Macleay Ecohealth Project 2015-2016

Assessment of River and Estuarine Condition

Final Technical Report

December 2016

Darren Ryder, Sarah Mika, Ben Vincent, Adrienne Burns and John Schmidt

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Cover Photo: Macleay River (A. Greig, 2015).

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Glossary of General Terms

Algal biomass	The mass of algae in a water body at a given time.
Aquatic macroinvertebrates	Larger aquatic invertebrates, functionally defined as those retained on a 500µm sieve. Their body length usually exceeds 1mm.
Bank slumping	The mass movement of bank material after failure.
Chlorophyll *a*	A green pigment found in plants that allows them to photosynthesise. Chlorophyll *a* measurements are an indicator of the amount of phytoplankton and algae in a water body.
Dissolved oxygen (DO)	The concentration of gaseous oxygen (O_2) dissolved in an aqueous solution.
Geomorphic condition	An assessment of bank condition (e.g. slope, bank slumping, exposed tree roots and undercutting), bed condition (active erosion and smothering of the bed substrate by high loads of fine sediment) and trampling by stock.
Ecohealth indicators	A selection of measurements that indicate if there are stresses to the aquatic ecosystem as a whole. Indicators include water quality (dissolved oxygen, salinity, acidity, turbidity, nutrients), riparian condition (vegetation composition, occurrence of riparian weeds, riparian habitat), geomorphic condition and composition of aquatic macroinvertebrate communities.
Oxides of nitrogen (NOx)	Compounds of nitrogen and oxygen, primarily NO, NO_2, N_2O and N_2O_5.
pH	The dissolved hydrogen ion concentration. Acidic solutions have a pH < 7, basic solutions have a pH > 7.
Riparian condition	The health of a riparian zone, based on an assessment of the occurrence of weeds, structure of riparian vegetation, habitat (e.g. logs) and management regime.
Riparian zone	The area of land adjoining rivers and streams that has a direct influence on the water and aquatic ecosystems within those rivers and streams. It includes stream banks and a strip of land of variable width along the banks.
SIGNAL2	SIGNAL stands for “Stream Invertebrate Grade Number – Average Level”. SIGNAL2 is a scoring system for Australian macroinvertebrates based on their sensitivity to pollution.
Soluble reactive phosphorus (SRP)	The concentration of inorganic ions of phosphorus (predominately HPO_4^{2-} and PO_4^{3-}) in water. These ions are available to be used by aquatic biota.
Total nitrogen (TN)	The concentration of nitrogen in the water, both in organic and inorganic forms.
Total phosphorus (TP)	The concentration of phosphorus in natural or anthropogenic substances that contain, or decompose to produce phosphate ions.
Total suspended solids (TSS)	All particles suspended in water that do not pass through a 1.2µm filter.
Turbidity	The cloudy appearance of water due to suspended material.

Glossary of Soil Terms

A horizon	The top soil layer containing the greatest concentration of organic material. Consists mainly of clay minerals and quartz with an absence of soluble minterals.
Anthroposol	Soils arising from human activities where soil horizons are profoundly modified, truncated or buried; the creation of new soil parent materials by mechanical means.
B horizon	The second soil layer comprising an illuvial concentration of silicate clay, iron, aluminium, humus, carbonates, gypsum or silica alone or in combination.
Dermosol	Soils having structured subsurface horizons with a lack of textural contrast between A and B horizons.
Ferrosol	Soils with subsurface horizons that are high in free iron oxide and that lack textural contrast between surface and subsurface horizons. Formed from basic or ultrabasic igneous rocks or alluvium derived from these.
Hydrosol	Soils other than organosols, podosols or vertosols in which the greater part of the soil profile is saturated for at least 2-3 months in most years.
Kandosol	Soils that lack strong textural contrast, have massive or weakly structured B horizons, have a maximum clay content exceeding 15% in the B2 horizon, and do not have a calcareous A horizon.
Kurosol	Soils with strong textural contrast between A horizons and strongly acid B horizons.
Podosol	Soils with B horizons dominated by the accumulation of organic matter, aluminium and/or iron.
Rudosol	Typically young soils with neglibile pedologic organization. These soils vary widely in texture and depth with many stratified and some highly saline.
Tenosol	Soils that have weak pedologic organization apart from the A horizon. These soils are diverse but includes soils having a peaty horizon or overlying a calcrete pan or hard, unweathered rock.
Vertosol	Clay soils (clay texture greater than 35%) with shrink-swell properties that exhibit strong cracking when dry and at depth, have slickensides and/or lenticular structure aggregates.

Glossary of Vegetation Terms

Canopy	Growth form: the tallest growing layer of vegetation in a plant community.
Continuity	The degree of continuous uninterrupted vegetation: is used as a measure of riparian condition.
Connectivity	Proximity of site to intact remnant stands of native vegetation.
EEC	Endangered Ecological Community, as determined by State and Federal Government.
Fire regime	Refers to the pattern, frequency and intensity of fire.
Forb/herb	A small non-woody flowering plant found in the understory.
Fringing vegetation	The terrestrial riparian vegetation directly adjacent to a water body/channel, specifically graminoides.
Graminoid	Growth form: a collective term for all monocotyledons - grasses, sedges and rushes.
Intact remnant	An area of native vegetation that has had little-to-no disturbance or alterations. Remnant conditions can vary from being intact to disturbed.
Leaf litter	The collective term for fallen leaves on the ground.
Macrophyte	Plant species found growing in water or wetland, which may be submergent, emergent or floating.
Midstorey	Growth form: those plants found growing to a height of greater than c.1.5 metres and less than 5 metres.
Proximity	How close the patch of vegetation under assessment is to a good condition, large remnant stand of native vegetation.
Riparian condition	The health of a riparian zone, based on an assessment of the occurrence of weeds, structure of riparian vegetation habitat (e.g. logs) and management regime.
Riparian zone	The area of land adjoining rivers and streams that has a direct influence on the water and aquatic ecosystems within those rivers and streams. It includes stream banks and a strip of land of variable width along the banks.
Phase-out strategy	Strategically staggered removal of a weed species (e.g. Camphor Laurel). Such removal allows time for native plantings to replace weed species, while simultaneously maintaining bank stability and wildlife habitat.
Species of Interest (SOI)	Refers to both exotic weeds (noxious and environmental), and native species that are rare, uncommon or are an indicator of condition in a vegetation system.
Weed control	Where environmental and noxious weed species are reduced or removed through chemical, mechanical, or physical means.
Weed monitoring	Where weed species are repeatedly surveyed for their range expansion and potential spread.
Understorey	Growth form: those plants found growing to a height of less than c.1.5 metres.
Vegetation	All flowering and non-flowering land and water plants.

Classes of Noxious Weeds

Class 1	State Prohibited Weed: *The plant must be eradicated from the land and that land must be kept free of the plant.*
Class 2	Regionally Prohibited Weed: *The plant must be eradicated from the land and that land must be kept free of the plant.*
Class 3	Regionally Controlled Weed: *The plant must be fully and continuously suppressed and destroyed and the plant must not be sold, propagated or knowingly distributed.*
Class 4	Locally Controlled Weed: *The growth of the plant must be managed in a manner that continuously inhibits the ability of the plant to spread.*
Class 5	Restricted Plant: *The requirements in the Noxious Weeds Act 1993 for a notifiable weed must be complied with.*

Summary

The development of a standardised means of collecting, analysing and presenting riverine, coastal and estuarine assessments of ecological condition has been identified as a key need for coastal Local Councils who are required to monitor natural resource condition, and water quality and quantity in these systems. Forty-four study sites were selected across the Macleay catchment; 32 freshwater sites and 12 estuarine sites and these were sampled 6 times from April 2015 to February 2016 to contribute to the assessment of the ecological condition of the catchment.

The Macleay River Catchment was divided into four major hydrological units across 22 sub-catchments: Tablelands, Macleay River main stem, freshwater tributaries and the estuarine tributaries. The project aimed to:

- Assess the health of coastal catchments using standardised indicators and reporting for estuaries, and freshwater river reaches using hydrology, water quality, riparian vegetation and habitat quality, geomorphic condition and macroinvertebrate assemblages as indicators of aquatic ecosystem health, and
- Contribute scientific information to the development of a report card system for communicating the health of the estuarine and freshwater systems in the Macleay catchment.

Report Card

The Overall Grade for the Macleay catchment was C-, ranging from an F in the Tia River, and Commissioners and Salisbury Waters, to a B- in the Styx River. Fifteen of the 26 river systems recorded a score of D+ or less. The estuarine tributaries were in the poorest condition, with an overall score of 56 (D+). This was very closely followed by the tableland tributaries with an overall score of 57 (D+). Water quality scores were consistently poor across the catchment, driven by high nutrient concentrations. Riparian and geomorphic scores were relatively consistent among and within each system, highlighting that issues with physical condition are affecting the long-term condition of the streams. Reference sites contained exceptionally high abundances and diversity of aquatic macroinvertebrates, lowering the relative scores of many sites across the catchment and highlighting the potential biodiversity improvement with site restoration actions.

Geomorphic Condition

Geomorphic condition in the Macleay shows most (82%) of the stream network is in good or moderate condition. Six subcatchments have more than 50% of their stream network in good condition. These include the upper Macleay and Styx Rivers, and Georges Creek that mostly comprise gorge country; and Five Day, Toorumbee and Dungay Creeks that mostly comprise planform-controlled, low sinuosity gravel-bed channels. Four subcatchments contained no stream reaches in poor condition: Yarrowitch River on the tablelands, and the freshwater tributaries of Mungay, Dungay and Collombatti Creeks. Four subcatchments had more than one-third of their stream network in poor condition: Commissioners Waters (65%), Salisbury Waters (56%), Bakers

Creek (34%), and Nulla Nulla Creek (47%), and generally comprised fine-grained and sandy sediments. All four subcatchments have been significantly cleared of catchment and riparian vegetation in the reaches with poor geomorphic condition.

Riparian Condition

The area within a riparian zone can contain valuable water resources, highly fertile soil and supports high levels of biodiversity as well as many social and economic functions. Riparian condition for the Macleay catchment was poor across the 44 sites of the Macleay River Catchment. The majority of Ecohealth sites contributing to this riparian condition grade were representative of the area of the Catchment that has been subjected to broadscale landuse and anthropogenic impact. The Macleay River Catchment was therefore assessed as one of high disturbance. For example, the Tableland tributaries were highly disturbed systems in a predominantly cleared, partially forested landscape and therefore received consistently poor scores. In contrast, the freshwater tributaries provided examples of high quality riparian vegetation (and other positive Ecohealth grades), identifying the important role of riparian restoration in the catchment. The overall Macleay Catchment score, however, does not reflect the riparian condition of wilderness areas which account for approximately 4,910km^2 of the 11,389 m^2, or 43% of the Macleay Catchment.

Of the 372 dominant riparian vegetation species recorded from the 44 Macleay Ecohealth sites, 126 were exotic species, while 246 species were native species. The main stressors to riparian condition were the dominance of invasive weeds, vegetation clearing causing reduced riparian continuity and isolation from large patches of remnant vegetation, and access by livestock. The most common dominant weed species were Prairie Grass (*Bromus catharticus*) in 66% of sites, Lantana (*Lantana camara*) in 61% of sites, Purpletop (*Verbena bonariensis*) in 61% of sites, Cobblers Pegs (*Bidens* sp.) in 57% of sites and Spear Thistle (*Cirsium vulgare*) in 57% of the 44 Macleay Ecohealth sites. Twenty-one noxious weed species were observed in the Macleay Catchment; 1 species was a class one, 3 species were class three, 15 species were class four and 2 species were class five noxious weed species. The influence of clearing and physical stressors (trampling and grazing) has reduced the recruitment of native vegetation in the riparian zone.

Strongly linked to riparian condition, the active restoration of native riparian vegetation as a long term action for improving geomorphic condition and aquatic macroinvertebrate habitat should be a priority in the Macleay. Management recommendations are given in Part 4.

Mangrove, seagrass and saltmarsh cover

Estuarine macrophytes are essential components of estuarine ecology. They improve water quality, contribute to the food chain, stabilise morphology by binding sediments, and provide both habitat and a nursery ground for fish and other marine species. Total estuarine macrophyte cover (i.e. grouped - mangroves, saltmarsh and seagrass) increased between 1980 and 2011 in both the Macleay River (8%) and South West Rocks Creek (also called Back Creek, 55%) estuaries, attributed to an increase in mangrove and saltmarsh cover, in both the Macleay River estuary (15% and 7%, respectively) and South West Rocks Creek estuary (49% and 102%, respectively). The largest proportional increases in mangrove cover were in the Pelican Island (21%) and Shark Island (10%) zones. Mangrove cover in Yarrahappinni and Clybucca Creek was considerably reduced (-100% and -35% respectively). In contrast, seagrass cover declined between 1980 and 2011 in both the Macleay River (20%) and South West Rocks Creek (96%). Only one estuary zone, Stuarts Point, recorded a proportional increase in seagrass cover (3%). The largest reductions in seagrass cover were in the Pelican Island estuary (-88%) and Clybucca Creek (-59%).

The significant decrease observed in seagrass cover is concerning. In addition to naturally occurring weather events such as storms, cyclones and floods, anthropogenic factors that can lead to seagrass degradation and decline include excessive turbidity and siltation that reduces light intensity, elevated nutrient levels, stormwater discharge, heavy metal and toxin deposition, exposure to low pH events, erosion, coastal development, moorings, boat propellers and introduced species. Management priorities should be focused on long-term monitoring and mapping of seagrass cover change and addressing direct causes of this estuarine macrophyte community decline. Future investment may include re-establishing seagrass in this estuary once the limiting factors are better understood.

Water Quality

Water quality was poor across the Macleay catchment, with an overall grade of D+ (Table 3.12). Water quality was consistently poorest in the Tablelands with the majority of sites recording scores less than 50, driven by low Dissolved Oxygen, elevated pH and exceptionally high nutrient concentrations. Freshwater reaches of the main stem of the Macleay consistently had the best water quality throughout the study recording a score of 72 (C+) with the best water quality recorded at MACR7 (Turners Flat) (76, B-). Nonetheless, many freshwater sites on the Macleay River consistently exceeded the ANZECC nutrient trigger values for nutrients in lowland freshwater systems. The Freshwater and Estuarine tributaries mimicked trends in Tablelands sites of low Dissolved Oxygen and high nutrient concentrations, particularly Nitrogen. Yet algal biomass as measured by chlorophyll *a* rarely exceeded ANZECC trigger values suggesting these trigger values require refining for this region to better predict ecosystem change associated with elevated nutrients. Peak algal productivity in the catchment was generally correlated with peak phosphorus concentrations suggesting the management of phosphorus should be a priority for maintaining water quality.

The estuarine reaches of the main stem received a score of 52 (D-) with the best water quality recorded at MACR6 (the tidal limit downstream of Bellgrave Falls; 64, C-). This contrasts with all other rivers in the North Coast that have been assessed through the Ecohealth program, where the tidal limit consistently records the poorest water quality as sites where freshwater and estuarine water quality issues converge.

Concentrations dissolved nutrients were substantially lower in the main stem of the Macleay River than the Tableland or Freshwater tributaries, despite the significant tributary inputs. It is likely that the extensive beds of aquatic macrophytes throughout the Macleay main stem play an important ecological role as nutrient sinks regulating water quality.

Antimony and Arsenic in Water and Sediments

Antimony (Sb) and arsenic (As) concentrations were measured in the water column and sediments at Bakers Creek (a historical source of contamination from mining), Georges Creek (a control site without contamination from mining), and seven sites along the main stem of the Macleay River from MACR10 immediately upstream of the confluence with Georges Creek through to MACR2 in the estuary at Jerseyville. Water column Sb at Bakers Creek exceeded the ANZECC guidelines for healthy aquatic ecosystems (Sb of 9µg/L) on all sampling occasions, peaking at 870µg/L following a rainfall event. Sediment Sb at Bakers Creek exceeded the national sediment guidelines for the high (25µg/g) trigger values on all sampling occasions. No other site in the Macleay exceeded the ANZECC Sb water column or sediment trigger value for healthy aquatic ecosystems. Water column As at Bakers Creek exceeded the ANZECC guidelines for healthy aquatic ecosystems (As of 24µg/L) on all sampling occasions, and MACR2 was the only other site to exceed trigger values. Only Bakers Creek exceeded the national sediment As high trigger values (70µg/g) on all sampling occasions.

Overall, there is a consistent longitudinal pattern in water column and sediment As along the main stem of the Macleay River: concentrations are low in the freshwater reaches, but consistently increase with distance downstream. This is worth further investigation to determine if this pattern arises from direct depositional accumulation of upstream arsenic inputs in the channel or from localized inputs and resuspension from the floodplain.

Aquatic Macroinvertebrates

Because many macroinvertebrates live in a river reach for an extended period of time, they can integrate the impacts on the ecosystem over an extended period of time, rather than just at the time of sampling. Selected sites in the Macleay catchment contained the greatest richness and abundance of aquatic macroinvertebrates observed in the Northern Rivers bioregion. In particular, Styx River contained 51 families and upper Five Day Creek contained 49 families. The highly diverse and abundant macroinvertebrate communities in remnant high quality reference sites resulted in the expected values in many upland sites to also be high. This potential for highly diverse macroinvertebrate sites to occur within the Macleay led to lower site scores and grades throughout much of the catchment when compared with the highest potential scores.

Tableland tributaries had the poorest aquatic macroinvertebrate condition in the Macleay catchment (the exception is the Styx River) and contributed disproportionally to lower the overall catchment score. These sites typically had very little riparian vegetation, extensively cleared subcatchments, were actively grazed with direct stock access to the channel, had channels of fine-grained sediments with minimal geomorphic complexity (and thus, low habitat availability), and experienced very poor water quality.

From a management perspective, sites assessed as having moderate aquatic macroinvertebrate condition generally contained an abundant and diverse macroinvertebrate community, but still reduced from the maximum potential. This high richness and abundance of aquatic macroinvertebrates in the reference sites means that these populations of macroinvertebrates indicative of good water quality will be able to colonise sites elsewhere in the catchment when good water quality and the availability of appropriate habitats co-occur. Thus, the Macleay catchment provides the potential as a regional hotspot for aquatic macroinvertebrate richness and abundance.

Fish

Across 27 sites in the Macleay catchment, freshwater fish communities were in good condition. Fish communities in Five Day Creek and Nulla Nulla Creek were in excellent condition, with communities in very good condition in Dungay Creek, Toorumbee Creek and the lower freshwater Macleay River. The upper freshwater Macleay and Chandler River sustained good fish communities. The Gara River had the lowest fish condition in the Macleay catchment. A detailed report of the fish survey has been prepared by the the NSW DPI (Fisheries) for the North Coast Local Land Services (www.kempsey.nsw.gov.au/environement/river-management/freshwater-fish-survey-macleay-basin.html).

Partnerships

This project was a successful partnership among Kempsey Shire Council, North Coast Local Land Services, Northern Tablelands Local Land Services, NSW Office of Environment and Heritage, NSW DPI Fisheries and the University of New England. Continued partnerships are essential to ensure project outcomes are maximized.

PART 1

ECOHEALTH PROGRAM AND OBJECTIVES

1.1 Background

The NSW Natural Resources Monitoring Evaluation and Reporting (MER) Strategy was prepared by the Natural Resources and Environment CEO Cluster of the NSW Government in response to the Natural Resources Commission standard and targets and was adopted in August 2006. The purpose of the Strategy is to refocus the resources of NSW natural resource and environment agencies and coordinate their efforts with Local Land Services (LLS), local governments, landholders and other natural resource managers to establish a system of monitoring, evaluation and reporting on natural resource condition.

At this time there was no consistent monitoring of estuarine or freshwater ecological condition in NSW. Working groups were formed to consider the most appropriate indicators and sampling designs to enable a statewide assessment of the ecological condition of rivers and estuaries. This report outlines the approach taken by stakeholders in the Macleay Catchment to supplement the MER monitoring and is aligned with the objectives of the Macleay River Estuary Coastal Zone Management Plan (CZMP) (Geolink, 2012).

1.2 Scope

Estuarine systems are focal points for the cumulative impacts of changed catchment land-use, and increasing urbanisation and development in coastal zones (Davis and Koop 2006). As a result, these ecosystems have become sensitive to nutrient enrichment and pollution, and degraded through habitat destruction, changes in biodiversity and loss of floodplain wetland health form excessive floodplain drainage.

The development of a standardised means of collecting, analysing and presenting riverine, coastal and estuarine assessments of ecological condition has been identified as a key need for coastal Local Land Services and local councils who are required to monitor and report on natural resource condition and water quality and quantity in these systems.

This project uses the Ecohealth framework that integrates the NSW Monitoring, Evaluation and Reporting (MER) Program currently monitoring NSW estuaries and coastal rivers on a bi- or tri-annual basis; NSW State of Environment (SoE) and State of Catchments (SoC) reports, EHMP Healthy Waterways program; proposed estuary report cards from the NLWRA (through WA Department of Water), NSW Estuary Management Policy and Coastal Zone Management Manual and relevant Estuary Management Plans; and sampling protocols developed by the CRC for Coastal Zone, Estuary and Waterway Management.

The Ecohealth Waterways Monitoring Program outlines a framework for the development of a catchment-based aquatic health monitoring program for rivers and estuaries with the aim of providing consistency in monitoring and reporting, and establishes the partnerships required for local and regional dissemination of outcomes. This project brings together major stakeholders in the management of coastal catchments in Northern NSW including state agencies (OEH, DPI Fisheries and Local Land Services), local councils and university researchers (UNE) to develop, refine, report and promote a standardised river and estuary health assessment tool.

This report provides the first baseline dataset for water quality, freshwater macroinvertebrates, and freshwater riparian and geomorphic condition in the Macleay catchment. This framework provides an effective reporting mechanism to communicate water quality and resource condition to the general public, stakeholders and managers through simple report cards. Additionally, this program provides specific monitoring and management plans for the study area using the generic framework that outlines a standardised (and tested) set of partnership, monitoring, data management and reporting protocols implemented in coastal catchments throughout the Northern Rivers region.

1.3 Project objectives

1. Assess the health of coastal catchments using standardised indicators and reporting for estuaries and freshwater river reaches using hydrology, water quality, macroinvertebrate assemblages, condition of riparian and aquatic vegetation, and geomorphic condition as indicators of ecosystem health in streams of the Macleay catchment;
2. Inform management priorities and actions for the subcatchments of the Macleay River; and
3. Contribute scientific information to the development of a report card system for communicating the health of the estuarine and freshwater systems in the Macleay catchment.

1.4 Report structure

Part 1 of the report provides the rationale and background of the Ecohealth program as well as outlining the specific structure of this Macleay Ecohealth program.

Part 2 of the report outlines the catchment characteristics of the Macleay catchment as context of the need for river and estuarine monitoring, and to provide the background to the study design and site selection processes:

2.1 **Study Area** provides information on the catchment characteristics of the rivers and estuaries of the Macleay River such as area, hydrology and landuses.

2.2 **Study Design** provides the detailed description of the study design and protocols for site selection.

2.3 **Study Sites** provides locations and the sampling regime for the 44 study sites.

2.4 **Sampling Methods and Indicators** includes the range of water quality conditions measured, analysis of aquatic macroinvertebrate communities in freshwater sites, geomorphic measures of channel and bank characteristics, riparian condition, and local management issues.

Part 3 of the report details the water chemistry and biophysical data collected from April 2015 to February 2016. Results for water chemistry, macroinvertebrates, riparian and geomorphic condition are reported for each of four major hydrological units (that is, tableland tributaries, the Macleay River main stem, freshwater tributaries, and estuarine tributaries (Figure 2.1)).

Water chemistry variables assessed include nutrients (nitrogen and phosphorus), chlorophyll *a* and suspended solids, as well as water column profiles for pH, salinity and dissolved oxygen. Exceedances of NSW MER or ANZECC guideline thresholds are identified.

Macroinvertebrate assemblages collected from freshwater sites in autumn 2015 and spring 2015 were used to assess long-term condition of in-channel habitats and health indicators using diversity, SIGNAL2 scores and percent EPT (see Section 2.4.3). Freshwater fish communities were sampled by NSW DPI (Fisheries) and are provided as a separate report.

The riparian condition assessments include habitat, native species presence, percentage cover, woody and non-woody debris, management issues, as well as identification of local-scale disturbances to riparian zones. The geomorphic condition assessments include site-scale bank and bed condition and management issues, as well as a sub-catchment scale assessment of geomorphic condition.

Condition scores are calculated for water chemistry, aquatic macroinvertebrate community assemblages (freshwater sites only), freshwater fish communities (where sampled), riparian condition and geomorphic condition. These form the basis of the report cards and are collated for the whole Macleay catchment, major hydrological units and sites.

The catchment, subcatchments and sites are organised accordingly:

3.1 Macleay catchment overall
3.2 Tableland tributaries
3.3 Macleay River main stem
3.4 Freshwater tributaries
3.5 Estuarine tributaries

Part 4 provides management recommendations for the future management of the instream and riparian condition in rivers and estuaries of the catchment, and identifies priorities for future monitoring within the Ecohealth framework.

PART 2

STUDY AREA, DESIGN AND SITE DESCRIPTIONS

2.1 Study area

The Macleay River Catchment covers some 11,389km^2, with its upper reaches draining the New England Tablelands. The river drains large areas of gorge and hill country before reaching the expansive alluvial floodplains and estuarine waters of the Mid North Coast of New South Wales, 340kms north of Sydney. Major town centres in the catchment include Armidale, Guyra, Uralla and Walcha on the Tablelands, Kempsey, Smithtown and Gladstone on the floodplains, and South West Rocks at the mouth where the Macleay River enters the Pacific Ocean.

The Macleay River Catchment is divided into four major hydrological units: Tablelands, Macleay River main stem, freshwater tributaries and the estuarine tributaries (Figure 2.1). Five distinct landform units comprise the catchment from west to east: the Tablelands, Escarpment and Ranges, Hills (low elevation), Coastal Floodplains, and Coastal Sandplains (Alluvium, 2012). Significant tributaries of the mid-to-upper Macleay Catchment include Salisbury Waters and the Gara, Tia, Apsley, Wollomombi, Chandler and Styx Rivers, Kunderang and Warbro Brooks, and Georges, Fiveday, Nulla Nulla, Toorumbee and Dungay Creeks (Figure 2.1).

The source of the Macleay River is located at the confluence of Salisbury Waters and Gara River in the gorge country of the Escarpment and Ranges landform unit. Tableland creek and river tributaries that form in the Great Dividing Range flow out across the New England Tablelands before descending into the rugged gorge country, contributing abiotic and biotic inputs to the main stem of Macleay River. The main stem of the River widens as it emerges from the Escarpment and Ranges and into the Hills (low elevation) at Georges Creek, meandering for a further 140km with additional inputs from freshwater tributaries until the tidal limit is reached at Belgrave Falls, 10km upstream of Kempsey. The tidal Macleay River extends for a further 54km through the low-lying Coastal Floodplains and Coastal Sandplains until it reaches the Pacific Ocean at South West Rocks.

The original inhabitants of the Macleay River Catchment were the Aboriginal peoples of the Dunghutti nation (WMA Water, 2009). Their country extended over the entire Macleay River valley including what is now the Oxyley Wild Rivers National Park. The Macleay floodplain and coast provided plentiful food for the Dunghutti people, and Clybucca and Stuarts Point in the Macleay estuary are home to the largest Aboriginal shell middens in New South Wales (Sullivan and Hughes, 1982).

European settlement occurred in the 1830s, with initial land use primarily timber gathering and ship building on the floodplains. Clearing on the tablelands, floodplains and floodplain valleys for cropping, livestock grazing and other agricultural pursuits followed, while accessible parts of the escarpment and gorge country were logged for timber and small areas within the gorge country were opened up for mining (WMA Water, 2009). Today, landuse in the Macleay River Catchment is diverse and includes fishing and oyster farming, horticulture and cropping, cattle and sheep grazing, dairying, mining and quarrying, forestry and agro-forestry, light and commercial industry, urban and tourist development and National Parks (WMA Water, 2009). Several previous studies detail catchment characteristics, ecological condition and historic and current landuses in the Macleay River Catchment (West et al., 2004; Gerand, 2005; WMA Water, 2009; Ruge, 2010; GHD, 2015).

Figure 2.1 *The location of the Macleay catchment in the Northern Rivers of NSW showing the subcatchments (white lines) divided into four major hydrological units (Tablelands (pink), Macleay River main stem (green), Freshwater tribtutaries (blue) and the Estuarine tributaries (yellow)), location of Ecohealth sites (red circles) and the LGA boundaries (black lines).*

2.1.1 Geology

Three major bedrock substrates - metasediments, granitoids and volcanics - collectively cover 94% of the Macleay River Catchment, with the remaining 6% of the catchment attributed to floodplain and estuary sediment deposits (alluvium) (WMA Water, 2009). Metasediments, formed during the Devonian and Permian periods, are a broad group predominantly derived from metamorphosed marine sediments with a quartz and feldspar composition (conglomerate, gneiss, greywacke, limestone, metasediments, mudstones, sandstone, schist, slate and wacke) and account for 73% of the Macleay Catchment. Macleay Catchment Volcanics, formed during Tertiary volcanic activity (basalt, dacite and metabasalt) account for 11% of the Catchment area, while the Granitoids, intrusive granitic rocks with a high quartz and feldspar and low mica content that formed during the Carboniferous to Triassic periods (granite, tonalite) occupy 10% of the Macleay Catchment. Two additional geological categories that occur outside these three major bedrock types are diorite, an intrusive igneous rocks with a composition halfway between granitoids and basalt; and sand plain, the quartz material remaining following extensive long-term weathering and parent material breakdown of granitoids and metasediments (Ashley and Graham, 2001; WMA Water, 2009). The dominant geologies of the Tableland are greywacke and wacke, granite and basalt, while the gorge country and midland hills is dominated by slate, conglomerate, sandstone, metasediment and to a lesser extent, granite and siltstone. Alluvium and coastal dunes are the dominant geological features of the coastal floodplains (Figure 2.2).

There are an estimated 534 known mineral deposits in the Macleay Catchment, with the most predominant deposits of gold (Au) antimony (Sb), arsenic (As) primarily associated with mesothermal vein deposits in metasedimentary and some granitoid rocks. Additional mineral deposits of copper (Cu), lead (Pb), zinc (Zn), silver (Ag), tin (Sn) and molybdenum (Mo) are associated with granitic intrusions (WMA Water, 2009; GHD, 2015). Due to naturally large concentrations and past mining activities, the Macleay River has elevated levels of As and Sb mineral deposits throughout 300kms of the main trunk of the Macleay River (GHD, 2015). Further detailed accounts of the geological description of the Macleay River Catchment can be found in the study by Ashley and Graham (2001) and from the Dorrigo – Coffs Harbour Metallogenic Map (Gilligan et al. 1992).

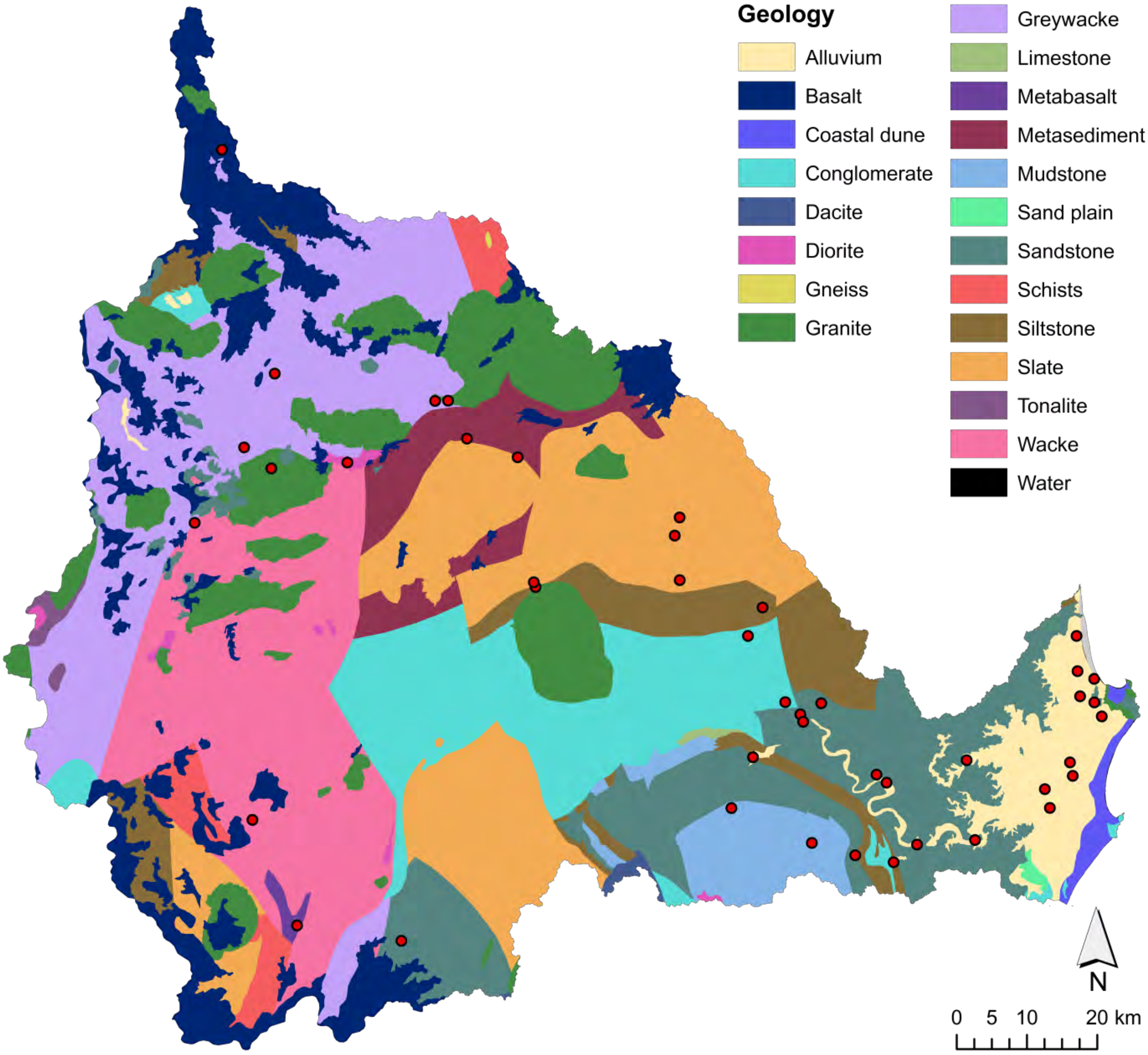


Figure 2.2 *Geology of the Macleay catchment.*

2.1.2 Soils

Soil formation is a result of the variable rates of weathering of the parent material, mineral composition and chemistry, topography and moisture. The dominant soil types in the Macleay Catchment were the closely related rudosols and tenosols (21%), followed by kurosols (13%), kandosols (12%), ferrosols (10%), dermosols (9%), kurosols (natric) (9%) and hydrosols (8%). The remaining soil types made up <20% of the Catchment, yet consisted of a variety of soil types (Figure 2.3).

Rudosols and tenosols are associated with metasedimentary parent material and are typically shallow, easily erodible soils of low fertility and low water holding capacity, occuring most frequently in the gorge, escarpment hills and midland hills country of the Macleay Catchment. Kurosols are also associated with metasediments, yet they are considered to be poorer in structure and fertility than rudosols and tenosols, occurring most frequently up on the tablelands and down on the floodplains. Kandosols are associated with both granite and metasediment parent materials in the Catchment and are soils of poor structure but moderate fertility and water holding capacity. Ferrosols, associated with volcanic parent material, are well drained, well structured, deep fertile soils that occur on the tablelands. Similarly to kandosols, dermosol soils are associated with both granite and metasediment parent materials in the catchment and are well structured, fertile soils with good water holding capacity that occur throughout the catchment. Kurosols (natric) are poor soils associated with metasediments that are very similar to the previously mentioned Kurosols, except that they contain a sodic B horizon. They are found throughout the tablelands and the floodplains. Hydrosols are associated with alluvium parent material and occur on the coastal floodplains, they are soils of high organic matter content, yet they often have poor drainage due to high clay content and excellent water holding capacity (Gray & Murphy, 2002).

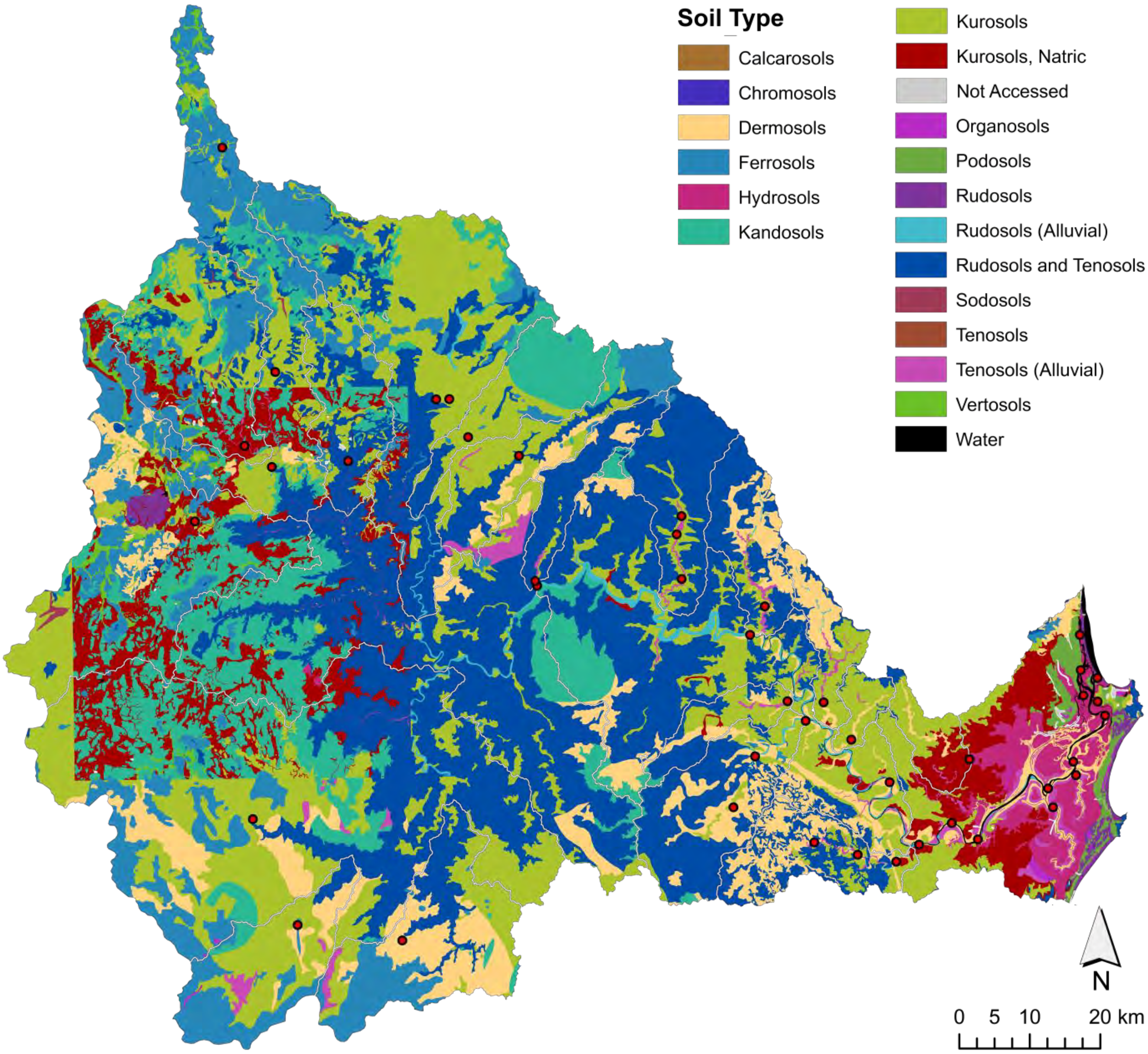


Figure 2.3 *Soils of the Macleay catchment.*

2.1.3 Climate, rainfall and stream discharge

The Macleay River catchment experiences a cool temperate-to-subtropical climate with climatic variations distinctly evident between coastal areas, the rugged mountainous regions of the escarpment and the tablelands at the top of the catchment. In general, the upper Macleay Catchment, particularly the New England Tablelands, has a relatively dry, cool temperate climate characterized by warm summers and cold winters. The coastal regions of the Macleay Catchment experience a relatively humid, sup-tropical climate characterized by warm to hot summers and mild winters. On the Tablelands at the top of the Macleay Catchment in Armidale, mean annual temperatures range from maximums of 12°C in July to 25.9°C in January and minimums of 1.2°C in July to 13.2°C in January (BOM, 2016). Mean annual temperatures on the Macleay Catchment floodplain in Kempsey range from maximums of 19.8°C in July to 29.2°C in January and minimums of 5°C in July to 17.9°C in February (BOM, 2016). Temperatures for summer, winter and autumn during the 2015-16 study period were similar to long-term average temperature observations in both locations. However, warmer spring minimum and maximum averages were observed for both Armidale and Kempsey during this time, despite a cooler than average September in both locations (Figures 2.4a and 2.4b).

Rainfall throughout the Macleay Catchment predominantly falls in summer, with Armidale at the top of the catchment receiving a moderate average annual rainfall total of 779.5mm and Kempsey at the bottom of the catchment receiving a relatively high average annual rainfall total of 1149.4mm (BOM, 2016). Much variability lies in annual rainfall predictions at this latitudinal range due to climatic, geographic and topographic influences. However, while moderate winter rainfall is experienced during some years, dry spells in Armidale typically occur towards the end of autumn and throughout winter, while Kempsey can experience dry spells at the end of winter and start of spring. Mixed rainfall totals were received throughout the Macleay Catchment during the 11 months of the 2015-2016 study period, with below-average rainfall recorded in Armidale (633.4mm or 12% reduction), and above-average rainfall recorded in Kempsey (1035.4mm or a 4% increase). Armidale experienced a wetter than average autumn followed by a particularly dry winter and a drier than average spring and summer period. Above average rainfall observations were recorded for the months of April and May 2015 and in January, 2016 (Figure 2.5a). Kempsey also experienced a wetter than average autumn followed by a particularly dry winter, spring was wetter than average while summer was drier than average. Above average rainfall observations were recorded for the months of April, May, September, October, November and December, 2015 (Figure 2.5b).

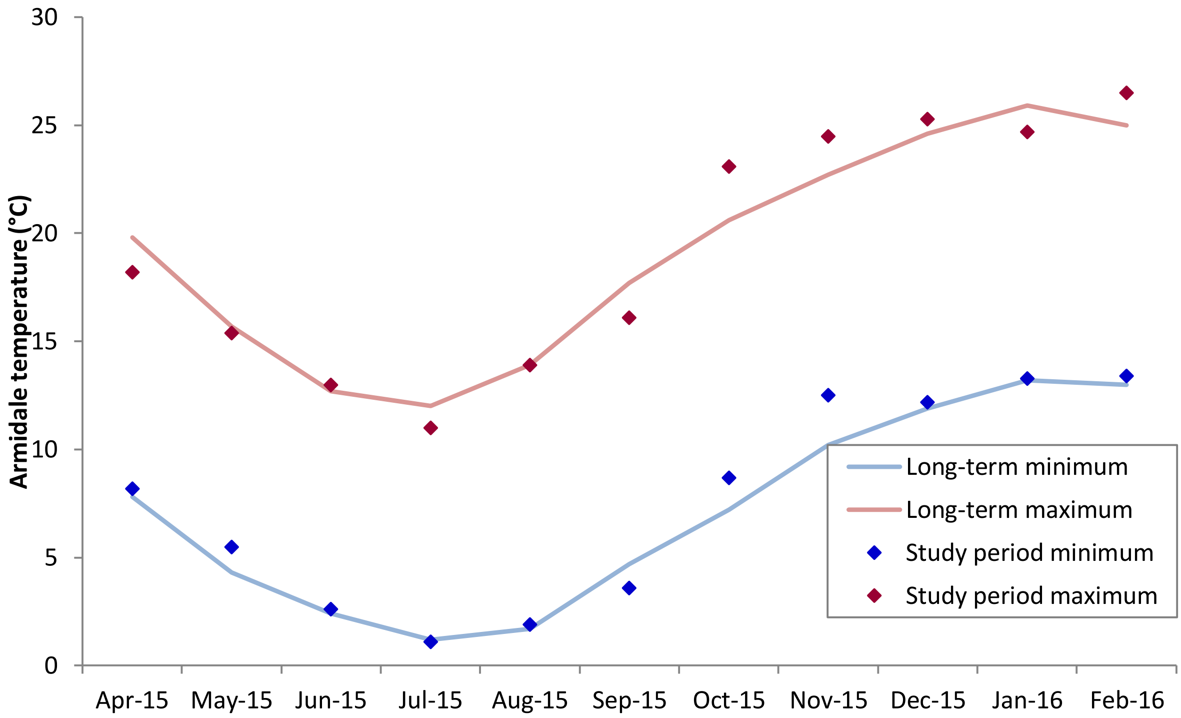


Figure 2.4a *Average monthly maximum and minimum temperatures over the study period in comparison to long-term average monthly maximum and minimum temperatures at Armidale Airport (BOM gauge 056238 for study period and for long-term averages).*

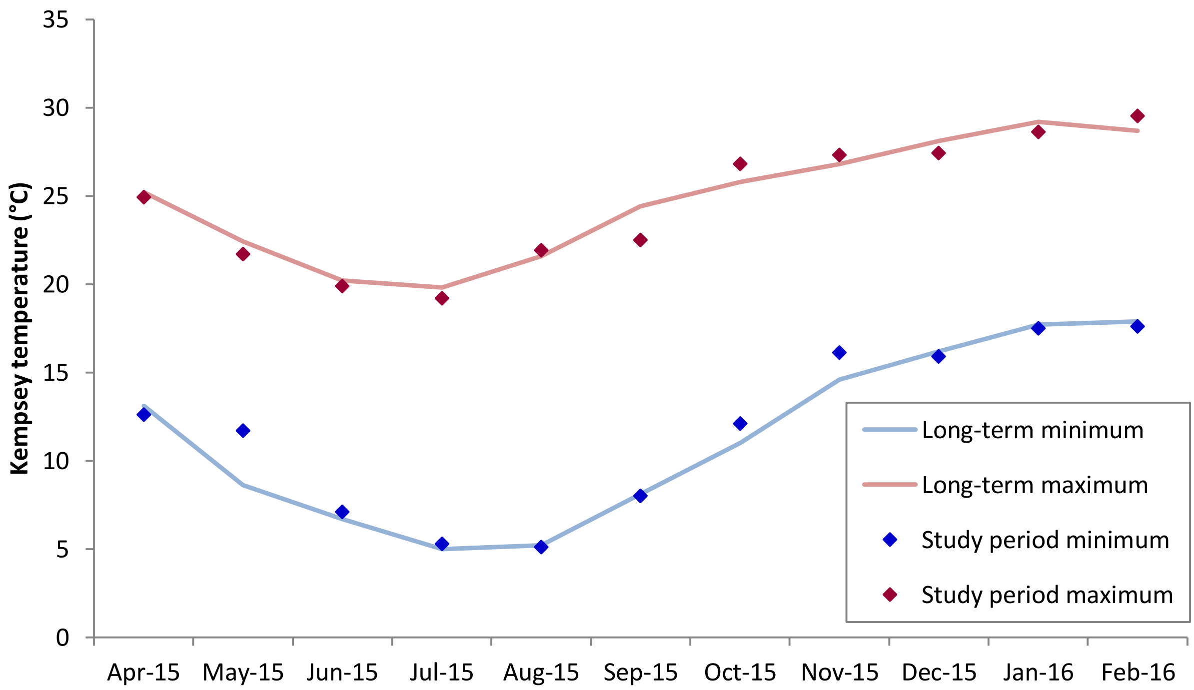


Figure 2.4b *Average monthly maximum and minimum temperatures over the study period in comparison to long-term average monthly maximum and minimum temperatures at Kempsey Airport (BOM gauge 059007 for study period and for long-term averages).*

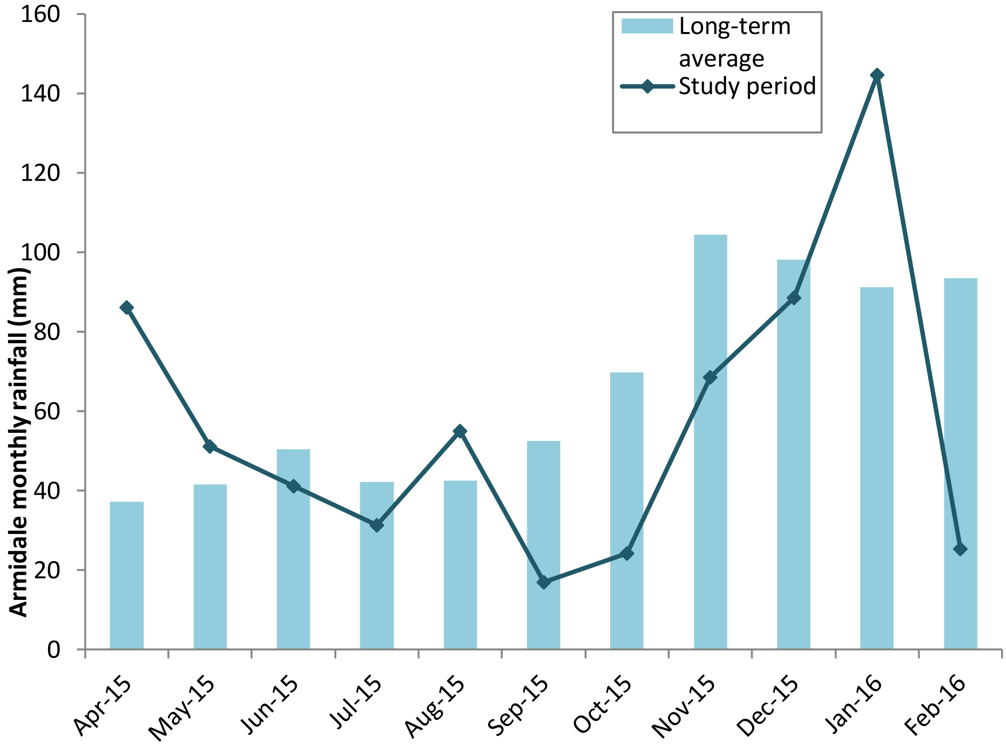


Figure 2.5a *Monthly rainfall over the study period in comparison to the long-term average monthly rainfall at Armidale Airport (BOM gauge 056238 for study period and for long-term averages).*

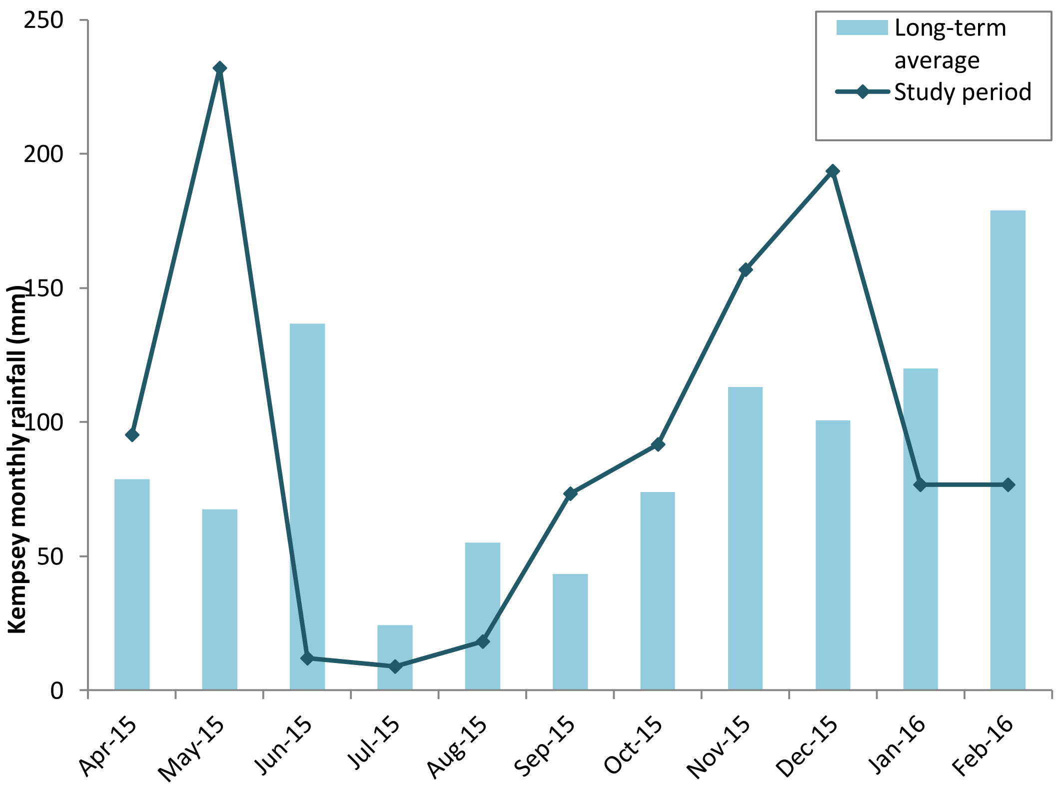


Figure 2.5b *Monthly rainfall over the study period in comparison to the long-term average monthly rainfall at Kempsey Airport (BOM gauge 059007 for study period and for long-term averages).*

Thirty-five significant floods, that is, floods exceeding 5.5m at the Kempsey Road Bridge gauge, have been recorded in the Macleay River Catchment since 1838. The record maximum Macleay River flood level was in August 1949, where it reached a height of 7.92m at Kempsey Road Bridge (Kempsey Shire Local Flood Plan, 2011). Despite the occurrence of three recent, yet relatively minor floods in 2012, 2011 and 2009 (FloodSafe, 2016), serious floods (>6m) have not been recorded in the Catchment since 1967 (Kempsey Shire Local Flood Plan, 2011).

Discharge in the Macleay River Catchment are recorded at several gauges throughout the tablelands and on the floodplains. Two key gauges in the main stem that account for approximately 87% of the total Macleay River discharge (NSW DPI, 2016) are Georges Junction (70%) and Turners Flat (an additional 17%). These two gauges record discharge rates in the Macleay River attributed to rainfall on the tablelands, adjacent gorge and escarpment hills country (Georges Junction), and rainfall attributed to the freshwater tributaries in the low hills and floodplains upstream of Kempsey (Turners Flat).

Long-term average monthly discharge in the Macleay River peaks in late summer to mid-autumn. A comparison of this historic discharge data with the 2015-16 study period data revealed lower than average discharge rates for all months except May 2015 at both the Georges Junction (NOW gauge 206024) and Turners Flat (NOW gauge 206011) gauges. The peak discharge observed in May recorded an average of 3,630ML/day at the Georges Junction gauge and 10,470ML/day at the Turners Flat gauge (Figures 2.6a and 2.6b).

The discharge data for the study period demonstrates a temporal lag in the above average rainfall events received both on the tablelands and the floodplains for the month of April 2015, and the May 2015 discharge events (Figures 2.5 and 2.6). Despite higher than average rainfall events recorded in January on the tablelands and throughout spring and early summer on the floodplains, discharge rates for the same period remained well below average. This is most likely a reflection of low levels of soil moisture content as a result of an extended dry winter period throughout the catchment and subsequent reductions in rainfall runoff. Outside of the peak discharge event in May, Macleay baseflows were well below average at both gauges for the majority of the study period (Figures 2.6a & 2.6b).

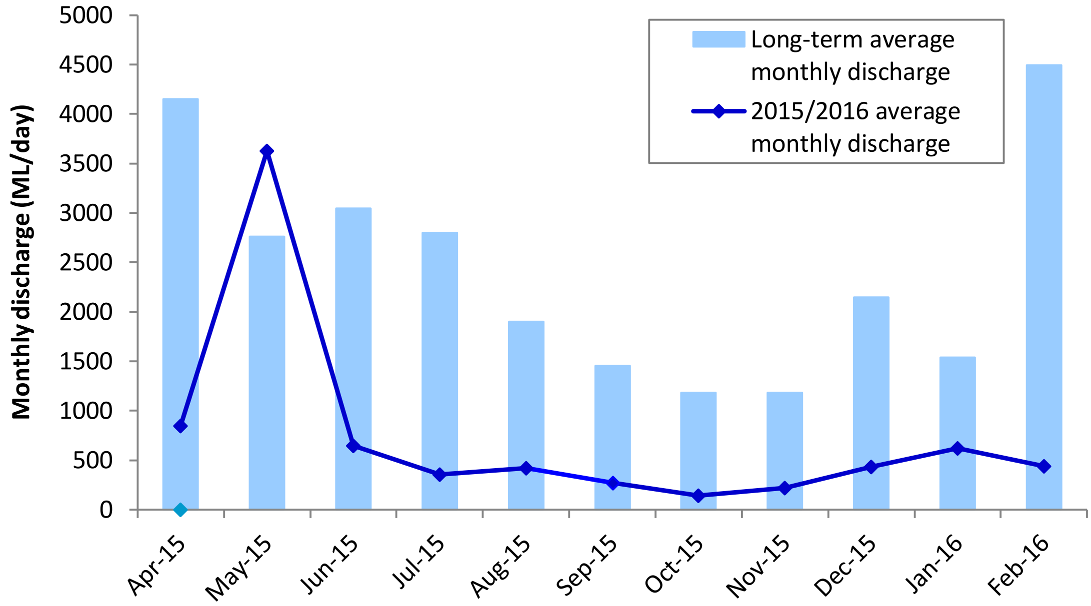


Figure 2.6a *Average monthly discharge over the 2015/2016 study period (April 2015 to February 2016) in comparison to the long-term average monthly discharge of the Macleay River at Georges Junction in the Macleay River main stem (NOW gauge 206024).*

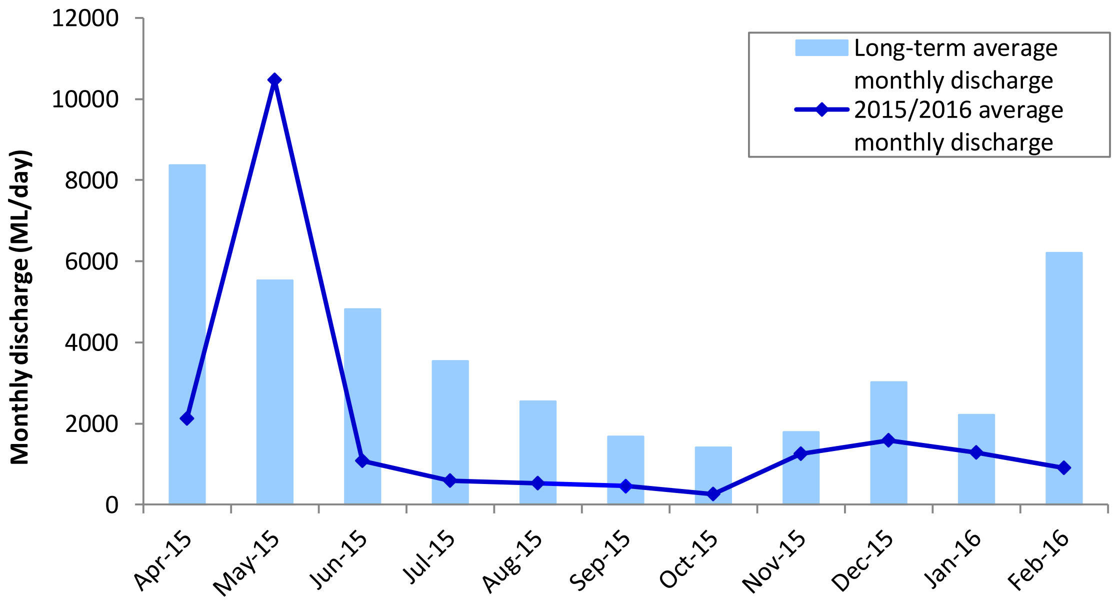


Figure 2.6b *Average monthly discharge over the 2015/2016 study period (April 2015 to February 2016) in comparison to the long-term average monthly discharge of the Macleay River at Turners Flat in the Macleay River main stem (NOW gauge 206011).*

2.1.4 Landuse

The dominant landuse throughout the Macleay Catchment is agricultural grazing land (6,051km^2 or 53%), most of which occurs on the tablelands, floodplains and floodplain valleys. The second most dominant landuse is vegetated cover (3,034km^2 or 26%), comprising both protected conservation areas and non-protected land with tree and shrub cover. The majority of this landuse exists throughout the escarpment ranges and midland hills in the Macleay Catchment, with vegetated cover expressed as national parks and private conservation agreements (2,309km^2 or 76%), state forests (609km^2 or 20%) and privately owned forested holdings (10km^2 or <1%) (Figure 2.7).

In relation to their total area in the Macleay Catchment, the remaining ten landuse categories contributed relatively little, with the three largest being urban areas (196km^2 or 1.7%), river and drainage systems (117km^2 or 1%) and wetlands (107km^2 or 1%) (Figure 2.7). While covering a relatively small total area, wetland cover on the Macleay River Floodplain accounts for approximately 15% of all Coastal Floodplain Wetlands in New South Wales, retaining ecologically significant aquatic and terrestrial flora, fauna and habitats (Kingsford et al. 2003).

Urban areas in the Macleay Catchment comprise the populated LGAs of Armidale (25,696), Walcha (3,276), Kempsey (28,856) and part of the Guyra (4,435) and Uralla (6,081) LGAs (ABS 2010 census).

While most of the rivers and creeks in the Macleay Catchment are unregulated (NSW DPI, 2016), several large dams are in operation for domestic water use. These include the major water storages of Malpas dam (13,000ML) on the Gara River, Dumaresq dam (380ML) on Dumaresq Creek and Puddledock dam (1,700ML) on Puddledock Creek in the Tableland LGAs. Steuart McIntyre Dam (2,500ML) on Fattorini Creek is the main source of domestic water on the floodplains (NSW DPI, 2016).

Four Sewage Treatment Plants (STPs) are operational in the Macleay Catchment and discharge directly into the Macleay River following treatment/maturation, including Armidale and Walcha on the Tablelands and West Kempsey and Gladstone/Smithtown on the floodplains.

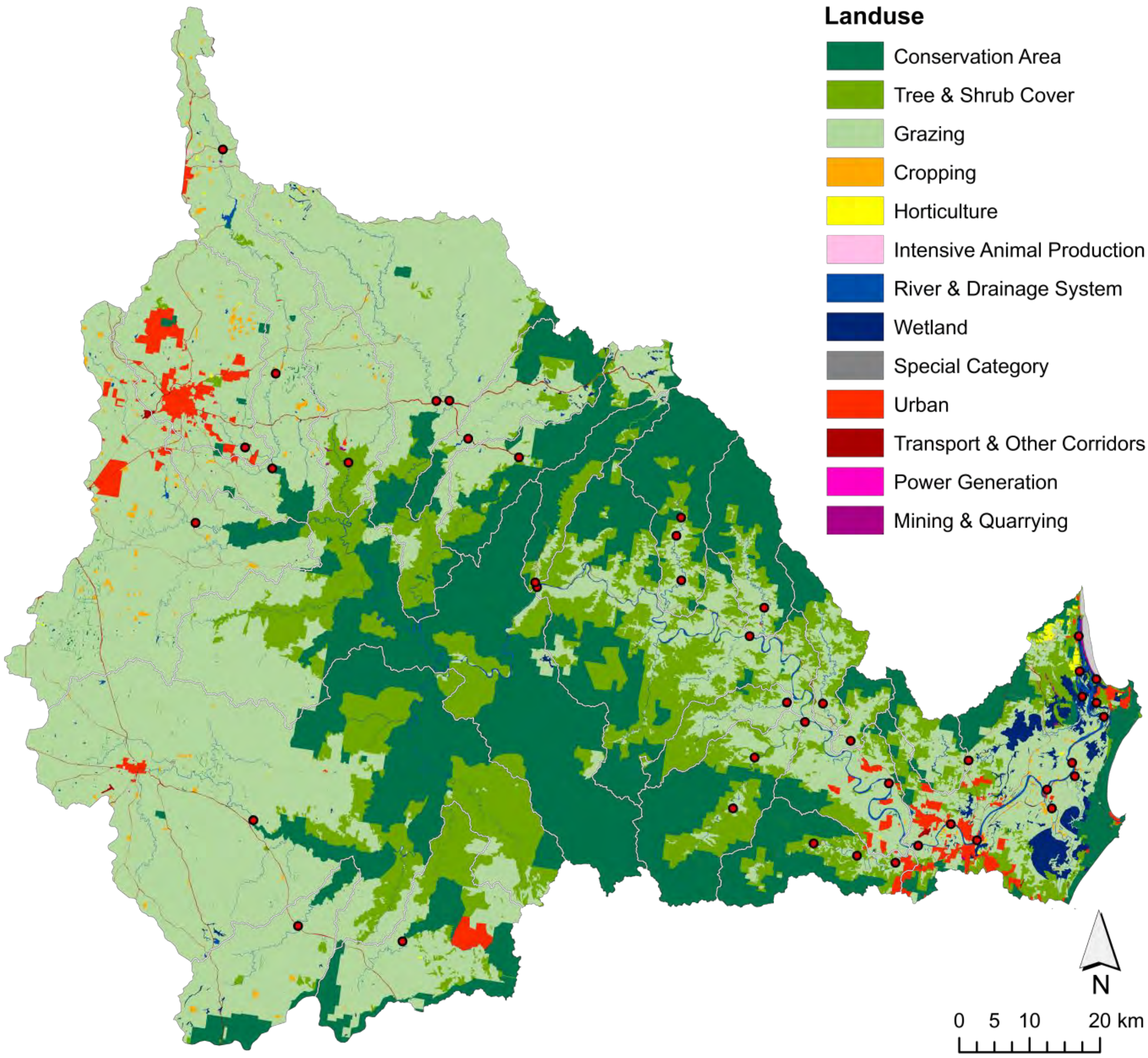


Figure 2.7 *Landuse of the Macleay catchment.*

2.1.5 River Styles

Confined valley setting (CVS) accounted for 50% of the total stream length in the Macleay River catchment, follow by partly confined valley settings (PCVS, 30%), swampy meadow group (SMG, 10%) and laterally unconfined valley setting – continuous channel (LUV CC, 9%). Less than 1% of stream channels are classified as water storages (Figure 2.8). Of the total catchment stream length assessed (5888.5km), 41% were considered to be in good geomorphic condition, 41% in moderate geomorphic condition and 18% in poor geomorphic condition (NC LLS, 2014). Stream channels in good condition were dominated by gorges (56%) and headwaters (16%), while the stream channels in poor condition predominantly comprise bedrock controlled, fine-grained channels (21%) and channelized fill (11%).

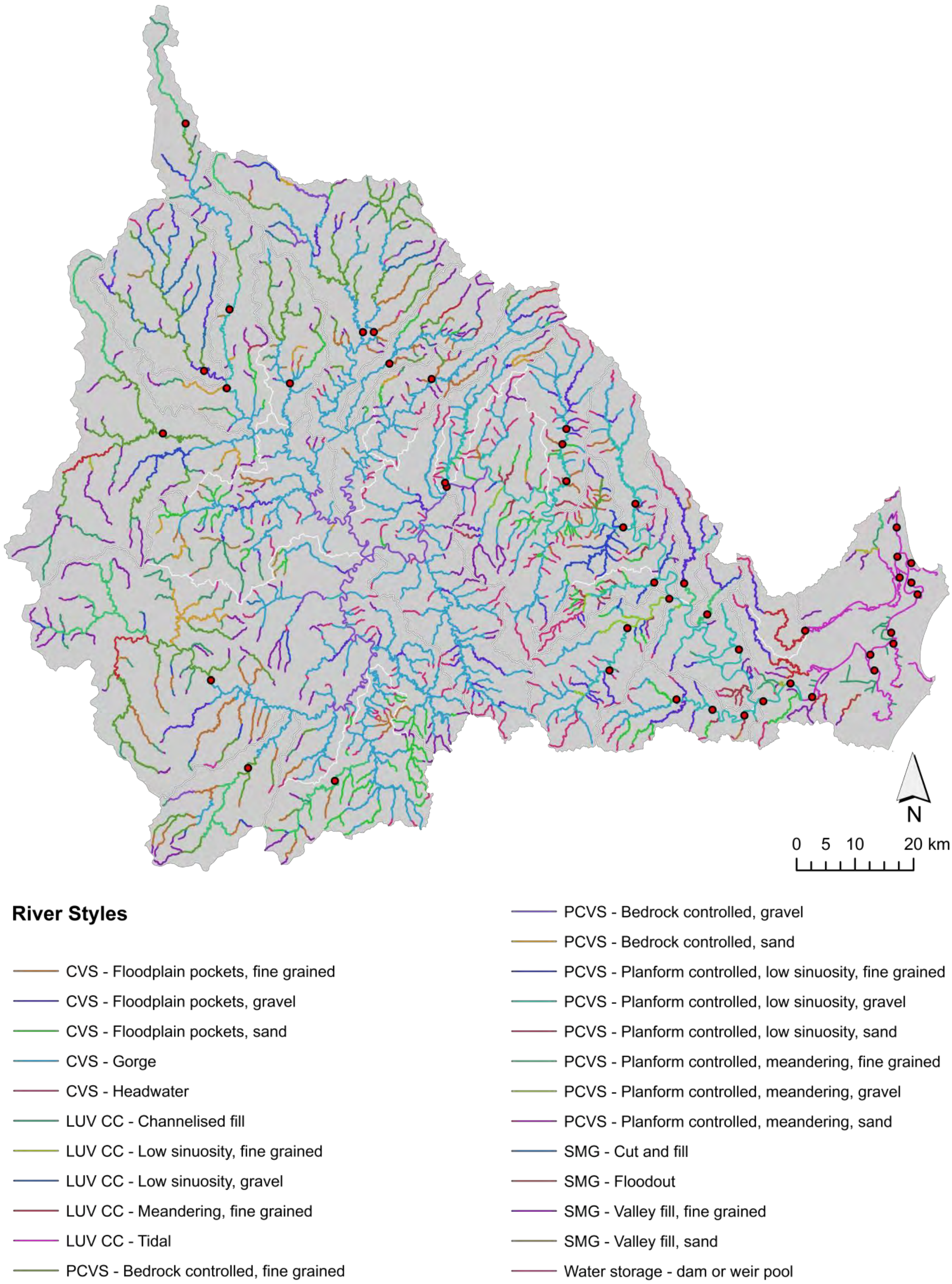


***Figure 2.8** River Styles in the Macleay catchment.*

2.2 Study design

The design of the Ecohealth freshwater/estuarine monitoring program for catchments in the Macleay catchment was based on Ecohealth standard methods (Ryder et al. 2016). The number and location of sample sites were designed to assess spatial and temporal variability of subcatchments with statistical robustness.

Locations of 32 freshwater monitoring sites were selected to:

- Assess end of system inputs from tributaries; and
- Compare River Styles, Condition and Recovery Potential, and elevation within and across subcatchments.

Locations of the 12 estuarine monitoring sites were selected to:

- Identify longitudinal change and potential point source (tributary) issues within the main stem of each river system and end of system flows; and
- Locate ecological changes at the point of the tidal limit.

The design of the Ecohealth program in the Macleay catchment required prioritization of sites to optimise available resources.

2.2.1 Sampling Schedule

Water chemistry was sampled 6 times and freshwater macroinvertebrates were sampled bi-annually in autumn and spring 2015. Riparian condition was assessed primarily in November 2015, with a preliminary assessment in August 2015 and a final assessment in February that focused on late-flowering grasses. Geomorphic condition was assessed once in October 2015. Water and sediment samples in the main stem of the Macleay River were assessed for antimony and arsenic concentrations in April, August and November 2015 (Table 2.1).

Sampling events typically comprised 5 days within a month. Multiple freshwater and estuarine sites were sampled on each sampling day to ensure consistency in freshwater discharge and tidal regime. Estuarine sites were sampled over the full tidal cycle to accurately assess water quality during base flows. OEH supplied the boat and skipper as in-kind support to the project. All freshwater sites were sampled via road access. Water quality, aquatic macroinvertebrates, riparian condition and geomorphic condition were assessed by staff from UNE, while freshwater fish were assessed by NSW DPI (Fisheries).

Table 2.1 *Sampling regime for field collection of water chemistry and biota.*

Sampling event	Month	Variables at freshwater sites	Variables at estuary sites
1	April 2015	Water quality, aquatic macroinvertebrates, heavy metals in water and sediments	Water quality, heavy metals in water and sediments
2	June 2015	Water quality	Water quality
3	August 2015	Water quality, riparian condition, heavy metals in water and sediments	Water quality, riparian condition, heavy metals in water and sediments
4	November 2015	Water quality, aquatic macroinvertebrates, riparian condition, geomorphic condition, heavy metals in water and sediments	Water quality, riparian condition, geomorphic condition, heavy metals in water and sediments
5	December 2015	Water quality	Water quality
6	February 2016	Water quality, riparian condition	Water quality, riparian condition

2.3 Study sites

Forty four sites were sampled within the Macleay River catchment with 32 freshwater sites and 12 estuarine sites spread across 22 subcatchments (Table 2.2). There were 13 sites located on Tableland tributaries: 3 on the Gara River, and end-of-system sites on Commissioners Waters, Salisbury Waters, Apsley River, Tia River, Yarrowitch River, Bakers Creek, Wollomombi River, Chandler River, Oaky River and Styx River. There were 4 freshwater sites and 6 estuarine sites located on the main stem of the Macleay River, with an additional 2 sites located on the North Arm of the Macleay River. There were 15 sites located on the freshwater tributaries of the Macleay River: 3 each on Five Day, Toorumbee and Dungay Creeks, and end-of-system sites on Georges Creek, Nulla Nulla Creek, Warbro Brook, Hickeys Creek, Mungay Creek and Collombatti Creek. There were 4 end-of-system sites located on estuarine tributaries: Belmore River, Kinchela Creek, Spencers Creek and Clybucca Creek.

***Table 2.2** Location of field sample sites in the Macleay catchment.*

Name	Site Code	Easting (m E)	Northing (m S)	Elevation (m)	Salinity Zone
Gara River	GARR3	377856	6659400	1241	Freshwater
	GARR2	385375	6627569	966	Freshwater
	GARR1	384876	6614091	918	Freshwater
Commissioners Waters	COMW1	384369	6615582	916	Freshwater
Salisbury Waters	SALW1	373968	6606356	974	Freshwater
Apsley River	APSR1	381803	6564973	1014	Freshwater
Tia River	TIAR1	388547	6549093	1042	Freshwater
Yarrowitch River	YARR1	403399	6546900	880	Freshwater
Bakers Creek	BAKC1	393627	6617037	509	Freshwater
Wollomombi River	WOLR1	408195	6623683	934	Freshwater
Chandler River	CHAR1	410050	6623716	927	Freshwater
Oaky River	OAKR1	412735	6618314	879	Freshwater
Styx River	STYR1	419942	6615670	841	Freshwater
Macleay River	MACR10	422475	6596949	136	Freshwater
	MACR9	452719	6590283	66	Freshwater
	MACR8	460151	6579270	39	Freshwater
	MACR7	472544	6569358	16	Freshwater
	MACR6	476702	6560514	2	Tidal limit
	MACR5	485561	6562689	2	Upper estuary; 0-15ppt
	MACR4	495016	6568476	1	Mid estuary; 15-30ppt
	MACR3	498590	6572267	1	Mid estuary; 15-30ppt
	MACR2	503107	6578808	0	Lower estuary; 30+ppt
	MACR1	502066	6584106	0	Lower estuary; 30+ppt
Georges Creek	GEOC1	422483	6598624	144	Freshwater
Five Day Creek	FIVC3	442429	6600582	155	Freshwater
	FIVC2	442902	6608138	146	Freshwater
	FIVC1	440947	6594274	128	Freshwater
Nulla Nulla Creek	NULC1	454131	6590526	84	Freshwater
Warbro Brook	WARB1	458055	6580837	57	Freshwater
Toorumbee Creek	TOOC3	449599	6565685	133	Freshwater

	TOOC2	454113	6573396	86	Freshwater
	TOOC1	460608	6578059	43	Freshwater
Hickeys Creek	HICC1	464564	6577848	50	Freshwater
Mungay Creek	MUNC1	471943	6571699	47	Freshwater
Dungay Creek	DUNC3	461883	6560683	87	Freshwater
	DUNC2	467994	6559082	50	Freshwater
	DUNC1	475243	6559212	15	Freshwater
Collombatti Creek	COLC1	483862	6572602	7	Freshwater
Belmore River	BELR1	495725	6565794	1	Estuary; tidal exchange
Kinchela Creek	KINC1	498980	6570367	1	Estuary; tidal exchange
Spencers Creek	SPEC1	501935	6580962	2	Estuary; tidal exchange
Clybucca Creek	CLYC1	499814	6581774	0	Estuary; tidal exchange
North Arm Macleay River	NAMR2	499589	6590347	0	Estuary; tidal exchange
	NAMR1	500212	6582733	0	Estuary; tidal exchange

2.4 Sampling methods and indicators

The indicators chosen focus on the condition of the system to best identify the stressors and pressures that cause change in ecological condition. The selection of indices (and groupings of indicators) represents elements of the structure, function and composition of riverine and estuarine ecosystems.

2.4.1 Water Quality Indicators

Assessing the impacts of land-use change on the ecological health of rivers and streams is an important issue for the management of water resources in Australia. Traditionally, these assessments have been dominated by the measurement of patterns in species distribution and abundance which contribute important information such as the status of threatened species and their habitat requirements. However, many goals of river management refer to concepts of sustainability, viability and resilience that require an implicit knowledge of ecosystem or landscape-level interactions and processes influencing these organisms or populations.

The water chemistry of rivers and estuaries can be an ideal measure of their ecological condition by providing an integrated response to a broad range of catchment disturbances (Table 2.3). Nutrients such as nitrogen, phosphorus, and carbon can play an integral role in regulating rates of primary production in these systems. However, anthropogenic changes to catchment land-use have led to increased supply of nutrients from diffuse or point sources, and altered light and turbidity regimes through increased suspended sediment loads and loss of riparian vegetation. These landscape-level processes define the supply of contaminants to a stream and provide the framework within which other processes operate at smaller spatial scales and shorter temporal scales to regulate their supply and availability.

Table 2.3 *Water chemistry indicators measured at all sites.*

In situ measurements	Water quality samples sent for laboratory analysis
Water depth pH Temperature Salinity/Conductivity Dissolved oxygen Turbidity	Total nutrients (nitrogen and phosphorus) Dissolved nutrients (nitrate-nitrite, and soluble reactive phosphate) Chlorophyll *a* Total Suspended Solids (TSS)

Field and laboratory methods

At each sampling site, *in situ* water quality measurements were measured with the use of a Hydrolab Quanta water quality multi-probe (pH, conductivity, dissolved oxygen (DO), temperature, salinity and turbidity). The following procedural steps are outlined to standardise the collection of these data and to identify quality control.

Water quality probe calibration and use

The water quality probe(s) were calibrated each day prior to use in the field. At each sample site, field measurements for the water column profile was taken at near surface (approx. 0.2m below surface), and at 1m intervals through the water column to a depth of 0.2m from the bottom. Measurements for each water quality parameter using the multi-probe were recorded at each interval. In freshwater sites that were less than 1m in depth, surface and epibenthic measurements were taken and maximum sampling depths noted. Data were recorded on proforma data recording sheets (Appendix 1).

Water quality sampling

Water samples were collected at each site for the determination of chlorophyll *a*, total and dissolved nutrients, total suspended solids and Secchi depth. Samples were collected at near surface (<0.2m) and obtained with the use of a hand held sampling device to ensure sample is taken at least 1.5m from the edge of the boat or riverbank. Samples were transferred to acid-washed and rinsed (thrice rinsed with sample water) 125mL containers. Duplicate samples for each parameter were taken from each site, and a third sample of each parameter was collected from a random subset of sites for quality assurance (QA) processing at an independent laboratory. The following procedures for sample collection and treatment are provided for each determination.

Chlorophyll a

Water column chlorophyll *a* is a measure of the photosynthetic biomass of algae/phytoplankton. These organisms are central to important nutrient and biogeochemical processes, and as such may respond to disturbance before effects on higher organisms are detected. This is because the higher organisms depend on processes mediated by algal communities. Consequently, they form the base of food webs supporting zooplankton, grazers such as crustaceans, insects, molluscs and some fish (Burns and Ryder 2001). The short generation time, responsiveness to environmental condition and the availability of sound, quantitative methodologies such as chlorophyll *a* make these measures of phytoplankton ideally suited as indicators of disturbance in aquatic systems. Information can be collected, processed and analysed at time scales relevant to both scientific and management interests.

In the field, a 1L bottle of water from 0.2m depth was collected using the hand held sampling device at each site, labelled, and placed on ice in an esky for transport to the laboratory. Sample processing was carried out within 48 hours of collection using the following steps;

1. Place a Whatman GF/C Glass Microfiber filter paper, using forceps, textured side up onto the filtration apparatus (EYELA Tokyo Rakahikai Coorperation Aspirator A-35) just prior to filtration.
2. Filter a sufficient amount of sample was filtered (100-1,000mL measured with a graduated cylinder), to produce a green colour on the filter paper, or until the flow through the filter paper at ½ atmosphere pressure (approx. 7PSI) is reduced to a trickle. When approximately 10-15mL of the sample remained on the filter, 5-10 drops of the $MgCO_3$ powder were added to preserve the chlorophyll. The filter apparatus and graduated cylinder were then rinsed thoroughly using a squirt bottle with deionised water and the filter drained to remove all signs of moisture.
3. The sample volume filtered was recorded. The amount of water filtered is subject to the level of turbidity at the sampling site.
4. Using forceps, the filter paper was folded and carefully placed into the bottom portion of the prelabled culture tube that was then sealed, wrapped in aluminium foil, placed into a labelled ziplock bag and refrigerated below 4°C.
5. The filter paper was then placed in 10mL of 90% acetone. The solution was refrigerated for 24 hours. The samples were then centrifuged. The absorption spectra were recorded using a UV-1700 Pharmaspec UV-visible spectrometer at 665nm and 750nm.

Total suspended solids

Total suspended solids (TSS) is a direct measure of turbidity of the water. In the field, a pre-labelled 1-L bottle of water from 0.2m depth was collected at each site using the hand held sampling device, and the sample placed into a cool, dark esky.

TSS were measured by filtering a sufficient amount of sample (100-1,000mL measured with a graduated cylinder) through a Whatman GF/C Glass Microfiber filter paper, with a known weight, using an EYELA Tokyo Rakahikai Coorperation Aspirator A-35 at ½ atmosphere pressure (approx. 7PSI). The volume of filtered sample was recorded and used to calculate mg/L of TSS. The filter apparatus and graduated cylinder were thoroughly rinsed using a squirt bottle with deionised water and the filter drained to remove all signs of moisture. The filter paper with retained material was then placed into a foil envelope and dried in an oven at 50°C. They were reweighed after they dried to gain a measure of the weight of the TSS on each sample.

Inorganic nutrients

For inorganic nutrients, two 125mL water samples were collected from 0.2m depth at each site using the hand held sampling device. Samples for total nitrogen and total phosphorus remained unfiltered and were transferred into pre-rinsed, pre-labelled, 125mL PET bottles and immediately placed in a cool, dark esky. Samples remained frozen until time of analysis. Duplicate samples for quality assurance processing at an independent laboratory remained frozen until analyzed. For organic nutrients, two 125mL water samples were collected from 0.2m depth at each site using the hand held sampling device. Approximately 125mL of water was passed through a Whatman GF/C filter paper (effective pore size 0.7µm) in the field and collected into pre-rinsed, pre-labelled, 125mL PET bottles and immediately placed in a cool, dark esky. Samples remained frozen until time of analysis. Duplicate samples for quality assurance processing at an independent laboratory remained frozen until analyzed.

Nitrogen was measured by digesting an unfiltered water sample in a digestion tube with 10mL of digestion mixture. This contained 40g of di-potassium-peroxodisulfate ($K_2S_2O_8$) and 9g of sodium hydroxide (NaOH) in 1000mL of Milli Q water. This sample was then digested in the autoclave for 20 minutes. Five mL of the sample was then placed into a 50mL acid-washed measuring cylinder and diluted to 50mL (Hosomi & Sudo 1986). Five mL of buffer solution was added: 100g of NH_4Cl, 20g sodium tetra borate and 1g EDTA to 1L with Milli Q water. Fifty mL of each sample was measured into a numbered jar. The samples were then filtered. Firstly, the cadmium reduction column was rinsed with 10% buffer solution, making sure the cadmium granules remained covered at all times by either the 10% buffer solution or the sample. The column was drained to 5mm above the cadmium granules, and 25mL of the first sample added. This was collected in a separate beaker as it drained through to rinse the column and was discarded. The column was then filled with the sample and 20mL was collected in the same sample jar. One mL of sulfanilamide solution was added and mixed thoroughly. After 2 minutes, 1mL of dihydrochloride solution was added and mixed. This was repeated for all water samples. After 10 minutes, the absorbance of each sample was measured using a UV-1700 Pharmaspec UV-visible spectrometer at 543nm. This colormetric determination of nitrogen can be used when nitrogen is in the range 0.0125 to 2.25μg/ml. Standards were also be prepared before analyzing the samples to calculate linear regression at 0μg/ml, 0.05μg/ml, 0.2μg/ml, 0.5μg/ml, 1μg/ml, 2μg/ml and 5μg/ml of known nitrogen concentration.

Phosphorus was measured by digesting an unfiltered water sample in a digestion tube with 10mL of digestion mixture. This contained 40g of di-potassium-peroxodisulfate ($K_2S_2O_8$) and 9g of sodium hydroxide (NaOH) in 1000mL of Milli Q water. This sample was then digested in the autoclave for 20 minutes. Twenty mL of sample was then added to a plastic SRP tube with 2mL of colour reagent: 20mL of ascorbic acid solution with 50mL of molybdate antimony solution. This was repeated for all water samples. After 8 minutes, the absorbance of each sample was measured using a UV-1700 Pharmaspec UV-visible spectrometer at 705nm. Standards were also be prepared before analyzing the samples to calculate linear regression at 0μg/ml, 0.05μg/ml, 0.2μg/ml, 0.5μg/ml, 1μg/ml, 2μg/ml and 5μg/ml of known nitrogen concentration.

2.4.2 ANZECC and MER water quality guidelines

The ANZECC Water Quality Guidelines (the guidelines) established in 1992 under the Commonwealth's National Water Quality Management Strategy (NWQMS), provide a scientifically informed framework for the water quality objectives required to maintain current and future water resources and environmental values (ANZECC 2000). The ANZECC guidelines were created in response to growing understanding of the potential for water quality to be a limiting factor to social and economic growth. The guidelines were derived from reviewing water quality guidelines developed overseas. However; Australian guidelines were also incorporated where available (ANZECC 1994).

The ANZECC *Australian Water Quality Guidelines for Fresh and Marine Waters* were released in 1992, and developed using two approaches:

1. An empirical approach which used the Precautionary Principle to create conservative trigger values from all available and acceptable national and international data. This method implemented data from only the most sensitive taxa in order to ensure the protection of these species.
2. The modeling of all available and acceptable national and international data into a statistical distribution with the confidence intervals of 90% and 50%.

Trigger values are conservative thresholds or desired concentration levels for different water quality indicators. When an indicator is below the trigger value there is a low risk present to the protection of that environment. However, when an indicator is above the trigger value, there is a risk that the ecosystem will not be protected. In cases where the trigger value is exceeded, further research and remediation of the risk identified should be conducted. Where a numerical value cannot be derived for a water quality indicator, a target load may be set, for example the salinity guideline; or a descriptive statement, for example for oil there should be no visible surface film; or an index of ecosystem health, for example percentage cover of an algal bloom.

The Australian and New Zealand Environment Conservation Council (ANZECC) Guidelines (2000 and 2006) provide threshold values for freshwater and estuarine systems for pH, dissolved oxygen (DO), electrical conductivity (EC), salinity and nutrients such as nitrogen (N) and phosphorus (P). In addition, we used region-based trigger values for estuarine chlorophyll *a* and turbidity developed by DECCW as part of the MER program (www.environment.nsw.gov.au/ieo/Macleay/report-02.htm). A combination of ANZECC (2000, 2006) and NSW MER developed trigger values were used to explore water quality across sites and sampling occasions (Table 2.4).

Table 2.4 *ANZECC Guidelines (2000) and NSW MER – Minimum and Maximum trigger values for freshwater reaches (above and below 150m elevation) and estuarine systems of southeast Australia. Variables with single values only have maximum trigger values. *Revised MER trigger values for reference condition coastal systems were used.*

Category	pH	DO (%)	EC (µScm)	Turbidity (NTU)	Chla (µgL)	NOx* (µgL)	SRP (µgL)	TN (µgL)	TP (µgL)
Freshwater sites >150m	6.5 – 7.5	80-110	30 - 350	25	4	25	15	250	20
Freshwater sites <150m	6.5 - 8	80-110	125 - 2200	50	4	40	20	500	50
Estuary sites	7 - 8.5	80-110	no ANZECC values	10	3.3	15	5	300	30

2.4.3 Freshwater macroinvertebrates

Aquatic macroinvertebrates are non-vertebrate aquatic animals (e.g., insects, crustaceans, snails and worms) that are visible to the naked eye and which live at least part of their life within a body of freshwater. Freshwater macroinvertebrates are important members of aquatic foodwebs. They feed on a wide range of food sources such as detritus (dead organic matter), bacteria, algal and plant material, and other animals. They in turn provide food for other animals such as fish and aquatic birds. Macroinvertebrates are useful as bio-indicators as many taxa are sensitive to stress and respond to changes in environmental conditions. Because many macroinvertebrates live in a river reach for an extended period of time, they integrate the impacts on the ecosystem over an extended period of time, rather than just at the time of sampling. In addition, many macroinvertebrates have widespread distributions, they are reasonably easy to collect and their taxonomy is well known.

Macroinvertebrates have been widely used in broad scale assessments of ‘river health’. The most common approach adopted for environmental monitoring has involved the analysis of the taxonomic richness of macroinvertebrates. SIGNAL stands for ‘Stream Invertebrate Grade Number – Average Level.’ It is a simple scoring system for macroinvertebrate samples from Australian rivers. A SIGNAL score gives an indication of water quality in the river from which the sample was collected. Rivers with high SIGNAL scores are likely to have low levels of salinity, turbidity and nutrients such as nitrogen and phosphorus. They are also likely to be high in dissolved oxygen. When considered together with macroinvertebrate richness (the number of types of macroinvertebrates), SIGNAL can provide indications of the types of pollution and other physical and chemical factors that are affecting the macroinvertebrate community. SIGNAL Scores range from 1 (pollution tolerant) to 10 (pollution intolerant). Another classification system uses the EPT index. This index claims that although different insect taxa vary widely in their sensitivity to sedimentation, the taxa from the orders Ephemeroptera (E), Plecoptera (P), and Trichoptera (T) behave similarly. However, a taxonomic group can exhibit a great deal of heterogeneity, so an assessment method like the EPT may be insensitive to changes in species composition unless composition is altered along with overall taxa richness. Multimetric and multivariate approaches can increase a model’s accuracy. These models evaluate the sampled community by comparing observed conditions to what conditions or taxa are expected to occur in the absence of disturbance.

Field and laboratory methods

Macroinvertebrates were sampled bi-annually (autumn and spring 2015) at the freshwater sites to align with the MER protocols. Kick net samples (250µm mesh) that comprise 10 linear meters of combined pool, riffle and edge habitats were taken from each of the 32 freshwater sites on each of the two sampling occasions. Only those habitats present at the time were sampled. Invertebrates were immediately preserved in 70% ethanol on site and transported to the laboratory for analysis. Each sample was passed through 2mm, 1mm and 250µm sieves. All taxa from the 2mm and 1mm sieves were recorded, with material retained on the 250µm sieve sorted for a standardized 30-minute period. Macroinvertebrates were identified to Family/genera level, assigned a SIGNAL2 score for pollution tolerance, and the EPT score calculated. Metrics of abundance, richness, and composition were recorded.

2.4.4 Riparian condition

Riparian zones are broadly defined as the interface between terrestrial and aquatic ecosystems (Gregory et al. 1991), and they are found where any body of water directly influences, or is influenced by adjacent land (Boulton et al. 2014). The riparian land is an intermediary semi-terrestrial zone with boundaries that extend outward from the water's edges to the limits of flooding and upward into the canopy of the riverside vegetation (Naiman et al. 2005). Riparian zones are therefore dynamic environmental transition zones that are regularly influenced by freshwater, and characterised by strong energy regimes, considerable habitat diversity, a variety of ecological processes and multidimensional gradients (Naiman et al. 2005).

The ecological functions of a riparian zone can be grouped into four main categories: nutrient flux, geomorphic control, temperature and light regulation, and litter input land (Boulton et al. 2014). Each of the four categories involves different attributes of the riparian zone and may encompass significantly different areas of channel bank. The area within a riparian zone contains valuable water resources, highly fertile soil and supports diverse habitats that contain high levels of biodiversity (Naiman et al. 2005). Riparian zones contribute to numerous ecological functions as well as fulfill many social and economic functions, both directly and indirectly. Given the importance of such systems, riparian health is essential.

Rapid Assessment of Riparian Condition

The Ecohealth Rapid Assessment of Riparian Condition (ERARC) is a multi-metric index of riparian condition, which has been modified from a combination of the Sub-Tropical Rapid Appraisal for Riparian Condition (STRARC) (Southwell 2011), the adapted Tropical Rapid Appraisal of Riparian Condition (TRARC) (Dixon et al. 2006), and the original Rapid Appraisal for Riparian Condition (RARC) (Jansen et al. 2004). The ERARC is comprised of 29 indicators which are grouped into five subindices that when combined with equal weighting, calculate to an overall index of riparian condition. The five subndices help to identify the general components that contribute to the condition of a site (Dixon et al. 2006). For the purposes of Ecohealth grading, the ERARC was modified to separate out geomorphic condition from riparian condition. Riparian condition subindices and their indicators are listed below in Table 2.5.

In summary the five riparian condition subindices describe:

1. Overall extent and condition of vegetation, and provision of habitat in the riparian zone (HABITAT).

2. Originality, weediness and overall quality of the riparian vegetation (NATIVE SPECIES).

3. Extent of the riparian vegetation footprint with regards to structural complexity (COVER).

4. Presence of dead and decaying vegetative material and fringing vegetation (DEBRIS).

5. Current and historic human induced influences on the riparian zone (MANAGEMENT).

HABITAT

Habitats within riparian zones are an important characteristic of riparian condition. Riparian zones play a crucial role in supporting wildlife by providing services such as nesting and roosting habitats, food and shelter from predators and harsh physical conditions, and migratory transport networks. The quality of such services is dependent upon structural complexity, stand age and vegetation continuity and connectivity to larger intact remnant vegetation stands. The HABITAT subindex assesses riparian condition by considering the extent and quality of vegetation, and provision of habitat within the riparian zone. This is achieved by quantifying riparian vegetation continuity and proximity to larger tracts of forest at a landscape scale, channel: riparian width ratio, structural complexity, and the presence of both large and hollow bearing native trees, otherwise known as 'habitat trees', which are known to provide habitat for approximately 15% of all Australian terrestrial vertebrate fauna at any point in time (Gibbons and Lindenmayer 2002). In addition to onsite surveys, spatial data layers from the SIX Maps Vegetation Map Viewer (OEH 2016) are used to assist with the assessment of the Habitat subindex.

