community opportunities – 0 = none, not explored, 3 = some potential, 5 = high potential (TSC works in the area)	**3/ 5**
Proximity to riparian zone/existing wetlands/forest - 0 = none, 1= >5km, 2 = 1-5 km, 3 = < 1 km , 4 = < 500m, 5 =adjacent/connected to existing riparian zone or existing wetlands.	**2 / 5**
RIPARIAN WIDTH (aerial) : 0 = >20 m, 3 = 5- 20m, 5 = <5 m	**5 /5**
TSC PRIORITY SITE score 5	**0 /5**
OTHER FACTORS : POSSIBLE POTENTIAL FOR HIGH WQ IMPROVEMENT - MEDIUM	
SITE ASSESSMENT SCORE – HIGHEST SCORES WILL BE PRIORITISED FOR RIPARIAN ASSESSMENT	**26 /50**

DATE : 15/1/08 LOCATION: Confluence wetlands15 (Robinsons Rd)

Notes: Likely acidic water on private property. An opportunity for a catchment scales treatment wetland or habitat feature – could be high priority fro rehabilitation to prevent acid export to Cobaki Creek, land owner letter required, potential difficulties. Potential zoning in LEP.

RIPARIAN SITE PRIORITISATION/ CLASSIFICATION SCORE (reach based 250m approx)	**SCORE**
SEPP 14 /other – score 10 for protection / 7.5 for adjacent to protected area/ 5 for across river, 0 for no protection.	**7.5 / 10**
Known ecological significance/ HCV – score 10 for ecological significance or for a site adjacent to an area of significance, 0 for no significance **note type:** Predominantly Blackbutt Open Forest complex (201), Brushbox Open Forest (207), and some lowland rainforest on floodplain (104) EEC, large areas cleared (1099)	**10 / 10**
Threatened flora or fauna species – score 5 for threatened species/ 0 for no threatened species recorded at sites **potential rainforest spp. and Koala habitat**	**5 / 5**
Location tenure - 1 = all private, 3 = public and private landholders, 5 = all public	**1/ 5**
Land management /community opportunities – 0 = none, not explored, 3 = some potential, 5 = high potential (TSC works in the area)	**3/ 5**
Proximity to riparian zone/existing wetlands/forest - 0 = none, 1= >5km, 2 = 1-5 km, 3 = < 1 km , 4 = < 500m, 5 =adjacent/connected to existing riparian zone or existing wetlands.	**2 / 5**
RIPARIAN WIDTH (aerial) : 0 = >20 m, 3 = 5- 20m, 5 = <5 m	**3 /5**
TSC PRIORITY SITE score 5	**5 /5**
OTHER FACTORS : POSSIBLE POTENTIAL FOR HIGH WQ IMPROVEMENT - HIGH	
SITE ASSESSMENT SCORE – HIGHEST SCORES WILL BE PRIORITISED FOR RIPARIAN ASSESSMENT	**36.5 /50**

DATE : 15/1/08 LOCATION: Cobaki Lakes / Lower Piggabeen 16
Notes:

RIPARIAN SITE PRIORITISATION/ CLASSIFICATION SCORE (reach based 250m approx)	**SCORE**
SEPP 14 /other – score 10 for protection / 7.5 for adjacent to protected area/ 5 for across river, 0 for no protection. EEC 601 Swamp oak, 603 Saltmarsh.	**10 / 10**
Known ecological significance/ HCV – score 10 for ecological significance or for a site adjacent to an area of significance, 0 for no significance **note type:** Blackbutt open forest (201), Swamp Oak EEC (601), potential saltmarsh (603) EEC identified in notes mapped as 903. Large areas mapped as cleared (1099). Overlaps with Brushbox (207), Lowland rainforest (104) regrowth rainforest and cleared (1099)	**10 / 10**
Threatened flora or fauna species – score 5 for threatened species/ 0 for no threatened species recorded at sites **potential koala habitat.**	**5 / 5**
Location tenure - 1 = all private, 3 = public and private landholders, 5 = all public – Leda Developments?	**3/ 5**
Land management /community opportunities – 0 = none, not explored, 3 = some potential, 5 = high potential (compliance /development perhaps)	**5/ 5**
Proximity to riparian zone/existing wetlands/forest - 0 = none, 1= >5km, 2 = 1-5 km, 3 = < 1 km , 4 = < 500m, 5 =adjacent/connected to existing riparian zone or existing wetlands.	**5 / 5**
RIPARIAN WIDTH (aerial) : 0 = >20 m, 3 = 5- 20m, 5 = <5 m	**5 /5**
TSC PRIORITY SITE score 5	**5 /5**
OTHER FACTORS : POSSIBLE POTENTIAL FOR HIGH WQ IMPROVEMENT - HIGH	
SITE ASSESSMENT SCORE – HIGHEST SCORES WILL BE PRIORITISED FOR RIPARIAN ASSESSMENT	**48 /50**

DATE : 15/1/08 LOCATION: Charles Bay 17
Notes:

RIPARIAN SITE PRIORITISATION/ CLASSIFICATION SCORE (reach based 250m approx)	**SCORE**
SEPP 14 /other – score 10 for protection / 7.5 for adjacent to protected area/ 5 for across river, 0 for no protection. EEC 601 Swamp oak, 603 Saltmarsh.	**10 / 10**
Known ecological significance/ HCV – score 10 for ecological significance or for a site adjacent to an area of significance, 0 for no significance **note type: adjacent to subtropical rainforest (102), some lowland rainforest on floodplain EEC (104),Swamp Oak EEC (601), saltmarsh (603)**	**10 / 10**
Threatened flora or fauna species – score 5 for threatened species/ 0 for no threatened species recorded at sites **potential rainforest spp.**	**5 / 5**
Location tenure - 1 = all private, 3 = public and private landholders, 5 = all public	**3/ 5**
Land management /community opportunities – 0 = none, not explored, 3 = some potential, 5 = high potential	**5/ 5**
Proximity to riparian zone/existing wetlands/forest - 0 = none, 1= >5km, 2 = 1-5 km, 3 = < 1 km , 4 = < 500m, 5 =adjacent/connected to existing riparian zone or existing wetlands.	**5 / 5**
RIPARIAN WIDTH (aerial) : 0 = >20 m, 3 = 5- 20m, 5 = <5 m	**3 /5**
TSC PRIORITY SITE score 5	**5 /5**
OTHER FACTORS: POSSIBLE POTENTIAL FOR HIGH WQ IMPROVEMENT - HIGH	
SITE ASSESSMENT SCORE – HIGHEST SCORES WILL BE PRIORITISED FOR RIPARIAN ASSESSMENT	**46 /50**

Appendix C: Field Site Locations – GPS Coordinates

Site No.	X – Coordinate	Y - Coordinate
1	548057.95257	6876895.35300
1a	547855.98234	6876825.04347
2	547538.27726	6876737.14074
3a	546487.37829	6876127.38838
5	546257.56632	6877773.02686
5a	546018.51568	6877603.26626
5b	545842.98091	6877790.34937
9	539774.32810	6875023.36705
8	542191.39572	6876071.95634
7	542913.16698	6876450.74190
3	545970.82101	6876094.49195
6	543675.38230	6876907.77079
17	542217.57737	6880361.01897
18	544080.88013	6881601.47817
19	545344.16544	6881914.49041
14	543727.70362	6879381.97356
13	543968.60292	6879818.59234
11	545526.76509	6880767.13156
12	544527.06870	6880148.98241
15	546360.20068	6880873.70900
16	541288.91690	6879885.80968
20	545556.29791	6877505.49574
6a	544216.60486	6877337.86423
6b	544676.41678	6877515.29165