NATIVE SPECIES

Invasive exotic plant species have the potential to threaten the ecological integrity and productivity of riparian zone ecosystems, by excluding native species, altering nutrient, light and moisture levels, and can have detrimental effects on natural processes such as terrestrial and aquatic invertebrate food webs. The originality and overall quality of the riparian vegetation is assessed at each structural layer with regards to native plant versus weedy plant species. The layers assessed are canopy, midstory, herbs and forbs, graminoids, and macrophytes or vines, depending on the vegetation community present (closed or open forest systems). The identification of the dominant floristics of each structural layer is a valuable additional measure of stand quality and condition, and allows for the important distinction between native and exotic plant species. In addition to onsite surveys, the Atlas of Living Australia (Atlas of Living Australia [ALA} 2016), is used to assist with the assessment of the Native Species subindex.

COVER

The number of naturally occurring vegetation layers and the percentage cover of each of these layers found in a system can be used as an indicator of the overall presence and extent of the riparian vegetation footprint. The contribution that each layer adds to the system is quantified and provides an overall indication of the presence of riparian vegetation, its structural complexity and its resilience to major flood and other disturbance events. Each of the five riparian structural layers, canopy, midstory, herbs and forbs, graminoids, and macrophytes/vines, is assessed for its completeness and contributes to overall riparian condition.

DEBRIS

Debris refers to the presence of dead and decaying vegetative material and fringing vegetation in the riparian zone. Debris assists with the regeneration of native woody species with the provision of protected habitats, while leaf litter and woody debris are essential for maintaining nutrient cycles and other aquatic and terrestrial ecological processes including food webs. In addition to providing shelter for smaller invertebrates, organic leaf litter is a source of course particulate organic matter, while woody debris in the form of fallen trees and logs provide instream habitat for spawning sites and areas for fish to hide from predators, and to avoid intense sunlight and high current velocities (Crook and Robertson 1999). In addition to the provision of core habitat, debris and fringing vegetation aid river bank stabilisation, and are an important foraging resource for a variety of mammals, birds, reptiles, invertebrates and microorganisms. Debris contributes to riparian condition and is assessed by quantifying woody and non-woody debris - dead standing and fallen trees, logs and branches, and leaf litter from both native and exotic species, along with fringing vegetation.

MANAGEMENT

This considers both current and historic anthropogenic influences on the riparian zone. A particularly important indicator of disturbance or the lack thereof is the presence and abundance of large trees, given the history of logging and land clearing within upper catchments. Vegetation clearing and the presence of livestock continue to accelerate the deterioration of riparian condition. The presence of fencing indicates that there has been an attempt made to exclude livestock from the site. The MANAGEMENT indicators assessed that contribute to riparian condition are tree clearing, fencing, animal impact, noxious weeds, exposed roots and woody regeneration. If left unchecked, human-induced impacts may be detrimental to the health and the complexity of the plant and animal species of the riparian zone, and accelerate the deterioration of riparian condition. The extent and success of site-level measures taken to improve the ecological condition and function of the riparian zone are also considered.

Riparian field methods

All 44 sites in the Macleay Catchment were sampled in both October 2015 and in February 2016 using the ERARC method developed for the Ecohealth project (Ryder et al. 2016). Two sampling periods were required to account for climatic variability, temporal variation in plant species and for collection of flowering plant material for identification (specifically grasses). Data for each of the five subindices were collected at the reach (100m) scale (Table 2.5), and via desktop survey using satellite imagery, vegetation datalayers and species record lists (Atlas of Living Australia [ALA] 2016, Office of Environment and Heritage [OEH] 2016).

__Table 2.5__ Vegetation condition subindices, their indicators and scores.

Subindices and their indicators	Assessment	Score
HABITAT		**20**
Channel width	Riparian vegetation width ÷ channel width	4
Proximity	Distance to closest stand of native vegetation	4
Continuity	Longitudinal continuity of riparian vegetation	4
Layers	Presence/absence of integral growth forms	4
Large native trees	Presence/absence of large trees (>30cm dbh)	2
Hollow-bearing trees	Presence/absence of hollow-bearing trees	2
NATIVE SPECIES		**20**
Native canopy species	Percentage of woody native species >5m tall	4
Native midstory species	Percentage of woody native species <5m tall	4
Native herb/forb species	Percentage of non-woody understory plants	4
Native graminoid species	Percentage of grass & grass-like plants	4
Native macrophyte species	Percentage of in-stream waterplants	4
SPECIES COVER		**20**
Canopy species	Percentage cover of woody native species >5m tall	4
Midstory species	Percentage cover of woody native species <5m tall	4
Herb/forb species	Percentage cover of non-woody understory plants	4
Graminoid species	Percentage cover of grass & grass-like plants	4
Macrophyte species	Percentage cover of in-stream waterplants	4
DEBRIS		**20**
Total leaf litter	Percentage cover of total leaf litter	3
Native leaf litter	Percentage cover of native leaf litter	3
Dead trees standing	Presence/absence of dead trees standing	3
Dead trees fallen	Presence/absence of dead trees fallen	3
Lying logs	Presence/absence of lying logs	4
Fringing vegetation	Presence/absence of graminoids	4
MANAGEMENT		**20**
Tree clearing	Clearing and age of stand assessment	4
Fencing	Presence/absence of riparian fencing	3
Animal impact	Evidence of livestock grazing	3
Species of interest	Presence of uncommon &/or noxious weed species	2
Exposed tree roots	Extent of exposed tree roots due to erosion	4
Native woody regeneration	Presence/absence of native woody species	2
Weedy woody regeneration	Presence/absence of weedy woody species	2

2.4.5 Mangrove, seagrass and saltmarsh cover in estuarine sites

Riparian and in-stream vegetation in estuaries also perform many functions by providing habitat for a wide range of organisms, preventing erosion of banks from storm surge and tidal action, and acting as a buffer to filter nutrients entering estuaries. In estuaries, mangroves are common in the riparian zone, providing crucial nursery habitat to many aquatic organisms including commercially important fish and prawn species. Seagrasses are also a critical part of estuaries and coastal lagoons. They provide primary production and stability to habitats, and support nurseries and food webs for important species including fish, prawns and invertebrates. One of the most common factors leading to the loss of seagrass is direct human disturbance (hauling nets, boat anchors) or indirect effects from increasing water turbidity and reducing light penetration.

Cover of estuarine macrophytes (mangroves, seagrass and saltmarsh) for both the Macleay River and South West Rocks Creek estuaries was calculated using the 2011 spatial dataset provided by NSW Department of Industry and Investment – Primary Industries and Energy. The total area of mangrove, seagrass and saltmarsh was calculated for each estuary system. In order to better detect any potential change in total mangrove and seagrass area the Macleay River estuary was divided further into five zones – Stuarts Point, Shark Island, Pelican Island, Yarrahapinni and Clybucca Creek – as per Middleton and others (1985; GeoLINK, 2010a).

Data from a series of previous Macleay River estuarine macrophyte surveys, undertaken in 1956, 1980, 2004, 2009 and 2011 (West et al., 1985; Middleton et al., 1985; CCA, 2006; and Creese et al., 2009), were used to provide a basis for assessing broad change in relation to estuarine macrophyte cover in the Macleay River and South West Rocks Creek estuaries. However, it is difficult to determine error arising from the differences in data collection and data processing methods among the datasets. Future surveys using the 2011 methods will provide a more accurate assessment of actual temporal change in estuarine macrophyte cover.

2.4.6 Geomorphic Condition

Fluvial geomorphology refers to the sediment dynamics of river systems, from the configuration of entire stream networks within catchments to the organisation of sediment particles within a single feature in a stream reach. These complex sediment erosion and transport processes form the physical template that regulates ecological habitat and processes in rivers. Human disturbances can negatively affect the equilibrium of these sediment erosion and transport processes. For example, catchment and riparian clearing can accelerate erosion and delivery of sediment to the stream channel, where it is stored and transported slowly over many floods. However, while the sediment is stored within the channel, it may negatively impact stream ecology by physically smothering habitat, releasing nutrients and contaminants into the streambed or water column, or damaging stream biota.

The condition of the geomorphic template is assessed once for each site during a low-flow period, usually concurrent with the riparian condition assessment. The assessment considers the condition of stream banks (freshwater and estuary sites), stream bed (freshwater sites), and local management that directly impacts reach-scale geomorphic condition. The assessment is conducted within the River Styles framework that classifies stream reaches according to the shape of the surrounding river valley, the shape and mobility of the channel within the valley and the dominant sediment size of the channel.

Geomorphic field methods

Geomorphic condition was assessed at two spatial scales. Subcatchment scores and grades were calaculated using the entire stream network for each subcatchment using the River Styles 2014 data layer supplied by NC LLS. The proportions of total subcatchment stream length in Good, Moderate and Poor Condition were calculated and weighted (3, 2, and 1 for Good, Moderate and Poor, respectively). These were summed to a total score, divided by 3 and converted to proportions. The standard Ecohealth grading structure was applied to each subcatchment proportions.

Site-level geomorphic condition is assessed by field surveys using the geomorphic indicators in Table 2.6. Field assessments are conducted over a 100-m reach for each site. Both bank and bed condition are assessed at freshwater sites, and bank condition is assessed at estuarine sites. Both these site-level geomorphic subindices comprise several indicators. All indicators are assessed on a scale of 1-5 where 1 is poor and 5 is very good, and indicators are equally weighted when calculating subindices.

The representativeness of sites in reporting geomorphic condition is considered at the subcatchment scale and for the site-specific River Style within the subcatchment. In practice, site-level grades are usually consistent with subcatchment grades, but may under-estimate the condition of specific River Styles (e.g. headwaters) due to the logistical constraints of accessing reaches in better condition.

Table 2.6 *Geomorphic condition subindices for bank and bed condition.*

Geomorphic condition subindices and their indicators	
BANK CONDITION	
- Exposed tree roots	Evidence of exposed tree roots
- Bank slumping	Evidence of bank slumping
- Pugging/trampling	Evidence of pugging and trampling
- Active erosion	Evidence of active erosion
BED CONDITION	
- Active erosion	Evidence of active erosion
- Pugging/trampling	Evidence of pugging and trampling
- Smothering fines	Evidence of smothering by fine-grained sediments

2.5 Calculating scores for Ecohealth Indices

2.5.1 Water Quality

A guideline trigger value is formally defined as the value that is commonly used to assess the ecological condition of a waterbody. An exceedance indicates that a variable is outside the expected range. Triggers are likely to be recalculated periodically as additional data from reference systems becomes available. A combination of ANZECC (2000, 2006) and NSW MER developed trigger values were used to explore water quality across sites and sampling occasions (Table 2.4).

Calculating non-compliance is the proportion of time that the measured values of the indicator are outside the adopted trigger values (number of samples non-compliant with trigger value divided by the total number of samples (expressed as a value between 0 and 1, with 0 equal to all values being compliant and 1 equal to all values non-compliant)). The result of this process is a score between 0 and 1 for each individual water quality parameter measured as part of Ecohealth monitoring. These scores are simply averaged to determine an overall score between 0 and 1 for Water Quality.

2.5.2 Freshwater macroinvertebrates

Regional trigger values must be developed from literature and past studies for Family Richness (number of families), Total Abundance, SIGNAL2 Score (pollution tolerance index), and EPT taxa (number of Mayflies, Stoneflies and Caddisflies) for each study. In the absence of these, the default threshold values reported in Chessman (2003) can be used for SIGNAL2. Alternatively, it should be determined if one or more sites sampled during the Ecohealth program in a specific catchment can be used as a 'reference condition' for Family Richness and EPT grade. In addition to a trigger value, a Worst Expected Value (WEV) must be calculated for Family Richness, Total Abundance, EPT score and SIGNAL2. The WEV scores are derived from either the 10^{th} and/or the 90^{th} percentile of data for all relevant available data, and represent a site that is the 'unhealthiest'. Calculation of a standardized score involves the comparison of each of the four macroinvertebrate indicators against the corresponding guideline value and WEV scenario. The maximum score for each indicator is 25 and indicators are equally weighted when calculating the Macroinvertebrate Condition Index.

2.5.3 Riparian Condition

The assessment of each site affords each indicator an average site score, where a minimum value of 0 represents a poor state and a maximum value represents pristine condition. These scores assessed both in the field and using a desktop data assessment are combined to produce summary scores for each sub-index, and an overall condition index (Table 2.5). Indicators that are assessed at three points along the transect required averaging to give only one number for each indicator, those recorded at the transect level have only one value for each site. The indicators are then grouped into the five subindices and summary scores for each grouping are calculated through simple averaging to produce a condition score out of 20 for each sub-index (i.e. Habitat, Native Species, Species Cover, Debris, and Management). These scores are then summed to a total score out of 100, standardised to a score ranging from 0 to 1 through simple division and assigned a final Ecohealth Report Card grade for riparian condition.

2.5.4 Mangrove, seagrass and saltmarsh cover in estuaries

As this is the first time mangrove, seagrass and saltmarsh are reported as part of an Ecohealth assessment of the Macleay Catchment, they do not contribute to Ecohealth scores. Area and patch size will be calculated during the next Ecohealth round if the surveys are updated, and these temporal changes will be used to assess system change which will contribute to estuarine riparian condition scores.

2.5.5 Geomorphic Condition

Site-level geomorphic condition is assessed by field surveys using the geomorphic indicators in Table 2.6. The assessment of each site affords each indicator a maximum score out of five, where a score of 1 represented the worst possible condition and a score of 5 represents pristine condition. The scores recorded in the field were combined to produce summary scores for both subindices and an overall condition index. The indicators are grouped into the 3 subindices and summary scores for each grouping are calculated through simple averaging to produce a condition score out of 5 for each sub-index (i.e. bank condition and bed condition). To calculate the Ecohealth Geomorphic Condition Index, these scores are then summed to a total score out of 10, and through simple division are standardised to a score ranging from 0 to 1.

2.6 Spatial Scales

The above process provides the methods for calculating standardized scores for each index used in a particular Ecohealth monitoring program for an individual site. Total scores for a site are simply calculated as an average of the 0 to 1 range of scores across all indices. The scores can then be 'pooled' at spatial scales relevant to reporting requirements such as site, river, sub-catchment, freshwater or estuarine, catchment and region.

2.7 Calculating grades

The condition scores were grouped in ranges and given a corresponding grade (see Table 2.7). This scoring and grading system is based on the traditional format of a school report, with primary ratings ranging from a high of 'A', through intermediate ratings of 'B', 'C' and 'D', to the lowest possible score of an F. Secondary grades of + and – are included to provide greater resolution within a grade, and to better help show improvements over time.

Table 2.7 *Standardised scores from 0-1 and their corresponding Ecohealth grades.*

Score	Grade	Condition	
≥0.95/1	A	Excellent	Environmental values met (The indicators measured meet all of the benchmark values for almost all of the year)
0.85/1	B	Good	Most environmental values met (The indicators measured meet all of the benchmark values for most of the year)
0.70/1	C	Fair	Some of the environmental values met (The indicators measured meet some of the benchmark values for some of the year)
0.55/1	D	Poor	Few of the environmental values met (The indicators measured meet few of the benchmark values for some of the year)
≤0.45/1	F	Very Poor	Very few of the environmental values met (The indicators measured meet very few of the benchmark values for almost all of the year)

2.8 Ecohealth report cards

The calculation and reporting of Ecohealth grades involves the synthesis all available indicators each with trigger values six times during the program. Scores are calculated for individual sites, but also must fulfill the broader aims of wider-scale reporting at river, sub-catchment, catchment and regional scales. To produce an Ecohealth grade, the value for each index – Water Quality, Freshwater Macroinvertebrates, Freshwater Fish, Riparian Condition and Geomorphic Condition– must be transformed into standardized scores that account for differing physical conditions and scales of measurement among indices and prevailing climate conditions. The result is a scoring system from 0 to 100, where 0 represents the most 'unhealthy' condition and 100 indicates a 'healthy' waterway.

PART 3

RESULTS

This section of the report provides detail of the water chemistry and biophysical data collected from April 2015 to February 2016. Results for water chemistry, macroinvertebrates, riparian condition, estuarine macrophytes and geomorphic condition are reported for each subcatchment. *Geomorphic condition* assessed site-scale condition of stream banks and bed at freshwater and estuarine sites, and subcatchment-scale assessment of the stream network. *Riparian condition* assessed freshwater and estuarine sites and included habitat, native species presence, percentage cover, woody and non-woody debris, management issues, as well as identification of local-scale disturbances to riparian zones. *Water quality* identified trends in nutrients (nitrogen (N) and phosphorus (P)), chlorophyll *a* (chl-*a*), suspended solids (TSS), as well as static variables such as pH, salinity, dissolved oxygen (DO) and temperature measured from water column profiles at each site. Attributes that exceed ANZECC or NSW MER guideline thresholds for aquatic ecosystem health are identified. *Aquatic macroinvertebrate* assemblages collected from freshwater sites in autumn and spring 2015 are used to assess long-term condition of channel habitats and water quality. The taxonomic richness and abundance reported, as well as health indicators using SIGNAL2 scores and EPT richness and abundance. All water chemistry and biophysical data are reported for the Macleay catchment overall and subcatchments are divided into their hydrological units:

3.1 Macleay catchment overall

3.2 Tableland tributaries (Gara River, Commissioners Waters, Salisbury Waters, Apsley River, Tia River, Yarrowitch River, Bakers Creek, Wollomombi River, Chandler River, Oaky River and Styx River)

3.3 Macleay River main stem (Freshwater reaches and estuarine reaches)

3.4 Freshwater tributaries (Georges Creek, Five Day Creek, Nulla Nulla Creek, Warbro Brook, Toorumbe Creek, Hickeys Creek, Mungay Creek, Dungay Creek and Collombatti Creek)

3.5 Estuarine tributaries (Belmore River, Kinchela Creek, Spencers Creek, Clybucca Creek and the North Arm Macleay River)

3.1 Macleay catchment

The overall grade for the Macleay catchment was C- (Table 3.1, Figure 3.1), ranging from an F in Commissioners Waters and Salisbury Waters to B- in the Styx River (Table 3.1). Overall, the tableland tributaries were in poorest condition and the freshwater tributaries were in best condition (Figure 3.1).

With the exception of freshwater fish communities, scores were typically consistent among indices, highlighting that biophysical stressors to aquatic ecosystem health are affecting short- and long-term condition of the streams (Figure 3.2). Riparian and geomorphic condition were closely related, reiterating that healthy riparian vegetation is critical to maintaining bank stability, and that riparian and geomorphic condition are similarly impacted by degrading landuse practices. Throughout the Macleay catchment, subcatchment geomorphic condition ranged from D- in Commissioners Waters and Salisbury Waters through to A- in the Macleay gorges (Figure 3.2a). The gorges were also characterized by good riparian condition, with tableland subcatchments (Commissioners Waters, Salisbury Waters and the Tia River) having poor riparian condition (Figure 3.2b).

Water quality was poorest in the Tableland tributaries (Figure 3.2c), with several sites regularly having nutrient concentrations many times the ANZECC trigger threshold for aquatic ecosystem health. Georges Creek and Warbro Brook had very poor water quality (Figure 3.2c), despite freshwater tributaries in general having the best water quality in the Macleay catchment.

Aquatic macroinvertebrates were found to be in very poor condition in many subcatchments and overall. In most subcatchments, poor water quality impacts aquatic macroinvertebrate communities (Table 3.1). The exception is Nulla Nulla Creek where aquatic macroinvertebrates have good water quality but poor habitat availability (as indicated by geomorphic condition). The poor water quality in Georges Creek was not reflected in aquatic macroinvertebrate communities, with Georges Creek and Five Day Creek containing very diverse and abundant aquatic macroinvertebrate communities including many taxa that require good water quality (Figure 3.2d).

Table 3.1 *Catchment and subcatchment Ecohealth grades for subcatchments in the Macleay. Geomorphic condition was assessed at the subcatchment scale.*

System	Water quality	Aquatic Macroinvertebrates	Fish	Riparian Condition	Geomorphic Condition	Overall
Macleay Catchment Overall	D+	D+	B-	D+	C	C-
Tableland Tributaries	F	D-	C+	D+	C	D+
Gara River	F	F	D-	D-	C	D-
Commissioners Waters	F	F		F	D-	F
Salisbury Waters	F	F		F	D+	F
Apsley River	F	F	C+	B-	B-	D+
Tia River	D-	F		F	D	F
Yarrowitch River	F	C-		D+	D	D
Bakers Creek	D+	C	C+	B	B-	C+
Wollomombi River	F	D		C	C+	D+
Chandler River	F	D-	B-	C-	C+	D+
Oaky River	D+	D+	C	D-	C-	D+
Styx River	D	C+		B+	A-	B-
Macleay Main Stem	D+	D+	C+	D	C+	C-
Freshwater Macleay	C-	D+	C	D+	C+	C-
Macleay estuary	D			D-	C-	D
Freshwater Tributaries	D+	C-	B+	C-	C-	C
Georges Creek	F	B+		C-	C	C-
Five Day Creek	C	B	A-	C-	D+	C
Nulla Nulla Creek	B-	D	A-	D+	D	C-
Warbro Book	F	C-		D+	C+	C-
Toorumbee Creek	C-	C+	B	C-	D+	C-
Hickeys Creek	D+	D-		C-	C+	D+
Mungay Creek	D	F		B	C-	D
Dungay Creek	C+	D+	B+	C	C+	C
Collombatti Creek	D-	F		C	C-	D-
Estuarine Tributaries	D-			D-	C	D+
Belmore River	F			D-	C	D-
Kinchela Creek	F			F	C	D-
Spencers Creek	D+			D-	C-	D+
Clybucca Creek	C-			C+	C+	C
North Arm Macleay River	D-			C	B-	C-

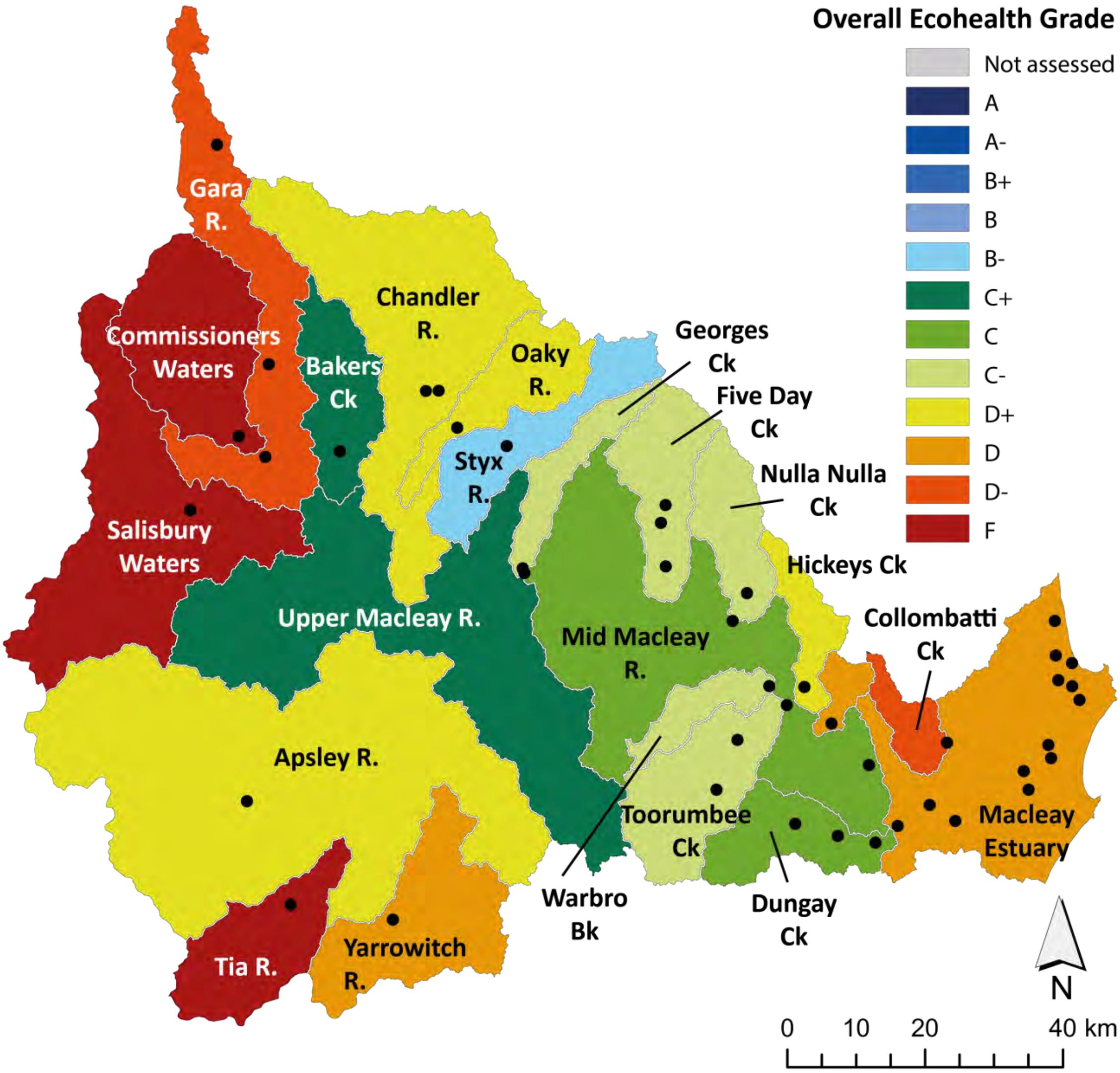
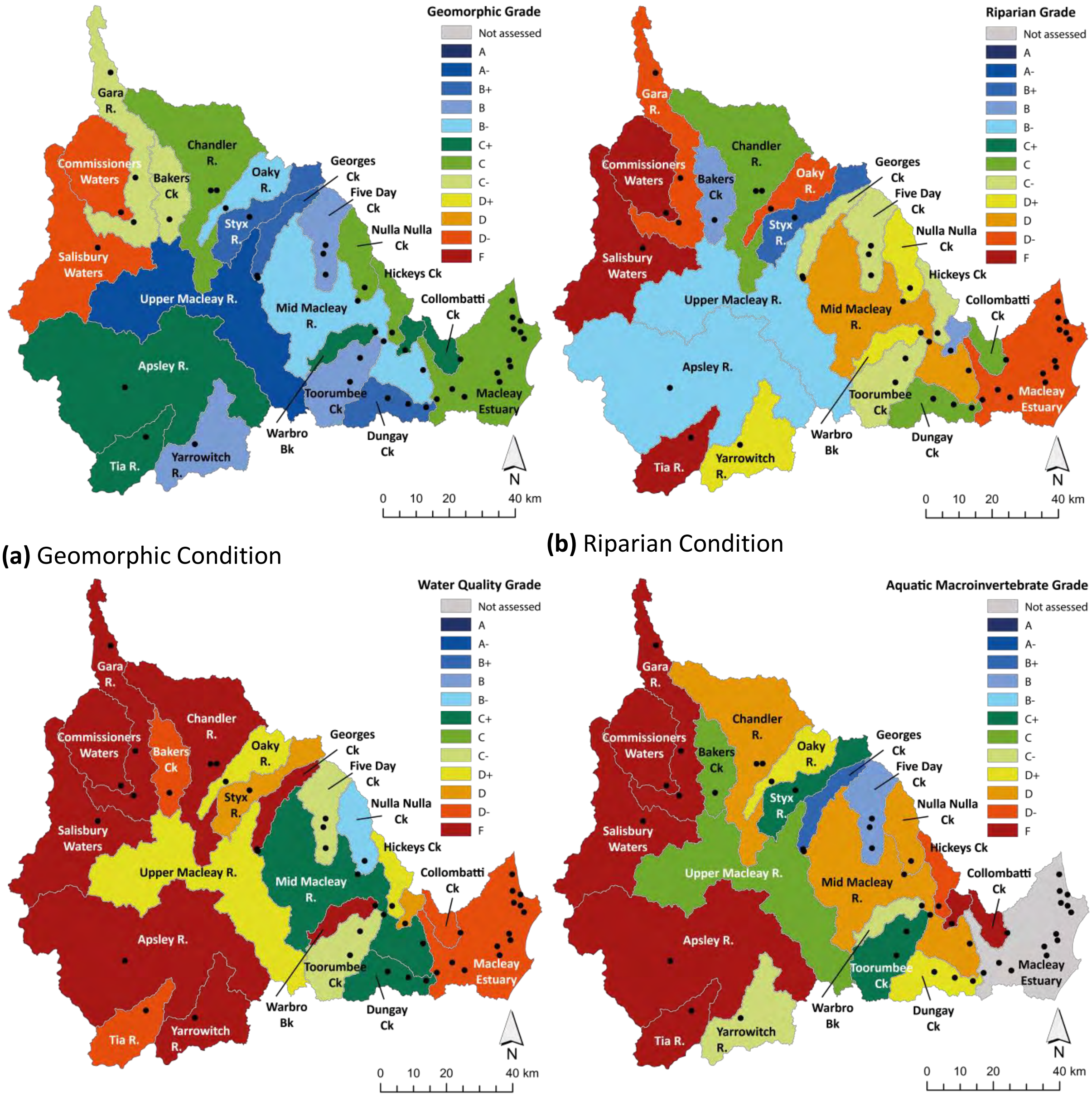


Figure 3.1 *Overall Ecohealth grades for the Macleay catchment.*



(a) Geomorphic Condition

(b) Riparian Condition

(c) Water Quality

(d) Aquatic Macroinvertebrates

Figure 3.2 *Subcatchment Ecohealth grades for (a) geomorphic condition, (b) riparian condition, (c) water quality, and (d) aquatic macroinvertebrate communities. Aquatic macroinvertebrate communities were not assessed for estuarine reaches.*

3.1.1 Geomorphic condition

Assessments of stream condition over the Macleay subcatchments show that most (82%) of the stream network is in good or moderate condition (Table 3.2, Figure 3.3). Overall, the Macleay catchment achieved a grade of C+ for subcatchment-scale geomorphic condition. Six subcatchments have more than 50% of their stream network in good condition (Table 3.2). These include the upper Macleay and Styx Rivers and Georges Creek that mostly comprise gorge country; and Five Day, Toorumbee and Dungay Creeks that mostly comprise planform-controlled, low sinuosity gravel-bed channels. While the gorges have low fragility, the planform-controlled gravel-bed channels have moderate fragility and management priorities in Five Day, Toorumbee and Dungay Creeks should continue to focus on maintaining the good geomorphic condition of these stream channels.

Four subcatchments contained no stream reaches in poor condition: Yarrowitch River on the tablelands, and the freshwater tributaries of Mungay, Dungay and Collombatti Creeks (Table 3.2). Four subcatchments had more than one-third of their stream network in poor condition: Commissioners Waters (65%), Salisbury Waters (56%), Bakers Creek (34%), and Nulla Nulla Creek (47%). For the tableland subcatchments of Commissioners Waters, Salisbury Waters and Bakers Creek, the channels in poor condition comprise fine-grained and sandy sediments. In contrast, poor stream condition in the Nulla Nulla Creek subcatchment is mostly the main stem which is a planform-controlled, low sinuosity, gravel-bed channel. All four subcatchments have been significantly cleared of catchment and riparian vegetation in the reaches with poor geomorphic condition.

Table 3.2 *Subcatchment scale geomorphic condition calculated over the subcatchments' total stream length using the 2014 River Styles datalayer from NC LLS.*

Subcatchment	% Good Condition	% Moderate Condition	% Poor Condition	Geomorphic Grade
Macleay catchment overall	41	41	18	C+
Gara River	12	61	27	C-
Commissioners Waters	11	24	65	D-
Salisbury Waters	6	38	56	D-
Upper Macleay River	80	15	5	A-
Apsley River	46	31	23	C+
Tia River	16	79	5	C+
Yarrowitch River	48	52	0	B
Bakers Creek	27	39	34	C-
Chandler River	23	50	27	C
Oaky River	36	55	9	B-
Styx River	74	18	8	B+
Georges Creek	65	33	2	B+
Mid Macleay River	35	59	6	B-
Five Day Creek	67	10	23	B
Nulla Nulla Creek	44	9	47	C
Warbro Brook	38	47	16	C+
Toorumbee Creek	60	31	9	B
Hickeys Creek	13	77	10	C
Mungay Creek	14	86	0	C+
Dungay Creek	67	33	0	B+
Collombatti Creek	21	79	0	C+
Macleay Estuary	15	75	19	C

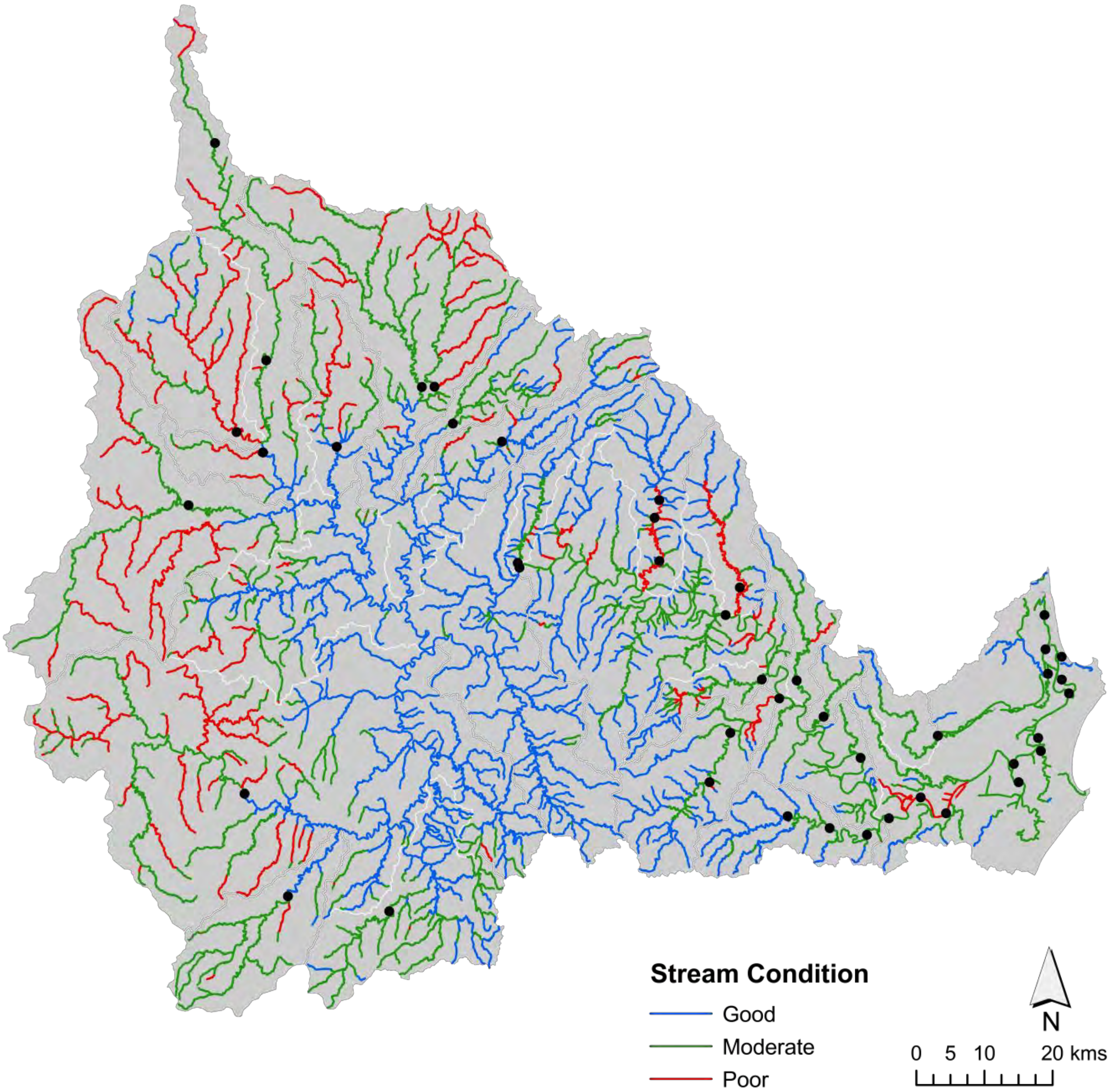


Figure 3.3 *Stream condition of the Macleay catchment. Black dots represent Ecohealth sites. Data from NC LLS 2014 Riverstyles.*

3.1.2 Riparian condition

The overall 2016 Ecohealth score for riparian condition at 44 sites across the Macleay River Catchment was 56.6, or D+. The majority of Ecohealth sites contributing to this riparian condition grade were representative of the area of the Catchment that has been subjected to broadscale landuse and anthropogenic impact. The Macleay River Catchment was therefore assessed as one of high disturbance. However, the overall Macleay Catchment score does not reflect the riparian condition of wilderness areas which account for approximately 4,910 km^2 of the 11,389 km^2, or 43% of the Macleay Catchment.

Vast tracts of forested wilderness areas in the Macleay Catchment include New England, Cunnawarra and Oxley Wild Rivers National Parks, Styx River, Nulla-five Day, Collombatti and Boonnanghi State Forests, Georges Creek and Willi Willi Caves Nature Reserves, private reserves, coastal marshes and estuarine swamps. Riparian vegetation sampled within or adjacent to these wilderness areas reflected a much higher average riparian condition score than that given to the overall Macleay Catchment. Low-to-mildly disturbed riparian zones representative of these wilderness tracts included eight Ecohealth sites, APSR1, BAKC1, MUNC1, DUNC3, GARR1, MACR10, NAMR1 and STYX1. Overall wilderness areas within the Catchment were assessed as being in good condition, receiving an average score of 79.7, or B-.

The Tableland tributaries consisted of 12 Ecohealth sites (APSR1, BAKC1, CHAR1, COMW1, GARR1-3, OAKR1, SALW1, STYR1, TIAR1, WOLR1 and YARR1). These were highly disturbed systems in a predominantly cleared, partially forested landscape. They received an overall riparian condition score of 55.1, a grade of D+, which was the second lowest in the Macleay Catchment.

The freshwater reach of the Macleay River main stem consisted of 4 Ecohealth sites (MACR7, MACR8, MACR9 and MACR10) and was a highly disturbed system in a predominantly cleared, partially forested landscape. It received an overall riparian condition score of 59.7, a grade of D+, which was the second highest in the Macleay Catchment. The estuarine reach of the Macleay River main stem consisted of 6 Ecohealth sites (MACR1, MACR2, MACR3, MACR4, MACR5 and MACR6) and was an extremely disturbed system in a predominantly cleared, partially forested landscape often dominated by weeds. It received an overall riparian condition score of 39.1, a grade of F, which was the lowest in the Macleay Catchment.

The freshwater tributaries consisted of 15 Ecohealth sites (COLC1, MUNC1, DUNC1-3, FIVC1-3, GEOR1, HICC1, NULC1, TOOC1-3 and WARB1). They were moderately disturbed systems in a partially cleared, partially forested landscape. They received an overall riparian condition score of 64.3, a grade of C- and the highest in the Macleay Catchment.

The coastal tributaries consisted of 6 Ecohealth sites (CLYC1, BELR1, KINC1, NAMR1, NAMR2 and SPEC1). They were highly disturbed systems in a predominantly cleared, partially forested landscape. They received an overall riparian condition score of 55.9, a grade of D+, which was the third highest in the Macleay Catchment.

Sites that scored between 80 and 100 (very good-to-excellent) were generally considered ‘intact’, low disturbance systems (STYR1, GARR1, BAKC1, MUNC1 and NAMR1). Riparian vegetation continuity and vegetation:channel width ratio was high and sites were connected to large remnant patches of native vegetation. Weeds encountered in these sites did not dominate their structural layer and were often only present at disturbed edge areas. Large native remnant habitat trees were typically common, woody and non-woody debris was present, fringing vegetation was abundant, and tree root exposure was low. At each structural layer, native species presence and cover was high and representative of the original vegetation community type. Generally, there was adequate riparian fencing, no sign of stock impact and significant native woody regeneration taking place.

Sites that scored between 60 and 80 (moderate-to-good) were generally considered moderate disturbance systems (APSR1, MACR10, DUNC3, TOOC2, CLYR1, WOLR1, COLC1, FIVC3, DUNC2, HICC1, CHAR1, FIVC1, GEOC1 and DUNC1). Riparian vegetation continuity and vegetation:channel width ratio was moderate and sites were often connected or in close proximity to large remnant patches of native vegetation. Weeds were often encountered throughout these sites and often dominated in one or two structural layers, typically the midstory and understory. Large native remnant habitat trees were common at these sites, woody and non-woody debris was present but often reduced, fringing vegetation was scattered to abundant, and tree root exposure was low-to-moderate. At each structural layer, native species presence and cover was good and representative of the original vegetation community type. Generally, there was partial riparian fencing in place, occasional animal impact from stock, low woody weed regeneration and significant native woody regeneration taking place.

Sites that scored between 40 and 60 (poor-to-fair) were generally considered high disturbance systems (BELR1, FIVC2, MACR1, MACR5, MACR6, MACR7, MACR8, MACR9, NAMR2, NULC1, OAKC1, SPEC1, TOOC1, TOOC3, WARB1 and YARR1). Riparian vegetation continuity and vegetation:channel width ratio was both disrupted and narrow. Sites were often disconnected but within 1km of large remnant patches of native vegetation. Weeds were common throughout these sites and often dominated in two or three structural layers, typically the midstory and understory. Although still present, large native remnant habitat trees were often reduced at these sites, while both large woody debris and non-woody debris levels were frequently reduced from their natural levels by approximately 75% and 50% respectively. Fringing vegetation remained scattered to abundant and tree root exposure was still low-to-moderate. At each structural layer, native species presence and cover was moderate-to-good with representative elements of the original vegetation community type still present throughout the system to varying degrees. Generally, there was inadequate riparian fencing in place and animal impact from stock was frequent, at least on one bank. Both woody weed and significant native woody regeneration commonly occurred at these sites.

Sites that scored less than 40 (very poor) were generally considered extreme disturbance systems (SALW1, MACR4, KINC1, COMR1, TIAR1, GARR2, MACR3, GARR3 and MACR2). Riparian vegetation continuity and vegetation:channel width ratio may have been highly disrupted or non-existent. Such sites were often isolated (>1km) from large remnant patches of native vegetation and weeds typically dominated each structural layer. Large native remnant habitat trees were rare as was large woody debris, while non woody debris was reduced to less than 75% of their natural levels. Fringing vegetation was commonly retained and scattered throughout the riparian zone while tree root exposure was moderate-to-high. Native species presence and cover was typically low throughout the canopy and midstory structural layers, with slight increases observed throughout the understory layer. Significant reductions in native species presence in combination with highly modified community structures meant that typically these systems were no longer indicative of the original vegetation community once found at these sites. Generally, there was inadequate riparian fencing in place and animal impact from stock was frequent, at least on one bank. Woody weed regeneration commonly occurred at these sites, while native woody regeneration was uncommon.

Of the 372 dominant riparian vegetation species recorded from the 44 Macleay Ecohealth sites, 126 were riparian as exotic species, while 246 species were native species. When averaged across all sites, native dominant species outweighed dominant weed species by approximately 2:1. When separated by growth forms, dominant weed species were most prevalent in the Herb/forb layer (51%, or 56 species), followed by Grasses (48%, or 28 species), Vines (30%, or 10 species), Shrubs (25%, or 15 species), Graminoides (23%, or 5 species), Trees (20%, or 8 species) and lastly the Macrophyte layer (11%, or 4 species). The most common dominant weed species were Prairie Grass (*Bromus catharticus*) in 66% (29) of sites, Lantana (*Lantana camara*) in 61% (27) of sites, Purpletop (*Verbena bonariensis*) in 61% (27) of sites, Cobblers Pegs (*Bidens* sp.) in 57% (25) of sites and Spear Thistle (*Cirsium vulgare*) in 57%, or 23 of the 44 Macleay Ecohealth sites in 2016 (Appendix 2).

Of the twenty-one noxious weed species observed in the Macleay Catchment throughout the sampling period, 1 species was a class one, 3 species were class three, 15 species were class four and 2 species were class five noxious weed species (Appendix 2). Lantana (*Lantana camara*) was the most commonly observed, occurring in 27 of the 44 sites (61%), followed by Fireweed (*Senecio madagascariensis*), 18 sites (41%), Willow (*Salix* sp.) at 14 sites (32%), Blackberry (*Rubus* sp.) at 13 sites (30%), and Small-leaved Privet (*Ligustrum sinense*) and Mexican Poppy (*Argemone mexicana*), both at 12 sites each (27%).

During the 2016 sampling there were weed species encountered that were not listed as being 'noxious' under the two Local Control Authorities (LCA's), Kempsey Shire Council and the New England Tablelands County Council, despite being listed as noxious elsewhere in New South Wales LCA's (New South Wales Department of Primary Industries [NSW DPI] 2016). Many of these weeds are invasive and have the potential to expand in range and out-compete native plant species. At the time of reporting, these species comprised White horehound (*Marrubium vulgare*), Japanese Honeysuckle (*Lonicera japonica*), Common Thornapple (*Datura stramonium*), Crofton Weed (*Ageratina adenophora*), Mistflower (*Ageratina riparia*), Senna (*Senna pendula* var. *glabrata*) and Arsenic Bush (*Senna septemtrionalis*). Additionally, Ox-eye Daisy (*Leucanthemum vulgare*) on the tablelands and Sharp Rush (*Juncus acutus*, also called Spinny Rush) down in the coastal estuaries, are currently not recognized as noxious weed species. However, both exotic species are capable of spreading quickly and outcompeting native grasses and herbaceous species and should be a focus of control and monitoring programs.

3.1.3 Mangrove, seagrass and saltmarsh cover

Estuarine macrophytes are essential components of estuarine ecology. They improve water quality, contribute to the food chain, stabilise morphology by binding sediments, and provide both habitat and a nursery ground for fish and other marine species (West and Williams 2008, Creese et al. 2009). As with most ecological systems, estuarine macrophyte boundaries are dynamic in nature and may fluctuate over time due to environmental variability (Clough 1982; Leadbitter et al. 1999; West and Williams 2008). However, direct pressures on these sytems (natural and anthropogenic) may influence community boundaries and can result in both positive and negative temporal change.

While this assessment found temporal differences in estuarine macrophytes, precision is low due to the broad scale used for mapping (Thomas et al. 1999), and we cannot quantify the uncertainty of methodological differences in the collection and processing of the two GIS datasets underlying our assessment (Creese et al. 2009; NSW Department of Industry and Investment – Primary Industries and Energy 2011; Russell and Walsh, 2015). In order to detect and report on real estuarine macrophyte cover change in Macleay River estuaries, it is recommended that future satellite imagery comparisons are made using methodology consistent to that used to capture and process the 2011 data. Despite these differences in data collection and processing, datasets identified similar estuarine macrophyte cover, thus providing a degree of confidence in temporal trends.

Total estuarine macrophyte cover (i.e. grouped - mangroves, saltmarsh and seagrass) increased in total cover between 1980 and 2011 throughout both the Macleay River (8%) and South West Rocks Creek (55%) estuaries (Table 3.3). This increase in total estuarine macrophyte cover can be attributed to an increase in both total mangrove and total saltmarsh cover over the same period, in both the Macleay River estuary (15% and 7%, respectively) and South West Rocks Creek estuary (49% and 102%, respectively) (Table 3.3). Despite the cover increase observed for both mangroves and saltmarsh, total seagrass cover declined between 1980 and 2011 in both the Macleay River (20%) and South West Rocks Creek (96%) (Table 3.3).

While mangrove and saltmarsh data collected between 1980 and 2011 indicated a potential range expansion/trending increase in cover throughout the Macleay River and South West Rocks Creek estuaries, a comparison of 1956 and 2011 Middleton Zone cover data revealed an overall net mangrove loss in the Macleay River estuaries, of 1.316km^2 (-28%) (Table 3.4). Considerable mangrove losses from the Yarrahapinni (1.996km^2) and Clybucca (0.898km^2) estuaries before 1980 suggest that while total mangrove cover appeared to be increasing throughout the Macleay River in 2011, it is also possible that mangroves may be returning to historic cover levels (Table 3.4). Neither, saltmarsh nor seagrass cover data was collected in the 1956 Middleton dataset and therefore a similar long-term cover observation could not be made for these estuarine macrophytes in the Macleay River for the same 55-year period.

Middleton Zone data were used to examine individual sections of the Macleay River estuary to determine where reductions/expansions in estuarine macrophyte cover were greatest. The largest proportional increases in mangrove cover were observed in the Pelican Island zone (21%), followed by Shark Island (10%) and Stuarts Point (1). Mangrove cover in Yarrahappinni and Clybucca Creek was considerably reduced (-100% and -35% respectively) (Table 3.4). Only one estuary zone, Stuarts

Point, recorded a proportional increase in seagrass cover (3%). Largest reductions in seagrass cover were observed in the Pelican Island estuary (-88%), followed by Clybucca Creek (-59%) and Shark Island (-1%) (Table 3.4).

The significant decrease observed in seagrass cover is concerning. In addition to naturally occurring weather events such as storms, cyclones and floods, anthropogenic factors that can lead to seagrass degradation and decline include global warming and sea-level rise, excessive turbidity, elevated nutrient levels, stormwater discharge, heavy metal and toxin deposition, erosion, increased turbidity and siltation that reduces light intensity, mining and dredging, coastal development, moorings, boat propellers and introduced species (Kirkman 1997, Leadbitter et al. 1999, West and Williams 2008). Management priorities should be focused on long-term monitoring and mapping of seagrass cover change and addressing direct causes of this estuarine macrophyte community decline (West and Williams 2008, Creese et al. 2009). Future investment may include re-establishing seagrass in this estuary once the limiting factors are better understood.

Table 3.3 *Summary of total macrophyte cover differences in the Macleay River and South West Rocks Creek estuaries, and cover differences by estuarine macrophyte for the periods 1956, 1980 and 2011 (mangroves),1980 and 2011 (saltmarsh) and 1980, 2004 and 2011 (seagrass).*

Estuary system	Total macrophyte cover difference 1980 - 2011 (km^2)	Total mangrove cover difference		Total saltmarsh cover difference 1980 - 2011 (km^2)	Total seagrass cover difference	
		1956 - 2011 (km^2)	1980 - 2011 (km^2)		1980 – 2011 (km^2)	2004 – 2011 (km^2)
Macleay River	+ 0.793 (8%)	- 2.335 (28%)	+ 0.764 (15%)	+ 0.25 (7%)	- 0.221 (20%)	- 0.081 (9%)
South West Rocks Creek	+ 0.379 (55%)	-	+ 0.256 (49%)	+ 0.145 (102%)	- 0.023 (96%)	- 0.001 (50%)
Totals	**+ 1.172 (10%)**	**- 2.335 (28%)**	**+ 1.02 (18%)**	**+ 0.395 (9%)**	**- 0.244 (22%)**	**- 0.082 (9%)**

Table 3.4 *Summary of total estuarine macrophyte cover differences for the Middleton Zones between 1956 and 2011 (mangroves) and 2004 and 2011 (seagrass).*

Estuary Zone	Total mangrove cover difference 1956 - 2011 (km^2)	Total seagrass cover difference 2004 - 2011 (km^2)
- Stuarts Point	+ 0.184 km^2 (1%)	+ 0.016 km^2 (3%)
- Shark Island	+ 0.188 km^2 (10%)	- 0.002 km^2 (1%)
- Pelican Island	+ 0.186 km^2 (21%)	- 0.063 km^2 (88%)
- Yarrahapinni	- 1.996 km^2 (100%)	-
- Clybucca Creek	- 0.898 km^2 (35%)	- 0.033 km^2 (59%)
Totals	**- 2.336** km^2 **(28%)**	**- 0.082** km^2 **(9%)**

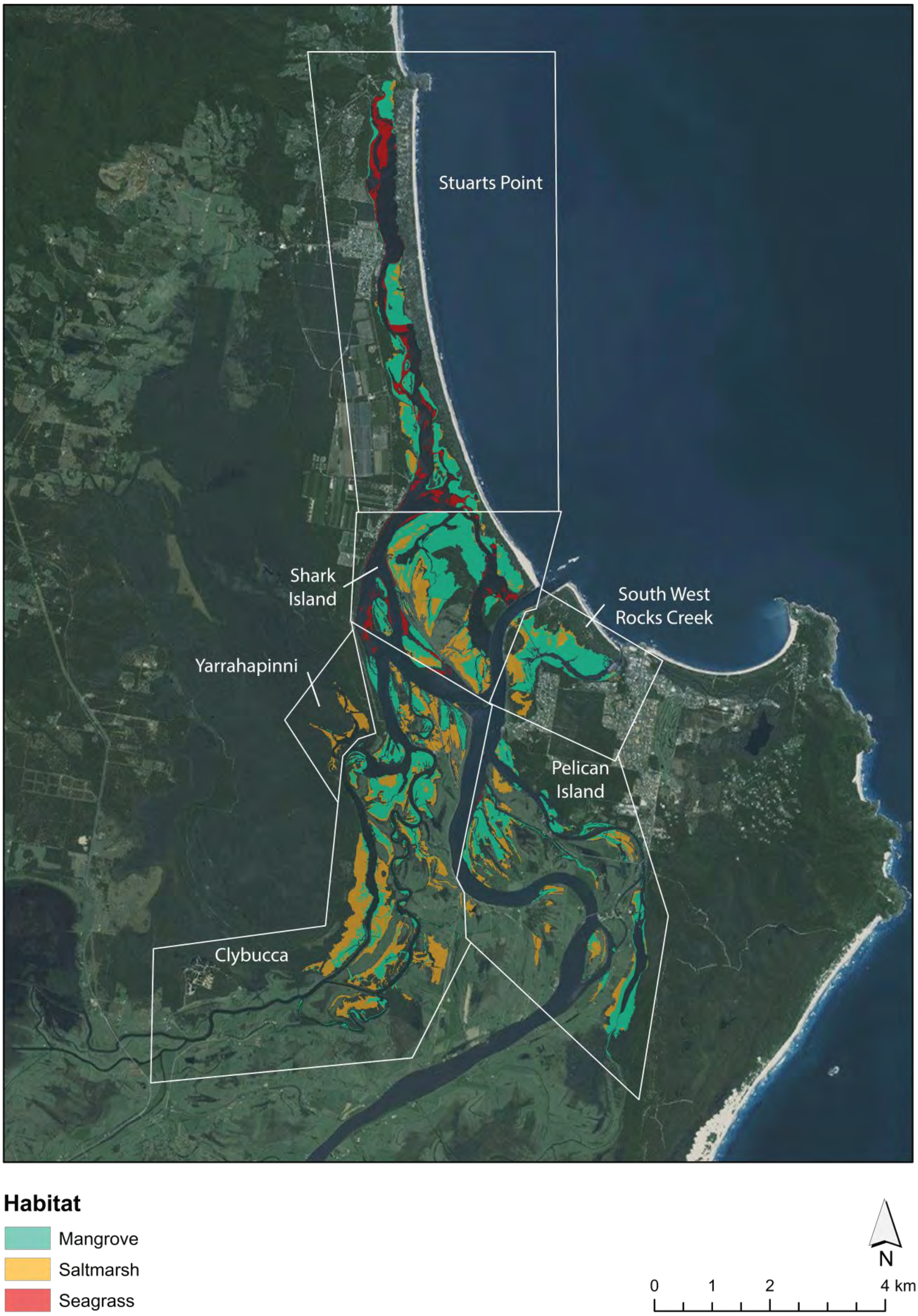


Figure 3.4 *Mangrove, seagrass and saltmarsh habitats in the Macleay River and South West Rocks Creek estuaries (NSW Department of Industry and Investment – Primary Industries and Energy 2011). The estuaries are divided into six zones for more detailed temporal analysis.*

Macleay River Estuarine Macrophytes

In 2011 mangroves were the dominant vegetation community in the Macleay River estuary, covering 5.965km^2, followed by saltmarsh (3.902km^2) and seagrass (0.876km^2) (Table 3.5). Total estuarine macrophyte cover in the Macleay River estuary increased by 8% between 1980 and 2011, as a result of increases in both mangrove and saltmarsh cover (Table 3.5). However, seagrass declined by 20% during this same period, from 1.097km^2 in 1980, to 0.876km^2 in 2011 (Table 3.5).

Table 3.5 *Total area covered by mangrove, seagrass and saltmarsh in Macleay River estuary in 1980, 2004, 2009 and 2011. Total estuary cover and % change for each of the three estuarine macrophytes.*

Vegetation community	Total area in 1980 (km^2)	Total area in 2004 (km^2)	Total area in 2009 (km^2)	Total area in 2011 (km^2)	% Change +/- (km^2)
Mangrove	5.201	5.665	5.710	5.965	**+ 0.764 (15%)**
Saltmarsh	3.652	4.213	4.247	3.902	**+ 0.25 (7%)**
Seagrass	1.097	0.957	0.881	0.876	**- 0.221 (20%)**
Estuary total	9.950	10.835	10.838	10.743	**+ 0.793 (8%)**

Zone-specific changes

Stuarts Point

In 2011, mangroves were the dominant vegetation community in the Stuarts Point estuary zone, covering 1.184km^2, followed by saltmarsh (0.176km^2) and seagrass (0.627km^2) (Table 3.6). Total mangrove cover in the Stuarts Point zone increased by 1% between 1956 and 2011, while total seagrass increased by 3% between 2004 and 2011. No saltmarsh data was collected before 2011 for the Stuarts Point zone.

Table 3.6 *Total area of estuarine macrophytes, mangrove, saltmarsh and seagrass, in the Stuarts Point zone, collected in 1956, 1980, 2004, 2009 and 2011.*

Vegetation community	Total area in 1956 (km^2)	Total area in 1980 (km^2)	Total area in 2004 (km^2)	Total area in 2009 (km^2)	Total area in 2011 (km^2)	% Change +/- (km^2)
Mangrove	1.000	1.000	1.150	-	1.184	**+ 0.184 (1%)**
Saltmarsh	-	-	-	-	0.176	**-**
Seagrass	-	-	0.611	0.599	0.627	**+ 0.016 (3%)**

Shark Island

In 2011, mangroves were the dominant vegetation community in the Shark Island estuary zone, covering 1.988km^2, followed by saltmarsh (0.821km^2) and seagrass (0.217km^2) (Table 3.7). Total mangrove cover in the Shark Island zone increased by 10% between 1956 and 2011, while total seagrass decreased by 1% between 2004 and 2011. No saltmarsh data was collected before 2011 for the Shark Island zone.

Table 3.7 *Total area of estuarine macrophytes, mangrove, saltmarsh and seagrass, in the Shark Island estuary zone, collected in 1956, 1980, 2004, 2009 and 2011.*

Vegetation community	Total area in 1956 (km^2)	Total area in 1980 (km^2)	Total area in 2004 (km^2)	Total area in 2009 (km^2)	Total area in 2011 (km^2)	% Change +/- (km^2)
Mangrove	1.80	1.90	1.92	-	1.988	**+ 0.188 (10%)**
Saltmarsh	-	-	-	-	0.821	**-**
Seagrass	-	-	0.219	0.245	0.217	**- 0.002 (1%)**

Pelican Island

In 2011, mangroves were the dominant vegetation community in the Pelican Island estuary zone, covering 1.086km^2, followed by saltmarsh (0.655km^2) and seagrass (0.009km^2) (Table 3.8). Total mangrove cover in the Pelican Island zone increased by 21% between 1956 and 2011, while total seagrass decreased by 88% between 2004 and 2011. No saltmarsh data was collected before 2011 for the Pelican Island zone.

Table 3.8 *Total area of estuarine macrophytes, mangrove, saltmarsh and seagrass, in the Pelican Island estuary zone, collected in 1956, 1980, 2004, 2009 and 2011.*

Vegetation community	Total area in 1956 (km^2)	Total area in 1980 (km^2)	Total area in 2004 (km^2)	Total area in 2009 (km^2)	Total area in 2011 (km^2)	% Change +/- (km^2)
Mangrove	0.90	0.80	0.99	-	1.086	**+ 0.186 (21%)**
Saltmarsh	-	-	-	-	0.655	**-**
Seagrass	-	-	0.072	0.009	0.009	**- 0.063 (88%)**

Yarrahapinni

In 2011, saltmarsh was the dominant vegetation community in the Yarrahapinni Island estuary zone, covering 0.164km^2, followed by mangrove (0.004km^2) with no seagrass recorded (Table 3.9). Total mangrove cover in the Yarrahapinni Island zone decreased by 100% between 1956 and 2011. No seagrass was recorded in the Yarrahapinni Island zone in 2004 and 2011, while no saltmarsh data was collected before 2011.

Table 3.9 *Total area of estuarine macrophytes, mangrove, saltmarsh and seagrass, in the Yarrahapinni estuary zone, collected in 1956, 1980, 2004, 2009 and 2011.*

Vegetation community	Total area in 1956 (km^2)	Total area in 1980 (km^2)	Total area in 2004 (km^2)	Total area in 2009 (km^2)	Total area in 2011 (km^2)	% Change +/- (km^2)
Mangrove	2.00	0.00	0.00	-	0.004	**- 1.996 (100%)**
Saltmarsh	-	-	-	-	0.164	-
Seagrass	-	-	-	-	-	-

Clybucca Creek

In 2011, saltmarsh was the dominant vegetation community in the Clybucca Creek estuary zone, covering 2.087km^2, followed by mangroves (1.702km^2) and seagrass (0.023km^2) (Table 3.10). Total mangrove cover in the Clybucca Creek zone decreased by 35% between 1956 and 2011, while total seagrass decreased by 59% between 2004 and 2011. No saltmarsh data was collected before 2011 for the Pelican Island zone.

Table 3.10 *Total area of estuarine macrophytes, mangrove, saltmarsh and seagrass, in the Clybucca Creek estuary zone, collected in 1956, 1980, 2004, 2009 and 2011.*

Vegetation community	Total area in 1956 (km^2)	Total area in 1980 (km^2)	Total area in 2004 (km^2)	Total area in 2009 (km^2)	Total area in 2011 (km^2)	% Change +/- (km^2)
Mangrove	2.60	1.60	1.61	-	1.702	**- 0.898 (35%)**
Saltmarsh	-	-	-	-	2.087	-
Seagrass	-	-	0.056	0.028	0.023	**- 0.033 (59%)**

South West Rocks Creek

In 2011, mangroves were the dominant vegetation community in the South West Rocks Creek estuary, covering 0.784km^2, followed by saltmarsh (0.286km^2) and seagrass (0.001km^2) (Table 3.11). Total estuarine macrophyte cover in the South West Rocks Creek estuary increased by 55% between 1980 and 2011 as a result of increases in both mangrove and saltmarsh cover. However, seagrass declined by 96% during this same period, from 0.024km^2 in 1980 to 0.001km^2 in 2011 (Table 3.11).

Table 3.11 *Total area covered by mangrove, seagrass and saltmarsh in South West Rocks Creek in 1980, 2004, 2009 and 2011. Total estuary cover and % change for each of the three estuarine macrophytes.*

Vegetation community	Total area in 1980 (km^2)	Total area in 2004 (km^2)	Total area in 2009 (km^2)	Total area in 2011 (km^2)	% Change +/- (km^2)
Mangrove	0.528	0.693	0.648	0.784	**+ 0.256 (49%)**
Saltmarsh	0.141	0.147	0.112	0.286	**+ 0.145 (102%)**
Seagrass	0.024	0.002	0.002	0.001	**- 0.023 (96%)**
Estuary total	0.693	0.860	0.762	1.072	**+ 0.379 (55%)**

3.1.4 Water quality

Water quality was poor across the Macleay catchment, with an overall grade of D+ (Table 3.12). There were several spatial and temporal patterns that were evident across the Macleay catchment. Water quality was consistently poorest in the Tablelands sites with the majority of sites recording scores less than 50, driven by low dissolved oxygen, elevated pH and exceptionally high nutrient concentrations. In particular, total nitrogen and total phosphorus concentrations in the Tia River exceeded the ANZECC nutrient trigger value by nine and six times respectively during the study. Dissolved nutrient concentrations had fewer exceedences, and may help explain why the elevated nutrients generally did not result in high chlorophyll *a* concentrations or evidence of algal blooms. Peak algal productivity in the catchment was generally correlated with peak phosphorus concentrations suggesting the management of phosphorus should be a priority for maintaining water quality.

Freshwater reaches of the Main Stem of the Macleay consistently had the best water quality throughout the study recording a score of 72 (C+) with the best water quality recorded at MACR7 (Turners Flat) (76, B-). Nonetheless, many freshwater sites on the Macleay River consistently exceeded the ANZECC nutrient trigger values for lowland freshwater systems, especially for total nitrogen, and to a lesser degree total phosphorus. The estuarine reaches of the main stem received a score of 52 (D-) with the best water quality recorded at MACR6 (the tidal limit downstream of Bellgrave Falls; 64, C-). This contrasts with all other rivers in the North Coast that have been assessed through the Ecohealth program, where the tidal limit consistently records the poorest water quality as sites where freshwater and estuarine water quality issues converge.

The Freshwater tributaries mimicked trends in Tablelands sites of low dissolved oxygen and high nutrient concentrations, particularly nitrogen. The Estuary tributaries in contrast had dissolved oxygen concentrations consistently within trigger values, but mirrored the trend evident throughout the catchment of very persistent and high nutrient concentrations. Yet algal biomass as measured by chlorophyll *a* rarely exceeded ANZECC trigger values suggesting these trigger values require refining for this region to better predict ecosystem change associated with elevated nutrients.

Concentrations of dissolved nutrients were substantially lower in the Main Stem of the Macleay River than the Tableland or Freshwater tributaries, despite the significant tributary inputs. It is likely that the extensive beds of aquatic macrophytes throughout the Macleay Main Stem play an important ecological role as nutrient sinks regulating water quality.

Water quality monitoring by KSC from 5 January 2015 to 22 March 2016 found similar patterns (Appendix 3). Low dissolved oxygen concentrations were observed at most sites, and generally on more than one occasion. Hypoxic events (where dissolved oxygen is less than 2mg/L and poses a significant risk to aquatic biota) were observed at end-of-system sites on Five Day Creek, Parrabel Creek, Dungay Creek and Euroka Creek, and at the Five Day bridge, Smithtown, Back Creek, Jerseyville and Rainbow Reach on the Macleay main stem, as well as the Clybucca Floodgates (Appendix 3).

Similar to Ecohealth monitoring, KSC water quality monitoring found pH to be consistently alkaline across most sites. However, Clybucca Floodgates recorded a site minimum of 5.47 and Nulla Nulla Creek recorded a site minimum of 3.94. The site minimum pH at Clybucca was observed during the latter stages of a fresh, but the site minimum at Nulla Nulla Creek was observed during very low flows as the creek approached a cease-to-flow event. pH did not remain acidic at the following sampling occasion at either site.

Table 3.12 *Subcatchment grades for water quality assessed in 2015-16.*

System	Water Quality Score	Water Quality Grade
Macleay Catchment Overall	58	D+
Tableland Tributaries	57	F
Gara River	34	F
Commissioners Waters	19	F
Salisbury Waters	44	F
Apsley River	37	F
Tia River	48	D-
Yarrowitch River	44	F
Bakers Creek	59	D+
Wollomombi River	35	F
Chandler River	35	F
Oaky River	59	D+
Styx River	54	D
Macleay Main Stem	57	D+
Freshwater Macleay	64	C-
Macleay estuary	52	D
Freshwater Tributaries	67	C-
Georges Creek	43	F
Five Day Creek	66	C
Nulla Nulla Creek	80	B-
Warbro Book	44	F
Toorumbee Creek	64	C-
Hickeys Creek	57	D+
Mungay Creek	52	D
Dungay Creek	72	C+
Collombatti Creek	48	D-
Estuarine Tributaries	56	D-
Belmore River	29	F
Kinchela Creek	45	F
Spencers Creek	57	D+
Clybucca Creek	69	C-
North Arm Macleay River	45	D-

3.1.5 Aquatic macroinvertebrates

The Macleay catchment contained the greatest richness and abundance of aquatic macroinvertebrates observed in the Northern Rivers bioregion. In particular, Styx River contained 51 families and upper Five Day Creek contained 49 families across both sampling times. The greatest abundance of macroinvertebrates was observed in Five Day Creek in autumn, with 2059 invertebrates collected within a 10 linear meter sample. Abundance and diversity of EPTs (Mayflies, Stoneflies and Caddisflies) were also high, with a maximum of 22 EPT families and 1363 EPT individuals collected in Five Day Creek in autumn. In comparison, the Hastings-Camden Haven catchment had a maximum site richness of 32 families and a maximum site abundance of 406 individuals in 2015, and the Coffs coastal catchments had a maximum site richness of 35 and a maximum site abundance of 610 individuals in 2015. Thus, the Macleay catchment is a regional hotspot for aquatic macroinvertebrate richness and abundance.

The highly diverse and abundant macroinvertebrate communities in remnant high quality reference sites resulted in the expected values in many upland sites to also be high. This potential for highly diverse macroinvertebrate sites to occur within the Macleay led to lower site scores and grades throughout much of the catchment when compared with the highest potential scores. Therefore, from a management perspective, sites assessed as having moderate aquatic macroinvertebrate condition generally contain an abundant and diverse macroinvertebrate community, but still reduced from the maximum potential. Furthermore, the high richness and abundance of aquatic macroinvertebrates in the reference sites means that these populations of macroinvertebrates indicative of good water quality will be able to colonise sites elsewhere in the catchment when good water quality and the availability of appropriate habitats co-occur.

Overall, the Macleay catchment scored 55, a D+, for aquatic macroinvertebrate communities (Table 3.13). Upland freshwater tributaries contained the best aquatic macroinvertebrate health, particularly Georges Creek, Five Day Creek, and to a lesser degree, Toorumbee Creek (Table 3.13). While Georges Creek and Five Day Creek scored highly for family richness, EPTs and SIGNAL2, Toorumbee Creek scored highly for total abundance. Aquatic macroinvertebrate condition in the Macleay main stem is similar to the catchment average (Table 3.13). There were clear longitudinal trends in Five Day Creek and the freshwater Macleay, where macroinvertebrate condition declined with distance downstream, likely due to the accumulative impacts of riparian and catchment clearing and stock access to the channel. In contrast, the upper reaches of Toorumbee Creek sustained poorer macroinvertebrate communities than the mid or lower reaches of Toorumbee Creek. Again, this is likely due to riparian and catchment clearing and stock access, which is greatest immediately upstream and adjacent to TOOC3.

The Tableland tributaries had the poorest aquatic macroinvertebrate condition in the Macleay catchment (the exception is the Styx River; Table 3.13) and contributed disproportionally to lower the overall catchment score. Six of the 13 sites had very poor macroinvertebrate condition (a grade of F). These sites typically had very little riparian vegetation, extensively cleared subcatchments, were actively grazed with direct stock access to the channel, had channels of fine-grained sediments with minimal geomorphic complexity (and thus, low habitat availability), and experienced very poor water quality. Collombatti Creek scored the lowest for aquatic macroinvertebrate condition with very low scores for all indicators (Table 3.13).

Table 3.13 *Summary of aquatic macroinvertebrate indicator scores and the overall macroinvertebrate grade for freshwater sites for 2015. Each indicator has a maximum score of 25.*

Site	Family Richness	Total Abundance	EPT	SIGNAL2	Macroinvertebrate Score	Macroinvertebrate Grade
Catchment Mean	**11**	**16**	**12**	**16**	**55**	**D+**
Tablelands Mean	***9***	***13***	***9***	***9***	***41***	***F***
GARR3	12	11	4	8	35	F
GARR2	7	14	7	8	37	F
GARR1	9	12	9	16	46	D-
COMW1	11	9	6	4	31	F
SALW1	2	10	6	2	21	F
APSR1	9	15	9	12	44	F
TIAR1	9	10	5	2	26	F
YARR1	11	22	15	14	63	C-
BAKC1	15	20	16	19	69	C
WOLR1	8	13	13	19	53	D
CHAR1	11	18	10	9	48	D-
OAKR1	12	17	12	16	56	D+
STYR1	25	12	19	18	74	C+
Main Stem Mean	***12***	***15***	***12***	***17***	***56***	***D+***
MACR10	13	17	17	20	66	C
MACR9	15	17	12	17	60	C-
MACR8	10	12	13	22	57	D+
MACR7	10	14	8	9	41	F
FW Tribs Mean	***12***	***17***	***15***	***19***	***63***	***C-***
GEOC1	23	18	24	24	89	B+
FIVC3	24	25	24	23	97	A
FIVC2	21	17	20	24	82	B
FIVC1	14	19	17	22	72	C+
NULC1	10	16	9	19	54	D
WARB1	16	21	11	16	64	C-
TOOC3	11	20	18	21	70	C
TOOC2	11	22	18	22	73	C+
TOOC1	16	17	18	20	71	C+
HICC1	6	17	10	13	46	D-
MUNC1	6	6	3	10	25	F
DUNC3	13	13	16	24	67	C+
DUNC2	11	10	18	25	64	C-
DUNC1	5	11	11	20	47	D-
COLC1	3	7	2	3	15	F

3.1.6 Freshwater fish

Freshwater fish communities were sampled across 27 sites in the Macleay catchment between 16th December 2014 and 18th February 2015 by Fisheries NSW. In total, 24 species of fish (18 native species) across 27,119 indivdiuals were caught using combinations of electrofishing, seine netting and bait trapping. The long-finned eel (*Anguilla reinhardtii*) was the most abundant large firsh by abundance and biomass. The exotic eastern mosquito fish (*Gambusia holbrooki*) was the most abundant small fish.

Community condition was assessed using three indicators: Expectedness, Nativeness and Recruitment. The Expectedness Indicator assesses the presence of native species 'expected' in the habitats sampled, and was typically Excellent, with only four sites having a Moderate grade and one site on Oaky River having a Poor grade. The Nativeness Indicator was generally high across the catchment, with 15, 8 and 3 sites receiving grades of Excellent, Moderate and Poor, respectively. Typically, the upper reaches of the Macleay received lower Expectedness and Nativeness grades. The Recruitment Indicator generally scored lower than Expectedness or Nativeness, especially in the Upland and Highland zones where it was assessed as being Very Poor.

Freshwater fish communities were in good condition (a grade of B-) (Butler et al. 2016). Fish communities in Five Day Creek and Nulla Nulla Creek were in excellent condition (A-), with communities in very good condition in Dungay Creek, Toorumbee Creek and the lower freshwater Macleay River (Figure 3.5). The upper freshwater Macleay and Chandler River sustained good fish communities. The Gara River had the lowest fish condition in the Macleay catchment, with a score of 47, a grade of D-. This study was the first comprehensive survey of freswahter fish in the Macleay catchment and the report is available at www.kempsey.nsw.gov.au/environment/river-management/freshwater-fish-survey-macleay-basin.html.

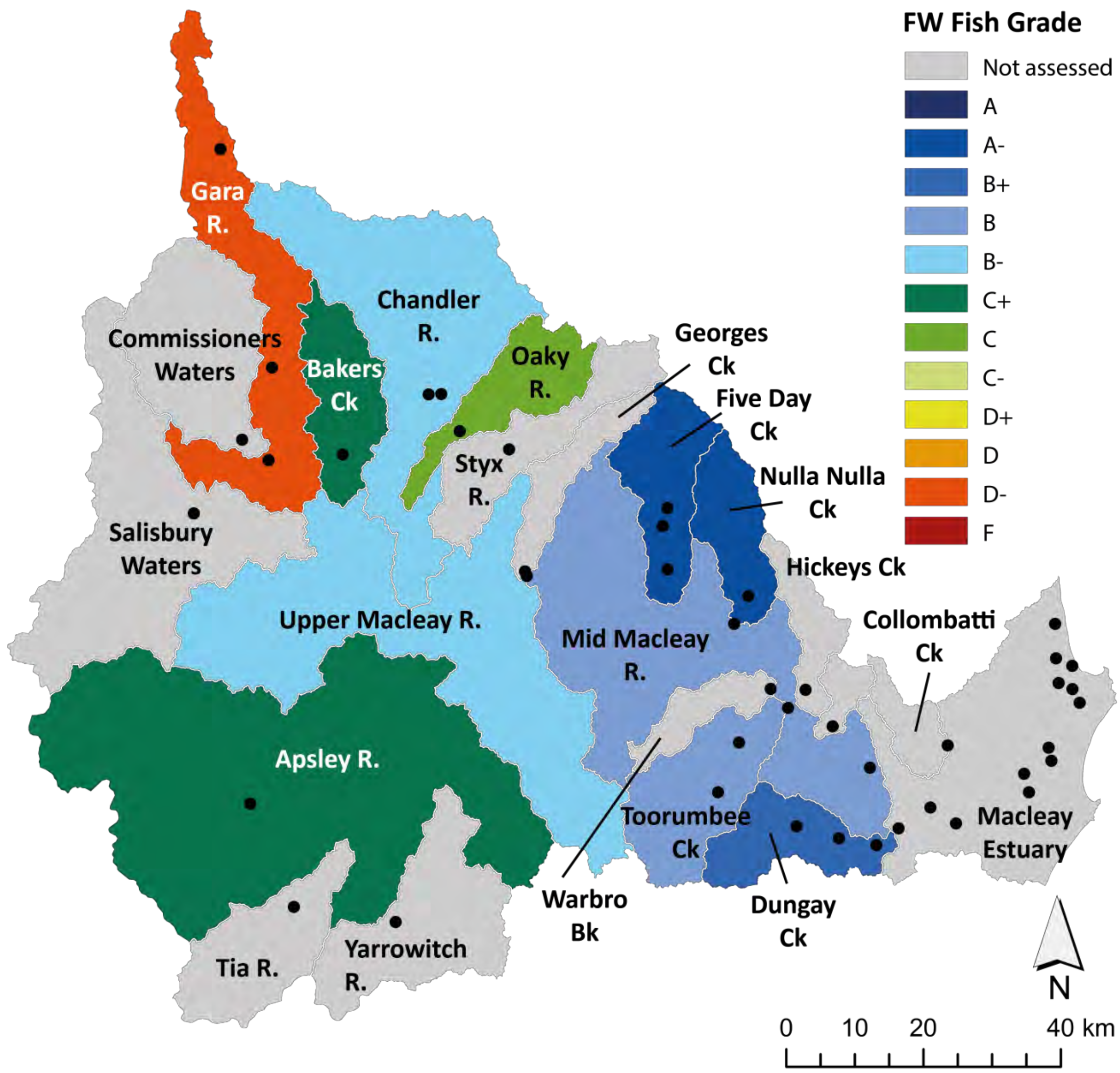


Figure 3.5 *Subcatchment Ecohealth grades for freshwater fish communities. Fish communities were not assessed in estuarine reaches. Data from NSW DPI Fisheries.*

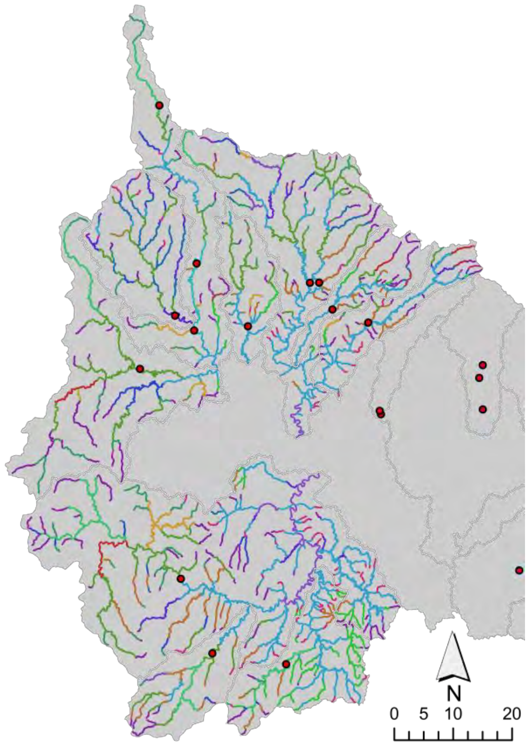
3.2 Tableland tributaries

3.2.1 Catchment description

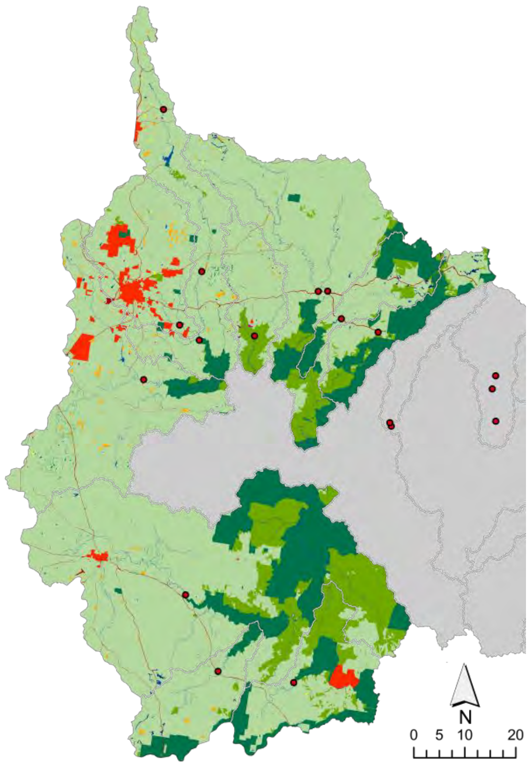
The tableland tributaries of the Macleay River comprise 6,515km^2 or 57% of the Macleay catchment (Figure 3.6). These tributaries include the Gara River (Table 3.14), Commissioners Waters (Table 3.15), Salisbury Waters (Table 3.16), Apsley River (Table 3.17), Tia River (Table 3.18), Yarrowitch River (Table 3.19), Bakers Creek (Table 3.20), Wollomombi and Chandler Rivers (Table 3.21), Oaky River (Table 3.22), and the Styx River (Table 3.23).

The dominant land use in all these subcatchments is grazing. Conservation areas are concentrated in the gorge country. Commissioners Waters has two point-source dischargers: The Armidale water treatment plant (WTP) and the Monckton (Armidale) aquatic centre, both of which have licences to discharge into the stream at any time. The Apsley River also has two point-source dischargers: the Walcha WTP and the Walcha sewerage treatment plant (STP). The Styx River as one point-source discharger: the Dutton Trout Hatchery.

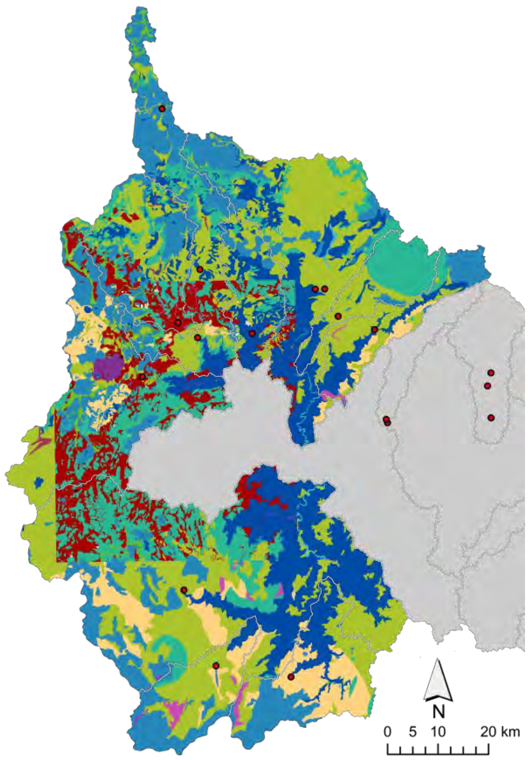
(a) Location of Ecohealth sites



(b) River Styles: refer to Figure 2.8 for key



(c) Landuse: refer to Figure 2.7 for key



(d) Soils: refer to Figure 2.3 for key

Figure 3.6 *The tableland tributaries of the Macleay River showing (a) locations of Ecohealth sites, (b) River Styles, (c) landuse, and (d) soils. Data layers from NC LLS (River Styles) and OEH (landuse and soils).*

Table 3.14 *Subcatchment description of the Gara River. Data from NC LLS and OEH.*

Variable	Subcatchment composition
Area	611.3km^2
Geology	39.5% igneous mafic volcanic, igneous fold-bearing volcanic; 21.8% feldspar- or lithic-rich arenite to rudite metasedimentary siliciclastic; 17.2% igneous felsic intrusive; 13.8% metasedimentary siliciclastic
Soils	37.8% Ferrosols; 22.1% Kurosols; 15.5% Kandosols; 9.4% Rudosols and Tenosols; 9.1% Natric Kurosols
River Styles	23% CVS – Gorge; 14.3% PCVS - Planform controlled, low sinuosity, gravel; 14.2% LUV CC - Channelised fill; 10.1% SMG - Valley fill, fine grained; 8.8% PCVS - Planform controlled, meandering, fine grained; 7.8% PCVS - Bedrock controlled, fine grained; 5.7% CVS - Floodplain pockets, sand
Landuse	90.1% Grazing; 4.1% National Park
Major point source discharge	Nil
Tree Cover	4.4%

Table 3.15 *Subcatchment description of Commissioners Waters. Data from NC LLS and OEH.*

Variable	Subcatchment composition
Area	476.4km^2
Geology	49.6% metasedimentary siliciclastic; 18.5% igneous mafic volcanic, igneous foid-bearing volcanic; 15.0% igneous felsic intrusive; 6.1% sedimentary siliciclastic
Soils	27.1%; Kurosols; 22.7% Kandosols; 21.1% Ferrosols; 16.0% Natric Kurosols; 8.7% Rudosols and Tenosols
River Styles	31.2% SMG - Cut and fill; 28.8% PCVS - Bedrock controlled, fine grained; 20.9% CVS - Floodplain pockets, gravel
Landuse	80.6% Grazing; 8.7% Public services; 4.1% Rural Residential; 1% National Park
Major point source discharge	Armidale Water Treatment Plant and Monckton Aquatic Centre (Armidale) – miscellaneous license to discharge to waters at any time
Tree Cover	1.6%

Table 3.16 *Subcatchment description of Salisbury Waters. Data from NC LLS and OEH.*

Variable	Subcatchment composition
Area	891.8km^2
Geology	55.4% metasedimentary siliciclastic; 15.1% igneous felsic intrusive; 13.9% igneous mafic volcanic, igneous foid-bearing volcanic; 7.3% feldspar- or lithic-rich arenite to rudite metasedimentary siliciclastic
Soils	22% Ferrosols; 21% Natric Kurosols; 20% Kandosols; 16% Kurosols; 9% Dermosols; 5% Rudosols and Tenosols; 4% Vertosols; 3% Rodosols
River Styles	31.2% PCVS - Bedrock controlled, fine grained; 22.6% SMG - Valley fill, fine grained; 12.4% LUV CC - Channelised fill; 8.9% PCVS - Planform controlled, low sinuosity, fine grained; 8.9% PCVS - Planform controlled, meandering, fine grained; 5.8% CVS - Gorge
Landuse	90.1% Grazing; 3.3% National Park; 1.7% Research Facility
Major point source discharge	Nil
Tree Cover	4.3%

Table 3.17 *Subcatchment description of the Apsley River. Data from NC LLS and OEH.*

Variable	Subcatchment composition
Area	1991.2km^2
Geology	13.7% feldspar- or lithic-rich arenite to rudite; 18.9% feldspar- or lithic-rich arenite to rudite metasedimentary siliciclastic; 10.8% igneous mafic; 34.2% metasedimentary siliciclastic; 18.4% sedimentary siliciclastic.
Soils	28.8 % Kurosols; 25.4% Rudosols and Tenosols; 17.5% Kandosols; 8.8% Natric Kurosols
River Styles	29.2% CVS Gorge; 12.1 SMG Valley fill, fine grains; 10.7% PCVS Bedrock controlled, fine grained; 7.1% PCVS Bedrock controlled, gravel; 5.7% PCVS Planform controlled, meandering, fine grained; 5.6% LUV CC Channelised fill
Landuse	62.3 % Grazing modified pastures; 19.5% Nature conservation; 0.7% River/Wetland
Major point source discharge	Walcha Water Treatment Plant – miscellaneous license to discharge to waters at any time; Walcha Small STP
Tree Cover	19.8%

Table 3.18 *Subcatchment description of the Tia River. Data from NC LLS and OEH.*

Variable	Subcatchment composition
Area	1991.2km^2
Geology	34.5% igneous mafic volcanic; 26.7% feldspar- or lithic-rich arenite to rudite; 17.4% metasedimentary siliciclastic; 12.8% sedimentary siliciclastic, metasedimentary siliciclastic
Soils	43.3% Kurosols; 33.8% Ferrosols; 10.8 % Dermosols
River Styles	26.6% PCVS - Bedrock controlled, fine grained; 18.4% PCVS - Planform controlled, meandering, fine grained; 18.1% CVS - Gorge; 17.9% CVS - Floodplain pockets, fine grained; 10.7% SMG - Valley fill, fine grained
Landuse	62.3 % Grazing; 19.5% National park; 16.3% Residual native cover; 1.3% River/Wetland
Major point source discharge	Nil
Tree Cover	19.7%

Table 3.19 *Subcatchment description of the Yarrowitch River. Data from NC LLS and OEH.*

Variable	Subcatchment composition
Area	457.9km^2
Geology	44.4% sedimentary siliciclastic; 23.1% metasedimentary siliciclastic, sedimentary non-carbonate chemical or biochemical; 22.2% igneous mafic volcanic; 8.7% feldspar- or lithic-rich arenite to rudite
Soils	33.8% Dermosols; 23.5% Ferrosols;20.5% Kurosols;18.8% Rudosols and Tenosols
River Styles	40.0% CVS – Gorge; 29.6% CVS - Floodplain pockets, sand; 9.8% PCVS - Planform controlled, meandering, fine grained; 8.2% CVS - Floodplain pockets, fine grained
Landuse	48.3% Grazing; 19.3% Residual native cover; 14.4% Forestry; 13.0% National Park
Major point source discharge	Nil
Tree Cover	27.3%

Table 3.20 *Subcatchment description of Bakers Creek. Data from NC LLS and OEH.*

Variable	Subcatchment composition
Area	264.0km^2
Geology	58.7% feldspar- or lithic-rich arenite to rudite, metasedimentary siliciclastic; 23.4% igneous felsic intrusive; 9.9% igneous mafic volcanic, igneous foid-bearing volcanic; 5.0% igneous intermediate intrusive
Soils	37.7% Rudosols and Tenosols; 29.9% Kurosols; 13.3% Kandosols; 11.5% Ferrosols; 6.6% Natric Kurosols
River Styles	37.9% PCVS - Bedrock controlled, fine grained; 35.9% CVS – Gorge; 8.0% CVS - Floodplain pockets, sand
Landuse	80.7% Grazing; 16.5% Residual native cover
Major point source discharge	Nil
Tree Cover	0.05%

Table 3.21 *Subcatchment description of the Chandler River (includes the Wollomombi River). Data from NC LLS and OEH.*

Variable	Subcatchment composition
Area	946.2km^2
Geology	35.8% feldspar- or lithic-rich arenite to rudite, metasedimentary siliciclastic; 20.8% igneous felsic intrusive; 15.6% metasedimentary siliciclastic; 14.3% igneous mafic volcanic, igneous foid-bearing volcanic; 12.7% sedimentary siliciclastic, metasedimentary siliciclastic
Soils	43.6% Kurosols; 6.9% Rudosols and Tenosols; 14.2% Ferrosols; 11.3% Kandosols
River Styles	34.0% CVS – Gorge; 24.9% PCVS - Bedrock controlled, fine grained; 7.7% CVS - Floodplain pockets, fine grained; 7.3% PCVS - Bedrock controlled, gravel; 5.8% SMG - Valley fill, fine grained
Landuse	80.5% Grazing; 9.3% Residual native cover; 7.0% National Park; 1.6% Forestry
Major point source discharge	Nil
Tree Cover	8.7%

Table 3.22 *Subcatchment description of the Oaky River. Data from NC LLS and OEH.*

Variable	Subcatchment composition
Area	248.9km^2
Geology	56.1% igneous felsic intrusive; 29.7% sedimentary siliciclastic, metasedimentary siliciclastic; 11.6% metasedimentary siliciclastic
Soils	51.8% Kandosols; 33.4% Kurosols; 10.5% Rudosols and Tenosols
River Styles	37.8% CVS – Gorge; 20.1% SMG - Valley fill, fine grained; 11.8% CVS - Floodplain pockets, fine grained; 8.0% PCVS - Bedrock controlled, fine grained; 7.2% CVS - Floodplain pockets, sand
Landuse	48.9% Grazing; 30.0% National Park; 10.3% Residual native cover; 8.3% Forestry
Major point source discharge	Nil
Tree Cover	38.3%

Table 3.23 *Subcatchment description of the Styx River. Data from NC LLS and OEH.*

Variable	Subcatchment composition
Area	294.9km^2
Geology	54.6% metasedimentary siliciclastic; 19.9% igneous mafic volcanic, igneous foid-bearing volcanic; 19.3% sedimentary siliciclastic, metasedimentary siliciclastic; 6.1% igneous felsic intrusive
Soils	37.5% Kurosols; 24.1% Rudosols and Tenosols; 18.8% Ferrosols; 11.9% Dermosols; 5.9% Kandosols
River Styles	50.3% CVS – Gorge; 11.2% CVS - Floodplain pockets, fine grained; 6.6% CVS – Headwater; 4.4% LUV CC - Meandering, fine grained
Landuse	38.7% Grazing; 38.3% Residual native cover; 33.5% Forestry; 12.8% National Park;
Major point source discharge	Dutton Trout Hatchery – aquaculture and mariculture.
Tree Cover	46.4%

3.2.2 Site descriptions

There were thirteen sites located on the Tablelands (Figure 3.6). Three sites were on the Gara River: GARR1 (Plate 3.1) is a planform controlled, low sinuosity gravel-bed river in a partially confined valley setting 1.7km downstream of the confluence of the Gara River and Commissioners Waters. GARR2 (Plate 3.2) is a planform controlled, low sinuosity gravel-bed river in a partially confined valley setting 20.5km upstream of GARR1. GARR3 (Plate 3.3) is a planform controlled, meandering, fine grained channel in a partially confined valley setting 10.6km upstream of Malpus Dam and 53km upstream of GARR2.

There were 10 sites located at or close to end-of-system tributaries of the Macleay River. COMW1 on Commissioners Waters (Plate 3.4) is a gravel-bed river in a confined valley setting with discontinuous floodplain pockets. The site is 420m upstream of the confluence of Commissioners Waters and the Gara River. SALW1 on Salisbury Waters (Plate 3.5) is a bedrock controlled, fine grained channel in a partially confined valley setting. The site is 8km upstream of where Salisbury Waters enters the Macleay gorges. APSR1 on the Apsley River (Plate 3.6) is a bedrock controlled, fine grained channel in a partially confined valley setting. The site is 2.4km upstream of the first waterfall at the entrance to the Apsley gorge. TIAR1 on the Tia River (Plate 3.7) is a bedrock controlled, fine grained channel in a partially confined valley setting. The site is 7.4km upstream of the first waterfall at the entrance to the Tia gorge. YARR1 on the Yarrowitch River (Plate 3.8) is a planform controlled, meandering, fine grained channel in a partially confined valley setting. The site is 1.2km upstream of the entrance to the Yarrowitch gorge.

BAKC1 (Plate 3.9) is in the Bakers Creek gorge (confined valley setting) 14km upstream of its confluence with the Macleay River. WOLR1 is in the Wollomombi River gorge (Plate 3.10) located 3.6km upstream of its confluence with the Chandler River. CHAR1 is in the Chandler River gorge (Plate 3.11) located 5.6km upstream of its confluence with the Wollomombi River. OAKR1 is in the Oaky River gorge (Plate 3.12) located 2.2km upstream of the Oaky Dam and 20km upstream of its confluence with the Chandler River. STYR1 is in the Styx River gorge (Plate 3.13) located 26.5km upstream of its confluence with the Chandler River.

Plate 3.1 *Site GARR1 on the Gara River northeast of Guyra (looking downstream).*

Plate 3.2 *Site GARR2 on the Gara River east of Armidale (looking downstream).*

Plate 3.3 *Site GARR3 on the Gara River at the start of the Gara Gorge (looking downstream).*

Plate 3.4 *Site COMW1 on Commissioners Waters (looking upstream).*

Plate 3.5 *Site SALW1 on Salisbury Waters (looking upstream).*

Plate 3.6 *Site APSR1 on the Apsley River (looking upstream 2.4km upstream of the Apsley Gorge).*

Plate 3.7 *Site TIAR1 on the Tia River upstream of the Oxley Highway bridge (looking upstream).*

Plate 3.8 *Site YARR1 on the Yarrowitch River upstream of the Gorge (looking upstream).*

Plate 3.9 *Site BAKC1 on Bakers Creek downstream of Hillgrove Mine (looking downstream).*

Plate 3.10 *Site WOLR1 on the Wollomombi River downstream of the Waterfall Way bridge (looking downstream).*

Plate 3.11 *Site CHAR1 on the Chandler River (looking upstream at the Waterfall Way bridge).*

Plate 3.12 *Site OAK1 on the Oaky River (looking downstream at the bridge on the Armidale-Kempsey Road).*

Plate 3.13 *Site STYR1 on the Styx River at Jeogla (looking downstream).*

3.2.3 Gara River (GARR3, GARR2 and GARR1)

3.2.3.1 Geomorphic condition

The geomorphic River Style at Gara River #3 (GARR3) is partially confined valley setting: planform controlled, meandering, fine grained. The bed sediments comprised very angular cobbles in a matrix filled contact framework containing 5-32% fine sediments. Banks comprised fine grained sediments with significant bank erosion (10-20m) concentrated as undercutting along the right bank at the downstream end of the site. Geomorphic complexity was minimal and consisted of a pool, run and riffle (30, 40 and 30% of reach length, respectively). GARR3 scored 49, a D- for BANK CONDITION and 68, a C, for BED CONDITION. The overall geomorphic condition for GARR3 was 59, a grade of D+.

The geomorphic River Style at Gara River #2 (GARR2) is partially confined valley setting: planform controlled, low sinuosity, gravel. The bed sediments comprised angular cobbles and gravel in a matrix filled contact framework containing 5-32% fine sediments. Banks comprised fine grained sediments with severe erosion (20-100m combined length of undercutting) on the left bank and minimal erosion (<5m combined length of undercutting) on the right bank. There was moderate slumping (5-10m combined length) of the left bank but significant slumping (10-20m combined length) of the right bank. GARR2 scored 49, a D- for BANK CONDITION and 68, a C, for BED CONDITION. The overall geomorphic condition for GARR2 was 59, a grade of D+.

The geomorphic River Style at Gara River #1 (GARR1) is partially confined valley setting: planform controlled, low sinuosity, gravel. Bed sediment was dominated by sub-angular cobbles with significant boulders in an open framework containing minimal fine sediment (<5%) and significant interstitial voids. Banks consisted of gravel with significant boulders and bedrock. Bank erosion was minimal and consisted of bank slumping (<5m combined length) associated with human trails. GARR1 scored 82, a B for BANK CONDITION and 85, a B, for BED CONDITION. The overall geomorphic condition for GARR1 was 83, a grade of B.

In summary, GARR3 and GARR2 were assessed as being in poor geomorphic condition, with bank erosion the most significant issue for site-level geomorphic condition. GARR1 was assessed as being in good geomorphic condition. Localised bank erosion is the most significant issue for site-level geomorphic condition at GARR1.

The desktop GIS assessment of subcatchment geomorphic condition found the Gara River subcatchment to be in fair condition with a grade of C-. The geomorphic condition at GARR3 and GARR2 were below the subcatchment average and GARR1 was above the subcatchment average.

3.2.3.2 Riparian condition

GARR3

High historic disturbance at GARR3 (Plate 3.14) has resulted in a highly modified riparian zone that predominantly comprises exotic species. However, the original riparian vegetation community at GARR3 could have been described as 'New England Riparian Shrubland', Community 23 (Benson & Ashby, 2000), or 'Tea-tree shrubland of drainage areas of the slopes and tablelands', plant community type ID 1270 (VIS, 2012), broadly classed as 'Eastern Riverine Forests', (Keith, 2004). However, very little original riparian vegetation remains and GARR3 received a very poor riparian condition score of 25, a grade of F (Table 3.24).

There were no canopy or midstory species present at GARR3. The understory was dominated by Clover (*Trifolium spp.*), Plantain (*Plantago lanceolata*), Ox-eye Daisy (*Leucanthemum vulgare*), Common Rush (*Juncus usitatus*), Golden Everlasting (*Xerochrysum bracteatum*), and the grasses Tall Fescue (*Festuca arundinaceae*), Prairie Grass (*Bromus catharticus*), and Tussock Grass (*Poa labilliardierrei*). The only vine species present was Blackberry (*Rubus* sp.), while the macrophyte layer included River Club Rush (*Schoenoplectus validus*), Pin Rush (*Eleocharis acuta*), and submerged species such as Water Ribbons (*Triglochin* sp.), Curly Pondweed (*Potamogeton crispus*), and Varried Water-milfoil (*Myriophyllum variifolium*).

Noxious weed species observed were Blackberry (*Rubus* sp.) (class 4). In addition to those above, other weedy species present included Common Bittercress (*Cardamine hirsuta*), Spear Thistle (*Cirsium vulgare*), White Horehound (*Marrubium vulgare*) and Vetch (*Vicia sp*.).

Summary: GARR3 was an extremely disturbed system in a cleared landscape of mixed native and exotic understory species. The surrounding rural landuse was predominantly agricultural grazing land. Two significant remnant stands of vegetation lay 3.2kms to the north and 5.4kms to the northeast. GARR3 scored poorly in all subindicors (Table 3.24), with representative elements of the remnant vegetation community present in only the understory and macrophyte structural layers. Riparian condition at GARR3 was affected by devoid riparian vegetation and vegetation continuity, poor habitat connectivity, the presence of weed and noxious weed species, a lack of woody debris and inadequate riparian fencing.

Management Recommendations: Riparian condition could be improved through the control/removal of invasive weed species followed by native riparian plantings to assist in site regeneration of native species. Riparian fencing should exclude livestock and, if strategically implemented, could be used in combination with native plantings to increase riparian vegetation width and continuity. Lastly, the introduction of large woody debris back into this system using best practice techniques could stabilise river banks in the long term, promote niche habitats for native woody regeneration, provide habitat for native animal species, and as instream snags, can redirect or reduce water energy from banks, reducing bank erosion.

Plate 3.14 *Riparian vegetation at GARR3 was extremely disturbed. Riparian condition would be improved by removing weed and noxious weed species such as Blackberry* (Rubus sp.)*, undertaking native plantings, introducing woody debris and fencing off the riparian zone.*

Table 3.24 *Site-level summary of Riparian condition of Gara River #3 showing the scores of individual indicators and the five subindices that comprise the Vegetation Condition Index.*

GARR3	Scores
HABITAT	**1/20**
Channel width	0
Proximity	0
Continuity	0
Layers	1
Large native trees	0
Hollow-bearing trees	0
NATIVE SPECIES	**6/20**
Native canopy species	0
Native midstory species	0
Native herb/forb species	1
Native graminoid species	1
Native macrophyte species	4
SPECIES COVER	**13/20**
Canopy species	0
Midstory species	0
Herb/forb species	4
Graminoid species	4
Macrophyte species	4
DEBRIS	**5/20**
Total leaf litter	1
Native leaf litter	1
Dead trees standing	1
Dead trees fallen	0
Lying logs	0
Fringing vegetation	3
MANAGEMENT	**0/20**
Tree clearing	0
Fencing	0
Animal impact	0
Species of interest	0
Exposed tree roots	0
Native woody regeneration	0
Weedy woody regeneration	0
TOTAL	**25/100**

GARR2

High historic disturbance at GARR2 (Plate 3.15) has resulted in a highly modified riparian zone that predominantly comprises exotic species. However, the original riparian vegetation community at GARR2 could have been described as ‘New England Riparian Shrubland’, Community 23 (Benson & Ashby, 2000), or ‘Tea-tree shrubland of drainage areas of the slopes and tablelands’, plant community type ID 1270 (VIS, 2012), broadly classed as ‘Eastern Riverine Forests’, (Keith, 2004). Very little original riparian vegetation remains and GARR2 received a very poor riparian condition score of 28.5, a grade of F (Table 3.25).

The only canopy species present was Willow (*Salix* sp.). The only midstory species present was River Bottlebrush (*Callistemon sieberi*). The understory was dominated by Clover (*Trifolium* spp.), Plantain (*Plantago lanceolata*), Bluebells (*Wahlenbergia* spp.), Common Rush (*Juncus usitatus*), and the grasses Couch (*Cynodon dactylon*), Wallaby Grass (*Rytidosperma spp.*) and Slender Rat’s Tail Grass (*Sporobolus crebra*). The only vine species present was Blackberry (*Rubus* sp.), while the macrophyte layer included River Club Rush (*Schoenoplectus validus*), Pin Rush (*Eleocharis acuta*) and submerged species such as Water Ribbons (*Triglochin* sp.), Elodea (*Elodea canadensis*) and Water Milfoil species (*Myriophyllum* spp.).

Noxious weed species observed were Willow (*Salix* sp.), and Blackberry (*Rubus* sp.) (both class 4), and Mexican Poppy (*Argemone* spp. – class 5). Other weedy species present included Elodea (*Elodea canadensis*), Squirrel Tail Fescue (*Vulpia bromoides*), Umbrella Sedge (*Cyperus eragrostis*), Cudweed (*Gamochaeta spp.*), Plantain (*Plantago lanceolata*), Clover spp. (*Trifolium* spp.), and Purpletop (*Verbena bonariensis*).

Summary: GARR2 was an extremely disturbed system in a relatively cleared landscape of scattered native and exotic canopy species and mixed native and exotic midstory and understory layers. The surrounding rural landuse was predominantly agricultural grazing land. Two significant remnant stands of vegetation lay to the northwest and to the northeast (2kms and 2.1kms respectively). GARR2 scored poorly in all sub indices (Table 3.25), with representative elements of the remnant vegetation community present in only the understory and macrophyte structural layers. Riparian condition at GARR2 was affected by devoid riparian vegetation continuity, poor habitat connectivity, sparse midstory and canopy cover, presence of weed and noxious weed species, a lack of woody debris and inadequate riparian fencing.

Management Recommendations: Riparian condition could be improved through the control/removal of invasive weed species followed by native riparian plantings to assist in site regeneration of native species and phase out and replace dominant canopy weed species such as Willow. Riparian fencing should exclude livestock and, if strategically implemented, could be used in combination with native plantings to increase riparian vegetation width and continuity. Lastly, the introduction of large woody debris back into this system using best practice techniques could stabilise river banks in the long term, promote niche habitats for native woody regeneration, provide habitat for native animal species, and as instream snags, can redirect or reduce water energy from banks, reducing bank erosion.

Plate 3.15 *Riparian vegetation at GARR2 was extremely disturbed. Riparian condition would be improved by removing weed and noxious weed species such as Blackberry* (Rubus sp.), *strategically phasing out Willow* (Salix sp.)*, undertaking native plantings, introducing woody debris and fencing off the riparian zone.*

Table 3.25 *Site-level summary of riparian condition of Gara River #2 showing the scores of individual indicators and the five subindices that comprise the Vegetation Condition Index.*

GARR2	Scores
HABITAT	**2/20**
Channel width	0
Proximity	0
Continuity	0
Layers	2
Large native trees	0
Hollow-bearing trees	0
NATIVE SPECIES	**7.5/20**
Native canopy species	0
Native midstory species	1
Native herb/forb species	1
Native graminoid species	2.5
Native macrophyte species	3
SPECIES COVER	**10/20**
Canopy species	0
Midstory species	1
Herb/forb species	2
Graminoid species	3
Macrophyte species	4
DEBRIS	**7/20**
Total leaf litter	1
Native leaf litter	2
Dead trees standing	0
Dead trees fallen	1
Lying logs	1
Fringing vegetation	2
MANAGEMENT	**2/20**
Tree clearing	0
Fencing	1
Animal impact	0
Species of interest	0
Exposed tree roots	0
Native woody regeneration	0
Weedy woody regeneration	1
TOTAL	**28.5/100**

GARR1

The riparian vegetation community at GARR1 (Plate 3.16) was described as 'River Oak forest and woodland wetland of the NSW South Western Slopes and South Eastern Highlands Bioregion', plant community type ID 85 (VIS, 2012), or more broadly classed 'Eastern Riverine Forests', (Keith, 2004). GARR1 received a very good riparian condition score of 83.5, a grade of B (Table 3.26).

The dominant canopy species present were River Oak (*Casuarina cunninghamiana* subsp. *cunninghamiana*), Blakely's Red Gum (*Eucalyptus blakelyi*) and the exotic Willow (*Salix* sp.). Dominant midstory species included River Bottlebrush (*Callistemon sieberi*), Tantoon (*Leptospermum polygalifolium* subsp. *transmontanum*), Velvet Mock Olive (Notelaea microcarpa), and the exotic species Small-leaved Privet (*Ligustrum sinense*). The understory was dominated by Scurvy Weed (*Commelina cyanea*), Austral Bugle (*Ajuga australis*), Pennywort (*Hydrocotyle tripartita*) and Couch (*Cynodon dactylon*), along with the exotic species Blue Water Speedwell (*Veronica anagallis-aquatica*), Prickly Lettuce (*Lactuca serriola*), Cobblers Pegs (*Bidens pilosa*), Prairie Grass (*Bromus catharticus*) and Cocksfoot (*Dactylis glomerata*). The only vine species present was Blackberry (*Rubus* sp.), while the macrophyte layer included Curly and Blunt Pondweeds (*Potamogeton crispus*, and *P.ochreatus*), Varied Water Milfoil (*Myriophyllum variifolium*), and the exotic species Elodea (*Elodea canadensis*).

Noxious weed species observed onsite were Willow (*Salix* sp.), Small-leaved Privet (*Ligustrum sinense*) and Blackberry (*Rubus* sp.), all class 4 weeds. Other weedy species present included Umbrella Sedge (*Cyperus eragrostis*), Plantain (*Plantago lanceolata*), Purpletop (*Verbena bonariensis*), Ox-eye Daisy (*Leucanthemum vulgare*), Cat's Ear (*Hypochaeris radicata*), Prickly Sowthistle (*Sonchus asper*), Sidratusa (*Sida rhombifolia*), Turnip Weed (*Rapistrum rugosum*), Fleabane (*Conyza bonariensis*) and Tall Fescue (*Festuca arundinaceae*).

Summary: GARR1 was a low disturbance system of mature forest, with a remnant canopy, and mixed native and exotic midstory and understory layers in a partially cleared, partially forested landscape. The surrounding rural landuse was predominantly National Park, beyond which was agricultural grazing land. GARR1 scored well for Habitat, Cover, and Management and moderately for Native Species, and Debris subindicators (Table 3.26) and retained representative elements of the remnant vegetation community in all structural layers.

Management Recommendations: Riparian condition at GARR1 was affected by the presence and regeneration of weed species, particularly throughout the mid- and understory structural layers. The debris subindex scored lower than expected values of leaf litter and woody debris, but was only a minor influence on the overall riparian grade at this site. The current riparian condition could be improved through the control/removal of invasive weed species in both the midstory and understory structural layers.

Plate 3.16 *Riparian vegetation at GARR1 was of low disturbance. Riparian condition would be improved through the continued control and removal of weed species such as Willow* (Salix sp.)*, Small-leaved Privet* (Ligustrum sinense) *and Blackberry* (Rubus sp.).

Table 3.26 *Site-level summary of riparian condition of Gara River #1 showing the scores of individual indicators and the five subindices that comprise the Vegetation Condition Index.*

GARR1	Scores
HABITAT	**20/20**
Channel width	4
Proximity	4
Continuity	4
Layers	4
Large native trees	2
Hollow-bearing trees	2
NATIVE SPECIES	**13/20**
Native canopy species	4
Native midstory species	3
Native herb/forb species	1.5
Native graminoid species	1.5
Native macrophyte species	3
SPECIES COVER	**18.5/20**
Canopy species	4
Midstory species	4
Herb/forb species	4
Graminoid species	2.5
Macrophyte species	4
DEBRIS	**15/20**
Total leaf litter	2
Native leaf litter	2
Dead trees standing	3
Dead trees fallen	2
Lying logs	3
Fringing vegetation	3
MANAGEMENT	**17/20**
Tree clearing	4
Fencing	3
Animal impact	3
Species of interest	1
Exposed tree roots	3
Native woody regeneration	2
Weedy woody regeneration	1
TOTAL	**83.5/100**

3.2.3.3 Water quality

The Gara River received a score of 34 (F) for water quality, with the best water quality recorded in the mid reaches at GARR2 (39, F). Both GARR1 and GARR3 received scores of 31, grades of F. Figures 3.7 and 3.8 show the key physicochemical and nutrient variables used in the assessment of water quality for the Tableland tributaries. ANZECC guidelines are shown as red reference lines in each of the graphs. Ranges and means for these variables are given in Table 3.27 and the exceedances are given in Table 3.28.

Mean pH increased longitudinally downstream the Gara River and all sites consistently exceeded the upper ANZECC upland freshwater trigger value of 7.5 (Figure 3.7b). Mean turbidity decreased longitudinally downstream the Gara River, although there were no exceedances during the sampling period (Figure 3.7d). Although there was no consistent spatial pattern in DO% concentrations along the Gara River (Figure 3.7a), the percentage of samples that fell below the minimum ANZECC trigger value of 80% decreased longitudinally downstream the Gara River from 3 observations (50% of samples) at GARR3 to 1 observation at GARR1 (Table 3.28).

Concentrations of water column chlorophyll *a* decreased longitudinally downstream the Gara River (Figure 3.7c) from a site mean of 2.08µg/L at GARR3 to a site mean of 0.43µg/L at GARR1 (Table 3.27). However, there was only one exceedance of the ANZECC upland freshwater trigger value (4µg/L) at GARR3, of 6.7µg/L in December 2015 (1.7 times the ANZECC trigger value).

Tableland sites consistently exceeded ANZECC nutrient trigger values for upland freshwater systems (Figure 3.8). Total nitrogen (TN) concentrations exceeded the ANZECC upland freshwater trigger value of 250µg/L on all sampling occasions at GARR1 and on 5 of the 6 sampling occasions at GARR2 and GARR3 (Table 3.28). Site minimum TN concentrations exceeded the ANZECC trigger value at GARR1 (1.6 times the trigger value) and GARR3 (1.4 times the trigger value) (Table 3.27). Site maximum TN concentrations were 11, 10.5 and 9.7 times the ANZECC trigger value at GARR3, GARR2 and GARR1, respectively (Table 3.27).

Total phosphorus (TP) concentrations exceeded the ANZECC upland freshwater trigger value of 20µg/L on all sampling occasions at all three GARR sites (Figure 3.8). Site minimum TP concentrations were 2.2, 1.6 and 2.8 times the ANZECC trigger value at GARR3, GARR2 and GARR1, respectively. Site maximum TP concentrations were 20, 45 and 64 times the ANZECC trigger value at GARR3, GARR2 and GARR1, respectively.

Bioavailable nitrogen (NOx) concentrations exceeded the ANZECC upland freshwater trigger value of 25µg/L on all sampling occasions at GARR3 and GARR1, and on 5 sampling occasions at GARR2 (Figure 3.8). Site minimum NOx concentrations were 5.1, and 3.9 times the ANZECC trigger value at GARR3 and GARR1, respectively. Site maximum NOx concentrations were 25, 21 and 14 times the ANZECC trigger value at GARR3, GARR2 and GARR1, respectively. There was a clear longitudinal decrease in the range and mean site NOx concentrations downstream the Gara River (Figure 3.8c).

Soluble reactive phosphorus (SRP) concentrations exceeded the ANZECC upland freshwater trigger value of 15µg/L on all sampling occasions at GARR3 and GARR1, and on 5 sampling occasions at GARR2 (Figure 3.8). Site minimum SRP concentrations were 1.3 times the ANZECC trigger value at

GARR3 and GARR1. Site maximum SRP concentrations were 59, 21 and 56 times the ANZECC trigger value at GARR3, GARR2 and GARR1, respectively. SRP concentrations increased longitudinally downstream the Gara River (Figure 3.8d).

Algal productivity in the water column (estimated by chlorophyll *a* concentrations) was correlated with NOx concentrations, with both variables decreasing longitudinally (Figures 3.7c, 3.8c). Therefore, although phosphorus concentrations in the Gara River are very high, management strategies that reduce nitrogen in the water column are more likely to target reduced algal productivity. However, it is important to note that despite high nitrogen and phosphorus concentrations, these did not result in excessive algal growth during the sampling period.

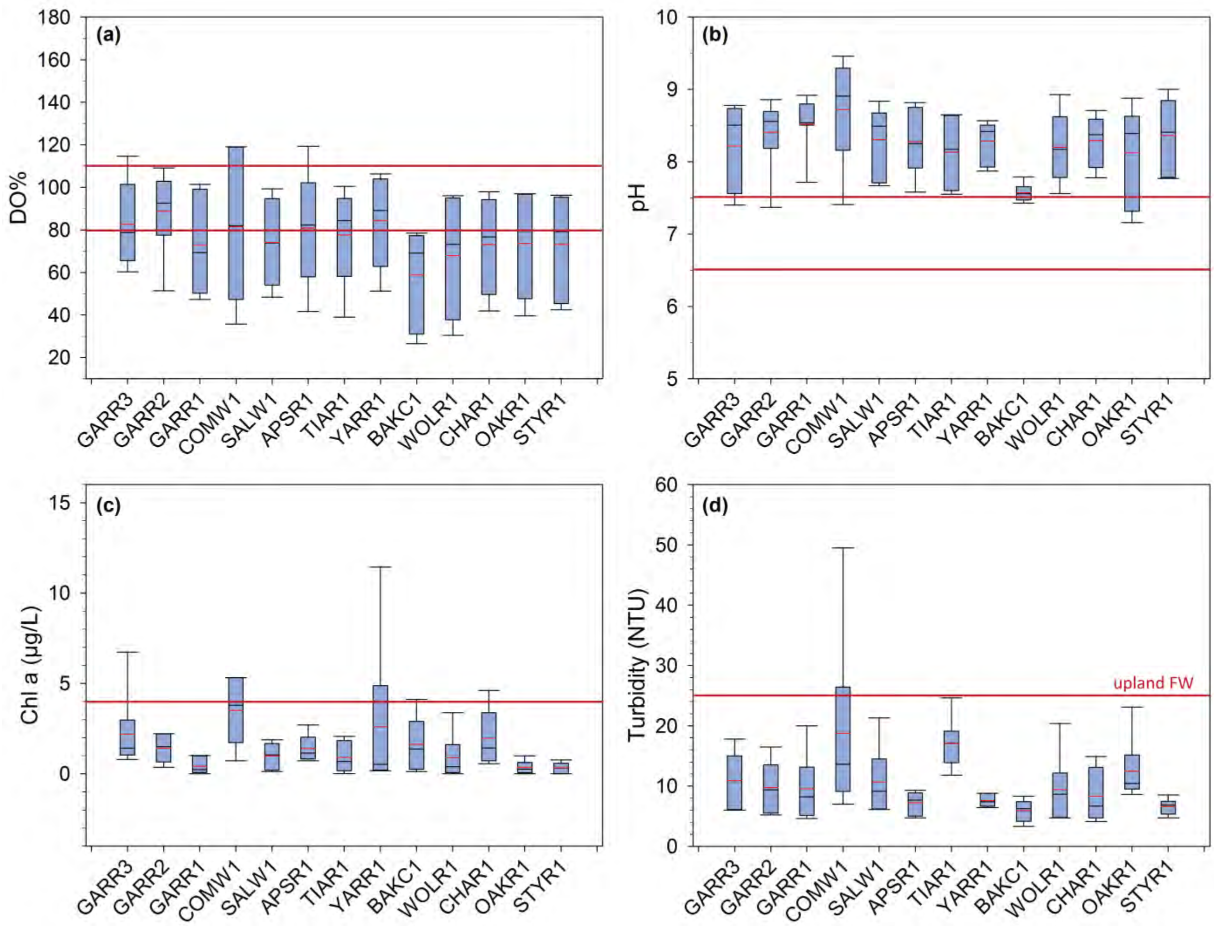


Figure 3.7 *Mean (red line), median (black line), 25th and 75th percentiles for (a) % saturated DO, (b) pH, (c) chlorophyll a and (d) turbidity in the Tableland sites. Horizontal red lines represent the ANZECC and MER trigger thresholds for upland freshwater systems. Two horizontal red lines represent minimum (lower) and maximum (upper) trigger thresholds while single horizontal red lines represent maximum trigger thresholds.*

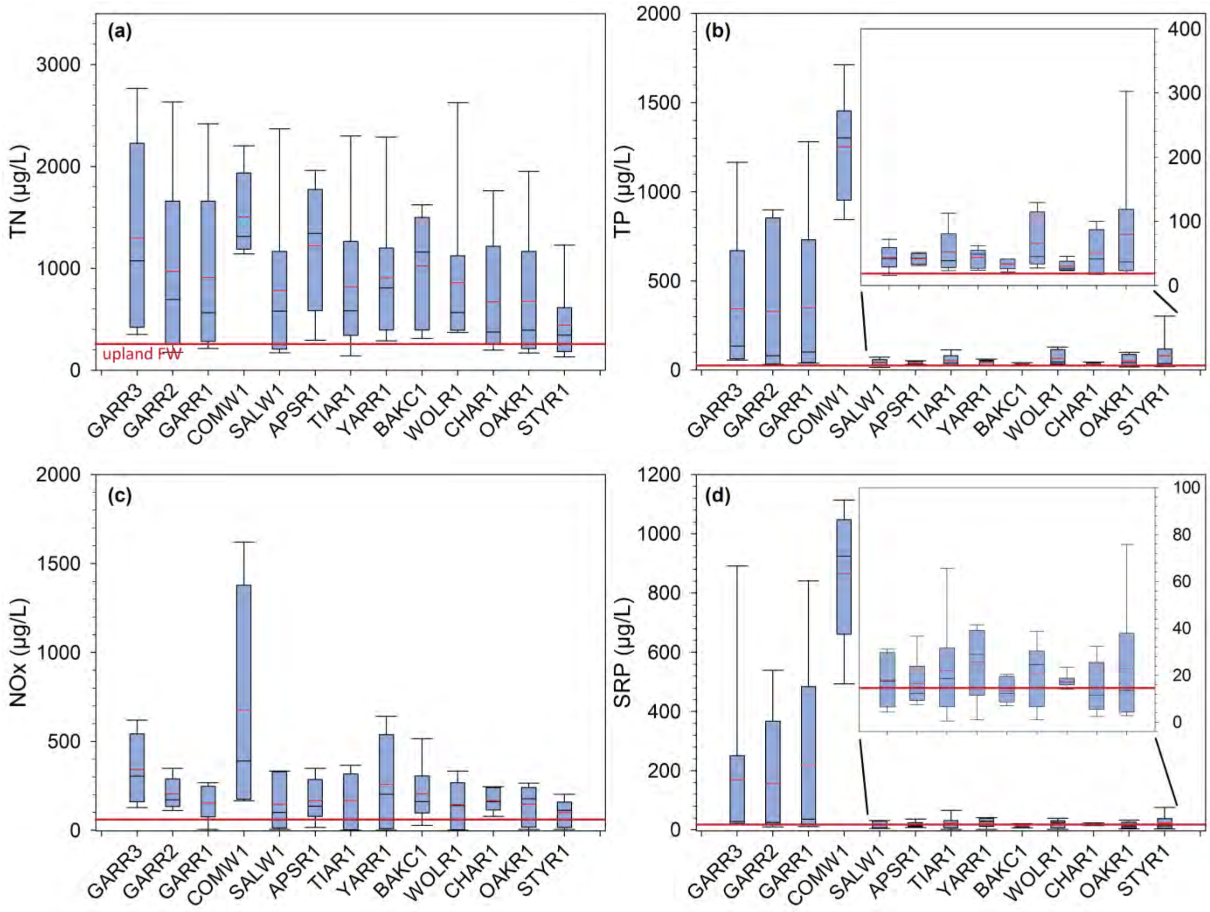


Figure 3.8 *Mean (red line), median (black line), 25th and 75th percentiles for (a) total nitrogen, (b) total phosphorus, (c) bioavailable nitrogen and (d) soluble reactive phosphorus in the Tableland sites. Horizontal red lines represent the maximum ANZECC and MER trigger thresholds for upland freshwater systems. Insets in (b) and (d) provide better resolution of sites where nutrient concentrations remained comparatively low.*

Table 3.27 *Minimums, maximums and means of measured water quality variables for the three sites on the Gara River.*

	GARR1			GARR2			GARR3		
Variable	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**
Temperature (°C)	10.22	42.54	20.58	11.55	28.41	19.74	9.52	20.65	14.65
pH	7.72	17.08	9.94	7.37	10.63	8.74	7.40	9.51	8.42
EC (mS/cm)	0.31	0.63	0.44	0.01	0.44	0.32	0.00	0.30	0.18
Salinity (PPT)	0.15	0.30	0.21	0.01	0.21	0.16	0.01	0.14	0.09
DO (mg/L)	4.48	10.07	7.88	3.75	9.99	7.38	5.40	10.71	8.06
DO (%)	51.20	104.90	87.20	51.40	109.20	86.27	60.30	114.70	85.10
Turbidity (NTU)	4.60	28.90	11.18	5.20	16.50	9.73	6.00	17.80	11.22
Max Depth	0.20	0.75	0.38	0.15	0.30	0.20	0.25	0.35	0.30
Chla (µg/L)	0.02	1.02	0.43	0.35	2.22	1.38	0.40	6.73	2.08
TSS (mg/L)	0.77	3.90	2.48	0.66	6.60	2.80	0.85	12.55	5.30
TN (µg/L)	400.00	2419.4	1091.5	175.49	2635.5	991.20	353.70	2766.9	1311.8
TP (µg/L)	44.50	1281.5	492.21	31.99	899.20	203.17	56.32	1165.5	393.36
NOx (µg/L)	98.12	348.64	210.71	0.20	515.66	197.86	127.35	620.04	305.55
SRP (µg/L)	20.15	840.79	307.88	10.14	310.04	71.63	19.30	891.01	197.61

Table 3.28 *Exceedances[1] observed in the tableland sites for pH, conductivity (EC), percent saturated dissolved oxygen (DO), turbidity, chlorophyll a (Chl-a), total nitrogen (TN) ,total phosphorus (TP), bioavailable nitrogen (NOx) and soluble reactive phosphorus (SRP).*

Site	pH	EC	DO %	Turbidity	Chl-a	TN	TP	NOx	SRP
GARR1	6(100%)0,6	6(100%)0,6	1(17%)1,0	1(17%)	0(0%)	6(100%)	6(100%)	6(100%)	6(100%)
GARR2	5(83%)0,5	5(83%)0,5	2(33%)2,0	0(0%)	0(0%)	5(83%)	6(100%)	5(83%)	5(83%)
GARR3	4(80%)0,4	3(60%)1,2	3(60%)3,0	0(0%)	1(17%)	5(83%)	6(100%)	6(100%)	6(100%)
COMW1	5(83%)0,5	6(100%)0,6	5(83%)3,2	1(17%)	3(50%)	6(100%)	6(100%)	6(100%)	6(100%)
SALW1	6(100%)0,6	6(100%)0,6	3(50%)3,0	0(0%)	0(0%)	4(67%)	5(83%)	3(50%)	3(50%)
BAKC1	4(67%)2,2	6(100%)0,6	6(100%)6,0	0(0%)	1(17%)	6(100%)	6(100%)	6(100%)	2(33%)
STYR1	6(100%)0,6	6(100%)0,6	3(50%)3,0	0(0%)	0(0%)	4(67%)	5(83%)	4(67%)	3(50%)
WOLR1	6(100%)0,6	5(83%)0,5	4(67%)4,0	0(0%)	0(0%)	6(100%)	6(100%)	4(67%)	4(67%)
CHAR1	6(100%)0,6	1(17%)0,1	3(50%)3,0	0(0%)	1(17%)	5(83%)	6(100%)	6(100%)	5(83%)
OAKR1	4(67%)0,4	0(0%)0,0	3(50%)3,0	0(0%)	0(0%)	4(67%)	4(67%)	4(67%)	3(50%)
TIAR1	6(100%)0,5	0(0%)0,0	3(50%)3,0	0(0%)	0(0%)	5(83%)	6(100%)	4(67%)	4(67%)
YARR1	6(100%)0,6	1(17%)0,1	3(50%)3,0	0(0%)	1(17%)	6(100%)	6(100%)	3(50%)	4(67%)
APSR1	6(100%)0,6	5(83%)0,5	4(67%)3,1	0(0%)	0(0%)	6(100%)	6(100%)	5(83%)	2(33%)

[1] Numbers in black represent the total number and percent of exceedances. Numbers in blue and red represent the numbers of measurements lower than the minimum threshold and higher than the maximum threshold, respectively. The number of exceedances includes all depths sampled so may be greater than the number of times sampled. Turbidity, chlorophyll a and nutrients only have maximum trigger thresholds.

3.2.3.4 Aquatic macroinvertebrates

GARR3 recorded 849 and 910 individual macroinvertebrates across 21 and 28 macroinvertebrate families during the 2015 autumn and spring sampling, respectively (Table 3.29). In autumn, abundance was dominated by Simuliids (Black Flies, 550 individuals) and richness was also dominated by Diperta (6 families). In contrast, although Simuliids were the most abundant family in spring (550 individuals), the dominant order in spring was Coleoptera (Aquatic Beetles) with 6 families. Family richness was higher in spring than autumn, primarily driven by the presence of aquatic beetles in spring. There were a number of rare taxa at the site, with 12 and 16 taxa recording fewer than 5 individuals in autumn and spring, respectively.

Mean SIGNAL2 scores for GARR3 were very different between autumn (4.5) and spring (2.6), although the range of SIGNAL2 scores did not change between seasons. The decrease in the mean SIGNAL2 at GARR3 in spring was due to high abundances of low scoring biota (e.g. Physidae snails and Corixid bugs (Water Boatmen).

GARR3 received an overall Ecohealth score of 35, a grade of F, for aquatic macroinvertebrate community condition. All macroinvertebrate indicators were below the Macleay catchment average, particularly mean SIGNAL2 score and EPT (Table 3.13). The macroinvertebrate indicators suggest the water quality and habitat conditions in the upper reaches of the Gara River are in very poor condition, but are able to support a diversity of macroinvertebrate fauna given the wide range of SIGNAL2 scores.

Table 3.29 *Summary of aquatic macroinvertebrate data for the Gara River.*

	GARR3		GARR2		GARR1	
Macroinvertebrate indicator	**Autumn 2015**	**Spring 2015**	**Autumn 2015**	**Spring 2015**	**Autumn 2015**	**Spring 2015**
Total abundance	849	910	745	384	709	725
Family richness	21	28	27	31	25	26
EPT abundance	34	131	27	83	101	217
EPT richness	5	4	8	10	8	9
Mean SIGNAL2 score	4.5	2.6	3.5	3.5	4.4	5.9
SIGNAL2 score range	1 - 8	1 - 8	1 - 9	1 - 8	2 - 8	1 - 8
Ecohealth score (grade)	**35 (F)**		**37 (F)**		**46 (D-)**	

GARR2 recorded 745 and 384 individual macroinvertebrates across 27 and 31 macroinvertebrate families during the 2015 autumn and spring sampling, respectively (Table 3.29). In autumn, abundance was dominated by Chironomid midges (386 individuals) and richness was also dominated by Diperta (8 families). While spring abundance was dominated by Chironomid midges and Physid aquatic snails (112 and 90 individuals, respectively), richness was dominated by Coleoptera (Aquatic Beetles) with 6 families and Trichoptera (Caddisflies) with 5 families. Family richness was higher in spring than autumn, primarily driven by the presence of insects in spring. There were a number of rare taxa at the site, with 18 and 17 taxa recording fewer than 5 individuals in autumn and spring, respectively.

Mean SIGNAL2 scores for GARR2 were the same between autumn and spring (3.5), although the range of SIGNAL2 scores was higher in autumn due to the presence of 2 Glossomatid caddisfly individuals.

GARR2 received an overall Ecohealth score of 37, a grade of F, for aquatic macroinvertebrate community condition. All macroinvertebrate indicators were below the Macleay catchment average, particularly EPT and mean SIGNAL2 score (Table 3.13). The macroinvertebrate indicators suggest the water quality and habitat conditions in the mid reaches of the Gara River are in very poor condition, but are able to support a diversity of macroinvertebrate fauna given the wide range of SIGNAL2 scores.

GARR1 recorded 709 and 725 individual macroinvertebrates across 25 and 26 macroinvertebrate families during the 2015 autumn and spring sampling, respectively (Table 3.29). In autumn, abundance was dominated by Chironomid midges (356 individuals) and richness was dominated by Coleoptera (Aquatic Beetles), Ephemeroptera (Mayflies) and Trichoptera (Caddisflies) (5 families each). Spring abundance was dominated by Baetid and Leptophlebid Mayflies (202 and 148 individuals, respectively), and richness was dominated by Coleoptera (Aquatic Beetles) with 7 families. Family richness was slightly higher in spring than autumn. There were a number of rare taxa at the site, with 14 and 11 taxa recording fewer than 5 individuals in autumn and spring, respectively.

Mean SIGNAL2 scores for GARR1 were different between autumn (4.4) and spring (5.9), although the range of SIGNAL2 scores remained similar across seasons (Table 3.29). The increase in the mean SIGNAL2 at GARR1 in spring was due to higher abundances of high scoring Leptophlebid Mayflies and Hydropsychid Caddisflies with SIGNAL2 of 8.

GARR1 received an overall Ecohealth score of 46, a grade of D-, for aquatic macroinvertebrate community condition. Three macroinvertebrate indicators were below the Macleay catchment average (the exception was mean SIGNAL2), particularly total abundance and EPT (Table 3.13). The macroinvertebrate indicators suggest poor water quality in the Gara River immediately upstream of the gorge, but GARR1 is able to support a diversity of macroinvertebrate fauna given the wide range of SIGNAL2 scores.

3.2.4 Commissioners Waters (COMW1)

3.2.4.1 Geomorphic condition

The geomorphic River Style at Commissioners Waters #1 (COMW1) is confined valley setting: floodplain pockets, gravel. The bed sediments comprised rounded gravel in a matrix dominated framework containing >60% fine sediments. Banks comprised fine grained sediments with severe bank erosion (20-100m) concentrated as undercutting along both banks. There was moderate (5-10m) slumping of the left bank and minimal (<5m) slumping of the right bank. Geomorphic complexity was minimal, with the site comprising a single run. COMW1 scored 44, an F for BANK CONDITION and 51, a D, for BED CONDITION. The overall geomorphic condition for COMW1 was 48, a grade of D-.

In summary, COMW1 was assessed as being in poor geomorphic condition, with bank erosion the most significant issue for site-level geomorphic condition. Fencing the riparian zone to exclude stock and allow for regeneration of native revegetation would assist to improve geomorphic condition at this site. The desktop GIS assessment of subcatchment geomorphic condition found the Commissioners Waters subcatchment to be in poor condition with a grade of D-. The geomorphic condition at COMW1 was representative of the subcatchment average.

3.2.4.2 Riparian condition

High historic disturbance at COMW1 (Plate3.17) has resulted in a highly modified riparian zone that predominantly comprises exotic species. However, the original riparian vegetation community at COMW1 could have been described as ‘New England Riparian Shrubland’, Community 23 (Benson & Ashby, 2000), or ‘Tea-tree shrubland of drainage areas of the slopes and tablelands’, plant community type ID 1270 (VIS, 2012), broadly classed as ‘Eastern Riverine Forests’, (Keith, 2004). COMW1 received a very poor riparian condition score of 31.2, a grade of F (Table 3.30).

The only canopy species present was Willow (*Salix* sp.). The dominant midstory species were the native tantoon (*Leptospermum polygalifolium* subsp. *transmontanum*), and River Bottlebrush (*Callistemon sieberi*). The understory was dominated by the native species Native Clover (*Lespedeza juncea*), Swamp Dock (Rumex brownii), Kidney Weed (*Dichondra repens*), Winged Everlasting (A*mmobium alatum*), Snow Grass (*Poa siebriana*) and Blady grass (*Imperata cylindrica*), and the exotic species Ox-eye Daisy (*Leucanthemum vulgare*), Wild Carrot (*Daucus carota*), Prickly Sowthistle (Sonchus asper), Sidratusa (*Sida rhombifolia*), Clover species (*Trifolium* and *Medic* spp.), Fleabane (*Conyza bonariensis*), Cocksfoot (*Dactylis glomerata*), Tall Fescue (*Festuca arundinaceae*) and Phalaris (*Phalaris aquatica*). The only vine species present was Blackberry (*Rubus* sp.), while the macrophyte layer included two species, Tall Spikerush (*Eleocharis sphacelata*) and Ribbonweed (*Valisneria australis*).

Noxious weed species observed were Willow (*Salix* sp.), Blackberry (*Rubus* sp.) (both class 4). In addition to those already mentioned, other weed species present included Umbrella Sedge (*Cyperus eragrostis*), Purpletop (*Verbena bonariensis*), Plantain (*Plantago lanceolata*), Cudweed (*Gamochaeta* spp.), Cat's Ear (*Hypochaeris radicata*), Vetch species (*Vicia* sp.) and Wimmera Grass (*Lolium rigidum*).

Summary: COMW1 was an extremely disturbed system in a predominantly cleared landscape of scattered native and exotic canopy species and mixed midstory and understory layers. The surrounding rural landuse was predominantly agricultural grazing land. Significant remnant systems in a Nature Reserve and a National Park were located 3.5 and 4kms from COMW1 respectively. Despite representative elements of the remnant vegetation community present in all but one of the structural layers, canopy, riparian condition at COMW1 scored poorly in all subindices except cover which received a moderate grade (Table 3.30). Devoid riparian vegetation width and continuity in the canopy layer and sparse cover in the midstory layer, poor habitat connectivity, the presence and regeneration of weed and noxious weed species, particularly in the understory, a lack of woody debris and inadequate riparian fencing were all factors contributing to the poor riparian grade at this site.

Management Recommendations: Riparian condition could be improved through control and removal of invasive weed species, particularly in the understory, and by undertaking native plantings to increase riparian vegetation width and continuity and assist in site regeneration of native species. Such plantings assist in phasing out and replacing dominant canopy weed species such as Willow. Riparian fencing should exclude livestock and, if strategically implemented, could be used in combination with native plantings to increase riparian vegetation width and continuity. Lastly, the introduction of large woody debris back into this system using best practice techniques could stabilise river banks in the long term, promote niche habitats for native woody regeneration, provide habitat for native animal species, and as instream snags, can redirect or reduce water energy from banks, reducing bank erosion.

Plate 3.17 *Riparian vegetation at COMW1 was extremely disturbed. Riparian condition would be improved through the monitoring and removal of weed and noxious weed species such as Blackberry* (Rubus sp.)*, strategically phasing out Willow* (Salix sp.)*, undertaking native plantings, introducing woody debris and fencing off the riparian zone.*

Table 3.30 *Site-level summary of riprian condition of Commissioners Waters #1 showing the scores of individual indicators and the five subindices that comprise the Vegetation Condition Index.*

COMW1	Scores
HABITAT	**2.7/20**
Channel width	0
Proximity	0
Continuity	0
Layers	2.7
Large native trees	0
Hollow-bearing trees	0
NATIVE SPECIES	**7/20**
Native canopy species	0
Native midstory species	3
Native herb/forb species	1
Native graminoid species	2
Native macrophyte species	1
SPECIES COVER	**13/20**
Canopy species	0
Midstory species	1
Herb/forb species	4
Graminoid species	4
Macrophyte species	4
DEBRIS	**4.5/20**
Total leaf litter	1
Native leaf litter	1
Dead trees standing	0
Dead trees fallen	1
Lying logs	0
Fringing vegetation	1.5
MANAGEMENT	**4/20**
Tree clearing	0
Fencing	1
Animal impact	1
Species of interest	0
Exposed tree roots	2
Native woody regeneration	0
Weedy woody regeneration	0
TOTAL	**31.2/100**

3.2.4.3 Water quality

Commissioners Waters received a score of 19 (F) for water quality. Figures 3.7 and 3.8 show the key physicochemical and nutrient variables used in the assessment of water quality for the Tableland tributaries. Ranges and means for these variables are given in Table 3.31 and the exceedances are given in Table 3.28.

pH exceeded the upper ANZECC upland freshwater trigger value of 7.5 on 5 of the 6 sampling occasions (Table 3.28). COMW1 had the largest range of turbidity of the tableland sites (Figure 3.7d), but only once exceeded the ANZECC upland freshwater guideline of 25NTU (Table 3.28). DO% was also highly variable at COMW1, falling below the minimum ANZECC trigger threshold on 3 sampling occasions and exceeding the maximum ANZECC trigger threshold on 2 sampling occasions (Table 3.28).

However, exceedances of the maximum DO% trigger threshold did not coincide with high chlorophyll *a* concentrations, so were not due to nuisance algal blooms. Nonetheless, algal productivity was relatively high at COMW1, with a site mean of 5.32µg/L; the ANZECC trigger threshold was exceeded on 50% of sampling occasions (Table 3.28).

TN concentrations exceeded the ANZECC upland freshwater trigger value of 250µg/L on all sampling occasions at COMW1 (Table 3.28). The site minimum TN concentration was 4.6 times the ANZECC trigger value and the site maximum TN concentration was 8.8 times the trigger value (Table 3.31). Similarly, TP concentrations exceeded the ANZECC upland freshwater trigger value of 20µg/L on all sampling occasions at COMW1 (Figure 3.8). The site minimum TP concentration was 42 times the ANZECC trigger value and the site maximum TN concentration was 86 times the ANZECC trigger value (Table 3.31).

NOx concentrations exceeded the ANZECC upland freshwater trigger value of 25µg/L on all sampling occasions at COMW1 (Table 3.28). The site minimum NOx concentration was 6.6 times the trigger value and the site maximum TN concentration was 65 times the trigger value (Table 3.31). SRP concentrations exceeded the ANZECC upland freshwater trigger value of 15µg/L on all sampling occasions at COMW1 (Table 3.28). The site minimum SRP concentration was 33 times the trigger value and the site maximum SRP concentration was 74 times the trigger value (Table 3.31).

Commissioners Waters joins the Gara River upstream of GARR1. It is likely that high nutrient concentrations from Commisioners Waters contributes to nutrient concentrations at GARR1, especially for TP and SRP (Figure 3.8b, d). However, this did not appear to influence algal productivity (chl *a*) at GARR1 over the sampling period (Figure 3.7c).

Table 3.31 *Minimums, maximums and means of measured water quality variables for Commissioners Waters and Salisbury Waters.*

	COMW1			SALW1		
Variable	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**
Temperature (°C)	11.87	25.31	17.98	10.22	25.17	17.20
pH	7.41	9.82	8.89	7.67	8.84	8.31
EC (mS/cm)	0.33	0.43	0.40	0.31	0.85	0.69
Salinity (PPT)	0.16	0.20	0.19	0.15	0.41	0.33
DO (mg/L)	2.84	11.47	7.24	3.76	9.57	6.67
DO (%)	35.80	119.10	81.48	48.40	99.30	74.08
Turbidity (NTU)	7.00	49.50	18.72	6.10	21.30	10.68
Max Depth	0.40	0.50	0.44	0.30	0.50	0.36
Chla (µg/L)	0.72	5.32	3.50	0.13	1.88	0.99
TSS (mg/L)	1.65	47.52	16.43	1.78	4.40	3.28
TN (µg/L)	1142.8	2203.3	1504.3	171.43	2368.6	780.88
TP (µg/L)	844.49	1713.1	1253.2	15.71	72.10	43.44
NOx (µg/L)	165.54	1620.69	673.34	4.18	334.46	146.56
SRP (µg/L)	493.23	1114.16	866.57	4.32	31.09	17.79

3.2.4.4 Aquatic macroinvertebrates

COMW1 recorded 911 and 786 individual macroinvertebrates across 22 and 23 macroinvertebrate families during the 2015 autumn and spring sampling, respectively (Table 3.32). In autumn, abundance was dominated by Corixids (Water Boatmen, 279 individuals) and richness was dominated by Ephemeroptera (Mayflies) and Trichoptera (Caddisflies) (4 families each). Corixids were also the most abundant family in spring (288 individuals), with family richness dominated by Trichoptera (Caddisflies) with 6 families. There were a number of rare taxa at the site, with 7 and 9 taxa recording fewer than 5 individuals in autumn and spring, respectively.

Mean SIGNAL2 scores for COMW1 were similar between autumn (2.9) and spring (2.7), and the range of SIGNAL2 scores changed little between seasons.

COMW1 received an overall Ecohealth score of 33, a grade of F, for aquatic macroinvertebrate community condition. Three macroinvertebrate indicators were below the Macleay catchment average, particularly mean SIGNAL2 score and EPT (Table 3.13). The macroinvertebrate indicators suggest the water quality and habitat conditions in Commissioners Waters are in very poor condition, but are able to support a diversity of macroinvertebrate fauna given the wide range of SIGNAL2 scores.

Table 3.32 *Summary of aquatic macroinvertebrate data for Commissioners Waters and Salisbury Waters.*

	COMW1		**SALW1**	
Macroinvertebrate indicator	**Autumn 2015**	**Spring 2015**	**Autumn 2015**	**Spring 2015**
Total abundance	911	786	206	245
Family richness	22	23	25	22
EPT abundance	92	44	42	37
EPT richness	6	6	8	5
Mean SIGNAL2 score	2.9	2.7	2.6	2.2
SIGNAL2 score range	2 - 8	1 - 8	1 - 8	1 - 7
Ecohealth score (grade)	**33 (F)**		**21 (F)**	

3.2.5 Salisbury Waters (SALW1)

3.2.5.1 Geomorphic condition

The geomorphic River Style at Salisbury Waters #1 (SALW1) is partially confined valley setting: bedrock controlled, fine grained. The bed sediments comprised sub-angular gravel in a framework dilated matrix containing 32-60% fine sediments. Banks comprised fine grained sediments with moderate bank erosion concentrated as moderate (5-10m) undercutting along the left bank and significant (10-20m) undercutting along the right bank. There was minimal (<5m) slumping of the left bank and moderate (5-10m) slumping of the right bank. Geomorphic complexity was moderate, with the site comprising a riffle, run and pool (10, 40 and 50%, of reach length, respectively). SALW1 scored 61, a C- for BANK CONDITION and 51, a D, for BED CONDITION. The overall geomorphic condition for SALW1 was 56, a grade of D+.

In summary, SALW1 was assessed as being in poor geomorphic condition, with bank erosion the most significant issue for site-level geomorphic condition. Fencing the riparian zone to exclude stock and allow for regeneration of native revegetation would assist to improve geomorphic condition at this site. The desktop GIS assessment of subcatchment geomorphic condition found the Salisbury Waters subcatchment to be in poor condition with a grade of D-. The geomorphic condition at SALW1 was slightly better than the subcatchment average.

3.2.5.2 Riparian condition

High historic disturbance at SALW1 (Plate 3.18) has resulted in a highly modified riparian zone that predominantly comprises exotic species. However, the original riparian vegetation community at SALW1 could have been described as 'New England Riparian Shrubland', Community 23 (Benson & Ashby, 2000), or 'Tea-tree shrubland of drainage areas of the slopes and tablelands', plant community type ID 1270 (VIS, 2012), broadly classed as 'Eastern Riverine Forests', (Keith, 2004). However, very little original riparian vegetation remains and SALW1 received a very poor riparian condition score of 38.2, a grade of F (Table 3.33).

The dominant canopy species present were Willow (*Salix* sp.), Snow Gum (*Eucalyptus pauciflora*), and New England Peppermint (*Eucalyptus nova-anglica*). Two midstory species were present, Tantoon (*Leptospermum polygalifolium* subsp. *transmontanum*), and River Bottlebrush (*Callistemon sieberi*). The understory was dominated by the native species Spiny-headed Mat-rush (*Lomandra longifolia*), Common Rush (*Juncus usitatus*), Native Clover (*Lespedeza juncea*), Bidgee-widgee (*Acaena novae-zelandiae*), Poa species (*P.siebrianna* and *P.labillardierrei*) and Kangaroo Grass (*Themeda australis*), and exotic species Clover (*Trifolium* spp.), Fleabane (*Conyza bonariensis*), Green Mullein (*Verbascum virgatum*), Phalaris (*Phalaris aquatica*), Yorkshire Fog (*Holcus lanatus*), Wild Oats (*Avena fatua*) and Tall Fescue (*Festuca arundinaceae*). The only vine species present was Blackberry (*Rubus* sp.), while the macrophyte layer included River Club Rush (*Schoenoplectus validus*), Water Primrose (*Ludwigia peploides*) and submerged species such as Varied Water-milfoil

(*Myriophyllum variifolium*), Pondweeds (*Potomogeton sulcatus* and *P.crispus*), Freshwater Eelgrass (*Vallisneria nana*) and Ribbonweed (*Vallisneria australis*).

Noxious weed species observed were Willow (*Salix* sp.) and Blackberry (*Rubus* sp.) (both class 4). Other weedy species present included Prairie Grass (*Bromus catharticus*), Umbrella Sedge (*Cyperus eragrostis*), Spear Thistle (*Cirsium vulgare*), Common Bittercress (*Cardamine hirsuta*), Plantain (*Plantago lanceolata*), Purpletop (*Verbena bonariensis*), Blue Water Speedwell (*Veronica anagallis-aquatica*) and Ox-eye Daisy (*Leucanthemum vulgare*).

Summary: SALW1 was an extremely disturbed system in a predominantly cleared landscape of scattered native and exotic canopy species and mixed native and exotic midstory and understory layers. The surrounding rural landuse was predominantly agricultural grazing land. Significant remnant stands of vegetation lie 3.5km to the east in Oxley Wild Rivers National Park. SALW1 scored poorly in all indices except the cover subindex (Table 3.33) despite containing representative elements of remnant vegetation community in all structural layers. Riparian condition was affected by poor riparian width, continuity, habitat connectivity and riparian vegetation dominated by weed and noxious weed species. A sparse, unhealthy canopy layer, a lack of woody debris and inadequate riparian fencing all contributed to the poor riparian grade at this site.

Management Recommendations: While obvious attempts to improve riparian condition on site have been made through previous native plantings, additional plantings on a larger scale are needed to ensure health and longevity of the native canopy species present. Such plantings assist in site regeneration of native species and phase out and replace dominant canopy weed species such as Willow. Riparian condition could be improved through the control/removal of invasive weed species. Riparian fencing should exclude livestock and, if strategically implemented, could be used in combination with native plantings to increase riparian vegetation width and continuity. Lastly, the introduction of large woody debris back into this system using best practice techniques could stabilise river banks in the long term, promote niche habitats for native woody regeneration, provide habitat for native animal species, and as instream snags, can redirect or reduce water energy from banks, reducing bank erosion.

Plate 3.18 *Riparian vegetation at SALW1 was extremely disturbed. Riparian condition would be improved by removing weed and noxious weed species such as Blackberry* (Rubus sp.), *strategically phasing out Willow* (Salix sp.)*, undertaking native plantings, introducing woody debris and fencing off the riparian zone.*

***Table 3.33** Site-level summary of riparian condition of Salisbury Waters #1 showing the scores of individual indicators and the five subindices that comprise the Vegetation Condition Index.*

SALW1	Scores
HABITAT	**3.7/20**
Channel width	0.7
Proximity	0
Continuity	0
Layers	3
Large native trees	0
Hollow-bearing trees	0
NATIVE SPECIES	**9.5/20**
Native canopy species	1
Native midstory species	1
Native herb/forb species	2
Native graminoid species	1.5
Native macrophyte species	4
SPECIES COVER	**15/20**
Canopy species	1
Midstory species	2
Herb/forb species	4
Graminoid species	4
Macrophyte species	4
DEBRIS	**7/20**
Total leaf litter	1
Native leaf litter	1
Dead trees standing	0
Dead trees fallen	1
Lying logs	1
Fringing vegetation	3
MANAGEMENT	**3/20**
Tree clearing	0
Fencing	1
Animal impact	1
Species of interest	1
Exposed tree roots	0
Native woody regeneration	0
Weedy woody regeneration	0
TOTAL	**38.2/100**

3.2.5.3 Water quality

Salisbury Waters received a score of 44 (F) for water quality. Figures 3.7 and 3.8 show the key physicochemical and nutrient variables used in the assessment of water quality for the Tableland tributaries. Ranges and means for these variables are given in Table 3.31 and the exceedances are given in Table 3.28.

pH exceeded the upper ANZECC upland freshwater trigger value of 7.5 on all sampling occasions (Table 3.28). SALW1 turbidities did not exceed the ANZECC upland freshwater guideline of 25NTU (Table 3.28). DO% fell below the minimum ANZECC trigger threshold on 3 sampling occasions during extreme low flows over the 2015 austral spring and summer (Table 3.28). Chlorophyll *a* did not exceed the ANZECC upland freshwater guideline of 4µg/L during the sampling period (Figure 3.7c).

TN concentrations exceeded the ANZECC upland freshwater trigger value of 250µg/L on 4 of 6 sampling occasions at SALW1 (Table 3.28). The site maximum TN concentration was 9.5 times the ANZECC trigger value (Table 3.31). Similarly, TP concentrations exceeded the ANZECC upland freshwater trigger value of 20µg/L on 5 of 6 sampling occasions at SALW1 (Figure 3.8). The site maximum TP concentration was 3.6 times the ANZECC trigger value (Table 3.31).

NOx concentrations exceeded the ANZECC upland freshwater trigger value of 25µg/L on 3 of 6 sampling occasions at SALW1 (Table 3.28). The site maximum NOx concentration was 6.6 times the trigger value (Table 3.31). SRP concentrations exceeded the ANZECC upland freshwater trigger value of 15µg/L on 3 of 6 sampling occasions at SALW1 (Table 3.28). The site maximum SRP concentration was 33 times the trigger value (Table 3.31).

3.2.5.4 Aquatic macroinvertebrates

SALW1 recorded 206 and 245 individual macroinvertebrates across 25 and 22 macroinvertebrate families during the 2015 autumn and spring sampling, respectively (Table 3.32). In autumn, abundance was dominated by Physid snails (80 individuals) and richness was dominated by Trichoptera (Caddisflies) with 7 families, although none comprised more than 5 individuals. Physid snails were also the most abundant family in spring (135 individuals). The most diverse order in spring was also Trichoptera (Caddisflies) with 4 families (although only 1 family comprised more than 5 individuals). Many taxa were present in low numbers, with 16 and 14 taxa recording fewer than 5 individuals in autumn and spring, respectively.

Mean SIGNAL2 scores for SALW1 were higher in autumn (2.6) than spring (2.2), although the range of SIGNAL2 scores was similar between seasons. The decrease in the mean SIGNAL2 at SALW1 in spring was due to the absence of three families with SIGNAL2 of 8 (Leptophlebiid Mayflies, Hydropsychid Caddisflies and Philopotamid Caddisflies).

SALW1 received an overall Ecohealth score of 21, a grade of F, for aquatic macroinvertebrate community condition. This was the second-lowest site score in the Macleay catchment. All macroinvertebrate indicators were below the Macleay catchment average, particularly mean SIGNAL2 score and family richness (Table 3.13). The macroinvertebrate indicators suggest the water quality and habitat conditions in Salisbury Waters are in very poor condition, but are able to support a diversity of macroinvertebrate fauna given the wide range of SIGNAL2 scores.

3.2.6 Apsley River (APSR1)

3.2.6.1 Geomorphic condition

The geomorphic River Style at Apsley River #1 (APSR1) is partially confined valley setting: bedrock controlled, fine grained. The bed sediments were dominated by bedrock with angular cobbles. Banks comprised fine grained sediments. There was no obvious bank erosion in the site reach. Geomorphic complexity was moderate, with the site comprising a rapid, glide and pool (15, 35 and 50%, of reach length, respectively). APSR1 scored 75, a C+ for BANK CONDITION and 85, a B, for BED CONDITION. The overall geomorphic condition for APSR1 was 80, a grade of B-.

In summary, APSR1 was assessed as being in good geomorphic condition. The desktop GIS assessment of subcatchment geomorphic condition found the Apsley River subcatchment to be in moderate condition with a grade of C+. Poor condition reaches were located on the Tablelands and good condition reaches in the Apsley gorge. The geomorphic condition at APSR1 (just upstream of the start of the gorge) was slightly better than the subcatchment average.

3.2.6.2 Riparian condition

The original riparian vegetation community at APSR1 (Plate 3.19) was described as 'New England Riparian Shrubland', Community 23 (Benson & Ashby, 2000), or 'Tea-tree shrubland of drainage areas of the slopes and tablelands', plant community type ID 1270 (VIS, 2012), broadly classed as 'Eastern Riverine Forests', (Keith, 2004). APSR1 received a good riparian condition score of 75.7, a grade of B- (Table 3.34).

The dominant canopy species present were eucalyptus species Manna Gum (*Eucalyptus viminalis*), Broad-leaved Stringybark (*E.caliginosa*), and Mountain Gum (*E.dalrympleana* subsp. *heptantha*). The dominant midstory species were tantoon (*Leptospermum polygalifolium* subsp. *transmontanum*), River Bottlebrush (*Callistemon sieberi*), Blackthorn (*Bursaria spinosa*). The understory was dominated by the native species Common Rush (*Juncus usitatus*), Tassel Sedge (*Carex fascicularis*), Spiny-headed Mat-rush (*Lomandra longifolia*), Native Geranium (*Geranium solanderi*) and the weed species Clover (*Trifolium* spp.), Plantain (*Plantago lanceolata*), Umbrella Sedge (*Cyperus eragrostis*), Coblers Pegs (*Bidens pilosa*), Fleabane (*Conyza bonariensis*), and the grasses Tall Fescue (*Festuca arundinaceae*) and Phalaris (*Phalaris aquatica*). The only vine species present was Blackberry (*Rubus* sp.), while the macrophyte layer included Broadleaf Cumbungi (*Typha orientalis*), Common Reed (*Phragmites australis*), River Club Rush (*Schoenoplectus validus*), Pin Rush (*Eleocharis acuta*) and submerged species such as Pondweed (*Potamogeton sulcatus*), Ribbonweed (*Vallisneria australis*), and Red Water-milfoil (*Myriophyllum verrucosum*).

Noxious weed species observed were Willow (*Salix* sp.) and Blackberry (*Rubus* sp.) (both class 4). In addition to those weed species listed above, other weed species included Ox-eye Daisy

(*Leucanthemum vulgare*), Spear Thistle (*Cirsium vulgare*), White Horehound (*Marrubium vulgare*) and Vetch (*Vicia* sp.).

Summary: APSR1 was a mildly disturbed system of mixed-aged closed woodland with remnant canopy and mixed native and exotic midstory and understory layers, in a partially cleared, partially forested landscape. The surrounding rural landuse was National Park and agricultural grazing land. APSR1 scored well for Habitat and Cover and moderately for Native Species, Debris and Management subindicators (Table 3.34), and contained representative elements of the remnant vegetation community in all structural layers. Disrupted vegetation continuity, the presence of weed and noxious weed species, particularly in the understory layer, contributed to a reduction in riparian grade at this site.

Management Recommendations: The current riparian condition could be improved by undertaking native plantings to increase riparian vegetation width and continuity and assist in site regeneration of native species, and through the control/removal of invasive weed species in the understory layer.

Plate 3.19 *Riparian vegetation at APSR1 was mildly disturbed. Riparian condition would be improved through the monitoring and removal of weed and noxious weed species such as Willow* (*Salix sp.*) *and Blackberry* (*Rubus* sp.), *and by undertaking native plantings.*

Table 3.34 *Site-level summary of riparian condition of Apsley River #1 showing the scores of individual indicators and the five subindices that comprise the Vegetation Condition Index.*

APSR1	Scores
HABITAT	**16.7/20**
Channel width	2.7
Proximity	4
Continuity	3
Layers	4
Large native trees	2
Hollow-bearing trees	1
NATIVE SPECIES	**14.5/20**
Native canopy species	4
Native midstory species	3
Native herb/forb species	1.5
Native graminoid species	2
Native macrophyte species	4
SPECIES COVER	**17/20**
Canopy species	2.5
Midstory species	2.5
Herb/forb species	4
Graminoid species	4
Macrophyte species	4
DEBRIS	**14/20**
Total leaf litter	1
Native leaf litter	2
Dead trees standing	2
Dead trees fallen	1
Lying logs	4
Fringing vegetation	4
MANAGEMENT	**13.5/20**
Tree clearing	3
Fencing	2
Animal impact	1.5
Species of interest	1
Exposed tree roots	3
Native woody regeneration	2
Weedy woody regeneration	1
TOTAL	**75.7/100**

3.2.6.3 Water quality

The Apsley River received a score of 37 (F) for water quality. Figures 3.7 and 3.8 show the key physicochemical and nutrient variables used in the assessment of water quality for the Tableland tributaries. Ranges and means for these variables are given in Table 3.35 and the exceedances are given in Table 3.28.

pH exceeded the upper ANZECC upland freshwater trigger value of 7.5 on all sampling occasions (Table 3.28). Turbidity did not exceed the ANZECC upland freshwater guideline during the sampling period (Figure 3.7b). DO% at APSR1 fell below the minimum ANZECC trigger threshold on 3 sampling occasions and exceeded the maximum ANZECC trigger threshold on 1 occasion (Table 3.28).

However, the exceedance of the maximum DO% trigger threshold did not coincide with a high chlorophyll *a* concentration, so was not indicative of high algal productivity. Algal productivity was relatively low at APSR1 (Figure 3.7c) and did not exceed the ANZECC trigger threshold (Table 3.28).

Concentrations of total nutrients were consistently high at APSR1, with both TN and TP concentrations exceeding the ANZECC upland freshwater trigger values on all sampling occasions (Table 3.28). The site minimum TN concentration was 1.2 times the trigger value and the site maximum TN concentration was 8 times the trigger value (Table 3.35). The site minimum TP concentration was 1.6 times the trigger value and the site maximum TP concentration was 3 times the trigger value (Table 3.35).

NOx concentrations exceeded the ANZECC upland freshwater trigger value of 25µg/L on 5 of the 6 sampling occasions at APSR1 (Table 3.28). The site maximum NOx concentration was 14 times the trigger value (Table 3.35). SRP concentrations exceeded the ANZECC upland freshwater trigger value of 15µg/L on 2 of the 6 sampling occasions at APSR1 (Table 3.28). The site maximum SRP concentration was 2.4 times the trigger value (Table 3.35).

Table 3.35 *Minimums, maximums and means of measured water quality variables for the Apsley, Tia and Yarrowitch Rivers.*

	APSR1			TIAR1			YARR1		
Variable	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**
Temperature (°C)	9.74	25.95	17.77	9.12	25.76	17.84	9.02	26.58	18.02
pH	7.58	9.24	8.44	7.55	9.16	8.30	7.87	9.49	8.62
EC	0.19	0.29	0.25	0.10	0.13	0.11	0.11	0.31	0.16
Salinity (PPT)	0.10	0.14	0.12	0.05	0.06	0.06	0.01	0.15	0.07
DO (mg/L)	3.32	9.76	7.07	3.19	10.34	6.94	4.14	10.45	7.44
DO %	41.70	119.30	80.95	39.00	100.50	77.65	51.30	106.40	84.30
Turbidity	4.70	9.30	7.18	11.80	24.60	17.08	6.40	8.80	7.57
Max Depth	0.25	0.50	0.35	0.00	1.00	0.56	0.40	0.40	0.40
Chla (µg/L)	0.73	2.70	1.40	0.02	2.07	0.91	0.17	11.43	2.60
TSS (mg/L)	1.60	4.56	2.73	0.95	9.88	3.49	1.07	85.60	18.14
TN (µg/L)	294.91	1961.8	1222.5	140.63	2300.8	822.43	288.14	2288.1	909.92
TP (µg/L)	31.18	51.48	41.69	23.26	112.83	52.18	23.82	61.79	43.97
NOx (µg/L)	17.04	348.64	166.52	0.20	366.97	167.80	0.20	642.20	260.00
SRP (µg/L)	7.49	36.70	16.37	0.48	65.64	22.07	1.03	41.49	25.61

3.2.6.4 Aquatic macroinvertebrates

ASPR1 recorded 1091 and 283 individual macroinvertebrates across 40 and 19 macroinvertebrate families during the 2015 autumn and spring sampling, respectively (Table 3.36). In autumn, abundance was dominated by Chironomid Midges and Hydropsychid Caddisflies (348 and 236 individuals, respectively), and richness was dominated by Coleoptera (Aquatic Beetles with 8 families). In contrast, although Atyidae (Freshwater Shrimps) were the most abundant family in spring (137 individuals), the most diverse orders in spring were Ephemeroptera (Mayflies) and Trichoptera (Caddisflies) (with 4 families each). Family richness and total abundance were significantly higher in autumn than spring, likely due to the extreme low flows preceeding and during the spring sampling event. There were a number of rare taxa at the site, with 16 and 11 taxa recording fewer than 5 individuals in autumn and spring, respectively.

Despite the significant difference in total abundance and family richness between seasons at ASPR1, mean SIGNAL2 scores were similar between autumn (4.6) and spring (4.0), and the range of SIGNAL2 scores did not change between seasons. The decrease in the mean SIGNAL2 at ASPR1 in spring was due to the reduced presence of high-scoring biota, with only 29 of the 283 individuals sampled in spring having SIGNAL2 scores greater than 5.

ASPR1 received an overall Ecohealth score of 44, a grade of F, for aquatic macroinvertebrate community condition. All macroinvertebrate indicators were below the Macleay catchment average, particularly family richness and EPT (Table 3.13). The macroinvertebrate indicators suggest the water quality and habitat conditions in the Apsley River immediately upstream of the gorge are in very poor condition, but are able to support a diversity of macroinvertebrate fauna given the wide range of SIGNAL2 scores.

Table 3.36 *Summary of aquatic macroinvertebrate data for the Apsley, Tia and Yarrowitch Rivers.*

	ASPR1		TIA1		YARR1	
Macroinvertebrate indicator	**Autumn 2015**	**Spring 2015**	**Autumn 2015**	**Spring 2015**	**Autumn 2015**	**Spring 2015**
Total abundance	1091	283	809	575	940	791
Family richness	40	19	22	24	41	38
EPT abundance	325	21	63	10	262	232
EPT richness	11	4	5	6	11	15
Mean SIGNAL2 score	4.6	4.0	2.7	1.9	4.6	5.0
SIGNAL2 score range	1 - 8	1 - 8	1 - 8	1 - 8	1 - 9	1 - 9
Ecohealth score (grade)	**44 (F)**		**26 (F)**		**63 (C-)**	

3.2.7 Tia River (TIAR1)

3.2.7.1 Geomorphic condition

The geomorphic River Style at Tia River #1 (TIAR1) is partially confined valley setting: bedrock controlled, fine grained. The bed sediments in the site reach were dominated by fine grained sediments (>60% fine sediment). Banks comprised cohesive fine grained sediments with severe bank erosion concentrated as severe (20-100m) undercutting along the left bank and significant (10-20m) undercutting along the right bank. There was significant (10-20m) slumping of the left bank and moderate (5-10m) slumping of the right bank. Geomorphic complexity was poor, with the site comprising a run. TIAR1 scored 41, an F for BANK CONDITION and 68, a C, for BED CONDITION. The overall geomorphic condition for TIAR1 was 55, a grade of D.

In summary, TIAR1 was assessed as being in poor geomorphic condition, with bank erosion the most significant issue for site-level geomorphic condition. Fencing the riparian zone to exclude stock and allow for regeneration of native revegetation would assist to improve geomorphic condition at this site. The desktop GIS assessment of subcatchment geomorphic condition found the Tiar River subcatchment to be in moderate condition with a grade of C+. The geomorphic condition at TIAR1 was slightly below the subcatchment average.

3.2.7.2 Riparian condition

High historic disturbance at TIAR1 (Plate 3.20) has resulted in a highly modified riparian zone that predominantly comprises exotic species. However, the original riparian vegetation community at TIAR1 could have been described as 'New England Riparian Shrubland', Community 23 (Benson & Ashby, 2000), or 'Tea-tree shrubland of drainage areas of the slopes and tablelands', plant community type ID 1270 (VIS, 2012), broadly classed as 'Eastern Riverine Forests', (Keith, 2004). However, very little original riparian vegetation remains and TIAR1 received a very poor riparian condition score of 29.8, a grade of F (Table 3.37).

The dominant canopy species present were Willow (*Salix* sp.) and Wattle-leaved Peppermint (*Eucalyptus acciaformis*). There were no midstory species onsite. The understory was dominated by Common Rush (*Juncus usitatus*), and the exotic species Haresfoot Clover (*Trifolium arvense*), Plantain (*Plantago lanceolata*), Ox-eye Daisy (*Leucanthemum vulgare*), Fleabane (*Conyza bonariensis*) and the grasses Tall Fescue (*Festuca arundinaceae*), Yorshire Fog (*Holcus lanatus*), Prairie Grass (*Bromus catharticus*), Cocksfoot (*Dactylis glomerata*) and Phalaris (*Phalaris aquatica*). Vine species present were exotic: Japanese Honeysuckle (*Lonicera japonica*) and Blackberry (*Rubus* sp.), while the macrophyte layer was made up of native species and included River Duck Weed (*Azolla* sp.), Pondweed (*Potamogeton sulcatus*) and Water-milfoil (*Myriophyllum* sp.).

Noxious weed species observed were Willow (*Salix* sp.), Blackberry (*Rubus* sp.) and Japanese Honeysuckle (*Lonicera japonica*), all class 4 noxious weed species. In addition to those already mentioned, other weed species present included Purpletop (*Verbena bonariensis*), Spear Thistle (*Cirsium vulgare*), Mullein species (*Verbascum Thapsus* and *V.virgatum*), Wild Carrot (*Daucus carota*) and Sweet Vernal Grass (*Anthoxanthum odoratum*).

Summary: TIAR1 was an extremely disturbed system in a predominantly cleared landscape of scattered native and exotic species, with an exotic midstory and mixed understory layers. The surrounding rural landuse was agricultural grazing land. Significant remnant stands of vegetation lie 3.5km to the north of TIAR1 in National Park. TIAR1 scored poorly in all indices except cover which received a moderate grade (Table 3.37). Representative elements of the remnant vegetation community were present throughout each structural layer as minor components except in the macrophyte layer, where native species dominated. Devoid riparian vegetation width and continuity, poor habitat connectivity, the presence of weed and noxious weed species, a lack of woody debris and inadequate riparian fencing were all factors contributing to the poor riparian grade at this site.

Management Recommendations: Riparian condition could be improved through control/removal of invasive weed species and by undertaking native plantings to increase riparian vegetation width and continuity and assist in site regeneration of native species. Such plantings assist in phasing out and replacing dominant canopy weed species such as Willow. Riparian fencing should exclude livestock and, if strategically implemented, could be used in combination with native plantings to increase riparian vegetation width and continuity. Lastly, structural works using best practice techniques such as rock revetment at the toe of the bank will improve bank stability. This may include the introduction of large woody debris which would also promote niche habitats for native woody regeneration, provide habitat for native animal species, and as instream snags, can redirect or reduce water energy from banks, reducing bank erosion.

Plate 3.20 *Riparian vegetation at TIAR1 was extremely disturbed. Riparian condition would be improved through the monitoring and removal of weed and noxious weed species such as Blackberry* (Rubus sp.) *and Japanese Honeysuckle* (Lonicera japonica)*, strategically phasing out Willow* (Salix sp.)*, undertaking native plantings, introducing woody debris and fencing off the riparian zone*.

***Table 3.37** Site-level summary of riparian condition of Tia River #1 showing the scores of individual indicators and the five subindices that comprise the Vegetation Condition Index.*

TIAR1	Scores
HABITAT	**3.3/20**
Channel width	0.3
Proximity	0
Continuity	0
Layers	2
Large native trees	1
Hollow-bearing trees	0
NATIVE SPECIES	**7/20**
Native canopy species	2
Native midstory species	0
Native herb/forb species	1
Native graminoid species	0
Native macrophyte species	4
SPECIES COVER	**11.5/20**
Canopy species	0.5
Midstory species	0
Herb/forb species	4
Graminoid species	4
Macrophyte species	3
DEBRIS	**6/20**
Total leaf litter	1
Native leaf litter	1.5
Dead trees standing	0
Dead trees fallen	0
Lying logs	1
Fringing vegetation	2.5
MANAGEMENT	**2/20**
Tree clearing	0
Fencing	1
Animal impact	0
Species of interest	0
Exposed tree roots	0
Native woody regeneration	0
Weedy woody regeneration	1
TOTAL	**29.8/100**

3.2.7.3 Water quality

The Tia River received a score of 48 (D-) for water quality. Figures 3.7 and 3.8 show the key physicochemical and nutrient variables used in the assessment of water quality for the Tableland tributaries. Ranges and means for these variables are given in Table 3.35 and the exceedances are given in Table 3.28.

pH exceeded the upper ANZECC upland freshwater trigger value of 7.5 on all sampling occasions (Table 3.28). TIAR1 had significantly higher turbidity than APSR1 or YARR1 in similar river systems (Figure 3.7d), but still did not exceed ANZECC upland freshwater guideline of 25NTU (Table 3.28). DO% fell below the minimum ANZECC trigger threshold on 3 sampling occasions, with a site minimum of 38% (Tables 3.28, 3.35).

Concentrations of total nutrients were consistently high at TIAR1, with TN and TP concentrations exceeding the ANZECC upland freshwater trigger values on 5 and 6 sampling occasions, respectively (Table 3.28). The maximum TN concentration was 9 times the trigger value (Table 3.35). The site minimum TP concentration was 1.2 times the trigger value and the site maximum TP concentration was 5.6 times the trigger value (Table 3.35).

There were fewer exceedances of dissolved nutrients, with NOx and SRP concentrations both exceeding the ANZECC upland freshwater trigger values on 4 of the 6 sampling occasions at TIAR1 (Table 3.28). The site maximum NOx concentration was 15 times the trigger value (Table 3.35). The site maximum SRP concentration was 4.4 times the trigger value (Table 3.35).

However, high nutrient concentrations did not correlate with increased algal productivity in the Tia River during the sampling period (Figure 3.7). Chlorophyll *a* concentrations remained below the ANZECC upland freshwater trigger value of 4µg/L at all times (Table 3.28).

3.2.7.4 Aquatic macroinvertebrates

TIAR1 recorded 809 and 575 individual macroinvertebrates across 22 and 24 macroinvertebrate families during the 2015 autumn and spring sampling, respectively (Table 3.36). In autumn, abundance was dominated by Dytiscidae (predacious Diving Beetles, 228 individuals) and richness was also dominated by Coleoptera (Aquatic Beetles, 5 families). In contrast, Notonectidae (Backswimmers) were the most abundant family in spring (300 individuals), and the most diverse order in spring remained Coleoptera (Aquatic Beetles) with 6 families. There were a number of rare taxa at the site, with 9 and 14 taxa recording fewer than 5 individuals in autumn and spring, respectively.

Mean SIGNAL2 scores for TIAR1 were very different between autumn (2.7) and spring (1.9), although the range of SIGNAL2 scores did not change between seasons. The decrease in the mean SIGNAL2 at TIAR1 in spring was due to a combination of high abundances of low-scoring biota (e.g. Notonectidae) and the absence of Leptocerid Caddisflies with SIGNAL2 of 6.

TIAR1 received an overall Ecohealth score of 26, a grade of F, for aquatic macroinvertebrate community condition. All macroinvertebrate indicators were below the Macleay catchment average, particularly EPT and mean SIGNAL2 score (Table 3.13). The macroinvertebrate indicators suggest the water quality and habitat conditions in the Tia River upstream of the gorge are in very poor condition, but are able to support a diversity of macroinvertebrate fauna given the wide range of SIGNAL2 scores.

3.2.8 Yarrowitch River (YARR1)

3.2.8.1 Geomorphic condition

The geomorphic River Style at Yarrowitch River #1 (YARR1) is partially confined valley setting: planform controlled, meandering, fine grained. The bed sediments comprised sub-angular gravel in a matrix dominated framework containing >60% fine sediments. Banks comprised fine grained sediments with severe bank erosion (20-100m) concentrated as severe undercutting (20-100m) along both banks. There was also severe (20-100m) slumping of both banks. Geomorphic complexity was moderate, with the site comprising a riffle and pool sequence (30 and 70% of the reach length, respectively). YARR1 scored 41, an F for BANK CONDITION and 68, a C, for BED CONDITION. The overall geomorphic condition for YARR1 was 54, a grade of D.

In summary, YARR1 was assessed as being in poor geomorphic condition, with bank erosion the most significant issue for site-level geomorphic condition. The desktop GIS assessment of subcatchment geomorphic condition found the Yarrowitch River subcatchment to be in good condition with a grade of B. The Yarrowitch River subcatchment comprises Tablelands (moderate geomorphic condition) and gorge country (good geomorphic condition). The geomorphic condition at YARR1 was below the subcatchment average.

3.2.8.2 Riparian condition

The original riparian vegetation community at YARR1 (Plate 3.21) was described as 'New England Riparian Shrubland', Community 23 (Benson & Ashby, 2000), or 'Tea-tree shrubland of drainage areas of the slopes and tablelands', plant community type ID 1270 (VIS, 2012), broadly classed as 'Eastern Riverine Forests', (Keith, 2004). YARR1 received a low riparian condition score of 56.5, a grade of D+ (Table 3.38).

The dominant canopy species present were eucalyptus species Manna Gum (*Eucalyptus viminalis*), Broad-leaved Stringybark (*E.caliginosa*), and Willow (*Salix* sp.). The dominant midstory species were the native tantoon (*Leptospermum polygalifolium* subsp. *transmontanum*) and River Bottlebrush (*Callistemon sieberi*). The understory was dominated by the native species Spiny-headed Mat-rush (*Lomandra longifolia*), Common Rush (*Juncus usitatus*), Swamp Dock (*Rumex brownii*), Winged Everlasting (A*mmobium alatum*), Snow Grass (*Poa siebriana*), and Water Couch (*Paspalum distichum*) and the exotic species Ox-eye Daisy (*Leucanthemum vulgare*), Wild Carrot (*Daucus carota*), Umbrella Sedge (*Cyperus eragrostis*), Spear Thistle (*Cirsium vulgare*), Tall Fescue (*Festuca arundinaceae*) and Yorshire Fog (*Holcus lanatus*). The only vine species present was Blackberry (*Rubus* sp.), while the macrophyte layer included Broadleaf Cumbungi (*Typha orientalis*), Common Reed (*Phragmites australis*), River Club Rush (*Schoenoplectus validus*), Marsh Club-rush (*Bolboschoenus fluviatilis*) and submerged species such as Pondweeds (*Potamogeton pefoliatus* and *P.sulcatus*) and Freshwater Eelweed (*Vallisneria nana*).

Noxious weed species observed were Willow (*Salix* sp.), Blackberry (*Rubus* sp.) and St. Johns Wort (*Hypericum perforatum*) (All class 4). In addition to those already mentioned, other weed species present included Sweet Briar (*Rosa rubiginosa*), Purpletop (*Verbena bonariensis*), Plantain (*Plantago lanceolata*), Fleabane (*Conyza bonariensis*), Cocksfoot (*Dactylis glomerata*) and Phalaris (*Phalaris aquatica*).

Summary: YARR1 was a highly disturbed mixed-aged woodland with remnant canopy and mixed exotic and native species throughout the midstory and understory layers, in a predominantly cleared, partially forested landscape. The surrounding rural landuse was a mix of grazing, forestry and National Park. Significant remnant stands of vegetation lay 600m to the north of YARR1 in National Park, with the immediate surrounding landuse predominantly grazing or forestry. YARR1 scored well for Habitat and Cover and moderately for Native Species, Debris and Management subindicators (Table 3.38), and contained representative elements of the remnant vegetation community in all structural layers. Disrupted vegetation width and continuity, the presence of weed and noxious weed species, a lack of woody debris and inadequate riparian fencing all contributed to the reduction in riparian grade at this site.

Management Recommendations: Riparian condition could be improved through control/removal of invasive weed species, and by undertaking native plantings to increase riparian vegetation width and continuity and assist in site regeneration of native species. Such plantings assist in phasing out and replacing dominant canopy weed species such as Willow. Riparian fencing should exclude livestock and, if strategically implemented, could be used in combination with native plantings to increase riparian vegetation width and continuity. Lastly, the introduction of large woody debris back into this system using best practice techniques could stabilise river banks in the long term, promote niche habitats for native woody regeneration, provide habitat for native animal species, and as instream snags, can redirect or reduce water energy from banks, reducing bank erosion.

Plate 3.21 *Riparian vegetation at YARR1 was highly disturbed. Riparian condition would be improved through the monitoring and removal of weed and noxious weed species such as Blackberry* (Rubus sp.)*, strategically phasing out Willow* (Salix sp.)*, undertaking native plantings, introducing woody debris and fencing off the riparian zone.*

Table 3.38 *Site-level summary of riparian condition of Yarrowitch River #1 showing the scores of individual indicators and the five subindices that comprise the Vegetation Condition Index.*

YARR1	Scores
HABITAT	**10.5/20**
Channel width	2
Proximity	2
Continuity	1.5
Layers	3
Large native trees	1
Hollow-bearing trees	1
NATIVE SPECIES	**12.5/20**
Native canopy species	4
Native midstory species	2.5
Native herb/forb species	1
Native graminoid species	1
Native macrophyte species	4
SPECIES COVER	**15.5/20**
Canopy species	1.5
Midstory species	2
Herb/forb species	4
Graminoid species	4
Macrophyte species	4
DEBRIS	**8.5/20**
Total leaf litter	1
Native leaf litter	1.5
Dead trees standing	1
Dead trees fallen	0
Lying logs	2
Fringing vegetation	3
MANAGEMENT	**9.5/20**
Tree clearing	1.5
Fencing	1
Animal impact	0
Species of interest	1
Exposed tree roots	3
Native woody regeneration	2
Weedy woody regeneration	1
TOTAL	**56.5/100**

3.2.8.3 Water quality

The Yarrowitch River received a score of 44 (F) for water quality. Figures 3.7 and 3.8 show the key physicochemical and nutrient variables used in the assessment of water quality for the Tableland tributaries. Ranges and means for these variables are given in Table 3.35 and the exceedances are given in Table 3.28.

pH exceeded the upper ANZECC upland freshwater trigger value of 7.5 on all sampling occasions (Table 3.28). YARR1 had the smallest range and lowest site mean for turbidity of all the tableland sites (Figure 3.7d), and did not exceed the ANZECC upland freshwater guideline of 25NTU (Table 3.28). DO% fell below the minimum ANZECC trigger threshold on 3 sampling occasions during the extreme low flows during the austral spring (Table 3.28), although the site minimum of 51% remained higher than APSR1 or TIAR1 in similar river systems.

Concentrations of total nutrients were consistently high at YARR1, with both TN and TP concentrations exceeding the ANZECC upland freshwater trigger values on all sampling occasions (Table 3.28). The site minimum TN concentration was 1.2 times the trigger value and the site maximum TN concentration was 9 times the trigger value (Table 3.35). The site minimum TP concentration was 1.2 times the trigger value and the site maximum TP concentration was 3 times the trigger value (Table 3.35).

Similar to the Tia River, there were fewer exceedances of dissolved nutrient concentrations in the Yarrowitch River. NOx concentrations exceeded the ANZECC upland freshwater trigger value of 25µg/L on 3 of the 6 sampling occasions (Table 3.28). The site maximum NOx concentration was 26 times the trigger value (Table 3.35). SRP concentrations exceeded the ANZECC upland freshwater trigger value of 15µg/L on 4 of the 6 sampling occasions at APSR1 (Table 3.28). The site maximum SRP concentration was 2.8 times the trigger value (Table 3.35).

High nutrient concentrations likely contributed to the single exceedance of chlorophyll *a* in the austral spring (when the site maximum of 11.43µg/L was almost 3 times the ANZECC trigger value). This peak algal productivity at YARR1 occurred during the site SRP maximum (41.49µg/L or almost 3 times the trigger value).

3.2.8.4 Aquatic macroinvertebrates

YARR1 recorded 940 and 791 individual macroinvertebrates across 41 and 38 macroinvertebrate families during the 2015 autumn and spring sampling, respectively (Table 3.36). In autumn, abundance was dominated by Platycnemid Damselflies (240 individuals) and richness was dominated by Trichoptera (Caddisflies with 11 families). Although Baetid Mayflies were the most abundant family in spring (270 individuals), the dominant order in spring remained Trichoptera (Caddisflies) with 10 families. Family richness was higher in autumn than spring, primarily due to higher diversities of Ephemeroptera (Mayflies) and Trichoptera (Caddisflies). There were a number of rare taxa at the site, with 19 and 16 taxa recording fewer than 5 individuals in autumn and spring, respectively.

Mean SIGNAL2 scores for YARR1 were slightly different between autumn (4.6) and spring (5.0), although the range of SIGNAL2 scores did not change between seasons. The increase in the mean SIGNAL2 at YARR1 in spring was due to high abundances of low scoring biota in autumn (e.g. the Platycnemid Damselflies with a SIGNAL2 score of 2).

YARR1 received an overall Ecohealth score of 63, a grade of C-, for aquatic macroinvertebrate community condition. Only mean SIGNAL2 score for YARR1 was below the Macleay catchment average, and the other three macroinvertebrate indicators were at or above the catchment average (Table 3.13). The macroinvertebrate indicators suggest the water quality and habitat conditions in the Yarrowtich River are in moderate-good condition, and are able to support a diversity of macroinvertebrate fauna given the wide range of SIGNAL2 scores.

3.2.9 Bakers Creek (BAKC1)

3.2.9.1 Geomorphic condition

The geomorphic River Style at Bakers Creek #1 (BAKC1) is confined valley setting: gorge. The bed sediments comprised angular cobbles in a framework dilated matrix containing 32-60% fine sediments. Banks comprised cobbles and bedrock with minimal erosion. There was no erosion on the right bank and minimal undercutting (<5m) of the left bank. Geomorphic complexity was good, with the site comprising pool - rapid sequences (50% each of reach length). BAKC1 scored 75, a C+ for BANK CONDITION and 77, a B-, for BED CONDITION. The overall geomorphic condition for BAKC was 76, a grade of B-.

In summary, BAKC1 was assessed as being in good geomorphic condition, with minor bank erosion the most significant issue for site-level geomorphic condition. The desktop GIS assessment of subcatchment geomorphic condition found the Bakers Creek subcatchment to be in moderate condition with a grade of C-. The geomorphic condition at BAKC1 was above the subcatchment average.

3.2.9.2 Riparian condition

The original riparian vegetation community at BAKC1 (Plate 3.22) was described as 'River Oak open forest of major streams, Sydney Basin Bioregion and South East Corner Bioregion', plant community type ID 1105 (VIS, 2012), broadly classed as 'Eastern Riverine Forests (Keith, 2004), grading into Blakely's Red Gum - Yellow Box grassy open forest or woodland of the New England Tableland Bioregion, plant community type ID 704 (VIS, 2012), broadly classed as 'New England Grassy Woodlands' (Keith, 2004), a recognized TEC (VIS, 2012). BAKC1 received a very good riparian condition score of 82, a grade of B (Table 3.39).

The dominant canopy species present were River Oak (*Casuarina cunninghamiana* subsp. *cunninghamiana*), Blakely's Red Gum (*Eucalyptus blakelyi*), Yellow Box (*Eucalyptus melliodora*) and Hard Alectryon (*Alectryon subdentatus f. subdentatus*). Dominant native midstory species included Sandpaper Fig (*Ficus coronata*), Tantoon (*Leptospermum polygalifolium* subsp. *transmontanum*), Tree Violet (*Melicytus dentatus*), and Wattles (*Acacia leiocalyx* and *A.dealbata*). The understory was dominated by native species Lomandra (*Lomandra longifolia*), Slender Knotweed (*Persicaria decipiens*), Stinging Nettle (*Urtica incisa*) Hard Water Fern (*Blechnum wattsii*), Scurvy Weed (*Commelina cyanea*), Common Everlasting (*Chrysocephalum apiculatum*), Swamp Dock (*Rumex brownii*) and Australian Basket Grass (*Oplismenus aemulus*), along with exotic species Purpletop (*Verbena bonariensis*), Fleabane (*Conyza bonariensis*), Cobblers Pegs (*Bidens pilosa*), Mouse-ear Chickweed (*Cerastium glomeratum*), Cat's Ear (*Hypochaeris radicata*), Prairie Grass (*Bromus catharticus*), Cocksfoot (*Dactylis glomerata*). A rich vine layer included the native species Native Raspberry (*Rubus parvifolius*), Silkpod (*Parsonsia straminea*), Snake Vine (*Stephania japonica*), Wonga Wonga Vine (*Pandorea pandorana*) and the exotic species Blackberry (*Rubus* sp.), while Stonewort (*Chara* sp.) was the only macrophyte present.

The one noxious weed species observed onsite was Blackberry (*Rubus* sp.), a class 4 noxious weed. Aside from those previously mentioned other weed species present included, Spear Thistle (*Cirsium vulgare*), Plantain (*Plantago lanceolata*) and Prickly Sowthistle (*Sonchus asper*).

Summary: BAKC1 was a low disturbance system of mature closed woodland with remnant canopy and midstory layers and mixed native and exotic species throughout the understory layer, in a forested landscape. The surrounding landuse was private lease under mining exploration and National Park. Significant remnant stands of vegetation surround the BAKC1 site on all sides in both the land owned by Hillgrove Resources Mine and in Oxley Wild Rivers National Park. BAKC1 scored full marks for Habitat, well for Native Species, Cover and Debris, and moderately for Management subindicators (Table 3.39), retaining representative elements of the remnant vegetation community in all structural layers. While riparian condition at BAKC1 was very good, the site was impacted by the presence of weed and noxious weed species, low species diversity in the macrophyte structural layer and grazing by feral animals.

Management Recommendations: Riparian condition could be improved through the control and removal of weed and noxious weed species, particularly throughout the understory layer. Controlling pest animal species that graze the site understory will promote native species regeneration and recruitment, decrease streambank erosion and limit the growth and spread of weedy species.