Appendix D: Stage 2 Riparian Assessment Field Sheet

Site Code: **Assessor:**

Site: **Date:**

Address/Landowner (if known):

GPS: **Functional Zone:**

Vegetation community type: ***Stream/ river width class: >10m OR <10m***

Photo numbers:

Native Vegetation	**Species**		
canopy dominant			
mid storey			
understorey			
Dominant weeds	**Species**		
canopy dominant			
Midstorey			
understorey			
1. LONGITUDINAL CONNECTIVITY **Length of vegetation (>5m wide) along stream** ***0 = < 100 m, 5 =>100 m***	**Assessment notes** ***Banks are designated (L)left, (R) Right, or (B)Both facing downstream***	**score**	**poss score**
Bank 1			*5*
Bank 2			*5*
TOTAL SCORE			*10*
2. WIDTH OF RIPARIAN VEGETATION (**determined from aerials for large rivers or on site)**			
Channel < 10 m wide, riparian vegetation width: 0 = <5 m vegetation, 2 = 5-9 m, 4 =10-29m, 6 =30-39 m, 8 = > 40 m - <100 m vegetated, 10= >100m (TOTAL BOTH SIDES)			
Channel ≥ 10 m wide: 0 =riparian width (rw)<1/2 channel width (CW), 2 = rw ½ to 1 x CW, 4 = rw 1- 2 x CW, 6= rw 3-4 x CW, 8 = rw 4 x CW., 10=rw10xCW			
Channel width (CW) m	***Vegetation width (m)***	**score**	**poss score**
			10
3. VEGETATION COVER		**score**	**poss score**
% cover class 0=0, 1 =1%, 2 = 2-10%, 3= 11-30%, 4 = 31-60%, 5 = 61-100%.			
% native class 0=0, 1 =1%, 2 = 2-10%, 3= 11-30%, 4 = 31-60%, 5 = 61-100%.			
Canopy	**% cover class**		*5*
	% native		*5*
Understorey	**% cover class**		*5*
	% native		*5*

TOTAL SCORE			*20*
4. HABITAT QUALITY ASSESSMENT		**score**	**poss score**
Veg community age class ***0 = no rip veg or isol. stag trees, 1= seedlings/ planting <5 yo with/without stag trees, 2 = regrowth 10yo, 4 = regrowth with stage trees, 5 = old growth .30 yo***			*5*
Tree hollows present	***0 = none, 5 present.***		*5*
Leaf litter class	***0 = none, 3 =1-60%, 5 =>60%***		*5*
Fallen logs	***0 =none, 3 = small debris, 5 = abundant***		*5*
Seed/ fruiting trees	***0 = none, 3 = 1-4 trees, 5 = > 5 trees***		*5*
Instream habitat (LWD overhang branches etc)	***0 = none, 3 = <50 % site with habitat features, 5 = > 50 % of site with habitat features***		*5*
Habitat connectivity instream/ pools/ riffles, water flow	***0= none, 5 = 50% continuous/some blockages, 10 = continuous***		*10*
Threatened sp habitat present	***absent = 0, present =10***		*10*
TOTAL SCORE			*50*
5. THREATENING PROCESSES	***Percentage severity score: 0 = > 40%, 10 =1- 39%, 20=no threat***		
Process	**Assessment notes**	**score**	**poss score**
nutrient export/ grazing			*20*
nutrient export / bank erosion			*20*
sedimentation/bank erosion			*20*
sedimentation land mgt			*20*
stormwater poll / agricultural runoff			*20*
other pollutant runoff			*20*
urban develop/human encroach			*20*
weed invasion			*20*
rubbish dumping			*20*
Other -			*20*
TOTAL SCORE			***200***
6. SITE WEED CONTROL ISSUES ***Percentage severity of weeds score: 0 = > 31-100%, 5= 10-30%,10 = <10% or no threat***	**Assessment notes**	**score**	**poss score**
canopy weeds			*10*
mid storey			*10*

Understorey			*10*
TOTAL SCORE			***30***
7. SITE REHABILITATION POTENTIAL	**Assessment notes**	**score**	**poss score**
Access: 3 = poor, steep or inaccessible, 2 = reasonable, 0 =good			*3*
adjacent land use - score 2 if not suitable to allow regeneration (eg road) / score 0 if suitable			*2*
Native regeneration/seedlings present 0 = none, 3 = few,scattered, 5 = abundant			*5*
Fencing options Flood zone			
Structural works required: 0= yes, 5 = no			*5*
Weed control works: Structural canopy (camphor laurel or woody weeds) 0= yes, 5 = no			*5*
Water Quality Improvement Factor	note possible remediation eg reveg/bank stabilization relevant to functional zone assessment		
Effect of all/any possible site remediation on catchment eg weed control vs sediment control High =0 / low = 10	**NOTE FUNCTIONAL ZONE**		*10*
8. BANK/BED STABILITY PARAMETER	**Assessment notes/description**	**score**	**poss score**
Geomorphic Stability			*20*
Creek Bed and Bank Condition			*20*
Recovery Potential			*10*
TOTAL SCORE			*50*
Weighted score			*100*

TOTAL RIPARIAN ASSESS. SCORES PARAMETER	**Total parameter score**	**Poss. score**	
1. longitudinal connectivity		*10*	
2. width of riparian vegetation		*10*	
3. native vegetation cover		*20*	
4. habitat quality assessment		*50*	
5. Ecological values score (from API)			*10*
Conservation values sub total			***100***
5. severity of threatening processes - low score = high severity		*200*	
6. site weed control issues /maintenance		*30*	
7. rehabilitation/WQ remediation pot.(low score = high remediation potential)		*30*	

8. bank /bed stability score (Tim)		*100*	
TOTAL SITE SCORE		*450*	0%
	RANKING		
Ranking for locations to prioritise riparian sites with <u>low</u> riparian vegetation values			
lowest 0 =80-100%,low 2=70-79%, medium 4= 60-69%, med/high 6=50-59%, high 8=30-49%, highest 10=0-30%			