Plate 3.22 *Riparian vegetation at BAKC1 was of low disturbance. Riparian condition would be improved through control and removal of weed and noxious weed species specifically Blackberry* (Rubus sp.) *and by limiting animal impact by feral species.*

***Table 3.39** Site-level summary of riparian condition of Bakers Creek #1 showing the scores of individual indicators and the five subindices that comprise the Vegetation Condition Index.*

BAKC1	Scores
HABITAT	**20/20**
Channel width	4
Proximity	4
Continuity	4
Layers	4
Large native trees	2
Hollow-bearing trees	2
NATIVE SPECIES	**15/20**
Native canopy species	4
Native midstory species	4
Native herb/forb species	3
Native graminoid species	3
Native macrophyte species	1
SPECIES COVER	**18/20**
Canopy species	4
Midstory species	4
Herb/forb species	4
Graminoid species	4
Macrophyte species	2
DEBRIS	**16/20**
Total leaf litter	3
Native leaf litter	3
Dead trees standing	3
Dead trees fallen	2
Lying logs	3
Fringing vegetation	2
MANAGEMENT	**13/20**
Tree clearing	3
Fencing	3
Animal impact	0
Species of interest	1
Exposed tree roots	3
Native woody regeneration	2
Weedy woody regeneration	1
TOTAL	**82/100**

3.2.9.3 Water quality

Bakers Creek received a score of 59 (D-) for water quality. Figures 3.7 and 3.8 show the key physicochemical and nutrient variables used in the assessment of water quality for the Tableland tributaries. Ranges and means for these variables are given in Table 3.40 and the exceedances are given in Table 3.28. These variables do not include the analysis of heavy metal contamination due to historical mining; this is reported separately in Section 3.3.5.

pH exceeded the upper ANZECC upland freshwater trigger value of 7.5 on 4 of the 6 sampling occasions (Table 3.28), although the range and site mean for BAKC1 was lower than the rest of the Tableland tributaries (Figure 3.7). BAKC1 also had very low turbidity (Figure 3.7d), and did not exceed the ANZECC upland freshwater guideline during the sampling period (Table 3.28). This is likely due to the extreme low flows experienced through Bakers Creek for most of the sampling period. These extreme low flows also impacted dissolved oxygen, with DO% at BAKC1 falling below the minimum ANZECC trigger threshold on all sampling occasions. The site minimum DO% was 36% (Table 3.40).

With the exception of TN, concentrations of nutrients were consistently lower at BAKC1 than most Tableland tributary sites (Figure 3.8). However, both TN and TP concentrations exceeded the ANZECC upland freshwater trigger values on all sampling occasions (Table 3.28). The site minimum TN concentration was 1.3 times the trigger value and the site maximum TN concentration was 7 times the trigger value (Table 3.35). The site minimum TP concentration was 1.6 times the trigger value and the site maximum TP concentration was 2.1 times the trigger value (Table 3.35).

NOx concentrations exceeded the ANZECC upland freshwater trigger value of 25µg/L on all sampling occasions at BAKC1 (Table 3.28). The site minimum NOx concentration was 1.1 times the trigger value and the site maximum NOx concentration was 13 times the trigger value (Table 3.40). SRP concentrations were relatively low at Bakers Creek, only exceeding the ANZECC upland freshwater trigger value of 15µg/L on 2 of the 6 sampling occasions (Table 3.28). The site maximum SRP concentration was 1.4 times the trigger value (Table 3.40).

High nutrient concentrations did not lead to high algal productivity at Bakers Creek, with only one exceedance, the site maximum chlorophylla *a* concentration of 4.11µg/L (ANZECC trigger value of 4 µg/L). All other chlorophyll *a* concentrations were well below the trigger value.

Table 3.40 *Minimums, maximums and means of measured water quality variables for Bakers Creek.*

	BAKC1		
Variable	**Min**	**Max**	**Mean**
Temperature (°C)	10.22	25.31	16.34
pH	7.41	9.82	8.45
EC	0.31	0.43	0.37
Salinity (PPT)	0.15	0.20	0.17
DO (mg/L)	2.84	11.47	6.33
DO %	35.80	119.10	71.20
Turbidity	6.10	49.50	20.33
Max Depth	0.3	0.6	0.3
Chla (µg/L)	0.03	4.11	0.93
TSS (mg/L)	171.43	2203.39	1255.51
TN (µg/L)	312.56	1622.88	1023.10
TP (µg/L)	21.31	41.38	33.19
NOx (µg/L)	27.52	515.66	204.19
SRP (µg/L)	7.13	20.33	13.41

3.2.9.4 Aquatic macroinvertebrates

BAKC1 recorded 864 and 1301 individual macroinvertebrates across 40 and 33 macroinvertebrate families during the 2015 autumn and spring sampling, respectively (Table 3.41). In autumn, abundance was dominated by Leptocerid Caddisflies and Leptophlebiid Mayflies (212 and 196 individuals, respectively) and richness was also dominated by Trichoptera (Caddisflies) (9 families). In spring, Leptophlebiidae Mayflies were the most abundant family (430 individuals), and richness was dominated by Coleoptera (Aquatic Beetles) with 8 families. Family richness was higher in spring than autumn, primarily driven by the presence of aquatic beetles in spring. There were a number of rare taxa at the site, with 12 taxa recording fewer than 5 individuals in autumn and spring.

Mean SIGNAL2 scores for BAKC1 were similar between autumn (5.6) and spring (5.9) and the range of SIGNAL2 scores did not change between seasons.

BAKC1 received an overall Ecohealth score of 69, a grade of C, for aquatic macroinvertebrate community condition. This was a surprising result given the heavy metal contamination known to be at this site (Section 3.3.3.5). All macroinvertebrate indicators were above the Macleay catchment average (Table 3.13). The macroinvertebrate indicators suggest the habitat conditions in the Bakers Creek gorge are in good condition, and a diversity of macroinvertebrate fauna can tolerate the heavy metal contamination at this site, including six taxa of EPT with SIGNAL2 scores of 8.

Table 3.41 *Summary of aquatic macroinvertebrate data for Bakers Creek.*

	BAKC1	
Macroinvertebrate indicator	**Autumn 2015**	**Spring 2015**
Total abundance	864	1301
Family richness	40	33
EPT abundance	280	659
EPT richness	13	8
Mean SIGNAL2 score	5.6	5.9
SIGNAL2 score range	1-8	1-8
Ecohealth score (grade)	**69 (C)**	

3.2.10 Wollomombi River (WOLR1)

3.2.10.1 Geomorphic condition

The geomorphic River Style at Wollomombi River #1 (WOLR1) is confined valley setting: gorge. The bed sediments comprised angular cobbles in a matrix dominated framework containing >60% fine sediments. Banks comprised sandy sediments with significant bolders and cobbles. There was moderate (5-10m) slumping of both banks but no undercutting. Geomorphic complexity was good, with the site comprising a rapid, riffle, glide and run (10, 25, 35 and 30% of the reach, respectively). WOLR1 scored 63, a C- for BANK CONDITION and 85, a B, for BED CONDITION. The overall geomorphic condition for WOLR1 was 74, a grade of C+.

In summary, WOLR1 was assessed as being in moderate geomorphic condition, with localized bank slumping the most significant issue for site-level geomorphic condition. The desktop GIS assessment of subcatchment geomorphic condition found the Chandler River subcatchment (including the Wollomombi River) to be in moderate condition with a grade of C. The geomorphic condition at WOLR1 was slightly above the subcatchment average.

3.2.10.2 Riparian condition

The original riparian vegetation community at WOLR1 (Plate 3.23) was described as 'River Oak forest and woodland wetland of the NSW South Western Slopes and South Eastern Highlands Bioregion', plant community type ID 85 (VIS, 2012), broadly classed as 'Eastern Riverine Forests', (Keith, 2004). WOLR1 received a moderate riparian condition score of 68.8, a grade of C (Table 3.42).

The dominant canopy species present were River Oak (*Casuarina cunninghamiana subsp. cunninghamiana*), Broad-leaved Stringybark (*Eucalyptus caliginosa*) and the exotic Willow (*Salix* sp.). Dominant midstory species included River Bottlebrush (*Callistemon sieberi*), Tantoon (*Leptospermum polygalifolium* subsp. *transmontanum*), Blackthorn (*Bursaria spinosa*) and Fern-leaved Wattle (*Acacia filicifolia*). The understory was dominated by native species Native Clover (*Lespedeza juncea*), Spiny-headed Mat-rush (*Lomandra longifolia*), Common Rush (*Juncus usitatus*), Rice grass (*Microlaena stipoides*), Couch (*Cynodon dactylon*), and Slender Rat's Tail Grass (*Sporobolus crebra*) along with the exotic species Blue Water Speedwell (*Veronica anagallis-aquatica*), Umbrella Sedge (*Cyperus eragrostis*), Purpletop (*Verbena bonariensis*), Sidratusa (*Sida rhombifolia*), Turnip Weed (*Rapistrum rugosum*), Fleabane (*Conyza bonariensis*), Spear Thistle (*Cirsium vulgare*), Cobblers Pegs (*Bidens pilosa*), Silvery Hairgrass (*Aira cupaiana*) and Prairie Grass (*Bromus catharticus*). The only vine species present was Blackberry (*Rubus* sp.), while the macrophyte layer included Common Reed (*Phragmites australis*), Triangular Club Rush (*Schoenoplectiella mucronata*) and the submerged species Varied Water Milfoil (*Myriophyllum variifolium*).

Noxious weed species observed were Willow (*Salix* sp.) and Blackberry (*Rubus* sp.), both class 4 weeds. In addition to those already mentioned, other weed species present included Clover species

(*Trifolium* spp.), Cat's Ear (*Hypochaeris radicata*), Prickly Sowthistle (*Sonchus asper*), Watercress (*Rorippa* sp.), Plantain (*Plantago lanceolata*) and Common Thornapple (*Datura stramonium*).

Summary: WOLR1 was a moderately disturbed system of mature forest with a predominantly remnant canopy and midstory and mixed native and exotic species throughout the understory layer, in a predominantly cleared, partially wooded landscape. The surrounding rural landuse was a mixture of agricultural grazing land and National Park (1.2km to the south). WOLR1 contained representative elements of the remnant vegetation community in all structural layers, scoring well for Habitat and Cover, and moderately for Native Species, Debris and Management subindicators (Table 3.42). Riparian condition at WOLR1 was most affected by the presence and regeneration of weed and noxious weed species, particularly throughout the understory layer. A lack of woody debris and inadequate riparian fencing all contributed to the reduced riparian grade at this site.

Management Recommendations: Riparian condition could be improved through the control and removal of weed and noxious weed species, particularly in the understory layer. Riparian fencing should exclude livestock, allow midstory recovery and limit the removal of woody debris from the TSR. The accumulation of woody debris stabilise river banks in the long term, promote niche habitats for native woody regeneration, provide habitat for native animal species, and as instream snags, can redirect or reduce water energy from banks, reducing bank erosion.

Plate 3.23 *Riparian vegetation at WOLR1 was moderately disturbed. Riparian condition would be improved through the monitoring and removal of weed and noxious weed species such as Blackberry* (Rubus sp.)*, strategically phasing out Willow* (Salix sp.) *and by fencing off the riparian zone.*

Table 3.42 *Site-level summary of riparian condition of Wollomombi River #1 showing the scores of individual indicators and the five subindices that comprise the Vegetation Condition Index.*

WOLR1	Scores
HABITAT	**18.3/20**
Channel width	3.3
Proximity	4
Continuity	3
Layers	4
Large native trees	2
Hollow-bearing trees	2
NATIVE SPECIES	**10/20**
Native canopy species	3
Native midstory species	3
Native herb/forb species	1.5
Native graminoid species	1.5
Native macrophyte species	3
SPECIES COVER	**15.5/20**
Canopy species	4
Midstory species	3
Herb/forb species	4
Graminoid species	4
Macrophyte species	2
DEBRIS	**11.5/20**
Total leaf litter	3
Native leaf litter	2
Dead trees standing	0
Dead trees fallen	1
Lying logs	3
Fringing vegetation	2.5
MANAGEMENT	**10/20**
Tree clearing	3
Fencing	1
Animal impact	1
Species of interest	0
Exposed tree roots	2
Native woody regeneration	2
Weedy woody regeneration	1
TOTAL	**68.8/100**

3.2.10.3 Water quality

The Wollomombi River received a score of 35 (F) for water quality. Figures 3.7 and 3.8 show the key physicochemical and nutrient variables used in the assessment of water quality for the Tableland tributaries. Ranges and means for these variables are given in Table 3.43 and the exceedances are given in Table 3.28.

pH exceeded the upper ANZECC upland freshwater trigger value of 7.5 on all the sampling occasions (Table 3.28). Turbidity did not exceed the ANZECC upland freshwater guideline during the sampling period (Table 3.28). DO% fell below the minimum ANZECC trigger threshold on 4 sampling occasions with a site minimum of 30.5% (Tables 3.28, 3.43).

Concentrations of total nutrients were realtively high at WOLR1, with both TN and TP concentrations exceeding the ANZECC upland freshwater trigger values on all sampling occasions (Table 3.28). The site minimum TN concentration was 1.5 times the trigger value and the site maximum TN concentration was 11 times the trigger value (Table 3.43). The site minimum TP concentration was 1.4 times the trigger value and the site maximum TP concentration was 7 times the trigger value (Table 3.43).

Similar to other tributaries on the Tablelands, there were fewer exceedances of dissolved nutrient concentrations in the Wollomombi River. NOx and SRP concentrations exceeded the ANZECC upland freshwater trigger values on 4 of the 6 sampling occasions (Table 3.28). The site maximum NOx concentration was 13 times the trigger value (Table 3.43). The site maximum SRP concentration was 2.6 times the trigger value (Table 3.43).

High nutrient concentrations did not result in high algal productivity at WOLR1 (Figure 3.7c). Chlorophyll *a* concentrations did not exceed the ANZECC trigger value during the sampling period.

Table 3.43 *Minimums, maximums and means of measured water quality variables for the Wollomombi and Chandler Rivers.*

	WOLR1			CHAR1		
Variable	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**
Temperature (°C)	8.92	22.67	16.14	10.57	25.30	18.37
pH	7.56	8.93	8.20	7.78	8.71	8.29
EC (mS/cm)	0.20	0.36	0.29	0.19	0.23	0.21
Salinity (PPT)	0.10	0.19	0.15	0.09	0.11	0.10
DO (mg/L)	2.68	9.71	6.20	3.44	9.73	6.45
DO (%)	30.50	96.00	68.00	41.90	97.90	73.10
Turbidity (NTU)	4.70	20.40	9.43	4.10	14.90	8.28
Max Depth	0.20	0.60	0.34	0.20	0.50	0.29
Chla (µg/L)	0.00	3.38	0.89	0.57	4.61	1.97
TSS (mg/L)	1.73	8.64	3.74	0.88	6.60	3.30
TN (µg/L)	371.43	2627.1	858.93	195.73	1762.7	670.92
TP (µg/L)	27.41	129.49	65.57	23.01	45.57	30.38
NOx (µg/L)	0.20	334.45	143.48	77.59	244.26	168.12
SRP (µg/L)	1.00	38.67	20.81	14.09	23.48	17.55

3.2.10.4 Aquatic macroinvertebrates

WOLR1 recorded 578 and 624 individual macroinvertebrates across 28 and 27 macroinvertebrate families during the 2015 autumn and spring sampling, respectively (Table 3.44). In autumn, abundance was dominated by Hydropsychid Caddisflies (83 individuals) and richness was dominated by Ephemeroptera (Mayflies) and Trichoptera (Caddisflies), both with 6 families. In contrast, Leptophlebiid Mayflies were the most abundant family in spring (224 individuals) and the dominant order in spring was Coleoptera (Aquatic Beetles) with 7 families. Family richness was similar between seasons. There were a number of rare taxa at the site, with 13 and 9 taxa recording fewer than 5 individuals in autumn and spring, respectively.

Mean SIGNAL2 scores for WOLR1 were higher in spring (6.3) than autumn (5.2), although the range of SIGNAL2 scores was similar between seasons. The increase in the mean SIGNAL2 at WOLR1 in spring was due to high abundances of Leptophlebiid Mayflies (370 individuals) with SIGNAL2 of 8.

WOLR1 received an overall Ecohealth score of 53, a grade of D, for aquatic macroinvertebrate community condition. Total abundance and family richness were below the Macleay catchment average, but mean SIGNAL2 score and EPT score were above the catchment average (Table 3.13). The macroinvertebrate indicators suggest the water quality and habitat conditions in the Wollomombi River upstream of the gorge are in poor condition, but are able to support a diversity of macroinvertebrate fauna given the wide range of SIGNAL2 scores.

Table 3.44 *Summary of aquatic macroinvertebrate data for the Wollomombi and Chandler Rivers.*

	WOLR1		CHAR1	
Macroinvertebrate indicator	**Autumn 2015**	**Spring 2015**	**Autumn 2015**	**Spring 2015**
Total abundance	578	624	851	848
Family richness	28	27	35	32
EPT abundance	241	442	126	330
EPT richness	11	9	9	8
Mean SIGNAL2 score	5.2	6.3	3.9	3.4
SIGNAL2 score range	2-9	1-9	1-8	1-8
Ecohealth score (grade)	**53 (D)**		**48 (D-)**	

3.2.11 Chandler River (CHAR1)

3.2.11.1 Geomorphic condition

The geomorphic River Style at Chandler River #1 (CHAR1) is confined valley setting: gorge. The bed sediments at the site reach comprised subangular gravel in a matrix dominated framework containing >60% fine sediments. Banks comprised fine grained sediments with significant bank slumping (10-20m) along both banks. Geomorphic complexity was fair, although the site reach was impacted by a sand slug. The reach comprised a glide, run, pool and backwater (20, 30, 40 and 10% of the reach length, respectively). CHAR1 scored 71, a C+ for BANK CONDITION and 77, a B-, for BED CONDITION. The overall geomorphic condition for CHAR1 was 74, a grade of C+.

In summary, CHAR1 was assessed as being in moderate geomorphic condition, with localized bank slumping the most significant issue for site-level geomorphic condition. The desktop GIS assessment of subcatchment geomorphic condition found the Chandler River subcatchment to be in moderate condition with a grade of C. The geomorphic condition at CHAR1 was slightly above the subcatchment average.

3.2.11.2 Riparian condition

The original riparian vegetation community at CHAR1 (Plate 3.24) was described as 'New England Riparian Shrubland', Community 23 (Benson & Ashby, 2000), or 'Tea-tree shrubland of drainage areas of the slopes and tablelands', plant community type ID 1270 (VIS, 2012), broadly classed as 'Eastern Riverine Forests', (Keith, 2004). CHAR1 received a good riparian condition score of 63.5, a grade of C- (Table 3.45).

The dominant canopy species present were eucalyptus species New-England Peppermint (*Eucalyptus nova-anglica*), Broad-leaved Stringybark (*E.caliginosa*) and the exotic species Willow (*Salix* sp.). The dominant midstory species were tantoon (*Leptospermum polygalifolium* subsp. *transmontanum*), River Bottlebrush (*Callistemon sieberi*), Red Wattle (*Acacia rubida*) and Fern-leaved Wattle (*Acacia filicifolia*). The understory was dominated by the native species Common Rush (*Juncus usitatus*), Spiny-headed Mat-rush (*Lomandra longifolia*), Knotweeds (*Persicaria strigosa* and *P.hydropiper*), Couch (*Cynodon dactylon*), Blady Grass (*Imperata cylindrica*), Slender Rat's Tail Grass (*Sporobolus crebra*) and the weed species Umbrella Sedge (*Cyperus eragrostis*), Coblers Pegs (*Bidens pilosa*), Fleabane (*Conyza bonariensis*), Turnip Weed (*Rapistrum rugosum*), Tall Fescue (*Festuca arundinaceae*), Cocksfoot (*Dactylis glomerata*) and Yorshire Fog (*Holcus lanatus*). The only vine species present was Blackberry (*Rubus* sp.), while the macrophyte layer included Water Primrose (*Ludwigia peploides*) and submerged species Pondweeds (*Potamogeton crispus* and *P.ochreatus*) and Water-milfoil species (*Myriophyllum variifolium* and *M.verrucosum*).

Noxious weed species observed were Willow (*Salix* sp.) and Blackberry (*Rubus* sp.), both class 4 noxious species and Mexican Poppy (*Argemone mexicana*), a class 5 noxious weed. In addition to those weed species listed above, other weed species included Common Thornapple (*Datura streamonium*), Wild Carrot (*Daucus carota*), Vetch (*Vicia* sp.), Great Mullein (*Verbascum thapsus*), Purpletop (*Verbena bonariensis*), Dandelion (*Taraxacum officianale*), Whisky Grass (*Andropogon viginicus*) and Prairie Grass (*Bromus catharticus*).

Summary: CHAR1 was a moderately disturbed system with a reduced remnant riparian canopy and mixed native and exotic species throughout the midstory and understory layers, in a predominantly cleared, partially forested landscape. The surrounding rural landuse was a mixture of agricultural grazing land and TSR. Significant remnant stands of vegetation lay adjacent to the site in a TSR on the right bank and 2.3km to the south in Oxley Wild Rivers National Park. CHAR1 scored well for Native Species and moderately for Habitat, Cover, Debris, and Management subindices (Table 3.45) and contained representative elements of the remnant vegetation community in all structural layers. Riparian condition at CHAR1 was affected by the presence and regeneration of weed species, particularly in the understory. Reduced midstory cover and riparian vegetation connectivity, limited leaf litter and standing woody debris and inadequate riparian fencing were all factors contributing to the poor riparian grade at this site.

Management Recommendations: Riparian condition could be improved through the control and removal of weed and noxious weed species, particularly throughout the understory layer. Undertaking native plantings would increase riparian vegetation width and continuity and assist in the site regeneration of native species. Riparian fencing should exclude livestock and, if strategically implemented, could be used in combination with native plantings to increase riparian vegetation width and continuity.

***Plate 3.24** Riparian vegetation at CHAR1 was moderately disturbed. Riparian condition would be improved through the monitoring and removal of weed and noxious weed species such as Willow (*Salix sp.*) and Blackberry (*Rubus sp.*), undertaking native plantings and fencing off the riparian zone.*

Table 3.45 *Site-level summary of riparian condition of Chandler River #1 showing the scores of individual indicators and the five subindices that comprise the Vegetation Condition Index.*

CHAR1	Scores
HABITAT	**14/20**
Channel width	4
Proximity	2.5
Continuity	1
Layers	3.5
Large native trees	2
Hollow-bearing trees	1
NATIVE SPECIES	**15/20**
Native canopy species	3
Native midstory species	3
Native herb/forb species	2.5
Native graminoid species	2.5
Native macrophyte species	4
SPECIES COVER	**11/20**
Canopy species	2
Midstory species	1
Herb/forb species	2.5
Graminoid species	2.5
Macrophyte species	3
DEBRIS	**11/20**
Total leaf litter	1.5
Native leaf litter	2
Dead trees standing	1
Dead trees fallen	3
Lying logs	2
Fringing vegetation	3
MANAGEMENT	**11/20**
Tree clearing	1.5
Fencing	1.5
Animal impact	2
Species of interest	1
Exposed tree roots	3
Native woody regeneration	1
Weedy woody regeneration	1
TOTAL	**63.5/100**

3.2.11.3 Water quality

The Chandler River received a score of 35 (F) for water quality. Figures 3.7 and 3.8 show the key physicochemical and nutrient variables used in the assessment of water quality for the Tableland tributaries. Ranges and means for these variables are given in Table 3.43 and the exceedances are given in Table 3.28.

pH exceeded the upper ANZECC upland freshwater trigger value of 7.5 on all sampling occasions (Table 3.28). Turbidity was consistently very low at CHAR1 (Figure 3.7d), and did not exceed the ANZECC upland freshwater guideline during the sampling period. DO% fell below the minimum ANZECC trigger threshold on 3 sampling occasions with a site minimum of 42% (Tables 3.28, 3.43).

Concentrations of total nutrients were consistently high at CHAR1 (Figure 3.8), with TN and TP concentrations exceeding the ANZECC upland freshwater trigger values on 5 and 6 (all) sampling occasions, respectively (Table 3.28). The site maximum TN concentration was 7 times the trigger value (Table 3.43). The site minimum TP concentration was 1.2 times the trigger value and the site maximum TP concentration was 2.3 times the trigger value (Table 3.43).

NOx concentrations exceeded the ANZECC upland freshwater trigger value of 25µg/L on all sampling occasions at CHAR1 (Table 3.28). The site minimum NOx concentration was 3 times the trigger value while the site maximum NOx concentration was 10 times the trigger value (Table 3.43). SRP concentrations exceeded the ANZECC upland freshwater trigger value of 15µg/L on 5 of the 6 sampling occasions at CHAR1 (Table 3.28). The site maximum SRP concentration was 1.6 times the trigger value (Table 3.43).

High nutrient concentrations did not lead to high algal productivity in the Chandler River, with only one exceedance, the site maximum chlorophylla *a* concentration of 4.61µg/L (ANZECC trigger value of 4 µg/L). All other chlorophyll *a* concentrations were well below the trigger value. The site maximum chlorophyll *a* concentration coincincided with the site maximum concentrations of TP and NOx, occurring in the austral summer (February 2016).

3.2.11.4 Aquatic macroinvertebrates

CHAR1 recorded 851 and 848 individual macroinvertebrates across 35 and 32 macroinvertebrate families during the 2015 autumn and spring sampling, respectively (Table 3.44). In autumn, abundance was dominated by Hydrophilid Beetles (221 individuals) and richness was also dominated by Coleoptera (Aquatic Beetles) with 8 families. In contrast, Caenid Mayflies were the most abundant family in spring (184 individuals), closely followed by the Hemiptera (True Bugs) Corixidae (Water Boatmen, 152 individuals) and Notonectidae (Backswimmers, 128 individuals). The most diverse order in spring remained Coleoptera (Aquatic Beetles) with 8 families. Family richness was slightly lower in spring than autumn, due to the fewer rarer taxa in spring. The number of rare taxa at the site was relatively high with 21 and 16 taxa recording fewer than 5 individuals in autumn and spring, respectively.

Mean SIGNAL2 scores for CHAR1 were similar between autumn (3.9) and spring (3.4), and the range of SIGNAL2 scores were the same between seasons. The decrease in the mean SIGNAL2 at CHAR1 in spring was due to the absence of Trichoptera (Caddisflies) with high SIGNAL2 scores (8) in spring.

CHAR1 received an overall Ecohealth score of 48, a grade of D-, for aquatic macroinvertebrate community condition. The EPT score and mean SIGNAL2 were below the Macleay catchment average, but total abundance and family richness were above the catchment average (Table 3.13). The macroinvertebrate indicators suggest the water quality and habitat conditions in the Chandler River upstream of the gorge are in poor condition, but are able to support a diversity of macroinvertebrate fauna given the wide range of SIGNAL2 scores.

3.2.12 Oaky River (OAKR1)

3.2.12.1 Geomorphic condition

The geomorphic River Style at Oaky River #1 (OAKR1) is confined valley setting: gorge. The bed sediments comprised angular cobbles in a matrix filled contact framework containing 5-32% fine sediments. Banks comprised gravel with significant bank erosion concentrated as significant (10-20m) undercutting on the left bank and moderate (5-10m) undercutting on the right bank. There was minimal (<5m) slumping of the left bank and significant (10-20m) slumping of the right bank. Geomorphic complexity was moderate, with the site comprising a riffle, run, pool and backwater (15, 50, 25 and 10% of the reach, respectively). OAKR1 scored 60, a D+ for BANK CONDITION and 68, a C, for BED CONDITION. The overall geomorphic condition for OAKR1 was 64, a grade of D-.

In summary, OAKR1 was assessed as being in poor geomorphic condition, with bank erosion the most significant issue for site-level geomorphic condition. The desktop GIS assessment of subcatchment geomorphic condition found the Oaky River subcatchment to be in good condition with a grade of B-. Poor condition reaches were located on the Tablelands and good condition reaches in the Apsley gorge. The geomorphic condition at OAKR1 was significantly below the subcatchment average, but representative of the Tablelands.

3.2.12.2 Riparian condition

High historic disturbance at OAKR1 (Plate 3.25) has resulted in a highly modified riparian zone that predominantly comprises exotic species. However, the original riparian vegetation community at OAKR1 could have been described as 'New England Riparian Shrubland', Community 23 (Benson & Ashby, 2000), or 'Tea-tree shrubland of drainage areas of the slopes and tablelands', plant community type ID 1270 (VIS, 2012) grading into 'River Oak forest and woodland wetland of the NSW South Western Slopes and South Eastern Highlands Bioregion', plant community type ID 85 (VIS, 2012), broadly classed as 'Eastern Riverine Forests', (Keith, 2004). OAKR1 received a poor riparian condition score of 47.5, a grade of F (Table 3.46).

While there was no actual riparian canopy present at OAKR1, there was evidence of canopy species regeneration in the form of River Oak (*Casuarina cunninghamiana* subsp. *cunninghamiana*). Dominant midstory species included River Bottlebrush (*Callistemon sieberi*), Red Wattle (*Acacia rubida*) and Small-fruit Hakea (*Hakea microcarpa*). The understory was dominated by the native species Golden Everlasting (*Xerochrysum bracteatum*), Billy Buttons (*Craspedia sp.*), Knotweeds (*Persicaria decipiens* and *P.hydropiper*), Common Rush (*Juncus ursitatus*), Spiny-headed Mat-rush (*Lomandra longifolia*), Snow Grass (*Poa siebrianna*) and Rice grass (*Microlaena stipoides*), along with the exotic species White Clover (*Trifolium repens*), Umbrella Sedge (*Cyperus eragrostis*), Purpletop (*Verbena bonariensis*), Ox-eye daisy (*Leucanthemum vulgare*), Fleabane (*Conyza bonariensis*), Yorkshire Fog (*Holcus lanatus*), Whiskey Grass (*Andropogon viginicus*) and Prairie Grass (*Bromus catharticus*). The only vine species present was Blackberry (*Rubus* sp.), while the macrophyte layer included Water Primrose (*Ludwigea peploides*) and the submerged species, Curly Pondweed (*Potamogeton crispus*) and Water-milfoil (*Myriophyllum* sp.).

Blackberry (*Rubus* sp.) was the only noxious weed species observed on site (class 4). In addition to those already mentioned, other weed species present included Scarlet Pimpernel (*Anagallis arvensis*), Plantain (*Plantago lanceolata*), Cat's Ear (*Hypochaeris radicata*), Proliferous Pink (*Petrorhagia nanteuilii*), Cocksfoot (*Dactylis glomerata*) and Wimmera Grass (*Lolium rigidum*).

Summary: OAKR1 was a very highly disturbed system without a riparian canopy and with mixed native and exotic species throughout the midstory and understory layers in a predominantly cleared, partially forested landscape. The surrounding rural landuse was a mixture of agricultural grazing land, water storage and TSR. Significant remnant stands of vegetation lay 2.5km to the south in Oxley Wild Rivers National Park, in a reserve 5km east and in a State Forest 7km east of the site. OAKR1 scored moderately in Native Species, Cover and Debris, and poorly in Habitat and Management subindices (Table 3.46). While there was no riparian canopy layer present, representative elements of the remnant vegetation community were present throughout each structural layer including canopy. Devoid riparian vegetation width, continuity and mature habitat trees, the presence and regeneration of weed and noxious weed species, limited leaf litter and fallen woody debris and inadequate riparian fencing were all factors contributing to the poor riparian grade at this site.

Management Recommendations: Riparian condition could be improved through control/removal of invasive weed species, and by undertaking native plantings to increase riparian vegetation width and continuity and assist in site regeneration of native canopy species. Riparian fencing should exclude livestock and, if strategically implemented, could be used in combination with native plantings to increase riparian vegetation width and continuity. Lastly, the introduction of large woody debris back into this system using best practice techniques could stabilise river banks in the long term, promote niche habitats for native woody regeneration, provide habitat for native animal species, and as instream snags, can redirect or reduce water energy from banks, reducing bank erosion.

Plate 3.25 *Riparian vegetation at OAKR1 was very highly disturbed. Riparian condition would be improved through the control and removal of weed and noxious weed species such as Blackberry* (Rubus sp.)*, undertaking native plantings, introducing woody debris and fencing off the riparian zone.*

Table 3.46 *Site-level summary of riparian condition of Oaky River #1 showing the scores of individual indicators and the five subindices that comprise the Vegetation Condition Index.*

OAKR1	Scores
HABITAT	**9/20**
Channel width	2
Proximity	3
Continuity	1
Layers	2
Large native trees	0
Hollow-bearing trees	1
NATIVE SPECIES	**11.5/20**
Native canopy species	0
Native midstory species	4
Native herb/forb species	2
Native graminoid species	1.5
Native macrophyte species	4
SPECIES COVER	**11/20**
Canopy species	0
Midstory species	1
Herb/forb species	4
Graminoid species	3
Macrophyte species	3
DEBRIS	**10.5/20**
Total leaf litter	1
Native leaf litter	2
Dead trees standing	1.5
Dead trees fallen	0
Lying logs	2
Fringing vegetation	4
MANAGEMENT	**5.5/20**
Tree clearing	0
Fencing	1.5
Animal impact	1
Species of interest	0
Exposed tree roots	2
Native woody regeneration	1
Weedy woody regeneration	0
TOTAL	**47.5/100**

3.2.12.3 Water quality

The Oaky River received a score of 59 (D+) for water quality. Figures 3.7 and 3.8 show the key physicochemical and nutrient variables used in the assessment of water quality for the Tableland tributaries. Ranges and means for these variables are given in Table 3.47 and the exceedances are given in Table 3.28.

pH exceeded the upper ANZECC upland freshwater trigger value of 7.5 on 4 of the 6 sampling occasions (Table 3.28). OAKR1 had relatively high turbidity compared with the other tableland sites (Figure 3.7d), but did not exceed the ANZECC upland freshwater guideline of 25NTU (Table 3.28). DO% fell below the minimum ANZECC trigger threshold on 3 sampling occasions with a site minimum of 40% (Tables 3.28, 3.47).

Concentrations of total nutrients were consistently high at OAKR1, with both TN and TP concentrations exceeding the ANZECC upland freshwater trigger values on 4 of 6 sampling occasions (Table 3.28). The site maximum TN concentration was 8 times the trigger value (Table 3.47). The site maximum TP concentration was 5 times the trigger value (Table 3.47).

Concentrations of dissolved nutrients were also consistently high at OAKR1. NOx concentrations exceeded the ANZECC upland freshwater trigger value of 25µg/L on 4 of the 6 sampling occasions (Table 3.28) and the site maximum NOx concentration was 11 times the trigger value (Table 3.47). SRP concentrations exceeded the ANZECC upland freshwater trigger value of 15µg/L on 3 of the 6 sampling occasions (Table 3.28) and the site maximum SRP concentration was 2.2 times the trigger value (Table 3.47).

High nutrient concentrations did not lead to high algal productivity in the Oaky River, with chlorophylla *a* concentrations never exceeding the ANZECC trigger value of 4 µg/L during the sampling period.

***Table 3.47** Minimums, maximums and means of measured water quality variables for the Oaky and Styx Rivers.*

	OAKR1			STYR1		
Variable	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**
Temperature (°C)	9.45	25.39	18.28	8.37	23.18	16.28
pH	7.16	8.88	8.12	7.77	9.00	8.36
EC (mS/cm)	0.05	0.07	0.06	0.03	0.04	0.04
Salinity (PPT)	0.02	0.09	0.04	0.02	0.02	0.02
DO (mg/L)	3.31	9.85	6.59	0.04	9.99	5.50
DO (%)	39.60	97.00	73.75	42.50	96.30	73.12
Turbidity (NTU)	8.60	23.10	12.48	4.70	8.50	6.58
Max Depth	0.25	0.40	0.34	0.35	0.50	0.43
Chla (µg/L)	0.00	1.00	0.35	0.03	0.77	0.32
TSS (mg/L)	0.61	5.35	2.49	1.60	17.79	9.92
TN (µg/L)	169.49	1953.3	673.61	130.60	1228.8	443.30
TP (µg/L)	17.22	100.19	50.45	19.17	302.41	79.61
NOx (µg/L)	4.18	265.14	146.44	4.18	202.51	99.34
SRP (µg/L)	2.48	32.42	14.60	2.80	75.82	22.66

3.2.12.4 Aquatic macroinvertebrates

OAKR1 recorded 719 and 1025 individual macroinvertebrates across 30 and 35 macroinvertebrate families during the 2015 autumn and spring sampling, respectively (Table 3.48). In autumn, abundance was dominated by Baetid Mayflies (211 individuals) and richness was dominated by Coleoptera(Aquatic Beetles, with 7 families). In spring, Leptophlebiid Mayflies (200 individuals) were the most abundant family and the most diverse order remained Coleoptera (Aquatic Beetles) with 9 families. Family richness was higher in spring than autumn, but the increase in taxa were spread across several orders. There were a number of rare taxa at the site, with 15 and 12 taxa recording fewer than 5 individuals in autumn and spring, respectively.

Mean SIGNAL2 scores for OAKR1 were similar between autumn (5.2) and spring (5.0), and the range of SIGNAL2 scores did not change between seasons.

OAKR1 received an overall Ecohealth score of 56, a grade of D+, for aquatic macroinvertebrate community condition. All macroinvertebrate indicators were at or slightly above the Macleay catchment average (Table 3.13). The macroinvertebrate indicators suggest the water quality and habitat conditions in the Oaky River upstream of the gorge are in poor condition, but are able to support a diversity of macroinvertebrate fauna given the wide range of SIGNAL2 scores.

Table 3.48 *Summary of aquatic macroinvertebrate data for the Oaky and Styx Rivers.*

	OAKR1		STYR1	
Macroinvertebrate indicator	**Autumn 2015**	**Spring 2015**	**Autumn 2015**	**Spring 2015**
Total abundance	719	1025	641	606
Family richness	30	35	51	50
EPT abundance	209	466	211	241
EPT richness	9	8	16	18
Mean SIGNAL2 score	5.2	5.0	5.7	5.0
SIGNAL2 score range	1-8	1-8	1-9	1-9
Ecohealth score (grade)	**56 (D+)**		**74 (C+)**	

3.2.13 Styx River (STYR1)

3.2.13.1 Geomorphic condition

The geomorphic River Style at Styx River #1 (STYR1) is confined valley setting: gorge. The bed sediments comprised very angular cobbles in a bedrock dominated reach containing little fine sediments (0-5%). Banks comprised bedrock with some fines and erosion was absent from the site reach. Geomorphic complexity was good, with the site comprising a cascade, rapid, run and pool (10, 5, 15 and 70% of the reach, respectively). STYR1 scored 91, an A- for BANK CONDITION and 95, an A-, for BED CONDITION. The overall geomorphic condition for STYR1 was 93, a grade of A-.

In summary, STYR1 was assessed as being in good geomorphic condition, with no site-level issues affecting geomorphic condition. The desktop GIS assessment of subcatchment geomorphic condition found the Styx River subcatchment to be in poor condition with a grade of B+. The geomorphic condition at STYR1 was above the subcatchment average.

3.2.13.2 Riparian condition

The original riparian vegetation community at STYR1 (Plate 3.26) was described as 'River Oak open forest of major streams, Sydney Basin Bioregion and South East Corner Bioregion', plant community type ID 1105 (VIS, 2012), broadly classed as 'Eastern Riverine Forests (Keith, 2004). STYR1 received a very good riparian condition score of 86.5, a grade of B+ (Table 3.49).

The dominant canopy species present were River Oak (*Casuarina cunninghamiana* subsp. *cunninghamiana*), New England Peppermint (*Eucalyptus nova-anglica*), Wattle-leaved Peppermint (*Eucalyptus acaciiformis*) and the exotic species Willow (*Salix* sp.). Dominant native midstory species included River Bottlebrush (*Callistemon sieberi*), Daphne Heath (*Brachyloma daphnoides*), Blackthorn (*Bursaria spinosa*), Tantoon (*Leptospermum polygalifolium* subsp. *transmontanum*) and Tree Violet (*Melicytus dentatus*). The understory was dominated by native species Lomandra (*Lomandra hystrix* and *L.longifolia*), Knotweeds (*Persicaria hydropiper* and *P.sp.*), Creamy Candles (*Stackhousia monogyna*), Common Bracken (*Pteridium esculentum*), Scurvy Weed (*Commelina cyanea*), Common Everlasting (*Chrysocephalum apiculatum*), Tassel Sedge (*Carex fascicularis*), Couch (*Cynodon dactylon*), Blady Grass (*Imperata cylindrica*) and Australian Basket Grass (*Oplismenus aemulus*), along with exotic species Purpletop (*Verbena bonariensis*), Fleabane (*Conyza bonariensis*), Cobblers Pegs (*Bidens pilosa*) and Sweet Vernal Grass (*Anthoxanthum odoratum*). Vines present included the native species Native Raspberry (*Rubus parvifolius*) and Glycine (*Glycine* sp.), while the macrophyte layer included Tall Sedge (*Carex appressa*), Marsh Club-rush (*Bolboschoenus fluviatilis*), Water-milfoil (*Myriophyllum* sp.) and the submerged exotic species Elodea (*Elodea canadensis*).

Noxious weed species observed onsite were Willow (*Salix* sp.) and Egeria (*Egeria densa*), both class 4 noxious weeds. Aside from those previously mentioned, the only other weed present was Common Starwort (*Callitriche stagnalis*).

Summary: STYR1 was a low disturbance system of mature closed woodland with a remnant canopy and midstory layer and a largely intact understory, in a predominantly forested, partially cleared landscape. The surrounding rural landuse was agricultural grazing land and National Park. Significant remnant stands of vegetation lie <2km to the south, east and northwest and in private land adjacent to the site. STYR1 scored full marks for Habitat, well for Native Species, Cover and Management, and moderately for Debris subindicators (Table 3.49), retaining representative elements of the remnant vegetation community in all structural layers. While riparian condition at STYR1 was in examplary condition, the site was impacted by the presence of weed and noxious weed species, particularly in the macrophyte structural layer. Low macrophyte cover and lower than expected levels of woody debris contributed to the reduction in riparian grade at this site.

Management Recommendations: Riparian condition could be improved through the control and removal of weed and noxious weed species, particularly throughout the understory layer.

Plate 3.26 *Riparian vegetation at STYR1 was of low disturbance. Riparian condition would be improved through control and removal of weed and noxious weed species, specifically Willow* (Salix sp.) *and Egeria* (Egeria densa)*.*

Table 3.49 *Site-level summary of riparian condition of Styx River #1 showing the scores of individual indicators and the five subindices that comprise the Vegetation Condition Index.*

STYR1	Scores
HABITAT	**20/20**
Channel width	4
Proximity	4
Continuity	4
Layers	4
Large native trees	2
Hollow-bearing trees	2
NATIVE SPECIES	**15.5/20**
Native canopy species	4
Native midstory species	4
Native herb/forb species	3.5
Native graminoid species	3
Native macrophyte species	1
SPECIES COVER	**18/20**
Canopy species	4
Midstory species	4
Herb/forb species	4
Graminoid species	4
Macrophyte species	2
DEBRIS	**14/20**
Total leaf litter	2
Native leaf litter	3
Dead trees standing	2
Dead trees fallen	1
Lying logs	2
Fringing vegetation	4
MANAGEMENT	**19/20**
Tree clearing	4
Fencing	3
Animal impact	3
Species of interest	1
Exposed tree roots	4
Native woody regeneration	2
Weedy woody regeneration	2
TOTAL	**86.5/100**

3.2.13.3 Water quality

The Styx River received a score of 54 (D) for water quality. Figures 3.7 and 3.8 show the key physicochemical and nutrient variables used in the assessment of water quality for the Tableland tributaries. Ranges and means for these variables are given in Table 3.47 and the exceedances are given in Table 3.28.

pH exceeded the upper ANZECC upland freshwater trigger value of 7.5 on all sampling occasions (Table 3.28). STYR1 had the lowest turbidity of the tableland sites (Figure 3.7d), and never exceeded the ANZECC upland freshwater guideline of 25NTU (Table 3.28). DO% fell below the minimum ANZECC trigger threshold on 3 sampling occasions with a site minimum of 43% (Tables 3.28, 3.47).

Concentrations of total nutrients were consistently high at STYR1, with TN concentrations exceeding the ANZECC upland freshwater trigger values on 4 of 6 sampling occasions (Table 3.28). The site maximum TN concentration was 5 times the trigger value (Table 3.47), which was the lowest for the Tableland tributaries (Figure 3.8a). TP concentrations exceeded the ANZECC upland freshwater trigger value of 20µg/L on 5 of 6 sampling occasions at STYR1 (Figure 3.8b). The site maximum TP concentration was 15 times the trigger value (Table 3.47).

Concentrations of dissolved nutrients were also consistently high at STYR1, although NOx concentrations at STYR1 were the lowest for the Tableland tributaries. NOx concentrations exceeded the ANZECC upland freshwater trigger value of 25µg/L on 4 of the 6 sampling occasions (Table 3.28). The site maximum NOx concentration was 8 times the trigger value (Table 3.47). SRP concentrations exceeded the ANZECC upland freshwater trigger value of 15µg/L on 3 of the 6 sampling occasions (Table 3.28). The site maximum SRP concentration was 5 times the trigger value (Table 3.47).

High nutrient concentrations did not lead to high algal productivity in the Styx River, with chlorophylla *a* concentrations never exceeding the ANZECC trigger value of 4µg/L during the sampling period.

3.2.13.4 Aquatic macroinvertebrates

STYR1 recorded 641 and 606 individual macroinvertebrates across 51 and 50 macroinvertebrate families during the 2015 autumn and spring sampling, respectively (Table 3.48). This is the greatest diversity of macroinvertebrate taxa found in the Macleay catchment. In autumn, abundance was dominated by Baetid Mayflies (130 individuals) and richness was dominated by Trichoptera (Caddisflies) with 13 families. In contrast, Leptophlebiid Mayflies were the most abundant family in spring (57 individuals), and the dominant order in spring remained Trichoptera with 15 families. Family richness was similar in spring than autumn. There were a number of rare taxa at the site with 23 and 25 taxa recording fewer than 5 individuals in autumn and spring, respectively.

Mean SIGNAL2 scores for STYR1 were slightly higher in autumn (5.7) than spring (5.0), although the range of SIGNAL2 scores did not change between seasons. The decrease in the mean SIGNAL2 at

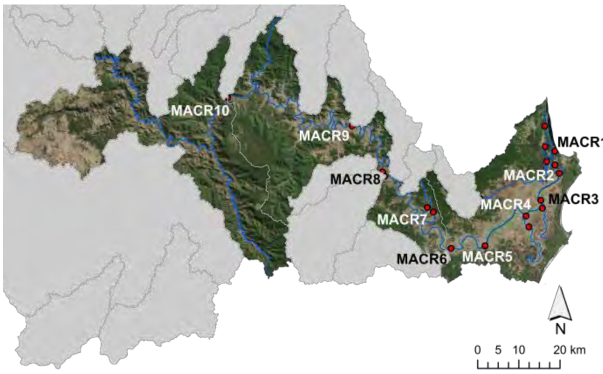
STYR1 in spring was due to high abundances of low scoring biota (e.g. Dytiscid Beetles with SIGNAL2 of 2), rather than the disappearance of high-scoring taxa.

STYR1 received an overall Ecohealth score of 74, a grade of C+, for aquatic macroinvertebrate community condition. This was the best Ecohealth macroinvertebrate grade in the Tableland sites. Only total abundance was below the Macleay catchmenet average, with all other macroinvertebrate indicators well above the catchment average (Table 3.13). The macroinvertebrate indicators suggest the water quality and habitat conditions in the Styx River gorge are in good condition, and are able to support a diversity of macroinvertebrate fauna given the wide range of SIGNAL2 scores.

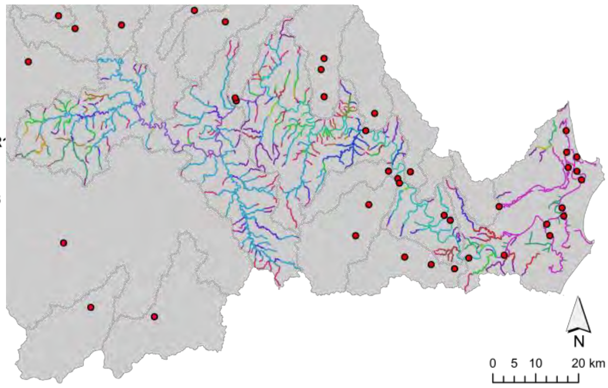
3.3 Macleay River main stem

3.3.1 Catchment description

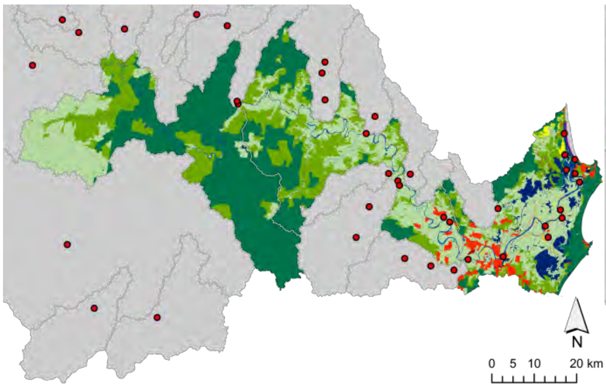
The main stem of the Macleay River (including the coastal floodplain and estuarine tributaries) covers an area of 3,249km^2, or 29% of the total catchment area. The upper freshwater Macleay River (draining upstream of MACR10 at Georges Junction) is the largest subcatchment of the main stem of the Macleay River (1322km^2, Table 3.50). The dominant land use (52%) is national park (Figure 3.9). The lower freshwater Macleay River (draining to the tidal limit at MACR6) covers 1067km^2 and the dominant land use is grazing (35%, Table 3.51). Nonetheless, tree cover remains high at 27%. The tidal Macleay River comprises 849km^2 and the dominant land use is also grazing (40%, Table 3.52). There is one point-source discharger to the estuarine Macleay: the Nestle factory at Smithtown that can discharge to the river at any time.



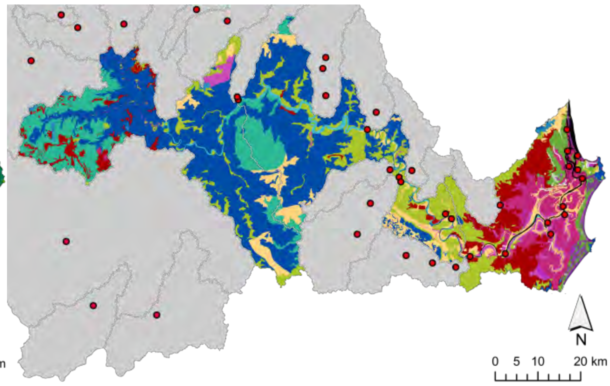
(a) Location of Ecohealth sites



(b) River Styles: refer to Figure 2.8 for key



(c) Landuse: refer to Figure 2.7 for key



(d) Soils: refer to Figure 2.3 for key

Figure 3.9 *The main stem of the Macleay River showing (a) locations of Ecohealth sites, (b) River Styles, (c) landuse, and (d) soils. Data layers from NC LLS (River Styles) and OEH (landuse and soils).*

Table 3.50 *Subcatchment description of the upper Macleay River. Data from NC LLS and OEH.*

Variable	Subcatchment composition
Area	1321.5km^2
Geology	36.9 % sedimentary siliciclastic; 28.7 % feldspar- or lithic-rich arenite to rudite, 10.3 % metasedimentary siliciclastic; 10.0% igneous felsic intrusive; 7.2% sedimentary siliciclastic, metasedimentary siliciclastic; 4.7% metasedimentary siliciclastic, sedimentary non-carbonate chemical or biochemical
Soils	53.4% Rudosols and Tenosols; 23.3% Kandosols; 8.1% Kurosols; 6.1% Natric Kurosols; 4.8% Dermosols; 1.1% Ferrosols; 1.7% Tenosols
River Styles	51.2 % CVS - Gorge; 11.7% PCVS - Bedrock controlled gravel; 5.5 % SMG - Valley fill, fine grained; 9.7% CVS - Headwater; 4.6 % LUV CC - Channelized fill
Landuse	52.0% National Park; 26.2% Grazing; 19.1% Residual native cover; 4.6% Production Forestry; 1.6% River/Wetland
Major point source discharge	Nil
Tree Cover	56.7%

Table 3.51 *Subcatchment description of the mid Macleay River. Data from NC LLS and OEH.*

Variable	Subcatchment composition
Area	1066.7km^2
Geology	68.5% sedimentary siliciclastic; 17.2% metasedimentary siliciclastic; 11.9% igneous felsic intrusive; 1.8% regolith
Soils	47.5% Rudosols and Tenosols; 23% Kurosols; 12.1% Dermosols; 11.0% Kandosols; 4.2% Rudosols (Alluvial)
River Styles	26.9% PCVS - Planform controlled, low sinuosity, gravel; 13.9% CVS - Gorge; 12.2% CVS - Headwater; 7.6% SMG - valley fill, fine grained; 7% CVS - Floodplain pockets, sand; 5.6% PCVS - Planform controlled, low sinuosity, sand
Landuse	35.1% Grazing; 31.7% Residual native cover; 21.1% National park; 7.2% Production forestry; 2.0% River/Wetland; 1.2% Rural residential with agriculture
Major point source discharge	Nil
Tree Cover	21.7%

Table 3.52 *Subcatchment description of the Macleay River estuary (including Belmore River, Kinchela Creek and Spencers Creek). Data from NC LLS and OEH.*

Variable	Subcatchment composition
Area	848.7km^2
Geology	18.9% feldspar- or lithic-rich arenite to rudite, metasedimentary siliciclastic; 16.9% metasedimentary siliciclastic; 14.4% metasedimentary siliciclastic, sedimentary non-carbonate chemical or biochemical; 13.7% feldspar- or lithic-rich arenite to rudite; 13.7% sedimentary siliciclastic; 9.6% igneous mafic volcanic
Soils	24.8% Hydrosols; 22.9% Natric Kurosols; 15.5% Kurosols; 9.4% Dermosols; 8.7% Podosols; 5.4% Tenosols (Alluvial).
River Styles	49.3% LUV CC – Tidal; 11.2% LUV CC - Channelised fill; 11.1% SMG - Valley fill, fine grained; 4.3% CVS - Floodplain pockets, gravel
Landuse	40.1% Grazing; 14.4% Residual native cover; 10.8% National Park; 8.5% Forestry; 4.5% Rural Residential; 2.9% River/Wetland; 1.6% Land under rehabilitation
Major point source discharge	Nestle Smithtown Factory – miscellaneous licensed discharge to waters at any time
Tree Cover	14.4%

3.3.2 Site descriptions

There were four sites in the freshwater reach of the Macleay River (Figure 3.9). MACR10 at Georges Junction on the Macleay River (Plate 3.27) is a bedrock controlled gravel-bed channel in a partially confined valley setting located 46km downstream of the Macleay gorge and 50m downstream of the confluence of the Macleay River and Georges Creek. MACR9 (Plate 3.28) is a planform controlled, low sinuosity gravel-bed channel in a partially confined valley setting. MACR9 is at Bellbrook, 61.5km downstream of MACR10. MACR8 at Toorooka (Plate 3.29) is a planform controlled, low sinuosity gravel-bed channel in a partially confined valley setting. MACR8 is 29.2km downstream of MACR9. MACR7 at Turners Flat (Plate 3.30) is a planform controlled, low sinuosity gravel-bed channel in a partially confined valley setting. MACR7 is 27km downstream of MACR8.

There were six sites in the estuarine reach of the Macleay River (Figure 3.9). MACR6 (Plate 3.31) is a planform controlled, low sinuosity gravel-bed channel in a partially confined valley setting at the tidal limit of the Macleay estuary with a salinity range of 0-15ppt. MACR6 was located 1.6km downstream of Bellgrave Falls and 21.4km downstream from MACR7. MACR5 (Plate 3.32) is in the upper estuary with a salinity range of 0-15ppt. MACR5 is a tidal laterally unconfined continuous channel located immediately downstream of Kempsey, 13km downstream of MACR6. MACR4 is in the mid estuary with a salinity range of 15-30ppt. MACR4 (Plate 3.33) is a tidal laterally unconfined continuous channel located immediately downstream of Smithtown, 16km downstream of MACR5. MACR3 is in the mid estuary with a salinity range of 15-30ppt. MACR3 (Plate 3.34) is a tidal laterally unconfined continuous channel located 1km downstream of the confluence with Kinchela Creek and 6.3km downstream of MACR4. MACR2 is in the lower estuary in the marine-influenced zone with a salinity range of +30ppt. MACR2 (Plate 3.35) is a tidal laterally unconfined continuous channel located at Jerseyville, 9.7km downstream of MACR3. MACR1 is in the lower estuary in the marine-influenced zone with a salinity range of +30ppt. MACR1 (Plate 3.36) is a tidal laterally unconfined continuous channel located adjacent to South West Rocks and 8km downstream of MACR2.

Plate 3.27 *Site MACR10 on the freshwater Macleay River immediately upstream of Georges Junction (looking upstream).*

Plate 3.28 *Site MACR9 on the freshwater Macleay River at Bellbrook (looking upstream).*

Plate 3.29 *Site MACR8 on the freshwater Macleay River downstream of Toorooka (looking upstream).*

Plate 3.30 *Site MACR7 on the freshwater Macleay River at Turners Flat (looking downstream).*

Plate 3.31 *Site MACR6 at the tidal limit of the Macleay River (looking upstream).*

Plate 3.32 *Site MACR5 on the upper Macleay estuary at Kempsey (looking upstream).*

Plate 3.33 *Site MACR4 on the Macleay estuary at Gladstone (looking downstream).*

Plate 3.34 *Site MACR3 on the Macleay estuary downstream of Kinchela Creek (looking downstream).*

Plate 3.35 *Site MACR2 on the Macleay estuary at Jerseyville (looking upstream).*

Plate 3.36 *Site MACR1 on the lower Macleay estuary at South West Rocks (looking downstream).*

3.3.3 Freshwater reach (MACR10, MACR9, MACR8 and MACR7)

3.3.3.1 Geomorphic condition

The geomorphic River Style at Macleay River #10 (MACR10) is partially confined valley setting: bedrock controlled, gravel. The bed sediments comprised subangular cobbles in an open matrix containing 0-5% fine sediments and significant interstitial voids. Banks comprised gravel with significant fine sediments and bedrock. Bank erosion was restricted to 4WD tracks and bed erosion was absent. The site is a depositional zone for sediment from the Georges Creek subcatchment. Geomorphic complexity was good, consisting of a pool and riffle sequence (50% each of reach length). MACR10 scored 77, a B- for BANK CONDITION and 85, a B, for BED CONDITION. The overall geomorphic condition for MACR10 was 81, a grade of B.

The geomorphic River Style at Macleay River #9 (MACR9) is partially confined valley setting: planform controlled, low sinuosity, gravel. The bed sediments comprised rounded cobbles and gravel in a matrix filled contact framework containing 5-32% fine sediments. Banks comprised fine grained sediments with minimal bank erosion. Minor bank erosion comprising undercutting (<5m) and slumping (<5m) on the right bank are likely due to cattle grazing the riparian zone. MACR9 scored 75, a C+ for BANK CONDITION and 77, a B-, for BED CONDITION. The overall geomorphic condition for MACR9 was 76, a grade of B-.

The geomorphic River Style at Macleay River #8 (MACR8) is partially confined valley setting: planform controlled, low sinuosity, gravel. Bed sediment was dominated by rounded cobbles and gravel in matrix filled contact framework containing 5-32% fine sediment. Banks consisted of cobbles and gravel. Undercutting was absent on the left bank, but there was significant slumping (10-20m). The left bank was actively grazed and several vehicle tracks traverse the site. There was moderate (5-10m) undercutting and minimal (<5m) slumping on the right bank. MACR8 scored 65, a C- for BANK CONDITION and 77, a B-, for BED CONDITION. The overall geomorphic condition for MACR8 was 71, a grade of C+.

The geomorphic River Style at Macleay River #7 (MACR7) is partially confined valley setting: planform controlled, low sinuosity, gravel. Bed sediment was dominated by rounded cobbles and gravel in matrix filled contact framework containing 5-32% fine sediment. Banks consisted of cobbles and gravel. Erosion was absent on the left bank, but there was minor (<5m) undercutting and minor (<5m) slumping on the right bank. MACR7 scored 68, a C for BANK CONDITION and 68, a C, for BED CONDITION. The overall geomorphic condition for MACR7 was 68, a grade of C.

In summary, MACR10 and MACR9 were assessed as being in good geomorphic condition, with bank erosion the most significant issue for site-level geomorphic condition. MACR8 and MACR7 were assessed as being in moderate geomorphic condition. Again bank erosion due to grazing of the riparian zone is the most significant issue for site-level geomorphic condition at these sites.

The desktop GIS assessment of geomorphic condition found the upper Macley River subcatchment (MACR10) to be in excellent condition with a grade of A-. The gorge reaches were in good condition, with geomorphic condition deteriorating in the bedrock controlled gravel-bed reaches. The geomorphic condition at MACR10 at the downstream end of the subcatchment was below the subcatchment average.

The desktop GIS assessment of geomorphic condition of the mid Macleay River subcatchment (MACR9-MACR7) found the subcatchment to be in good condition with a grade of B-. The geomorphic condition at MACR9 was representative of the subcatchment average. However, the geomorphic condition at MACR8 and MACR7 were below the subcatchment average.

3.3.3.2 Riparian condition

MACR10

The original riparian vegetation community at MACR10 (Plate 3.37) was described as 'River Oak riparian woodland of the NSW North Coast Bioregion and northern Sydney Basin Bioregion', plant community type ID 1106 (VIS, 2012), broadly classed as 'Eastern Riverine Forests' (Keith, 2004). MACR10 received a good riparian condition score of 75.5, a grade of B- (Table 3.53).

The dominant canopy species present were River Oak (*Casuarina cunninghamiana* subsp. *cunninghamiana*), Forest Red Gum (*Eucalyptus tereticornis*), White Cedar (*Melia azedarach*) and Red Kamala (*Mallotus philippensis*), and the exotic species Willow (*Salix* sp.). Dominant native midstory species included Weeping Bottlebrush (*Callistemon viminalis*), Sandpaper Fig (*Ficus coronata*), Cheese Tree (*Glochidion fernandi*), Black Tea-tree (*Melaleuca bracteata*), along with the exotic species Lantana (*Lantana camara*), Narrow-leaved Vetch (*Gomphocarpus fruiticosus*), Small-leaved Privet (*Ligustrum sinense*) and Wild Tobacco (S*olanum mauritianum*). The understory was dominated by native species Soft Lomandra (*Lomandra hystrix*), Common Rush (*Juncus usitatus*), Tassel Sedge (*Carex fascicularis*) Knotweeds (*Persicaria strigosa* and *P.hydropiper*), Scurvy Weed (*Commelina cyanea*), Couch (*Cynodon dactylon*) and Australian Basket Grass (*Oplismenus aemulus*), along with exotic species Purpletop (*Verbena bonariensis*), Sidratusa (*Sida rhombifolia*), Blue Water Speedwell (*Veronica anagallis-aquatica*), Turnip Weed (*Rapistrum rugosum*), Mexican Poppy (*Argemone mexicana*), Paspalum (*Paspalum dilatatum*) and Pigeon Grass (*Setaria* sp.). Vine species included the native Wombat Berry (*Eustrephus latifolius*) and Milk Vine (*Marsdenia rostrata*) and exotic species Passionfruit (*Passiflora* sp.) and Blackberry (*Rubus* sp.), while a rich macrophyte layer included Triangular Club Rush (*Schoenoplectiella mucronata*), Hastings River Reed (*Potamophila parviflora*), Water Couch (*Paspalum distichum*), Freshwater Eelgrass (*Vallisneria nana*), Clasped Pondweed (*Potamogeton perfoliatus*), Red Water-milfoil (*Myriophyllum verrucosum*), and the exotic species Elodea (*Elodea canadensis*) and Egeria (*Egeria densa*).

Noxious weed species observed onsite were Willow (*Salix* sp.), Lantana (*Lantana camara*), Noogoora Burr (*Xanthium occidentale*), Spiny Pest Pear (*Opuntia stricta*), Blackberry (*Rubus* sp.), Fireweed (*Senecio madagascariensis*) and Egeria (*Egeria densa*), all class 4 noxious weeds, as well as Mexican Poppy (*Argemone mexicana*), a class 5 noxious weed. In addition to those already mentioned, other weed species present included White Clover (*Trifolium repens*), Spear Thistle (*Cirsium vulgare*), Coblers Pegs (*Bidens pilosa*), Umbrella Sedge (*Cyperus eragrostis*) and Prairie Grass (*Bromus catharticus*).

Summary: MACR10 was a mildly disturbed system of mixed-aged closed forest with a remnant canopy and mixed native and exotic species throughout the midstory and understory layers, in a predominantly forested, partially cleared landscape. The surrounding landuse was agricultural grazing land, National Park, State Forest and Nature Reserve. Significant remnant stands of vegetation surround the site on all sides, on private land and in Cunnawarra and Oxley Wild Rivers National Parks. MACR10 scored full marks for Cover, well for Habitat, and moderately for Native Species, Debris and Management subindices (Table 3.53), retaining representative elements of the remnant vegetation community in all structural layers. Riparian condition at MACR10 was impacted by the presence and regeneration of weed and noxious weed species particularly in the midstory and understory structural layers. Limited habitat trees, a reduction in woody and non-woody debris, inadequate riparian fencing and animal impact also contributed to the reduction in riparian grade at this site.

Management Recommendations: Riparian condition could be improved through the control and removal of weed and noxious weed species, particularly throughout the midstory and understory layers. Riparian fencing should exclude livestock and allow for midstory and understory native species recovery and woody debris accumulation.

Plate 3.37 *Riparian vegetation at MACR10 was mildly disturbed. Riparian condition would be improved through control and removal of weed and noxious weed species specifically Willow* (Salix sp.)*, Lantana* (Lantana camara)*, Noogoora Burr* (Xanthium occidentale)*, Spiny Pest Pear* (Opuntia stricta) *and Blackberry* (Rubus sp.) *and by limiting animal impact by fencing off the riparian zone.*

***Table 3.53** Site-level summary of riparian condition of Macleay River #10 showing the scores of individual indicators and the five subindices that comprise the Vegetation Condition Index.*

MACR10	Scores
HABITAT	**18/20**
Channel width	4
Proximity	4
Continuity	4
Layers	4
Large native trees	1
Hollow-bearing trees	1
NATIVE SPECIES	**14.5/20**
Native canopy species	4
Native midstory species	3
Native herb/forb species	1.5
Native graminoid species	2
Native macrophyte species	4
SPECIES COVER	**20/20**
Canopy species	4
Midstory species	4
Herb/forb species	4
Graminoid species	4
Macrophyte species	4
DEBRIS	**12.5/20**
Total leaf litter	1
Native leaf litter	3
Dead trees standing	3
Dead trees fallen	1
Lying logs	2
Fringing vegetation	2.5
MANAGEMENT	**10.5/20**
Tree clearing	3
Fencing	0
Animal impact	0
Species of interest	1
Exposed tree roots	3.5
Native woody regeneration	2
Weedy woody regeneration	1
TOTAL	**75.5/100**

MACR9

The original riparian vegetation community at MACR9 (Plate 3.38) was described as 'River Oak riparian woodland of the NSW North Coast Bioregion and northern Sydney Basin Bioregion', plant community type ID 1106 (VIS, 2012), broadly classed as 'Eastern Riverine Forests' (Keith, 2004). MACR9 received a low riparian condition score of 51.8, a grade of D (Table 3.54).

The dominant canopy species present were River Oak (*Casuarina cunninghamiana* subsp. *cunninghamiana*), Port Jackson Fig (*Ficus rubiginosa*), Silky Oak (*Grevillea robusta*) and the exotic species Camphor Laurel (*Cinnamomum camphora*). Dominant native midstory species included Weeping Bottlebrush (*Callistemon viminalis*), Sandpaper Fig (*Ficus coronata*), Black Tea-tree (*Melaleuca bracteata*), along with the exotic species Lantana (*Lantana camara*) and Wild Tobacco (S*olanum mauritianum*). The understory was dominated by native species Soft Lomandra (*Lomandra hystrix*), Common Rush (*Juncus usitatus*), Knotweeds (*Persicaria strigosa* and *P.hydropiper*), Scurvy Weed (*Commelina cyanea*), Couch (*Cynodon dactylon*), Matgrass (*Hemarthria uncinata*) and Australian Basket Grass (*Oplismenus aemulus*), along with exotic species Purpletop (*Verbena bonariensis*), Blue Billy Goat Weed (*Ageratum houstonianum*), Turnip Weed (*Rapistrum rugosum*), Mexican Poppy (*Argemone mexicana*), Japanese Lionstail (*Leonurus japonicas*), Paspalum (*Paspalum dilatatum*), Buffalo Grass (*Stenotaphrum secundatum*) and Pigeon Grass (*Setaria* sp.). The only vine species present was the exotic species Cat's Claw Creeper (*Dolichandra unguis-cati*), while a rich macrophyte layer included Triangular Club Rush (*Schoenoplectiella mucronata*), Water Couch (*Paspalum distichum*), Freshwater Eelgrass (*Vallisneria nana*), Clasped Pondweed (*Potamogeton perfoliatus*), Red Water-milfoil (*Myriophyllum verrucosum*), Water Thyme (*Hydrilla verticillata*), and the exotic species Elodea (*Elodea canadensis*).

Noxious weed species observed onsite were Cat's Claw Creeper (*Dolichandra unguis-cati*), a class 3 noxious weed; Camphor Laurel (*Cinnamomum camphora*), Lantana (*Lantana camara*), Fireweed (*Senecio madagascariensis*), all class 4 noxious weeds; and Mexican Poppy (*Argemone mexicana*), a class 5 noxious weed. In addition to those already mentioned, other weed species present included Crofton Weed (*Ageratina adenophora*), Spear Thistle (*Cirsium vulgare*), Coblers Pegs (*Bidens pilosa*), Green Mullein (*Verbascum virgatum*), Umbrella Sedge (*Cyperus eragrostis*), Red Natal Grass (*Melinis repens*), Whisky Grass (*Andropogon viginicus*) and Prairie Grass (*Bromus catharticus*).

Summary: MACR9 was a highly disturbed system of mixed-aged closed forest with mixed native and exotic species throughout all structural layers, in a predominantly cleared landscape. The surrounding landuse was agricultural grazing land and urban settlement. Significant remnant stands of vegetation lie 1.5km north of MACR9 in private land, 3.5km to the northeast in Thumb Creek State Forest and 4.5km to the south in Gads Sugarloaf Nature Reserve. MACR9 scored well for Cover, moderately for Native Species and poorly for Habitat, Debris and Management subindices (Table 3.54), retaining representative elements of the remnant vegetation community in all structural layers. Riparian condition at MACR9 was affected by poor riparian vegetation width and habitat connectivity, the absence of large trees, and by the presence and regeneration of weed and noxious weed species, particularly in the canopy and understory structural layers. Low vegetation cover levels were observed in both the canopy and understory structural layers. Limited fringing vegetation, a reduction in woody and non-woody debris, inadequate riparian fencing and animal impact also contributed to the reduction in riparian grade at this site.

Management Recommendations: Riparian condition could be improved through the control and removal of weed and noxious weed species, and by undertaking native plantings to promote site regeneration of native species. Such plantings assist in phasing out and replacing dominant canopy weed species such as Camphor Laurel. Riparian fencing should exclude livestock, promote woody and non-woody debris accumulation and allow for midstory and understory native species recovery, and if strategically implemented could be used in combination with native plantings to increase riparian vegetation width and to improve proximity to intact remnant stands of vegetation.

Plate 3.38 *Riparian vegetation at MACR9 was highly disturbed. Riparian condition would be improved through control and removal of weed and noxious weed species specifically Cat's Claw Creeper* (Dolichandra unguis-cati)*, Camphor Laurel* (Cinnamomum camphora)*, Lantana* (Lantana camara)*, undertaking native plantings and by limiting animal impact by fencing off the riparian zone.*

Table 3.54 *Site-level summary of riparian condition of Macleay River #9 showing the scores of individual indicators and the five subindices that comprise the Vegetation Condition Index.*

MACR9	Scores
HABITAT	**7.8/20**
Channel width	1.3
Proximity	0
Continuity	3
Layers	3
Large native trees	0.5
Hollow-bearing trees	0
NATIVE SPECIES	**7.8/20**
Native canopy species	1.5
Native midstory species	3
Native herb/forb species	2
Native graminoid species	2
Native macrophyte species	4
SPECIES COVER	**15/20**
Canopy species	2
Midstory species	3
Herb/forb species	4
Graminoid species	2
Macrophyte species	4
DEBRIS	**8/20**
Total leaf litter	1.5
Native leaf litter	1.5
Dead trees standing	1
Dead trees fallen	1
Lying logs	2
Fringing vegetation	1
MANAGEMENT	**8.5/20**
Tree clearing	2.5
Fencing	0
Animal impact	0
Species of interest	0
Exposed tree roots	3
Native woody regeneration	2
Weedy woody regeneration	1
TOTAL	**51.8/100**

MACR8

The original riparian vegetation community at MACR8 (Plate 3.39) was described as ‘River Oak riparian woodland of the NSW North Coast Bioregion and northern Sydney Basin Bioregion’, plant community type ID 1106 (VIS, 2012), broadly classed as ‘Eastern Riverine Forests’ (Keith, 2004). MACR8 received a low riparian condition score of 56.2, a grade of D+ (Table 3.55).

The dominant canopy species present was River Oak (*Casuarina cunninghamiana* subsp. *cunninghamiana*). Dominant native midstory species included Weeping Bottlebrush (*Callistemon viminalis*), Sandpaper Fig (*Ficus coronata*), Cheese Tree (*Glochidion fernandi*), Black Tea-tree (*Melaleuca bracteata*), along with the exotic species Lantana (*Lantana camara*), Castor Oil Plant (*Ricinus communis*) and Wild Tobacco (S*olanum mauritianum*). The understory was dominated by native species Soft Lomandra (*Lomandra hystrix*), Knotweeds (*Persicaria strigosa* and *P.hydropiper*), Scurvy Weed (*Commelina cyanea*), Couch (*Cynodon dactylon*), Barbed Wire Grass (*Cymbopogon refractus*), Rice grass (*Microlaena stipoides*) and Australian Basket Grass (*Oplismenus aemulus*), along with exotic species Purpletop (*Verbena bonariensis*), Turnip Weed (*Rapistrum rugosum*), Mother of Millions (*Bryophyllum delagoense*), Mexican Poppy (*Argemone mexicana*), Shepherds Purse (*Capsella bursa-pastoris*), Paspalum (*Paspalum dilatatum*) and Pigeon Grass (*Setaria* sp.). Vine species present were the native Silkpod (*Parsonsia straminea*) and the exotic Common Passionfruit (*Passiflora* sp.), while the macrophyte layer included Freshwater Eelgrass (*Vallisneria nana*), Clasped Pondweed (*Potamogeton perfoliatus*), Red Water-milfoil (*Myriophyllum verrucosum*) and the exotic species Elodea (*Elodea canadensis*).

Noxious weed species observed onsite were Lantana (*Lantana camara*), Mother of Millions (*Bryophyllum delagoense*), Fireweed (*Senecio madagascariensis*), all class 4 noxious weeds, as well as Mexican Poppy (*Argemone mexicana*), a class 5 noxious weed. In addition to those already mentioned, other weed species present included Spear Thistle (*Cirsium vulgare*), Coblers Pegs (*Bidens pilosa*), Curled Dock (*Rumex crispus*), Red Natal Grass (*Melinis repens*), Rhodes Grass (*Chloris gayana*) and Prairie Grass (*Bromus catharticus*).

Summary: MACR8 was a highly disturbed system of mixed-aged forest with a remnant canopy and mixed native and exotic species throughout the midstory and understory layers, in a predominantly cleared, partially forested landscape. The surrounding landuse was agricultural grazing land and private forested land. Significant remnant stands of vegetation lie 4.2km north and 5.3km northeast in Collombatti State Forest, 5.7km southwest in Boonanghi Nature Reserve and 4km west in private land. MACR8 scored well for Cover, moderately for Habitat and Native Species and poorly for Debris and Management subindices (Table 3.55), retaining representative elements of the remnant vegetation community in all structural layers. Riparian condition at MACR8 was affected by poor riparian vegetation width and habitat connectivity and by the presence and regeneration of weed and noxious weed species, particularly in the midstory understory and macrophyte structural layers. Reduced levels of woody debris, historic clearing, inadequate riparian fencing and animal impact also contributed to the reduction in riparian grade at this site.

Management Recommendations: Riparian condition could be improved through the control and removal of weed and noxious weed species, and by undertaking native plantings to promote site regeneration of native species. Riparian fencing should exclude livestock, promote woody and non-woody debris accumulation and allow for midstory and understory native species recovery, and if strategically implemented, could be used in combination with native plantings to increase riparian vegetation width and to improve proximity to intact remnant stands of vegetation.

Plate 3.39 *Riparian vegetation at MACR8 was highly disturbed. Riparian condition would be improved through control and removal of weed and noxious weed species specifically Lantana* (Lantana camara) *and Mother of Millions* (Bryophyllum delagoense)*, undertaking native plantings and by limiting animal impact by fencing off the riparian zone.*

Table 3.55 *Site-level summary of riparian condition of Macleay River #8 showing the scores of individual indicators and the five subindices that comprise the Vegetation Condition Index.*

MACR8	Scores
HABITAT	**11.2/20**
Channel width	0.7
Proximity	1
Continuity	2
Layers	3.5
Large native trees	2.5
Hollow-bearing trees	1.5
NATIVE SPECIES	**13.5/20**
Native canopy species	4
Native midstory species	3
Native herb/forb species	2
Native graminoid species	2.5
Native macrophyte species	2
SPECIES COVER	**17/20**
Canopy species	2.5
Midstory species	3.5
Herb/forb species	3.5
Graminoid species	3.5
Macrophyte species	4
DEBRIS	**7/20**
Total leaf litter	2
Native leaf litter	2
Dead trees standing	0
Dead trees fallen	0
Lying logs	1
Fringing vegetation	2
MANAGEMENT	**7.5/20**
Tree clearing	1.5
Fencing	0
Animal impact	0
Species of interest	0
Exposed tree roots	3
Native woody regeneration	2
Weedy woody regeneration	1
TOTAL	**56.2/100**

MACR7

The original riparian vegetation community at MACR7 (Plate 3.40) was described as 'River Oak riparian woodland of the NSW North Coast Bioregion and northern Sydney Basin Bioregion', plant community type ID 1106 (VIS, 2012), broadly classed as 'Eastern Riverine Forests' (Keith, 2004). MACR7 received a low riparian condition score of 55.4, a grade of D+ (Table 3.56).

The dominant canopy species present was River Oak (*Casuarina cunninghamiana* subsp. *cunninghamiana*). Dominant native midstory species included Weeping Bottlebrush (*Callistemon viminalis*), along with the exotic species Lantana (*Lantana camara*), Castor Oil Plant (*Ricinus communis*), Wild Tobacco (S*olanum mauritianum*) and Arsenic Bush (*Senna septemtrionalis*). The understory was dominated by native species Soft Lomandra (*Lomandra hystrix*), Knotweeds (*Persicaria decipiens* and *P.hydropiper*), Lesser Joyweed (*Alternanthera denticulata*), Matgrass (*Hemarthria uncinata*), Forest Hedgehog Grass (*Echinopogon ovatus*), Couch (*Cynodon dactylon*) and Australian Basket Grass (*Oplismenus aemulus*), along with exotic species Turnip Weed (*Rapistrum rugosum*), Mexican Poppy (*Argemone mexicana*), Wandering Jew (*Tradescantia fluminensis*), Sidratusa (*Sida rhombifolia*), Umbrella Sedge (*Cyperus eragrostis*), Prairie Grass (*Bromus catharticus*) and Pigeon Grass (*Setaria* sp.). Exotic vine species dominated and included Cat's Claw Creeper (*Dolichandra unguis-cati*), Balloon Vine (*Cardiospermum grandiflorum*) and Common Passionfruit (*Passiflora* sp.), while a rich macrophyte layer included Hastings River Reed (*Potamophila parviflora*), Water Primrose (*Ludwigia peploides*), Freshwater Eelgrass (*Vallisneria nana*), Waternymph (*Najas tenuifolia*), Red Water-milfoil (*Myriophyllum verrucosum*) and the exotic species Elodea (*Elodea canadensis*).

Noxious weed species observed onsite were Cat's Claw Creeper (*Dolichandra unguis-cati*), a class 3 noxious weed; Lantana (*Lantana camara*), Fireweed (*Senecio madagascariensis*) and Balloon Vine (*Cardiospermum grandiflorum*), all class 4 noxious weeds; and Mexican Poppy (*Argemone mexicana*), a class 5 noxious weed. In addition to those already mentioned, other weed species present included Blue Billy Goat Weed (*Ageratum houstonianum*), Spear Thistle (*Cirsium vulgare*), Green Mullein (*Verbascum virgatum*), Coblers Pegs (*Bidens pilosa*), Slender Celery (*Cyclospermum leptophyllum*) and Wimmera Grass (*Lolium rigidum*).

Summary: MACR7 was a highly disturbed system of mixed-aged forest with mixed native and exotic species throughout all structural layers, in a predominantly cleared, partially forested landscape. The surrounding landuse was agricultural grazing land, Nature Reserve and private forested land. Significant remnant stands of vegetation lie 1km east in Skillion Nature Reserve, 2.2km southeast in Yarravel Nature Reserve and 8.4km southwest in Boonanghi Nature Reserve. MACR7 scored well for Cover, moderately for Native Species and Debris and poorly for Habitat and Management subindices (Table 3.56), retaining representative elements of the remnant vegetation community in all structural layers. Riparian condition at MACR7 was affected by poor riparian vegetation width, continuity and habitat connectivity and by the presence and regeneration of weed and noxious weed species, particularly in the midstory and understory structural layers. Reduced levels of woody debris, historic clearing, limited large habitat trees, inadequate riparian fencing and animal impact also contributed to the reduction in riparian grade at this site.

Management Recommendations: Riparian condition could be improved through the control and removal of weed and noxious weed species, and by undertaking native plantings to promote site regeneration of native species. Riparian fencing should exclude livestock, promote woody and non-woody debris accumulation and allow for midstory and understory native species recovery, and if strategically implemented, could be used in combination with native plantings to increase riparian vegetation width and to improve proximity to intact remnant stands of vegetation.

Plate 3.40 *Riparian vegetation at MACR7 was highly disturbed. Riparian condition would be improved through control and removal of weed and noxious weed species specifically Cat's Claw Creeper* (Dolichandra unguis-cati)*, Lantana* (Lantana camara) *and Balloon Vine* (Cardiospermum grandiflorum)*, undertaking native plantings and by limiting animal impact by fencing off the riparian zone.*

***Table 3.56** Site-level summary of riparian condition of Macleay River #7 showing the scores of individual indicators and the five subindices that comprise the Vegetation Condition Index.*

MACR7	Scores
HABITAT	**7.7/20**
Channel width	0.7
Proximity	1
Continuity	1
Layers	3
Large native trees	1
Hollow-bearing trees	1
NATIVE SPECIES	**10.5/20**
Native canopy species	3
Native midstory species	2
Native herb/forb species	1
Native graminoid species	1.5
Native macrophyte species	3
SPECIES COVER	**18.3/20**
Canopy species	3
Midstory species	3.25
Herb/forb species	4
Graminoid species	4
Macrophyte species	4
DEBRIS	**10.5/20**
Total leaf litter	1
Native leaf litter	1
Dead trees standing	3
Dead trees fallen	1
Lying logs	1.5
Fringing vegetation	3
MANAGEMENT	**8.5/20**
Tree clearing	1.5
Fencing	0
Animal impact	1.5
Species of interest	0
Exposed tree roots	3.5
Native woody regeneration	2
Weedy woody regeneration	0
TOTAL	**55.4/100**

3.3.3.3 Aquatic macrophyte communities

During summer 2015-2016 Kempsey Shire Council (KSC) funded a study conducted by the University of New England's Aquatic Ecology and Restoration Research Group into the freshwater macrophyte communities in the main trunk of the Macleay River. The study aimed to address one of KSC's high priority management issues assessing the extent of Egeria (Egeria densa), a declared type 4 noxious weed in the Macleay River and by providing both a literature review and recommendations for the management of this invasive species. An additional aim of the study was to document and map in a GIS platform, species composition, range, habitat and cover data of both native macrophyte beds and other introduced weedy macrophyte species in the Macleay.

The 215km study section of the main trunk of the Macleay River spanned over half of the total river length, from Halls peak to Kempsey, with the 201km section of freshwater surveyed by kayak and the remaining 14km estuarine section by boat. Cover values were visually assessed using a bathyscope and macrophyte species were assigned to both a habitat class (4) within a landform unit (3). In the field mapping and data collection was transcribed onto gridded waterproof paper and a handheld GPS was used to ground truth coordinate accuracy. Field sheets were scanned and ortho-rectified in the lab for data processing, resulting in a GIS macrophyte layer of the study area from which polygon data could be extracted and exported to excel for data analysis of cover.

Twenty-one species of macrophytes consisting of fifteen native species and six exotic species were found throughout the study area (Figure 3.10). Egeria was spread throughout the entire study area, occurring at very high cover (>60%) in 10% of the study area with greatest cover values occuring on the Coastal Plain and throughout Edge habitats. Elodea, an exotic species, was the most common macrophyte species throughout the study area, occurring as a dominant species in the Edge and Channel habitats in the Escarpment Ranges and Midland Hills. Point source populations were identified for three of the five noxious weed species observed throughout the study area (Salvinia, Sagittaria and Water Hyacinth). The most common native species were Red Water-milfoil, Ribbon Weed and Hydrilla. Total macrophyte species richness was highest in the middle of the catchment in the Midland Hills, while exotic species cover and richness was highest in both the Midland Hills and Coastal Plain sections of the study area.

Water Hyacinth, Salvinia and Sagittaria have the capacity to spread rapidly, making control of these species a management priority. The removal of exotic macrophyte species such as Egeria and Elodea is likely to be environmentally detrimental, expensive and ultimately ineffective, given the species ease and propensity with which they propagate. Long-term management of these species in the Macleay River is likely to be a combination of reduced nutrient inputs and anthropogenic disturbance, improved land management practices and restoration of riparian vegetation. Future studies should, a) give a comparable account of temporal change, and b) consider the ecological roles of these species in the ecosystems of the Macleay River.

Further information on study findings can be found by contacting KSC and requesting the following report: Vincent, B.E., Mika, S. and Ryder, D. (2016). Freshwater Macrophyte Communities of the Macleay River 2015-2016: Final report to Kempsey Shire Council. University of New England, Armidale, Australia.

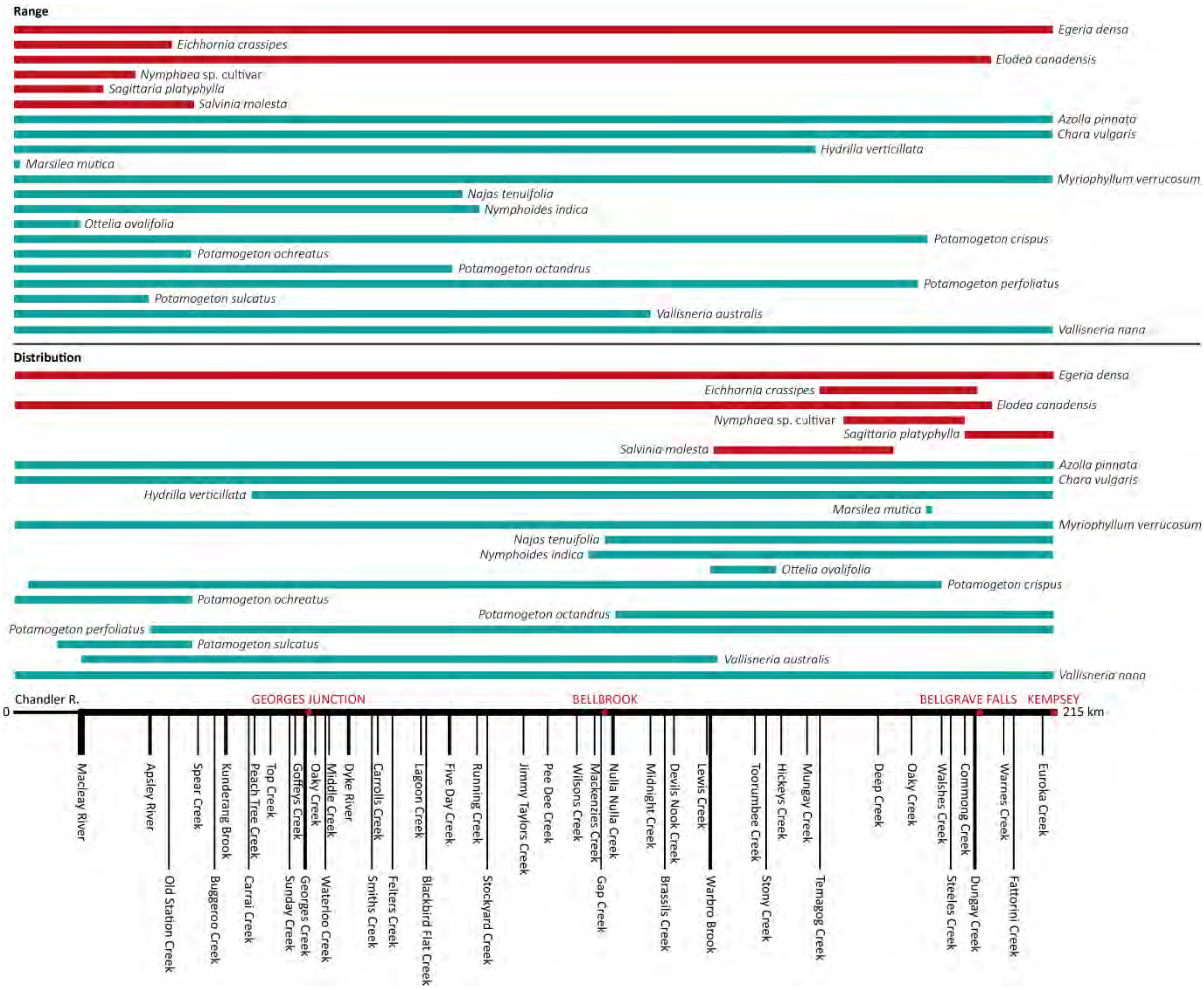


Figure 3.10 *Schematic diagram of Macleay macrophyte species distribution and range in relation to significant tributaries and the survey reach of the Macleay River (to scale where position on diagram represents longitudinal position in study reach).*

3.3.3.4 Water quality

The freshwater reach received a score of 72 (C+) with the best water quality recorded at MACR7 (Turners Flat) (76, B-). MACR10 at Georges Junction received a score of 56 (D+), MACR9 at Bellbrook received a score of 72 (C+) and MACR8 at Toorooka received a score of 69 (C). Figures 3.11 and 3.12 show the key physicochemical and nutrient variables used in the assessment of water quality for the main stem of the Macleay River. ANZECC guidelines are shown as red reference lines in each of the graphs. Ranges and means for these variables are given in Table 3.57 and the exceedances are given in Table 3.58. These variables do not include the analysis of heavy metal contamination due to historical mining; this is reported separately in Section 3.3.5.

There was no clear longitudinal pattern in pH through the freshwater reach of the Macleay River, but all sites frequently exceeded the upper ANZECC lowland freshwater trigger value of 8 (Figure 3.11b, Table 3.58). Mean turbidity in the freshwater Macleay River increased longitudinally downstream of Bellbrook (MACR9), although all four freshwater sites remained well below the ANZECC lowland freshwater trigger value during the sampling period (Figure 3.11d). DO% followed a similar longitudinal pattern to turbidity, with the lowest range and site mean at Bellbrook (MACR9), likely due to the site located at the tail of a deep pool approximately 1km long. The percentage of samples that fell below the minimum ANZECC trigger value of 80% decreased longitudinally downstream from 4 observations (67% of samples) at MACR9 to 2 observations at MACR7 (Table 3.58). However, MACR7 had the lowest site minimum, with 45% DO (Table 3.57).

Freshwater sites on the Macleay River consistently exceeded ANZECC nutrient trigger values for lowland freshwater systems, especially for nitrogen (Figure 3.12). TN concentrations exceeded the ANZECC trigger value of 500µg/L on 3 sampling occasions at MACR10 and MACR7 and on 2 of the 6 sampling occasions at MACR9 and MACR8 (Table 3.58). Site maximum TN concentrations were 2.1, 3.4, 3.6 and 3 times the ANZECC trigger value at MACR10, MACR9, MACR8 and MACR7, respectively (Table 3.57).

Total phosphorus (TP) concentrations exceeded the ANZECC lowland freshwater trigger value of 50µg/L on 4 sampling occasions at MACR10, and 2 sampling occasions at MACR9 and MACR8 (Table 3.58). Site maximum TP concentrations were 3.8, 1.8 and 1.3 times the ANZECC trigger value at MACR10, MACR9 and MACR8, respectively. TP concentrations at MACR7 did not exceed the ANZECC trigger value during the sampling period (Figure 3.12b).

Bioavailable nitrogen (NOx) concentrations exceeded the ANZECC lowland freshwater trigger value of 40µg/L more frequently than TN concentrations. NOx concentrations exceeded the ANZECC trigger value on 5 of the 6 sampling occasions at MACR10 and MACR8, and on 4 sampling occasions at MACR9 and MACR7 (Table 3.58). Site maximum NOx concentrations were 8.4, 5.8, 10.3, and 6.1 times the ANZECC trigger value at MACR10, MACR9, MACR8 and MACR7, respectively.

SRP concentrations closely followed the spatial and temporal patterns in TP concentrations (Figure 3.12b, d), although exceedances were less frequent (Table 3.58). SRP concentrations exceeded the ANZECC trigger value on 3 of the 6 sampling occasions at MACR10, and on 1 sampling occasion at MACR9 and MACR8 (Table 3.58). Site maximum SRP concentrations were 4.2, 1.3 and 1.8 times the ANZECC trigger value at MACR10, MACR9 and MACR8, respectively.

Concentrations of total and dissolved nutrients were significantly lower in the main stem of the Macleay River than the Tableland tributaries, despite the significant tributary inputs (compare Figures 3.8 and 3.12). It is likely that the extensive beds of aquatic macrophytes throughout the Macleay main stem play an important ecological role as nutrient sinks regulating water quality. Without these dense macrophyte beds, excess nutrients in the water column could lead to increases in the frequency, duration and magnitude of nuisance algal blooms in the Macleay River and estuary. Secondly, the Macleay River is a gravel-bed channel of pool-riffle sequences. It is likely that extensive exchange of water, solutes such as nutrients and fine particulate organic matter occurs between the surface water and the alluvial aquifer (that is, hyporheic exchange). This exchange occurs across the saturated sediments of the streambed and banks, and in rivers like the Macleay, can extend laterally for significant distances into the floodplain. These saturated sediments support diverse and abundant microbial communities and have been shown elsewhere to be ecologically important in nutrient retention and regulating water quality (Boulton et al. 2010).

High nutrient concentrations did not lead to high algal productivity in the freshwater Macleay River, with chlorophylla *a* concentrations never exceeding the ANZECC trigger value of 4 µg/L during the sampling period.