Appendix E: Stage 2 Riparian Assessment Raw Scores

				Longit Conn			Veg Cover : Canop		Veg Cover: U/st			Habitat Quality Assessment									Threatening Processes										Site Weed Control Issues				Remediation Potential								
SITE	Stream width	Channel width (CW) m	Vegetation width score	Bank 1	Bank 2	TOTAL SCORE	% cover class	% native	% cover class	% native	TOTAL SCORE	Veg community age class	Tree hollows present	Leaf litter class	Fallen logs	Seed/ fruiting trees	Instream habitat	Habitat connectivity	Threatened sp habitat	TOTAL SCORE	nutrient export/ grazing/land mgt	nutrient export / bank erosion	sedimentation/bank erosion	sedimentation from land mgt	stormwater poll / ag runoff	urban develop/human encroach	weed invasion	rubbish dumping	Other -	TOTAL SCORE	canopy weeds	mid storey	understorey	TOTAL SCORE	Access	adjacent land use	Native seedlings present	Structural works req'd	Weed control works	WQ Improvement Factor	TOTAL SCORE	Geomorphic/Bed Bank Stability	TOTAL RIPARIAN ASSESS. SCORE
1DL	<10	8	0	0	0	0	3	4	2	1	10	4	0	3	0	3	3	10	10	33	10	10	10	20	20	10	10	N	N	90	0	5	0	5	0	0	3	5	0	30	38	38	**213.5**
2DT		8	0	0	0	0	0	0	5	0	5	0	0	0	10	0	3	5	0	18	20	10	10	10	0	10	0	N	N	60	0	0	0	0	0	0	0	5	0	0	5	30	**117.5**
3DM	<10	5	0	0	0	0	3	2	5	0	10	5	5	3	3	3	5	10	10	44	10	10	20	20	10	20	10	N	N	100	0	5	10	15	0	0	3	0	0	0	3	33	**204.5**
3aDM	<10	3	0	0	0	0	0	0	4	0	4	0	0	0	0	3	3	10	10	26	20	0	0	0	20	0	0	N	N	40	5	0	10	15	0	0	0	0	0	0	0	23	**108**
5BL	>10	30	0	0	5	5	2	1	3	2	8	0	5	3	0	3	3	10	10	34	0	10	10	10	10	0	0	N	N	40	0	5	0	5	0	0	3	5	0	0	8	38	**137.5**
6BM	<10	5	2	5	0	5	3	2	3	2	10	0	0	3	3	3	3	5	0	17	10	0	0	0	0	20	0	N	N	30	5	5	5	15	2	0	0	5	0	0	7	34	**119.5**
7 BM	<10	5	0	0	0	0	3	3	5	3	14	0	0	0	0	0	0	5	0	5	10	0	0	0	n	0	0	n	n	10	5	5	0	10	2	0	0	5	0	0	7	31	**76.5**
8BM	<10	5	0	0	0	0	2	0	5	0	7	0	0	0	3	3	3	5	0	14	0	0	0	0	10	10	10	y	n	30	5	5	0	10	3	0	3	5	0	0	11	34	**105.5**
9BU	<10	6	0	0	0	0	4	3	3	1	11	1	0	3	5	5	3	5	10	32	20	10	10	10	20	10	0	n	n	80	0	5	0	5	2	0	3	0	0	30	35	39	**202**
11CT	<10	5	0	0	0	0	1	2	5	0	8	0	0	0	0	0	3	3	10	16	0	0	0	0	0	20	20	N	N	40	0	0	0	0	0	0	0	0	0	0	0	11	**75**
12CM	<10	7	0	0	0	0	2	1	5	0	8	0	0	0	3	0	3	10	0	16	0	0	0	0	0	20	0	N	N	20	0	0	0	0	3	0	0	5	0	0	8	15	**67**
13CM	<10	5	0	0	0	0	3	3	5	1	12	2	0	3	3	3	3	5	0	19	20	0	0	0	20	10	0	N	N	50	5	5	0	10	0	0	0	0	0	0	0	21	**112**
14CM	<10	0	0	0	0	0	2	1	4	1	8	0	0	0	3	0	3	10	0	16	10	10	10	10	20	20	0	N	N	80	0	0	0	0	0	0	3	5	0	0	8	30	**141.5**
15CL	>10	12	0	0	5	5	4	4	5	2	15	4	5	5	5	5	5	10	10	49	10	10	10	10	10	20	10	N	N	80	5	10	10	25	3	0	3	5	5	30	46	40	**260**
16PU	<10	3	0	0	5	5	1	5	3	0	9	0	0	0	0	3	3	10	10	26	0	0	0	0	0	20	20	N	N	40	10	10	0	20	0	0	0	5	5	30	40	31	**170.5**
17PM	<10	3	0	0	0	0	0	1	4	3	8	0	0	0	0	0	0	10	0	10	0	0	0	0	0	0	20	N	N	20	5	5	0	10	0	0	0	5	0	30	35	32	**114.5**
18PM	<10	5	0	0	0	0	3	1	5	0	9	1	5	3	3	0	3	10	0	25	0	0	0	0	0	10	0	N	N	10	0	0	0	0	0	0	0	5	0	0	5	16	**65**
19PL	<10	4	0	5	5	10	4	5	5	3	17	2	5	3	3	3	5	10	10	41	10	10	10	10	20	10	0	N	N	70	0	0	0	0	2	0	3	5	0	0	10	25	**173**
20BT	<10	8	2	0	0	0	3	3	4	2	12	2	5	3	3	3	3	10	0	29	10	10	10	20	10	0	0	N	N	60	0	5	0	5	0	0	0	5	5	30	40	30	**178**

Note:
D = Duroby Creek
B = Bilambil Creek
C = Cobaki Creek
P = Piggabeen Creek
L = Lower functional zone
T = Transition functional zone
M = Mid functional zone
U = Upper functional zone

Geomorphic Assessment and Prioritisation Scores
(Riparian Engineering)

Site	Geomorphic Stability	Geomorphic Condition	Recovery Potential	Ram Weighted Score	Priority
1	15	15	7.5	37.5	Level 4
1a	13	11	5.5	29.5	Level 1
2	13	11	5.5	29.5	Level 3
3	13	13	6.5	32.5	Level 3
3a	8	10	5	23	Level 2
5	15	15	7.5	37.5	Level 4
5a	14	15	7.5	36.5	Level 4
5b	8	10	5	23	Level 2
6	13	13	7.5	33.5	Level 3
6a	11	9	5.5	25.5	Level 2
6b	13	10	6	29	Level 3
7	13	11	6.5	30.5	Level 3
8	15	14	7.5	36.5	Level 4
9	16	15	8	39	Level 4
20	11	12	7	30	Level 3
11	1	6	4	11	Level 1
12	5	6	4	15	Level 1
13	8	8	5	21	Level 1
14	12	11	6.5	29.5	Level 3
15	15	16	9	40	Level 4
16	10	13	7.5	30.5	Level 3
17	15	10	6.5	31.5	Level 3
18	3	8	5	16	Level 1
19	7	12	6	25	Level 1

Appendix F: Riparian Baseline FPC and Width

	Ranking Score											
Sub-catchment	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Duroby Ck (m)	3216	2500	236	370	184	527	2748	868	0	0	2484	1767
Bilambil Ck (m)	8435	2444	58	636	0	1321	1253	312	0	0	1194	2592
Cobaki Ck (m)	5379	3431	1068	0	0	0	2293	323	0	240	298	1154
Piggabeen Ck (m)	6702	3277	1200	228	0	0	354	0	0	202	0	1508

Appendix G: Memorandum of Understanding – Cobaki Broadwater

MEMORANDUM OF UNDERSTANDING

In relation to the cooperative management of the Cobaki Broadwater and its catchment

PREAMBLE

The Cobaki Broadwater and catchment form part of the Tweed River Estuary. The Cobaki catchment extends over some $50km^2$ and includes Cobaki and Piggabeen Creeks. A small portion of the catchment extends across the border into Queensland. The area has recognised high scenic values and contains significant terrestrial and aquatic ecosystems including SEPP 14 Coastal wetlands, rainforest, migratory and non-migratory bird habitat, and important fish breeding and nursery habitat.

The area is also significant to Aboriginal people with a history of regular large gatherings. This is evidenced by numerous physical indicators, including middens and campsites. The area has other important Aboriginal cultural links.

A range of land tenures exist, including Commonwealth land, substantial areas of state Crown land, and freehold land. The Broadwater and catchment is subject to a number of existing land uses and activities, most notably an international airport, national highway, urban/industrial development, waste landfill and rural uses.

Incremental development and disparate management regimes of the responsible government agencies over time has contributed to habitat loss and resource degradation, potentially compromising the values and beneficial uses of the area. These pressures have accelerated in recent years with increased development including significant road works (Tugun by-pass) and expanding residential and industrial subdivision. Concurrently and in response to this, community concern, including that of the Aboriginal community, has increased, emphasising the need for better and more coordinated management and protection of the area's values.

This Memorandum of Understanding (MoU) is the outcome of two meetings of representatives of the key agencies and other bodies with responsibilities and/or major roles in the planning, management or utilisation of the area. The initial meeting was conducted on 27 June 2007 and the second meeting, at which an initial draft of this MoU was considered, was held just over a year later on 23 July 2008.