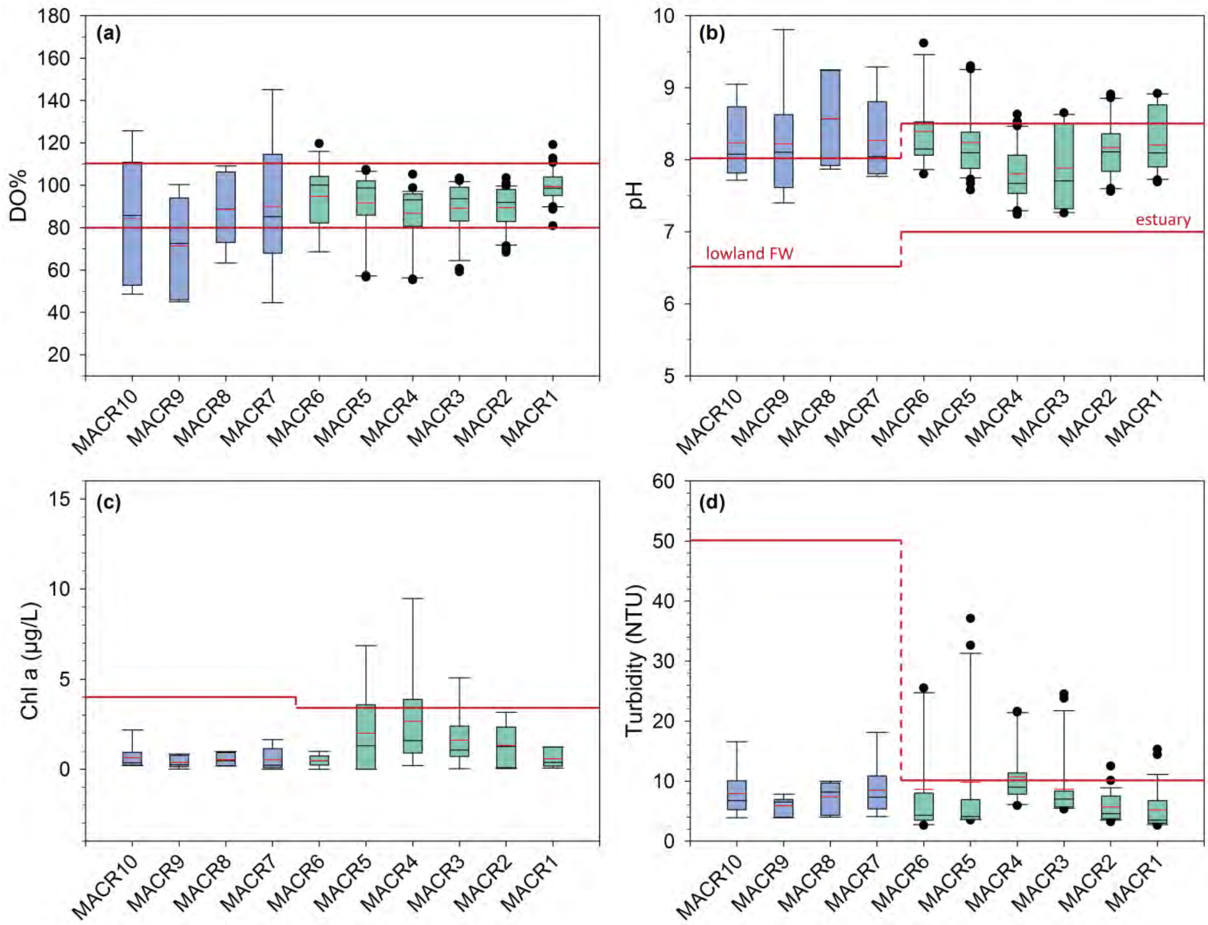


Figure 3.11 *Mean (red line), median (black line), 25th and 75th percentiles for (a) % saturated DO, (b) pH, (c) chlorophyll a and (d) turbidity in the main stem of the Macleay River. Outliers are represented by black dots. Horizontal red lines represent the ANZECC and MER trigger thresholds for lowland freshwater or estuarine systems (represented by blue or green boxes, respectively). Two horizontal red lines represent minimum (lower) and maximum (upper) trigger thresholds while single horizontal red lines represent maximum trigger thresholds.*

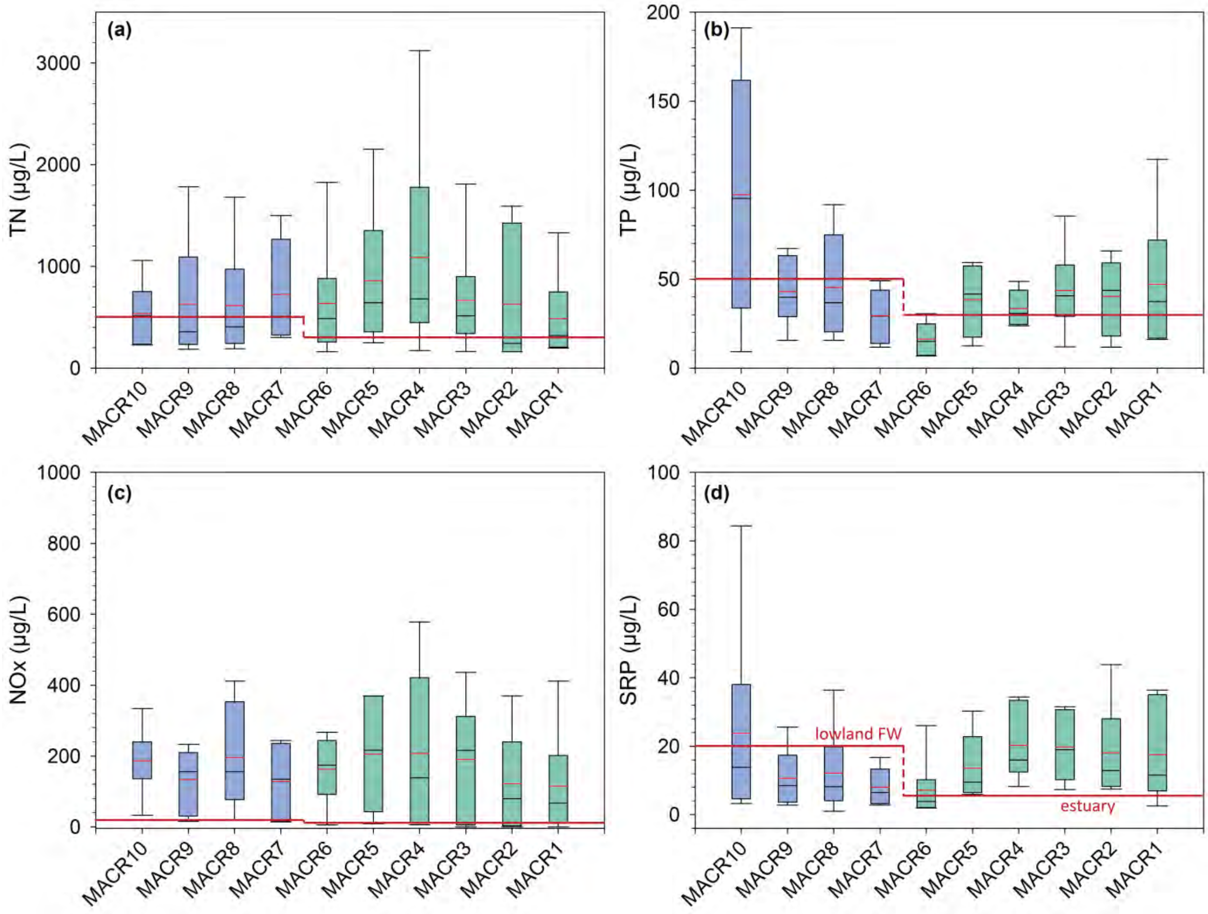


Figure 3.12 *Mean (red line), median (black line), 25th and 75th percentiles for (a) total nitrogen, (b) total phosphorus, (c) bioavailable nitrogen and (d) soluble reactive phosphorus in the main stem of the Macleay River. Horizontal red lines represent the maximum ANZECC and MER trigger thresholds for lowland freshwater or estuarine systems (represented by blue or green boxes, respectively).*

Table 3.57 *Minimums, maximums and means of measured water quality variables for the four freshwater sites on the Macleay River.*

	MACR10			MACR9			MACR8			MACR7		
Variable	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**
Temperature (°C)	14.21	29.03	22.19	13.10	27.95	21.93	12.37	29.05	21.53	15.52	29.99	22.63
pH	7.72	9.05	8.24	7.87	9.25	8.57	7.40	9.81	8.22	7.77	9.29	8.27
EC (mS/cm)	0.03	0.15	0.08	0.13	0.16	0.14	0.01	0.15	0.12	0.13	0.15	0.14
Salinity (PPT)	3.24	9.72	6.80	0.06	0.08	0.07	0.06	0.07	0.07	0.06	0.07	0.07
DO (mg/L)	0.01	0.07	0.04	4.57	8.96	7.09	3.12	9.09	5.92	3.30	11.14	7.23
DO (%)	48.60	125.6	84.32	63.30	109.1	88.60	45.10	100.4	71.45	44.50	145.1	90.03
Turbidity (NTU)	3.90	16.60	7.93	4.00	10.00	7.40	3.90	7.80	5.90	4.10	18.10	8.52
Max Depth	0.25	0.40	0.30	0.30	0.40	0.34	0.30	0.50	0.38	0.30	0.60	0.42
Chla (µg/L)	0.21	2.18	0.64	0.00	0.98	0.38	0.01	0.85	0.38	0.00	1.65	0.53
TSS (mg/L)	1.18	17.98	8.93	0.67	7.43	2.46	0.10	5.69	1.89	0.48	6.90	1.92
TN (µg/L)	228.81	1059.3	534.71	188.92	1682.2	613.35	186.08	1783.9	632.79	304.26	1500.0	724.98
TP (µg/L)	9.30	191.20	97.54	15.71	91.90	45.35	15.71	67.26	43.01	11.78	49.15	29.35
NOx (µg/L)	32.76	334.46	186.41	15.52	233.11	133.17	17.04	411.27	195.27	13.79	244.26	129.10
SRP (µg/L)	3.23	84.42	23.82	2.76	25.59	10.63	0.97	36.40	12.15	2.71	16.73	7.94

Table 3.58 *Exceedances[1] observed in the sites on the main stem of the Macleay River for pH, conductivity (EC), percent saturated dissolved oxygen (DO), turbidity, chlorophyll a (Chl-a), total nitrogen (TN) ,total phosphorus (TP), bioavailable nitrogen (NOx) and soluble reactive phosphorus (SRP).*

Site	pH	EC	DO %	Turbidity	Chl-a	TN	TP	NOx	SRP
MACR10	2(33%) 0,2	0(0%) 0,0	4(67%) 3,1	0 (0%)	3(50%)	3(50%)	4(67%)	5(83%)	3(50%)
MACR9	1(17%) 0,1	0(0%) 0,0	4(67%) 4,0	0 (0%)	1(17%)	2(33%)	2(33%)	4(67%)	1(17%)
MACR8	3(50%) 0,3	0(0%) 0,0	3(50%) 3,3	0 (0%)	1(17%)	2(33%)	2(33%)	5(83%)	1(17%)
MACR7	2(33%) 0,3	0(0%) 0,0	3(50%) 2,1	0 (0%)	1(17%)	3(50%)	0(0%)	4(67%)	0(0%)
MACR6	5(29%) 0,5	NA	6(35%) 3,3	3 (20%)	1(17%)	4(67%)	1(17%)	5(83%)	1(17%)
MACR5	6(19%) 0,6	NA	5(16%) 5,0	6 (22%)	4(67%)	5(83%)	4(67%)	5(83%)	6(100%)
MACR4	2(7%) 0,2	NA	6(20%) 6,0	9 (36%)	1(17%)	5(83%)	3(50%)	4(67%)	6(100%)
MACR3	8(26%) 0,8	NA	3(10%) 3,0	3 (12%)	1(17%)	5(83%)	5(83%)	4(67%)	6(100%)
MACR2	7(23%) 0,7	NA	6(19%) 6,0	2(7%)	4(67%)	3(50%)	4(67%)	4(67%)	6(100%)
MACR1	8(27%) 0,8	NA	3(10%) 0,3	2 (8%)	0(0%)	3(50%)	3(50%)	5(83%)	5(83%)

[1] Numbers in black represent the total number and percent of exceedances. Numbers in blue and red represent the numbers of measurements lower than the minimum threshold and higher than the maximum threshold, respectively. The number of exceedances includes all depths sampled so may be greater than the number of times sampled. Turbidity, chlorophyll a and nutrients only have maximum trigger thresholds.

3.3.3.5 Aquatic macroinvertebrates

MACR10 recorded 714 and 1251 individual macroinvertebrates across 30 and 34 macroinvertebrate families during the 2015 autumn and spring sampling, respectively (Table 3.59). In autumn, abundance was dominated by Baetid Mayflies (400 individuals), and richness was dominated by Ephemeroptera (Mayflies) and Trichoptera (Caddisflies), both with 6 families. In contrast, Hydropsychid Caddisflies were the most abundant family in spring (400 individuals), and the most diverse order in spring was Coleoptera (Aquatic Beetles) with 8 families. Family richness was higher in spring than autumn, primarily driven by the presence of aquatic beetles in spring. There were a number of rare taxa at the site, with 16 and 14 taxa recording fewer than 5 individuals in autumn and spring, respectively.

Mean SIGNAL2 scores for MACR10 were higher in spring (6.3) than autumn (5.5), although the range of SIGNAL2 scores was similar between seasons. The increase in the mean SIGNAL2 at MACR10 in spring was due to high abundances of high-scoring Trichoptera (Caddisflies).

MACR10 received an overall Ecohealth score of 66, a grade of C-, for aquatic macroinvertebrate community condition. All macroinvertebrate indicators were above the Macleay catchment average, particularly mean SIGNAL2 score (Table 3.13). The macroinvertebrate indicators suggest the water quality and habitat conditions in the Macleay River downstream of the gorge are in good condition, and are able to support a diversity of macroinvertebrate fauna given the wide range of SIGNAL2 scores.

MACR9 recorded 1295 and 989 individual macroinvertebrates across 30 and 34 macroinvertebrate families during the 2015 autumn and spring sampling, respectively (Table 3.59). In autumn, abundance was dominated by Baetid Mayflies (635 individuals), and richness was dominated by Coleoptera (Aquatic Bettles) with 7 families (but only 16 individuals). In contrast, Hydropsychid Caddisflies were the most abundant family in spring (208 individuals), and diversity was dominated by Coleoptera (Aquatic Beetles) and Trichoptera (Caddisflies), both with 8 families. Family richness was higher in spring than autumn, primarily driven by the presence of caddisflies in spring. There were a number of rare taxa at the site, with 11 taxa recording fewer than 5 individuals in autumn and spring.

Mean SIGNAL2 scores for MACR9 were slightly higher in autumn (5.4) than spring (5.2), although the range of SIGNAL2 scores was the same between seasons.

MACR9 received an overall Ecohealth score of 60, a grade of C-, for aquatic macroinvertebrate community condition. All macroinvertebrate indicators were below the Macleay catchment average, particularly EPT score and mean SIGNAL2 score (Table 3.13). The macroinvertebrate indicators suggest the water quality and habitat conditions in the Macleay River at Bellbrook are in moderate condition, and are able to support a diversity of macroinvertebrate fauna given the wide range of SIGNAL2 scores.

Table 3.59 *Summary of aquatic macroinvertebrate data for freshwater sites on the Macleay River.*

	MACR10		MACR9	
Macroinvertebrate indicator	**Autumn 2015**	**Spring 2015**	**Autumn 2015**	**Spring 2015**
Total abundance	714	1251	1295	989
Family richness	30	34	30	34
EPT abundance	603	680	353	344
EPT richness	12	12	9	7
Mean SIGNAL2 score	5.5	6.3	5.4	5.2
SIGNAL2 score range	1 - 8	1 - 9	1 - 8	1 - 8
Ecohealth score (grade)	**66 (C-)**		**60(C-)**	
	MACR8		**MACR7**	
Macroinvertebrate indicator	**Autumn 2015**	**Spring 2015**	**Autumn 2015**	**Spring 2015**
Total abundance	922	681	598	926
Family richness	27	24	28	30
EPT abundance	590	370	138	180
EPT richness	9	7	7	7
Mean SIGNAL2 score	6.5	6.1	3.5	3.9
SIGNAL2 score range	1 - 8	1 - 8	1 - 8	1 - 8
Ecohealth score (grade)	**57 (D+)**		**41 (F)**	

MACR8 recorded 922 and 681 individual macroinvertebrates across 27 and 24 macroinvertebrate families during the 2015 autumn and spring sampling, respectively (Table 3.59). In autumn, abundance was dominated by Philopotamid Caddisflies (215 individuals), and richness was dominated by Ephemeroptera (Mayflies) with 7 families. In contrast, Hydropsychid Caddisflies were the most abundant family in spring (274 individuals), and the most diverse order in spring was Trichoptera (Caddisflies) with 6 families. There were a number of rare taxa at the site, with 9 and 6 taxa recording fewer than 5 individuals in autumn and spring, respectively.

Mean SIGNAL2 scores for MACR8 were slightly higher in autumn (6.5) than spring (6.1), although the range of SIGNAL2 scores was similar between seasons. The decrease in the mean SIGNAL2 at MACR10 in spring was due to lower abundances of high-scoring Ephemeroptera (Mayflies) and Trichoptera (Caddisflies) in spring.

MACR8 received an overall Ecohealth score of 57, a grade of D+, for aquatic macroinvertebrate community condition. All macroinvertebrate indicators were above the Macleay catchment average, particularly mean SIGNAL2 score (Table 3.13). The macroinvertebrate indicators suggest the water quality and habitat conditions in the Macleay River at Toorooka are in poor condition, but are able to support a diversity of macroinvertebrate fauna given the wide range of SIGNAL2 scores.

MACR7 recorded 598 and 926 individual macroinvertebrates across 28 and 30 macroinvertebrate families during the 2015 autumn and spring sampling, respectively (Table 3.59). In autumn, abundance was dominated by Platycnemid Damselflies (160 individuals), and richness was dominated by Coleoptera (Aquatic Bettles) with 7 families. In contrast, Atyid shrimps were the most abundant family in spring (564 individuals), and diversity was co-dominated by Coleoptera (Aquatic Beetles), Odonata (Dragonflies and Damselflies) and Trichoptera (Caddisflies), all with 6 families. There were a number of rare taxa at the site, with 15 and 17 taxa recording fewer than 5 individuals in autumn and spring, respectively.

Mean SIGNAL2 scores for MACR7 were slightly higher in spring (3.9) than autumn (3.5), although the range of SIGNAL2 scores was the same between seasons. This is due to both the loss of a few high-scoring biota (Ephemeroptera with SIGNAL2 of 8) and the high abundance of freshwater shrimp with SIGNAL2 of 4 in spring. Interestingly, there was a significant decline in mean SIGNAL2 scores between MACR8 at Toorooka and MACR7 at Turners Flat, that consistent between seasons (Table 3.59).

MACR7 received an overall Ecohealth score of 41, a grade of F, for aquatic macroinvertebrate community condition. All macroinvertebrate indicators were below the Macleay catchment average (Table 3.13). The macroinvertebrate indicators suggest the water quality and habitat conditions in the Macleay River at Turners Flat are in poor condition, but are able to support a diversity of macroinvertebrate fauna given the wide range of SIGNAL2 scores.

3.3.4 Macleay estuary (MACR6, MACR5, MACR4, MACR3, MACR2 and MACR1)

3.3.4.1 Geomorphic condition

The geomorphic River Style at Macleay River #6 (MACR6) is partially confined valley setting: planform controlled, low sinuosity, gravel. The bed sediments comprised rounded gravel in a framework dilated matrix containing 32-60% fine sediments. Banks comprised fine sediments. There was significant bank erosion on the left bank comprising undercutting (10-20m) well above the high tide mark. This is likely minor flood erosion exacerbated by cattle grazing in the riparian zone. There was moderate (5-10m) slumping of the right bank. Bed erosion was absent with mobile sand deposits draping the gravel substrate and macrophyte beds. Geomorphic complexity was low as expected for the tidal limit. MACR6 scored 54, a D for BANK CONDITION with BED CONDITION not assessed. The overall geomorphic condition for MACR6 was 54, a grade of D.

The geomorphic River Style at Macleay River #5 (MACR5) is laterally unconfined valley setting: continuous channel, tidal. The bed sediments comprised rounded gravel and sand in a matrix dominated framework containing >60% fine sediments. Mobile sand deposits draped the gravel substrate and macrophyte beds. Banks comprised fine grained sediments. Moderate bank erosion comprising moderate slumping (5-10m) and minor undercutting (<5m) was observed on the left bank. Moderate (5-10m) slumping and minor (5-10m) undercutting was observed on the right bank. MACR5 scored 73, a C+ for BANK CONDITION and BED CONDITION was not assessed. The overall geomorphic condition for MACR5 was 73, a grade of C+.

The geomorphic River Style at Macleay River #4 (MACR4) is laterally unconfined valley setting: continuous channel, tidal. Bed sediment was dominated by rounded gravel and sand in a matrix dominated framework containing >60% fine sediments. Banks consisted of cohesive fine sediments. There was significant (10-20m) undercutting and significant (10-20m) slumping on the left bank with areas of rock revetment in the site reach. There was significant (10-20m) slumping on the right bank associated with tidal and wave action as expected in a mid-estuarine reach. MACR4 scored 61, a C- for BANK CONDITION and BED CONDITION was not assessed. The overall geomorphic condition for MACR4 was 61, a grade of C-.

The geomorphic River Style at Macleay River #3 (MACR3) is laterally unconfined valley setting: continuous channel, tidal. Bed sediment was dominated by silty sand in a matrix dominated framework containing >60% fine sediments. Banks consisted of fine sediments. There was significant (20-100m) undercutting and significant (20-100m) slumping on both banks associated with tidal and wave action as expected in a mid-estuarine reach. MACR3 scored 71, a C+ for BANK CONDITION and BED CONDITION was not assessed. The overall geomorphic condition for MACR3 was 71, a grade of C+.

The geomorphic River Style at Macleay River #2 (MACR2) is laterally unconfined valley setting: continuous channel, tidal. Bed sediment was sand. Banks consisted of fine sediments. Rock revetment covered the entire site reach along both banks. MACR2 scored 61, a C+ for BANK

CONDITION and BED CONDITION was not assessed. The overall geomorphic condition for MACR2 was 71, a grade of C+.

The geomorphic River Style at Macleay River #1 (MACR1) is laterally unconfined valley setting: continuous channel, tidal. Bed sediment was sand. Banks consisted of fine sediments. Rock revetment covered the entire site reach along both banks. MACR1 scored 71, a C+ for BANK CONDITION and BED CONDITION was not assessed. The overall geomorphic condition for MACR1 was 71, a grade of C+.

In summary, MACR6 was assessed as being in poor geomorphic condition, with bank erosion the most significant issue for site-level geomorphic condition. MACR5, MACR4, MACR3, MACR2 and MACR1 were assessed as being in moderate geomorphic condition.

The desktop GIS assessment of geomorphic condition found the Macley Estuary subcatchment (MACR6-MACR1) to be in moderate condition with a grade of C. The geomorphic condition at MACR6 at the tidal limit was below the subcatchment average. The geomorphic condition at MACR4 in the mid estuary was slightly below the subcatchment average. The geomorphic condition at MACR5 in the upper estuary, MACR3 in the mid estuary, and MACR2 and MACR1 in the lower estuary were assessed as being slightly above the subcatchment average.

3.3.4.2 Riparian condition

MACR6

The original riparian vegetation community at MACR6 (Plate 3.41) was described as 'River Oak riparian woodland of the NSW North Coast Bioregion and northern Sydney Basin Bioregion', plant community type ID 1106 (VIS, 2012), broadly classed as 'Eastern Riverine Forests' (Keith, 2004), grading into 'Black Bean - Weeping Lilly Pilly - Water Gum riparian rainforest of the NSW North Coast Bioregion' plant community type ID 669 (VIS, 2012), broadly classed as 'Dry Rainforest' (Keith, 2004), or 'Floodplain Riparian Forest' (Telfer, 2005), a recognized TEC (VIS, 2012). MACR6 received a poor riparian condition score of 48.5, a grade of D- (Table 3.60).

The dominant canopy species present were River Oak (*Casuarina cunninghamiana* subsp. *cunninghamiana*), Watergum (*Tristaniopsis laurina*), Rough-leaved Elm (*Aphananthe philippinensis*) and the exotic species Camphor Laurel (*Cinnamomum camphora*). Dominant native midstory species included Weeping Bottlebrush (*Callistemon viminalis*), Sandpaper Fig (*Ficus coronata*), Cheese Tree (*Glochidion fernandi*), Silver Weeping Tea Tree (*Leptospermum brachyandrum*), along with the exotic species Lantana (*Lantana camara*), Castor Oil Plant (*Ricinus communis*), Small-leaved Privet (*Ligustrum sinense*) and Arsenic Bush (*Senna septemtrionalis*). The understory was dominated by native species Soft Lomandra (*Lomandra hystrix*), Knotweeds (*Persicaria stigosa* and *P.hydropiper*), Common Bracken (*Pteridium esculentum*), Lesser Joyweed (*Alternanthera denticulata*), Scurvy Weed (*Commelina cyanea*), Couch (*Cynodon dactylon*) and Australian Basket Grass (*Oplismenus aemulus*), along with exotic species Blue Billy Goat Weed (*Ageratum houstonianum*), Wandering Jew (*Tradescantia fluminensis*), Sidratusa (*Sida rhombifolia*), Umbrella Sedge (*Cyperus eragrostis*), Prairie Grass (*Bromus catharticus*), Panic Veldtgrass (*Ehrharta erecta*) and Pigeon Grass (*Setaria* sp.). The only vine species present was Common Passionfruit (*Passiflora* sp.), while a rich macrophyte layer included Broadleaf Cumbungi (*Typha orientalis*), Triangular Club Rush (*Schoenoplectiella mucronata*), Freshwater Eelgrass (*Vallisneria nana*), Red Water-milfoil (*Myriophyllum verrucosum*) and the exotic species Elodea (*Elodea canadensis*) and Egeria (*Egeria densa*).

Noxious weed species observed onsite were Camphor Laurel (*Cinnamomum camphora*), Lantana (*Lantana camara*), Small-leaved Privet (*Ligustrum sinense*), Fireweed (*Senecio madagascariensis*) and Egeria (*Egeria densa*), all class 4 noxious weeds. In addition to those already mentioned, other weed species present included Read Head Cotton Bush (*Asclepias curassavica*), Japanese Lionstail (*Leonurus japonicas*), Coblers Pegs (*Bidens pilosa*), Rhodes Grass (*Chloris gayana*), Red Natal Grass (*Melinis repens*), Paspalum (*Paspalum dilatatum*) and Wimmera Grass (*Lolium rigidum*).

Summary: MACR6 was a very highly disturbed system of regrowth forest with a remnant canopy and mixed native and exotic species throughout the midstory and understory layers, in a predominantly cleared rural landscape. The surrounding landuse was grazing country beyond which was predominantly State Forest and Nature Reserve. Significant remnant stands of vegetation lie 4.6km south in Maria River State Forest, 3.3km southeast in Kalateenee State Forest, 7km southwest in Yessabah State Forest, 5.8km north in Yarravel Nature Reserve and 9.4km west in Boonanghi State Forest. MACR6 scored well for Cover, moderately for Native Species, poorly for Management and very poorly for Habitat and Debris subindices (Table 3.60), retaining representative elements of the remnant vegetation community in all structural layers. Riparian condition at MACR6 was affected by poor riparian vegetation width, continuity and habitat connectivity and by the presence and regeneration of weed and noxious weed species, particularly in the midstory and understory structural layers. Reduced levels of cover in the canopy and midstory, limited habitat trees, woody and non-woody debris, inadequate riparian fencing and animal impact also contributed to the reduction in riparian grade at this site.

Management Recommendations: Riparian condition could be improved through the control and removal of weed and noxious weed species and by undertaking native plantings to promote vegetation continuity and site regeneration of native species. Riparian fencing should exclude livestock, promote woody and non-woody debris accumulation and allow for canopy, midstory and understory native species recovery, and if strategically implemented could be used in combination with native plantings to increase riparian vegetation width and to improve proximity to intact remnant stands of vegetation.

Plate 3.41 *Riparian vegetation at MACR6 was very highly disturbed. Riparian condition would be improved through control and removal of weed and noxious weed species specifically Camphor Laurel* (Cinnamomum camphora)*, Lantana* (Lantana camara) *and Small-leaved Privet* (Ligustrum sinense)*, undertaking native plantings and by limiting animal impact by fencing off the riparian zone.*

Table 3.60 *Site-level summary of riparian condition of Macleay River #6 showing the scores of individual indicators and the five subindices that comprise the Vegetation Condition Index.*

MACR6	Scores
HABITAT	**6.5/20**
Channel width	0
Proximity	0
Continuity	0
Layers	4
Large native trees	1.5
Hollow-bearing trees	1
NATIVE SPECIES	**12.5/20**
Native canopy species	4
Native midstory species	2
Native herb/forb species	1
Native graminoid species	1.5
Native macrophyte species	4
SPECIES COVER	**15/20**
Canopy species	2
Midstory species	3
Herb/forb species	2
Graminoid species	4
Macrophyte species	4
DEBRIS	**1/20**
Total leaf litter	1
Native leaf litter	2
Dead trees standing	0
Dead trees fallen	0
Lying logs	1
Fringing vegetation	2.5
MANAGEMENT	**8/20**
Tree clearing	3
Fencing	0
Animal impact	0
Species of interest	1
Exposed tree roots	3
Native woody regeneration	1
Weedy woody regeneration	0
TOTAL	**48.5/100**

MACR5

High historic disturbance at MACR5 (Plate 3.42) has resulted in a highly modified riparian zone that predominantly comprises exotic species. However, the original riparian vegetation community at MACR5 could have been described as 'River Oak riparian woodland of the NSW North Coast Bioregion and northern Sydney Basin Bioregion', plant community type ID 1106 (VIS, 2012), broadly classed as 'Eastern Riverine Forests' (Keith, 2004), grading into 'Black Bean - Weeping Lilly Pilly - Water Gum riparian rainforest of the NSW North Coast Bioregion' plant community type ID 669 (VIS, 2012), broadly classed as 'Dry Rainforest' (Keith, 2004), or 'Floodplain Riparian Forest' (Telfer, 2005), a recognized TEC (VIS, 2012). MACR5 received a poor riparian condition score of 48.3, a grade of D- (Table 3.61).

The dominant canopy species present were Swamp Oak (*Casuarina glauca*), Silky Oak (*Grevillea robusta*) and the exotic species Camphor Laurel (*Cinnamomum camphora*), Jacaranda (*Jacaranda mimosifolia*) and White Mulberry (*Morus alba*). Dominant native midstory species included Weeping Bottlebrush (*Callistemon viminalis*) and Silver Weeping Tea Tree (*Leptospermum brachyandrum*), along with the exotic species Lantana (*Lantana camara*), Castor Oil Plant (*Ricinus communis*), Small-leaved Privet (*Ligustrum sinense*), Senna (*Senna pendula* var. *glabrata*) and Bamboo (*Bambusa* sp.). The understory was dominated by native species Sea Rush (*Juncus krausii* subsp. *Australiensis*), Knotweed (*Persicaria hydropiper*), Couch (*Cynodon dactylon*) and Brown Beetle Grass (*Diplachne fusca*), along with exotic species Blue Billy Goat Weed (*Ageratum houstonianum*), Fleabane (*Conyza bonariensis*), Prairie Grass (*Bromus catharticus*), Pigeon Grass (*Setaria* sp.), Green Panic (*Megathyrsus maximus* var. *pubiglumis*) and Phalaris (*Phalaris aquatica*). Vine species present were the exotic Morning Glory species (*Ipomoea cairica* and *I.purpurea*), while a rich macrophyte layer included Common Reed (*Phragmites australis*), Marsh Club-rush (*Bolboschoenus fluviatilis*), Freshwater Eelgrass (*Vallisneria nana*), Clasped Pondweed (*Potomogeton perfoliatus*), Red Water-milfoil (*Myriophyllum verrucosum*), Water Thyme (*Hydrilla verticillata*) and the exotic species Egeria (*Egeria densa*).

Noxious weed species observed onsite were Camphor Laurel (*Cinnamomum camphora*), Lantana (*Lantana camara*), Small-leaved Privet (*Ligustrum sinense*), Coastal Morning Glory (*Ipomoea cairica*) and Egeria (*Egeria densa*), all class 4 noxious weeds. In addition to those already mentioned, other weed species present included Wild Tobacco (*Solanum mauritianum*), Turnip Weed (*Rapistrum rugosum*), Coblers Pegs (*Bidens pilosa*) and Rhodes Grass (*Chloris gayana*).

Summary: MACR5 was a very highly disturbed system of regrowth forest with a remnant canopy and mixed native and exotic species throughout the midstory and understory layers, in a predominantly cleared rural landscape. The surrounding landuse was urban settlement and agricultural grazing land. Significant remnant stands of vegetation are 4km southwest in Kalateenee State Forest. MACR5 scored moderately for Cover and Management and poorly for Habitat, Native Species and Debris subindices (Table 3.61), retaining representative elements of the remnant vegetation community in all structural layers. Riparian condition at MACR5 was affected by poor riparian vegetation width, continuity and habitat connectivity and by the presence and regeneration of weed and noxious weed species, particularly in the midstory and understory structural layers. Historic clearing, reduced levels of cover in the canopy and understory, limited habitat trees and reduced woody and non-woody debris also contributed to the reduction in riparian grade at this site.

Management Recommendations: Riparian condition could be improved through the control and removal of weed and noxious weed species and by undertaking native plantings to promote vegetation continuity, habitat connectivity and site regeneration of native species. Such plantings assist in phasing out and replacing dominant canopy weed species such as Camphor Laurel (*Cinnamomum camphora*) and Bamboo (*Bambusa sp.*) with the latter supporting a flying-fox (Pteropus sp.) colony at the time of surveying . While riparian vegetation width will remain constrained due to urban settlement, it too could be increased where there is scope.

Plate 3.42 *Riparian vegetation at MACR5 was very highly disturbed. Riparian condition would be improved through control and removal of weed and noxious weed species specifically Camphor Laurel* (Cinnamomum camphora)*, Lantana* (Lantana camara)*, Small-leaved Privet* (Ligustrum sinense) *and Coastal Morning Glory* (Ipomoea cairica) *and by undertaking native plantings.*

Table 3.61 *Site-level summary of riparian condition of Macleay River #5 showing the scores of individual indicators and the five subindices that comprise the Vegetation Condition Index.*

MACR5	Scores
HABITAT	**8.3/20**
Channel width	0.3
Proximity	0
Continuity	1
Layers	4
Large native trees	2
Hollow-bearing trees	1
NATIVE SPECIES	**8.5/20**
Native canopy species	3
Native midstory species	0.5
Native herb/forb species	0
Native graminoid species	1
Native macrophyte species	4
SPECIES COVER	**12.5/20**
Canopy species	1.5
Midstory species	3
Herb/forb species	1
Graminoid species	4
Macrophyte species	3
DEBRIS	**6/20**
Total leaf litter	1
Native leaf litter	1
Dead trees standing	0
Dead trees fallen	0
Lying logs	1
Fringing vegetation	3
MANAGEMENT	**13/20**
Tree clearing	1
Fencing	3
Animal impact	3
Species of interest	1
Exposed tree roots	2
Native woody regeneration	2
Weedy woody regeneration	1
TOTAL	**48.3/100**

MACR4

High historic disturbance at MACR4 (Plate 3.43) has resulted in a highly modified riparian zone that predominantly comprises exotic species. The significant loss of native species and highly modified community structure meant that this community was unable to be described using either of the two description methods previously used (Keith, 2004), (VIS, 2012). MACR4 received a very poor riparian condition score of 35, a grade of F (Table 3.62).

The dominant canopy species present were Swamp Oak (*Casuarina glauca*), and the exotic species Coral Tree (*Erythrina crista-galli*), Jacaranda (*Jacaranda mimosifolia*), White Mulberry (*Morus alba*) and Banana species (*Musa* sp.). Dominant native midstory species included Tuckeroo (*Cupaniopsis anacardioides*), Cheese Tree (*Glochidion fernandi*), along with the exotic species Lantana (*Lantana camara*), Castor Oil Plant (*Ricinus communis*) and Wild Tobacco (*Solanum mauritianum*). The understory was dominated by the native species Swamp Lily (*Crinium pedunculatum*), along with exotic species Nasturtium (*Tropaeolum majus*), Fennel (*Foeniculum vulgare*), Kikuyu (*Pennisetum clandestinum*) and Buffalo Grass (*Stenotaphrum secundatum*). Vine species present were the exotic species Coastal Morning Glory (*Ipomoea cairica*) and Baloon Vine (*Cardiospermum grandiflorum*), while the macrophyte layer included Common Reed (*Phragmites australis*), Water Thyme (*Hydrilla verticillata*), Curly Pondweed (*Potamogeton crispus*) and the exotic species Papyrus (*Cyperus papyrus*).

Noxious weed species observed onsite were Coral Tree (*Erythrina crista-galli*), a class 3 noxious weed; and Lantana (*Lantana camara*), Coastal Morning Glory (*Ipomoea cairica*) and Baloon Vine (*Cardiospermum grandiflorum*), all class 4 noxious weeds.

Summary: MACR4 was an extremely disturbed system of regrowth forest with mixed native and exotic species throughout all structural layers, in a cleared rural landscape. The surrounding landuse was predominantly urban settlement and agricultural grazing land, boarded by an artificial riparian breakwall perimeter. A significant remnant stand of vegetation lies 6km east of MACR4 in Hat Head National Park. MACR4 scored moderately for Cover, poorly for Debris and Management and very poorly for Habitat and Native Species subindices (Table 3.62). Despite retaining native elements in all structural layers, riparian condition at MACR4 was affected by poor riparian vegetation width, continuity and habitat connectivity and by the dominance and regeneration of weed and noxious weed species in all structural layers. Historic clearing, reduced levels of cover in the canopy and an absence of native species regeneration, habitat trees and of woody and non-woody debris contributed to the reduction in riparian grade at this site.

Management Recommendations: Riparian condition could be improved through the control and removal of weed and noxious weed species and by undertaking native plantings which phase-out and replace dominant canopy weed species and promote vegetation continuity, habitat connectivity and site regeneration of native species. Structural works using best practice techniques such as rock revetment at the toe of the bank will improve bank stability. This may include the introduction of large woody debris which would also promote niche habitats for native woody regeneration, provide habitat for native animal species, and as instream snags, can redirect or reduce water energy from banks, reducing bank erosion. While riparian vegetation width will remain constrained due to urban settlement, it too could be increased where there is scope.

Plate 3.43 *Riparian vegetation at MACR4 was extremely disturbed. Riparian condition would be improved through control and removal of weed and noxious weed species specifically Coral Tree (*Erythrina x sykesii*), Lantana* (Lantana camara)*, Coastal Morning Glory* (Ipomoea cairica) *and Baloon Vine* (Cardiospermum grandiflorum) *and by undertaking native plantings.*

Table 3.62 *Site-level summary of riparian condition of Macleay River #4 showing the scores of individual indicators and the five subindices that comprise the Vegetation Condition Index.*

MACR4	Scores
HABITAT	**4/20**
Channel width	0
Proximity	0
Continuity	0
Layers	4
Large native trees	0
Hollow-bearing trees	0
NATIVE SPECIES	**4.5/20**
Native canopy species	0.5
Native midstory species	0.5
Native herb/forb species	0.5
Native graminoid species	1
Native macrophyte species	2
SPECIES COVER	**14.5/20**
Canopy species	0.5
Midstory species	3
Herb/forb species	4
Graminoid species	4
Macrophyte species	3
DEBRIS	**6/20**
Total leaf litter	2
Native leaf litter	0
Dead trees standing	0
Dead trees fallen	0
Lying logs	0
Fringing vegetation	4
MANAGEMENT	**6/20**
Tree clearing	0
Fencing	2
Animal impact	2
Species of interest	0
Exposed tree roots	2
Native woody regeneration	0
Weedy woody regeneration	0
TOTAL	**35/100**

MACR3

High historic disturbance at MACR3 (Plate 3.44) has resulted in a highly modified riparian zone that predominantly comprises exotic species. The significant loss of native species and highly modified community structure meant that this community was unable to be described using either of the two description methods previously used (Keith, 2004), (VIS, 2012). MACR3 received a very poor riparian condition score of 27.5, a grade of F (Table 3.63).

The dominant canopy species present were Swamp Oak (*Casuarina glauca*), and the exotic species Coral Tree (*Erythrina crista-galli*). One dominant midstory species was observed, the exotic Lantana Lantana (*Lantana camara*). The understory was dominated by the native species Slender Knotweed (*Persicaria decipiens*), Sea Rush (*Juncus krausii* subsp. *Australiensis*), Couch (*Cynodon dactylon*) and Black-seeded Panic (*Panicum bisulcatum*), along with exotic species Purpletop (*Verbena bonariensis*), Wandering Jew (*Tradescatia fluminensis*), Fleabane (*Conyza bonariensis*), Benghal Dayflower (*Commelina benghalensis*), Umbrella Sedge (*Cyperus eragrostis*), Kikuyu (*Pennisetum clandestinum*), Vasey Grass (*Paspalum urvillei*), Buffalo Grass (*Stenotaphrum secundatum*), Panic Veldtgrass (*Ehrharta erecta*) and Pigeon Grass (*Setaria* sp.). The dominant vine species present was the exotic species Coastal Morning Glory (*Ipomoea cairica*), while the macrophyte layer included Common Reed (*Phragmites australis*), River Club Rush (*Schoenoplectus validus*) and Marsh Club-rush (*Bolboschoenus fluviatilis*).

Noxious weed species observed onsite were Coral Tree (*Erythrina crista-galli*), a class 3 noxious weed; Lantana (*Lantana camara*), Coastal Morning Glory (*Ipomoea cairica*) and Fireweed (*Senecio madagascariensis*), all class 4 noxious weeds; and Mosman River Grass (*Cenchrus echinatus*), a class 5 noxious weed. In addition to those already mentioned, other weed species present included Prickly Sowthistle (*Sonchus asper*), Coblers Pegs (*Bidens pilosa*) and Prairie Grass (*Bromus catharticus*).

Summary: MACR3 was an extremely disturbed system of regrowth forest with mixed native and exotic species throughout all structural layers, in a cleared rural landscape. The surrounding landuse was predominantly urban settlement and agricultural grazing land. A significant remnant stand of vegetation lies 3.5km east of MACR3 in Hat Head National Park. MACR3 scored poorly for Habitat, Native Species, Cover and Management and very poorly for Debris subindices (Table 3.63). Despite retaining native elements in all structural layers, riparian condition at MACR3 was affected by poor riparian vegetation width, continuity and habitat connectivity, inadequate riparian fencing and animal impact and by the dominance and regeneration of weed and noxious weed species in all structural layers. Historic clearing, reduced levels of cover across all structural layers except in the understory, limited native species regeneration, an absence of habitat trees and of woody and non-woody debris contributed to the reduction in riparian grade at this site.

Management Recommendations: Riparian condition could be improved through the control and removal of weed and noxious weed species and by undertaking native plantings which phase-out and replace dominant canopy weed species and promote vegetation continuity, habitat connectivity and assist site regeneration of native species. Structural works using best practice techniques such as rock revetment at the toe of the bank will improve bank stability. This may include the introduction of large woody debris which would also promote niche habitats for native woody regeneration, provide habitat for native animal species, and as instream snags, can redirect or reduce water energy from banks, reducing bank erosion. Riparian fencing should exclude livestock, promote woody and non-woody debris accumulation and allow for canopy, midstory and understory native species recovery, and if strategically implemented could be used in combination with native plantings to increase riparian vegetation width, continuity and to improve proximity to intact remnant stands of vegetation.

Plate 3.44 *Riparian vegetation at MACR3 was extremely disturbed. Riparian condition would be improved through control and removal of weed and noxious weed species specifically Coral Tree* (Erythrina x sykesii)*, Lantana* (Lantana camara)*, Coastal Morning Glory* (Ipomoea cairica)*, by undertaking native plantings and fencing off the riparian zone.*

Table 3.63 *Site-level summary of riparian condition of Macleay River #3 showing the scores of individual indicators and the five subindices that comprise the Vegetation Condition Index.*

MACR3	Scores
HABITAT	**5/20**
Channel width	0
Proximity	0
Continuity	0
Layers	4
Large native trees	1
Hollow-bearing trees	0
NATIVE SPECIES	**6.5/20**
Native canopy species	2
Native midstory species	0
Native herb/forb species	0.5
Native graminoid species	1
Native macrophyte species	3
SPECIES COVER	**8/20**
Canopy species	0.5
Midstory species	0.5
Herb/forb species	2.5
Graminoid species	4
Macrophyte species	0.5
DEBRIS	**2/20**
Total leaf litter	0
Native leaf litter	0
Dead trees standing	0
Dead trees fallen	0
Lying logs	0
Fringing vegetation	2
MANAGEMENT	**11/20**
Tree clearing	0
Fencing	0
Animal impact	0
Species of interest	1
Exposed tree roots	3
Native woody regeneration	1
Weedy woody regeneration	1
TOTAL	**27.5/100**

MACR2

High historic disturbance at MACR2 (Plate 3.45) has resulted in a highly modified riparian zone that predominantly comprises exotic species. The significant loss of native species and highly modified community structure meant that this community was unable to be described using either of the two description methods previously used (Keith, 2004), (VIS, 2012). MACR2 received a very poor riparian condition score of 19.5, a grade of F (Table 3.64).

The one native canopy species present was Morton Bay Fig (*Ficus macrophylla*) while in the midstory layer it was Tuckeroo (*Cupaniopsis anacardioides*). The understory was dominated by the native species Creeping Raspwort (*Gonocarpus micranthus*) and Couch (*Cynodon dactylon*), along with exotic species Blue Billy Goat Weed (*Ageratum houstonianum*), Indian Pennywort (*Centella asiatica*), Slender Celery (*Cyclospermum leptophyllum*), Fireweed (*Senecio madagascariensis*), Kikuyu (*Pennisetum clandestinum*), Buffalo Grass (*Stenotaphrum secundatum*), Prairie Grass (*Bromus catharticus*), Parramatta Grass (*Sporobolus africanus*) and Pigeon Grass (*Setaria* sp.). Dominant vine species present was the exotic species Coastal Morning Glory (*Ipomoea cairica*), while macrophytes were absent.

Fireweed (*Senecio madagascariensis*), a class 4 noxious weed, was the only noxious weed observed at this site.

Summary: MACR2 was an extremely disturbed system in a predominantly cleared landscape of mixed native and exotic understory species. The surrounding landuse was agricultural grazing land and urban settlement boarded by an artificial riparian breakwall perimeter, beyond which was Historic Reserve and National Park. Significant remnant stands of vegetation lie 1km east in Hat Head National Park, 800m west on private land and 3.7km West of MACR2 in Clybucca Historical Site. MACR2 scored poorly for Habitat and Cover and very poorly for Native Species, Debris and Management subindices (Table 3.64). Riparian condition at MACR2 was impacted by the relative absence of both the canopy and midstory layers. MACR2 had no riparian vegetation width, continuity or habitat connectivity and no woody native regeneration was observed onsite. Riparian condition at MACR2 was further affected by the dominance and regeneration of weed and noxious weed species in the understory layer, inadequate riparian fencing and animal impact. Historic clearing, an absence of woody and non-woody debris and reduced levels of cover across all structural layers except the understory contributed to the reduction in riparian grade at this site.

Management Recommendations: Riparian condition could be improved by undertaking native plantings to promote vegetation width, continuity, habitat connectivity and site regeneration of native species. The introduction of large woody debris would promote niche habitats for native woody regeneration and for native animal species. Riparian fencing should exclude livestock, promote woody and non-woody debris accumulation and allow for canopy, midstory and understory native species recovery, and if strategically implemented could be used in combination with native plantings to increase riparian vegetation width, continuity and to improve proximity to intact remnant stands of vegetation.

Plate 3.45 *Riparian vegetation at MACR2 was extremely disturbed. Riparian condition would be improved through control and removal of weed and noxious weed species, by undertaking native plantings and fencing off the riparian zone.*

Table 3.64 *Site-level summary of riparian condition of Macleay River #2 showing the scores of individual indicators and the five subindices that comprise the Vegetation Condition Index.*

MACR2	Scores
HABITAT	**5/20**
Channel width	0
Proximity	1
Continuity	0
Layers	2
Large native trees	1
Hollow-bearing trees	1
NATIVE SPECIES	**4.5/20**
Native canopy species	2
Native midstory species	0
Native herb/forb species	0.5
Native graminoid species	2
Native macrophyte species	0
SPECIES COVER	**5.5/20**
Canopy species	0.5
Midstory species	0
Herb/forb species	1
Graminoid species	4
Macrophyte species	0
DEBRIS	**0.5/20**
Total leaf litter	0
Native leaf litter	0
Dead trees standing	0
Dead trees fallen	0
Lying logs	0.5
Fringing vegetation	0
MANAGEMENT	**4/20**
Tree clearing	0
Fencing	0
Animal impact	0
Species of interest	0
Exposed tree roots	4
Native woody regeneration	0
Weedy woody regeneration	0
TOTAL	**19.5/100**

MACR1

High historic disturbance at MACR1 (Plate 3.46) has resulted in a highly modified riparian zone that predominantly comprises exotic species. However, the original riparian vegetation community at MACR1 could have been described as 'Mangrove forest in estuaries of the Sydney Basin Bioregion and South East Corner Bioregion' plant community type ID 920 (VIS, 2012), broadly classed as 'Mangrove Swamps' (Keith, 2004), grading into 'Tuckeroo – Riberry – Yellow tulipwood littoral rainforest of the NSW North Coast Bioregion' plant community type ID 1275 (VIS, 2012), or Tuckeroo *Cupaniopsis anacardioides* Littoral Rainforest, [24] (0502) (Telfer, 2005), broadly classed as 'Littoral Rainforest' (Keith, 2004), a recognized EEC (VIS, 2012). MACR1 received a low riparian condition score of 56, a grade of D+ (Table 3.65).

The dominant canopy species present were Morton Bay Fig (*Ficus macrophylla*), Swamp Oak (*Casuarina glauca*), River Mangrove (*Aegiceras corniculatum*) and Grey Mangrove (*Avicennia marina* subsp. *Australasica*). Dominant native midstory species included Tuckeroo (*Cupaniopsis anacardioides*), Coast Banksia (*Banksia integrifolia* subsp. *intergrifolia*), Acacia (*Acacia longifolia* subsp. *sophorae*), Cheese Tree (*Glochidion fernandi*), along with the exotic species Lantana (*Lantana camara*), Spiny Pest Pear (*Opuntia stricta*) and Bitou Bush (*Chrysanthemoides monilifera* subsp. *rotundata*). The understory was dominated by native species Spiny-headed Mat-rush (*Lomandra longifolia*), Knobby club-rush (*Ficinia nodosa*), Berry Saltbush (*Einadia hastata*), New Zealand Spinach (*Tetragonia tetragoniodes*), Pigface (*Carpobrotus glaucescens*), Barbed Wire Grass (*Cymbopogon refractus*), Australian Basket Grass (*Oplismenus aemulus*), along with exotic species Mother of Millions (*Bryophyllum delagoense*), Purpletop (*Verbena bonariensis*), Fleabane (*Conyza bonariensis*), Sidratusa (*Sida rhombifolia*), Benghal Dayflower (*Commelina benghalensis*), Prairie Grass (*Bromus catharticus*), Rhodes Grass (*Chloris gayana*), Panic Veldtgrass (*Ehrharta erecta*) and Broadleaf Paspalum (*Paspalum mandiocanum*). Vine species present were the native Beach Morning Glory (*Ipomoea brasiliensis*), Wombat Berry (*Eustrephus latifolius*), Dune Bean (*Vigna marina*), and the exotic species Coastal Morning Glory (*Ipomoea cairica*) and Siratro (*Macroptilium atropurpureum*). A rich estuarine macrophyte layer included Common Reed (*Phragmites australis*), Saltwater Couch (*Paspalum vaginatum*), River Club Rush (*Schoenoplectus validus*), Creeping Brookweed (*Samolus repens*) and Austral Seablite (*Suaeda australis*).

Noxious weed species observed onsite were Lantana (*Lantana camara*), Bitou Bush (*Chrysanthemoides monilifera* subsp. *rotundata*), Mother of Millions (*Bryophyllum delagoense*), Spiny Pest Pear (*Opuntia stricta*) and Coastal Morning Glory (*Ipomoea cairica*), all class 4 noxious weeds. In addition to those already mentioned, other weed species present included Coblers Pegs (*Bidens pilosa*), Plantain (*Plantago lanceolata*), Slender Celery (*Cyclospermum leptophyllum*), Red Natal Grass (*Melinis repens*) and Prairie Grass (*Bromus catharticus*).

Summary: MACR1 was a highly disturbed system in a predominantly forested landscape of mixed-aged native canopy and mixed midstory and understory species. The surrounding landuse was a forested island of Crown Land boarded by an artificial riparian breakwall perimeter, beyond which was a mix of estuary, urban settlement and ocean. Significant remnant stands of vegetation lie adjacent to the site to the west and on private land on surrounding estuarine islands. MACR1 scored moderately for Habitat, Native Species, Cover and Management and poorly for Debris subindices

(Table 3.65). Habitat trees, fringing riparian vegetation, riparian vegetation continuity and cover were each directly impacted by the artificial riparian rockwall structure and influenced the riparian condition at MACR1. The presence and regeneration of weed and noxious weed species particularly in the midstory and understory structural layers and an absence of woody and non-woody debris contributed to the reduction in riparian grade at this site.

Management Recommendations: Riparian condition could be improved through the control and removal of invasive weed species and potentially by undertaking native plantings which assist site regeneration of native species, promote fringing vegetation.

Plate 3.46 *Riparian vegetation at MACR1 was highly disturbed. Riparian condition would be improved through control and removal of weed and noxious weed species such as were Lantana (Lantana camara), Bitou Bush (Chrysanthemoides monilifera subsp. rotundata), Mother of Millions* (Bryophyllum delagoense)*, Spiny Pest Pear* (Opuntia stricta) *and Coastal Morning Glory* (Ipomoea cairica), *and by undertaking native plantings.*

Table 3.65 *Site-level summary of riparian condition of Macleay River #1 showing the scores of individual indicators and the five subindices that comprise the Vegetation Condition Index.*

MACR1	Scores
HABITAT	**13/20**
Channel width	4
Proximity	3
Continuity	1
Layers	4
Large native trees	1
Hollow-bearing trees	0
NATIVE SPECIES	**12/20**
Native canopy species	4
Native midstory species	2
Native herb/forb species	1
Native graminoid species	1
Native macrophyte species	4
SPECIES COVER	**11.5/20**
Canopy species	2
Midstory species	2
Herb/forb species	3
Graminoid species	3
Macrophyte species	2
DEBRIS	**6/20**
Total leaf litter	2
Native leaf litter	2
Dead trees standing	0
Dead trees fallen	0
Lying logs	2
Fringing vegetation	0
MANAGEMENT	**13.5/20**
Tree clearing	2
Fencing	3
Animal impact	3
Species of interest	0
Exposed tree roots	4
Native woody regeneration	2
Weedy woody regeneration	0
TOTAL	**56/100**

3.3.4.3 Water quality

The estuarine reach received a score of 52 (D-) with the best water quality recorded at MACR6 (the tidal limit downstream of Bellgrave Falls; 64, C-). This contrasts with all other rivers in the North Coast that have been assessed through the Ecohealth program, where the tidal limit consistently records the poorest water quality as sites where freshwater and estuarine water quality issues converge. MACR5 at Kempsey received a score of 43 (F), MACR4 at Smithtown received a score of 53 (D), MACR3 at Kinchela received a score of 50 (D), MACR2 at Jerseyville received a score of 50 (D) and MACR1 at South West Rocks received a score of 61 (C-). Figures 3.11 and 3.12 show the key physicochemical and nutrient variables used in the assessment of water quality for the main stem of the Macleay River including the estuary. Ranges and means for these variables are given in Tables 3.66 and 3.67, and the exceedances are given in Table 3.58.

There was no clear longitudinal pattern in pH through the Macleay estuary, but all sites had infrequent exceedances of the upper ANZECC estuarine trigger value of 8.5 (Figure 3.11b, Table 3.58). Mean turbidity at estuarine sites generally decreased longitudinally downstream (Figure 3.11d), with infrequent exceedances of the ANZECC estuarine trigger value during the sampling period (Table 3.58). DO% generally remained within the ANZECC trigger values, although there was a single sampling occasion (November 2015) where DO% fell below the minimum ANZECC trigger value at all estuarine sites (Table 3.58). The lowest site minimum was 55% at MACR4. DO% at MACR1 exceeded the maximum ANZECC trigger value in August 2015, but this was due to wave action rather than high algal productivity.

The Macleay estuary consistently exceeded ANZECC nutrient trigger values for estuarine systems, especially for nitrogen (Figure 3.12). This is similar to the freshwater reach. MACR4 (Smithtown) had the highest site mean and range of TN and NOx. TN concentrations exceeded the ANZECC trigger value of 300µg/L on 5 sampling occasions at MACR5, MACR4 and MACR3, on 4 sampling occasions at MACR6 and on 3 sampling occasions at MACR2 and MACR1 (Table 3.58). Site maximum TN concentrations were 6.1, 7.2, 10.4, 6, 5.3 and 4.4 times the ANZECC trigger value at MACR6, MACR5, MACR4, MACR3, MACR2 and MACR1, respectively (Tables 3.66, 3.67).

Total phosphorus (TP) concentrations exceeded the ANZECC estuarine trigger value of 30µg/L on 5 sampling occasions at MACR3, 4 sampling occasions at MACR5 and MACR2, 3 sampling occasions at MACR4 and MACR1, and 1 sampling occasion at MACR6 (Table 3.58). Site maximum TP concentrations were 1.02, 2, 1.6, 2.8, 2.2 and 3.9 times the ANZECC trigger value at MACR6, MACR5, MACR4, MACR3, MACR2 and MACR1, respectively (Tables 3.66, 3.67).

Bioavailable nitrogen (NOx) concentrations exceeded the ANZECC estuarine trigger value of 15µg/L more frequently than TN concentrations at the tidal limit (MACR6) and lower estuary (MACR2 and MACR3). NOx concentrations exceeded the ANZECC trigger value on 5 of the 6 sampling occasions at MACR6, MACR5 and MACR1, and on 4 sampling occasions at MACR4, MACR3 and MACR2 (Table 3.58). Site maximum NOx concentrations were 18, 25, 39, 29, 25 and 27 times the ANZECC trigger value at MACR6, MACR5, MACR4, MACR3, MACR2 and MACR1, respectively (Tables 3.66, 3.67).

SRPconcentrations exceeded the ANZECC estuarine trigger value of 5µg/L more frequently than TP concentrations at all estuarine sites except the tidal limit (MACR6). SRP concentrations exceeded the ANZECC trigger value on all sampling occasions at MACR5, MACR4 and MACR3, on 5 sampling occasions at MACR1 and on 1 sampling occasion at MACR6 (Table 3.58). Site maximum SRP concentrations were 5.2, 6, 7, 6.3, 9 and 7 times the ANZECC trigger value at MACR6, MACR5, MACR4, MACR3, MACR2 and MACR1, respectively (Tables 3.66, 3.67).

Spatially, peak algal productivity in the estuary was generally correlated with peak nutrient concentrations, specifically at MACR4 and MACR2 (TN, NOx and SRP; Figures 3.11, 3.12). Temporally, peak algal productivity occurred in April 2015 (MACR2 and MACR4) and November 2015 (MACR1 and MACR5). Chlorophyll *a* concentrations exceeded the ANZECC trigger value on 4 sampling occasions at MACR5 and MACR2 and on 1 sampling occasion at MACR6, MACR4 and MACR3 (Table 3.58). Site maximum chorophyll *a* concentrations were 2.1, 2.9, 1.5 and 4.2 times the ANZECC trigger value at MACR5, MACR4, MACR3 and MACR2, respectively (Tables 3.66, 3.67).

Table 3.66 *Minimums, maximums and means of measured water quality variables for the sites in the upper Macleay River estuary.*

	MACR6			MACR5			MACR4		
Variable	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**
Temperature (°C)	14.91	29.13	22.34	15.30	28.99	22.05	15.28	28.85	22.01
pH	7.80	9.62	8.40	7.58	9.30	8.25	7.24	8.63	7.80
EC (mS/cm)	0.06	0.07	0.07	0.07	0.16	0.14	0.02	9.31	2.95
Salinity (PPT)	0.12	0.15	0.14	0.05	7.92	1.33	0.09	5.21	1.69
DO (mg/L)	5.26	10.28	7.48	4.23	9.51	7.29	4.14	9.89	7.15
DO (%)	68.60	119.60	94.78	56.60	107.40	91.38	55.30	105.10	86.99
Turbidity (NTU)	2.60	25.50	8.64	3.50	37.10	9.83	5.90	21.60	10.75
Max Depth	1.00	2.60	2.15	3.80	14.80	6.67	4.10	6.30	4.46
Chla (µg/L)	0.00	0.99	0.48	0.00	6.86	1.99	0.21	9.47	2.67
TSS (mg/L)	1.30	7.96	2.72	1.33	6.37	4.61	3.70	10.20	6.93
TN (µg/L)	161.02	1826.2	637.02	250.00	2152.5	860.80	173.73	3122.8	1088.5
TP (µg/L)	6.76	30.61	16.31	12.51	59.27	38.50	23.85	48.71	33.49
NOx (µg/L)	5.17	266.89	162.68	8.62	369.52	205.57	5.43	578.29	206.88
SRP (µg/L)	1.90	26.05	7.10	5.86	30.23	13.66	8.22	34.37	20.24

Table 3.67 *Minimums, maximums and means of measured water quality variables for the sites in the lower Macleay River estuary.*

	MACR3			MACR2			MACR1		
Variable	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**
Temperature (°C)	15.65	28.76	22.13	16.62	28.11	22.24	18.31	26.60	22.29
pH	7.26	8.65	7.89	7.56	8.91	8.17	7.69	8.92	8.21
EC (mS/cm)	0.36	25.49	11.06	4.02	43.70	28.76	43.10	55.10	52.01
Salinity (PPT)	0.17	13.62	6.16	4.55	32.68	21.12	27.44	36.42	34.12
DO (mg/L)	4.45	9.18	6.94	5.05	7.94	6.28	5.14	9.75	6.57
DO (%)	59.10	103.30	89.10	68.30	103.40	89.38	80.80	119.10	99.47
Turbidity (NTU)	5.30	24.50	8.71	3.20	12.50	5.66	2.60	15.30	5.20
Max Depth	2.50	8.50	6.12	0.03	3.17	1.32	2.70	8.00	5.84
Chla (µg/L)	0.22	5.07	1.64	1.46	13.81	6.67	0.06	1.23	0.58
TSS (mg/L)	4.58	13.40	8.05	3.00	5.90	4.43	1.58	16.02	8.73
TN (µg/L)	165.25	1809.3	666.45	160.14	1593.2	628.81	195.73	1330.5	488.54
TP (µg/L)	11.93	85.42	43.73	11.88	65.87	40.35	16.22	117.35	47.06
NOx (µg/L)	0.20	435.81	190.81	0.20	369.52	121.41	0.20	411.27	115.25
SRP (µg/L)	7.26	31.51	19.74	7.41	43.87	18.03	2.52	36.40	17.49

3.3.5 Antimony and arsenic concentrations in water and sediments (GEOC1, BAKC1, MACR10, MACR9, MACR7, MACR5, MACR4, MACR3 and MACR2)

Antimony

Antimony (Sb) and arsenic (As) concentrations were measured in the water column and sediments at Bakers Creek (a historical source of contamination from mining), Georges Creek (a control site without contamination from mining), and seven sites along the main stem of the Macleay River from MACR10 immediately upstream of the confluence with Georges Creek through to MACR2 in the estuary at Jerseyville. Samples were taken in April, August and November 2015, and February 2016. Field sampling and laboratory analyses were undertaken as part of a separate project funded by UNE.

Water column Sb at Bakers Creek exceeded the ANZECC guidelines for healthy aquatic ecosystems (Sb of 9µg/L) on all sampling occasions (Figure 3.13). The peak exceedance (870µg/L) in August 2015 following a rainfall event, was approximately 96 times the ANZECC trigger value for healthy aquatic ecosystems. The lowest exceedance at Bakers Creek (340µg/L) in November 2015 following a prolonged low flow period, was approximately 37 times the ANZECC trigger value for healthy aquatic ecosystems.

No other site in the Macleay exceeded the ANZECC Sb water column trigger value for healthy aquatic ecosystems (Figure 3.13 inset). However, Georges Creek (GEOC1) exceeded the ANZECC Sb water column trigger value for drinking water (3µg/L) once, in February 2016. A clear longitudinal decrease in water column Sb along the main stem of the Macleay River was only observed in November 2015 (Figure 3.13 inset).

Sediment Sb at Bakers Creek exceeded the national sediment guidelines for both the high (25µg/g) and low (2µg/g) trigger values on all sampling occasions (Figure 3.13). The peak exceedance at Bakers Creek (328µg/g) in February 2016 was approximately 13 times the high sediment trigger value and 164 times the low sediment trigger value. The lowest exceedance at Bakers Creek (144µg/g) in August 2015, was approximately 6 times the high sediment trigger value and 72 times the low sediment trigger value.

No other site exceeded the high Sb sediment trigger value during the sampling period (Figure 3.13). However, the low sediment trigger value was regularly exceeded (Figure 3.13 inset). In April 2015, exceedances were observed at MACR10 (Georges Junction), MACR9 (Bellbrook), MACR3 (downstream of the confluence with Kinchela Creek) and MACR2 (Jerseyville). In November 2015, exceedances were observed at MACR10 and MACR7 (Turners Flat). Only the GEOC1 and BAKC1 results were supplied for February 2016, but these show an exceedance at Georges Creek that requires further investigation as this is the control site and an exceedance here is unexpected. There are no clear spatial or temporal relationships between Sb concentrations in the water column or sediments.

Arsenic

Water column As at Bakers Creek exceeded the ANZECC guidelines for healthy aquatic ecosystems (As of 24 µg/L) on all sampling occasions (Figure 3.14). The peak exceedance (64µg/L) in February 2016, was approximately 2.7 times the ANZECC trigger value for healthy aquatic ecosystems. The lowest exceedance at Bakers Creek (34µg/L) in August 2015, was approximately 1.4 times the ANZECC trigger value for healthy aquatic ecosystems.

MACR2 was the only other site to exceed the ANZECC As water column trigger value for healthy aquatic ecosystems, once in November 2015 with a water column As concentration of 26µg/L (Figure 3.14). However, in the Macleay main stem, As consistently peaked in the mid-lower estuary (from MACR3 downstream of the Kinchela Creek confluence to MACR2 at Jerseyville). MACR2 was the only site on the Macleay main stem to exceed the ANZECC As drinking water trigger value (Figure 3.14). The exceedance was persistent, across all of the water samples taken at MACR2 and increasing with successive sampling. This is worth further investigation to determine if this pattern arises from direct depositional accumulation of upstream arsenic inputs in the channel or from localized inputs and resuspension from the floodplain. Overall, there is a consistent longitudinal pattern in water column As along the main stem of the Macleay River: concentrations are low in the freshwater reach, but consistently increase with distance downstream. Concentrations are low in the upper estuary (e.g. MACR4 at Smithtown), but then increase rapidly to peak in the lower estuary at MACR2.

Sediment As at Bakers Creek exceeded the national sediment guidelines for both the high (70µg/g) and low (20µg/g) trigger values on all sampling occasions (Figure 3.14). The peak exceedance at Bakers Creek (136µg/g) in August 2015 was approximately 2 times the high sediment trigger value and 7 times the low sediment trigger value. The lowest exceedance at Bakers Creek (88µg/g) in February 2016 was approximately 1.3 times the high sediment trigger value and 4.4 times the low sediment trigger value.

No other site exceeded the high or low As sediment trigger value during the sampling period (Figure 3.14). Sediment As concentrations follow a similar longitudinal pattern to water column As in the main stem of the Macleay River. Concentrations decrease consistently until the upper estuary (in this case, MACR5 at Kempsey). Concentrations then increase from MACR4 (Smithtown) with inconsistent spatio-temporal patterns in the lower estuary (Figure 3.14).

Summary: Although water column Sb at Bakers Creek ranged from 37 to 96 times the ANZECC guidelines for healthy aquatic ecosystems, no site on the Macleay River exceeded the ANZECC Sb trigger value for water quality. Sediment Sb at Bakers Creek ranged from 72 to 164 the national sediment low guideline value. Sediments in the Macleay channel at Georges Junction, Bellbrook, Kinchela and Jerseyville also exceeded the national sediment low guideline value.

Water column As at Bakers Creek ranged from 1.4 to 2.7 times the ANZECC guidelines for healthy aquatic ecosystems. As was observed in the water column at Jerseyville on multiple sampling occasions, but only exceeded the ANZECC guidelines for healthy aquatic ecosystems once, in November 2015. Sediment As at Bakers Creek ranged from 4.4 to 7 times the national sediment low guideline value, but no site in the the Macleay main stem exceeded the national sediment low guideline value during the study.

Management Recommendations:

- collaborate with NSW Derelict Mines to seek multi-agency funding to strategically remediate historic mine sites identified as posing a high risk to water quality in the Macleay (a report prioritizing sites commissioned by NSW Derelict Mines will be released soon)
- continue to support targeted research into understanding the movement, deposition and accumulation of As and Sb in the Macleay catchment
- continue to actively participate in the Macleay River Working Group in its role as a forum for collaborating on research, facilitating strategic implementation of Strategy 30 in the Macleay River Estuary Plan and providing advice to the community.

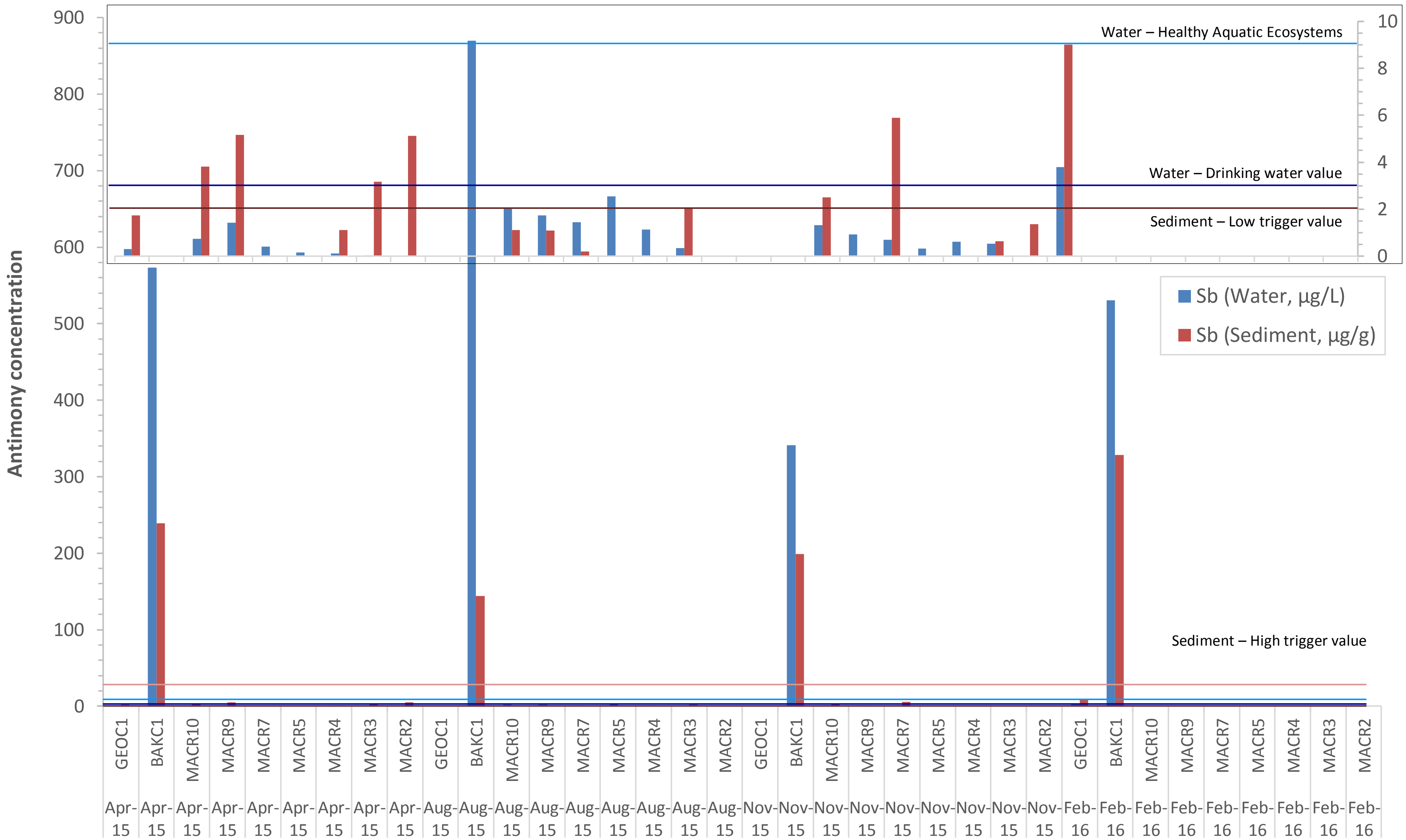


Figure 3.13 *Antimony (Sb) concentrations in water (µg/L) and sediment (µg/g) in Bakers Creek (primary source of contamination), Georges Creek (background control site) and the Macleay River. The inset at the top shows concentrations at all sites except Bakers Creek that remained below 10µg.*

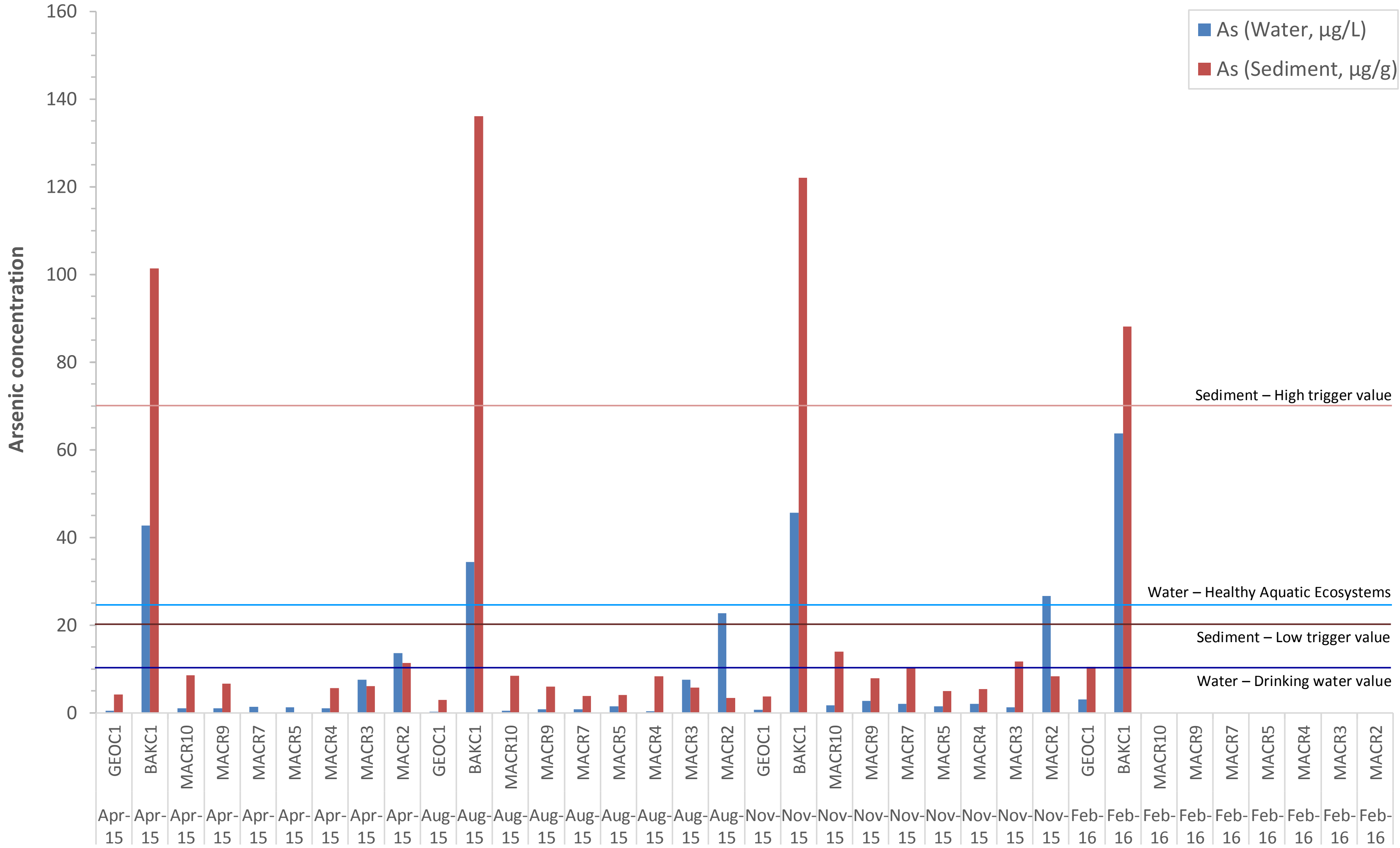


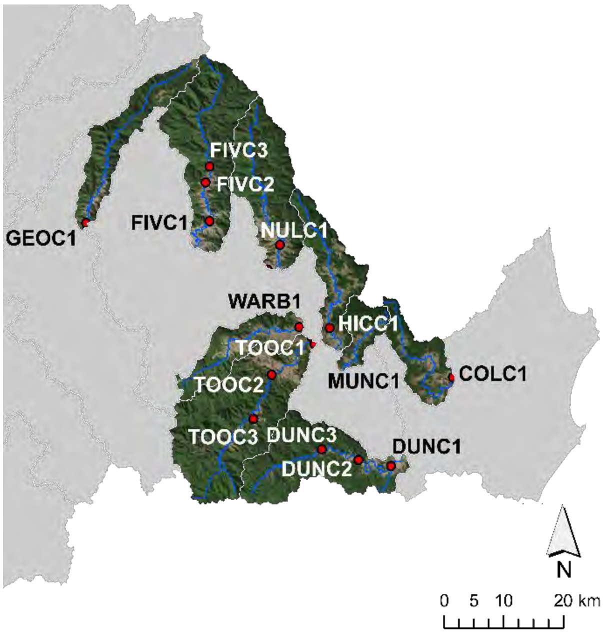
Figure 3.14 *Arsenic (As) concentrations in water (µg/L) and sediment (µg/g) in Bakers Creek (primary source of contamination), Georges Creek (background control site) and the Macleay River.*

3.4 Freshwater tributaries

3.4.1 Catchment description

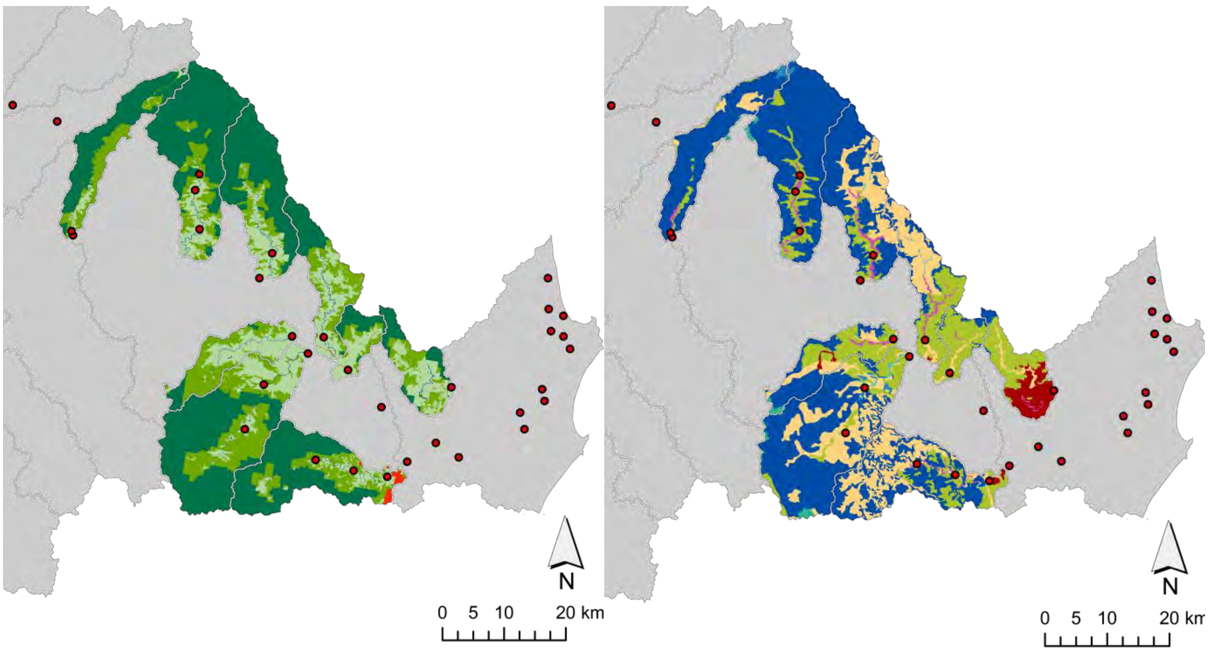
The freshwater tributaries of the Macleay River comprise 1,354km^2 or 13% of the Macleay catchment (Figure 3.15). These tributaries include Georges Creek (Table 3.68), Five Day Creek (Table 3.69), Nulla Nulla Creek (Table 3.70), Warbro Brook (Table 3.71), Toorumbee Creek (Table 3.72), Hickeys Creek (Table 3.73), Mungay Creek (Table 3.74), Dungay Creek (Table 3.75) and Collombatti Creek (Table 3.76).

The dominant land use in Georges, Five Day, Nulla Nulla and Toorumbee Creeks is national parks. The dominant land use in Dungay Creek is forestry (Table 3.75). Grazing is the dominant land use in Hickeys, Mungay and Collombatti Creeks. There are no point-source dischargers licensed in the freshwater tributaries of the Macleay.



(a) Location of Ecohealth sites

(b) River Styles: refer to Figure 2.8 for key



(c) Landuse: refer to Figure 2.7 for key

(d) Soils: refer to Figure 2.3 for key

Figure 3.15 *Freshwater tributaries of the Macleay catchment showing (a) locations of Ecohealth sites, (b) River Styles, (c) landuse, and (d) soils. Data layers from NC LLS (River Styles) and OEH (landuse and soils).*

Table 3.68 *Subcatchment description of Georges Creek. Data from NC LLS and OEH.*

Variable	Subcatchment composition
Area	150.4km^2
Geology	78.1% metasedimentary siliciclastic; 9.6% igneous felsic intrusive; 6.5% sedimentary siliciclastic, metasedimentary siliciclastic; 5.5% igneous mafic volcanic, igneous foid-bearing volcanic
Soils	81.0% Rudosols and Tenosols; 8.9% Dermosols; 5.1% Kurosols
River Styles	39.4% CVS – Gorge; 25.0% PCVS - Planform controlled, low sinuosity, gravel; 15.4% CVS – Headwater; 7.9% PCVS - Bedrock controlled, sand
Landuse	64.6% National Park; 26.8% Residual native cover; 7.2% Grazing
Major point source discharge	Nil
Tree Cover	65.5%

Table 3.69 *Subcatchment description of Five Day Creek. Data from NC LLS and OEH.*

Variable	Subcatchment composition
Area	274.5km^2
Geology	89.2% metasedimentary siliciclastic; 6.5% sedimentary siliciclastic
Soils	81.3% Rudosols and Tenosols; 14.9% Kurosols
River Styles	35.5% CVS – Gorge; 19.3% PCVS - Planform controlled, low sinuosity, gravel; 15.6% CVS - Floodplain pockets, gravel; 13.4% CVS – Headwater; 8.6% CVS - Floodplain pockets, fine grained
Landuse	62.0% National Park; 17.1% Residual native cover; 14.3% Grazing; 5.4% Forestry
Major point source discharge	Nil
Tree Cover	67.4%

Table 3.70 *Subcatchment description of Nulla Nulla Creek. Data from NC LLS and OEH.*

Variable	Subcatchment composition
Area	213.1km^2
Geology	80.6% metasedimentary siliciclastic; 19.4 % sedimentary siliciclastic
Soils	59.6% Rudosols and Tenosols; 27.8% Dermosols; 8.7% Kurosols
River Styles	47.4% PCVS - Planform controlled, low sinuosity, gravel; 28.0% CVS – Gorge; 10.7% CVS – Headwater; 6.1% CVS - Floodplain pockets, fine grained
Landuse	63.0% National Park; 18.8% Grazing; 14.2% Residual native cover; 2.5% Forestry
Major point source discharge	Nil
Tree Cover	65.5%

Table 3.71 *Subcatchment description of Warbro Brook. Data from NC LLS and OEH.*

Variable	Subcatchment composition
Area	116.7km^2
Geology	92.3% sedimentary siliciclastic; 7.1% sedimentary carbonate
Soils	39.4% Kurosols; 38.4% Rudosols and Tenosols; 15.4% Dermosols
River Styles	28.8% CVS – Headwater; 23.8% PCVS - Planform controlled, low sinuosity, gravel; 15.7% CVS - Floodplain pockets, sand; 13.3% PCVS - Planform controlled, low sinuosity, sand; 5.1% PCVS - Planform controlled, low sinuosity, fine grained
Landuse	47.3% Residual native cover; 41.0% grazing; 7.3% Forestry; 1.9% National Park
Major point source discharge	Nil
Tree Cover	9.1%

Table 3.72 *Subcatchment description of Toorumbee Creek. Data from NC LLS and OEH.*

Variable	Subcatchment composition
Area	353.9km^2
Geology	70.8% sedimentary siliciclastic; 25.9% argillaceous detrital sediment, igneous felsic-intermediate intrusive
Soils	58.2% Rudosols and Tenosols; 25.6% Dermosols; 12.5% Kurosols
River Styles	30.5% CVS – Gorge; 17.9% CVS – Headwater;16.2% PCVS - Planform controlled, low sinuosity, gravel; 10.6% CVS - Floodplain pockets, gravel
Landuse	52.1% National Park; 27.8% Residual native cover; 16.6% Grazing; 2.4% Forestry
Major point source discharge	Nil
Tree Cover	54.6%

Table 3.73 *Subcatchment description of Hickeys Creek. Data from NC LLS and OEH.*

Variable	Subcatchment composition
Area ()	133.6km^2
Geology	83.5% sedimentary siliciclastic; 16.4% metasedimentary siliciclastic
Soils	39.8% Dermosols; 38.9% Kurosols; 16.5% Rudosols and Tensols
River Styles	52.0% CVS - Floodplain pockets, gravel; 19.7% CVS – Headwater; 13.1% PCVS - Planform controlled, meandering, fine grained; 10.1% PCVS - Planform controlled, low sinuosity, gravel; 5.1% CVS - Floodplain pockets, fine grained
Landuse	38.4% Grazing; 32.3% Residual native cover; 25.5% National Park; 1.5% River/Wetland
Major point source discharge	Nil
Tree Cover	26.5%

Table 3.74 *Subcatchment description of Mungay Creek. Data from NC LLS and OEH.*

Variable	Subcatchment composition
Area	58.9km^2
Geology	99.6% sedimentary siliciclastic
Soils	83.0% Kurosols; 9.1% Rudosols and Tenosols; 7.0% Dermosols
River Styles	45.9% PCVS - Planform controlled, meandering, fine grained; 21.7% CVS - Floodplain pockets, gravel; 18.9% PCVS - Planform controlled, low sinuosity, fine grained; 13.5% CVS - Headwater
Landuse	42.7% Grazing;
Major point source discharge	Nil
Tree Cover	35.0%

Table 3.75 *Subcatchment description of Dungay Creek. Data from NC LLS and OEH.*

Variable	Subcatchment composition
Area	237.1km^2
Geology	75.6% argillaceous detrital sediment, igneous felsic-intermediate intrusive; 20.2% sedimentary siliciclastic
Soils	44.3% Rudosols and Tenosols; 37.9% Dermosols; 14.8% Kurosols
River Styles	23.6% CVS – Gorge; 21.8% PCVS - Planform controlled, low sinuosity, gravel; 19.4% CVS - Floodplain pockets, sand; 15.9% CVS - Floodplain pockets, gravel; 13.2% CVS - Headwater
Landuse	33.6% Forestry; 28.1% National Park; 21.7% Residual Native Cover; 10.7% grazing; 2.8% Rural Residential; 1.4% degraded land
Major point source discharge	Nil
Tree Cover	61.7%

Table 3.76 *Subcatchment description of Collombatti Creek. Data from NC LLS and OEH.*

Variable	Subcatchment composition
Area	99.5km^2
Geology	89.0% sedimentary siliciclastic; 11.0% regolith
Soils	44.3% Rudosols and Tenosols; 37.9% Dermosols; 14.8% Kurosols
River Styles	62.9% LUV CC - Meandering, fine grained; 23.8% CVS - Floodplain pockets, gravel; 12.9% CVS - Headwater
Landuse	43.7% Grazing; 23.5% Forestry; 7.2% National park; 1.5% Land under rehabilitation
Major point source discharge	Nil
Tree Cover	35.96%

3.4.2 Site descriptions

There were fifteen sites located in the freshwater tributaries of the Macleay River (Figure 3.15). Three subcatchments were >200km^2 and contained three sites to assess longitudinal patterns in aquatic ecosystem health: Five Day Creek, Toorumbee Creek and Dungay Creek. In Five Day Creek subcatchment, FIVC1 (Plate 3.47) is a planform controlled, low sinuosity gravel-bed channel in a partially confined valley setting located 11.5km from the confluence of Five Day Creek and the Macleay River. FIVC1 was moved upstream from its initial location 1.1km from the confluence due to issues with site access. FIVC2 (Plate 3.48) is a planform controlled, low sinuosity gravel-bed channel in a partially confined valley setting located 11.8km upstream of FIVC1. FIVC3 (Plate 3.49) is a planform controlled, low sinuosity gravel-bed channel in a partially confined valley setting located 4.2km upstream of FIVC2.

In Toorumbee Creek subcatchment, TOOC1 (Plate 3.50) is a planform controlled, meandering fine-grained channel in a partially confined valley setting located 500m from the confluence of Toorumbee Creek and the Macleay River. TOOC2 (Plate 3.51) is a planform controlled, low sinuosity, gravel-bed channel located 12.2km upstream of TOOC1. TOOC3 (Plate 3.52) is a planform controlled, low sinuosity, gravel-bed channel located 11.8km upstream of TOOC2. In Dungay Creek subcatchment, DUNC1 (Plate 3.53) is a planform contolled, low sinuosity, gravel-bed river in a partially confined valley setting located at Dongdingalong 4.2km from the confluence of Dungay Creek and the Macleay River. DUNC2 (Plate 3.54) is a planform controlled, low sinuosity, gravel-bed channel in a partially confined valley setting located at Wittitrin, 12.1km upstream of DUNC1. DUNC3 (Plate 3.55) is a gorge (confined valley setting) located 9.8km upstream of DUNC2.

There were six sites located at or close to end-of-system tributuaries of the Macleay River. GEOC1 (Plate 3.56) is a planform controlled, low sinuosity, gravel-bed channel in a partially confined valley setting located on Georges Creek 900m upstream of its confluence with the Macleay River. NULC1 (Plate 3.57) is a planform controlled, low sinuosity, gravel-bed channel in a partially confined valley setting located on Nulla Nulla Creek 7.6km upstream of its confluence with the Macleay River. WARB1 (Plate 3.58) is a planform controlled, low sinuosity, gravel-bed channel in a partially confined valley setting located on Warbro Brook 2.5km from its confluence with the Macleay River. HICC1 (Plate 3.59) is a planform controlled, meandering fine grained channel in a partially confined valley setting located on Hickeys Creek 8.5km upstream of its confluence with the Macleay River. MUNC1 (Plate 3.60) is a planform controlled, low sinuosity, gravel-bed channel in a partially confined valley setting located on Mungay Creek 4.4km upstream of its confluence with the Macleay River. COLC1 (Plate 3.61) is a meandering, fine grained, continuous channel in a laterally unconfined valley setting located on Collombatti Creek immediately downstream of the bridge on Collombatti-Fredrickton Road.

Plate 3.47 *Site FIVC1 on Five Day Creek (looking downstream from the right bank).*

Plate 3.48 *Site FIVC2 on Five Day Creek (looking from the right bank across to the left bank).*

Plate 3.49 *Site FIVC3 on Five Day Creek (looking upstream along the right bank).*

Plate 3.50 *Site TOOC1 on Toorumbee Creek (looking from the left bank across to the right bank).*

Plate 3.51 *Site TOOC2 on Toorumbee Creek (looking upstream).*

Plate 3.52 *Site TOOC3 on Toorumbee Creek (looking from the left bank across to the right bank).*

Plate 3.53 *Site DUNC1 on Dungay Creek (looking across to the right bank).*

Plate 3.54 *Site DUNC2 on Dungay Creek (looking upstream along the right bank).*

***Plate 3.55** Site DUNC3 on Dungay Creek (looking downstream along the right bank).*

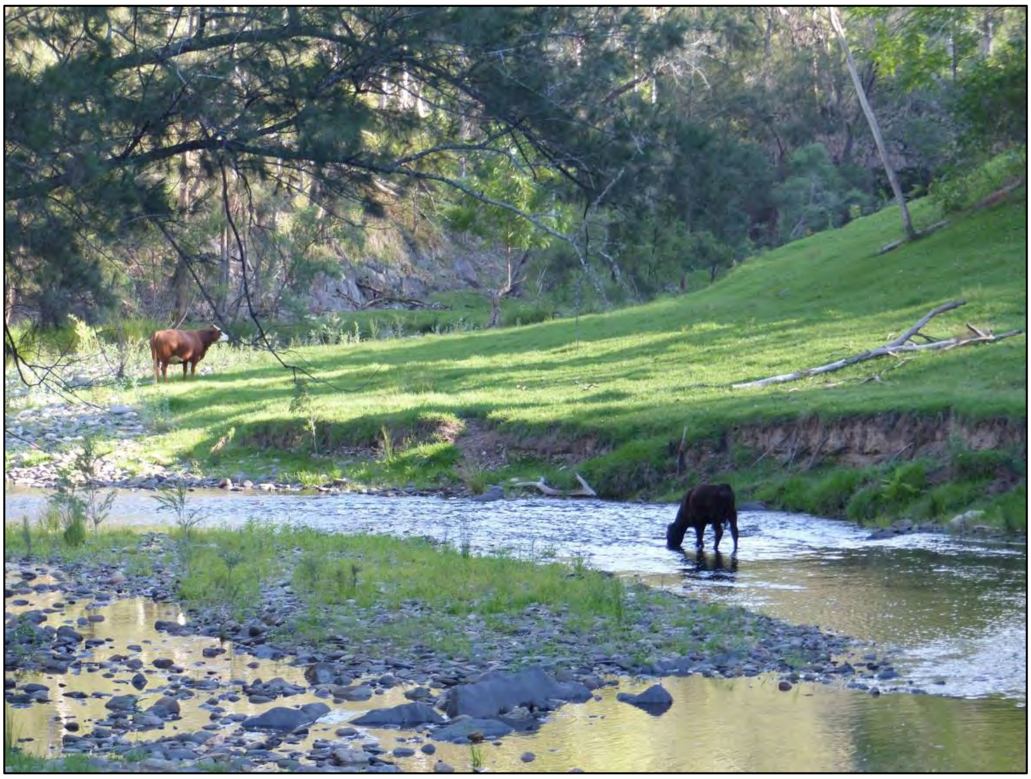


***Plate 3.56** Site GEOC1 on Georges Creek (looking downstream across to the right bank).*

Plate 3.57 *Site NULC1 on Nulla Nulla Creek (looking downstream).*

Plate 3.58 *Site WARB1 on Warbro Brook (looking upstream).*

Plate 3.59 *Site HICC1 on Hickeys Creek (looking downstream).*

Plate 3.60 *Site MUNC1 on Mungay Creek (looking upstream from left bank).*

Plate 3.61 *Site COLC1 on Collombatti Creek (looking downstream).*

3.4.3 Georges Creek (GEOC1)

3.4.3.1 Geomorphic condition

The geomorphic River Style at Georges Creek #1 (GEOC1) is partially confined valley setting: planform controlled, low sinuosity, gravel. The bed sediments comprised subangular cobbles with gravel in a framework dilated matrix containing 32-60% fine sediments. There was no obvious bed erosion. Banks comprised fine sediments with gravel. There was minor erosion on the left bank with minor (<5m) undercutting and minor (<5m) slumping. There was significant erosion on the right bank with significant (10-20m) undercutting and significant (10-20m) slumping. Geomorphic complexity was good, with the site comprising pool – riffle or pool – rapid sequences (rapid 10%, riffle 25%, glide 15%, run 15% and pool 35% of reach length). GEOC1 scored 54, a D for BANK CONDITION and 77, a B-, for BED CONDITION. The overall geomorphic condition for GEOC1 was 65, a grade of C.