In parallel, but separate to this process, Tweed Shire Council commissioned the preparation of a management plan encompassing the Cobaki Broadwater catchment. This plan is being prepared in accordance with the NSW *Coastal Protection Act 1979*. Once finalised, and if adopted by the Minister, the plan will be administered by Tweed Shire Council and will bind the Crown. One of the particular objects of the *Coastal Protection Act* is *' to ensure coordination of the policies and activities of the government and public authorities relating to the coastal region and to facilitate the proper integration of their management activities'*.

This MoU provides a formal mechanism for coordination and integration and will complement the management plan, which will detail and prioritise required management activities.

PARTIES

This Memorandum of Understanding is made between:
Tweed Shire Council (TSC)
NSW Department of Lands (DoL)
NSW Department of Environment and Climate Change (DECC)
NSW Roads and Traffic Authority (RTA)
QLD Department of Main Roads (DMR)
Gold Coast City Council (GCCC)
NSW Department of Planning (DoP)
NSW Department of Primary Industries - Fisheries (DPIF)
NSW Northern Rivers Catchment Management Authority (CMA)
Commonwealth Department of Infrastructure, Transport, Regional Development & Local Government (DITRDLG)
Tweed Byron Local Aboriginal Land Council (TBLALC)
Gold Coast Native Title Group (GCNTG)
Gold Coast Airport Pty Ltd (GCAL)
Leda Developments Pty Ltd (LD)

PURPOSE

The purpose of this MoU is to:

1. identify those government agencies and other bodies (the parties) with responsibilities or major roles in the planning, management or utilisation of the Cobaki Broadwater and catchment;
2. articulate a set of fundamental overarching principles to guide the parties planning, management, and utilisation of the area; and
3. provide a framework for the parties to foster and enhance communication, cooperation and collaboration related to the planning, management and utilisation of the area.

PRINCIPLES

The parties agree that the Cobaki Broadwater and catchment is a regionally and nationally significant area with outstanding natural and Aboriginal cultural heritage values and plays a significant role in the local and regional economy.

The parties agree that the values of the area require protection and that a proactive, cooperative and integrated approach to the planning, management and utilisation of the area is required.

The parties agree the community and stakeholders need to be assured that a cooperative and integrated approach is being taken by the parties to protect and manage the areas values.

The parties agree that their day-to-day and strategic planning, management and utilisation of the area will be guided and influenced by the following overarching principles:

1. Proactive catchment stakeholder communication and information sharing and collaborative land use planning and management will be facilitated in all but emergency activities.

2. Wherever feasible and appropriate, significant land use planning, management and utilisation decision making will be preceded by timely, adequate, transparent and actively sought community and catchment stakeholder consultation and input.
3. Aboriginal physical, cultural, and spiritual values will be considered in a culturally appropriate way in all levels of catchment land use planning, management and utilisation decision making processes.
4. Protection and maintenance or improvement of the area's aesthetic amenity and the condition of native terrestrial and aquatic ecosystems will be a significant focus of management planning, investment and decision making.
5. Management actions will aim to maintain or improve the ecological health of the catchment and ensure the long term sustainability of essential catchment biophysical processes and services.
6. Remnant areas of high conservation value will be accorded protection and maintained through appropriate protection measures.
7. As resources allow, environmentally degraded areas will be rehabilitated and their biophysical functions restored.
8. Wherever feasible, non-sustainable and environmentally degrading processes will be progressively replaced with more efficient and less degrading alternatives.
9. Beneficial uses which are non-degrading will be encouraged.

The parties acknowledge that the context for implementation or application of these overarching principles varies between each of the parties. It is also acknowledged that the principles do not fetter the rights of any parties to exercise any legal entitlement or activity over lands under their control.

OPERATION

The parties agree to establish, maintain and resource a coordinating group known as the Cobaki Coordinating Group (CCG). Core members of the CCG will comprise those parties that own or are responsible for the planning and management of the area's land and water resources. Each party will be represented by a senior officer and the group will be chaired by the Tweed Shire Council representative. The CCG will operate as a sub-group of the Tweed River Committee.

The function of this group is to initiate, oversee and administer this MoU to foster and enhance communication and cooperation between the parties in the coordination and integration of the planning, management and utilisation of the area.

The specific task of the CCG will be to ensure the following initial and on-going actions are resourced and undertaken, and to periodically report on their status and provide recommendations to the Tweed River Committee.

Initial Actions

The parties agree to resource and undertake the following initial actions to be completed by the first anniversary of this MoU:

a. review existing management arrangements and strategic and management plans to ascertain gaps, deficiencies, overlaps and inconsistencies and provide a report to the CCG recommending options to redress identified deficiencies;
b. establish and implement processes for consultation with Aboriginal people and foster their partnering in the planning, management and utilisation of the area.

Ongoing Actions

The parties agree to resource and undertake the following ongoing actions:

a. meet twice yearly, prior to (March) and shortly following (September) each financial year, to discuss business and investment plans and clarify and confirm opportunities for, and outcomes of, cooperation and collaboration between the parties;
b. consult in the preparation of strategic, management and development plans for the area or in amendments to existing plans, and aim to ensure such plans have been guided by the overarching principles set out in this MoU and provide for complementary policies and management practices throughout the area; and
c. annually, identify and integrate, as appropriate, an agreed program of works or activities for the following 12 months. This program to have regard to the actions and priorities detailed in the current catchment management plan made under the *Coastal Protection Act 1979*.

CONTACT
Tom Alletson, Tweed Shire Council

TERM
This MoU shall continue for a period of five years from the date of commencement. Prior to expiry, the parties will review the agreement and determine whether it should be renewed, varied or terminated.

REVIEW
The parties will review the MoU at each anniversary.

VARIATION
The MoU may be amended or varied from time to time provided that such amendment or variation is evidenced in writing and signed by the parties.

NO LEGAL EFFECT
This document is a Memorandum of Understanding and is not intended to, nor does it, create binding or legal obligations on or between the parties.

DATE
This Memorandum is made on XXXXXX

SIGNED by the parties:

Tweed Shire Council

NSW Department of Lands

NSW Department of Environment and Climate Change

NSW Roads and Traffic Authority

QLD Department of Main Roads

NSW Department of Primary Industries - Fisheries

NSW Department of Planning

NSW Northern Rivers Catchment Management Authority

Commonwealth Department of Infrastructure, Transport, Regional Development & Local Government

Tweed Byron Local Aboriginal Land Council

Gold Coast Native Title Group (GCNTG)

Gold Coast Airport Pty Ltd (GCAL)

Leda Developments Pty Ltd (LD)

Appendix H: Catchment Pollutant Export Modelling

MUSIC (Model for Urban Stormwater Improvement Conceptualisation) is a computer software package developed by the Cooperative Research Centre for Catchment Hydology and is widely used throughout the stormwater industry. The program uses local rainfall and catchment parameters, treatment characteristics and certain default parameters to estimate the concentration and loads of pollutants in stormwater and the likely performance of stormwater treatment measures.

The aim of the pollutant modelling was to develop a model of catchment pollutant exports (nitrogen, phosphorus and suspended solids) to understand existing loadings and loadings anticipated in future development scenarios. These results have been incorporated into the assimilative modelling to determine the capacity of the broadwaters to assimilate pollutants from catchment runoff. The assimilative modelling can then determine whether the broadwaters can continue to act as a sink for nutrients under existing and future anticipated loadings, or if the assimilative capacity is likely to be exceeded. MUSIC modelling also assists with the identification of 'hotspot' areas of the catchment that are likely to be contributing high pollutant loads that can be prioritised for stormwater quality improvement device (SQID) retrofitting.

> The results of catchment pollutant modeling have been incorporated into the assimilative modeling to determine whether the broadwaters can continue to act as a sink for nutrients under existing and future anticipated loadings, or if the assimilative capacity is likely to be exceeded.

H.1 Scope

Modelling included two scenarios:

1. Existing catchment (no mitigation measures)
2. Future development (Cobaki Lakes, Bilambil Heights, Area E) with no treatment measures to represent the 'worst case' scenario

H.2 Methodology and Assumptions

Scenarios were modelled in accordance with the Tweed Shire Council MUSIC guidelines, as outlined in D7 – Stormwater Quality: Development Design Specification (Tweed Shire Council, 2004). The model was set up to represent various landuse nodes and their hydrological connections as well as their physical and pollutant export characteristics. Parameter values are also consistent with those used in modelling undertaken as part of the Banora Point and Tweed Heads West WRP Reclaimed Water Management Strategy EIS (GHD, 2005).

H.2.1 Catchment Data

The catchment was divided into 49 sub-catchments which have been summarised by locality into five main sub-catchments: Cobaki, Terranora, Terranora Inlet North, Terranora Inlet South and Dry Dock. The catchment has also been divided based on the identified functional zones of each sub-catchment to provide an understanding of the contribution of pollutants by functional zone (Upper, Mid, Transition, Estuarine).

The catchment areas and layout were determined using Mapinfo TIS software and a Digital Terrain Model supplied by Tweed Shire Council. Landuse based on the Tweed Shire Council Local Environmental Plan (LEP). Area of landuse for each sub-catchment was calculated using GIS data.

H.2.2 Climate Data

Rainfall data was sourced from the Elanora station (ID 40609) and obtained from the Bureau of Meteorology. The year 1990 was selected as it represented a typical wet year with a total rainfall of 2055 mm/year. Rainfall data from 1989 was included in the dataset only to enable the model to incorporate groundwater storage recharge. The analysis of results does not use this year of rainfall. Subsequent modelling using 2007 and 2008 rainfall data was undertaken to maintain consistency with monitoring data collected for the same time period (2008).

Potential evapotranspiration values were sourced form the Tweed Shire Council MUSIC guidelines, outlined in D7 – Stormwater Quality: Development Design Specification (Tweed Shire Council, 2004). Average Monthly Pan Evaporation (mm) is as follows:

Month	Pan Evaporation (mm)
January	165
February	135
March	135
April	100
May	70
June	60
July	60
August	75
September	105
October	135
November	150
December	165

H.2.3 Input Parameters

Rainfall/runoff parameters and default pollutant export parameters were sourced from the Tweed Shire Council MUSIC guidelines outlined in D7 – Stormwater Quality: Development Design Specification (Tweed Shire Council, 2004). Tweed Shire Council MUSIC guidelines have three land uses available to characterise the hydrological and pollutant export properties of each sub-catchment: rural, urban and forest/undeveloped. The default values used in the modelling are shown in Tables H.1-H.3 below.

Table H.0.1. Input parameters for urban areas

Parameter				Input
Source node type				Urban
Area				ha
Pervious area				50%
Impervious area				50%
Rainfall runoff parameters		Rainfall threshold		1mm/day
		Soil storage capacity		150 mm
		Initial storage		25%
		Field capacity		50mm
		Infiltration capacity coefficient – a		50
		Infiltration capacity exponent – b		2
	Ground water	Initial depth		50mm
		Daily recharge rate		0.65%
		Daily base flow rate		0.85%
		Daily deep seepage rate		0
Total suspended solids parameters (log mg/L)		Base flow	mean	0.80
			SD	0.200
		Storm flow	mean	2.00
			SD	0.145
Total phosphorus parameters (log mg/L)		Base flow	mean	-1.00
			SD	0.34
		Storm flow	mean	-0.68
			SD	0.28
Total nitrogen parameters (log mg/L)		Base flow	mean	-0.10
			SD	0.05
		Storm flow	mean	0.193
			SD	0.05

Table H.2 Input parameters for undeveloped areas

Parameter				Input
Source node type				Undeveloped
Area				ha
Pervious area				100%
Impervious area				0%
Rainfall runoff parameters		Rainfall threshold		1mm/day
		Soil storage capacity		150 mm
		Initial storage		25%
		Field capacity		50mm
		Infiltration capacity coefficient – a		50
		Infiltration capacity exponent – b		2
	Ground water	Initial depth		50mm
		Daily recharge rate		0.65%
		Daily base flow rate		0.85%
		Daily deep seepage rate		0
Total suspended solids parameters (log mg/L)		Base flow	mean	0.80
			SD	0.200
		Storm flow	mean	1.20
			SD	0.145
Total phosphorus parameters (log mg/L)		Base flow	mean	-1.00
			SD	0.34
		Storm flow	mean	-1.47
			SD	0.30

Total nitrogen parameters (log mg/L)	Base flow	mean	-0.10
		SD	0.05
	Storm flow	mean	-0.9
		SD	0.1

Table H.3. Input parameters for rural areas

Parameter				**Input**
Source node type				Rural
Area				ha
Pervious area				80%
Impervious area				20%
Rainfall runoff parameters	Rainfall threshold			1mm/day
	Soil storage capacity			150 mm
	Initial storage			25%
	Field capacity			50mm
	Infiltration capacity coefficient – a			50
	Infiltration capacity exponent – b			2
	Ground water	Initial depth		50mm
		Daily recharge rate		0.65%
		Daily base flow rate		0.85%
		Daily deep seepage rate		0
Total suspended solids parameters (log mg/L)	Base flow	mean		0.6
		SD		0.200
	Storm flow	mean		1.627
		SD		0.20
Total phosphorus parameters (log mg/L)	Base flow	mean		-1.40
		SD		0.40
	Storm flow	mean		-0.95
		SD		0.10
Total nitrogen parameters (log mg/L)	Base flow	mean		-0.150
		SD		0.40
	Storm flow	mean		-0.250
		SD		0.197

The rainfall data and default parameters above were applied to each sub-catchment. A summary of the landuse applied to each sub-catchment, its area and associated fraction impervious is shown below in Table H.4.

H.3 Results and Discussion

The modelling of the existing catchment reflects the impact landuses make to pollutant loadings with the heavily developed urban areas delivering far greater loads in general. Due to the size of some upper sub-catchments, these rural areas can be significant contributors also (Ter 2n, Ter 1s). The highest urban area contributions included Tweed Heads, Tweed Heads South, Tweed Heads West, Banora Point, Cobaki Lakes and the Gold Coast Airport (units Ter3e, Ter 2e, Cob17n, Cob10un, Cob11n, Cob5us, Tin2, Dry Dock 1, Tis1). A large part of Banora Point stormwater flows through the Western Drainage Scheme which discharges to the north-west corner of Trutes Bay. This was also modelled, the results of which are displayed in Figure H.1 The results for modelling undertaken on the existing catchment landuse are provided in Table H.4 and in Figures H.2 and H.3 below.

Modelling was also undertaken to consider the change in pollutant load that could result from the three major developments planned for the catchment: the development known as Area E to the south of Terranora Broadwater, Cobaki Lakes to the north-east of Cobaki Broadwater and Bilambil Heights to the south of Cobaki Creek. Table H.4 provides the predicted unmitigated change to pollutant loads likely to result from each development, representing the effect of the change in landuse from rural/undeveloped to urban. Results indicate that the largest volume increase is likely to result from the Bilambil Heights development due to the large area of this development. However, the greatest percentage increase in pollutants found between the existing position and post development (unmitigated) is likely to be from Cobaki Lakes with 237% increase in TSS, 231% increase in TP and 270% increase in TN.