In summary, GEOC1 was assessed as being in moderate geomorphic condition, with erosion of the right bank the most significant issue for site-level geomorphic condition. The desktop GIS assessment of subcatchment geomorphic condition found the Georges Creek subcatchment to be in good condition with a grade of B+. The geomorphic condition at GEOC1 was below the subcatchment average.

3.4.3.2 Riparian condition

The original riparian vegetation community at GEOC1 (Plate 3.62) was described as 'River Oak riparian woodland of the NSW North Coast Bioregion and northern Sydney Basin Bioregion', plant community type ID 1106 (VIS, 2012), broadly classed as 'Eastern Riverine Forests' (Keith, 2004). GEOC1 received a moderate riparian condition score of 61.5, a grade of C- (Table 3.77).

The dominant canopy species present were River Oak (*Casuarina cunninghamiana* subsp. *cunninghamiana*), Silky Oak (*Grevillea robusta*), Cabbage Gum (*Eucalyptus amplifolia*) and the exotic species Willow (*Salix* sp.). Dominant native midstory species included Weeping Bottlebrush (*Callistemon viminalis*), Sandpaper Fig (*Ficus coronata*) and Kangaroo Apple (*Solanum arviculare*), along with the exotic species Lantana (*Lantana camara*), Narrow-leaved Vetch (*Gomphocarpus fruiticosus*), Ink Weed (*Phytolacca octandra*) and Wild Tobacco (S*olanum mauritianum*). The understory was dominated by native species Soft Lomandra (*Lomandra hystrix*), Common Rush (*Juncus usitatus*), Knotweeds (*Persicaria strigosa* and *P.hydropiper*), Common Bracken (*Pteridium esculentum*), Scurvy Weed (*Commelina cyanea*), Couch (*Cynodon dactylon*) and Australian Basket Grass (*Oplismenus aemulus*), along with exotic species Sidratusa (*Sida rhombifolia*), Fleabane (*Conyza bonariensis*), Blue Billy Goat Weed (*Ageratum houstonianum*), Paspalum (*Paspalum dilatatum*) and Buffalo Grass (*Stenotaphrum secundatum*). Vine species included the native Wombat Berry (*Eustrephus latifolius*) and Milk Vine (*Marsdenia rostrata*) and the exotic Blackberry (*Rubus* sp.), while a rich macrophyte layer included Hastings River Reed (*Potamophila parviflora*), Triangular Club Rush (*Schoenoplectiella mucronata*), Water Couch (*Paspalum distichum*), Freshwater Eelgrass

(*Vallisneria nana*), Clasped Pondweed (*Potamogeton perfoliatus*), Red Water-milfoil (*Myriophyllum verrucosum*) and the exotic species Elodea (*Elodea canadensis*).

Noxious weed species observed onsite were Willow (*Salix* sp.), Lantana (*Lantana camara*), Blackberry (*Rubus* sp.) and Fireweed (*Senecio madagascariensis*), all class 4 noxious weeds; and Mexican Poppy (*Argemone mexicana*), a class 5 noxious weed. In addition to those already mentioned, other weed species present included Read Head Cotton Bush (*Asclepias curassavica*), Spear Thistle (*Cirsium vulgare*), White Eye (*Richardia brassiliensis*), Mouse-ear Chickweed (*Cerastium glomeratum*), Coblers Pegs (*Bidens pilosa*) and Yorshire Fog (*Holcus lanatus*).

Summary: GEOC1 was a moderately disturbed system of mixed-aged closed forest with a remnant canopy and mixed native and exotic species throughout the midstory and understory layers, in a partially cleared, partially forested landscape. The surrounding landuse was agricultural grazing land, National Park, State Forest and Nature Reserve. Significant remnant stands of vegetation surround the site on all sides, on private land and in Cunnawarra National Park. GEOC1 scored well for Habitat, moderately for Native Species, Cover and Debris and poorly for Management subindices (Table 3.77), retaining representative elements of the remnant vegetation community in all structural layers. Riparian condition at GEOC1 was impacted by the presence and regeneration of weed and noxious weed species, particularly in the midstory and understory structural layers. Reduced midstory cover, limited leaf litter and woody debris, inadequate riparian fencing and animal impact also contributed to the reduction in riparian grade at this site.

Management Recommendations: Riparian condition could be improved through the control and removal of weed and noxious weed species, particularly throughout the midstory and understory layers. Riparian fencing should exclude livestock and allow for midstory and understory native species recovery and woody debris accumulation.

Plate 3.62 *Riparian vegetation at GEOC1 was moderately disturbed. Riparian condition would be improved through control and removal of weed and noxious weed species specifically Willow* (Salix sp.)*, Lantana* (Lantana camara) *and Blackberry* (Rubus sp.) *and by limiting animal impact by fencing off the riparian zone.*

Table 3.77 *Site-level summary of riparian condition of Georges Creek #1 showing the scores of individual indicators and the five subindices that comprise the Vegetation Condition Index.*

GEOC1	Scores
HABITAT	**16/20**
Channel width	3
Proximity	3
Continuity	3
Layers	3.5
Large native trees	1.5
Hollow-bearing trees	2
NATIVE SPECIES	**11/20**
Native canopy species	4
Native midstory species	1
Native herb/forb species	1
Native graminoid species	1
Native macrophyte species	3
SPECIES COVER	**15/20**
Canopy species	2
Midstory species	1
Herb/forb species	3
Graminoid species	4
Macrophyte species	4
DEBRIS	**13.5/20**
Total leaf litter	1
Native leaf litter	3
Dead trees standing	3
Dead trees fallen	1
Lying logs	4
Fringing vegetation	1.5
MANAGEMENT	**8/20**
Tree clearing	2
Fencing	0
Animal impact	0
Species of interest	0
Exposed tree roots	3
Native woody regeneration	2
Weedy woody regeneration	1
TOTAL	**61.5/100**

3.4.3.3 Water quality

Georges Creek received a score of 43 (F) for water quality. Figures 3.16 and 3.17 show the key physicochemical and nutrient variables used in the assessment of water quality for the freshwater tributaries. Ranges and means for these variables are given in Table 3.78 and the exceedances are given in Table 3.79.

pH exceeded the upper ANZECC lowland freshwater trigger value of 8 on all sampling occasions (Table 3.79). Turbidity at GEOC1 remained below the ANZECC lowland freshwater guideline of 50NTU for the duration of the sampling period (Figure 3.16d). DO% fell below the minimum ANZECC trigger threshold on 3 sampling occasions with a site minimum of 40% (Tables 3.78, 3.79). The site maximum DO% of 110.8% just exceeded the maximum ANZECC trigger value of 110%.

Concentrations of total nutrients were consistently high at GEOC1, with TN concentrations exceeding the ANZECC lowland freshwater trigger value of 500µg/L on 4 of 6 sampling occasions (Table 3.79). The site maximum TN concentration was 4.1 times the trigger value (Table 3.78). TP concentrations exceeded the ANZECC lowland freshwater trigger value of 50µg/L on 5 sampling occasions (Figure 3.17b). The site maximum TP concentration was 1.6 times the trigger value (Table 3.78).

Concentrations of dissolved nutrients were also consistently high at GEOC1. NOx concentrations exceeded the ANZECC lowland freshwater trigger value of 40µg/L on all sampling occasions (Table 3.78). The site minimum NOx concentration was 2 times the trigger value and the site maximum NOx concentration was 23 times the trigger value (Table 3.78). SRP concentrations exceeded the ANZECC lowland freshwater trigger value of 20µg/L on 3 sampling occasions (Table 3.79). The site maximum SRP concentration was 2 times the trigger value (Table 3.78).

Chlorophylla *a* concentrations exceeded the ANZECC trigger value of 4µg/L twice during the sampling period, in November and December 2015. The site maximum chlorophyll *a* concentration was 13.3 µg/L, 3.3 times the trigger value (Table 3.78). Peak algal productivity coincided with extreme low flows during the austral spring and summer, but not peak nutrient concentrations. Nonetheless, TP, NOx and SRP concentrations all exceeded the ANZECC trigger values during the spring and summer sampling occasions when algal productivity was high.

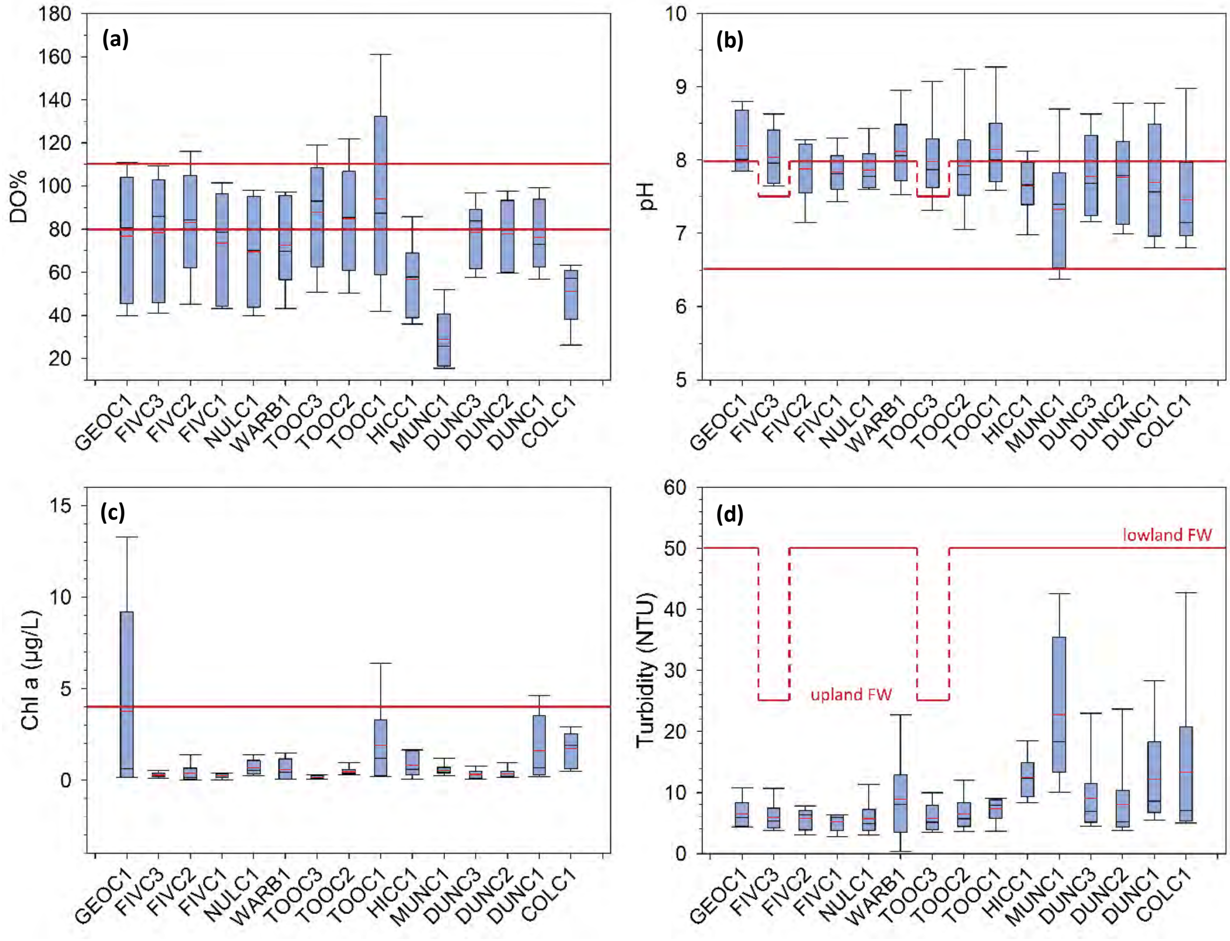


Figure 3.16 *Mean (red line), median (black line), 25th and 75th percentiles for (a) % saturated DO, (b) pH, (c) chlorophyll a and (d) turbidity in the freshwater tributaries of the Macleay River. Horizontal red lines represent the ANZECC and MER trigger thresholds for upland or lowland freshwater systems. Two horizontal red lines represent minimum (lower) and maximum (upper) trigger thresholds while single horizontal red lines represent maximum trigger thresholds.*

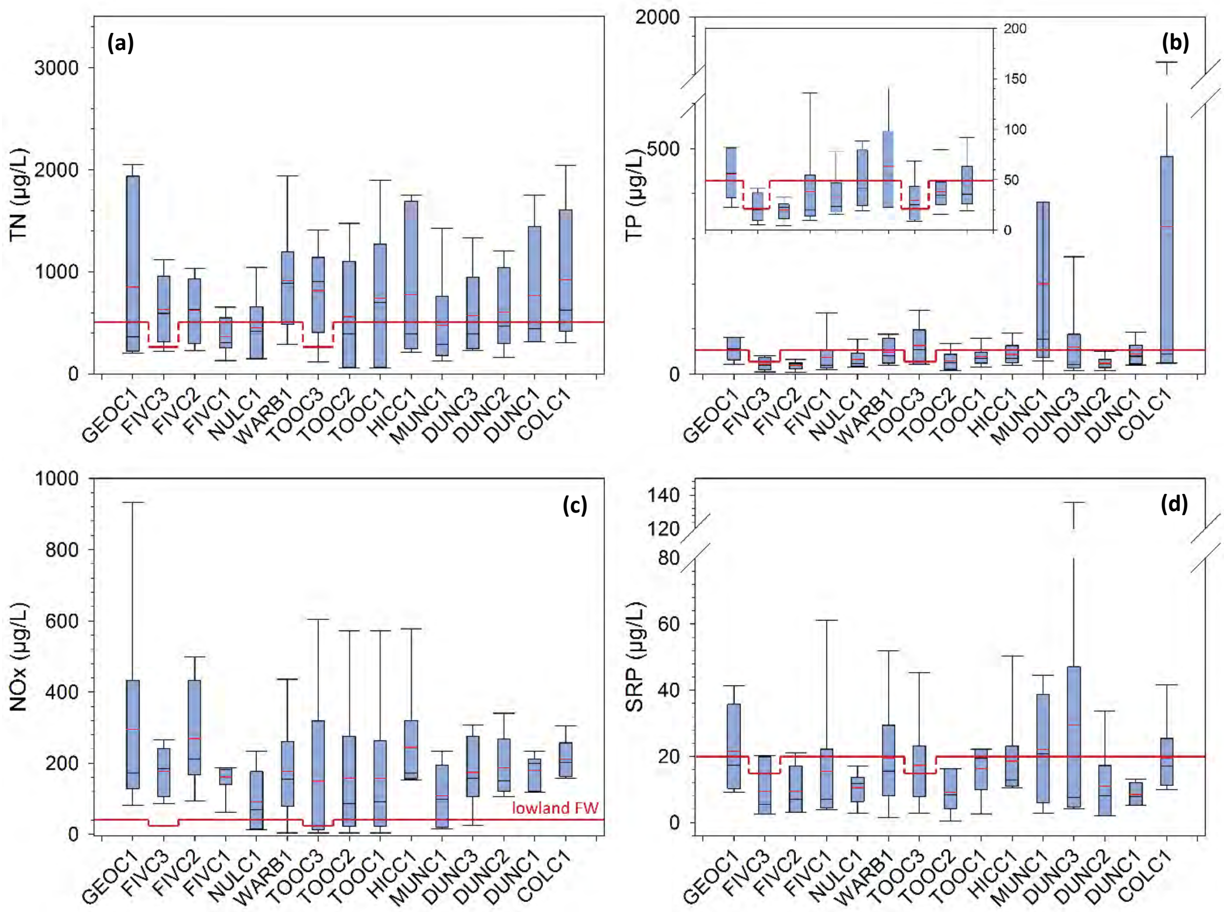


Figure 3.17 *Mean (red line), median (black line), 25th and 75th percentiles for (a) total nitrogen, (b) total phosphorus, (c) bioavailable nitrogen and (d) soluble reactive phosphorus in the freshwater tributaries of the Macleay River. Horizontal red lines represent the maximum ANZECC and MER trigger thresholds for upland or lowland freshwater systems. Inset in (b) provides better resolution of sites where nutrient concentrations remained comparatively low.*

***Table 3.78** Minimums, maximums and means of measured water quality variables for Georges Creek.*

	GEOC1		
Variable	**Min**	**Max**	**Mean**
Temperature (°C)	13.24	27.92	20.69
pH	7.85	8.80	8.19
EC (mS/cm)	0.06	0.07	0.06
Salinity (PPT)	0.03	0.04	0.03
DO (mg/L)	3.03	9.33	6.39
DO (%)	39.70	110.80	76.78
Turbidity (NTU)	4.40	10.80	6.48
Max Depth	0.20	0.40	0.31
Chla (µg/L)	0.15	13.28	3.78
TSS (mg/L)	0.19	11.80	3.52
TN (µg/L)	205.61	2050.8	851.40
TP (µg/L)	22.50	81.97	55.51
NOx (µg/L)	81.42	933.19	295.44
SRP (µg/L)	9.17	41.37	21.61

***Table 3.79** Exceedances[1] observed in the freshwater tributary sites for pH, conductivity (EC), percent saturated dissolved oxygen (DO), turbidity, chlorophyll a (Chl-a), total nitrogen (TN) ,total phosphorus (TP), bioavailable nitrogen (NOx) and soluble reactive phosphorus (SRP).*

Site	pH	EC	DO %	Turbidity	Chl-a	TN	TP	NOx	SRP
GEOC1	6(100%) 0,6	0(0%) 0,0	4(67%) 3,1	0(0%)	0(0%)	4(67%)	5(83%)	6(100%)	3(50%)
FIVC3	6(100%) 0,6	0(0%) 0,0	3(50%) 3,0	0(0%)	0(0%)	5(83%)	3(50%)	6(100%)	2(33%)
FIVC2	3(50%) 0,3	0(0%) 0,0	2(33%) 2,0	0(0%)	0(0%)	3(50%)	1(17%)	6(100%)	1(17%)
FIVC1	1(17%) 0,1	0(0%) 0,0	3(50%) 3,0	0(0%)	0(0%)	2(33%)	1(17%)	6(100%)	1(17%)
NULC1	1(17%) 0,1	0(0%) 0,0	4(67%) 4,0	0(0%)	0(0%)	2(33%)	1(17%)	3(50%)	0(0%)
WARB1	4(67%) 0,4	6(100%) 0,6	4(67%) 4,0	0(0%)	0(0%)	5(83%)	3(50%)	5(83%)	3(50%)
TOOC3	5(83%) 0,5	1(17%) 1,0	3(50%) 2,1	0(0%)	0(0%)	5(83%)	6(100%)	3(50%)	3(50%)
TOOC2	1(17%) 0,1	0(0%) 0,0	4(67%) 3,1	0(0%)	0(0%)	3(50%)	1(17%)	4(67%)	0(0%)
TOOC1	3(50%) 0,3	0(0%) 0,0	5(83%) 3,2	0(0%)	1(17%)	4(67%)	1(17%)	3(50%)	3(50%)
HICC1	1(17%) 0,1	6(100%) 0,6	5(83%) 5,0	0(0%)	0(0%)	2(33%)	2(33%)	6(100%)	1(17%)
MUNC1	2(33%) 1,1	1(17%) 1,0	5(83%) 5,0	0(0%)	0(0%)	2(33%)	4(67%)	3(50%)	3(50%)
DUNC3	2(33%) 0,2	0(0%) 0,0	2(33%) 2,0	0(0%)	0(0%)	2(33%)	1(17%)	5(83%)	1(17%)
DUNC2	2(33%) 0,2	0(0%) 0,0	3(50%) 3,0	0(0%)	0(0%)	2(33%)	1(17%)	6(100%)	1(17%)
DUNC1	2(33%) 0,2	0(0%) 0,0	4(67%) 4,0	0(0%)	1(17%)	3(50%)	2(33%)	6(100%)	0(0%)
COLC1	1(17%) 0,1	6(100%) 0,6	6 (100%) 6,0	0(0%)	0(0%)	4(67%)	3(50%)	6(100%)	2(33%)

[1] Numbers in black represent the total number and percent of exceedances. Numbers in blue and red represent the numbers of measurements lower than the minimum threshold and higher than the maximum threshold, respectively. The number of exceedances includes all depths sampled so may be greater than the number of times sampled. Turbidity, chlorophyll a and nutrients only have maximum trigger thresholds.

3.4.3.4 Aquatic macroinvertebrates

GEOC1 recorded 1875 and 1485 individual macroinvertebrates across 32 and 36 macroinvertebrate families during the 2015 autumn and spring sampling, respectively (Table 3.80). These abundances were the second-highest found across all sites in the Macleay catchment. In autumn, abundance was dominated by Baetid Mayflies (416 individuals) and richness was dominated by Trichoptera (Caddisflies, with 8 families). In contrast, Philopotamid Caddisflies were the most abundant family in spring (404 individuals), and the most diverse order in spring remained Trichoptera with 12 families. Family richness was higher in spring than autumn, driven entirely by the additional Caddisfly families in spring. There were a number of rare taxa at the site, with 8 and 15 taxa recording fewer than 5 individuals in autumn and spring, respectively.

Mean SIGNAL2 scores for GEOC1 were higher in spring (7.2) than autumn (6.5), although the range of SIGNAL2 scores was similar between seasons. The increase in the mean SIGNAL2 at GEOC1 in spring was due to higher abundances of high-scoring Trichoptera (Caddisflies) with SIGNAL2 scores of 8 and 9.

GEOC1 received an overall Ecohealth score of 89, a grade of B+, for aquatic macroinvertebrate community condition. This was the second-highest site score for macroinvertebrate health in the Macleay catchment. All macroinvertebrate indicators were well above the Macleay catchment average (Table 3.13). The macroinvertebrate indicators suggest the water quality and habitat conditions in Georges Creek are in good condition, and are able to support a diversity of macroinvertebrate fauna given the wide range of SIGNAL2 scores.

Table 3.80 *Summary of aquatic macroinvertebrate data for Georges Creek.*

	GEOC1	
Macroinvertebrate indicator	**Autumn 2015**	**Spring 2015**
Total abundance	1875	1485
Family richness	32	36
EPT abundance	899	991
EPT richness	11	13
Mean SIGNAL2 score	6.5	7.2
SIGNAL2 score range	2-8	2-9
Ecohealth score (grade)	**89 (B+)**	

3.4.4 Five Day Creek (FIVC3, FIVC2 and FIVC1)

3.4.4.1 Geomorphic condition

The geomorphic River Style at Five Day Creek #3 (FIVC3) is partially confined valley setting: planform controlled, low sinuosity, gravel. The bed sediments comprised subangular cobbles with gravel in a matrix filled contact framework containing 5-32% fine sediments. There was significant bed erosion on the left bank immediately downstream of the ford on Postman's Trail; this erosion was due to eddy currents around a fallen tree. Banks comprised fine sediments with gravel. There was significant eroson on the left bank with significant (10-20m) undercutting associated with the fallen tree and minor (<5m) slumping further downstream. There was significant erosion on the right bank with severe (20-100m) undercutting and significant (10-20m) slumping. Erosion appears to be flood related. Geomorphic complexity was good, with the site comprising pool – riffle sequences (riffle 20%, glide 20%, pool 50% and backwater 10% of reach length). FIVC3 scored 44, an F for BANK CONDITION and 51, a D, for BED CONDITION. The overall geomorphic condition for FIVC3 was 48, a grade of D-.

The geomorphic River Style at Five Day Creek #2 (FIVC2) is partially confined valley setting: planform controlled, low sinuosity, gravel. The bed sediments comprised subangular cobbles with gravel in a framework dilated matrix containing 32-60% fine sediments. There was minor bed erosion along the right bank at the downstream end of the reach. Banks comprised fine sediments with gravel. There was significant eroson on the left bank with significant (10-20m) undercutting and significant (10-20m) slumping. There was significant erosion on the right bank with significant (10-20m) undercutting and significant (10-20m) slumping. Geomorphic complexity was moderate, with the site comprising a pool – riffle sequence (riffle 15%, glide 75% and pool 10% of reach length). FIVC2 scored 41, an F for BANK CONDITION and 68, a C, for BED CONDITION. The overall geomorphic condition for FIVC2 was 54, a grade of D.

The geomorphic River Style at Five Day Creek #1 (FIVC1) is partially confined valley setting: planform controlled, low sinuosity, gravel. The bed sediments comprised gravel with subangular cobbles in a matrix dominated framework containing >60% fine sediments. Bed erosion was not observed within the site reach although there was significant deposition of fine sediments smothering the cobble substrate. Banks comprised fine sediments. There was minor eroson on the left bank with minor (<5m) undercutting and minor (<5m) slumping adjacent to the ford. There was minor erosion on the right bank with minor (<5m) undercutting and minor (<5m) slumping. The slumping was associated with the ford, with the undercutting observed upstream of the ford. Geomorphic complexity was good, with the site comprising pool – riffle sequences (riffle 40%, run 30% and pool 30% of reach length). FIVC1 scored 61, a C- for BANK CONDITION and 68, a C, for BED CONDITION. The overall geomorphic condition for FIVC1 was 65, a grade of C-.

In summary, FIVC3 and FIVC2 were assessed as being in poor geomorphic condition and FIVC1 was assessed as being in moderate geomorphic condition, with bank erosion associated with fords the most significant issue for site-level geomorphic condition. The desktop GIS assessment of subcatchment geomorphic condition found the Five Day Creek subcatchment to be in good condition with a grade of B. The geomorphic condition at FIVC1-FIVC3 were below the subcatchment average.

3.4.4.2 Riparian condition

FIVC3

The original riparian vegetation community at FIVC3 (Plate 3.63) was described as 'River Oak forest and woodland wetland of the NSW South Western Slopes and South Eastern Highlands Bioregion', plant community type ID 85 (VIS, 2012), broadly classed as 'Eastern Riverine Forests' (Keith, 2004), grading into 'Black Bean - Weeping Lilly Pilly - Water Gum riparian rainforest of the NSW North Coast Bioregion' plant community type ID 669 (VIS, 2012), broadly classed as 'Dry rainforest' (Keith, 2004), a recognized TEC (VIS, 2012). FIVC3 received a moderate riparian condition score of 67.2, a grade of C (Table 3.81).

The dominant canopy species present were River Oak (*Casuarina cunninghamiana* subsp. *cunninghamiana*), Flooded Gum (*Eucalyptus grandis*), Silky Oak (*Grevillea robusta*) and White Cedar (*Melia azedarach*). Dominant native midstory species included Lilly Pilly (*Acmena smithii*), Sandpaper Fig (*Ficus coronata*), Native Rosella (*Hibiscus heterophyllus*), along with the exotic species Lantana (*Lantana camara*), Small-leaved Privet (*Ligustrum sinense*), Wild Tobacco (*Solanum mauritianum*), Castor Oil Plant (*Ricinus communis*). The understory was dominated by native species Soft Lomandra (*Lomandra hystrix*), Common Rush (*Juncus usitatus*), Knotweeds (*Persicaria decipiens* and *P.hydropiper*), Stinging Nettle (*Urtica incisa*), Common Bracken (*Pteridium esculentum*), Couch (*Cynodon dactylon*), Australian Basket Grass (*Oplismenus aemulus*) and Rice Grass (*Microlaena stipoides*), along with exotic species Purpletop (*Verbena bonariensis*), Spear Thistle (*Cirsium vulgare*), Wandering Jew (*Tradescantia fluminensis*) and Paspalum species (*Paspalum dilatatum* and *P.orbiculare*). Only one vine species was present, the exotic Cat's Claw Creeper (*Dolichandra unguis-*cati), while the macrophyte layer included Pennywort (*Hydrocotyle tripartita*), Water Couch (*Paspalum distichum*), and the exotic species Elodea (*Elodea canadensis*).

Noxious weed species observed onsite were Cat's Claw Creeper (*Dolichandra unguis-cati*), a class 3 noxious weed; and Lantana (*Lantana camara*) and Small-leaved Privet (*Ligustrum sinense*), both class 4 noxious weeds. In addition to those already mentioned, other weed species present included Arsenic Bush (*Senna septemtrionalis*), Ink Weed (*Phytolacca octandra*), Crofton Weed (*Ageratina adenophora*), Mistflower (*Ageratina riparia*), Coblers Pegs (*Bidens pilosa*) and Pigeon Grass (*Setaria* sp.).

Summary: FIVC3 was a moderately disturbed system of mixed-aged closed forest with a remnant canopy and mixed native and exotic species throughout the midstory and understory layers, in a predominantly forested, partially cleared landscape. The surrounding rural landuse was a mixture of agricultural grazing land and State Forest. Significant remnant stands of vegetation in Nulla-Five Day State Forest surrounded the FIVC3 site in all directions except south. FIVC3 scored well for Habitat, Cover and Debris, moderately for Native Species, and poorly for Management subindices (Table 3.81), and retained representative elements of the remnant vegetation community in all structural layers. Riparian condition at FIVC3 was affected by the presence and regeneration of weed and noxious weed species, particularly in the midstory and understory structural layers. Inadequate riparian fencing and animal impact also contributed to the reduction in riparian grade at this site.

Management Recommendations: Riparian condition could be improved through the control and removal of weed and noxious weed species, particularly throughout the midstory and understory layers. Riparian fencing should exclude livestock and allow for midstory and understory native species recovery and woody debris accumulation.

Plate 3.63 *Riparian vegetation at FIVC3 was moderately disturbed.Riparian condition would be improved through control and removal of weed and noxious weed species such as Cat's Claw Creeper* (Dolichandra unguis-cati)*, Lantana* (Lantana camara)*, Small-leaved Privet* (Ligustrum sinense)*, and by fencing off the riparian zone.*

***Table 3.81** Site-level summary of riparian condition of Five Day Creek #3 showing the scores of individual indicators and the five subindices that comprise the Vegetation Condition Index.*

FIVC3	Scores
HABITAT	**16.7/20**
Channel width	2.7
Proximity	3
Continuity	4
Layers	4
Large native trees	2
Hollow-bearing trees	1
NATIVE SPECIES	**12/20**
Native canopy species	4
Native midstory species	1
Native herb/forb species	1
Native graminoid species	3
Native macrophyte species	3
SPECIES COVER	**16/20**
Canopy species	3
Midstory species	2
Herb/forb species	3
Graminoid species	4
Macrophyte species	4
DEBRIS	**15/20**
Total leaf litter	2
Native leaf litter	2
Dead trees standing	1
Dead trees fallen	3
Lying logs	4
Fringing vegetation	3
MANAGEMENT	**7.5/20**
Tree clearing	2
Fencing	1
Animal impact	0
Species of interest	0
Exposed tree roots	2.5
Native woody regeneration	2
Weedy woody regeneration	0
TOTAL	**67.2/100**

FIVC2

The original riparian vegetation community at FIVC2 (Plate 3.64) was described as 'River Oak forest and woodland wetland of the NSW South Western Slopes and South Eastern Highlands Bioregion', plant community type ID 85 (VIS, 2012), broadly classed as 'Eastern Riverine Forests' (Keith, 2004), grading into 'Black Bean - Weeping Lilly Pilly - Water Gum riparian rainforest of the NSW North Coast Bioregion' plant community type ID 669 (VIS, 2012), broadly classed as 'Dry Rainforest' (Keith, 2004), a recognized TEC (VIS, 2012). FIVC2 received a low riparian condition score of 53.5, a grade of D (Table 3.82).

The dominant canopy species present were River Oak (*Casuarina cunninghamiana* subsp. *cunninghamiana*), Forest red gum (*Eucalyptus tereticornis*) and Rough-leaved Elm (*Aphananthe philippinensis*). Dominant native midstory species included Lilly Pilly (*Acmena smithii*), along with the exotic species Lantana (*Lantana camara*), Small-leaved Privet (*Ligustrum sinense*), Narrow-leaved Vetch (*Gomphocarpus fruiticosus*), Read Head Cotton Bush (*Asclepias curassavica*) and Wild Tobacco (*Solanum mauritianum*). The understory was dominated by native species Soft Lomandra (*Lomandra hystrix*), Common Rush (*Juncus usitatus*), Slender Knotweed (*Persicaria decipiens*), Couch (*Cynodon dactylon*), Australian Basket Grass (*Oplismenus aemulus*) and Rice Grass (*Microlaena stipoides*), along with exotic species Purpletop (*Verbena bonariensis*), Spear Thistle (*Cirsium vulgare*), Wandering Jew (*Tradescantia fluminensis*), Fireweed (*Senecio madagascariensis*), Prairie Grass (*Bromus catharticus*) and Paspalum (*Paspalum dilatatum*). Vine species present included the native species Cockspur Thorn (*Maclura cochinchinensis*), Wombat Berry (*Eustrephus latifolius*) and the exotic species Common Passionfruit (*Passiflora* sp.) and Blackberry (*Rubus* sp.). The macrophyte layer included Club Rush (*Schoenoplectiella mucronata*), Water Couch (*Paspalum distichum*), and the exotic species Elodea (*Elodea canadensis*).

Noxious weed species observed onsite were Lantana (*Lantana camara*), Small-leaved Privet (*Ligustrum sinense*), Blackberry (*Rubus* sp.) and Fireweed (*Senecio madagascariensis*), all class 4 noxious weeds; and Mexican Poppy (*Argemone mexicana*), a class 5 noxious weed. In addition to those already mentioned, other weed species present included Senna (*Senna pendula* var. *glabrata*), Sidratusa (*Sida rhombifolia*), Coblers Pegs (*Bidens pilosa*), Spear Thistle (*Cirsium vulgare*) and Fleabane (*Conyza bonariensis*).

Summary: FIVC2 was a highly disturbed system of mixed-aged closed forest with mixed native and exotic species throughout all structural layers, in a predominantly cleared, partially forested landscape. The surrounding rural landuse was predominantly agricultural grazing land and State Forest. Significant remnant stands of vegetation lie north, east and west in Nulla-Five Day State Forest, 2.5km, 2km and 1.5km from FIVC2 respectively. FIVC2 scored well for Cover, moderately for Habitat and poorly for Native Species, Debris and Management subindices (Table 3.82), and retained representative elements of the remnant vegetation community in all structural layers. Riparian condition at FIVC2 was impacted by poor riparian vegetation continuity and habitat connectivity and the presence and regeneration of weed and noxious weed species, particularly in the midstory, understory and macrophyte structural layers. Reduced cover in both the canopy and midstory, reduced woody debris, inadequate riparian fencing and animal impact all contributed to the reduction in riparian grade at this site.

Management Recommendations: Riparian condition could be improved through the control and removal of weed and noxious weed species, particularly throughout the midstory and understory layers. Riparian fencing should exclude livestock and could be used in combination with native plantings to increase riparian vegetation width and continuity, woody debris accumulation and midstory and understory native species recovery.

Plate 3.64 *Riparian vegetation at FIVC2 was highly disturbed. Riparian condition would be improved through control and removal of weed and noxious weed species such as Lantana* (Lantana camara)*, Small-leaved Privet* (Ligustrum sinense) *and Blackberry* (Rubus sp.)*, undertaking native plantings, and fencing off the riparian zone.*

Table 3.82 *Site-level summary of riparian condition of Five Day Creek #2 showing the scores of individual indicators and the five subindices that comprise the Vegetation Condition Index.*

FIVC2	Scores
HABITAT	**11.5/20**
Channel width	2
Proximity	1
Continuity	1
Layers	4
Large native trees	1.5
Hollow-bearing trees	2
NATIVE SPECIES	**9/20**
Native canopy species	3
Native midstory species	1
Native herb/forb species	1
Native graminoid species	3
Native macrophyte species	1
SPECIES COVER	**15/20**
Canopy species	2
Midstory species	2
Herb/forb species	3
Graminoid species	4
Macrophyte species	4
DEBRIS	**9.5/20**
Total leaf litter	1.5
Native leaf litter	2
Dead trees standing	2
Dead trees fallen	1
Lying logs	1
Fringing vegetation	2
MANAGEMENT	**8.5/20**
Tree clearing	3
Fencing	1
Animal impact	0
Species of interest	0
Exposed tree roots	3.5
Native woody regeneration	1
Weedy woody regeneration	0
TOTAL	**53.5/100**

FIVC1

The original riparian vegetation community at FIVC1 (Plate 3.65) was described as 'River Oak forest and woodland wetland of the NSW South Western Slopes and South Eastern Highlands Bioregion', plant community type ID 85 (VIS, 2012), broadly classed as 'Eastern Riverine Forests' (Keith, 2004), grading into 'Black Bean - Weeping Lilly Pilly - Water Gum riparian rainforest of the NSW North Coast Bioregion' plant community type ID 669 (VIS, 2012), broadly classed as 'Dry Rainforest' (Keith, 2004), a recognized TEC (VIS, 2012). FIVC1 received a moderate riparian condition score of 60.2, a grade of C- (Table 3.83).

The dominant canopy species present were River Oak (*Casuarina cunninghamiana* subsp. *cunninghamiana*), Forest red gum (*Eucalyptus tereticornis*) and Rough-leaved Elm (*Aphananthe philippinensis*). Dominant native midstory species included Weeping Bottlebrush (*Callistemon viminalis*), Sandpaper Fig (*Ficus coronata*), Kangaroo Apple (*Solanum arviculare*), Black Tea-tree (*Melaleuca bracteata*), along with the exotic species Small-leaved Privet (*Ligustrum sinense*), Narrow-leaved Vetch (*Gomphocarpus fruiticosus*), Read Head Cotton Bush (*Asclepias curassavica*) and Wild Tobacco (*Solanum mauritianum*). The understory was dominated by native species Soft Lomandra (*Lomandra hystrix*), Common Rush (*Juncus usitatus*), Harsh Ground Fern (*Hypolepis muelleri*), Knotweeds (*Persicaria decipiens* and *P.hydropiper*), Couch (*Cynodon dactylon*), Australian Basket Grass (*Oplismenus aemulus*) and Rice Grass (*Microlaena stipoides*), along with exotic species Wandering Jew (*Tradescantia fluminensis*), Fireweed (*Senecio madagascariensis*) and Paspalum (*Paspalum dilatatum*). Only one vine species was present, the exotic Cat's Claw Creeper (*Dolichandra unguis-cati*), while the macrophyte layer included Club Rush (*Schoenoplectiella mucronata*), Freshwater Eelgrass (*Vallisneria nana*), Clasped Pondweed (*Potomogeton perfoliatus*), and the exotic species Elodea (*Elodea canadensis*).

Noxious weed species observed onsite were Tropical Soda Apple (*Solanum viarum*), a class 1 noxious weed; Cat's Claw Creeper (*Dolichandra unguis-cati*), a class 3 noxious weed; Small-leaved Privet (*Ligustrum sinense*) and Fireweed (*Senecio madagascariensis*), both class 4 noxious weeds; and Mexican Poppy (*Argemone mexicana*), a class 5 noxious weed. In addition to those already mentioned, other weed species present included Coblers Pegs (*Bidens pilosa*), Spear Thistle (*Cirsium vulgare*), Ditch Millet (*Paspalum orbiculare*) and Prairie Grass (*Bromus catharticus*).

Summary: FIVC1 was a moderately disturbed system of mixed-aged closed forest with a remnant canopy and mixed native and exotic species throughout the midstory and understory layers, in a predominantly cleared, partially forested landscape. The surrounding rural landuse was predominantly agricultural grazing land. Significant remnant stands of vegetation lie 2km to the east in Pee Dee Nature Reserve and 1km to the northwest on private land. FIVC1 scored well for Habitat, Native Species and Cover, and poorly for Habitat and Management subindices (Table 3.83), and retained representative elements of the remnant vegetation community in all structural layers. Riparian condition at FIVC1 was impacted by poor riparian vegetation width and habitat connectivity. The presence and regeneration of weed and noxious weed species, reduced woody debris, inadequate riparian fencing and animal impact all contributed to the reduction in riparian grade at this site.

Management Recommendations: Riparian condition could be improved through the control and removal of weed and noxious weed species, particularly throughout the midstory and understory layers. Riparian fencing should exclude livestock and allow for increased vegetation width and woody debris accumulation.

Plate 3.65 *Riparian vegetation at FIVC1 was moderately disturbed. Riparian condition would be improved through control and removal of weed and noxious weed species such as Tropical Soda Apple* (Solanum viarum)*, Cat's Claw Creeper* (Dolichandra unguis-cati) *and Small-leaved Privet* (Ligustrum sinense)*, and by fencing off the riparian zone.*

Table 3.83 *Site-level summary of riparian condition of Five Day Creek #1 showing the scores of individual indicators and the five subindices that comprise the Vegetation Condition Index.*

FIVC1	Scores
HABITAT	**15.7/20**
Channel width	1.7
Proximity	1
Continuity	3
Layers	4
Large native trees	2
Hollow-bearing trees	2
NATIVE SPECIES	**13/20**
Native canopy species	4
Native midstory species	3
Native herb/forb species	2
Native graminoid species	3
Native macrophyte species	3
SPECIES COVER	**15.5/20**
Canopy species	2
Midstory species	2.5
Herb/forb species	3
Graminoid species	4
Macrophyte species	4
DEBRIS	**8.5/20**
Total leaf litter	1.5
Native leaf litter	2
Dead trees standing	0
Dead trees fallen	1
Lying logs	1
Fringing vegetation	3
MANAGEMENT	**7.5/20**
Tree clearing	2.5
Fencing	0
Animal impact	0
Species of interest	0
Exposed tree roots	3
Native woody regeneration	1
Weedy woody regeneration	1
TOTAL	**60.2/100**

3.4.4.3 Water quality

Five Day Creek received a score of 66 (C) for water quality. FIVC3 (upper reach) received a score of 54 (D), FIVC2 (mid reach) received a score of 70 (C+) and FIVC1 (lower reach) received a score of 74 (C+). Figures 3.16 and 3.17 show the key physicochemical and nutrient variables used in the assessment of water quality for the freshwater tributaries. Ranges and means for these variables are given in Table 3.84 and the exceedances are given in Table 3.79.

pH exceeded the upper ANZECC upland freshwater trigger value of 7.5 on all sampling occasions at FIVC3, and the lowland freshwater trigger value of 8 on 3 and 1 sampling occasions at FIVC2 and FIVC1 (Table 3.79). Turbidity in Five Day Creek remained below the ANZECC trigger values for the duration of the sampling period (Figure 3.16d). DO% fell below the minimum ANZECC trigger threshold on 3 sampling occasions at FIVC3 and FIVC1 and on 2 sampling occasions at FIVC2. Site minimum DO% were 41%, 44% and 43% at FIVC3, FIVC2 and FIVC1, respectively (Table 3.84). Low DO% occurred during the extreme low flows in the austral spring and summer (November and December 2015). DO% exceeded the maximum ANZECC trigger value twice at FIVC2 (August 2015 and February 2016), with a site maximum DO% of 146%. This peak DO% did not coincide with high algal productivity.

There were no clear longitudinal trends in nutrient concentrations along Five Day Creek (Figure 3.17), although nitrogen exceedances were more frequent than phosphorus exceedances (Table 3.79). TN concentrations exceeded the ANZECC upland freshwater trigger value of 300µg/L on 5 sampling occasions at FIVC3, and the ANZECC lowland freshwater trigger value of 500µg/L on 3 and 2 sampling occasions at FIVC2 and FIVC1, respectively (Table 3.79). Site maximum TN concentrations were 1.03, 5.3 and 2.2 times the trigger values at FIVC3, FIVC2 and FIVC1, respectively (Table 3.84). TP concentrations exceeded the ANZECC upland freshwater trigger value of 30µg/L on 3 sampling occasions at FIVC3, and the ANZECC lowland freshwater trigger value of 50µg/L on 1 sampling occasion at FIVC2 and FIVC1 (Table 3.79). Site maximum TP concentrations were 1.3, 2.1 and 2.7 times the trigger values at FIVC3, FIVC2 and FIVC1, respectively (Table 3.84).

NOx concentrations exceeded the ANZECC trigger values on all sampling occasions at all sites on Five Day Creek (Table 3.79). Site maximum NOx concentrations were 4.7, 12 and 5.8 times the trigger values at FIVC3, FIVC2 and FIVC1, respectively (Table 3.84). SRP exceedances were far less frequent in Five Day Creek and the magnitudes of the exceedances were also smaller. SRP concentrations exceeded the upland ANZECC freshwater trigger value of 15µg/L on 2 sampling occasions at FIVC3, and the ANZECC lowland freshwater trigger value of 20µg/L once at FIVC2 and FIVC1 (Table 3.79). Site maximum SRP concentrations were 3, 1.9 and 1.01 times the trigger values at FIVC3, FIVC2 and FIVC1, respectively (Table 3.84).

High nutrient concentrations did not lead to high algal productivity in Five Day Creek, as chlorophyll *a* concentrations remained well below the ANZECC trigger value of 4µg/L during the sampling period (Figure 3.17c).

Table 3.84 *Minimums, maximums and means of measured water quality variables for the three sites on Five Day Creek.*

	FIVC1			FIVC2			FIVC3		
Variable	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**
Temperature (°C)	13.13	26.04	19.41	15.47	28.02	23.41	14.17	24.55	19.33
pH	7.66	8.30	7.91	7.81	8.28	8.05	7.70	8.63	8.12
EC (mS/cm)	0.08	0.09	0.09	0.07	0.18	0.10	0.07	0.08	0.07
Salinity (PPT)	0.04	0.05	0.04	0.04	0.08	0.05	0.04	0.04	0.04
DO (mg/L)	3.03	8.45	5.74	3.16	13.58	7.17	3.06	9.23	6.11
DO (%)	43.30	94.70	67.98	44.40	146.00	85.52	41.00	100.70	72.20
Turbidity (NTU)	2.80	6.30	4.98	3.10	14.10	6.88	3.80	10.70	5.88
Max Depth	0.03	0.40	0.25	0.20	0.45	0.29	0.15	0.35	0.28
Chla (µg/L)	0.03	0.40	0.23	0.03	1.53	0.46	0.12	0.31	0.24
TSS (mg/L)	0.38	5.05	2.60	0.40	2.58	1.52	0.89	1.57	1.19
TN (µg/L)	132.10	516.01	310.44	227.30	2644.1	891.10	218.70	1122.9	574.60
TP (µg/L)	9.62	135.9	40.67	4.34	106.6	36.05	4.97	41.11	21.66
NOx (µg/L)	62.07	187.25	157.12	93.10	498.03	262.18	85.59	233.11	160.39
SRP (µg/L)	4.61	61.20	17.78	2.99	38.17	13.98	2.57	20.25	10.37

3.4.4.4 Aquatic macroinvertebrates

FIVC3 recorded 1585 and 1942 individual macroinvertebrates across 49 and 36 macroinvertebrate families during the 2015 autumn and spring sampling, respectively (Table 3.85). These abundances were the highest found across all sites in the Macleay catchment. In autumn, abundance was dominated by Baetid Mayflies (504 individuals) and richness was co-dominated by Coleoptera (Aquatic Beetles) and Trichoptera (Caddisflies), with 13 and 12 families, respectively. Philopotamid Caddisflies were the most abundant family in spring (464 individuals), and the most diverse order in spring was Coleoptera with 10 families. Family richness was higher in autumn than spring, driven entirely by the additional Caddisfly families in autumn. There were a number of rare taxa at the site, with 26 and 8 taxa recording fewer than 5 individuals in autumn and spring, respectively.

Mean SIGNAL2 scores for FIVC3 were higher in spring (7.1) than autumn (6.3), although the range of SIGNAL2 scores was similar between seasons. The increase in the mean SIGNAL2 at FIVC3 in spring was due to higher abundances of high-scoring Trichoptera (Caddisflies) with SIGNAL2 scores of 8 and 9.

FIVC3 received an overall Ecohealth score of 97, a grade of A, for aquatic macroinvertebrate community condition. This was the highest site score for macroinvertebrate health in the Macleay catchment. All macroinvertebrate indicators were well above the Macleay catchment average (Table 3.13). The macroinvertebrate indicators suggest the water quality and habitat conditions in the upper reaches of Five Day Creek are in excellent condition, and are able to support a diversity of macroinvertebrate fauna given the wide range of SIGNAL2 scores.

FIVC2 recorded 2059 and 970 individual macroinvertebrates across 33 macroinvertebrate families during the 2015 autumn and spring sampling (Table 3.85). In autumn, abundance was dominated by Atyid Shrimp (452 individuals) and richness was dominated by Trichoptera (Caddisflies, with 9 families). In contrast, Philopotamid Caddisflies were the most abundant family in spring (310 individuals), and the most diverse orders in spring were Trichoptera and Coleoptera (Aquatic Beetles), both with 9 families. There were a number of rare taxa at the site, with 10 and 15 taxa recording fewer than 5 individuals in autumn and spring, respectively.

Mean SIGNAL2 scores for FIVC2 were higher in spring (7.1) than autumn (6.3), although the range of SIGNAL2 scores was the same between seasons. The increase in the mean SIGNAL2 at FIVC2 in spring was due to higher abundances of high-scoring Trichoptera (Caddisflies) with SIGNAL2 scores of 8 and 9, and a greater abundance of Leptophlebiid Mayflies with a SIGNAL2 score of 8.

FIVC2 received an overall Ecohealth score of 82, a grade of B, for aquatic macroinvertebrate community condition. This was the third-highest site score for macroinvertebrate health in the Macleay catchment. All macroinvertebrate indicators were well above the Macleay catchment average (Table 3.13). The macroinvertebrate indicators suggest the water quality and habitat conditions in the mid reaches of Five Day Creek are in good condition, and are able to support a diversity of macroinvertebrate fauna given the wide range of SIGNAL2 scores.

FIVC1 recorded 1237 and 808 individual macroinvertebrates across 33 and 37 macroinvertebrate families during the 2015 autumn and spring sampling, respectively (Table 3.85). In autumn, abundance was dominated by Hydropsychid Caddisflies (370 individuals) and richness was co-dominated by Trichoptera (Caddisflies) and Coleoptera (Aquatic Beetles), both with 8 families. In spring, Philopotamid Caddisflies were the most abundant family (165 individuals), and the most diverse order in spring was Trichoptera with 10 families. Family richness was higher in spring than autumn, driven entirely by the additional Caddisfly families in spring. There were a number of rare taxa at the site, with 14 and 12 taxa recording fewer than 5 individuals in autumn and spring, respectively.

The mean SIGNAL2 score for FIVC1 was slightly higher in autumn (6.6) than spring (6.3), although the range of SIGNAL2 scores was similar between seasons. The decrease in the mean SIGNAL2 at FIVC1 in spring was due to lower abundances of high-scoring Trichoptera (Caddisflies) with SIGNAL2 scores of 8 and 9.

FIVC1 received an overall Ecohealth score of 72, a grade of C+, for aquatic macroinvertebrate community condition. All macroinvertebrate indicators were well above the Macleay catchment average (Table 3.13). The macroinvertebrate indicators suggest the water quality and habitat conditions in the lower reaches of Five Day Creek are in moderate condition, and are able to support a diversity of macroinvertebrate fauna given the wide range of SIGNAL2 scores.

***Table 3.85** Summary of aquatic macroinvertebrate data for Five Day Creek.*

	FIVC3		FIVC2		FIVC1	
Macroinvertebrate indicator	**Autumn 2015**	**Spring 2015**	**Autumn 2015**	**Spring 2015**	**Autumn 2015**	**Spring 2015**
Total abundance	1585	1942	2059	970	1237	808
Family richness	49	36	33	33	33	37
EPT abundance	628	1032	925	563	654	381
EPT richness	16	12	10	13	11	12
Mean SIGNAL2 score	6.3	7.1	6.3	7.1	6.6	6.3
SIGNAL2 score range	1 - 9	2 - 9	2 - 9	2 - 9	2 - 9	1 - 9
Ecohealth score (grade)	**97 (A)**		**82 (B)**		**72 (C+)**	

3.4.5 Nulla Nulla Creek (NULC1)

3.4.5.1 Geomorphic condition

The geomorphic River Style at Nulla Nulla Creek #1 (NULC1) is partially confined valley setting: planform controlled, low sinuosity, gravel. The bed sediments comprised rounded gravel in a matrix dominated framework containing >60% fine sediments. Bed erosion was not observed in the site reach, but there was significant deposition of fine sediments smothering the gravel substrate. Banks comprised fine sediments. There was significant erosion on the left bank with significant (10-20m) undercutting and moderate (5-10m) slumping. There was severe erosion on the right bank with severe (20-100m) undercutting and severe (20-100m) slumping. Geomorphic complexity was good, with the site comprising pool - riffle sequence (riffle 40%, glide 30%, run 30% and pool 20% of reach length). NULC1 scored 61, a D for BANK CONDITION and 43, a B-, for BED CONDITION. The overall geomorphic condition for NULC was 52, a grade of C.

In summary, NULC1 was assessed as being in moderate geomorphic condition, with bank erosion the most significant issue for site-level geomorphic condition. The desktop GIS assessment of subcatchment geomorphic condition found the Nulla nulla Creek subcatchment to be in moderate condition with a grade of C. The geomorphic condition at NULC1 was representative of the subcatchment average.

3.4.5.2 Riparian condition

The original riparian vegetation community at NULC1 (Plate 3.66) was described as ‘River Oak forest and woodland wetland of the NSW South Western Slopes and South Eastern Highlands Bioregion’, plant community type ID 85 (VIS, 2012), broadly classed as ‘Eastern Riverine Forests’ (Keith, 2004). NULC1 received a low riparian condition score of 58.2, a grade of D+ (Table 3.86).

The dominant canopy species present were River Oak (*Casuarina cunninghamiana* subsp. *cunninghamiana*), Morton Bay Fig (*Ficus macrophylla*) and Red Kamala (*Mallotus philippensis*). Dominant native midstory species included Lilly Pilly (*Acmena smithii*), Weeping Bottlebrush (*Callistemon viminalis*) and Sandpaper Fig (*Ficus coronata*), along with the exotic species Small-leaved Privet (*Ligustrum sinense*), Lantana (*Lantana camara*), Arsenic Bush (*Senna septemtrionalis*) and Wild Tobacco (*Solanum mauritianum*).The understory was dominated by native species Soft Lomandra (*Lomandra hystrix*), Harsh Ground Fern (*Hypolepis muelleri*), Knotweeds (*Persicaria decipiens* and *P.hydropiper*), Couch (*Cynodon dactylon*), Creeping Beard Grass (*Oplismenus imbicillis*) and Rice Grass (*Microlaena stipoides*), along with exotic species Purpletop (*Verbena bonariensis*), Crofton Weed (Ageratina adenophora), Mistflower (Ageratina riparia), Wandering Jew (*Tradescantia fluminensis*), Spear Thistle (*Cirsium vulgare*), Cobblers Pegs (*Bidens pilosa*), Broadleaf Paspalum (*P.mandiocanum*) and Buffalo Grass (*Stenotaphrum secundatum*). Only a single native vine species was present, Water Vine (*Cissus hypoglauca*), while the macrophyte layer included Red Water-milfoil

(*Myriophyllum verrucosum*), Freshwater Eelgrass (*Vallisneria nana*) and the submerged exotic species Elodea (*Elodea canadensis*).

Noxious weed species observed onsite were Lantana (*Lantana camara*), Small-leaved Privet (*Ligustrum sinense*) and Fireweed (*Senecio madagascariensis*), all class 4 noxious weeds; and Mexican Poppy (*Argemone mexicana*), a class 5 noxious weed. In addition to those already mentioned, other weed species present included Arsenic Bush (*Senna septemtrionalis*), Crofton Weed (*Ageratina adenophora*), Mistflower (*Ageratina riparia*), Blue Billy Goat Weed (*Ageratum houstonianum*), Prickly Sowthistle (*Sonchus asper*) and Prairie Grass (*Bromus catharticus*).

Summary: NULC1 was a highly disturbed system of mixed-aged forest with a remnant canopy and mixed native and exotic species throughout the midstory and understory layers, in a predominantly cleared partially forested landscape. The surrounding rural landuse was a mixture of agricultural grazing land and State Forest. Significant remnant stands of vegetation lie 2km to the east in Thumb Creek State Forest and 1.5km to the west-southwest in private land. NULC1 scored moderately for all subindices except Management, for which it scored poorly (Table 3.86) and retained representative elements of the remnant vegetation community in all structural layers. Riparian condition at NULC1 was impacted by poor habitat continuity and habitat connectivity. The absence of habitat trees and of native species in the midstory and understory combined with the presence of weed and noxious weed species, woody weed regeneration, inadequate riparian fencing and animal impact all contributed to the reduction in riparian grade at this site.

Management Recommendations: Riparian condition could be improved through the control and removal of weed and noxious weed species, particularly throughout the midstory and understory layers. The implementation of riparian fencing should exclude livestock, promote the accumulation of woody debris, and increase riparian vegetation width and continuity by allowing for midstory and understory native species recovery.

Plate 3.66 *Riparian vegetation at NULC1 was highly disturbed. Riparian condition would be improved through control and removal of weed and noxious weed species such as Lantana* (Lantana camara)*, Small-leaved Privet* (Ligustrum sinense), *and by fencing off the riparian zone.*

Table 3.86 *Site-level summary of riparian condition of Nulla Nulla Creek #1 showing the scores of individual indicators and the five subindices that comprise the Vegetation Condition Index.*

NULC1	Scores
HABITAT	**12.7/20**
Channel width	2.7
Proximity	1
Continuity	2
Layers	4
Large native trees	2
Hollow-bearing trees	1
NATIVE SPECIES	**12/20**
Native canopy species	4
Native midstory species	1
Native herb/forb species	1
Native graminoid species	3
Native macrophyte species	3
SPECIES COVER	**14.5/20**
Canopy species	2
Midstory species	3
Herb/forb species	4
Graminoid species	4
Macrophyte species	1.5
DEBRIS	**11.5/20**
Total leaf litter	2
Native leaf litter	1.5
Dead trees standing	2
Dead trees fallen	2
Lying logs	2
Fringing vegetation	2
MANAGEMENT	**7.5/20**
Tree clearing	1.5
Fencing	1
Animal impact	0
Species of interest	0
Exposed tree roots	3
Native woody regeneration	2
Weedy woody regeneration	0
TOTAL	**58.2/100**

3.4.5.3 Water quality

Nulla Nulla Creek received a score of 80 (B-) for water quality. This was the highest site-level water quality score in the Macleay catchment, shared by DUNC3 (Section 3.4.10.3) and TOOC2 (Section 3.4.7.3). Figures 3.16 and 3.17 show the key physicochemical and nutrient variables used in the assessment of water quality for the freshwater tributaries. Ranges and means for these variables are given in Table 3.87 and the exceedances are given in Table 3.79.

pH exceeded the upper ANZECC lowland freshwater trigger value of 8 once, in December 2015 (Table 3.79). Turbidity at NULC1 remained below the ANZECC lowland freshwater guideline of 50NTU for the duration of the sampling period (Figure 3.16d). DO% was consistently below the minimum ANZECC trigger threshold (4 sampling occasions), with a site minimum of 40% (Tables 3.87, 3.79).

Concentrations of total nutrients were relatively low in Nulla Nulla Creek, with TN concentrations exceeding the ANZECC lowland freshwater trigger value on 2 sampling occasions (Table 3.79). The site maximum TN concentration was 2 times the trigger value (Table 3.87). TP concentrations exceeded the ANZECC lowland freshwater trigger value once (Table 3.78). The site maximum TP concentration was 1.6 times the trigger value (Table 3.78).

Concentrations of dissolved nutrients were also relatively low at NULC1. NOx concentrations exceeded the ANZECC lowland freshwater trigger value on 3 sampling occasions (Table 3.79). The site maximum NOx concentration was 5.8 times the trigger value (Table 3.87). SRP concentrations remained below the ANZECC lowland freshwater trigger value for the duration of the sampling period (Table 3.79).

Chlorophylla *a* concentrations remained below the ANZECC trigger value during the sampling period. Nulla Nulla Creek had good water quality during the sampling period.

Table 3.87 *Minimums, maximums and means of measured water quality variables for Nulla Nulla Creek.*

	NULC1		
Variable	**Min**	**Max**	**Mean**
Temperature (°C)	14.41	27.06	21.12
pH	7.60	8.43	7.87
EC (mS/cm)	0.02	0.14	0.11
Salinity (PPT)	0.06	0.07	0.06
DO (mg/L)	2.82	8.34	5.76
DO (%)	39.90	98.10	69.53
Turbidity (NTU)	3.00	11.30	5.68
Max Depth	0.25	0.60	0.36
Chla (µg/L)	0.04	1.39	0.64
TSS (mg/L)	0.69	23.40	13.19
TN (µg/L)	148.31	1046.6	451.80
TP (µg/L)	15.90	77.53	32.54
NOx (µg/L)	13.57	233.11	92.24
SRP (µg/L)	2.87	17.16	10.60

3.4.5.4 Aquatic macroinvertebrates

NULC1 recorded 522 and 1037 individual macroinvertebrates across 27 and 34 macroinvertebrate families during the 2015 autumn and spring sampling, respectively (Table 3.88). In autumn, abundance was dominated by Leptocerid Caddisflies (82 individuals) and richness was co-dominated by Trichoptera (Caddisflies) and Coleoptera (Aquatic Beetles), both with 6 families. In contrast, Elmid Beetles were the most abundant family in spring (269 individuals), and the most diverse order in spring remained Trichoptera with 8 families. Family richness was higher in spring than autumn, due to the presence of additional families across a range of orders. There were a number of rare taxa at the site, with 11 and 10 taxa recording fewer than 5 individuals in autumn and spring, respectively.

Mean SIGNAL2 scores for NULC1 were higher in spring (6.1) than autumn (5.6), although the range of SIGNAL2 scores was similar between seasons. The increase in the mean SIGNAL2 at NULC1 in spring was due to higher abundances of high-scoring Trichoptera (Caddisflies) with SIGNAL2 scores of 8 and 9 and Ephemeroptera (Mayflies) with SIGNAL2 scores of 8.

NULC1 received an overall Ecohealth score of 54, a grade of D, for aquatic macroinvertebrate community condition. Family richness and EPT score were the only indicators below the Macleay catchment average (Table 3.13). The macroinvertebrate indicators suggest the water quality and habitat conditions in the lower reaches of Nulla Nulla Creek are in poor condition, but are able to support a diversity of macroinvertebrate fauna given the wide range of SIGNAL2 scores.

Table 3.88 *Summary of aquatic macroinvertebrate data for Nulla Nulla Creek.*

	NULC1	
Macroinvertebrate indicator	**Autumn 2015**	**Spring 2015**
Total abundance	522	1037
Family richness	27	34
EPT abundance	79	291
EPT richness	5	11
Mean SIGNAL2 score	5.6	6.1
SIGNAL2 score range	2 - 9	1 - 9
Ecohealth score (grade)	**54 (D)**	

3.4.6 Warbro Brook (WARB1)

3.4.6.1 Geomorphic condition

The geomorphic River Style at Warbro Brook #1 (WARB1) is partially confined valley setting: planform controlled, low sinuosity, gravel. The bed sediments comprised rounded cobbles with gravel in a matrix filled contact framework containing 5-32% fine sediments. Bed erosion was absent in the site reach. Banks comprised fine sediments with gravel. There was minor erosion on the left bank with moderate (5-10m) undercutting and minor (<5m) slumping associated with the bridge. There was minor erosion on the right bank with moderate (5-10m) undercutting associated with the bridge and no slumping. Geomorphic complexity was moderate, with the site comprising a pool – riffle sequence (riffle 10%, run 80% and pool 10% of reach length). WARB1 scored 70, a C for BANK CONDITION and 77, a B-, for BED CONDITION. The overall geomorphic condition for WARB1 was 73, a grade of C+.

In summary, WARB1 was assessed as being in moderate geomorphic condition, with minor erosion adjacent to the bridge the most significant issue for site-level geomorphic condition. The desktop GIS assessment of subcatchment geomorphic condition found the Warbro Brook subcatchment to be in moderate condition with a grade of C+. The geomorphic condition at GEOC1 was representative of the subcatchment average.

3.4.6.2 Riparian condition

The original riparian vegetation community at WARB1 (Plate 3.67) was described as 'River Oak riparian woodland of the NSW North Coast Bioregion and northern Sydney Basin', plant community type ID 1106 (VIS, 2012), broadly classed as 'Eastern Riverine Forests (Keith, 2004). WARB1 received a low riparian condition score of 59.5, a grade of D+ (Table 3.89).

The single dominant canopy species present was River Oak (*Casuarina cunninghamiana* subsp. *cunninghamiana*). Dominant native midstory species included Weeping Bottlebrush (*Callistemon viminalis*), Sandpaper Fig (*Ficus coronata*), Lantana (*Lantana camara*) and Wild Tobacco (*Solanum mauritianum*). The understory was dominated by native species Soft Lomandra (*Lomandra hystrix*), Knotweeds (*Persicaria decipiens* and *P.hydropiper*), Gristle Fern (*Blechnum cartilagineum*), Couch (*Cynodon dactylon*), Blady Grass (*Imperata cylindrica*), Australian Basket Grass (*Oplismenus aemulus*) and Rice Grass (*Microlaena stipoides*), along with exotic species Purpletop (*Verbena bonariensis*), Sidratusa (*Sida rhombifolia*), Fleabane (*Conyza bonariensis*), Spear Thistle (*Cirsium vulgare*), Cobblers Pegs (*Bidens pilosa*), Blue Billy Goat Weed (*Ageratum houstonianum*), Wandering Jew (*Tradescantia fluminensis*) and Paspalum (*Paspalum dilatatum*). Vine species included the native species Cockspur Thorn (*Maclura cochinchinensis*) and the exotic species Cat's Claw Creeper (*Dolichandra unguis-cati*) and Common Passionfruit (*Passiflora* sp.). The macrophyte layer included Water-milfoil (*Myriophyllum gracile*), Freshwater Eelweed (*Vallisneria nana*), Clasped Pondweed (*Potamogeton perfoliatus*) and the submerged exotic species Elodea (*Elodea canadensis*).

Noxious weed species observed onsite were Cat's Claw Creeper (*Dolichandra unguis-cati*), a class 3 noxious weed; and Lantana (*Lantana camara*) and Fireweed (*Senecio madagascariensis*), both class 4 noxious weeds. In addition to those already mentioned, other weed species present included Slender Celery (*Cyclospermum leptophyllum*) and Mouse-ear Chickweed (*Cerastium glomeratum*).

Summary: WARB1 was a highly disturbed system of regrowth forest with mixed native and exotic species throughout all structural layers, in a predominantly cleared, partially forested landscape. The surrounding rural landuse was predominantly agricultural grazing land. Significant remnant stands of vegetation lie 1.2km northwest in private property and 5.5km to the northwest of WARB1 in Gads Sugarloaf Nature Reserve. WARB1 scored well for Cover, moderately for Habitat, Native Species and Debris and poorly for Management subindices (Table 3.89), retaining representative elements of the remnant vegetation community in all structural layers. Riparian condition at WARB1 was impacted by poor habitat connectivity and the presence of weed and noxious weed species, particularly in the midstory and understory layers. Reduced quantities of large woody debris, inadequate riparian fencing and animal impact all contributed to the reduction in riparian grade at this site.

Management Recommendations: Riparian condition could be improved through the control and removal of weed and noxious weed species, particularly throughout the midstory and understory layers. Completed riparian fencing should exclude livestock and allow for woody debris accumulation and midstory and understory native species recovery.

Plate 3.67 *Riparian vegetation at WARB1 was of low disturbance. Riparian condition would be improved through control and removal of weed and noxious weed species specifically Cat's Claw Creeper* (Dolichandra unguis-cati) *and Lantana* (Lantana camara), *and by fencing off the riparian zone.*

Table 3.89 *Site-level summary of riparian condition of Warbro Brook #1 showing the scores of individual indicators and the five subindices that comprise the Vegetation Condition Index.*

WARB1	Scores
HABITAT	**13.5/20**
Channel width	3
Proximity	1
Continuity	3
Layers	3
Large native trees	1.5
Hollow-bearing trees	2
NATIVE SPECIES	**10.5/20**
Native canopy species	3
Native midstory species	1.5
Native herb/forb species	1
Native graminoid species	3
Native macrophyte species	2
SPECIES COVER	**16/20**
Canopy species	2
Midstory species	2
Herb/forb species	4
Graminoid species	4
Macrophyte species	4
DEBRIS	**10/20**
Total leaf litter	3
Native leaf litter	2
Dead trees standing	0
Dead trees fallen	0
Lying logs	1
Fringing vegetation	4
MANAGEMENT	**9.5/20**
Tree clearing	2
Fencing	1
Animal impact	2
Species of interest	0
Exposed tree roots	3.5
Native woody regeneration	1
Weedy woody regeneration	0
TOTAL	**59.5/100**

3.4.6.3 Water quality

Warbro Book received a score of 44 (F) for water quality. Figures 3.16 and 3.17 show the key physicochemical and nutrient variables used in the assessment of water quality for the freshwater tributaries. Ranges and means for these variables are given in Table 3.90 and the exceedances are given in Table 3.79.

pH exceeded the upper ANZECC lowland freshwater trigger value on 4 sampling occasions (Table 3.79). The site maximum pH was 8.95 (Table 3.90). Turbidity at WARB1 remained below the ANZECC lowland freshwater guideline for the duration of the sampling period (Figure 3.16d). DO% consistently fell below the minimum ANZECC trigger threshold (4 sampling occasions), with a site minimum of 43% (Tables 3.79, 3.90).

Concentrations of total nutrients were consistently high at WARB1, with TN concentrations exceeding the ANZECC lowland freshwater trigger value on 5 sampling occasions (Table 3.79). The site maximum TN concentration was 3.9 times the trigger value (Table 3.90). TP concentrations exceeded the ANZECC lowland freshwater trigger value less frequently (3 sampling occasions, Table 3.79). The site maximum TP concentration was 1.8 times the trigger value (Table 3.90).

Concentrations of dissolved nutrients followed the same temporal pattern of exceedances at WARB1. NOx concentrations exceeded the ANZECC lowland freshwater trigger value on 5 sampling occasions (Table 3.79). The site maximum NOx concentration was 11 times the trigger value (Table 3.90). SRP concentrations exceeded the ANZECC lowland freshwater trigger value on 3 sampling occasions (Table 3.79). The site maximum SRP concentration was 2.6 times the trigger value (Table 3.90).

High nutrient concentrations did not lead to high algal productivity in Warbro Brook during the sampling period as chlorophylla *a* concentrations remained well below the ANZECC trigger value.

Table 3.90 *Minimums, maximums and means of measured water quality variables for Warbro Brook.*

	WARB1		
Variable	**Min**	**Max**	**Mean**
Temperature (°C)	11.15	25.50	19.10
pH	7.53	8.95	8.12
EC (mS/cm)	0.30	0.39	0.34
Salinity (PPT)	0.14	0.19	0.16
DO (mg/L)	3.36	8.79	6.24
DO (%)	43.20	97.10	72.63
Turbidity (NTU)	0.30	22.70	8.90
Max Depth	0.30	0.60	0.41
Chla (µg/L)	0.00	1.07	0.35
TSS (mg/L)	0.86	6.35	2.32
TN (µg/L)	285.71	1940.7	916.64
TP (µg/L)	19.36	88.25	48.73
NOx (µg/L)	4.18	435.81	176.09
SRP (µg/L)	1.51	51.88	19.48

3.4.6.4 Aquatic macroinvertebrates

WARB1 recorded 1884 and 489 individual macroinvertebrates across 40 and 36 macroinvertebrate families during the 2015 autumn and spring sampling, respectively (Table 3.91). The reduced abundance and diversity of macroinvertebrates observed in spring may have been due to the extreme low flows occurring at the time of spring sampling. In autumn, abundance was dominated by Baetid Mayflies (775 individuals) and richness was co-dominated by Trichoptera (Caddisflies) and Coleoptera (Aquatic Beetles), both with 9 families. In contrast, Atyid Shrimp were the most abundant family in spring (87 individuals), and the most diverse order in spring remained Coleoptera with 10 families. There were a number of rare taxa at the site, with 11 and 20 taxa recording fewer than 5 individuals in autumn and spring, respectively.

Mean SIGNAL2 scores for WARB1 were similar between autumn (5.2) than spring (5.0), and the ranges of SIGNAL2 scores was similar between seasons.

WARB1 received an overall Ecohealth score of 64, a grade of C-, for aquatic macroinvertebrate community condition. Only EPT score was slightly below the catchment average for the Macleay, with all other macroinvertebrate indicators at or above the catchment average (Table 3.13). The macroinvertebrate indicators suggest the water quality and habitat conditions in the lower reaches of Warbro Brook are in moderate condition, and are able to support a diversity of macroinvertebrate fauna given the wide range of SIGNAL2 scores.

Table 3.91 *Summary of aquatic macroinvertebrate data for Warbro Brook.*

	WARB1	
Macroinvertebrate indicator	**Autumn 2015**	**Spring 2015**
Total abundance	1884	489
Family richness	40	36
EPT abundance	274	101
EPT richness	10	9
Mean SIGNAL2 score	5.2	5.0
SIGNAL2 score range	1 - 9	1 - 8
Ecohealth score (grade)	**64 (C-)**	

3.4.7 Toorumbee Creek (TOOC3, TOOC2 and TOOC1)

3.4.7.1 Geomorphic condition

The geomorphic River Style at Toorumbee Creek #3 (TOOC3) is partially confined valley setting: planform controlled, low sinuosity, gravel. The bed sediments comprised angular cobbles with gravel in a framework dilated matrix containing 32-60% fine sediments. Banks comprised fine sediments with gravel. There was significant erosion on the left bank with severe (20-100m) undercutting and significant (10-20m) slumping. There was significant erosion on the right bank with severe (20-100m) undercutting and severe (20-100m) slumping. Cattle trampling the fine grained bank sediments are most likely the primary cause of bank erosion with flood erosion a secondary cause. Geomorphic complexity was moderate, with the site comprising a riffle – glide sequence (riffle 5% and glide 95% of reach length). TOOC3 scored 60, a D+ for BANK CONDITION and 68, a C, for BED CONDITION. The overall geomorphic condition for TOOC3 was 64, a grade of C-.

The geomorphic River Style at Toorumbee Creek #2 (TOOC2) is partially confined valley setting: planform controlled, low sinuosity, gravel. The bed sediments comprised subangular cobbles in an open framework containing <5% fine sediments. Banks comprised gravel with significant fine sediments. There was significant erosion on the left bank with severe (20-100m) undercutting and significant (10-20m) slumping. There was minor erosion on the right bank with minor (<5m) undercutting and no slumping. Geomorphic complexity was moderate, with the site comprising a riffle - pool sequence (riffle 10%, run 70% and pool 20% of reach length). TOOC2 scored 61, a C- for BANK CONDITION and 77, a B-, for BED CONDITION. The overall geomorphic condition for TOOC2 was 69, a grade of C.

The geomorphic River Style at Toorumbee Creek #1 (TOOC1) is partially confined valley setting: planform controlled, meandering, gravel. The bed sediments comprised rounded cobbles with gravel in a framework dilated matrix containing 32-60% fine sediments. This site was severely impacted by a low causeway with a partially blocked pipe close to the right bank. This causeway prevented downstream gravel movement and formed a weir at low flows (Plate 3.50). Upstream of the causeway, unconsolidated and highly mobile sediment deposits smother the channel. Downstream of the causeway, surface flow is restricted to higher flows. A small flood scoured the streambed downstream of the causeway with the streambed becoming highly armoured. Banks comprised gravel with fine sediments. There was minor erosion on the left bank with no undercutting and moderate (5-10m) slumping. There was moderate erosion on the right bank with moderate (5-10m) undercutting immediately downstream of the causeway and significant (10-20m) slumping. Geomorphic complexity was poor and highly disturbed, with the site comprising a riffle 10%, pool 30% and backwater 60% of reach length). TOOC1 scored 41, an F for BANK CONDITION and 34, an F, for BED CONDITION. The overall geomorphic condition for TOOC1 was 37, a grade of F.

Summary and recommendations: TOOC3 and TOOC2 were assessed as being in moderate geomorphic condition, with bank erosion the most significant issue for site-level geomorphic condition. TOOC1 was assessed as being in very poor geomorphic condition, with the low, blocked causeway severing longitudinal connectivity of sediment, water, solutes (e.g. nutrients) and biota (e.g. fish). Replacing this causeway is the singlemost important means of improving the aquatic health at this site. The desktop GIS assessment of subcatchment geomorphic condition found the Toorumbee Creek subcatchment to be in good condition with a grade of B. The geomorphic condition at TOOC3, TOOC2 and TOOC1 are below the subcatchment average.

3.4.7.2 Riparian condition

TOOC3

The original riparian vegetation community at TOOC3 (Plate 3.68) was described as 'River Oak forest and woodland wetland of the NSW South Western Slopes and South Eastern Highlands Bioregion', plant community type ID 85 (VIS, 2012), broadly classed as 'Eastern Riverine Forests' (Keith, 2004). TOOC3 received a low riparian condition score of 58, a grade of D+ (Table 3.92).

The dominant canopy species present were River Oak (*Casuarina cunninghamiana* subsp. *cunninghamiana*), White Cedar (*Melia azedarach*) and Watergum (*Tristaniopsis laurina*). Dominant native midstory species included Weeping Bottlebrush (*Callistemon viminalis*), White Sally Wattle (*Acacia floribunda*) and Ironwood (*Backhousia myrtifolia*), along with the exotic species Lantana (*Lantana camara*) and Arsenic Bush (*Senna septemtrionalis*). The understory was dominated by native species Soft Lomandra (*Lomandra hystrix*), Knotweeds (*Persicaria decipiens* and *P.hydropiper*), Scurvy Weed (*Commelina cyanea*), Stinging Nettle (*Urtica incisa*), Leafy Panic (*Urochloa foliosa*), Hairy Panic (*Panicum effusum*), Couch (*Cynodon dactylon*), along with exotic species Purpletop (*Verbena bonariensis*), Sidratusa (*Sida rhombifolia*), Spear Thistle (*Cirsium vulgare*) and Paspalum species (*Paspalum longifolium*). Vine species included the native species Cockspur Thorn (*Maclura cochinchinensis*) and Silkpod (*Parsonsia straminea*), while the macrophye layer included Triangular Club Rush (*Schoenoplectiella mucronata*), Clasped Pondweed (*Potomogeton perfoliatus*) and Water Primrose (*Ludwigia peploides*).

Two noxious weed species were observed onsite, Lantana (*Lantana camara*) and Fireweed (*Senecio madagascariensis*), both class 4 noxious weeds. In addition to those already mentioned, other weed species present included Rough Lemon (*Citrus x taitensis*), Senna (*Senna floribunda*), Narrow-leaved Vetch (*Gomphocarpus fruiticosus*) and Pigeon Grass (*Setaria* sp.).

Summary: TOOC3 was a highly disturbed system of closed mixed-aged forest with a remnant canopy and mixed native and exotic species throughout the midstory and understory layers, in a predominantly forested, partially cleared landscape. The surrounding rural landuse was a mixture of agricultural grazing land and National Park. Significant remnant stands of vegetation in Willi Willi National Park surround TOOC3, 1.5km to the North, 500m to the East, 600m to the South and 700m to the West of the site. TOOC3 scored well for Cover, moderately for Habitat, Native Species and Debris and poorly for Management subindices (Table 3.92), and retained representative elements of the remnant vegetation community in all structural layers. Riparian condition at TOOC3 was impacted by the absence of habitat trees and large woody debris. Low macrophyte presence, inadequate riparian fencing and animal impact all contributed to the reduction in riparian grade at this site.

Management Recommendations: Riparian condition could be improved through the control and removal of weed and noxious weed species, particularly throughout the midstory and understory layers. The introduction of large woody debris back into this system using best practice techniques could stabilise river banks in the long term, promote niche habitats for native woody regeneration, provide habitat for native animal species, and as instream snags, can redirect or reduce water energy from banks, reducing bank erosion. Riparian fencing should exclude livestock, allow understory recovery and could be used in combination with native plantings to increase riparian vegetation width and continuity.

Plate 3.68 *Riparian vegetation at TOOC3 was highly disturbed. Riparian condition would be improved through control and removal of weed and noxious weed species such as Lantana* (Lantana camara)*, undertaking native plantings, introducing woody debris and by fencing off the riparian zone.*

Table 3.92 *Site-level summary of riparian condition of Toorumbee Creek #3 showing the scores of individual indicators and the five subindices that comprise the Vegetation Condition Index.*

TOOC3	Scores
HABITAT	**11.5/20**
Channel width	2
Proximity	2
Continuity	2
Layers	4
Large native trees	1.5
Hollow-bearing trees	0
NATIVE SPECIES	**13/20**
Native canopy species	4
Native midstory species	3
Native herb/forb species	2
Native graminoid species	3
Native macrophyte species	1
SPECIES COVER	**15/20**
Canopy species	3
Midstory species	4
Herb/forb species	3
Graminoid species	4
Macrophyte species	1
DEBRIS	**12/20**
Total leaf litter	2
Native leaf litter	3
Dead trees standing	1
Dead trees fallen	1
Lying logs	3
Fringing vegetation	2
MANAGEMENT	**6.5/20**
Tree clearing	2
Fencing	0
Animal impact	0.5
Species of interest	0
Exposed tree roots	3
Native woody regeneration	1
Weedy woody regeneration	0
TOTAL	**58/100**

TOOC2

The original riparian vegetation community at TOOC2 (Plate 3.69) was described as 'River Oak riparian woodland of the NSW North Coast Bioregion and northern Sydney Basin', plant community type ID 1106 (VIS, 2012), broadly classed as 'Eastern Riverine Forests' (Keith, 2004), grading into Weeping Lilly Pilly - WaterGum riparian rainforest of the southern NSW North Coast Bioregion, plant community type ID 1294 (VIS, 2012), broadly classed as 'Dry Rainforest' (Keith, 2004). TOOC2 received a good riparian condition score of 73.6, a grade of C+ (Table 3.93).

The dominant canopy species present were River Oak (*Casuarina cunninghamiana* subsp. *cunninghamiana*), Forest Red Gum (*Eucalyptus tereticornis*), White Cedar (*Melia azedarach*) and Watergum (*Tristaniopsis laurina*). Dominant native midstory species included Weeping Bottlebrush (*Callistemon viminalis*), White Sally Wattle (*Acacia floribunda*), Sandpaper Fig (*Ficus coronata*), Cheese Tree (*Glochidion fernandi*) and Ironwood (*Backhousia myrtifolia*), along with the exotic species Lantana (*Lantana camara*) and Wild Tobacco (*Solanum mauritianum*). The understory was dominated by native species Soft Lomandra (*Lomandra hystrix*), Knotweeds (*Persicaria decipiens* and *P.hydropiper*), Lesser Joyweed (*Altenanthera denticulata*), Common Rush (*Juncus usitatus*), Couch (*Cynodon dactylon*), Australian Basket Grass (*Oplismenus aemulus*), along with exotic species Purpletop (*Verbena bonariensis*), Sidratusa (*Sida rhombifolia*), Fleabane (*Conyza bonariensis*), Spear Thistle (*Cirsium vulgare*), Cobblers Pegs (*Bidens pilosa*), Japanese Lionstail (*Leonurus japonicus*), Panic Veldtgrass (*Ehrharta erecta*) and Paspalum species (*Paspalum orbiculare* and *P.mandiocanum*). Vine species included the native species Kangaroo and Water Vines (*Cissus antarctica* and *C.hypoglauca*), while the limited macrophye layer included Hastings River Reed (*Potamophila parviflora*), Elodea (*Elodea canadensis*) and Triangular Club Rush (*Schoenoplectiella mucronata*).

One noxious weed species was observed onsite, Lantana (*Lantana camara*), a class 4 noxious weed. In addition to those already mentioned, other weed species present included Arsenic Bush (*Senna septemtrionalis*), Blue Billy Goat Weed (*Ageratum houstonianum*), Slender Celery (*Cyclospermum leptophyllum*), Black-berry Nightshade (*Solanum nigrum*) and Prickly Sowthistle (*Sonchus asper*).

Summary: TOOC2 was a mildly disturbed system of closed mixed-aged forest with a remnant canopy and mixed native and exotic species throughout the midstory and understory layers, in a predominantly forested, partially cleared landscape. The surrounding rural landuse was a mixture of agricultural grazing land and National Park. Significant remnant stands of vegetation lay in Boonanghi Nature Reserve 1km to the south and southeast and Willi Willi National Park 1.5km to the southwest. TOOC2 scored well for Habitat and Cover, and moderately for Native Species, Debris and Management subindices (Table 3.93), retaining representative elements of the remnant vegetation community in all structural layers. Riparian condition at TOOC2 was impacted by the presence and regeneration of noxious weed species, specifically Lantana (*Lantana camara*) throughout the midstory structural layer. Low macrophyte diversity and cover, low standing and lying woody debris values all contributed to the reduction in riparian grade at this site.

Management Recommendations: Riparian condition could be improved through the control and removal of weed and noxious weed species, particularly throughout the midstory layer, allowing for native woody regeneration. The introduction of large woody debris back into this system using best practice techniques could stabilise river banks in the long term, promote niche habitats for native woody regeneration, provide habitat for native animal species, and as instream snags, can redirect or reduce water energy from banks, reducing bank erosion.

Plate 3.69 *Riparian vegetation at TOOC2 was mildly disturbed. Riparian condition would be improved through control and removal of weed and noxious weed species such as Lantana* (Lantana camara), *and through the introduction of woody debris.*

Table 3.93 *Site-level summary of riparian condition of Toorumbee Creek #2 showing the scores of individual indicators and the five subindices that comprise the Vegetation Condition Index.*

TOOC2	Scores
HABITAT	**17/20**
Channel width	2
Proximity	3
Continuity	4
Layers	4
Large native trees	2
Hollow-bearing trees	2
NATIVE SPECIES	**12.6/20**
Native canopy species	4
Native midstory species	2.6
Native herb/forb species	3
Native graminoid species	3
Native macrophyte species	1
SPECIES COVER	**18/20**
Canopy species	4
Midstory species	4
Herb/forb species	4
Graminoid species	4
Macrophyte species	1
DEBRIS	**14/20**
Total leaf litter	3
Native leaf litter	2
Dead trees standing	1
Dead trees fallen	1
Lying logs	3
Fringing vegetation	4
MANAGEMENT	**12/20**
Tree clearing	3
Fencing	2
Animal impact	2
Species of interest	0
Exposed tree roots	3
Native woody regeneration	2
Weedy woody regeneration	0
TOTAL	**73.6/100**

TOOC1

The original riparian vegetation community at TOOC1 (Plate 3.70) was described as 'River Oak riparian woodland, eastern NSW', community 71 (Keith, 2004), or 'River Oak riparian woodland of the NSW North Coast Bioregion and northern Sydney Basin', plant community type ID 1106 (VIS, 2012), broadly classed as 'Eastern Riverine Forests', (Keith, 2004). TOOC1 received a low riparian condition score of 59.2, a grade of D+ (Table 3.94).

The dominant canopy species present were River Oak (*Casuarina cunninghamiana* subsp. *cunninghamiana*), Forest Red Gum (*Eucalyptus tereticornis*) and Camphor Laurel (*Cinnamomum camphora*). Dominant native midstory species included Weeping Bottlebrush (*Callistemon viminalis*), White Sally Wattle (*Acacia floribunda*), Sandpaper Fig (*Ficus coronata*) and Ironwood (*Backhousia myrtifolia*), along with the exotic species Narrow-leaved Vetch (*Gomphocarpus fruiticosus*), Lantana (*Lantana camara*) and Wild Tobacco (*Solanum mauritianum*). The understory was dominated by native species Soft Lomandra (*Lomandra hystrix*), Knotweeds (*Persicaria decipiens* and *P.hydropiper*), Couch (*Cynodon dactylon*), Australian Basket Grass (*Oplismenus aemulus*) and Rice Grass (*Microlaena stipoides*), along with exotic species Purpletop (*Verbena bonariensis*), Sidratusa (*Sida rhombifolia*), Fleabane (*Conyza bonariensis*), Spear Thistle (*Cirsium vulgare*), Cobblers Pegs (*Bidens pilosa*), Paspalum species (*Paspalum dilatatum* and *P.mandiocanum*) and Prairie Grass (*Bromus catharticus*). Vine species included the native species Cockspur Thorn (*Maclura cochinchinensis*) and Silkpod (*Parsonsia straminea*), and the exotic species White Passionfruit (*Passiflora subpeltata*) and Climbing Nightshade (*Solanum seaforthianum*). The macrophyte layer included Triangular Club Rush (*Schoenoplectiella mucronata*), Varied Water Milfoil (*Myriophyllum variifolium*), and the submerged exotic species Elodea (*Elodea canadensis*).

Noxious weed species observed onsite were Camphor Laurel (*Cinnamomum camphora*), Lantana (*Lantana camara*), Crofton Weed (*Ageratina adenophora*) and Fireweed (*Senecio madagascariensis*), all class 4 noxious weeds; and Mexican Poppy (*Argemone mexicana*), a class 5 noxious weed. In addition to those already mentioned, other weed species present included Arsenic Bush (*Senna septemtrionalis*), Clover species (*Trifolium* spp.), Cat's Ear (*Hypochaeris radicata*), Wandering Jew (*Tradescantia fluminensis*), Blue Billy Goat Weed (*Ageratum houstonianum*), Buffalo Grass (*Stenotaphrum secundatum*) and Pigeon Grass (*Settaria* sp.).

Summary: TOOC1 was a highly disturbed system of mixed-aged forest with a predominantly remnant canopy and mixed native and exotic species throughout the midstory and understory layers, in a partially cleared, partially forested landscape. The surrounding rural landuse was a mixture of agricultural grazing land, river quarry excavation and private reserve. Significant remnant stands of vegetation lie 5km to the northeast of TOOC1 in Collombatti State Forest, 10km to the northwest in Gads Sugarloaf Nature Reserve, and 7km to the south in Boonanghi Nature Reserve. Despite representative elements of the remnant vegetation community present in all structural layers, TOOC1 only scored well in one subindex, Debris. TOOC1 scored moderately for Cover, Native Species and Habitat, and poorly for Management subindices (Table 3.94). Disrupted vegetation width, poor habitat connectivity, the presence of weed and noxious weed species, particularly in the mid- and understory layers, inadequate riparian fencing and animal impact all contributed to the reduction in riparian grade at this site.

Management Recommendations: Riparian condition could be improved through the control and removal of weed and noxious weed species, particularly throughout the understory layer. Riparian fencing should exclude livestock and allow understory recovery.

Plate 3.70 *Riparian vegetation at TOOC1 was highly disturbed. Riparian condition would be improved through control and removal of weed and noxious weed species such as Camphor Laurel* (Cinnamomum camphora)*, Lantana* (Lantana camara)*, Crofton Weed* (Ageratina adenophora) *and by fencing off the riparian zone.*

Table 3.94 *Site-level summary of riparian condition of Toorumbee Creek #1 showing the scores of individual indicators and the five subindices that comprise the Vegetation Condition Index.*

TOOC1	Scores
HABITAT	**11.7/20**
Channel width	0.7
Proximity	1
Continuity	2.5
Layers	4
Large native trees	1.5
Hollow-bearing trees	2
NATIVE SPECIES	**11.5/20**
Native canopy species	3.5
Native midstory species	3
Native herb/forb species	1
Native graminoid species	2
Native macrophyte species	2
SPECIES COVER	**13.5/20**
Canopy species	2
Midstory species	4
Herb/forb species	3.5
Graminoid species	3
Macrophyte species	1
DEBRIS	**15.5/20**
Total leaf litter	3
Native leaf litter	3
Dead trees standing	1
Dead trees fallen	3
Lying logs	3
Fringing vegetation	2.5
MANAGEMENT	**7/20**
Tree clearing	3
Fencing	1
Animal impact	0
Species of interest	0
Exposed tree roots	1
Native woody regeneration	2
Weedy woody regeneration	0
TOTAL	**59.2/100**

3.4.7.3 Water quality

Toorumbee Creek received a score of 64 (C-) for water quality. TOOC2 (mid reach) received a score of 76 (B-), TOOC1 (lower reach) received a score of 65 (C-) and TOOC3 (upper reach) received a score of 52 (D). Figures 3.16 and 3.17 show the key physicochemical and nutrient variables used in the assessment of water quality for the freshwater tributaries. Ranges and means for these variables are given in Table 3.95 and the exceedances are given in Table 3.79.

pH exceeded the upper ANZECC upland freshwater trigger value on 5 sampling occasions at TOOC3, and the lowland freshwater trigger value on 1 and 3 sampling occasions at TOOC2 and TOOC1, respectively (Table 3.79). Site maximums are given in Table 3.95. Turbidity in Toorumbee Creek remained below the ANZECC trigger values for the duration of the sampling period (Figure 3.16d). DO% fell below the minimum ANZECC trigger threshold on 3 sampling occasions at TOOC2 and TOOC1 and on 2 sampling occasions at TOOC3. Site minimum DO% were 51%, 50% and 50% at TOOC3, TOOC2 and TOOC1, respectively (Table 3.95). DO% exceeded the maximum ANZECC trigger value once at TOOC2 and TOOC3 (February 2016), and twice at TOOC1 (June 2015 and February 2016). Site maximum DO% were 119%, 122% and 161% at TOOC3, TOOC2 and TOOC1, respectively. Peak DO% did not coincide with high algal productivity at TOOC2 or TOOC3, but was clearly caused by a nuisance algal bloom at TOOC1 (Plate 3.50). This resulted in chlorophyll *a* exceeding the ANZECC trigger value once, with a site maximum concentration 1.6 times the trigger value (Table 3.95).

There were no clear longitudinal trends in TN concentrations along Toorumbee Creek, but both TP and SRP increased longitudinally downstream (Figure 3.17). TN concentrations exceeded the ANZECC upland freshwater trigger value on 5 sampling occasions at TOOC3, and the ANZECC lowland freshwater trigger value on 3 and 4 sampling occasions at TOOC2 and TOOC1, respectively (Table 3.79). Site maximum TN concentrations were 2.8, 2.9 and 3.8 times the trigger values at TOOC3, TOOC2 and TOOC1, respectively (Table 3.95). TP concentrations exceeded the ANZECC upland freshwater trigger value on all sampling occasions at TOOC3, and the ANZECC lowland freshwater trigger value once at TOOC2 and TOOC1 (Table 3.79). The site minimum TP concentration at TOOC1 was 1.1 times the trigger value (Table 3.95). Site maximum TP concentrations were 2.8, 1.3 and 1.6 times the trigger values at TOOC3, TOOC2 and TOOC1, respectively (Table 3.95).

NOx concentrations exceeded the ANZECC upland freshwater trigger value of 25µg/L on 3 sampling occasions at TOOC3 and the ANZECC lowland freshwater trigger value of 40µg/L on 4 and 3 sampling occasions at TOOC2 and TOOC1, respectively (Table 3.79). Site maximum NOx concentrations were 15, 14 and 14 times the trigger values at TOOC3, TOOC2 and TOOC1, respectively (Table 3.95). SRP concentrations exceeded the upland ANZECC freshwater trigger value of 15µg/L on 3 sampling occasions at TOOC3, and the ANZECC lowland freshwater trigger value of 20µg/L on 3 sampling occasions at TOOC1 (Table 3.79). Site maximum SRP concentrations were 7.4 and 1.11 times the trigger values at TOOC3 and TOOC1, respectively (Table 3.95).