It is important to note that in addition to the modelled pollutant load there is the discharge from the STP which has been previously modelled as part of the EIS for Banora Point STP Reclaimed Water Release report (GHD, 2005). These results were considered in the modelling undertaken in the current study to determine the assimilative capacity of the Broadwaters.

Table H.0.2. Land use applied to each sub-catchment and resulting annual pollutant load for existing catchment landuse

Sub-catchment Modelling Unit	Functional Zone	Sub-catchment Surface Area (ha)	MUSIC Fraction Impervious	Assigned Land Use	TSS (kg/yr)	TP (kg/yr)	TN (kg/yr)
Terranora Catchment							
Ter1e	Bilambil estuarine	227.65	0	Undeveloped	29,100	76	460
Ter1n	Bilambil upper	890.35	0	Undeveloped	19,000	72	272
Ter1s	Duroby upper	732.52	0.2	Rural	100,000	249	1,860
Ter2e	Bilambil estuarine	228.71	0.5	Urban	136,000	365	1,890
Ter2n	Bilambil mid	765.22	0.2	Rural	116,000	284	1,403
Ter2s	Duroby mid	484.55	0.2	Rural	48,900	145	958
Ter3e	Bilambil estuarine	393.62	0.5	Urban	228,000	554	3,400
Ter3n	Bilambil mid	532.35	0.2	Rural	69,700	185	1,140
Ter3s	Bilambil estuarine	467.09	0.2	Rural	57,900	152	907
Ter4n	Bilambil transition	18.10	0.5	Urban	10,600	24	160
Ter4s	Duroby transition	99.57	0.5	Urban	56,000	129	870
Ter5n	Bilambil estuarine	110.69	0.5	Urban	59,400	132	960
Ter6n	Bilambil estuarine	325.71	0.2	Rural	45,000	112	753
Ter7n	Bilambil estuarine	142.50	0.2	Undeveloped	2,930	11	39
Ter8n	Bilambil transition	145.35	0.2	Rural	22,100	52	278
Ter9n	Bilambil estuarine	70.52	0.5	Urban	38,700	93	593

Sub-catchment Modelling Unit	Functional Zone	Sub-catchment Surface Area (ha)	MUSIC Fraction Impervious	Assigned Land Use	TSS (kg/yr)	TP (kg/yr)	TN (kg/yr)
Sub total		***5634.50***			***1,039,330***	***2,635***	***15,943***
Dry Dock Catchment							
DryDock1	Terranora Ck estuarine	107.80	0.5	Urban	70,100	177	924
DryDock2	Terranora Ck estuarine	53.33	0.5	Urban	31,000	87	465
Sub total		***161.13***			101,100	264	1,389
Cobaki Catchment							
Cob10un	Cobaki transition	154.50	0.5	Urban	96,300	227	1,340
Cob11n	Cobaki transition	157.09	0.5	Urban	91,100	218	1,390
Cob12n	Cobaki transition	29.67	0	Undeveloped	758	3	9
Cob13n	Cobaki transition	116.87	0	Undeveloped	2,130	6	32
Cob14n	Cobaki estuarine	31.40	0	Undeveloped	596	2	9
Cob15n	Cobaki estuarine	159.43	0	Undeveloped	3,840	15	45
Cob15s	Cobaki estuarine	73.22	0.2	Rural	10,800	25	146
Cob16s	Cobaki estuarine	57.17	0.5	Urban	32,000	76	483
Cob17n	Cobaki estuarine	205.96	0.5	Urban	124,000	292	1,740
Cob1n	Piggabeen upper	437.52	0.2	Rural	68,800	158	774
Cob1s	Cobaki upper	467.99	0.2	Rural	69,300	158	901
Cob1us	Bilambil heights	73.65	0.5	Urban	43,100	95	626
Cob2n	Piggabeen middle	459.71	0.2	Rural	67,900	165	940
Cob2s	Cobaki middle	363.83	0.2	Rural	51,700	123	698
Cob2us	Cobaki transition	65.45	0.5	Urban	36,800	83	568
Cob3n	Piggabeen middle	258.76	0.2	Rural	29,100	84	543
Cob3s	Cobaki middle	251.15	0.2	Rural	36,100	89	459
Cob3us	Bilambil heights	58.66	0	Undeveloped	1,360	4	16
Cob4n	Cobaki transition	183.14	0.2	Rural	26,700	63	328
Cob4s	Cobaki transition	52.93	0.2	Rural	8,180	19	98
Cob4us	Bilambil heights	295.98	0.2	Rural	36,500	99	606
Cob5n	Cobaki transition	167.28	0.2	Rural	23,000	62	327
Cob5us	Bilambil heights	143.93	0.5	Urban	86,500	220	1,230

Sub-catchment Modelling Unit	Functional Zone	Sub-catchment Surface Area (ha)	MUSIC Fraction Impervious	Assigned Land Use	TSS (kg/yr)	TP (kg/yr)	TN (kg/yr)
Cob6d	Cobaki transition	138.68	0.2	Rural	17,400	45	248
Cob6us	Cobaki estuarine	145.28	0	Undeveloped	2,920	10	39
Cob7us	Cobaki estuarine	52.22	0.2	Rural	7,190	18	92
Cob8un	Cobaki estuarine	136.55	0.2	Undeveloped	21,400	50	314
Cob9un	Cobaki transition	70.89	0	Undeveloped	11,400	26	131
Sub total		***4808.90***			***1,006,874***	***2,435***	***14,132***
Terranora Inlet North Catchment							
Tin1	Terranora Ck estuarine	63.00	0.5	Urban	39,200	101	537
Tin2	Terranora Ck estuarine	118.47	0.5	Urban	67,800	158	1,040
Sub total		***181.47***			***107,000***	***259***	***1,577***
Terranora South InletCatchment							
T is1	Terranora Ck estuarine	131.52	0.5	Urban	77,300	207	1,120
Sub total		***131.52***			***77,300***	***207***	***1,120***
Total					**2,224,604**	**5,541**	**32,584**