Reducing dissolved nutrients by fencing riparian zones to exclude direct stock access combined with replanting native vegetation may help reduce high algal productivity over the long term in Toorumbee Creek. However, the most important management strategy to improve water quality in Toorumbee Creek would be to replace the low causeway on Dowlings Falls Road to ensure longitudinal connectivity of streamflow. This causeway functions as a barrier to flow during low flows, preventing the downstream movement of water, sediment, biota and nutrients. It is likely to be a barrier to fish movement as well.

***Table 3.95** Minimums, maximums and means of measured water quality variables for Toorumbee Creek.*

	TOOC1			TOOC2			TOOC3		
Variable	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**
Temperature (°C)	14.77	28.32	21.61	12.03	27.89	20.17	12.33	29.05	21.00
pH	7.59	9.27	8.14	7.05	9.24	7.92	7.32	9.07	7.98
EC (mS/cm)	0.10	0.11	0.11	0.07	0.11	0.08	0.00	0.08	0.06
Salinity (PPT)	0.05	0.06	0.05	0.04	0.05	0.04	0.01	0.05	0.04
DO (mg/L)	3.22	12.58	7.70	3.82	9.60	7.10	3.68	9.16	7.29
DO (%)	41.90	161.00	94.12	50.40	121.90	84.80	50.70	119.10	87.87
Turbidity (NTU)	3.70	9.10	7.33	3.60	12.00	6.47	3.50	10.00	5.82
Max Depth	0.25	0.30	0.27	0.30	0.60	0.40	0.20	0.50	0.33
Chla (µg/L)	0.21	6.41	1.92	0.04	0.96	0.42	0.07	0.31	0.16
TSS (mg/L)	0.61	13.56	6.49	0.29	1.79	0.83	0.10	3.85	1.37
TN (µg/L)	57.14	1898.3	746.73	57.14	1474.5	559.87	114.29	1411.0	815.04
TP (µg/L)	15.65	79.71	38.35	8.67	68.15	29.03	22.06	140.80	63.25
NOx (µg/L)	4.18	570.95	157.86	4.18	570.95	158.52	4.18	604.73	148.89
SRP (µg/L)	2.69	22.20	16.39	0.48	16.21	9.18	2.90	45.34	17.21

3.4.7.4 Aquatic macroinvertebrates

TOOC3 recorded 509 and 1107 individual macroinvertebrates across 36 and 37 macroinvertebrate families during the 2015 autumn and spring sampling, respectively (Table 3.96). In autumn, abundance was dominated by Baetid Mayflies (120 individuals) and richness was dominated by Ephemeroptera (Mayflies, with 7 families). In contrast, Leptophlebiid Mayflies were the most abundant family in spring (415 individuals), and the most diverse order in spring was Trichoptera (Caddisflies) with 10 families. There were a number of rare taxa at the site, with 17 and 16 taxa recording fewer than 5 individuals in autumn and spring, respectively.

Mean SIGNAL2 scores for TOOC3 were higher in spring (6.6) than autumn (5.7), and the range of SIGNAL2 scores was also higher in autumn than spring. The spring biota with high SIGNAL2 scores were Calocid and Helicophid Caddisflies (with SIGNAL2 of 9 and 10, respectively).

TOOC3 received an overall Ecohealth score of 70, a grade of C, for aquatic macroinvertebrate community condition. All macroinvertebrate indicators were above the Macleay catchment average, particularly total abundance and SIGNAL2 (Table 3.13). The macroinvertebrate indicators suggest the water quality and habitat conditions in upper reaches of Toorumbee Creek are in moderate condition, and are able to support a diversity of macroinvertebrate fauna given the wide range of SIGNAL2 scores.

TOOC2 recorded 989 and 651 individual macroinvertebrates across 39 and 38 macroinvertebrate families during the 2015 autumn and spring sampling, respectively (Table 3.96). In autumn, abundance was dominated by Simuliids (Black Flies, 230 individuals) and richness was dominated by Trichoptera (Caddisflies, with 11 families). In contrast, Philopotamid Caddisflies were the most abundant family in spring (212 individuals), and the most diverse order in spring remained Trichoptera (Caddisflies) with 10 families. There were a number of rare taxa at the site, with 16 and 17 taxa recording fewer than 5 individuals in autumn and spring, respectively.

Mean SIGNAL2 scores for TOOC2 were higher in spring (6.9) than autumn (6.1), reflecting the differences in ranges of SIGNAL2 scores between autumn and spring. The decrease in the mean SIGNAL2 at TOOC2 in spring was due to the loss of Helicophid Caddisflies with a SIGNAL2 of 10.

TOOC2 received an overall Ecohealth score of 73, a grade of C+, for aquatic macroinvertebrate community condition. All macroinvertebrate indicators were above the Macleay catchment average, particularly total abundance and SIGNAL2 (Table 3.13). The macroinvertebrate indicators suggest the water quality and habitat conditions in the mid reaches of Toorumbee Creek are in moderate condition, and are able to support a diversity of macroinvertebrate fauna given the wide range of SIGNAL2 scores.

TOOC1 recorded 1602 and 694 individual macroinvertebrates across 32 and 34 macroinvertebrate families during the 2015 autumn and spring sampling, respectively (Table 3.96). In autumn, abundance was dominated by Leptophlebiid Mayflies (725 individuals) and richness was dominated by Trichoptera (Caddisflies, with 9 families). Similarly in spring, Leptophlebidd Mayflies were the most abundant family (138 individuals), and the most diverse order in spring remained Trichoptera

(Caddisflies) with 10 families. There were a number of rare taxa at the site, with 11 and 17 taxa recording fewer than 5 individuals in autumn and spring, respectively.

Mean SIGNAL2 scores for TOOC1 were higher in autumn (6.7) than spring (5.3), reflecting the differences in ranges of SIGNAL2 scores between autumn and spring. The decrease in the mean SIGNAL2 at TOOC1 in spring was due to the loss of Calocid Caddisflies with a SIGNAL2 of 9.

TOOC1 received an overall Ecohealth score of 71, a grade of C+, for aquatic macroinvertebrate community condition. All macroinvertebrate indicators were above the Macleay catchment average, particularly EPT score and SIGNAL2 score (Table 3.13). The macroinvertebrate indicators suggest the water quality and habitat conditions in the lower reaches of Toorumbee Creek are in moderate condition, and are able to support a diversity of macroinvertebrate fauna given the wide range of SIGNAL2 scores.

Table 3.96 *Summary of aquatic macroinvertebrate data for Toorumbee Creek.*

	TOOC3		TOOC2		TOOC1	
Macroinvertebrate indicator	**Autumn 2015**	**Spring 2015**	**Autumn 2015**	**Spring 2015**	**Autumn 2015**	**Spring 2015**
Total abundance	509	1107	989	651	1602	694
Family richness	36	37	39	38	32	34
EPT abundance	159	669	334	397	838	370
EPT richness	14	14	16	13	12	10
Mean SIGNAL2 score	5.7	6.6	6.1	6.9	6.7	5.3
SIGNAL2 score range	2 - 10	2 - 9	1 - 10	2 - 9	2 - 9	1 - 8
Ecohealth score (grade)	**70 (C)**		**73 (C+)**		**71 (C+)**	

3.4.8 Hickeys Creek (HICC1)

3.4.8.1 Geomorphic condition

The geomorphic River Style at Hickeys Creek #1 (HICC1) is partially confined valley setting: planform controlled, meandering, fine grained. The bed sediments comprised fine sediments. There was no bed erosion in the site reach. Banks comprised fine sediments. There was moderate erosion on the left bank with minor (<5m) undercutting and significant (10-20m) slumping. There was minor erosion on the right bank with moderate (5-10m) undercutting and minor (<5m) slumping. Geomorphic complexity was moderate, with the site comprising a pool – riffle sequence (riffle 15%, run 35%, pool 40% and backwater 10% of reach length). HICC1 scored 65, a C- for BANK CONDITION and 76, a B-, for BED CONDITION. The overall geomorphic condition for HICC1 was 70, a grade of C+.

In summary, HICC1 was assessed as being in moderate geomorphic condition, with erosion of the left bank the most significant issue for site-level geomorphic condition. The desktop GIS assessment of subcatchment geomorphic condition found the Hickeys Creek subcatchment to be in moderate condition with a grade of C. The geomorphic condition at HICC1 was slightly above the subcatchment average.

3.4.8.2 Riparian condition

The original riparian vegetation community at HICC1 (Plate 3.71) was described as 'River Oak forest and woodland wetland of the NSW South Western Slopes and South Eastern Highlands Bioregion', plant community type ID 85 (VIS, 2012), broadly classed as 'Eastern Riverine Forests' (Keith, 2004), grading into 'Black Bean - Weeping Lilly Pilly - Water Gum riparian rainforest of the NSW North Coast Bioregion' plant community type ID 669 (VIS, 2012) , broadly classed as 'Dry Rainforest' (Keith, 2004), a recognized TEC (VIS, 2012). HICC1 received a moderate riparian condition score of 64.7, a grade of C- (Table 3.97).

The dominant canopy species present were River Oak (*Casuarina cunninghamiana* subsp. *cunninghamiana*) and Red Kamala (*Mallotus philippensis*). Dominant native midstory species included Lilly Pilly (*Acmena smithii*), Cheese Tree (*Glochidion fernandi*), Weeping Bottlebrush (*Callistemon viminalis*) and Sandpaper Fig (*Ficus coronata*), along with the exotic species Small-leaved Privet (*Ligustrum sinense*), Lantana (*Lantana camara*) and Wild Tobacco (*Solanum mauritianum*). The understory was dominated by native species Soft Lomandra (*Lomandra hystrix*), Gristle Fern (*Blechnum cartilagineum*), Knotweeds (*Persicaria decipiens* and *P.hydropiper*), Couch (*Cynodon dactylon*), Creeping Beard Grass (*Oplismenus imbicillis*) and Rice Grass (*Microlaena stipoides*), along with exotic species Crofton Weed (*Ageratina adenophora*), Wandering Jew (*Tradescantia fluminensis*), and Paspalum species (*Paspalum dilatatum* and *P.mandiocanum*). Native vine species present were Kangaroo Vine (*Cissus antarctica*), Silkpod (*Parsonsia straminea*) and Sweet Sarsaparilla (*Smilax glyciphylla*), while the macrophyte layer included Water Primrose (*Ludwigia peploides*), Blunt Pondweed (*Potomogeton ochreatus*) and Swamp Lily (*Ottelia ovalifolia*).

Noxious weed species observed onsite were Lantana (*Lantana camara*), Small-leaved Privet (*Ligustrum sinense*), and Fireweed (*Senecio madagascariensis*), all class 4 noxious weeds. In addition to those already mentioned, other weed species present included Rough Lemon (*Citrus x taitensis*) and Blue Billy Goat Weed (*Ageratum houstonianum*).

Summary: HICC1 was a moderately disturbed system of mixed-aged closed forest with a remnant canopy and mixed native and exotic species throughout the midstory and understory layers, in a predominantly cleared, partially forested landscape. The surrounding rural landuse was predominantly agricultural grazing land. Significant remnant stands of vegetation lie 2 km to the east-northeast in Collombatti State Forest. HICC1 scored well for Native Species and Cover, moderately for Habitat and Debris and poorly for Management subindices (Table 3.97) and retained representative elements of the remnant vegetation community in all structural layers. Riparian condition at HICC1 was impacted by poor habitat connectivity and the presence and regeneration of weed and noxious weed species, particularly in the midstory and understory structural layers. Reduced woody debris, inadequate riparian fencing and animal impact also contributed to the reduction in riparian grade at this site.

Management Recommendations: Riparian condition could be improved through the control and removal of weed and noxious weed species, particularly throughout the midstory and understory layers. Riparian fencing should exclude livestock, and allow for midstory and understory native species recovery and woody debris accumulation over time.

***Plate 3.71** Riparian vegetation at HICC1 was moderately disturbed. Riparian condition would be improved through control and removal of weed and noxious weed species such as Lantana* (Lantana camara)*, Small-leaved Privet* (Ligustrum sinense)*, and by fencing off the riparian zone.*

***Table 3.97** Site-level summary of riparian condition of Hickeys Creek #1 showing the scores of individual indicators and the five subindices that comprise the Vegetation Condition Index.*

HICC1	Scores
HABITAT	**14.2/20**
Channel width	2.7
Proximity	1
Continuity	3
Layers	4
Large native trees	1.5
Hollow-bearing trees	2
NATIVE SPECIES	**15/20**
Native canopy species	4
Native midstory species	2
Native herb/forb species	2
Native graminoid species	3
Native macrophyte species	4
SPECIES COVER	**15/20**
Canopy species	3
Midstory species	3
Herb/forb species	3
Graminoid species	4
Macrophyte species	2
DEBRIS	**11/20**
Total leaf litter	2
Native leaf litter	3
Dead trees standing	1
Dead trees fallen	2
Lying logs	1
Fringing vegetation	2
MANAGEMENT	**9.5/20**
Tree clearing	2.5
Fencing	0
Animal impact	0
Species of interest	1
Exposed tree roots	3
Native woody regeneration	2
Weedy woody regeneration	1
TOTAL	**64.7/20**

3.4.8.3 Water quality

Hickeys Creek received a score of 57 (D+) for water quality. Figures 3.16 and 3.17 show the key physicochemical and nutrient variables used in the assessment of water quality for the freshwater tributaries. Ranges and means for these variables are given in Table 3.98 and the exceedances are given in Table 3.79.

pH exceeded the upper ANZECC lowland freshwater trigger value once, in December 2015 (Table 3.79). The site maximum pH was 8.12. Electrical conductivity (a measure of the dissolved ions in water, including salts) at HICC1 exceeded the upper ANZECC lowland freshwater trigger value of 0.20mS/cm on all sampling occasions (Table 3.79). Only Collomombatti Creek had the same frequency of exceedance across the Macleay catchment. Turbidity at HICC1 remained below the ANZECC lowland freshwater guideline for the duration of the sampling period (Figure 3.16d). DO% was consistently below the minimum ANZECC trigger threshold (5 sampling occasions), with a site minimum of 36% (Tables 3.79, 3.98).

With the exception of dissolved nitrogen, exceedances of ANZECC nutrient guidelines were relatively infrequent. Total nutrient concentrations exceeded the ANZECC lowland freshwater trigger value twice, in August 2015 and February 2016 (Table 3.79). The site maximum TN concentration was 3.5 times the trigger value and the site maximum TP concentration was 1.8 times the trigger value (Table 3.98).

NOx concentrations exceeded the ANZECC lowland freshwater trigger value on all sampling occasions (Table 3.79). The site minimum NOx concentration was 3.8 times the trigger value while the site maximum NOx concentration was 14 times the trigger value (Table 3.98). SRP concentrations exceeded the ANZECC lowland freshwater trigger value once, in August 2015 (Table 3.79). The site maximum SRP concentration was 2.5 times the trigger value (Table 3.98).

Exceedances in nutrient concentrations did not lead to high algal productivity in Hickeys Creek during the sampling period as chlorophylla *a* concentrations remained well below the ANZECC trigger value.

Table 3.98 *Minimums, maximums and means of measured water quality variables for Hickeys and Mungay Creeks.*

	HICC1			MUNC1		
Variable	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**
Temperature (°C)	11.98	23.64	18.40	12.04	21.91	17.80
pH	6.98	8.12	7.65	6.38	8.70	7.33
EC (mS/cm)	0.23	0.32	0.29	0.00	0.28	0.18
Salinity (PPT)	0.11	0.15	0.14	0.01	0.13	0.09
DO (mg/L)	2.81	8.02	5.02	1.36	4.08	2.56
DO (%)	36.00	85.70	56.80	12.04	21.91	17.80
Turbidity (NTU)	8.30	18.50	12.48	15.40	51.90	28.75
Max Depth	0.30	0.50	0.40	10.10	42.60	22.82
Chla (µg/L)	8.30	18.50	12.48	0.27	1.21	0.58
TSS (mg/L)	0.06	1.65	0.82	0.49	13.67	6.04
TN (µg/L)	209.76	1754.2	778.77	122.88	1427.9	477.66
TP (µg/L)	18.98	91.83	43.92	30.05	706.58	200.96
NOx (µg/L)	153.32	578.29	244.67	14.61	233.11	107.86
SRP (µg/L)	10.41	50.39	18.58	2.90	44.60	22.12

3.4.8.4 Aquatic macroinvertebrates

HICC1 recorded 607 and 344 individual macroinvertebrates across 33 and 32 macroinvertebrate families during the 2015 autumn and spring sampling, respectively (Table 3.99). In autumn, abundance was dominated by Chironomid Midges (128 individuals) and richness was dominated by Coleoptera (Aquatic Beetles, with 10 families). Similarly, Chironomid Midges were the most abundant family in spring (140 individuals), and the most diverse order in spring remained Coleoptera with 8 families. There were a number of rare taxa at the site, with 13 and 18 taxa recording fewer than 5 individuals in autumn and spring, respectively.

Mean SIGNAL2 scores for HICC1 were the same across autumn and spring (4.6), as were the range of SIGNAL2 scores.

HICC1 received an overall Ecohealth score of 46, a grade of D-, for aquatic macroinvertebrate community condition. While total abundance at HICC1 was above the Macleay catchment average, all other indicators were below the catchment average, particularly family richness (Table 3.13). The macroinvertebrate indicators suggest the water quality and habitat conditions in the lower reaches of Hickeys Creek are in poor condition, but are able to support a diversity of macroinvertebrate fauna given the wide range of SIGNAL2 scores.

Table 3.99 *Summary of aquatic macroinvertebrate data for the Oaky and Styx Rivers.*

	HICC1		MUNC1	
Macroinvertebrate indicator	**Autumn 2015**	**Spring 2015**	**Autumn 2015**	**Spring 2015**
Total abundance	607	344	511	482
Family richness	33	32	21	15
EPT abundance	168	88	69	14
EPT richness	7	12	5	2
Mean SIGNAL2 score	4.6	4.6	3.1	4.6
SIGNAL2 score range	1 - 8	1 - 8	1 - 8	2 - 8
Ecohealth score (grade)	**46 (D-)**		**25 (F)**	

3.4.9 Mungay Creek

3.4.9.1 Geomorphic condition

The geomorphic River Style at Mungay Creek #1 (MUNC1) is partially confined valley setting: planform controlled, meandering, fine grained. The bed sediments comprised rounded cobbles and gravel in a matrix filled contact framework with 5-32% fine sediments. There was no bed erosion in the site reach. Banks comprised fine sediments. There was significant erosion on the left bank with severe (20-100m) undercutting and moderate (5-10m) slumping. There was significant erosion on the right bank with severe (20-100m) undercutting and moderate (5-10m) slumping. Bank erosion was consistently above the low flow channel suggesting it was occurred during flooding. Geomorphic complexity was moderate, with the site comprising a pool – riffle sequence (riffle 20%, glide 30%, run 30% and pool 20% of reach length). MUNC1 scored 54, a D for BANK CONDITION and 68, a C, for BED CONDITION. The overall geomorphic condition for MUNC1 was 61, a grade of C-.

In summary, MUNC1 was assessed as being in moderate geomorphic condition, with bank erosion the most significant issue for site-level geomorphic condition. The desktop GIS assessment of subcatchment geomorphic condition found the Mungay Creek subcatchment to be in moderate condition with a grade of C+. The geomorphic condition at MUNC1 was slightly below the subcatchment average.

3.4.9.2 Riparian condition

The original riparian vegetation community at MUNC1 (Plate 3.72) was described as 'Flooded Gum - Brush Box moist forest of the coastal ranges of the North Coast', plant community type ID 827 (VIS, 2012), broadly classed as 'North Coast Wet Sclerophyll Forests' (Keith, 2004), grading into 'Black Bean - Weeping Lilly Pilly - Water Gum riparian rainforest of the NSW North Coast Bioregion' plant community type ID 669 (VIS, 2012), broadly classed as 'Dry Rainforest' (Keith, 2004), a recognized TEC (VIS, 2012). MUNC1 received a very good riparian condition score of 81, a grade of B (Table 3.100).

The dominant canopy species present were Flooded Gum (*Eucalyptus grandis*), Red Mahogany (*Eucalyptus resinifera*), Spotted Gum (*Corymbia maculata*), Red Ash (*Alphitonia excelsa*), Rough-leaved Elm (*Aphananthe philippinensis*), Water Gum (*Tristaniopsis laurina*) and Thick-leaved Laurel (*Cryptocarya meisneriana*). Dominant native midstory species included Lilly Pilly (*Acmena smithii*), Sandpaper Fig (*Ficus coronata*), Cheese Tree (*Glochidion fernandi*), Orange Thorn (*Pittosporum multiflorum*), Native Rosella (*Hibiscus heterophyllus*) and Narrow-leaved Palm Lily (*Cordyline stricta*), along with the exotic species Lantana (*Lantana camara*). The understory was dominated by native species Soft Lomandra (*Lomandra hystrix*), Common Bracken (*Pteridium esculentum*), Wild Violet (*Viola banksii*), Scurvy Weed (*Commelina cyanea*), Tassel Sedge (*Carex fascicularis*), Couch (*Cynodon dactylon*), Australian Basket Grass (*Oplismenus aemulus*), and Blady Grass (*Imperata cylindrica*), along with the exotic species Paspalum (*Paspalum dilatatum*) and Pigeon Grass (*Setaria* sp.). While the macrophyte layer was absent at MUNC1, native vine species were abundant with the dominant species being Silkpod (*Parsonsia straminea*), Kangaroo Vine (*Cissus antarctica*), Sweet Morinda (*Morinda jasminoides*), Wonga Wonga Vine (*Pandorea pandorana*) and Snake Vine (*Stephania japonica*).

The one noxious weed species observed onsite was Lantana (*Lantana camara*), a class 4 noxious weed. In addition to those already mentioned, other weed species present included Rhodes Grass (*Chloris gayana*), Prickly Sowthistle (*Sonchus asper*) and Slender Celery (*Cyclospermum leptophyllum*).

Summary: MUNC1 was a low disturbance system of mixed-aged closed forest with a remnant canopy and mixed native and exotic species throughout the midstory and understory layers, in a partially cleared, partially forested landscape. The surrounding rural landuse was a mixture of agricultural grazing land, Nature Reserve and State Forest. Significant remnant stands of vegetation lie 1.2km to the southeast in Skillion Nature Reserve and 1km northeast in private land, beyond which is Collombatti State Forest. MUNC1 received full marks for Habitat and Cover, scored well for Native Species and moderately for Debris and Management subindices (Table 3.100), retaining representative elements of the remnant vegetation community in all structural layers. Riparian condition at MUNC1 was impacted by the presence and regeneration of weed and noxious weed species, particularly Lantana (*Lantana camara*). Limited large woody debris, inadequate riparian fencing and animal impact also contributed to the reduction in riparian grade at this site.

Management Recommendations: Riparian condition could be improved through the control and removal of weed and noxious weed species, particularly throughout the midstory and understory layers. Completed riparian fencing should exclude livestock and allow for woody debris accumulation and midstory and understory native species recovery.

Plate 3.72 *Riparian vegetation at MUNC1 was of low disturbance. Riparian condition would be improved through control and removal of weed and noxious weed species specifically Lantana* (Lantana camara) *and fencing off the riparian zone.*

Table 3.100 *Site-level summary of riparian condition of Mungay Creek #1 showing the scores of individual indicators and the five subindices that comprise the Vegetation Condition Index.*

MUNC1	**Scores**
HABITAT	**20/20**
Channel width	4
Proximity	4
Continuity	4
Layers	4
Large native trees	2
Hollow-bearing trees	2
NATIVE SPECIES	**15/20**
Native canopy species	4
Native midstory species	2
Native herb/forb species	2
Native graminoid species	3
Native macrophyte species	4
SPECIES COVER	**20/20**
Canopy species	4
Midstory species	4
Herb/forb species	4
Graminoid species	4
Macrophyte species	4
DEBRIS	**14/20**
Total leaf litter	3
Native leaf litter	3
Dead trees standing	2
Dead trees fallen	1
Lying logs	2
Fringing vegetation	3
MANAGEMENT	**12/20**
Tree clearing	3
Fencing	1
Animal impact	1
Species of interest	1
Exposed tree roots	3
Native woody regeneration	2
Weedy woody regeneration	1
TOTAL	**81/100**

3.4.9.3 Water quality

Mungay Creek received a score of 52 (D) for water quality. Figures 3.16 and 3.17 show the key physicochemical and nutrient variables used in the assessment of water quality for the freshwater tributaries. Ranges and means for these variables are given in Table 3.98 and the exceedances are given in Table 3.79.

pH exceeded the upper ANZECC lowland freshwater trigger value once (December 2015) and fell below the minimum ANZECC lowland freshwater trigger value once (August 2015) (Table 3.79). The site minimum pH was 6.38 while the site maximum pH was 8.7 (Table 3.98). MUNC1 was the only site that recorded pH more acidic (lower) than the ANZECC guidelines during the sampling period. Turbidity at MUNC1 remained below the ANZECC lowland freshwater guideline for the duration of the sampling period (Figure 3.16d). DO% consistently fell below the minimum ANZECC trigger threshold (5 sampling occasions) with a site minimum of 15% (Tables 3.79, 3.98). This is the lowest site minimum DO% recorded across the Macleay catchment. This DO% is at the concentration that would severely impact aquatic fauna.

TN concentrations exceeded the ANZECC lowland freshwater trigger value on 2 sampling occasions (Table 3.79). The site maximum TN concentration was 2.9 times the trigger value (Table 3.98). TP concentrations exceeded the ANZECC lowland freshwater trigger value on 4 sampling occasions (Table 3.79). The site maximum TP concentration was 14 times the trigger value (Table 3.98).

Dissolved nutrient concentrations exceeded the ANZECC lowland freshwater trigger value on 3 sampling occasions (Table 3.79). The site maximum NOx concentration was 5.8 times the trigger value (Table 3.98). The site maximum SRP concentration was 2.2 times the trigger value (Table 3.98).

High nutrient concentrations did not lead to high algal productivity in Mungay Creek during the sampling period as chlorophylla *a* concentrations remained well below the ANZECC trigger value (Figure 3.16c). Further investigation is recommended to identify the source of TP in Mungay Creek. TP concentrations persistently exceeded the ANZECC trigger value, and the exceedances were by high magnitudes (up to 14 times the value). Nonetheless, very high total P did not result in very high dissolved P or high algal productivity in Mungay Creek during the sampling period.

3.4.9.4 Aquatic macroinvertebrates

MUNC1 recorded 511 and 482 individual macroinvertebrates across 21 and 15 macroinvertebrate families during the 2015 autumn and spring sampling, respectively (Table 3.99). In autumn, abundance was dominated by Veliidae (Small Water Striders, 129 individuals) and Chironomid Midges (128 individuals). Richness was co-dominated by Coleoptera (Aquatic Beatles) and Diptera (Flies, Midges and Mosquitos), both with 4 families. Chironomid Midges were the most abundant family in spring (113 individuals), and the most diverse order in spring remained Coleoptera with 5 families. There were a number of rare taxa at the site, with 8 and 9 taxa recording fewer than 5 individuals in autumn and spring, respectively.

Mean SIGNAL2 scores for MUNC1 were lower in spring (4.6) than autumn (5.6), although the range of SIGNAL2 scores was similar between seasons. The decrease in the mean SIGNAL2 at MUNC1 in spring was due to lower abundances of high-scoring Leptophlebiid Mayflies with SIGNAL2 scores of 8 observed in spring, likely due to extreme low flows leading up to spring sampling.

MUNC1 received an overall Ecohealth score of 23, a grade of F, for aquatic macroinvertebrate community condition. This is the third-lowest site score for macroinvertebrate health in the Macleay catchment. All macroinvertebrate indicators were well below the Macleay catchment average (Table 3.13). The macroinvertebrate indicators suggest the water quality and habitat conditions in the lower reaches of Mungay Creek are in very poor condition, but are able to support a diversity of macroinvertebrate fauna given the wide range of SIGNAL2 scores.

3.4.10 Dungay Creek (DUNC3, DUNC2 and DUNC1)

3.4.10.1 Geomorphic condition

The geomorphic River Style at Dungay Creek #3 (DUNC3) is confined valley setting: gorge. The bed sediments comprised subangular cobbles in an open framework containing <5% fine sediments. No bed erosion was observed in the site reach. Banks comprised gravel and there was no bank erosion observed in the site reach. Geomorphic complexity was good, with the site comprising a pool – riffle sequence (riffle 50%, run 25% and pool 25% of reach length). DUNC3 scored 82, a B for BANK CONDITION and 86, a B+, for BED CONDITION. The overall geomorphic condition for DUNC3 was 84, a grade of B.

The geomorphic River Style at Dungay Creek #2 (DUNC2) is partially confined valley setting: planform controlled, low sinuosity, gravel. The bed sediments comprised rounded cobbles in a matrix filled contact framework containing 5-32% fine sediments. No bed erosion was observed in the site reach. Banks comprised cobbles with fine sediments. There was severe erosion on the left bank with severe (20-100m) undercutting and moderate (5-10m) slumping. There was severe erosion on the right bank with severe (20-100m) undercutting and severe (20-100m) slumping. Geomorphic complexity was good, with the site comprising a pool – riffle sequence (riffle 20%, run 50% and pool 30% of reach length). DUNC2 scored 48, a D- for BANK CONDITION and 68, a C, for BED CONDITION. The overall geomorphic condition for DUNC2 was 58, a grade of D+.

The geomorphic River Style at Dungay Creek #1 (DUNC1) is partially confined valley setting: planform controlled, low sinuosity, gravel. The bed sediments comprised rounded cobbles with gravel in a matrix filled contact framework containing 5-32% fine sediments. No bed erosion was observed in the site reach. Banks comprised gravel with fine sediments. There was minor erosion on the left bank with no undercutting and minor (<5m) slumping. There was minor erosion on the right bank with no undercutting and minor (<5m) slumping. Geomorphic complexity was poor, with the site comprising a run (run 100% of reach length). DUNC1 scored 77, a B- for BANK CONDITION and 68, a C, for BED CONDITION. The overall geomorphic condition for DUNC1 was 72, a grade of C+.

In summary, DUNC3 was assessed as being in good geomorphic condition. DUNC2 was assessed as being in poor geomorphic condition, with bank erosion the most significant issue for site-level geomorphic condition. DUNC1 was assessed as being in moderate geomorphic condition. The desktop GIS assessment of subcatchment geomorphic condition found the Dungay Creek subcatchment to be in good condition with a grade of B+. The geomorphic condition at DUNC3 was representative of the subcatchment average while DUNC2 and DUNC1 were below the subcatchment average.

3.4.10.2 Riparian condition

DUNC3

The original riparian vegetation community at DUNC3 (Plate 3.73) was described as ‘River Oak forest and woodland wetland of the NSW South Western Slopes and South Eastern Highlands Bioregion’, plant community type ID 85 (VIS, 2012), grading into ‘Black Bean - Weeping Lilly Pilly - Water Gum riparian rainforest of the NSW North Coast Bioregion’ plant community type ID 669 (VIS, 2012), broadly classed as ‘Dry Rainforest’ (Keith, 2004), a recognized TEC (VIS, 2012). DUNC3 received a good riparian condition score of 73.2, a grade of C+ (Table 3.101).

The dominant canopy species present were River Oak (*Casuarina cunninghamiana* subsp. *cunninghamiana*), Water Gum (*Tristaniopsis laurina*), White Cedar (*Melia azedarach*), Forest red gum (*Eucalyptus tereticornis*) and Red Kamala (*Mallotus philippensis*). Dominant native midstory species included Lilly Pilly (*Acmena smithii*), Sandpaper Fig (*Ficus coronata*), Weeping Bottlebrush (*Callistemon viminalis*), Silver Weeping Tea Tree (*Leptospermum brachyandrum*), Ironwood (*Backhousia myrtifolia*) and Cheese Tree (*Glochidion fernandi*), along with the exotic species Lantana (*Lantana camara*) and Arsenic Bush (*Senna septemtrionalis*). The understory was dominated by native species Soft Lomandra (*Lomandra hystrix*), Common Rush (*Juncus usitatus*), Knotweeds (*Persicaria* spp.), Common Maidenhair (*Adiantum aethiopicum*), Gristle Fern (*Blechnum cartilagineum*), Couch (*Cynodon dactylon*), Australian Basket Grass (*Oplismenus aemulus*), and Blady Grass (*Imperata cylindrica*), along with exotic species Sidratusa (*Sida rhombifolia*), Fireweed (*Senecio madagascariensis*), Umbrella Sedge (*Cyperus eragrostis*) and Pigeon Grass (*Setaria* sp.). Native vine species were Cockspur Thorn (*Maclura cochinchinensis*), Silkpod (*Parsonsia straminea*) and Kangaroo Vine (*Cissus antarctica*), while the macrophyte layer comprised Hastings River Reed (*Potamophila parviflora*), Water-milfoil (*Myriophyllum gracile*).

Noxious weed species observed onsite were Lantana (*Lantana camara*) and Fireweed (*Senecio madagascariensis*), both class 4 noxious weeds. In addition to those already mentioned, other weed species present included Coblers Pegs (*Bidens pilosa*), Mouse-ear Chickweed (*Cerastium glomeratum*) and Scarlet Pimpernel (*Anagallis arvensis*).

Summary: DUNC3 was a mildly disturbed system of mixed-aged closed forest with a remnant canopy and mixed native and exotic species throughout the midstory and understory layers, in a predominantly forested, partially cleared landscape. The surrounding rural landuse was a mixture of agricultural grazing land and State Forest. Significant remnant stands of vegetation lie 1.2km to the north in Boonanghi State Forest and 2.5km to the south in Yessabah State Forest. DUNC3 scored well for Habitat and Cover, and moderately for Native Species, Debris and Management subindices (Table 3.101), retaining representative elements of the remnant vegetation community in all structural layers. Riparian condition at DUNC3 was impacted by the presence and regeneration of weed and noxious weed species particularly in the midstory and understory structural layers. Limited habitat trees, large woody debris and inadequate riparian fencing and animal impact also contributed to the reduction in riparian grade at this site.

Management Recommendations: Obvious attempts at removing sections of Lantana had recently been made. Riparian condition could be improved through the control and removal of weed and noxious weed species, particularly throughout the midstory and understory layers. Riparian fencing should exclude livestock and allow for midstory and understory native species recovery and woody debris accumulation.

Plate 3.73 *Riparian vegetation at DUNC3 was mildly disturbed. Riparian condition would be improved through control and removal of weed and noxious weed species specifically Lantana* (Lantana camara) *and by fencing off the riparian zone.*

Table 3.101 *Site-level summary of riparian condition of Dungay Creek #3 showing the scores of individual indicators and the five subindices that comprise the Vegetation Condition Index.*

DUNC3	Scores
HABITAT	**15.7/20**
Channel width	2.7
Proximity	3
Continuity	3
Layers	4
Large native trees	2
Hollow-bearing trees	1
NATIVE SPECIES	**14.5/20**
Native canopy species	4
Native midstory species	2
Native herb/forb species	1.5
Native graminoid species	3
Native macrophyte species	4
SPECIES COVER	**18/20**
Canopy species	3
Midstory species	4
Herb/forb species	4
Graminoid species	4
Macrophyte species	3
DEBRIS	**12/20**
Total leaf litter	3
Native leaf litter	2
Dead trees standing	1
Dead trees fallen	1
Lying logs	2
Fringing vegetation	3
MANAGEMENT	**13/20**
Tree clearing	3
Fencing	1
Animal impact	1
Species of interest	3
Exposed tree roots	3
Native woody regeneration	2
Weedy woody regeneration	0
TOTAL	**73.2/100**

DUNC2

The original riparian vegetation community at DUNC2 (Plate 3.74) was described as 'River Oak forest and woodland wetland of the NSW South Western Slopes and South Eastern Highlands Bioregion', plant community type ID 85 (VIS, 2012), broadly classed as 'Eastern Riverine Forests' (Keith, 2004), grading into 'Black Bean - Weeping Lilly Pilly - Water Gum riparian rainforest of the NSW North Coast Bioregion' plant community type ID 669 (VIS, 2012), broadly classed as 'Dry Rainforest' (Keith, 2004). DUNC2 received a moderate riparian condition score of 65.4, a grade of C (Table 3.102).

The dominant canopy species present were River Oak (*Casuarina cunninghamiana* subsp. *cunninghamiana*), Silky Oak (*Grevillea robusta*), Water Gum (*Tristaniopsis laurina*), White Cedar (*Melia azedarach*), Forest Red Gum (*Eucalyptus tereticornis*) and the exotic species Willow (*Salix* sp.). Dominant native midstory species included Lilly Pilly (*Acmena smithii*), Sandpaper Fig (*Ficus coronata*), Silver Weeping Tea Tree (*Leptospermum brachyandrum*), along with the exotic species Lantana (*Lantana camara*), Small-leaved Privet (*Ligustrum sinense*) and Arsenic Bush (*Senna septemtrionalis*). The understory was dominated by native species Soft Lomandra (*Lomandra hystrix*), Common Rush (*Juncus usitatus*), Hairy Knotweed (*Persicaria strigosa*), Common Maidenhair (*Adiantum aethiopicum*), Common Bracken (*Pteridium esculentum*), Gristle Fern (*Blechnum cartilagineum*), Couch (*Cynodon dactylon*), Australian Basket Grass (*Oplismenus aemulus*) and Blady Grass (*Imperata cylindrica*), along with exotic species Sidratusa (*Sida rhombifolia*), Wandering Jew (*Tradescantia fluminensis*), Mistflower (*Ageratina riparia*), Fleabane (*Conyza bonariensis*), Pigeon Grass (*Setaria* sp.) and Broadleaf Paspalum (*Paspalum mandiocanum*). Native vine species were Cockspur Thorn (*Maclura cochinchinensis*), Silkpod (*Parsonsia straminea*), while the macrophyte layer comprised Water-milfoil species (*Myriophyllum* spp.).

Noxious weed species observed onsite were Willow (*Salix* sp.), Lantana (*Lantana camara*), Small-leaved Privet (*Ligustrum sinense*) and Fireweed (*Senecio madagascariensis*), all class 4 noxious weeds. In addition to those already mentioned, other weed species present included Spear Thistle (*Cirsium vulgare*), Slender Celery (*Cyclospermum leptophyllum*) and Scarlet Pimpernel (*Anagallis arvensis*).

Summary: DUNC2 was a moderately disturbed system of mixed-aged closed forest with mixed native and exotic species throughout all structural layers, in a partially cleared, partially forested landscape. The surrounding rural landuse was a mixture of agricultural grazing land and private forested land. Significant remnant stands of vegetation lie 3km to the north in Boonanghi State Forest and 2.8km to the south in Yessabah State Forest. DUNC2 scored well for Cover and moderately for Habitat, Native Species, Debris and Management subindices (Table 3.102), retaining representative elements of the remnant vegetation community in all structural layers. Riparian condition at DUNC2 was impacted by reduced riparian vegetation width and the presence and regeneration of weed and noxious weed species, particularly in the midstory and understory structural layers. Limited woody debris also contributed to the reduction in riparian grade at this site.

Management Recommendations: Riparian condition could be improved through the control and removal of weed and noxious weed species, particularly throughout the midstory and understory layers. Completed riparian fencing should exclude livestock and allow for woody debris accumulation and midstory and understory native species recovery.

Plate 3.74 *Riparian vegetation at DUNC2 was moderately disturbed. Riparian condition would be improved through control and removal of weed and noxious weed species such as Willow* (Salix sp.)*, Lantana* (Lantana camara)*, Small-leaved Privet* (Ligustrum sinense) *and completing riparian fencing.*

***Table 3.102** Site-level summary of riparian condition of Dungay Creek #2 showing the scores of individual indicators and the five subindices that comprise the Vegetation Condition Index.*

DUNC2	Scores
HABITAT	**14.7/20**
Channel width	1.7
Proximity	2
Continuity	3
Layers	4
Large native trees	2
Hollow-bearing trees	2
NATIVE SPECIES	**10.8/20**
Native canopy species	3
Native midstory species	1.8
Native herb/forb species	2
Native graminoid species	1
Native macrophyte species	3
SPECIES COVER	**16.5/20**
Canopy species	3.5
Midstory species	4
Herb/forb species	4
Graminoid species	4
Macrophyte species	1
DEBRIS	**13.5/20**
Total leaf litter	3
Native leaf litter	2
Dead trees standing	2.5
Dead trees fallen	1
Lying logs	2
Fringing vegetation	2.5
MANAGEMENT	**10.5/20**
Tree clearing	2.5
Fencing	2
Animal impact	2
Species of interest	0
Exposed tree roots	2
Native woody regeneration	2
Weedy woody regeneration	0
TOTAL	**65.4/100**

DUNC1

The original riparian vegetation community at DUNC1 (Plate 3.75) was described as 'River Oak forest and woodland wetland of the NSW South Western Slopes and South Eastern Highlands Bioregion', plant community type ID 85 (VIS, 2012), broadly classed as 'Eastern Riverine Forests' (Keith, 2004), grading into 'Black Bean - Weeping Lilly Pilly - Water Gum riparian rainforest of the NSW North Coast Bioregion' plant community type ID 669 (VIS, 2012), broadly classed as 'Dry Rainforest' (Keith, 2004), a recognized TEC (VIS, 2012). DUNC1 received a moderate riparian condition score of 60.5, a grade of C- (Table 3.103).

The dominant canopy species present were River Oak (*Casuarina cunninghamiana* subsp. *cunninghamiana*), Swamp Oak (*Casuarina glauca*), Silky Oak (*Grevillea robusta*), Water Gum (*Tristaniopsis laurina*), White Cedar (*Melia azedarach*) and the exotic species Camphor Laurel (*Cinamomum camphora*) and Willow (*Salix* sp.). Dominant native midstory species included Lilly Pilly (*Acmena smithii*), Sandpaper Fig (*Ficus coronata*), Silver Weeping Tea Tree (*Leptospermum brachyandrum*) and Cheese Tree (*Glochidion fernandi*), along with the exotic species Lantana (*Lantana camara*), Wild Tobacco (*Solanum mauritianum*) and Castor Oil Plant (*Ricinus communis*). The understory was dominated by native species Soft Lomandra (*Lomandra hystrix*), Common Rush (*Juncus usitatus*), Knotweeds (*Persicaria decipiens* and *P.hydropiper*), Couch (*Cynodon dactylon*), and Australian Basket Grass (*Oplismenus aemulus*), along with exotic species Purpletop (*Verbena bonariensis*), Spear Thistle (*Cirsium vulgare*), Sidratusa (*Sida rhombifolia*), Wandering Jew (*Tradescantia fluminensis*) and Broadleaf Paspalum (*Paspalum mandiocanum*). Only one vine species was present, the exotic Japanese Honeysuckle (*Lonicera japonica*), while the macrophyte layer comprised Pondweed (*Potamogeton javanicus*) and Water Couch (*Paspalum distichum*).

Noxious weed species observed onsite were Willow (*Salix* sp.), Camphor Laurel (*Cinamomum camphora*) and Lantana (*Lantana camara*), all class 4 noxious weeds; and Mexican Poppy (*Argemone mexicana*), a class 5 noxious weed. In addition to those already mentioned, other weed species present included Curled Dock (*Rumex crispus*), Coblers Pegs (*Bidens pilosa*), Umbrella Sedge (*Cyperus eragrostis*), Prairie Grass (*Bromus catharticus*) and Common Starwort (*Callitriche stagnalis*).

Summary: DUNC1 was a moderately disturbed system of mixed-aged closed forest with mixed native and exotic species throughout all structural layers, in a predominantly cleared, partially forested landscape. The surrounding rural landuse was predominantly agricultural grazing land. Significant remnant stands of vegetation lie 2.5km to the southeast in Maria State Forest, 3km to the southwest in Yessabah State Forest and 7km west in Boonanghi State Forest. DUNC1 scored well for Cover, moderately for Habitat, Debris and Management and poorly for Native Species subindices (Table 3.103), and retained representative elements of the remnant vegetation community in all structural layers. Riparian condition at DUNC1 was impacted by poor habitat connectivity, the presence and regeneration of weed and noxious weed species, particularly in the understory and macrophyte structural layers. Limited woody debris and habitat trees also contributed to the reduction in riparian grade at this site.

Management Recommendations: Riparian condition could be improved through the control and removal of weed and noxious weed species, particularly throughout the midstory and understory layers. The introduction of large woody debris back into this system using best practice techniques could stabilise river banks in the long term, promote niche habitats for native woody regeneration, provide habitat for native animal species, and as instream snags, can redirect or reduce water energy from banks, reducing bank erosion.

Plate 3.75 *Riparian vegetation at DUNC1 was moderately disturbed. Riparian condition would be improved through control and removal of weed and noxious weed species such as Camphor Laurel* (Cinamomum camphora)*, Willow* (Salix sp.) *and Lantana* (Lantana camara)*, and through the introduction of woody debris.*

Table 3.103 *Site-level summary of riparian condition of Dungay Creek #1 showing the scores of individual indicators and the five subindices that comprise the Vegetation Condition Index.*

DUNC1	Scores
HABITAT	**13/20**
Channel width	2
Proximity	1
Continuity	3
Layers	4
Large native trees	2
Hollow-bearing trees	1
NATIVE SPECIES	**7/20**
Native canopy species	3
Native midstory species	2
Native herb/forb species	0.5
Native graminoid species	0.5
Native macrophyte species	1
SPECIES COVER	**15.5/20**
Canopy species	2.5
Midstory species	4
Herb/forb species	4
Graminoid species	4
Macrophyte species	1
DEBRIS	**12.5/20**
Total leaf litter	3
Native leaf litter	3
Dead trees standing	1
Dead trees fallen	1
Lying logs	2
Fringing vegetation	2.5
MANAGEMENT	**12.5/20**
Tree clearing	2.5
Fencing	2
Animal impact	3
Species of interest	0
Exposed tree roots	3
Native woody regeneration	2
Weedy woody regeneration	0
TOTAL	**60.5/100**

3.4.10.3 Water quality

Dungay Creek received a score of 72 (C+) for water quality. DUNC3 (upper reach) received a score of 76 (B-), DUNC2 (mid reach) received a score of 72 (C+) and DUNC1 (lower reach) received a score of 67 (C). Figures 3.16 and 3.17 show the key physicochemical and nutrient variables used in the assessment of water quality for the freshwater tributaries. Ranges and means for these variables are given in Table 3.104 and the exceedances are given in Table 3.79.

pH exceeded the upper ANZECC lowland freshwater trigger value on 2 sampling occasions (November and December 2015) at all sites on Dungay Creek (Table 3.79). Turbidity in Dungay Day Creek remained below the ANZECC trigger values for the duration of the sampling period (Figure 3.16d). DO% fell below the minimum ANZECC trigger threshold on 2 sampling occasions at DUNC3, 3 sampling occasions at DUNC2 and 4 sampling occasions at DUNC1 (Table 3.79). Site minimum DO% were 57%, 60% and 57% at DUNC3, DUNC2 and DUNC1, respectively (Table 3.104).

Concentrations of TN increased longitudinally downstream Dungay Creek (Figure 3.17). TN concentrations exceeded the ANZECC lowland freshwater trigger value on 2 sampling occasions at DUNC3 and DUNC2, and 3 sampling occasions at DUNC1 (Table 3.79). Site maximum TN concentrations waere 2.7, 2.4 and 3.5 times the trigger values at DUNC3, DUNC2 and DUNC1, respectively (Table 3.104). TP concentrations exceeded the ANZECC lowland freshwater trigger value once DUNC3 and DUNC2, and twice at DUNC1 (Table 3.79). Site maximum TP concentrations were 5.2, 1.02 and 1.9 times the trigger values at DUNC3, DUNC2 and DUNC1, respectively (Table 3.104).

NOx followed a similar longitudinal pattern to TN in Dungay Creek. NOx concentrations exceeded the ANZECC lowland freshwater trigger value on 5 sampling occasions at DUNC3 and all sampling occasions at DUNC2 and DUNC1 (Table 3.79). The site minimum NOx at DUNC3 was 2.6 times the ANZECC trigger value. Site maximum NOx concentrations were 7.7, 8.5 and 5.8 times the trigger values at DUNC3, DUNC2 and DUNC1, respectively (Table 3.104). SRP exceedances were far less frequent in Dungay Creek and the magnitudes of the exceedances were also smaller. SRP concentrations exceeded the ANZECC lowland freshwater trigger value once at DUNC3 and DUNC2, but remained below the trigger value at DUNC1 (Table 3.79). Site maximum SRP concentrations were 6.8 and 1.7 times the trigger values at DUNC3 and DUNC2, respectively (Table 3.104).

High nutrient concentrations did not lead to high algal productivity at DUNC3 or DUNC2, as chlorophyll *a* concentrations at both sites remained well below the ANZECC trigger value of 4µg/L during the sampling period (Figure 3.17c). However, chorophyll *a* exceeded the trigger value once at DUNC1 (in December 2015). The site maximum concentration was 1.2 times the trigger value (Table 3.104). This coincided with peak NOx concentration at DUNC1.

Table 3.104 *Minimums, maximums and means of measured water quality variables for Dungay Creek.*

	DUNC1			DUNC2			DUNC3		
Variable	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**
Temperature (°C)	13.48	25.34	20.74	12.80	25.11	20.05	13.92	23.88	19.67
pH	6.80	8.78	7.69	6.99	8.78	7.77	7.16	8.63	7.78
EC (mS/cm)	0.06	0.18	0.13	0.11	0.22	0.14	0.10	0.14	0.12
Salinity (PPT)	0.03	0.08	0.07	0.05	0.10	0.07	0.05	0.07	0.06
DO (mg/L)	4.25	8.10	6.34	4.41	9.04	6.66	4.15	7.98	6.76
DO (%)	56.90	99.20	76.38	59.70	97.70	77.98	57.40	96.60	78.50
Turbidity (NTU)	5.50	28.40	12.17	3.80	23.70	8.10	4.50	23.00	9.07
Max Depth	0.20	0.50	0.31	0.30	0.50	0.42	0.30	0.40	0.34
Chla (µg/L)	0.19	4.63	1.61	0.15	0.94	0.35	0.05	0.77	0.32
TSS (mg/L)	0.69	48.45	14.62	0.91	8.22	3.75	0.20	4.15	2.20
TN (µg/L)	314.29	1754.24	768.85	165.25	1203.39	607.08	228.81	1330.51	570.48
TP (µg/L)	20.87	92.84	45.15	8.23	51.48	24.73	7.67	260.10	59.86
NOx (µg/L)	116.91	233.11	179.18	105.17	340.57	186.58	24.14	306.65	173.68
SRP (µg/L)	5.18	13.07	8.44	2.00	33.62	10.92	4.18	135.65	29.59

3.4.10.4 Aquatic macroinvertebrates

DUNC3 recorded 847 and 1125 individual macroinvertebrates across 31 and 23 macroinvertebrate families during the 2015 autumn and spring sampling, respectively (Table 3.105). In autumn, abundance was dominated by Baetid Mayflies (213 individuals) and richness was dominated by Trichoptera (Caddisflies) and Coleoptera (Aquatic Beetles), both with 8 families. In contrast, Philopotamid Caddisflies were the most abundant family in spring (360 individuals), and the most diverse order in spring remained Trichoptera with 8 families. There were a number of rare taxa at the site, with 15 and 9 taxa recording fewer than 5 individuals in autumn and spring, respectively.

Mean SIGNAL2 scores for DUNC3 were higher in spring (7.1) than autumn (6.6), reflecting the difference in range of SIGNAL2 scores between seasons. The increase in the mean SIGNAL2 at DUNC3 in spring was due to higher abundances of high-scoring Trichoptera (Caddisflies) with SIGNAL2 scores of 8 and 9.

DUNC3 received an overall Ecohealth score of 67, a grade of C, for aquatic macroinvertebrate community condition. Three of the four macroinvertebrate indicators were above the catchment average for the Macleay catchment, particularly SIGNAL2 score (Table 3.13). Only total abundance was below the catchment average (Table 3.13). The macroinvertebrate indicators suggest the water quality and habitat conditions in the upper reaches of Dungay Creek are in good condition, and are able to support a diversity of macroinvertebrate fauna given the wide range of SIGNAL2 scores.

DUNC2 recorded 918 and 812 individual macroinvertebrates across 23 macroinvertebrate families during the 2015 autumn and spring sampling, respectively (Table 3.105). In autumn, abundance was dominated by Hydropsychid Caddisflies (276 individuals) and richness was dominated by Trichoptera (Caddisflies) with 7 families. In contrast, Philopotamid Caddisflies were the most abundant family in spring (340 individuals), and richness was dominated by Trichoptera and Coleoptera (Aquatic Beetles), both with 6 families. There were a number of rare taxa at the site, with 9 and 11 taxa recording fewer than 5 individuals in autumn and spring, respectively.

Mean SIGNAL2 scores for DUNC2 were higher in spring (7.4) than autumn (6.9), despite similar ranges of SIGNAL2 scores between seasons. The increase in the mean SIGNAL2 at DUNC2 in spring was due to higher abundances of high-scoring Trichoptera (Caddisflies) and Ephemeroptera (Mayflies) with SIGNAL2 scores of 8.

DUNC2 received an overall Ecohealth score of 64, a grade of C-, for aquatic macroinvertebrate community condition. Three of the four macroinvertebrate indicators were below the catchment average for the Macleay catchment, particularly SIGNAL2 score (Table 3.13). Only total abundance was below the catchment average (Table 3.13). The macroinvertebrate indicators suggest the water quality and habitat conditions in the mid reaches of Dungay Creek are in good condition, and are able to support a diversity of macroinvertebrate fauna given the wide range of SIGNAL2 scores.

DUNC1 recorded 444 and 417 individual macroinvertebrates across 25 macroinvertebrate families during the 2015 autumn and spring sampling, respectively (Table 3.105). In autumn, abundance was dominated by Leptophlebiid Mayflies (126 individuals) and richness was dominated by Ephemeroptera (Mayflies), with 7 families. Similarly, Leptophlebiid Mayflies were the most abundant family in spring (140 individuals), and the most diverse order in spring remained Ephemeroptera with 7 families. There were a number of rare taxa at the site, with 16 and 13 taxa recording fewer than 5 individuals in autumn and spring, respectively.

Mean SIGNAL2 scores for DUNC1 were higher in autumn (6.6) than autumn (5.5), despite the same ranges of SIGNAL2 scores between seasons. The decrease in the mean SIGNAL2 at DUNC1 in spring was due to very low abundances of high-scoring Trichoptera (Caddisflies).

DUNC1 received an overall Ecohealth score of 47, a grade of D-, for aquatic macroinvertebrate community condition. Three of the four macroinvertebrate indicators were above the catchment average for the Macleay catchment, i.e. total abundance, family richness and EPT score (Table 3.13). The macroinvertebrate indicators suggest the water quality and habitat conditions in the lower reaches of Dungay Creek are in poor condition, although are able to support a diversity of macroinvertebrate fauna given the wide range of SIGNAL2 scores.

Table 3.105 *Summary of aquatic macroinvertebrate data for Dungay Creek.*

	DUNC3		DUNC2		DUNC1	
Macroinvertebrate indicator	**Autumn 2015**	**Spring 2015**	**Autumn 2015**	**Spring 2015**	**Autumn 2015**	**Spring 2015**
Total abundance	847	1125	918	812	444	417
Family richness	31	23	23	23	25	25
EPT abundance	475	715	623	669	311	187
EPT richness	11	8	10	8	9	8
Mean SIGNAL2 score	6.6	7.1	6.9	7.4	6.6	5.5
SIGNAL2 score range	1 - 8	3 - 9	3 - 8	2 - 8	1 - 8	1 - 8
Ecohealth score (grade)	**67 (C)**		**64 (C-)**		**47 (D-)**	

3.4.11 Collombatti Creek (COLC1)

3.4.11.1 Geomorphic condition

The geomorphic River Style at Collombatti Creek #1 (COLC1) is laterally unconfined valley setting: meandering, fine grained. The bed sediments comprised fine grained sediments. Bed erosion was not observed in the site reach. Banks comprised fine sediments. There was moderate erosion on the left bank with moderate (5-10m) undercutting and minor (<5m) slumping. There was minor erosion on the right bank with minor (<5m) undercutting and minor (<5m) slumping. Bank erosion was concentrated around the bridge (i.e. bridge scour). Geomorphic complexity was moderate, with the site comprising a run and a pool (run 30% and pool 70% of reach length). COLC1 scored 58, a D+ for BANK CONDITION and 68, a C, for BED CONDITION. The overall geomorphic condition for COLC1 was 63, a grade of C-.

In summary, COLC1 was assessed as being in moderate geomorphic condition, with bridge scour on both banks the most significant issue for site-level geomorphic condition. The desktop GIS assessment of subcatchment geomorphic condition found the Collombatti Creek subcatchment to be in moderate condition with a grade of C+. The geomorphic condition at COLC1 was slightly below the subcatchment average.

3.4.11.2 Riparian condition

The original riparian vegetation community at COLC1 (Plate 3.76) was described as ‘Paperbark swamp forest of the coastal lowlands of the NSW North Coast Bioregion and Sydney Basin Bioregion’ plant community type ID 1064 (VIS, 2012), broadly classed as ‘Coastal Swamp Wetlands’ (Keith, 2004), grading into ‘Swamp Oak swamp forest of the coastal lowlands of the NSW North Coast Bioregion’ plant community type ID 1235 (VIS, 2012), broadly classed as ‘Coastal Floodplain Wetlands’ (Keith, 2004), both of which are recognized TEC’s (VIS, 2012). COLC1 received a moderate riparian condition score of 68.7, a grade of C (Table 3.106).

The dominant canopy species present were Swamp Oak (*Casuarina glauca*), Forest Red Gum (*Eucalyptus tereticornis*), Red Ash (*Alphitonia excelsa*) and the exotic species Camphor Laurel (*Cinnamomum camphora*). Dominant native midstory species included Willow Bottlebrush (*Callistemon salignus*), Flax-leaved Paperbark (*Melaleuca linariifolia*), Prickely-leaved Tea-tree (*Melaleuca styphelioides*), Tuckeroo (*Cupaniopsis anacardioides*) and Cheese Tree (*Glochidion fernandi*), along with the exotic species Lantana (*Lantana camara*), Wild Tobacco (*Solanum mauritianum*) and Senna (*Senna pendula* var. *glabrata*). The understory was dominated by the native species Soft Lomandra (*Lomandra hystrix*), Common Rush (*Juncus usitatus*), Swamp Lily (*Crinium pedunculatum*), Knotweed species (*Persicaria decipiens*, *P.hydropiper*, *P.orientalis* and *P.strigosa*), Scurvy Weed (*Commelina cyanea*), Couch (*Cynodon dactylon*), Blady Grass (*Imperata cylindrica*) and Creeping Beard Grass (*Oplismenus imbecillis*), along with exotic species Sidratusa (*Sida rhombifolia*), Plantain (*Plantago lanceolata*), Spear Thistle (*Cirsium vulgare*), Buffalo Grass

(*Stenotaphrum secundatum*), Pigeon Grasses (*Setaria* sp.), Paspalum (*Paspalum dilatatum*) and Phalaris (*Phalaris aquatica*). Vine species present were the native species Wombat Berry (*Eustrephus latifolius*) and Silkpod (*Parsonsia straminea*). A rich macrophyte layer included Marsh Club-rush (*Bolboschoenus fluviatilis*), Water Primrose (*Ludwigia peploides*), Giant Waterlily (*Nymphaea gigantea*), Pondweed (*Potomogeton octandrus*), Water Thyme (*Hydrilla verticillata*) and Water Snowflake (*Nymphoides indica*).

Noxious weed species observed onsite were Camphor Laurel (*Cinnamomum camphora*) and Lantana (*Lantana camara*), both class 4 noxious weeds. In addition to those already mentioned, other weed species present included Silver nightshade (*Solanum* sp.), Coblers Pegs (*Bidens pilosa*), Slender Celery (*Cyclospermum leptophyllum*), Shivery Grass (*Briza minor*), Whisky Grass (*Andropogon viginicus*) and Prairie Grass (*Bromus catharticus*).

Summary: COLC1 was a moderately disturbed system of mixed-aged forest with mixed native and exotic species throughout the canopy and midstory layers and native species throughout the understory layer, in a predominantly cleared, partially forested rural landscape. The surrounding rural landuse was predominantly agricultural grazing land, private forested land and State Forest. Significant remnant stands of vegetation lie 1.2km north and 2.1km southwest of COLC1 in Tamban State Forest. COLC1 scored well for Cover and moderately for Habitat, Native Species, Debris and Management subindices (Table 3.106). Riparian condition at COLC1 was affected by reduced riparian vegetation width and continuity and poor habitat connectivity. The presence and regeneration of weed and noxious weed species particularly in the midstory and understory structural layers, reduced levels of woody debris and fringing vegetation, inadequate riparian fencing and animal impact contributed to the reduction in riparian grade at this site.

Management Recommendations: Riparian condition could be improved through the control and removal of weed and noxious weed species and by undertaking native plantings which phase-out and replace dominant canopy weed species and promote vegetation width, continuity, habitat connectivity and assist site regeneration of native species. Riparian fencing should exclude livestock, promote woody and non-woody debris accumulation and allow for canopy, midstory and understory native species recovery. If strategically implemented, riparian fencing could be used in combination with native plantings to increase riparian vegetation width, continuity and to improve proximity to intact remnant stands of vegetation.

Plate 3.76 *Riparian vegetation at COLC1 was moderately disturbed. Riparian condition would be improved through control and removal of weed and noxious weed species specifically Camphor Laurel* (Cinnamomum camphora) *and Lantana* (Lantana camara), *and by fencing off the riparian zone.*

Table 3.106 *Site-level summary of riparian condition of Collombatti Creek #1 showing the scores of individual indicators and the five subindices that comprise the Vegetation Condition Index.*

COLC1	Scores
HABITAT	**14.7/20**
Channel width	2.7
Proximity	2.5
Continuity	2.5
Layers	4
Large native trees	12
Hollow-bearing trees	1
NATIVE SPECIES	**13/20**
Native canopy species	3
Native midstory species	1.5
Native herb/forb species	2.5
Native graminoid species	2
Native macrophyte species	4
SPECIES COVER	**18/20**
Canopy species	3
Midstory species	3
Herb/forb species	4
Graminoid species	4
Macrophyte species	4
DEBRIS	**12.5/20**
Total leaf litter	3
Native leaf litter	2
Dead trees standing	0
Dead trees fallen	2
Lying logs	3
Fringing vegetation	2.5
MANAGEMENT	**10.5/20**
Tree clearing	3
Fencing	0.5
Animal impact	0
Species of interest	1
Exposed tree roots	4
Native woody regeneration	2
Weedy woody regeneration	0
TOTAL	**68.7/100**

3.4.11.3 Water quality

Collombatti Creek received a score of 48 (D-) for water quality. Figures 3.16 and 3.17 show the key physicochemical and nutrient variables used in the assessment of water quality for the freshwater tributaries. Ranges and means for these variables are given in Table 3.107 and the exceedances are given in Table 3.79.

pH exceeded the upper ANZECC lowland freshwater trigger value once, in December 2015 (Table 3.79). The site maximum pH was 8.98 (Table 3.107). Turbidity at COLC1 remained below the ANZECC lowland freshwater guideline for the duration of the sampling period (Figure 3.16d). EC exceeded the upper ANZECC lowland freshwater trigger value of 0.20mS/cm on all sampling occasions (Table 3.79). The site maximum EC was 0.59mS/cm (Table 3.107). DO% remained below the minimum ANZECC trigger threshold for the duration of the sampling period with a site minimum of 26% (Tables 3.79, 3.107). This DO% equated to 2.10mg/L which is likely to severely impact aquatic fauna.

TN concentrations exceeded the ANZECC lowland freshwater trigger value on 4 sampling occasions (Table 3.79). The site maximum TN concentration was 4.1 times the trigger value (Table 3.107). TP concentrations exceeded the ANZECC lowland freshwater trigger value on 3 sampling occasions (Table 3.79). The site maximum TP concentration was 35 times the trigger value (Table 3.107).

NOx concentrations exceeded the ANZECC lowland freshwater trigger value on all sampling occasions (Table 3.79). The site minimum NOx concentration was 3.9 times the trigger value and the site maximum NOx concentration was 7.6 times the trigger value (Table 3.107). SRP concentrations exceeded the ANZECC lowland freshwater trigger value on 2 sampling occasions (Table 3.79). The site maximum SRP concentration was 58 times the trigger value (Table 3.78).

High nutrient concentrations did not lead to high algal productivity in Collombatti Creek during the sampling period as chlorophylla *a* concentrations remained well below the ANZECC trigger value (Figure 3.16c). Further investigation is recommended to identify the source of TP in Collombatti Creek. Although TP concentrations did not persistently exceed the ANZECC trigger value, the magnitudes of the exceedances were very high (up to 35 times the trigger value). High TP concentrations generally coincided with high SRP concentrations, and the magnitude of the SRP exceedances were exceptionally high (up to 58 times the trigger value). Nonetheless, very high phosphorus concentrations did not result in high algal productivity in Collombatti Creek during the sampling period.

Table 3.107 *Minimums, maximums and means of measured water quality variables for Collombatti Creek.*

	COLC1		
Variable	**Min**	**Max**	**Mean**
Temperature (°C)	12.07	28.10	21.22
pH	6.81	8.98	7.46
EC (mS/cm)	0.23	0.59	0.37
Salinity (PPT)	0.11	0.28	0.18
DO (mg/L)	2.10	5.88	4.34
DO (%)	26.20	63.20	50.95
Turbidity (NTU)	5.00	42.70	13.42
Max Depth	0.01	0.01	0.01
Chla (µg/L)	0.40	0.60	0.56
TSS (mg/L)	0.00	2.91	1.43
TN (µg/L)	305.30	2046.6	919.71
TP (µg/L)	24.65	1764.72	326.85
NOx (µg/L)	157.27	305.29	212.07
SRP (µg/L)	9.89	1155.57	210.21

3.4.11.4 Aquatic macroinvertebrates

COLC1 recorded 80 and 509 individual macroinvertebrates across 10 and 29 macroinvertebrate families during the 2015 autumn and spring sampling, respectively (Table 3.108). COLC1 had the lowest abundance and diversity of all sites in the Macleay catchment. In autumn, abundance was dominated by Dytiscid Beetles (52 individuals) and richness was dominated by Diptera (Flies, Midges and Mosquitos), with 3 families. In contrast, Corixid Bugs (Water Boatmen) were the most abundant family in spring (208 individuals), and the most diverse order in was Trichoptera with 6 families. Family richness was significantly higher in spring than autumn, due to the additional Coleoptera, Ephemeroptera and Trichoptera (Aquatic Beatles, Mayflies and Caddisflies) families in spring. In autumn, 8 of the 10 taxa comprised fewer than 5 individuals, while in spring 15 of the 29 taxa comprised fewer than 5 individuals.

Mean SIGNAL2 scores for COLC1 were slightly higher in spring (2.7) than autumn (2.2), reflective of the increased range in SIGNAL2 scores observed in spring. The increase in the mean SIGNAL2 at COLC1 in spring was due to the additional presence of mid- and high-scoring Trichoptera (Caddisflies) with SIGNAL2 scores up to 8.

COLC1 received an overall Ecohealth score of 15, a grade of F, for aquatic macroinvertebrate community condition. This was the lowest site score for macroinvertebrate health in the Macleay catchment. All macroinvertebrate indicators were well below the Macleay catchment average, particularly EPT score and mean SIGNAL2 score (Table 3.13). The macroinvertebrate indicators suggest the water quality and habitat conditions in the lower Collombatti Creek are in very poor condition, but may be able to support a diversity of macroinvertebrate fauna given the greater range of SIGNAL2 scores observed in spring.

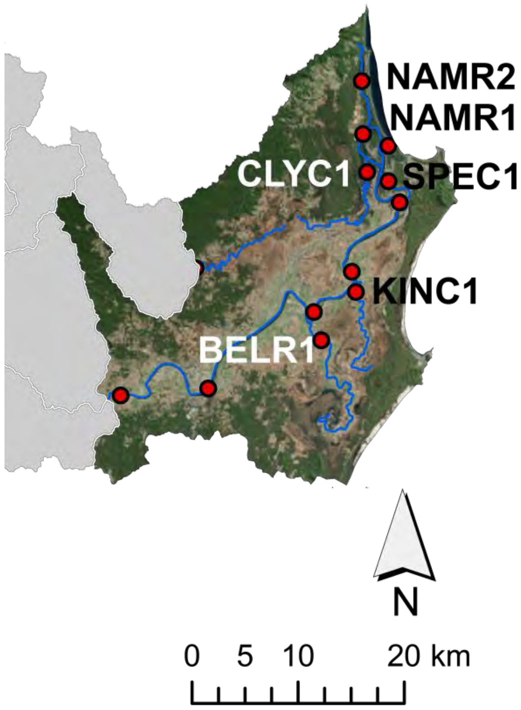
Table 3.108 *Summary of aquatic macroinvertebrate data for Collombatti Creek.*

	COLC1	
Macroinvertebrate indicator	**Autumn 2015**	**Spring 2015**
Total abundance	80	509
Family richness	10	29
EPT abundance	1	22
EPT richness	1	4
Mean SIGNAL2 score	2.2	2.7
SIGNAL2 score range	1 - 5	1 - 8
Ecohealth score (grade)	**15 (F)**	

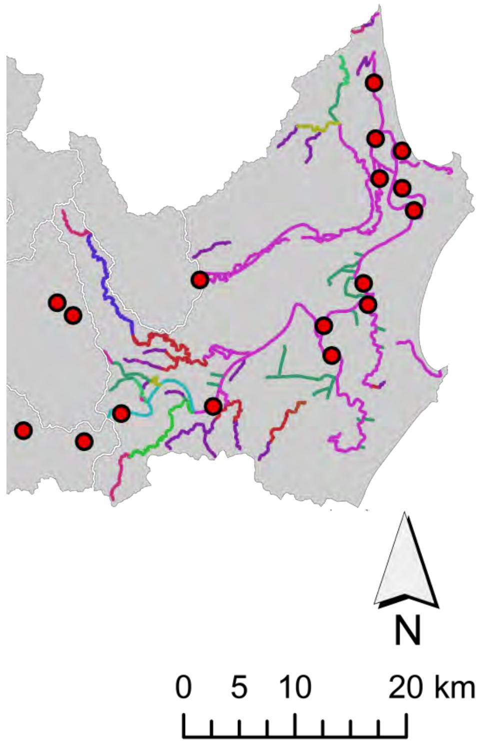
3.5 Estuarine tributaries

3.5.1 Catchment description

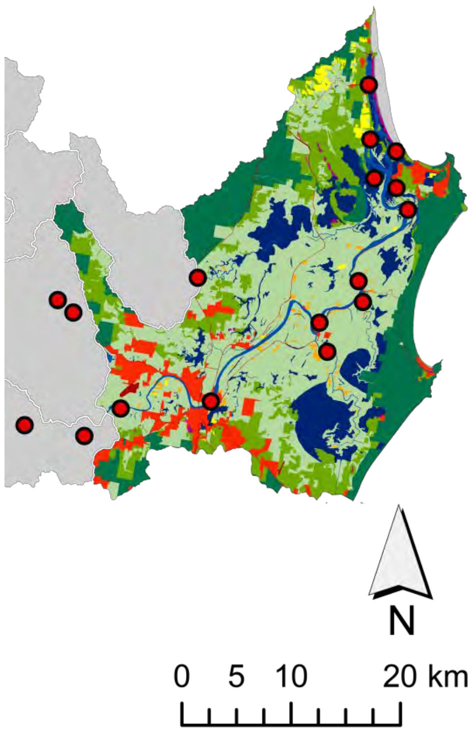
The estuarine tributaries include Belmore River, Kinchela Creek, Spencers Creek, Clybucca Creek and the North Arm of the Macleay River (Figure 3.18). These subcatchments were grouped with the coastal Macleay subcatchment in the original datafiles from NC LLS, so their characteristics (land use, soils, river styles, point-source dischargers) are included in those reported for the coastal Macleay subcatchment (Table 3.52).



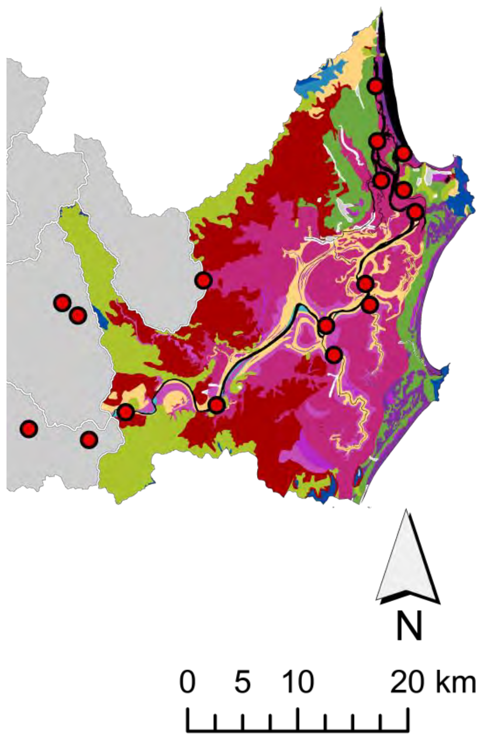
(a) Location of Ecohealth sites.



(b) River Styles: refer to Figure 2.8 for key



(c) Landuse: refer to Figure 2.7 for key



(d) Soils: refer to Figure 2.3 for key

Figure 3.18 *The Macleay estuary including the estuarine tributaries showing (a) locations of Ecohealth sites, (b) River Styles, (c) landuse, and (d) soils. Data layers from NC LLS (River Styles) and OEH (landuse and soils).*

3.5.2 Site descriptions

There were five sites located at or close to end-of-system tributaries of the Macleay River estuary (Figure 3.18). All these five sites are tidal systems with continuous channels in laterally unconfined valley settings. BELR1 on the Belmore River (Plate 3.77) is 2.5km upstream of its confluence with the Macleay estuary. BELR1 discharges 1.2km upstream of MACR4. KINC1 on Kinchela Creek (Plate 3.78) is 1.6km upstream of its confluence with the Macleay estuary. KINC1 discharges 1km upstream of MACR3. SPEC1 on Spencers Creek (Plate 3.79) is 800m upstream of its confluence with the Macleay estuary. SPEC1 discharges 2.9km upstream of MACR1. CLYC1 on Clybucca Creek (Plate 3.80) is 1.5km upstream of its confluence with the North Arm of the Macleay River. CLYC1 discharges 900m upstream of NAMR1. NAMR1 on the North Arm of the Macleay River (Plate 3.81) is 1.2km upstream of its confluence with the main stem of the Macleay estuary and discharges 1.8km upstream of MACR1. NAMR2 on the North Arm of the Macleay River (Plate 3.82) is at Stuarts Point, 8.4km upstream of NAMR1.

Plate 3.77 *Site BELR1 on the Belmore River (looking upstream).*

Plate 3.78 *Site KINC1 on Kinchela Creek (looking downstream).*

Plate 3.79 *Site SPEC1 on Spencers Creek (looking at the right bank).*

Plate 3.80 *Site CLYC1 on Clybucca Creek.*

Plate 3.81 *Site NAMR1 on the North Arm of the Macleay River (looking at the left bank).*

Plate 3.82 *Site NAMR2 on the North Arm of the Macleay River (looking at the left bank).*

3.5.3 Belmore River (BELR1)

3.5.3.1 Geomorphic condition

The River Style at Belmore River #1 (BELR1) is laterally unconfined valley setting: continuous channel, tidal. Bed and bank sediments comprised fine grained sediment. Undercutting was moderate, occurring in the intertidal zone on each bank. No slumping was observed in the site reach. BELR1 scored 70, a grade of C for BANK CONDITION. With an overall Ecohealth geomorphic condition of 70, a grade of C, BELR1 was assessed as being in moderate geomorphic condition. The desktop GIS assessment of subcatchment geomorphic condition found the Macleay estuary (including Belmore River) to be in moderate condition with a grade of C. The site-level grade for BELR1 is representative of the average subcatchment condition.

3.5.3.2 Riparian condition

High historic disturbance at BELR1 (Plate 3.83) has resulted in a highly modified riparian zone that predominantly comprises exotic species. However, the original riparian vegetation community at BELR1 could have been described as 'Swamp Oak swamp forest fringing estuaries, Sydney Basin Bioregion and South East Corner Bioregion' plant community type ID 1234 (VIS, 2012), broadly classed as 'Coastal Floodplain Wetlands' (Keith, 2004), a recognized TEC (VIS, 2012). BELR1 received a poor riparian condition score of 45, a grade of D- (Table 3.109).

The dominant canopy species present were native Swamp Oak (*Casuarina glauca*), and exotic species Camphor Laurel (*Cinnamomum camphora*), Coral Tree (*Erythrina crista-galli*), broad-leaf Privet (*Ligustrum lucidum*), and White Mulberry (*Morus alba*). Dominant native midstory species included Prickely-leaved Tea Tree (*Melaleuca styphelioides*), Cheese Tree (*Glochidion fernandi*), Sandpaper Fig (*Ficus coronata*), and Weeping Bottlebrush (*Callistemon viminalis*), along with exotic species Lantana (*Lantana camara*), Castor Oil Plant (*Ricinus communis*), Small-leaved Privet (*Ligustrum sinense*) and Wild Tobacco (*Solanum mauritianum*). The understory was dominated by the native species Swamp Lily (*Crinum pedunculatum*), Hairy Knotweed (*Persicaria strigosa*), Lesser Joyweed (*Alternanthera denticulata*), along with exotic species Sidratusa (*Sida rhombifolia*), Crofton Weed (*Ageratina adenophora*), Blue Billy Goat Weed (*Ageratum houstonianum*), Wandering Jew (*Tradescatia fluminensis*), Benghal Dayflower (*Commelina benghalensis*) and Broadleaf Paspalum (*Paspalum mandiocanum*). The dominant vine species present were the native species Silkpod (*Parsonsia straminea*) and Cockspur Thorn (*Maclura cochinchinensis*) and the exotic species Coastal Morning Glory (*Ipomoea cairica*), while the macrophyte layer included Common Reed (*Phragmites australis*), Marsh Club-rush (*Bolboschoenus fluviatilis*), Curly Pondweed (*Potamogeton crispus*) and Freshwater Eelgrass (*Vallisneria nana*).

Noxious weed species observed onsite were Coral Tree (*Erythrina crista-galli*), a class 3 noxious weed; and Camphor Laurel (*Cinnamomum camphora*), Lantana (*Lantana camara*), Broad-leaf Privet (*Ligustrum lucidum*), Small-leaved Privet (*Ligustrum sinense*) and Coastal Morning Glory (*Ipomoea cairica*), all class 4 noxious weeds. In addition to those already mentioned, other weed species present included Japanese Lionstail (*Leonurus japonicus*), Mouse-ear Chickweed (*Cerastium glomeratum*) and Prairie Grass (*Bromus catharticus*).

Summary: BELR1 was a very highly disturbed system of regrowth forest with mixed native and exotic species throughout all structural layers, in a predominantly cleared landscape. The surrounding rural landuse was agricultural grazing land, urban settlement and horticulture. A significant remnant stand of vegetation lies 5.2km east of BELR1 in Hat Head National Park. BELR1 scored moderately for Cover and poorly for all other subindices, Habitat, Native Species, Debris and Management (Table 3.109). Despite retaining native elements in all structural layers, riparian condition at BELR1 was affected by poor riparian vegetation width and habitat connectivity, by the dominance and regeneration of weed and noxious weed species in all structural layers, inadequate riparian fencing and animal impact. Reduced levels of cover across all but the macrophyte structural layer, limited native species regeneration, absence of habitat trees and reduced woody and non-woody debris contributed to the reduction in riparian grade at this site.

Management Recommendations: Riparian condition could be improved through the control and removal of weed and noxious weed species and by undertaking native plantings which phase-out and replace dominant canopy weed species and promote vegetation width, continuity, habitat connectivity and assist site regeneration of native species. The introduction of large woody debris back into this system using best practice techniques could stabilise river banks in the long term, promote niche habitats for native woody regeneration and for native animal species. Riparian fencing should exclude livestock, promote woody and non-woody debris accumulation and allow for canopy, midstory and understory native species recovery, and if strategically implemented could be used in combination with native plantings to increase riparian vegetation width, continuity and to improve proximity to intact remnant stands of vegetation.

Plate 3.83 *Riparian vegetation at BELR1 was very highly disturbed. Riparian condition would be improved through control and removal of weed and noxious weed species such as Coral Tree* (Erythrina x sykesii)*, Camphor Laurel* (Cinnamomum camphora)*, Lantana* (Lantana camara)*, Broad-leaf Privet* (Ligustrum lucidum), *Small-leaved Privet* (Ligustrum sinense) *and Coastal Morning Glory* (Ipomoea cairica)*, by undertaking native plantings and fencing off the riparian zone.*

***Table 3.109** Site-level summary of riparian condition of Belmore River #1 showing the scores of individual indicators and the five subindices that comprise the Vegetation Condition Index.*

BELR1	Scores
HABITAT	**7.5/20**
Channel width	0
Proximity	0
Continuity	2
Layers	4
Large native trees	1.5
Hollow-bearing trees	0
NATIVE SPECIES	**8.5/20**
Native canopy species	2
Native midstory species	1
Native herb/forb species	1
Native graminoid species	0.5
Native macrophyte species	4
SPECIES COVER	**13.5/20**
Canopy species	2
Midstory species	2.5
Herb/forb species	3
Graminoid species	4
Macrophyte species	2
DEBRIS	**9/20**
Total leaf litter	1
Native leaf litter	2
Dead trees standing	0
Dead trees fallen	1
Lying logs	1
Fringing vegetation	4
MANAGEMENT	**6.5/20**
Tree clearing	1.5
Fencing	1
Animal impact	0
Species of interest	0
Exposed tree roots	3
Native woody regeneration	1
Weedy woody regeneration	0
TOTAL	**45/100**

3.5.3.3 Water quality

The Belmore River received a score of 29 (F) for water quality. Figures 3.19 and 3.20 show the key physicochemical and nutrient variables used in the assessment of water quality for the estuarine tributaries. Ranges and means for these variables are given in Table 3.110 and the exceedances are given in Table 3.111.

pH exceeded the upper ANZECC estuarine trigger value of 8.5 on 2 of 6 sampling occasions (Table 3.111). Turbidity exceeded the ANZECC estuarine guideline at all depths on 3 of 6 sampling occasions (Table 3.111). The site maximum turbidity was 2.5 times the ANZECC trigger value (Table 3.110). DO% at BELR1 fell below the minimum ANZECC trigger threshold at all depths on 2 sampling occasions; in June and December 2015 (Table 3.110). The site minimum DO% was 57% (Table 3.110).

Concentrations of TN at BELR1 exceeded the ANZECC trigger value on 5 sampling occasions. The site maximum TN concentration was 6.1 times the trigger value (Table 3.110). TP concentrations at BELR1 exceeded the ANZECC trigger value on all sampling occasions (Figure 3.20). The site minimum TP concentration was 1.1 times the trigger value and the site maximum TP concentration was 2.3 times the trigger value (Table 3.110).

Concentrations of dissolved nutrients at BELR1 exceeded the ANZECC trigger values on all sampling occasions (Table 3.111). The site minimum NOx concentration was 4.3 the trigger value and the site maximum NOx concentration was 48 times the trigger value (Table 3.110). The site minimum SRP concentration was 1.6 times the trigger value and the site maximum SRP concentration was 9 times the trigger value (Table 3.110).

Chlorophyll *a* concentrations exceeded the ANZECC trigger value twice (in April and December 2015), and exceedances were 1.1 and 2.3 times the ANZECC trigger value, respectively. Peak chlorophyll *a* concentrations did not correlate with peak nutrient concentrations or result in supersaturated DO%.

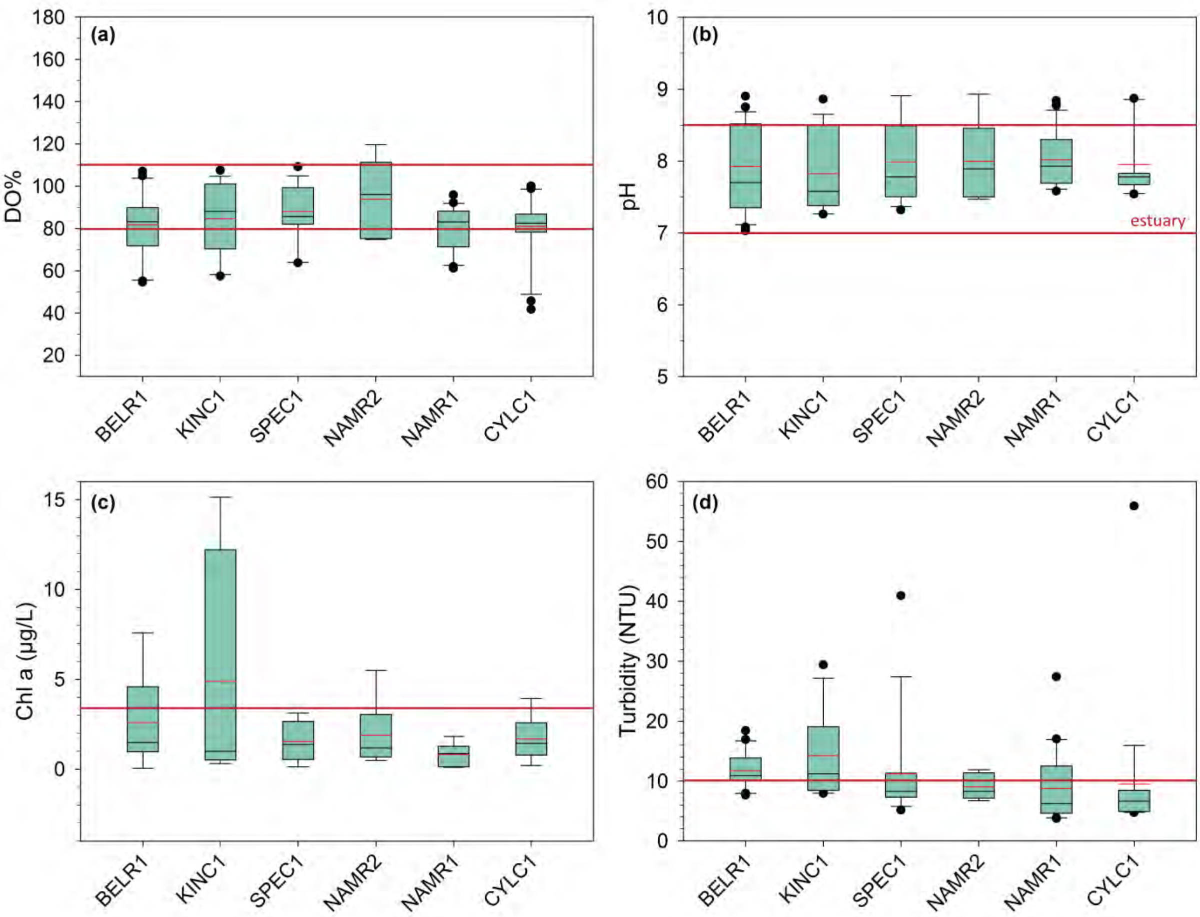


Figure 3.19 *Mean (red line), median (black line), 25th and 75th percentiles for (a) % saturated DO, (b) pH, (c) chlorophyll a and (d) turbidity in tidal tributaries of the Macleay estuary. Outliers are represented by black dots. Horizontal red lines represent the ANZECC and MER trigger thresholds for estuarine systems. Two horizontal red lines represent minimum (lower) and maximum (upper) trigger thresholds while single horizontal red lines represent maximum trigger thresholds.*

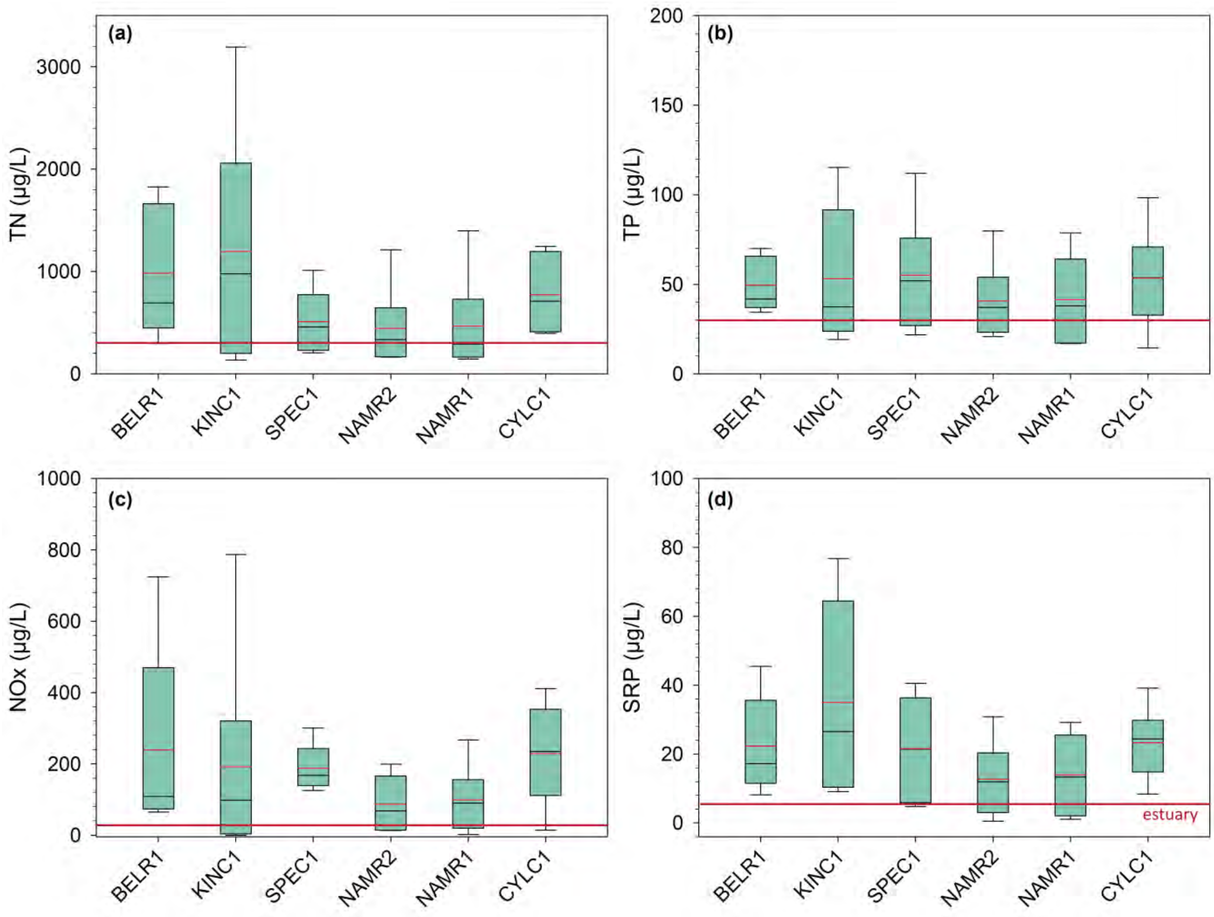


Figure 3.20 *Mean (red line), median (black line), 25th and 75th percentiles for (a) total nitrogen, (b) total phosphorus, (c) bioavailable nitrogen and (d) soluble reactive phosphorus in the tidal tributaries of the Macleay estuary. Horizontal red lines represent the maximum ANZECC and MER trigger thresholds for estuarine systems.*

Table 3.110 *Minimums, maximums and means of measured water quality variables for the Belmore River and Kinchela and Spencers Creeks.*

	BELR1			KINC1			SPEC1		
Variable	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**
Temperature (°C)	12.19	29.30	22.33	14.83	29.31	20.91	16.30	29.85	23.42
pH	7.03	8.90	7.93	7.26	8.86	7.91	7.32	8.91	7.99
EC (mS/cm)	0.20	2.52	1.48	0.26	15.30	5.75	18.00	51.30	40.19
Salinity (PPT)	0.10	1.30	0.74	0.13	8.91	3.26	10.60	33.62	25.75
DO (mg/L)	4.89	8.55	6.53	4.37	11.98	6.83	4.53	6.88	5.92
DO (%)	54.60	107.00	81.88	57.40	107.40	82.42	63.70	109.10	87.95
Turbidity (NTU)	7.60	18.40	11.73	7.90	29.40	14.21	5.10	40.90	11.20
Max Depth	NA	NA	NA	2.30	2.90	2.49	1.20	3.80	2.29
Chla (µg/L)	0.06	7.58	2.58	0.06	11.24	2.37	0.07	3.14	1.20
TSS (mg/L)	2.78	6.60	4.20	0.31	15.15	4.88	0.14	3.14	1.54
TN (µg/L)	295.95	1826.2	929.34	134.94	3194.9	1198.5	204.5	1012.7	510.27
TP (µg/L)	34.45	70.02	49.31	19.11	115.28	53.04	21.87	112.07	55.02
NOx (µg/L)	64.19	724.43	219.24	0.02	787.06	192.26	125.26	300.68	188.16
SRP (µg/L)	8.13	45.49	23.09	1.63	12.93	5.82	1.98	22.86	9.98

Table 3.111 *Exceedances[1] observed in the estuarine tributary sites for pH, conductivity (EC), percent saturated dissolved oxygen (DO), turbidity, chlorophyll a (Chl-a), total nitrogen (TN) ,total phosphorus (TP), bioavailable nitrogen (NOx) and soluble reactive phosphorus (SRP).*

Site	pH	EC	DO %	Turbidity	Chl-a	TN	TP	NOx	SRP
BELR1	4(30%) 0,4	NA	9(39%) 9,0	10(16%)	2(33%)	5(83%)	6(100%)	6(100%)	6(100%)
KINC1	4(29%) 0,4	NA	6(43%) 6,0	10(71%)	1(17%)	4(67%)	5(83%)	5(83%)	5(83%)
SPEC1	4(24%) 0,4	NA	2(12%) 2,0	5(36%)	0(0%)	3(50%)	5(83%)	5(83%)	5(83%)
CLYC1	4(20%) 0,4	NA	7(35%) 7,0	3(17%)	1(17%)	6(100%)	5(83%)	5(83%)	5(83%)
NAMR1	5(22%) 0,5	NA	9(39%) 8,1	6(29%)	0(0%)	4(67%)	3(50%)	5(83%)	4(67%)
NAMR2	1(17%) 0,1	NA	4(67%) 1,3	3(50%)	5(83%)	4(67%	2(33%)	5(83%)	5(83%)

[1] Numbers in black represent the total number and percent of exceedances. Numbers in blue and red represent the numbers of measurements lower than the minimum threshold and higher than the maximum threshold, respectively. The number of exceedances includes all depths sampled so may be greater than the number of times sampled. Turbidity, chlorophyll a and nutrients only have maximum trigger thresholds.

3.5.4 Kinchela Creek (KINC1)

3.5.4.1 Geomorphic condition

The River Style at Kinchela Creek #1 (KINC1) is laterally unconfined valley setting: continuous channel, tidal. Bed and bank sediments comprised fine grained sediment. Undercutting was significant (10-20m), occurring in the intertidal zone on each bank. Slumping was also significant (10-20m), particularly on the left bank where stock accessed the riparian zone. KINC1 scored 66, a grade of C for BANK CONDITION. With an overall Ecohealth geomorphic condition of 70, a grade of C, KINC1 was assessed as being in moderate geomorphic condition. The desktop GIS assessment of subcatchment geomorphic condition found the Macleay estuary (including Kinchela Creek) to be in moderate condition with a grade of C. The site-level grade for KINC1 is representative of the average subcatchment condition.