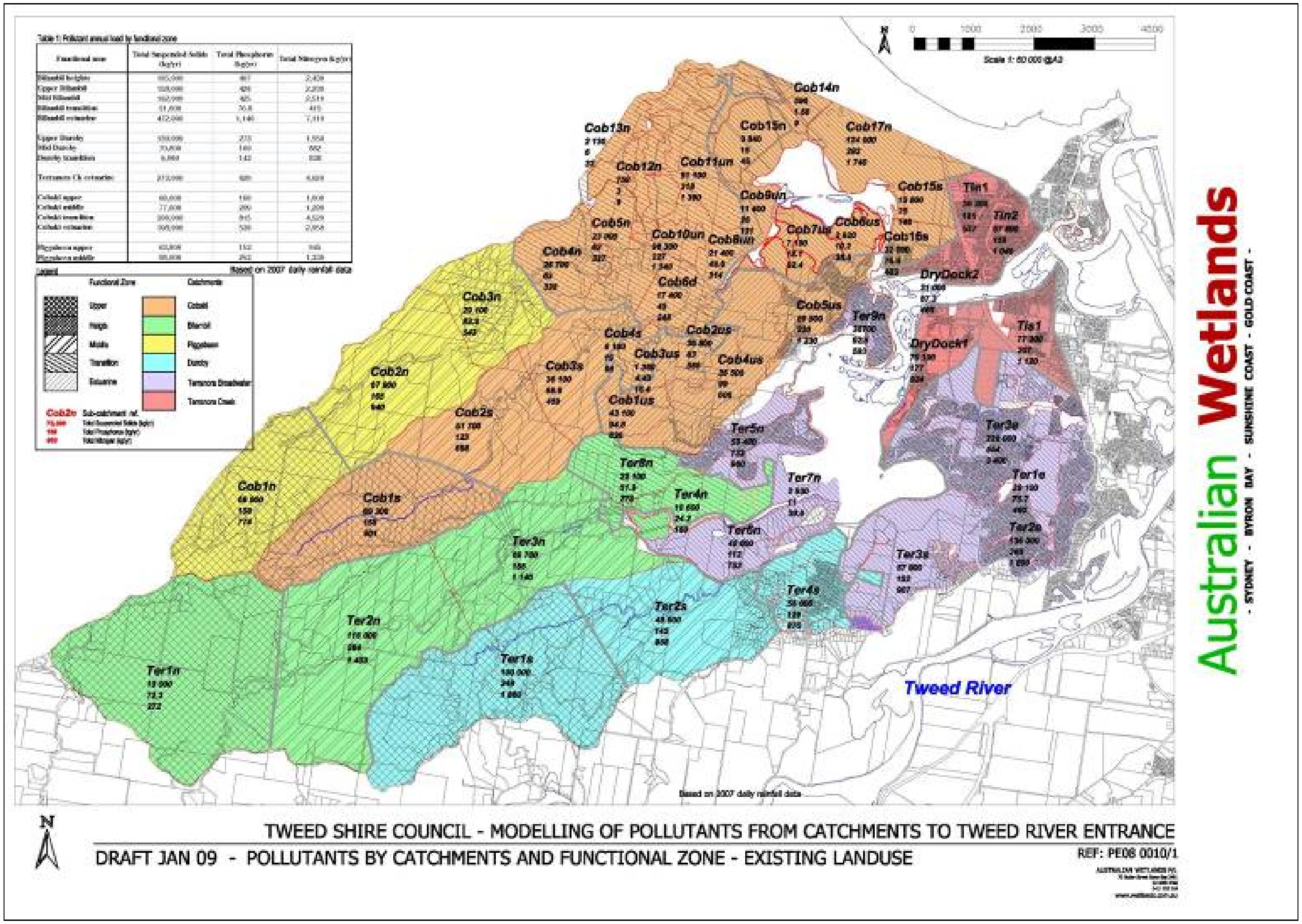


Figure H.0.1. Estimate of pollutant discharged from existing subcatchments and functional zones

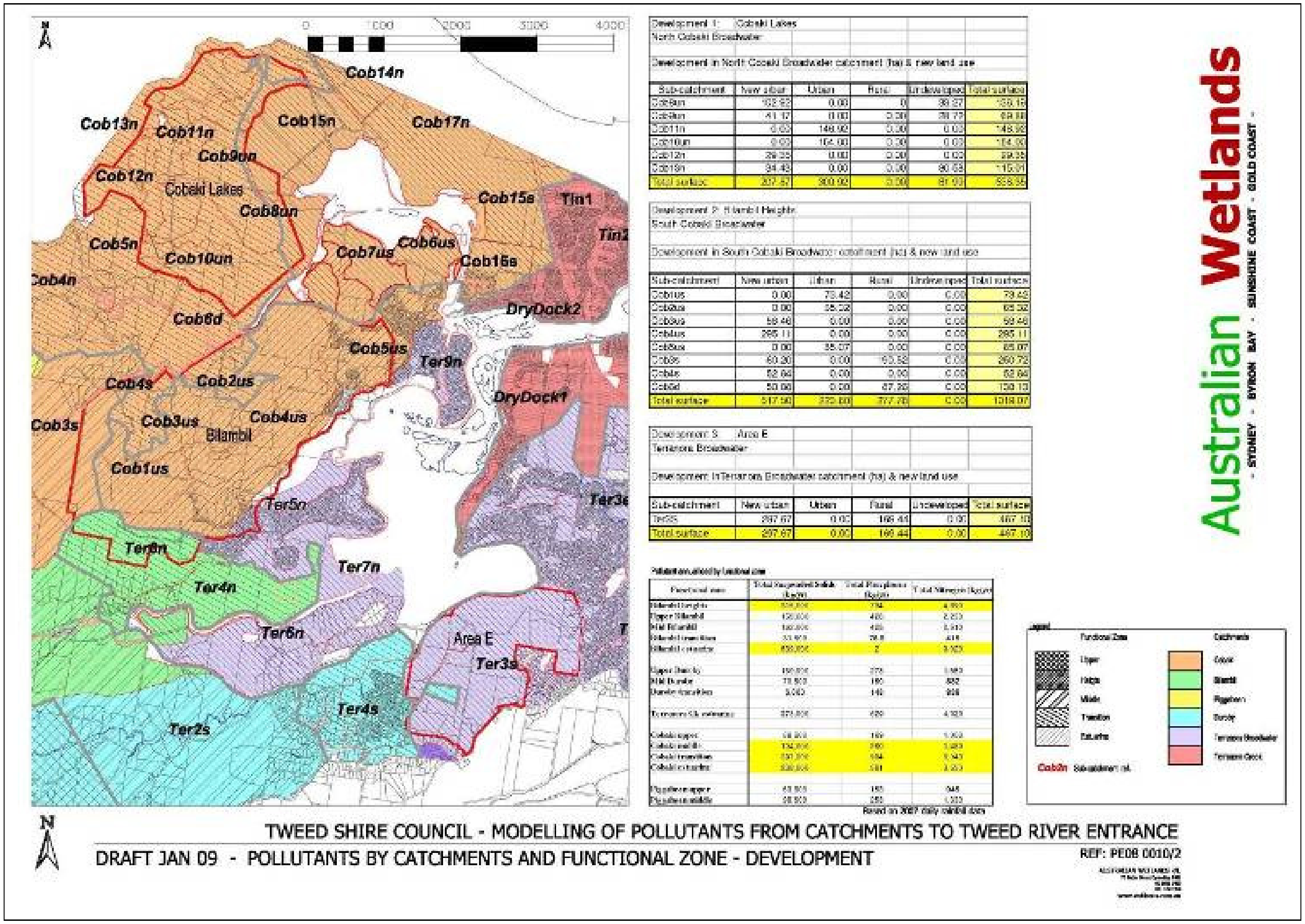


Figure H.0.2. Estimate of pollutants discharged post development without treatment

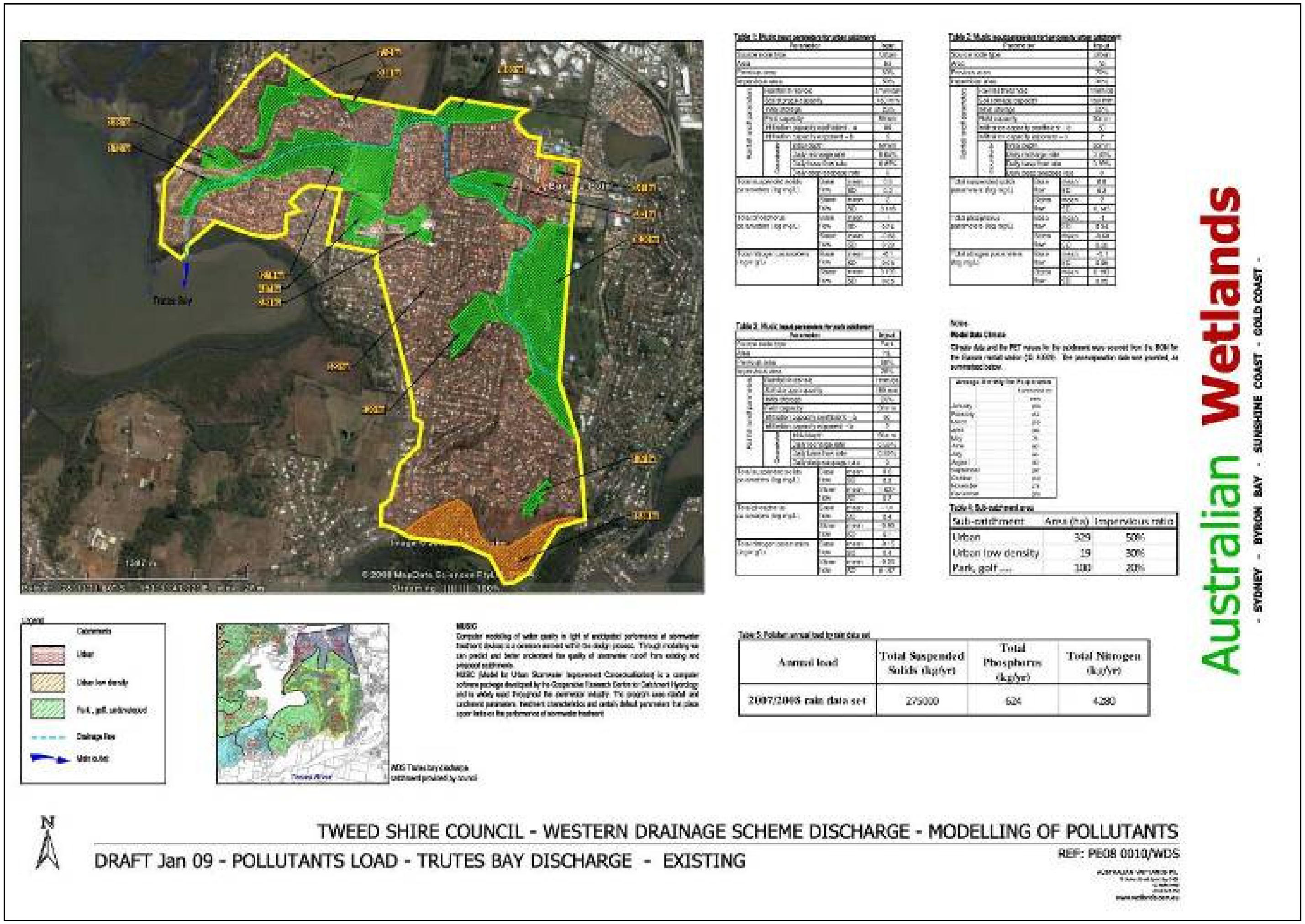


Figure H.0.3. Estimate of pollutants discharged from existing Western Drainage Scheme

Table H.0.3. Predicted unmitigated change to pollutant loads resulting from new development

Sub-catchment Modelling Unit	Functional Zone	Surface Area (ha)	Existing Assigned Land Use	TSS (kg/yr) existing	TSS (kg/yr) new dev	TP (kg/yr) existing	TP (kg/yr) new dev	TN (kg/yr) existing	TN (kg/yr) new dev	New dev area
Ter3s	Bilambil estuarine	467.09	Rural	57,900	158,000	152	350	907	2500	Area E
Total Increase					**100,100**		**198**		**1,593**	
% Increase					**173%**		**130%**		**176%**	
Cob4us	Bilambil heights	295.98	Rural	36,500	187,000	99	473	606	2670	Bilambil Heights
Cob3s	Cobaki middle	251.15	Rural	36,100	32,900	89	82	459	514	
Cob6d	Cobaki transition	138.68	Rural	17,400	31,100	45	78	248	456	
Cob4s	Cobaki transition	52.93	Rural	8,180	29,400	19	81	98	463	
Cob3us	Bilambil heights	58.66	Undeveloped	1,360	29,300	4	69	16	528	
Total				*99,540*	*309,700*	*256*	*783*	*1,427*	*4631*	
Total Increase					**210,160**		**527**		**3,204**	
% Increase					**211%**		**206%**		**225%**	
Cob8un	Cobaki estuarine	136.55	Undeveloped	21,400	56,900	50	122	314	904	Cobaki Lakes
Cob9un	Cobaki transition	70.89	Undeveloped	11,400	25,500	26	65	131	353	
Cob13n	Cobaki transition	116.87	Undeveloped	2,130	20,400	6	57	32	292	
Cob12n	Cobaki transition	29.67	Undeveloped	758	17,400	3	37	9	248	
Total				*35,688*	*120,200*	*85*	*281*	*486*	*1,797*	
Total Increase					**84,512**		**196**		**1,311**	
% Increase					**237%**		**231%**		**270%**	

Note: These sub-catchment units are only those predicted to have a landuse change as a result of development. Existing urban areas within the new development footprint are not included in these figures.

Appendix I: Costs to Implement High Priority Actions

The following table contains a summary of high priority actions from the action plan in Section 12 that are scheduled to be undertaken within the first year of adoption of this management plan. For the complete set of actions, refer to Section 12. The following assumptions were made in order to approximate the cost to implement the following high priority actions:

- Only the High priority actions that have a dollar value attributed to them have been included.
- For riparian restoration, costings assumed 3km of works to be achieved within the first year. Costings were based on the average planting cost, the cheapest fencing option, and do not include costs for off creek stock watering.
- Rehabilitation of Broadwater riparian remnants will need to be calculated following site investigations and action plan development.

Strategy	Action Summary		Cost
1. Geomorphic Structural Works			
Riparian zone of major creeks	1.1	Detailed geomorphic investigations at Level 1 priority sites	$30,000/site x 7 sites = $210,000
Sub-total			**$210,000**
2./3. Broadwater Foreshore and Rural Catchment Riparian Rehabilitation			
	2.1	Develop urban HCV remnant action plans for T1, T3, T4 and T7 to address key threatening processes for the ecological restoration of Level 1 priority remnants	$5,000/remnant = $20,000
	2.5 / 3.1	(a) Develop site-based action plans for 3 km of riparian zone - prioritising road reserve along both banks of Bilambil Creek (T8), transition – mid catchment (b) Fencing and restoration (c) Maintenance for one year	For 3km: (a) $3,000/site x 3 sites? = $9,000 (b) $7,500 (fencing) + $135,000 (planting) + $12,000 (weed removal) + $15,000 (initial watering) = $169,500 (c) $ 30,000 Total = $208,500
	2.7	Develop urban remnant action plan for HCV T9 to address key	$5,000

		threatening processes for the ecological restoration	
	3.2	Employ a permanent extension officer to facilitate the development of site-based action plans with landowners	$70,000
Sub-total			**$303,500**
5. Urban Stormwater			
	5.1	Water quality sampling at major outlets of Western Drainage Scheme	$30,000
	5.2	Sediment analysis of Western Drainage Scheme	$35,000
	5.3	Workshop with key Council staff to discuss feasibility of retrofitting and redesign of Western Drainage Scheme	$15,000
	5.4	Ongoing maintenance of Western Drainage Scheme.	Condition-dependent
	5.11	Investigate the impacts of soil acidification and potentially contaminated runoff discharged from surface drains at Tugun Bypass site.	$20,000
Sub-total			**$100,000**
7. Ecology			
	7.3	Construction of spring tide shorebird roost at Tommy's Island (a) Discuss feasibility with state agencies (b) Undertake EIA.	(a) N.A. (b) $10,000
Sub-total			**$10,000**
8. Cultural Heritage			
	8.3	Establish a formal policy of appropriate consultation protocols with the local Aboriginal community.	$50,000
Sub-total			**$50,000**
9. Recreation			
	9.4	Complete final design and obtain approvals for construction of foreshore walkway in Dog Bay, Terranora Broadwater.	$100,000
	9.5	Replace destroyed interpretive signage along foreshore in Bingham Bay.	$10,000
Sub-total			**$110,000**
Total			**$783,500**