3.5.4.2 Riparian condition

High historic disturbance at KINC1 (Plate 3.84) has resulted in a highly modified riparian zone that predominantly comprises exotic species. However, the original riparian vegetation community at KINC1 could have been described as 'Swamp Oak swamp forest fringing estuaries, Sydney Basin Bioregion and South East Corner Bioregion' plant community type ID 1234 (VIS, 2012), broadly classed as 'Coastal Floodplain Wetlands' (Keith, 2004), a recognized TEC (VIS, 2012). KINC1 received a very poor riparian condition score of 32.5, a grade of F (Table 3.112).

The dominant canopy species present were native Swamp Oak (*Casuarina glauca*), and exotic species Coral Tree (*Erythrina crista-galli*) and White Mulberry (*Morus alba*). One dominant native midstory species was present, Weeping Bottlebrush (*Callistemon viminalis*), along with exotic species Lantana (*Lantana camara*), Castor Oil Plant (*Ricinus communis*), Small-leaved Privet (*Ligustrum sinense*) and Wild Tobacco (*Solanum mauritianum*). The understory was dominated by the native species Swamp Lily (*Crinum pedunculatum*), Knotweed (*Persicaria hydropiper*), Gristle Fern (*Blechnum cartilagineum*), along with exotic species Fleabane (*Conyza bonariensis*), Blue Billy Goat Weed (*Ageratum houstonianum*), Spear Thistle (*Cirsium vulgare*), Wandering Jew (*Tradescatia fluminensis*), Benghal Dayflower (*Commelina benghalensis*) and Buffalo Grass (*Stenotaphrum secundatum*). The dominant vine species present was the exotic species Coastal Morning Glory (*Ipomoea cairica*), while the macrophyte layer included Common Reed (*Phragmites australis*), Marsh Club-rush (*Bolboschoenus fluviatilis*) and River Club Rush (*Schoenoplectus validus*).

Noxious weed species observed onsite were Coral Tree (*Erythrina crista-galli*), a class 3 noxious weed; and Lantana (*Lantana camara*), Small-leaved Privet (*Ligustrum sinense*) Coastal Morning Glory (*Ipomoea cairica*) and Fireweed (*Senecio madagascariensis*), all class 4 noxious weeds. In addition to those already mentioned, other weed species present included Common Starwort (*Callitriche stagnalis*), Kikuyu (*Pennisetum clandestinum*) and Prairie Grass (*Bromus catharticus*).

Summary: KINC1 was an extremely disturbed system of regrowth forest with mixed native and exotic species throughout all structural layers, in a cleared landscape. The surrounding rural landuse was agricultural grazing land, urban settlement and National Park. A significant remnant stand of vegetation lies 3.2km east of KINC1 in Hat Head National Park. KINC1 scored moderately for Management, poorly for Native Species, Cover and Debris, and very poorly for Habitat subindices (Table 3.112). Despite retaining native elements in all structural layers, riparian condition at KINC1 was affected by an absence of riparian vegetation width, continuity and habitat connectivity and by the dominance and regeneration of weed and noxious weed species in all structural layers. Low vegetation cover levels throughout all structural layers except understory, no woody native species regeneration, and an absence of habitat trees, woody and non-woody debris contributed to the reduction in riparian grade at this site.

Management Recommendations: Riparian condition could be improved through the control and removal of weed and noxious weed species and by undertaking native plantings which phase-out and replace dominant canopy weed species and promote vegetation width, continuity, habitat connectivity and assist site regeneration of native species. Structural works using best practice techniques such as rock revetment at the toe of the bank will improve bank stability. This may include the introduction of large woody debris which would also promote niche habitats for native woody regeneration and for native animal species. While existing riparian fencing excludes livestock and promotes woody and non-woody debris accumulation, an increase in riparian vegetation width should be considered due its direct relationship with the width of the creek channel. Increasing the width of this zone and planting it out with native species can allow for canopy and midstory recovery and if strategically implemented could be used to increase riparian vegetation continuity and to improve proximity to intact remnant stands of vegetation.

***Plate 3.84** Riparian vegetation at KINC1 was extremely disturbed. Riparian condition would be improved through control and removal of weed and noxious weed species such as Coral Tree* (Erythrina x sykesii)*, a class 3 noxious weed, and Lantana* (Lantana camara)*, Small-leaved Privet* (Ligustrum sinense) *Coastal Morning Glory* (Ipomoea cairica)*, by undertaking native plantings and widening the fenced-off riparian zone.*

***Table 3.112** Site-level summary of riparian condition of Kinchela Creek #1 showing the scores of individual indicators and the five subindices that comprise the Vegetation Condition Index.*

KINC1	Scores
HABITAT	**13/20**
Channel width	4
Proximity	3
Continuity	1
Layers	4
Large native trees	1
Hollow-bearing trees	0
NATIVE SPECIES	**12/20**
Native canopy species	4
Native midstory species	2
Native herb/forb species	1
Native graminoid species	1
Native macrophyte species	4
SPECIES COVER	**11.5/20**
Canopy species	2
Midstory species	2
Herb/forb species	3
Graminoid species	3
Macrophyte species	2
DEBRIS	**6/20**
Total leaf litter	2
Native leaf litter	2
Dead trees standing	0
Dead trees fallen	0
Lying logs	2
Fringing vegetation	0
MANAGEMENT	**13.5/20**
Tree clearing	2
Fencing	3
Animal impact	3
Species of interest	0
Exposed tree roots	4
Native woody regeneration	2
Weedy woody regeneration	0
TOTAL	**32.5/100**

3.5.4.3 Water quality

Kinchela Creek received a score of 45 (F) for water quality. Figures 3.19 and 3.20 show the key physicochemical and nutrient variables used in the assessment of water quality for the estuarine tributaries. Ranges and means for these variables are given in Table 3.110 and the exceedances are given in Table 3.111.

pH exceeded the upper ANZECC estuarine trigger value of 8.5 on 2 of 6 sampling occasions (Table 3.111). Turbidity exceeded the ANZECC estuarine guideline at all depths on 4 of 6 sampling occasions (Table 3.111). The site maximum turbidity was 2.9 times the ANZECC trigger value (Table 3.110). DO% at KINC1 fell below the minimum ANZECC trigger threshold at all depths on 2 sampling occasions; in June and November 2015 (Table 3.110). The site minimum DO% was 57% (Table 3.110).

Concentrations of TN at KINC1 exceeded the ANZECC trigger value on 4 sampling occasions. The site maximum TN concentration was 11 times the trigger value (Table 3.110). TP concentrations at KINC1 exceeded the ANZECC trigger value on 5 sampling occasions (Figure 3.20). The site maximum TP concentration was 3.8 times the trigger value (Table 3.110).

Concentrations of dissolved nutrients at BELR1 exceeded the ANZECC trigger values on 5 sampling occasions (Table 3.111). The site maximum NOx concentration was 52 times the trigger value (Table 3.110). The site maximum SRP concentration was 2.6 times the trigger value (Table 3.110).

The chlorophyll *a* concentration exceeded the ANZECC trigger value once (in April 2015), and the site maximum chlorophyll *a* concentration was 3.4 times the ANZECC trigger value. Peak chlorophyll *a* concentration coincided with the peak NOx concentration. Managing nitrogen inputs into Kinchela Creek would improve water quality and likely reduce algal productivity. Grazing occurs adjacent to KINC1. Although the riparian zone at KINC1 is fenced (preventing direct stock access to the channel), riparian vegetation is depauperate (Plate 3.84). Revegetating the riparian zone in Kinchela Creek with native shrubs and trees would mediate nutrient inputs to the channel (and therefore, Macleay estuary) over the long-term.

3.5.5 Spencers Creek (SPEC1)

3.5.5.1 Geomorphic condition

The River Style at Spencers Creek #1 (SPEC1) is laterally unconfined valley setting: continuous channel, tidal. Bed and bank sediments comprised fine grained sediment. The well vegetated right bank was in good geomorphic condition (Plate 3.79), with minimal undercutting within the intertidal zone and no slumping observed in the site reach. However, left bank was in poor geomorphic condition with severe (20-100m) erosion along the interface of the intertidal and riparian zones (Plate 3.85). SPEC1 scored 65, a grade of C- for BANK CONDITION. With an overall Ecohealth geomorphic condition of 65, a grade of C-, SPEC1 was assessed as being in moderate geomorphic condition. The desktop GIS assessment of subcatchment geomorphic condition found the Macleay estuary (including Spencers Creek) to be in moderate condition with a grade of C. The site-level grade for SPEC1 is slightly below the average subcatchment condition.

3.5.5.2 Riparian condition

The original riparian vegetation community at SPEC1 (Plate 3.85) was described as 'Mangrove forest in estuaries of the Sydney Basin Bioregion and South East Corner Bioregion' plant community type ID 920 (VIS, 2012), broadly classed as 'Mangrove Swamps' (Keith, 2004), grading into 'Swamp Oak swamp forest fringing estuaries, Sydney Basin Bioregion and South East Corner Bioregion' plant community type ID 1234 (VIS, 2012), broadly classed as 'Coastal Floodplain Wetlands' (Keith, 2004), a recognized TEC (VIS, 2012). SPEC1 received a poor riparian condition score of 47.3, a grade of D- (Table 3.113).

The dominant canopy and midstory species present were Swamp Oak (*Casuarina glauca*), River Mangrove (*Aegiceras corniculatum*) and Grey Mangrove (*Avicennia marina* subsp. *Australasica*). The understory was dominated by native species Sea Rush (*Juncus krausii* subsp. *Australiensis*), Bergalia Tussock (*Carex longebrachiata*), Common Rush (*Juncus usitatus*), Knob Sedge (*Carex inversa*) and Couch (*Cynodon dactylon*), along with exotic species Sharp Rush (*Juncus acutus*), Kikuyu (*Pennisetum clandestinum*), Parramatta Grass (*Sporobolus africanus*) and Buffalo Grass (*Stenotaphrum secundatum*). While no vine species were present, two species of interest included the native She-oak Mistletoe (*Amyema cambagei*) and Rat's Tail Orchid (*Dendrobium teretifolium*), both observed onsite in Swamp Oaks (*Casuarina glauca*). The estuarine macrophyte layer included Sand Couch (*Sporobolus virginicus*), River Club Rush (*Schoenoplectus validus*) and Seagrass (*Zostera muelleri* subsp. *capricorni*).

While no listed noxious weeds were encountered onsite, the invasive exotic species Sharp Rush (*Juncus acutus*) was present.

Summary: SPEC1 was a very highly disturbed system of mixed-aged forest with remnant canopy and midstory species and mixed native and exotic species throughout the understory layer, in a predominantly cleared, partially forested landscape. The surrounding landuse was agricultural grazing land, urban settlement, forested private and Crown Land, and National Park. Significant remnant stands of vegetation lie adjacent to the site to the north on private and on crown land, 500m southwest on private land and 2.5km southeast of the site in Hat Head National Park. SPEC1 scored well for Native Species, moderately for Habitat and Debris, and poorly for Cover and Management subindices (Table 3.113). Riparian condition at SPEC1 was impacted by very low riparian vegetation width, continuity and cover throughout all structural layers, exposed tree roots and the presence and regeneration of weed and noxious weed species in the understory layer. Low regeneration rates of native woody species, reduced woody and non-woody debris, inadequate riparian fencing and animal impact contributed to the reduction in riparian grade at this site.

Despite this, there were species of interest on-site, such as the Rat's Tail Orchid (*Dendrobium teretifolium*) and the opposite side of the river retained good condition remnant riparian vegetation.

Management Recommendations: Riparian condition could be improved through the control and removal of weed and noxious weed species and by undertaking native plantings which phase-out and replace dominant canopy weed species and promote vegetation width, continuity, habitat connectivity and assist site regeneration of native species. Structural works using best practice techniques such as rock revetment at the toe of the bank will improve bank stability. This may include the introduction of large woody debris which would also promote niche habitats for native woody regeneration and for native animal species, and as instream snags, can redirect or reduce water energy from banks, reducing bank erosion. Riparian fencing should exclude livestock, promote woody and non-woody debris accumulation and allow for canopy, midstory and understory native species recovery. If strategically implemented riparian fencing could be used in combination with native plantings to increase riparian vegetation width, continuity and to improve proximity to intact remnant stands of vegetation.

***Plate 3.85** Riparian vegetation at SPEC1 was very highly disturbed. Riparian condition would be improved through control and removal of weed and noxious weed species such as Sharp Rush* (Juncus acutus)*, by undertaking native plantings and fencing-off the riparian zone.*

Table 3.113 *Site-level summary of riparian condition of Spencers Creek #1 showing the scores of individual indicators and the five subindices that comprise the Vegetation Condition Index.*

SPEC1	Scores
HABITAT	**12.3/20**
Channel width	1.3
Proximity	3
Continuity	1
Layers	3
Large native trees	2
Hollow-bearing trees	2
NATIVE SPECIES	**15/20**
Native canopy species	4
Native midstory species	4
Native herb/forb species	3
Native graminoid species	2
Native macrophyte species	2
SPECIES COVER	**5/20**
Canopy species	0.5
Midstory species	0.5
Herb/forb species	1
Graminoid species	1
Macrophyte species	2
DEBRIS	**11/20**
Total leaf litter	1
Native leaf litter	3
Dead trees standing	1
Dead trees fallen	2
Lying logs	2
Fringing vegetation	2
MANAGEMENT	**5/20**
Tree clearing	1
Fencing	1
Animal impact	1
Species of interest	1
Exposed tree roots	0
Native woody regeneration	1
Weedy woody regeneration	0
TOTAL	**47.3/100**

3.5.5.3 Water quality

Spencers Creek received a score of 60 (D-) for water quality. Figures 3.19 and 3.20 show the key physicochemical and nutrient variables used in the assessment of water quality for the estuarine tributaries. Ranges and means for these variables are given in Table 3.110 and the exceedances are given in Table 3.111.

pH exceeded the upper ANZECC estuarine trigger value of 8.5 all depths on 1 sampling occasion (Table 3.111). Turbidity exceeded the ANZECC estuarine guideline on 3 sampling occasions, but consistently only at the lower depths (Table 3.111). The site maximum turbidity was 4.1 times the ANZECC trigger value (Table 3.110). DO% at SPEC1 fell below the minimum ANZECC trigger threshold at all depths once, in November 2015 (Table 3.110). The site minimum DO% was 64% (Table 3.110).

Concentrations of TN at SPEC1 exceeded the ANZECC trigger value on 3 sampling occasions. The site maximum TN concentration was 3.4 times the trigger value (Table 3.110). TP concentrations at SPEC1 exceeded the ANZECC trigger value on 5 sampling occasions (Figure 3.20). The site maximum TP concentration was 3.7 times the trigger value (Table 3.110).

Concentrations of dissolved nutrients at SPEC1 exceeded the ANZECC trigger values on 5 sampling occasions (Table 3.111). The site maximum NOx concentration was 20 times the trigger value (Table 3.110). The site maximum SRP concentration was 4.6 times the trigger value (Table 3.110).

Chlorophyll *a* concentrations did not exceed the ANZECC trigger value in Spencers Creek (Figure 3.19). Thus, exceedances of ANZECC nutrient trigger values did not result in high algal productivity in Spencers Creek during the sampling period.

3.5.6 Clybucca Creek (CLYC1)

3.5.6.1 Geomorphic condition

The River Style at Clybucca Creek #1 (CLYC1) is laterally unconfined valley setting: continuous channel, tidal. Bed and bank sediments comprised fine grained sediment. The well vegetated banks were in good geomorphic condition (Plate 3.80), with minor (<5m) undercutting within the intertidal zone and no slumping observed in the site reach. CLYC1 scored 76, a grade of B- for BANK CONDITION. With an overall Ecohealth geomorphic condition of 76, a grade of B-, CLYC1 was assessed as being in good geomorphic condition. The desktop GIS assessment of subcatchment geomorphic condition found the Macleay estuary (including Clybucca Creek) to be in moderate condition with a grade of C. The site-level grade for CLYC1 is above the average subcatchment condition.

3.5.6.2 Riparian condition

The original riparian vegetation community at CLYC1 (Plate 3.86) was described as ‘Mangrove forest in estuaries of the Sydney Basin Bioregion and South East Corner Bioregion’ plant community type ID 920 (VIS, 2012), broadly classed as ‘Mangrove Swamps’ (Keith, 2004), grading into ‘Saltmarsh in estuaries of the Sydney Basin Bioregion and South East Coast Bioregion’ plant community type ID 1126 (VIS, 2012), broadly classed as ‘Saltmarsh’ (Keith, 2004), grading into ‘Swamp Oak swamp forest fringing estuaries, Sydney Basin Bioregion and South East Corner Bioregion’ plant community type ID 1234 (VIS, 2012), broadly classed as ‘Coastal Floodplain Wetlands’ (Keith, 2004), a recognized TEC (VIS, 2012). CLYC1 received a good riparian condition score of 70.3, a grade of C+ (Table 3.114).

The dominant canopy and midstory species present were Swamp Oak (*Casuarina glauca*), River Mangrove (*Aegiceras corniculatum*), Grey Mangrove (*Avicennia marina* subsp. *Australasica*) and Coastal Wattle (*Acacia longifolia* subsp. *sophorae*). The understory was dominated by native species Sea Rush (*Juncus krausii* subsp. *Australiensis*), New Zealand Spinach (*Tetragonia tetragoniodes*), Common Fringe Sedge (*Fimbristylis dichotoma*) and the exotic species Prickly Sowthistle (*Sonchus asper*). Vine species present were the native species Wombat Berry (*Eustrephus latifolius*), Silkpod (*Parsonsia straminea*) and Stiff Jasmine (*Jasminum volubile*) and the exotic species Coastal Morning Glory (*Ipomoea cairica*) and Climbing Nightshade (*Solanum seaforthianum*). A rich estuarine macrophyte layer included Austral Seablite (*Suaeda australis*), Creeping Brookweed (*Samolus repens*), Mangrove Vine (*Cynanchum carnosum*), Saltwater Couch (*Paspalum vaginatum*), Marine Couch (*Sporobolus virginicus* var. *minor*) and Seagrass (*Zostera muelleri* subsp. *capricorni*).

One noxious weed species was observed onsite, Coastal Morning Glory (*Ipomoea cairica*), a class 4 noxious weed.

Summary: CLYC1 was a mildly disturbed system of mixed-aged forest with remnant canopy and native understory species and mixed native and exotic species throughout the midstory layer, in a partially cleared, partially forested landscape. The surrounding landuse was a mix of historic grazing, oyster farming, horticulture, urban settlement and forested land. Significant remnant stands of vegetation lie on neighbouring islands 200m to the south, 200m to the west and 1km further west on crown land. CLYC1 scored well for Native Species and Cover, and moderately for Habitat, Debris and Management subindicees (Table 3.114). Riparian condition at CLYC1 was impacted by reduced riparian vegetation width and continuity, cover throughout the canopy layer and the presence of weed and noxious weed species in the mid and understory layer. Historic clearing, a reduction in large trees and habitat trees, fewer woody debris, inadequate riparian fencing and animal impact contributed to the reduction in riparian grade at this site.

Management Recommendations: Riparian condition could be improved through the control and removal of weed and noxious weed species. Riparian condition could be improved by strategically implementing riparian fencing that could be used in combination with native plantings to increase riparian vegetation width, continuity, proximity to intact remnant stands of vegetation and to assist with site regeneration of native species. Riparian fencing excludes livestock, promotes woody and non-woody debris accumulation and allows for canopy, midstory and understory native species recovery.

Plate 3.86 *Riparian vegetation at CLYC1 was mildly disturbed. Riparian condition would be improved through control and removal of weed and noxious weed species such as Coastal Morning Glory* (Ipomoea cairica)*, undertaking native plantings and by fencing-off the riparian zone.*

Table 3.114 *Site-level summary of riparian condition of Clybucca Creek #1 showing the scores of individual indicators and the five subindices that comprise the Vegetation Condition Index.*

CLYC1	Scores
HABITAT	**10.3/20**
Channel width	1.3
Proximity	2
Continuity	1
Layers	4
Large native trees	1
Hollow-bearing trees	1
NATIVE SPECIES	**19/20**
Native canopy species	4
Native midstory species	3
Native herb/forb species	4
Native graminoid species	4
Native macrophyte species	4
SPECIES COVER	**16/20**
Canopy species	2
Midstory species	4
Herb/forb species	3
Graminoid species	3
Macrophyte species	4
DEBRIS	**13/20**
Total leaf litter	3
Native leaf litter	4
Dead trees standing	1
Dead trees fallen	0
Lying logs	1
Fringing vegetation	4
MANAGEMENT	**12/20**
Tree clearing	1
Fencing	0
Animal impact	2
Species of interest	1
Exposed tree roots	4
Native woody regeneration	2
Weedy woody regeneration	2
TOTAL	**70.3/100**

3.5.6.3 Water quality

Clybucca Creek received a score of 62 (D-) for water quality. Figures 3.19 and 3.20 show the key physicochemical and nutrient variables used in the assessment of water quality for the estuarine tributaries. Ranges and means for these variables are given in Table 3.115 and the exceedances are given in Table 3.111.

pH exceeded the upper ANZECC estuarine trigger value of 8.5 at all depths once, in December 2015 (Table 3.111). Turbidity exceeded the ANZECC estuarine guideline at all depths once, in November 2015 (Table 3.111). The site maximum turbidity was 1.2 times the ANZECC trigger value (Table 3.110). DO% at CLYC1 fell below the minimum ANZECC trigger threshold on 3 sampling occasions; in April, November and December 2015 (Table 3.110). The site minimum DO% was 42% (Table 3.110), which is the lowest recorded across the estuarine tributaries (Figure 3.19a).

Concentrations of TN at CLYC1 exceeded the ANZECC trigger value on all sampling occasions. The site minimum TN concentration was 1.3 times the trigger value and the site maximum TN concentration was 4.1 times the trigger value (Table 3.110). TP concentrations at CLYC1 exceeded the ANZECC trigger value on 5 sampling occasions (Figure 3.20). The site maximum TP concentration was 3.3 times the trigger value (Table 3.110).

Concentrations of dissolved nutrients at CLYC1 exceeded the ANZECC trigger values on 5 sampling occasions (Table 3.111). The site maximum NOx concentration was 27 times the trigger value (Table 3.110). The site maximum SRP concentration was 8 times the trigger value (Table 3.110).

The chlorophyll *a* concentration exceeded the ANZECC trigger value once (in November 2015), and the exceedance was 1.2 times the ANZECC trigger value. Peak chlorophyll *a* concentrations did not coincide with peak concentrations for either total or dissolved nutrients, but did coincide with the site minimum DO%. This was likely due to the extreme low flows experienced during October and November 2015.

Table 3.115 *Minimums, maximums and means of measured water quality variables for Clybucca Creek and the North Arm of the Macleay River.*

	CLYC1			NAMR1			NAMR2		
Variable	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**
Temperature (°C)	16.24	27.36	21.70	16.74	29.09	23.65	16.60	47.63	22.08
pH	7.54	8.87	7.95	7.47	8.93	8.00	7.58	8.84	8.03
EC (mS/cm)	14.05	50.50	43.08	35.10	46.20	40.28	35.00	68.70	46.54
Salinity (PPT)	8.19	33.12	27.64	22.10	29.56	25.69	21.97	43.04	29.89
DO (mg/L)	3.24	6.85	5.44	4.69	7.81	5.99	3.77	9.33	5.68
DO (%)	41.70	100.00	80.94	73.50	119.60	90.45	61.10	136.70	83.30
Turbidity (NTU)	4.70	11.5	6.76	6.70	16.70	10.33	3.70	44.10	9.17
Max Depth	2.20	4.50	3.23	0.30	1.90	0.80	2.20	4.80	3.77
Chla (µg/L)	0.21	3.93	1.69	0.15	1.83	0.82	0.11	5.50	1.69
TSS (mg/L)	0.64	22.90	10.22	2.38	29.23	14.54	2.38	36.13	16.10
TN (µg/L)	394.60	1245.8	775.53	169.49	1398.3	494.08	168.27	1398.3	651.54
TP (µg/L)	14.39	98.37	53.48	20.87	138.98	50.59	14.42	266.89	88.28
NOx (µg/L)	14.42	411.27	228.66	2.38	266.90	53.91	16.85	78.76	34.95
SRP (µg/L)	8.32	39.17	23.30	1.72	266.89	100.87	0.48	30.81	14.23

3.5.7 North Arm Macleay River (NAMR2 and NAMR1)

3.5.7.1 Geomorphic condition

The River Style at the North Arm Macleay River #1 (NAMR1) is laterally unconfined valley setting: continuous channel, tidal. Bed and bank sediments comprised sand. The well vegetated banks were in good geomorphic condition (Plate 3.81), with no bank erosion observed in the site reach. NAMR1 scored 78, a grade of B- for BANK CONDITION. With an overall Ecohealth geomorphic condition of 78, a grade of B-, NAMR1 was assessed as being in good geomorphic condition. The desktop GIS assessment of subcatchment geomorphic condition found the Macleay estuary (including the North Arm) to be in moderate condition with a grade of C. The site-level grade for NAMR1 is above the average subcatchment condition.

The River Style at the North Arm Macleay River #2 (NAMR2) is laterally unconfined valley setting: continuous channel, tidal. Bed and bank sediments comprised sand. The left bank was predominantly vegetated and bank erosion was restricted to minor (<5m) areas of high human access at Stuarts Point. NAMR2 scored 73, a grade of C+ for BANK CONDITION. With an overall Ecohealth geomorphic condition of 73, a grade of C+, NAMR2 was assessed as being in moderate geomorphic condition. The desktop GIS assessment of subcatchment geomorphic condition found the Macleay estuary (including the North Arm) to be in moderate condition with a grade of C. The site-level grade for NAMR2 is representative of the average subcatchment condition.

3.5.7.2 Riparian condition

NAMR2

The original riparian vegetation community at NAMR2 (Plate 3.87) was described as ‘Mangrove forest in estuaries of the Sydney Basin Bioregion and South East Corner Bioregion’ plant community type ID 920 (VIS, 2012), broadly classed as ‘Mangrove Swamps’ (Keith, 2004), grading into ‘Saltmarsh in estuaries of the Sydney Basin Bioregion and South East Coast Bioregion’ plant community type ID 1126 (VIS, 2012), broadly classed as ‘Saltmarsh’ (Keith, 2004), a recognized TEC (VIS, 2012), grading into ‘Swamp Oak swamp forest fringing estuaries, Sydney Basin Bioregion and South East Corner Bioregion’ plant community type ID 1234 (VIS, 2012), broadly classed as ‘Coastal Floodplain Wetlands’ (Keith, 2004), also a recognized TEC (VIS, 2012). NAMR2 received a low riparian condition score of 59.1, a grade of D+ (Table 3.116).

The dominant canopy and midstory species present were Swamp Oak (*Casuarina glauca*), River Mangrove (*Aegiceras corniculatum*), Grey Mangrove (*Avicennia marina* subsp. *Australasica*) and exotic species Camphor Laurel (*Cinnamomum camphora*), Lantana (*Lantana camara*) and Bitou Bush (*Chrysanthemoides monilifera* subsp. *Rotundata*). The understory was dominated by native species Sea Rush (*Juncus krausii* subsp. *Australiensis*), New Zealand Spinach (*Tetragonia tetragoniodes*), Common Bracken (*Pteridium esculentum*) and the exotic species Asparugus Fern (*Asparagus aethiopicus*), Clover (*Trifolium sp.*), Fleabane (*Conyza bonariensis*), Sidratusa (*Sida rhombifolia*), Coblers Pegs (*Bidens pilosa*), Buffalo Grass (*Stenotaphrum secundatum*), Parramatta Grass (*Sporobolus africanus*) and Panic Veldtgrass (*Ehrharta erecta*). Vine species present were the exotic species Coastal Morning Glory (*Ipomoea cairica*) and Japanese Honeysuckle (*Lonicera japonica*). The estuarine macrophyte layer included Austral Seablite (*Suaeda australis*), Marine Couch (*Sporobolus virginicus* var. *minor*), Seagrass (*Zostera muelleri* subsp. *capricorni*) and Paddle Weed (*Halophila ovalis*).

Noxious weed species observed onsite were Camphor Laurel (*Cinnamomum camphora*), Lantana (*Lantana camara*), Bitou Bush (*Chrysanthemoides monilifera* subsp. *Rotundata*), Asparugus Fern (*Asparagus aethiopicus*), Coastal Morning Glory (*Ipomoea cairica*), all class 4 noxious weeds. In addition to those already mentioned, other weed species present included Pine Mountain Coral Tree (*Erythrina numerosa*), Umbrella Tree (*Schefflera actinophylla*), Umbrella Sedge (*Cyperus eragrostis*), Silver nightshade (*Solanum* sp.), Vasey Grass (*Paspalum urvillei*) and Prairie Grass (*Bromus catharticus*).

Summary: NAMR2 was a high disturbance system of mixed-aged forest with mixed native and exotic species throughout all structural layers, in a partially cleared, partially forested landscape. The surrounding landuse was a mixture of urban settlement, horticulture, recreation, periodically inundated mangrove and saltmarsh tidal flats and forested land. Significant remnant stands of vegetation lie 1km southwest on crown land, and 1.9km west in Way Way State Forest. NAMR2 scored well for Cover, moderately for Habitat, Native Species and Debris and poorly for Management subindices (Table 3.116). Riparian condition at NAMR2 was impacted by reduced riparian vegetation width and continuity and the presence and regeneration of weed and noxious weed species, particularly in the midstory and understory structural layers. A reduction in large trees and habitat trees and woody debris, historic clearing and inadequate riparian fencing contributed to the reduction in riparian grade at this site.

Management Recommendations: Riparian condition could be improved through the early control and removal of weed and noxious weed species, which reduces the likelihood of potential exotic weed infestations which may otherwise degrade a vegetation community by outcompeting native species. In high traffic areas riparian fencing can exclude anthropogenic disturbances that may otherwise impact on native vegetation. The strategic implementation of riparian fencing in combination with native plantings would increase riparian vegetation width and continuity, assist with site regeneration of native canopy, midstory and understory species and promote the accumulation of woody and non-woody debris which through the provision of niche habitats supports native woody regeneration and native animal species.

Plate 3.87 *Riparian vegetation at NAMR2 was highly disturbed. Riparian condition would be improved through control and removal of weed and noxious weed species such as Camphor Laurel* (Cinnamomum camphora)*, Lantana* (Lantana camara)*, Bitou Bush* (Chrysanthemoides monilifera subsp. Rotundata)*, Asparugus Fern* (Asparagus aethiopicus) *and Coastal Morning Glory* (Ipomoea cairica)*, by undertaking native plantings and fencing-off the riparian zone.*

Table 3.116 *Site-level summary of riparian condition of North Arm Macleay River #2 showing the scores of individual indicators and the five subindices that comprise the Vegetation Condition Index.*

NAMR2	**Scores**
HABITAT	**10/20**
Channel width	0
Proximity	3
Continuity	1
Layers	4
Large native trees	1
Hollow-bearing trees	1
NATIVE SPECIES	**10.5/20**
Native canopy species	3
Native midstory species	1.5
Native herb/forb species	1
Native graminoid species	1
Native macrophyte species	4
SPECIES COVER	**17/20**
Canopy species	3
Midstory species	3
Herb/forb species	4
Graminoid species	4
Macrophyte species	3
DEBRIS	**12/20**
Total leaf litter	3
Native leaf litter	2
Dead trees standing	3
Dead trees fallen	1
Lying logs	1
Fringing vegetation	2
MANAGEMENT	**9.6/20**
Tree clearing	1.6
Fencing	0
Animal impact	2
Species of interest	0
Exposed tree roots	4
Native woody regeneration	2
Weedy woody regeneration	0
TOTAL	**59.1/100**

NAMR1

The original riparian vegetation community at NAMR1 (Plate 3.88) was described as ‘Mangrove forest in estuaries of the Sydney Basin Bioregion and South East Corner Bioregion’ plant community type ID 920 (VIS, 2012), broadly classed as ‘Mangrove Swamps’ (Keith, 2004), grading into ‘Saltmarsh in estuaries of the Sydney Basin Bioregion and South East Coast Bioregion’ plant community type ID 1126 (VIS, 2012), broadly classed as ‘Saltmarsh’ (Keith, 2004), a recognized TEC (VIS, 2012), grading into ‘Swamp Oak swamp forest fringing estuaries, Sydney Basin Bioregion and South East Corner Bioregion’ plant community type ID 1234 (VIS, 2012), broadly classed as ‘Coastal Floodplain Wetlands’ (Keith, 2004), also a recognized TEC (VIS, 2012). NAMR1 received a very good riparian condition score of 80.5, a grade of B (Table 3.117).

The dominant canopy and midstory species present were Swamp Oak (*Casuarina glauca*), River Mangrove (*Aegiceras corniculatum*), Grey Mangrove (*Avicennia marina* subsp. *Australasica*) Tuckeroo (*Cupaniopsis anacardioides*), Boobialla (*Myoporum acuminatum*), along with the exotic species Lantana (*Lantana camara*), Groundsel Bush (*Baccharis halimifolia*) and Bitou Bush (*Chrysanthemoides monilifera* subsp. *Rotundata*). The understory was dominated by native species Sea Rush (*Juncus krausii* subsp. *Australiensis*), New Zealand Spinach (*Tetragonia tetragoniodes*), Common Fringe Sedge (*Fimbristylis dichotoma*), Bunchy sedge (*Cyperus polystachyos*). One dominant vine species was present, the exotic species Coastal Morning Glory (*Ipomoea cairica*), while a rich estuarine macrophyte layer included Chaffy Saw Sedge (*Gahnia filum*), Austral Seablite (*Suaeda australis*), Samphire (*Sarcocornia quinqueflora*), Creeping Brookweed (*Samolus repens*), Mangrove Vine (*Cynanchum carnosum*), Saltwater Couch (*Paspalum vaginatum*), Marine Couch (*Sporobolus virginicus* var. *minor*) and Seagrass (*Zostera muelleri* subsp. *capricorni*).

Noxious weed species observed onsite were Groundsel Bush (*Baccharis halimifolia*), a class 3 noxious weed; and Lantana (*Lantana camara*), Bitou Bush (*Chrysanthemoides monilifera* subsp. *Rotundata*) and Coastal Morning Glory (*Ipomoea cairica*), all class 4 noxious weed species.

Summary: NAMR1 was a low disturbance system of mature closed forest with remnant canopy and understory layers and a mixed midstory layer of native and exotic species, in both a forested and an understory species dominated landscape. The surrounding landuse was a mix of historic grazing, oyster farming, horticulture, urban settlement and forested land. The vegetation at NAMR1 was part of a larger significant remnant stand of vegetation on Mackenzies Island. Additional remnant stands were 500m east on the neighboring Shark Island and 1km west on both private land and on Crown Land. NAMR1 scored well for Habitat, Native Species and Cover and moderately for Debris and Management subindices (Table 3.117). Riparian condition at NAMR1 was impacted by reduced riparian vegetation continuity and the presence of weed and noxious weed species in the mid and understory layer. Reduced woody and non-woody debris, inadequate riparian fencing and minor animal impact also contributed to the reduction in riparian grade at this site.

Management Recommendations: Riparian condition could be improved through the early control and removal of weed and noxious weed species, which reduces the likelihood of potential exotic weed infestations which may otherwise degrade a vegetation community by outcompeting native species. Riparian fencing excludes livestock, promotes woody and non-woody debris accumulation and allows for canopy, midstory and understory native species recovery. Riparian fencing could be strategically implemented towards the northern end of Mackenzies Island to increase riparian vegetation width, assist with site regeneration of native species and to maintain the current riparian condition.

Plate 3.88 *Riparian vegetation at NAMR1 was of low disturbance. Riparian condition would be improved through control and removal of weed and noxious weed species such as Groundsel* Bush (Baccharis halimifolia)*, Lantana* (Lantana camara)*, Groundsel Bush* (Baccharis halimifolia)*, Bitou Bush* (Chrysanthemoides monilifera subsp. Rotundata) *and Coastal Morning Glory* (Ipomoea cairica) and by excluding stock*.*

Table 3.117 *Site-level summary of riparian condition of North Arm Macleay River #1 showing the scores of individual indicators and the five subindices that comprise the Vegetation Condition Index.*

NAMR1	Scores
HABITAT	**15.5/20**
Channel width	2
Proximity	3
Continuity	2.5
Layers	4
Large native trees	2
Hollow-bearing trees	2
NATIVE SPECIES	**19/20**
Native canopy species	4
Native midstory species	3
Native herb/forb species	4
Native graminoid species	4
Native macrophyte species	4
SPECIES COVER	**18/20**
Canopy species	4
Midstory species	4
Herb/forb species	4
Graminoid species	4
Macrophyte species	2
DEBRIS	**14/20**
Total leaf litter	2
Native leaf litter	4
Dead trees standing	2
Dead trees fallen	0
Lying logs	2
Fringing vegetation	4
MANAGEMENT	**14/20**
Tree clearing	3
Fencing	0
Animal impact	2
Species of interest	1
Exposed tree roots	4
Native woody regeneration	2
Weedy woody regeneration	2
TOTAL	**80.5/100**

3.5.7.3 Water quality

The North Arm of the Macleay River received a score of 46 (D-) for water quality, with NAMR1 (near South West Rocks) receiving a score of 51 (D) and NAMR2 (Stuarts Point) receiving a score of 40 (F). Figures 3.19 and 3.20 show the key physicochemical and nutrient variables used in the assessment of water quality for the estuarine tributaries. Ranges and means for these variables are given in Table 3.115 and the exceedances are given in Table 3.111.

pH at NAMR1 and NAMR2 exceeded the upper ANZECC estuarine trigger value of 8.5 at all depths once, in December 2015 (Table 3.111). Turbidity at both NAMR1 and NAMR2 exceeded the ANZECC estuarine guideline at all depths on 3 of 6 sampling occasions (Table 3.111). The site maximum turbidities at NAMR1 and NAMR2 were 1.7 and 4.4 times the ANZECC trigger value, respectively (Table 3.115). DO% at NAMR1 fell below the minimum ANZECC trigger threshold on 3 sampling occasions and exceeded the maximum ANZECC trigger threshold once, in November 2015 (Table 3.115). The site minimum DO% was 61% and the site maximum DO% was 137% (Table 3.115). The supersaturation of DO% at NAMR1 was likely due to wave action, as lower depths in the November sampling occasion fell below the minimum ANZECC trigger value. Additionally, chlorophyll *a* concentrations at NAMR1 remained well below the ANZECC trigger value for the duration of the sampling period (Figure 3.19c). DO% at NAMR2 also fell below the minimum trigger value on 3 sampling occasions (Table 3.115). Site minimum DO% at NAMR2 was 74%.

Concentrations of TN in the North Arm of the Macleay River exceeded the ANZECC trigger value on 4 sampling occasions. Site maximum TN concentratios were 4.6 times the trigger value at both NAMR1 and NAMR2 (Table 3.115). TP concentrations exceeded the ANZECC trigger value on 3 and 2 sampling occasions at NAMR1 and NAMR2, respectively (Figure 3.20). Site maximum TP concentrations were 4.6 and 9 times the trigger value at NAMR1 and NAMR2, respectively (Table 3.115).

Concentrations of NOx exceeded the ANZECC trigger values on 5 sampling occasions at NAMR1 and NAMR2 (Table 3.111). Site maximum NOx concentrations were 18 and 1.1 times the trigger value at NAMR1 and NAMR2, respectively (Table 3.115). Concentrations of SRP exceeded the ANZECC trigger values on 4 and 5 sampling occasions at NAMR1 and NAMR2, respectively (Table 3.111). Site maximum SRP concentrations were 53 and 6.2 times the trigger value at NAMR1 and NAMR2, respectively (Table 3.115).

Chlorophyll *a* concentrations exceeded the ANZECC trigger value once at NAMR2 (in December 2015), and the site maximum concentration was 1.7 times the ANZECC trigger value. Peak chlorophyll *a* concentration correlated with peak TP concentration and peak DO%.

PART 4

SUMMARY AND RECOMMENDATIONS

4.1 Background

The development of a standardised framework for collecting, analyzing and presenting riverine, coastal and estuarine assessments of ecological condition has been identified as a key need for coastal Councils and State natural resource management agencies, who are required to monitor natural resource condition, and water quality and quantity in these systems. This project was conducted over a 11-month period from April 2015 to February 2016 in the Macleay catchment covering the subcatchments of the Gara, Apsley, Tia, Yarrowitch, Wollomombi, Chandler, Oaky, Styx, Bemore and Macleay Rivers; Commissioners and Salisbury Waters; Bakers, Georges, Five Day, Nulla Nulla, Toorumbee, Hickeys, Mungay, Dungay, Collombatti, Kinchela, Spencers and Clybucca Creeks and Warbro Brook. This project aimed to contribute to the assessment of the ecological condition of these subcatchments by:

- Assessing the health of coastal catchments using standardised indicators and reporting for estuaries and freshwater river reaches using hydrology, water quality, riparian vegetation, geomorphic condition, aquatic macroinvertebrate communities and fish as indicators of aquatic ecosystem health, and
- Contributing scientific information to the development of report cards for communicating the health of the estuarine and freshwater systems of the Macleay catchment.

This section provides a summary for each of the study subcatchments, identifying major issues with geomorphic condition, riparian condition, water quality and aquatic macroinvertebrate communities, and the potential drivers of change in these systems. Management priorities are provided for each site based on the Ecohealth data contained in this report. However, these are long-term recommendations and we emphasize that Council weigh these against their short- and intermediate NRM priorities when incorporating these into their long-term NRM strategy.

Prioritizing recommendations for investment in the Kempsey LGA

Recommendations made in this 2016 Ecohealth report stem from issues observed at the site scale. However, we anticipate that these issues are common themes extending further into the broader sub-catchments of these representative Ecohealth sites. All 44 sites require some form of weed control and monitoring. Riparian fencing is recommended for 35 sites, native plantings in 25 sites, the introduction of woody debris as instream habitat in 11 sites, a phasing-out strategy for dominant weed species is recommended in 7 sites, and a pest animal control program is recommended in 1 of the 44 Macleay Ecohealth sites (Table 4.1).

Table 4.1 *A summary of recommendations to improve riparian condition at each of the 44 Macleay Ecohealth sites.*

Recommendations	Weed monitoring	Weed control	Native plantings	Fencing	Weed species phase-out	Woody debris	Pest animal control
APSR1	Y	Y	Y				
BAKC1	Y	Y					Y
BELR1	Y	Y	Y	Y	Y	Y	
CHAR1	Y	Y	Y	Y			
CLYR1	Y	Y	Y	Y			
COLC1	Y	Y	Y	Y			
COMR1	Y	Y	Y	Y	Y		
DUNC1	Y	Y				Y	
DUNC2	Y	Y		Y			
DUNC3	Y	Y		Y			
FIVC1	Y	Y		Y			
FIVC2	Y	Y	Y	Y			
FIVC3	Y	Y		Y			
GARR1	Y	Y					
GARR2	Y	Y	Y	Y	Y		
GARR3	Y	Y	Y	Y			
GEOC1	Y	Y		Y			
HICC1	Y	Y		Y			
KINC1	Y	Y	Y	Y		Y	
MACR1	Y	Y	Y				
MACR2	Y	Y	Y	Y		Y	
MACR3	Y	Y	Y	Y		Y	
MACR4	Y	Y	Y			Y	
MACR5	Y	Y	Y				
MACR6	Y	Y	Y	Y			
MACR7	Y	Y	Y	Y			
MACR8	Y	Y	Y	Y			
MACR9	Y	Y	Y	Y	Y		
MACR10	Y	Y		Y			
MUNC1	Y	Y		Y			
NAMR1	Y	Y		Y			
NAMR2	Y	Y	Y	Y			
NULC1	Y	Y		Y			
OAKC1	Y	Y	Y	Y		Y	
SALW1	Y	Y	Y	Y	Y		
SPEC1	Y	Y	Y	Y		Y	
STYR1	Y	Y					
TIAR1	Y	Y	Y	Y	Y	Y	
TOOC1	Y	Y		Y			
TOOC2	Y	Y				Y	
TOOC3	Y	Y		Y		Y	
WARB1	Y	Y		Y			
WOLR1	Y	Y		Y			
YARR1	Y	Y	Y	Y	Y		
Totals	44	44	25	35	7	11	1

Given the large spatial scale at which these recommendations need to be employed in addition to practical and resource limitations, there is a strong argument for prioritising recommendations. The highest priority should be given to conserving those sites/systems that are in good condition, ensuring riparian condition is maintained, followed by rehabilitatioin works in sites/systems where degradation has and is occurring. This recommendation follows the positive ecological condition (water quality, macroinvertebrates, fish) identified at sites with excellent riparian and geomorphic condition.

Both short-term and long-term goals should be considered. For example, a site such as COLC1 might have short-term goals of removing Lantana, monitoring woody weeds and erecting riparian fencing, while a long-term goal for the same site may be to undertake riparian plantings and improve riparian continuity by linking remnant tracts of vegetation through both natural regeneration and additional native plantings. Short-term goals in a site that performed very poorly, such as MACR2 might be to erect riparian fencing, undertake native plantings and monitor weeds, while long-term goals for the site may be to introduce woody debris and link riparian plantings with those of neighbouring sites, such as MACR3 and MACR4.

Following this process for the Kempsey LGA, recommended investment priorities in the short- to intermediate-term are as follows:

1. Collobrate with DPI Fisheries to replace the causeway on Dowlings Falls Road (TOOC1). This will significantly improve the longitudinal movement of sediment, water, nutrients and biota such as fish. Combining this with the replacement of the causeway on Moparrabah Road (between TOOC1 and TOOC2) will remove the two significant fish barriers from the Toorumbee Creek subcatchment and reconnect significant areas of good-quality habitat for native fish species.
2. Rehabilitate the saltmarsh community on the left bank of lower Spencers Creek (SPEC1) by working with landowners to fence the riparian zone to exclude stock and remove the invasive *Juncus acutus*. A relatively small investment is likely to significantly improve the saltmarsh habitat over time.
3. Protect subcatchments containing high-quality aquatic ecosystems in Five Day Creek and Nulla Nulla Creek and promote riparian fencing, off-stream watering of stock and regeneration/revegetation of native riparian plants. Despite significant clearing and grazing in Five Day Creek and Nulla Nulla Creek, Five Day Creek supported excellent aquatic macroinvertebrate communities and Nulla Nulla Creek had good water quality.
4. Maintain forested areas in the escarpment ranges and midland hills. These areas are critical in improving the very poor water quality exported from tableland reaches, such as by reducing high nutrient loads.
5. Improve small areas of poor-quality habitat upstream of good-quality habitat in Toorumbee Creek. Riparian fencing and off-stream stock watering in the reaches upstream and downstream of TOOC3 will improve riparian condition, aquatic habitat and water quality upstream of the existing good-quality habit located lower in the catchment. Over time, this will connect good-quality riparian and aquatic habitat in the upper catchment to good-quality habitat in the mid catchment.

6. Investigate the source of elevated nutrients in the subcatchments of Warbro Brook, Toorumbee Creek, Hickeys Creek, Mungay Creek, Collambatti Creek, Clybucca Creek, Kinchela Creek, Spencers Creek, the Belmore River and the North Arm of the Macleay River.

4.2 Subcatchment summaries

4.2.1 Tableland tributaries

Gara River

- Geomorphic condition was poor at GARR3: significant bank erosion on right bank.
- Riparian condition was very poor at GARR3: extremely disturbed riparian zone with only understory and macrophytes.
- Water quality was very poor at GARR3: persistent high nutrient concentrations (TP, TN, NOx, SRP).
- Aquatic macroinvertebrates were very poor at GARR3: below average total abundance, family richness, EPT score and SIGNAL2 score.

- Geomorphic condition was poor at GARR2: severe erosion on left bank, moderate on left bank and significant slumping on right bank.
- Riparian condition was very poor at GARR2: extremely disturbed riparian zone with sparse midstory and canopy cover.
- Water quality was very poor at GARR2: persistent high nutrient concentrations (TP, TN, NOx, SRP).
- Aquatic macroinvertebrates were very poor at GARR2: below average total abundance, family richness and EPT score.

- Geomorphic condition was good at GARR1: minimal erosion on left bank associated with human trails.
- Riparian condition was good at GARR1: minimal disturbance and contained all structural layers.
- Water quality was very poor at GARR1: persistent high nutrient concentrations (TP, TN, NOx, SRP).
- Aquatic macroinvertebrates were poor at GARR2: below average total abundance, family richness and EPT score.

Management Priorities – GARR1, GARR2 and GARR3

- Weed monitoring: for the movement and spread of weed species
- Weed control: for the removal of noxious and environmental weed species
- Investigate sources of elevated nutrient inputs (nitrogen and phosphorus) in the subcatchment and identify remediation options available

Management Priorities – GARR2 and GARR3

- Native riparian plantings: for site rehabilitation, native regeneration assistance, increased riparian continuity and connectivity to larger tracts of remnant vegetation, reduce indirect nutrient inputs to channel
- Riparian fencing: to reduce livestock impact, encourage regeneration of native vegetation, accumulation of woody debris, to reduce streambank erosion, and reduce direct nutrient inputs to channel

Management Priorities – GARR2

- Phase out Willow: promotion of native canopy species and Willow removal over time

Management Priorities – GARR3

- Use best practice techniques to stabilize stream banks and protect riparian zones

Commisioners Waters

- Geomorphic condition was poor at COMW1: severe bank erosion on both banks.
- Riparian condition was very poor at COMW1: extremely disturbed riparian zone lacking a canopy layer.
- Water quality was very poor at COMW1: persistent very high nutrient concentrations (TP, TN, NOx, SRP), and consistent high algal productivity.
- Aquatic macroinvertebrates were very poor at COMW1: below average total abundance, family richness, EPT score and SIGNAL2 score.

Management Priorities – COMW1

- Weed monitoring: for the movement and spread of weed species
- Weed control: for the removal of noxious and environmental weed species
- Riparian fencing: to reduce livestock impact, encourage regeneration of native vegetation, accumulation of woody debris,reduce streambank erosion and reduce direct nutrient inputs to channel
- Native riparian plantings: for site rehabilitation, native regeneration assistance, increased riparian continuity and connectivity to larger tracts of remnant vegetation, reduce indirect nutrient inputs to channel
- Phase out Willow: promotion of native canopy species and Willow removal over time
- Use best practice techniques to stabilize stream banks and protect riparian zones
- Investigate sources of high nutrient inputs (nitrogen and phosphorus) in the subcatchment and identify remediation options available

Salisbury Waters

- Geomorphic condition was poor at SALW1: significant erosion on right bank, moderate erosion on left bank.
- Riparian condition was very poor at SALW1: extremely disturbed riparian zone with exotic weed species.
- Water quality was very poor at SALW1: persistent very high nutrient concentrations (TP, TN, NOx, SRP). SRP was up to 33 times the ANZECC trigger value.
- Aquatic macroinvertebrates were very poor at SALW1: below average total abundance, family richness, EPT score and SIGNAL2 score. Second-lowest site score in Macleay catchment.

Management Priorities – SALW1

- Weed monitoring: for the movement and spread of weed species
- Weed control: for the removal of noxious and environmental weed species
- Riparian fencing: to reduce livestock impact, encourage regeneration of native vegetation, accumulation of woody debris,reduce streambank erosion, and reduce direct nutrient inputs to channel
- Use best practice techniques to stabilize stream banks and protect riparian zones
- Native riparian plantings: for site rehabilitation, native regeneration assistance, increased riparian continuity and connectivity to larger tracts of remnant vegetation, reduce indirect nutrient inputs to channel
- Phase out Willow: promotion of native canopy species and Willow removal over time
- Investigate sources of high nutrient inputs (SRP) in the subcatchment and remediation options available

Apsley River

- Geomorphic condition was good at APSR1: no bank erosion and moderate bed complexity.
- Riparian condition was good at APSR1: mildly disturbed riparian zone with some weed species.
- Water quality was very poor at APSR1: persistent very high nutrient concentrations (TP, TN, NOx, SRP). NOx was up to 14 times the ANZECC trigger value.
- Aquatic macroinvertebrates were very poor at ASPR1: below average total abundance, family richness, EPT score and SIGNAL2 score.

Management Priorities – APSR1

- Weed monitoring: for the movement and spread of weed species
- Weed control: for the removal of noxious and environmental weed species
- Native riparian plantings: for site rehabilitation, native regeneration assistance, increased riparian continuity and connectivity to larger tracts of remnant vegetation
- Investigate sources of elevated nutrient inputs (nitrogen and phosphorus) in the subcatchment and remediation options available

Tia River

- Geomorphic condition was moderate at TIAR1: severe erosion on left bank and significant erosion on right bank.
- Riparian condition was very poor at TIAR1: extremely disturbed riparian zone lacking midstorey and canopy structural layers.
- Water quality was poor at TIAR1: persistent very high nutrient concentrations (TP, TN, NOx, SRP). NOx was up to 15 times the ANZECC trigger value.
- Aquatic macroinvertebrates were very poor at TIAR1: below average total abundance, family richness, EPT score and SIGNAL2 score.

Management Priorities – TIAR1

- Weed monitoring: for the movement and spread of weed species
- Weed control: for the removal of noxious and environmental weed species
- Introduction of woody debris: for bank stabilisation and the provision of habitat for flora and fauna
- Riparian fencing: to reduce livestock impact, encourage regeneration of native vegetation, accumulation of woody debris, to reduce streambank erosion, and reduce direct nutrient inputs to the channel
- Use best practice techniques to stabilize stream banks and protect riparian zones
- Native riparian plantings: for site rehabilitation, native regeneration assistance, increased riparian continuity and connectivity to larger tracts of remnant vegetation, and to reduce indirect nutrient inputs to the channel
- Phase out Willow: promotion of native canopy species and Willow removal over time
- Investigate sources of high nutrient inputs (nitrogen and phosphorus) in the subcatchment and remediation options available

Yarrowitch River

- Geomorphic condition was poor at YARR1: severe erosion on both banks.
- Riparian condition was poor at YARR1: highly disturbed riparian zone with weeds and noxious species present.
- Water quality was very poor at YARR1: persistent very high nutrient concentrations (TP, TN, NOx, SRP). NOx was up to 26 times the ANZECC trigger value.
- Aquatic macroinvertebrates were moderate at YARR1: with at or above average total abundance, family richness and EPT score, and below average SIGNAL2 score.

Management Priorities – YARR1

- Weed monitoring: for the movement and spread of weed species
- Weed control: for the removal of noxious and environmental weed species
- Riparian fencing: to reduce livestock impact, encourage regeneration of native vegetation, accumulation of woody debris, to reduce streambank erosion, and reduce the direct inputs of nutrients to the channel
- Native riparian plantings: for site rehabilitation, native regeneration assistance, increased riparian continuity and connectivity to larger tracts of remnant vegetation, and to reduce indirect nutrient inputs to the channel
- Phase out Willow: promotion of native canopy species and Willow removal over time
- Investigate sources of high nutrient inputs (nitrogen and phosphorus) in the subcatchment and remediation options available

Bakers Creek

- Geomorphic condition was good at BAKC1: minimal erosion on left bank and good streambed complexity.
- Riparian condition was very good at BAKC1: low disturbance riparian zone with some noxious weed species.
- Water quality was poor at BAKC1: persistent high nutrient concentrations (TP, TN, NOx, SRP). NOx was up to 13 times the ANZECC trigger value.
- Water column Sb ranged from 37 to 96 times the ANZECC guidelines for healthy aquatic ecosystems. Sediment Sb ranged from 72 to 164 the national sediment low guideline value.
- Water column As ranged from 1.4 to 2.7 times the ANZECC guidelines for healthy aquatic ecosystems. Sediment As ranged from 4.4 to 7 times the national sediment low guideline value.
- Aquatic macroinvertebrates were moderate at BAKC1: above average total abundance, family richness, EPT score and SIGNAL2 score.

Management Priorities – BAKC1

- Weed monitoring: for the movement and spread of weed species
- Weed control: for the removal of various noxious and environmental weed species, specifically Blackberry (*Rubus sp.*)
- Pest species control: to reduce streambank erosion and the spread of exotic species and promote native midstory and understory species
- Investigate sources of elevated nutrient inputs (nitrogen and phosphorus) in the subcatchment and remediation options available

Wollomombi River

- Geomorphic condition was moderate at WOLR1: moderate slumping of both banks and bed complexity is reduced by a sand slug.
- Riparian condition was moderate at WOLR1: moderately disturbed riparian zone impacted by noxious weeds in the understory.
- Water quality was very poor at WOLR1: persistent very high nutrient concentrations (TP, TN, NOx, SRP). TN was up to 11 times the ANZECC trigger value. NOx was up to 13 times the ANZECC trigger value.
- Aquatic macroinvertebrates were poor at WOLR1: below average total abundance and family richness, and above average EPT score and SIGNAL2 score.

Management Priorities – WOLR1

- Weed monitoring: for the movement and spread of weed species
- Weed control: for the removal of noxious and environmental weed species, namely Willow (*Salix sp.*) and Blackberry (*Rubus sp.*).
- Riparian fencing: to reduce livestock impact, encourage regeneration of native vegetation, accumulation of woody debris and to reduce streambank erosion, and reduce direct nutrient inputs to the channel
- Investigate sources of high nutrient inputs (nitrogen and phosphorus) in the subcatchment and remediation options available

Chandler River

- Geomorphic condition was moderate at CHAR1: significant slumping on both banks and the streambed is impacted by a sand slug.
- Riparian condition was good at CHAR1: moderately disturbed riparian zone lacking midstorey and canopy structural layers.
- Water quality was very poor at CHAR1: persistent very high nutrient concentrations (TP, TN, NOx, SRP). NOx was up to 10 times the ANZECC trigger value.
- Aquatic macroinvertebrates were poor at CHAR1: below average EPT score and SIGNAL2 score, and above average total abundance, family richness.

Management Priorities – CHAR1

- Weed monitoring: for the movement and spread of weed species
- Weed control: for the removal of noxious and environmental weed species
- Riparian fencing: to reduce livestock impact, encourage regeneration of native vegetation, accumulation of woody debris, to reduce streambank erosion, and to reduce direct nutrient inputs to the channel
- Native riparian plantings: for site rehabilitation, native regeneration assistance, increased riparian continuity and connectivity to larger tracts of remnant vegetation, and to reduce direct nutrient inputs to the channel
- Investigate sources of nutrients (nitrogen and phosphorus) in the subcatchment and remediation options available

Oaky River

- Geomorphic condition was poor at OAKR1: significant erosion on left bank and moderate erosion on right bank.
- Riparian condition was poor at OAKR1: highly disturbed riparian zone lacking a canopy layer.
- Water quality was poor at OAKR1: persistent very high nutrient concentrations (TP, TN, NOx, SRP). TN was up to 8 times the ANZECC trigger value, NOx was up to 11 times the ANZECC trigger value.
- Aquatic macroinvertebrates were poor at OAKR1: at or above average total abundance, family richness, EPT score and SIGNAL2 score.

Management Priorities – OAKR1

- Weed monitoring: for the movement and spread of weed species
- Weed control: for the removal of noxious and environmental weed species
- Introduction of woody debris: for bank stabilisation and the provision of habitat for flora and fauna
- Riparian fencing: to reduce livestock impact, encourage regeneration of native vegetation, accumulation of woody debris, to reduce streambank erosion and reduce direct nutrient inputs to the channel
- Native riparian plantings: for site rehabilitation, native regeneration assistance, increased riparian continuity and connectivity to larger tracts of remnant vegetation, and to reduce indirect nutrient inputs to the channel
- Investigate elevated nutrient sources (nitrogen and phosphorus) within the subcatchment and remediation options available

Styx River

- Geomorphic condition was excellent at STYR1: No bank erosion and very good bed complexity.
- Riparian condition was very good at STYR1: low disturbance riparian zone with remnant vegetation in all structural layers.
- Water quality was poor at STYR1: persistent high nutrient concentrations (TP, TN, NOx, SRP). TP was up to 15 times the ANZECC trigger value.
- Aquatic macroinvertebrates were moderate at TIAR1: below average total abundance, and above average family richness, EPT score and SIGNAL2 score. The highest grade of the Tableland tributaries.

Management Priorities – STYR1

- Weed monitoring: for the movement and spread of weed species
- Weed control: for the removal of various noxious and environmental weed species, specifically Willow (*Salix sp.*) and Egeria (*Egeria densa*)
- Investigate elevated nutrient sources (nitrogen and phosphorus) within the subcatchment and remediation options available

4.2.2 Macleay River main stem

Freshwater reaches

- Geomorphic condition was good at MACR10: concentrated bank erosion due to 4wd traffic.
- Riparian condition was good at MACR10: mildly disturbed riparian zone with weeds through midstory and understory.
- Water quality was poor at MACR10: persistent high nutrient concentrations (TP, TN, NOx, SRP).
- Aquatic macroinvertebrates were moderate at MACR10: above average total abundance, family richness, EPT score and SIGNAL2 score.

- Geomorphic condition was good at MACR9: minor erosion on right bank.
- Riparian condition was poor at MACR9: highly disturbed riparian zone with no large trees and noxious weeds in the canopy and understory.
- Water quality was moderate at MACR9: persistent high nutrient concentrations (TP, TN, NOx, SRP).
- Aquatic macroinvertebrates were moderate at MACR9: below average total abundance, family richness, EPT score and SIGNAL2 score.

- Geomorphic condition was moderate at MACR8: significant slumping on left bank and moderate erosion on right bank.
- Riparian condition was poor at MACR8: highly disturbed with noxious weeds in the midstory and macrophyte layers.
- Water quality was moderate at MACR8: persistent high nutrient concentrations (TP, TN, NOx, SRP).
- Aquatic macroinvertebrates were poor at MACR8: below average total abundance, family richness and EPT score.

- Geomorphic condition was moderate at MACR7: minor erosion on right bank.
- Riparian condition was poor at MACR7: highly disturbed with noxious weeds in the midstory and understory.
- Water quality was good at MACR7: persistent high nutrient concentrations (TP, TN, NOx, SRP).
- Aquatic macroinvertebrates were very poor at MACR7: below average total abundance, family richness, and score and SIGNAL2 score. The lowest grade of the freshwater Macleay.

Management Priorities – MACR7, MACR8, MACR9, MACR10

- Weed monitoring: for the movement and spread of weed species
- Weed control: for the removal of various noxious and environmental weed species, specifically Camphor Laurel (*Cinnamomum camphora*) and Willow (*Salix* sp.), Lantana (*Lantana camara*), Noogoora Burr (*Xanthium occidentale*), Spiny Pest Pear (*Opuntia stricta*), Mother of Millions (*Bryophyllum delagoense*), Blackberry (*Rubus sp.*), Cat's Claw Creeper (*Dolichandra unguis-cati*) and Balloon Vine (*Cardiospermum grandiflorum*)
- Riparian fencing: to reduce livestock impact, encourage regeneration of native vegetation, accumulation of woody debris, to reduce streambank erosion, and to reduce direct nutrient inputs to the channel
- Investigate elevated nutrient sources (nitrogen and phosphorus) within the subcatchment and remediation options available
- Investigate movement, depositional and accumulation pathways of As and Sb in the sediments and aquatic food web

Management Priorities – MACR7, MACR8, MACR9

- Native riparian plantings: for site rehabilitation, native regeneration assistance, increased riparian continuity and connectivity to larger tracts of remnant vegetation, and to reduce indirect nutrient inputs to the channel

Management Priorities – MACR9

- Phase out Camphor Laurel: planting of native canopy species to replace strategic removal of exotic canopy

Macleay estuary

- Geomorphic condition was poor at MACR6: significant erosion on left bank and moderate slumping on right bank.
- Riparian condition was poor at MACR6: highly disturbed riparian zone with noxious weeds in the midstory and understory.
- Water quality was moderate at MACR6: persistent high nutrient concentrations (TP, TN, NOx, SRP). NOx up to 18 times the ANZECC trigger value.

- Geomorphic condition was moderate at MACR5: moderate erosion on both banks.
- Riparian condition was poor at MACR5: highly disturbed riparian zone with noxious weeds in the midstory and understory.
- Water quality was very poor at MACR5: persistent high nutrient concentrations (TP, TN, NOx, SRP). NOx up to 25 times the ANZECC trigger value.

- Geomorphic condition was moderate at MACR4: significant erosion on both banks.
- Riparian condition was very poor at MACR4: extremely disturbed riparian zone with noxious weeds in all structural layers.
- Water quality was poor at MACR4: persistent high nutrient concentrations (TP, TN, NOx, SRP). NOx up to 39 times the ANZECC trigger value.

- Geomorphic condition was moderate at MACR3: significant bank erosion on both banks.
- Riparian condition was very poor at MACR3: extremely disturbed riparian zone with noxious weeds in all structural layers.
- Water quality was poor at MACR3: persistent high nutrient concentrations (TP, TN, NOx, SRP). NOx up to 29 times the ANZECC trigger value.

- Geomorphic condition was moderate at MACR2: rock revetment controls both banks.
- Riparian condition was very poor at MACR2: extremely disturbed riparian zone with no midstory or canopy structural layers.
- Water quality was poor at MACRR2: persistent high nutrient concentrations (TP, TN, NOx, SRP). NOx up to 25 times the ANZECC trigger value.

- Geomorphic condition was moderate at MACR1: rock revetment controls both banks.
- Riparian condition was poor at MACR1: highly disturbed with noxious weeds in the midstory and understory.
- Water quality was moderate at MACR1: persistent high nutrient concentrations (TP, TN, NOx, SRP). NOx up to 27 times the ANZECC trigger value.

Management Priorities – MACR1, MACR2, MACR3, MACR4, MACR5, MACR6

- Weed monitoring: for the movement and spread of weed species
- Weed control: for the removal of various noxious and environmental weed species, specifically Camphor Laurel (*Cinnamomum camphora*), Coral Tree (*Erythrina crista-galli*), Lantana (*Lantana camara*), Small-leaved Privet (*Ligustrum sinense*) and Coastal Morning Glory (*Ipomoea cairica*)
- Native riparian plantings: for site rehabilitation, native regeneration assistance, increased riparian width, continuity and connectivity to larger tracts of remnant vegetation, and to reduce indirect nutrient inputs to the channel
- Phase out exotic dominants: planting of native canopy species to replace strategic removal of exotic canopy and midstory species
- Investigate sources of elevated nutrients (nitrogen) in the subcatchment and remediation options available
- Investigate pathways of As and Sb movement, deposition and accumulation in the Macleay estuary and floodplain
- Investigate As and Sb floodwater export from Macleay catchment to nearshore coastal habitats
- Investigate As and Sb uptake and accumulation in Macleay estuarine food web

Management Priorities – MACR2, MACR3, MACR4

- Bank stabilisation using best practice techniques: stabilize banks and provide habitat for flora and fauna

Management Priorities – MACR2, MACR3, MACR6

- Riparian fencing: to reduce livestock impact, encourage regeneration of native vegetation, accumulation of woody debris, to reduce streambank erosion, and to reduce direct nutrient inputs to the channel

4.2.3 Freshwater tributaries

Georges Creek

- Geomorphic condition was moderate at GEOC1: significant erosion on right bank, minor erosion on left bank.
- Riparian condition was moderate at GEOC1: moderately disturbed riparian zone with exotic weed species.
- Water quality was very poor at GEOC1: persistent very high nutrient concentrations (TP, TN, NOx, SRP). Maximum NOx was 23 times the ANZECC trigger value.
- Aquatic macroinvertebrates were very good at GEOC1: well above average total abundance, family richness, EPT score and SIGNAL2 score. Second-highest site score in Macleay catchment.

Management Priorities – GEOC1

- Weed monitoring: for the movement and spread of weed species
- Weed control: for the removal of various noxious and environmental weed species, specifically Willow (*Salix* sp.), Lantana (*Lantana camara*) and Blackberry (*Rubus sp.*)
- Riparian fencing: to reduce livestock impact, encourage regeneration of native vegetation, accumulation of woody debris, reduce streambank erosion, and reduce direct nutrient inputs to channel
- Investigate sources of high nutrient inputs (nitrogen and phosphorus) in the subcatchment and remediation options available

Five Day Creek

- Geomorphic condition was poor at FIVC3: significant erosion on both banks.
- Riparian condition was moderate at FIVC3: moderately disturbed riparian zone with exotic weed species.
- Water quality was moderate at FIVC3: persistently high nutrient concentrations (TP, TN, NOx, SRP). Maximum NOx was 5 times the ANZECC trigger value.
- Aquatic macroinvertebrates were excellent at FIVC3: well above average total abundance, family richness, EPT score and SIGNAL2 score. Highest site score in Macleay catchment.

- Geomorphic condition was poor at FIVC2: significant erosion on left bank, minor erosion on right bank.
- Riparian condition was poor at FIVC2: highly disturbed riparian zone with exotic weed species.
- Water quality was moderate at FIVC2: persistently high nutrient concentrations (TP, TN, NOx, SRP). Maximum NOx was 12 times the ANZECC trigger value.
- Aquatic macroinvertebrates were very good at FIVC2: well above average total abundance, family richness, EPT score and SIGNAL2 score. Third-highest site score in Macleay catchment.

- Geomorphic condition was moderate at FIVC1: minor erosion on both banks.
- Riparian condition was moderate at FIVC1: moderately disturbed riparian zone with exotic weed species.
- Water quality was moderate at FIVC1: persistently high nutrient concentrations (TP, TN, NOx, SRP). Maximum NOx was 6 times the ANZECC trigger value.
- Aquatic macroinvertebrates were moderate at FIVC1: well above average total abundance, family richness, EPT score and SIGNAL2 score.

Management Priorities – FIVC1, FIVC2 and FIVC3

- Weed monitoring: for the movement and spread of weed species
- Weed control: for the removal of various noxious and environmental weed species, namely Tropical Soda Apple (*Solanum viarum*), Cat's Claw Creeper (*Dolichandra unguis-cati*) Small-leaved Privet (*Ligustrum sinense*) and Lantana (*Lantana camara*)
- Riparian fencing: to reduce livestock impact, encourage regeneration of native vegetation, accumulation of woody debris, reduce streambank erosion, and reduce direct nutrient inputs to channel
- Investigate sources of high nutrient inputs (nitrogen and phosphorus) in the subcatchment and remediation options available

Management Priorities – FIVC2

- Native riparian plantings: for site rehabilitation, native regeneration assistance, increased riparian continuity and connectivity to larger tracts of remnant vegetation, reduce indirect nutrient inputs to channel

Nulla Nulla Creek

- Geomorphic condition was moderate at NULC1: significant erosion on the left bank, severe erosion on the right bank.
- Riparian condition was moderate at NULC1: highly disturbed riparian zone with exotic weed species.
- Water quality was good at NULC1: relatively low nutrient concentrations (TP, TN, NOx, SRP). Maximum NOx was 6 times the ANZECC trigger value. Equal highest site score in Macleay catchment.
- Aquatic macroinvertebrates were poor at NULC1: family richness and EPT below average score. At or above average total abundance and SIGNAL2 score.

Management Priorities – NULC1

- Weed monitoring: for the movement and spread of weed species
- Weed control: for the removal of noxious and environmental weed species, namely Lantana (*Lantana camara*) and Small-leaved Privet (*Ligustrum sinense*).
- Riparian fencing: to reduce livestock impact, encourage regeneration of native vegetation, accumulation of woody debris, reduce streambank erosion, and reduce direct nutrient inputs to channel

Warbro Book

- Geomorphic condition was moderate at WARB1: minor erosion on right bank, minor erosion on left bank.
- Riparian condition was moderate at WARB1: highly disturbed riparian zone with exotic weed species.
- Water quality was very poor at WARB1: persistent very high nutrient concentrations (TP, TN, NOx, SRP). Maximum NOx was 11 times the ANZECC trigger value.
- Aquatic macroinvertebrates were moderate at WARB1: EPT below average score. At or above average family richness, total abundance and SIGNAL2 score.

Management Priorities – WARB1

- Weed monitoring: for the movement and spread of weed species
- Weed control: for the removal of various noxious and environmental weed species, specifically Cat's Claw Creeper (*Dolichandra unguis-cati*) and Lantana (*Lantana camara*)
- Riparian fencing: to reduce livestock impact, encourage regeneration of native vegetation, accumulation of woody debris, reduce streambank erosion, and reduce direct nutrient inputs to channel
- Investigate sources of high nutrient inputs (nitrogen and phosphorus) in the subcatchment and remediation options available

Toorumbee Creek

- Geomorphic condition was poor at TOOC3: significant erosion on both banks.
- Riparian condition was moderate at TOOC3: highly disturbed riparian zone with exotic weed species.
- Water quality was poor at TOOC3: persistently high nutrient concentrations (TP, TN, NOx, SRP). Maximum NOx was 15 times and maximum SRP was 7.4 times the ANZECC trigger value.
- Aquatic macroinvertebrates were moderate at TOOC3: above average total abundance, family richness, EPT score and SIGNAL2 score.

- Geomorphic condition was moderate at TOOC2: significant erosion on left bank, minor erosion on right bank.
- Riparian condition was good at TOOC2: mildly disturbed riparian zone with exotic weed species.
- Water quality was good at TOOC2: relatively low nutrient concentrations (TP, TN, NOx, SRP). Maximum NOx was 14 times the ANZECC trigger value. Equal highest site score in Macleay catchment.
- Aquatic macroinvertebrates were moderate at TOOC2: above average total abundance, family richness, EPT score and SIGNAL2 score.

- Geomorphic condition was very poor at TOOC1: significant bed erosion, minor erosion on left bank, moderate erosion on right bank.
- Riparian condition was moderate at TOOC1: highly disturbed riparian zone with exotic weed species.
- Water quality was moderate at TOOC1: persistently high nutrient concentrations (TP, TN, NOx, SRP). Maximum NOx was 14 times and maximum SRP 14 times the ANZECC trigger value.
- Aquatic macroinvertebrates were moderate at TOOC1: above average total abundance, family richness, EPT score and SIGNAL2 score.

Management Priorities – TOOC1

- Replace blocked pipe and low causeway on Dowling Falls Road: improve sediment movement, fish access, flushing of high nutrients and algae

Management Priorities – TOOC1, TOOC2 and TOOC3

- Weed monitoring: for the movement and spread of weed species
- Weed control: for the removal of noxious and environmental weed species, namely Lantana (*Lantana camara*), Camphor Laurel (*Cinamomum camphora*) and Arsenic Bush (*Senna semptemtrionalis*)
- Investigate sources of high nutrient inputs (nitrogen and phosphorus) in the subcatchment and remediation options available

Management Priorities – TOOC1 and TOOC3

- Riparian fencing: to reduce livestock impact, encourage regeneration of native vegetation, accumulation of woody debris, reduce streambank erosion, and reduce direct nutrient inputs to channel

Management Priorities – TOOC2 and TOOC3

- Introduction of woody debris: for bank stabilisation and the provision of habitat for flora and fauna

Hickeys Creek

- Geomorphic condition was moderate at HICC1: minor erosion on right bank, moderate erosion on left bank.
- Riparian condition was moderate at HICC1: moderately disturbed riparian zone with exotic weed species.
- Water quality was poor at HICC1: consistent high nutrient concentrations (TP, TN, NOx, SRP). NOx up to 14 times ANZECC trigger value.
- Aquatic macroinvertebrates were poor at HICC1: Total abundance above, average family richness, EPT score and SIGNAL2 score below average score.

Management Priorities – HICC1

- Weed monitoring: for the movement and spread of weed species
- Weed control: for the removal of noxious and environmental weed species, namely Lantana (*Lantana camara*), Small-leaved Privet (*Ligustrum sinense*)
- Riparian fencing: to reduce livestock impact, encourage regeneration of native vegetation, accumulation of woody debris and to reduce streambank erosion
- Investigate sources of high nutrient inputs (nitrogen and phosphorus) in the subcatchment and remediation options available

Mungay Creek

- Geomorphic condition was modeate at MUNC1: significant erosion on both banks.
- Riparian condition was good at MUNC1: low disturbance riparian zone with noxious weeds in midstory.
- Water quality was poor at MUNC1: persistently high nutrient concentrations (TP, TN, NOx, SRP). TP up to 14 times the ANZECC trigger value.
- Aquatic macroinvertebrates were very poor at MUNC1: below average total abundance, family richness, EPT score and SIGNAL2 score.

Management Priorities – MUNC1

- Weed monitoring: for the movement and spread of weed species
- Weed control: for the removal of various noxious and environmental weed species, specifically Lantana (*Lantana camara*)
- Riparian fencing: to reduce livestock impact, encourage regeneration of native vegetation, accumulation of woody debris, to reduce streambank erosion, and to reduce direct nutrient inputs to the channel
- Investigate sources of high nutrient inputs (nitrogen and phosphorus) in the subcatchment and remediation options available

Dungay Creek

- Geomorphic condition was good at DUNC3: no bank erosion observed at site.
- Riparian condition was moderate at DUNC3: mildly disturbed riparian zone with noxious weeds in midstory and understory.
- Water quality was good at DUNC3: high nutrient concentrations (TP, TN, NOx, SRP).
- Aquatic macroinvertebrates were moderate at DUNC3: below average total abundance, above average family richness, EPT score and SIGNAL2 score.

- Geomorphic condition was poor at DUNC2: severe erosion both banks.
- Riparian condition was moderate at DUNC2: moderately disturbed riparian zone with noxious weeds in midstory and understory.
- Water quality was moderate at DUNC2: high nutrient concentrations (TP, TN, NOx, SRP).
- Aquatic macroinvertebrates were moderate at DUNC2: below average family richness, EPT score and SIGNAL2 score, and above average total abundance.

- Geomorphic condition was moderate at DUNC1: minor erosion on both banks.
- Riparian condition was moderate at DUNC1: moderately disturbed riparian zone with noxious weeds in understory and macrophyte layers.
- Water quality was moderate at DUNC1: high nutrient concentrations (TP, TN, NOx, SRP).
- Aquatic macroinvertebrates were poor at DUNC1: above average total abundance, family richness and EPT score, and below average SIGNAL2 score.

Management Priorities – DUNC1, DUNC2 and DUNC3

- Weed monitoring: for the movement and spread of weed species
- Weed control: for the removal of various noxious and environmental weed species, namely Willow (Salix sp.), Camphor Laurel (*Cinamomum camphora*), Lantana (*Lantana camara*) and Small-leaved Privet (*Ligustrum sinense*)
- Investigate sources of high nutrient inputs (nitrogen and phosphorus) in the subcatchment and remediation options available

Management Priorities – DUNC2 and DUNC3

- Riparian fencing: to reduce livestock impact, encourage regeneration of native vegetation, accumulation of woody debris, to reduce streambank erosion, and to reduce direct nutrient inputs to the channel

Management Priorities – DUNC1

- Introduction of woody debris: for bank stabilisation and the provision of habitat for flora and fauna

Management Priorities – DUNC2

- Use best practice techniques to stabilize stream banks and protect riparian zones

Collombatti Creek

- Geomorphic condition was moderate at COLC1: moderate erosion on left bank and minor erosion on right bank.
- Riparian condition was moderate at COLC1: moderately disturbed riparian zone with noxious weeds in midstory and understory.
- Water quality was poor at COLC1: persistent high nutrient concentrations (TP, TN, NOx, SRP). TP up to 35 times and SRP up to 58 times the ANZECC trigger values.
- Aquatic macroinvertebrates were very poor at COLC1: below average total abundance, family richness, EPT score and SIGNAL2 score. Lowest site score in the Macleay catchment.

Management Priorities – COLC1

- Weed monitoring: for the movement and spread of weed species
- Weed control: for the removal of various noxious and environmental weed species, specifically Camphor Laurel (*Cinnamomum camphora*) and Lantana (*Lantana camara*)
- Riparian fencing: to reduce livestock impact, encourage regeneration of native vegetation, accumulation of woody debris, to reduce streambank erosion, and to reduce direct nutrient inputs to the channel
- Native riparian plantings: for site rehabilitation, native regeneration assistance, increased riparian width, continuity and connectivity to larger tracts of remnant vegetation, and to reduce indirect nutrient inputs to the channel
- Investigate sources of very high nutrient inputs (nitrogen and phosphorus) in the subcatchment and remediation options available

4.2.4 Estuarine tributaries

Belmore River

- Geomorphic condition was moderate at BELR1 moderate undercutting due to tidal action.
- Riparian condition was poor at BELR1: highly disturbed riparian zone with noxious weeds dominating all structural layers.
- Water quality was very poor at BELR1: persistent high nutrient concentrations (TP, TN, NOx, SRP). NOx up to 48 times the ANZECC trigger value.

Management Priorities – BELR1

- Weed monitoring: for the movement and spread of weed species
- Weed control: for the removal of various noxious and environmental weed species, specifically Camphor Laurel (*Cinnamomum camphora*), Coral Tree (*Erythrina crista-galli*), Lantana (*Lantana camara*), Broad-leaf Privet (*Ligustrum lucidum*), Small-leaved Privet (*Ligustrum sinense*) and Coastal Morning Glory (*Ipomoea cairica*)
- Phase out exotic dominants: planting of native canopy species to replace strategic removal of exotic canopy and midstory species
- Native riparian plantings: for site rehabilitation, native regeneration assistance, increased riparian width, continuity and connectivity to larger tracts of remnant vegetation, and to reduce indirect nutrient inputs to the channel
- Bank stabilisation using best practice techniques: stabilize banks and provide habitat for flora and fauna
- Riparian fencing: to reduce livestock impact, encourage regeneration of native vegetation, accumulation of woody debris, to reduce streambank erosion, and to reduce direct nutrient inputs to the channel
- Investigate sources of very high nutrient inputs (nitrogen and phosphorus) in the subcatchment and remediation options available
- Investigate effects of floodplain swamp discharge on water quality (pH, DO%, turbidity, nutrients)

Kinchela Creek

- Geomorphic condition was moderate at KINC1: significant undercutting due to tidal action.
- Riparian condition was very poor at KINC1: extremely disturbed riparian zone with noxious weeds dominating all structural layers.
- Water quality was very poor at KINC1: persistent high nutrient concentrations (TP, TN, NOx, SRP). NOx up to 52 times the ANZECC trigger value.

Management Priorities – KINC1

- Weed monitoring: for the movement and spread of weed species
- Weed control: for the removal of various noxious and environmental weed species, specifically Coral Tree (*Erythrina crista-galli*), Lantana (*Lantana camara*), Small-leaved Privet (*Ligustrum sinense*) and Coastal Morning Glory (*Ipomoea cairica*)
- Native riparian plantings: for site rehabilitation, native regeneration assistance, increased riparian width, continuity and connectivity to larger tracts of remnant vegetation, and to reduce indirect nutrient intputs to the channel
- Bank stabilisation using best practice techniques: stabilize banks and provide habitat for flora and fauna
- Widening riparian fencing: to accommodate and promote riparian vegetation width, reduce livestock impact, encourage regeneration of native vegetation, accumulation of woody debris, to reduce streambank erosion, and to reduce direct nutrient inputs to the channel
- Investigate sources of very high nutrient inputs (nitrogen and phosphorus) in the subcatchment and remediation options available
- Investigate effects of floodplain swamp discharge on water quality (pH, DO%, turbidity, nutrients)

Spencers Creek

- Geomorphic condition was moderate at SPEC1: severe erosion along left bank.
- Riparian condition was poor at SPEC1: very highly disturbed riparian zone with noxious weeds in the understory.
- Water quality was poor at SPEC1: persistent high nutrient concentrations (TP, TN, NOx, SRP). NOx up to 20 times the ANZECC trigger value.

Management Priorities – SPEC1

- Weed monitoring: for the movement and spread of weed species
- Weed control: for the removal of various noxious and environmental weed species, specifically *Sharp Rush (Juncus acutus)*
- Native riparian plantings: for site rehabilitation, native regeneration assistance, increased riparian width, continuity and connectivity to larger tracts of remnant vegetation, and to reduce indirect nutrient inputs to the channel
- Bank stabilisation using best practice techniques: stabilize banks and provide habitat for flora and fauna
- Riparian fencing: to reduce livestock impact, encourage regeneration of native vegetation, accumulation of woody debris, to reduce streambank erosion, and to reduce direct nutrient inputs to the channel
- Investigate sources of very high nutrient inputs (nitrogen and phosphorus) in the subcatchment and remediation options available

Clybucca Creek

- Geomorphic condition was good at CLYC1: minor undercutting due to tidal action.
- Riparian condition was moderate at CLYC1: mildly disturbed riparian zone with noxious weeds through midstory and understory.
- Water quality was poor at CLYC1: persistent high nutrient concentrations (TP, TN, NOx, SRP). NOx up to 27 times the ANZECC trigger value.

Management Priorities – CLYC1

- Weed monitoring: for the movement and spread of weed species
- Weed control: for the removal of various noxious and environmental weed species, specifically Coastal Morning Glory (*Ipomoea cairica*)
- Native riparian plantings: for site rehabilitation, native regeneration assistance, increased riparian width, continuity and connectivity to larger tracts of remnant vegetation, and to reduce indirect nutrient inputs to the channel
- Riparian fencing: to reduce livestock impact, encourage regeneration of native vegetation, accumulation of woody debris, to reduce streambank erosion and to reduce direct nutrient inputs to the channel
- Investigate sources of very high nutrient inputs (nitrogen and phosphorus) in the subcatchment and remediation options available
- Investigate effects of floodplain swamp discharge on water quality (pH, DO%, turbidity, nutrients)

North Arm Macleay River

- Geomorphic condition was good at NAMR1: no bank erosion observed at site.
- Riparian condition was very good at NAMR1: low disturbance riparian zone with weeds through midstory and understory.
- Water quality was poor at NAMR1: persistent high nutrient concentrations (TP, TN, NOx, SRP). NOx up to 18 times the ANZECC trigger value. SRP up to 53 times the ANZECC trigger value.

- Geomorphic condition was moderate at NAMR2: minor bank erosion due to high human traffic at Stuarts Point.
- Riparian condition was poor at NAMR2: highly disturbed riparian zone with noxious weeds through midstory and understory.
- Water quality was very poor at NAMR2: persistent high nutrient concentrations (TP, TN, NOx, SRP).

Management Priorities – NAMR1, NAMR2

- Weed monitoring: for the movement and spread of weed species
- Weed control: for the removal of various noxious and environmental weed species, specifically Camphor Laurel (*Cinnamomum camphora*), Lantana (*Lantana camara*), Groundsel Bush (*Baccharis halimifolia*), Bitou Bush (*Chrysanthemoides monilifera subsp. Rotundata*) Asparugus Fern (*Asparagus aethiopicus*) and Coastal Morning Glory (*Ipomoea cairica*)
- Riparian fencing: to reduce livestock impact, encourage regeneration of native vegetation, accumulation of woody debris, to maintain the current riparian condition, and reduce direct inputs of nutrients to the channel

Management Priorities – NAMR2

- Native riparian plantings: for site rehabilitation, native regeneration assistance, increased riparian width, continuity and connectivity to larger tracts of remnant vegetation, and to reduce indirect inputs of nutrients to the channel.

Management Priorities – NAMR2

- Investigate causes of very high nutrient concentrations to NAMR1 (including auditing the effect of onsite wastewater systems on SRP) and remediation options available

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APPENDIX 1 *Ecohealth data sheets.*

Date:________________________________

Site Name:___________________________ Site ID:_________________________

Location: Easting__________________ Northing____________ Datum _________

Decimal degrees - Lat _________ Long____________Elevation _______

Field Personnel ____

Start Time (24 hr) ________________________ End time (24hr) _________________

High Tide Time/Height _____________________ Low Tide Time/Height ____________

Equipment: (Make/Model)_______________________ Serial/ID number________________

Calibrated by: __________________________ Calibration Log Complete? Y N

Air Temp _________________________

Weather Conditions

Water Surface: ☐ flat ☐ choppy ☐ rough

Wind: ☐ nil ☐ light ☐ moderate

Rainfall: ☐ nil ☐ light ☐ moderate ☐ heavy in last ☐ 24 hours ☐ 2-5 days

Sky: ☐ sunny ☐ overcast

Depth (m)	Temp (C)	pH	Cond (mS/cm)	Salinity (ppt)	DO (mg/L)	DO (% sat)	Turb (NTU)
0.1							
1.0							

Ecohealth Water Quality Data Sheet (page 2)

Secchi Depth (m)	
Maximum depth (m)	
Water Velocity (m.sec^{-1}) – *freshwater sites only*	

Bacterial sample – *At mouth of estuary only*	Yes	No	Sample ID:	
Duplicate TN/TP sample	Yes	No	Sample ID:	
Duplicate SRP/NOx sample	Yes	No	Sample ID:	
Chl a volume filtered (mL)			Sample ID:	
TSS volume filtered (mL)			Sample ID:	

Samples Forwarded to (Lab Name): ____

Chain of custody form completed: Y N

Comments

APPENDIX 2 *Dominant plant species recorded at the 44 Ecohealth sites assessed in the 2015 survey. Rows in red indicate exotic species.*

						Tableland sites													Macleay River - freshwater sites				Macleay River - esturine sites						Coastal tributary sites						Freshwater tributary sites														
Growth Form	Native/Exotic	Family	Genus	Species	Common Name	APSR 1	BACK 1	CHAR 1	COMM 1	GARR 1	GARR 2	GARR 3	OAKC 1	SALW 1	STYX 1	TIAR 1	YARR 1	WOLR 1	MACR 7	MACR 8	MACR 9	MACR 10	MACR 1	MACR 2	MACR 3	MACR 4	MACR 5	MACR 6	CLYR 1	BELR 1	KINC 1	NAMR 1	NAMR 2	SPEC 1	COLC 1	DEEC 1	DUNC 1	DUNC 2	DUNC 3	FIVC 1	FIVC 2	FIVC 3	GEOC 1	HICC 1	NULC 1	TOOC 1	TOOC 2	TOOC 3	WARB 1
Graminoides	N	*Cyperaceae*	*Carex*	*fascicularis*	Tassel Sedge	Y									Y	Y	Y					Y														Y		Y	Y				Y						
Graminoides	N	*Cyperaceae*	*Carex*	*gaudichaudiana*	Fen Sedge							Y		Y																																			
Graminoides	N	*Cyperaceae*	*Carex*	*inversa*	Knob Sedge													Y													Y			Y															
Graminoides	N	*Cyperaceae*	*Carex*	*longebrachiata*	Bergalia Tussock																													Y										Y					
Graminoides	N	*Cyperaceae*	*Carex*	*sp.*	Carex														Y		Y																												
Graminoides	E	*Cyperaceae*	*Cyperus*	*eragrostis*	Umbrella Sedge	Y		Y	Y	Y	Y		Y	Y			Y	Y	Y		Y	Y			Y			Y					Y				Y		Y								Y		
Graminoides	N	*Cyperaceae*	*Cyperus*	*exaltatus*	Umbrella Sedge			Y							Y																																		
Graminoides	N	*Cyperaceae*	*Cyperus*	*polystachyos*	Bunchy Sedge																											Y																	
Graminoides	E	*Cyperaceae*	*Cyperus*	*rotundus*	Nut Grass			Y					Y																																				
Graminoides	E	*Cyperaceae*	*Cyperus*	*sesquiflorus*	White Knob Sedge																																											Y	
Graminoides	N	*Cyperaceae*	*Cyperus*	*sp.*	Cyperus										Y																Y		Y								Y						Y		
Graminoides	E	*Cyperaceae*	*Cyperus*	*papyrus*	Papyrus																					Y																							
Graminoides	N	*Cyperaceae*	*Ficinia*	*nodosa*	Knobby club-rush																		Y																										
Graminoides	N	*Cyperaceae*	*Fimbristylis*	*dichotoma*	Common Fringe Sedge																								Y			Y																	
Graminoides	N	*Cyperaceae*	*Fimbristylis*	*sp.*	Fringe Sedge						Y				Y										Y																								
Graminoides	N	*Cyperaceae*	*Ghania*	*sp.*	Saw Sedge														Y	Y												Y																	
Graminoides	E	*Juncaceae*	*Juncus*	*acutus*	Sharp Rush																													Y															
Graminoides	N	*Juncaceae*	*Juncus*	*australis*	Austral Rush										Y																																		
Graminoides	N	*Juncaceae*	*Juncus*	*krausii subsp. australiensis*	Sea Rush																				Y		Y		Y		Y	Y	Y	Y															
Graminoides	N	*Juncaceae*	*Juncus*	*usitatus*	Common Rush	Y	Y	Y		Y	Y	Y	Y	Y		Y	Y	Y	Y		Y	Y						Y					Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	
Graminoides	N	*Lomandraceae*	*Lomandra*	*hystrix*	Soft Lomandra										Y				Y	Y	Y	Y						Y							Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y		Y
Graminoides	N	*Lomandraceae*	*Lomandra*	*longifolia*	Spiny-headed Mat-rush	Y	Y	Y	Y	Y			Y	Y	Y	Y	Y	Y					Y																										
Grasses	E	*Poaceae*	*Aira*	*cupaniana*	Silvery Hairgrass													Y																															
Grasses	E	*Poaceae*	*Andropogon*	*viginicus*	Whisky Grass			Y					Y								Y														Y														
Grasses	E	*Poaceae*	*Anthoxanthum*	*odoratum*	Sweet Vernal Grass										Y	Y																																	
Grasses	N	*Poaceae*	*Aristida*	*ramosa*	Purple Wiregrass	Y																																											
Grasses	N	*Poaceae*	*Aristida*	*vagans*	Threeawn Speargrass															Y																													
Grasses	E	*Poaceae*	*Avena*	*fatua*	Wild Oats									Y																																			
Grasses	E	*Poaceae*	*Bambusa*	*sp.*	Bamboo																						Y																						
Grasses	N	*Poaceae*	*Bothriochloa*	*macra*	Red Grass													Y																															
Grasses	E	*Poaceae*	*Briza*	*minor*	Shivery Grass											Y							Y												Y														
Grasses	E	*Poaceae*	*Bromus*	*catharticus*	Prairie Grass		Y	Y	Y	Y		Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y		Y	Y		Y	Y		Y		Y		Y	Y		Y	Y				Y	Y			
Grasses	E	*Poaceae*	*Cenchrus*	*echinatus*	Mosman River Grass																				Y																								
Grasses	E	*Poaceae*	*Chloris*	*gayana*	Rhodes Grass															Y			Y				Y	Y								Y													
Grasses	N	*Poaceae*	*Chloris*	*sp.*	Windmill grass			Y												Y					Y																								
Grasses	N	*Poaceae*	*Cymbopogon*	*refractus*	Barbed Wire Grass															Y			Y																									Y	
Grasses	N	*Poaceae*	*Cynodon*	*dactylon*	Couch			Y		Y	Y				Y			Y	Y	Y	Y	Y		Y	Y		Y	Y			Y		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Grasses	E	*Poaceae*	*Dactylis*	*glomerata*	Cocksfoot		Y	Y		Y			Y			Y	Y																																
Grasses	N	*Poaceae*	*Dicanthium*	*sericeum*	QLD Blue Grass															Y		Y	Y																										
Grasses	N	*Poaceae*	*Diplachne*	*fusca*	Brown Beetle Grass																						Y																						
Grasses	N	*Poaceae*	*Echinochloa*	*telmatophila*	Swamp Barnyard Grass																														Y														
Grasses	N	*Poaceae*	*Echinopogon*	*ovatus*	Forest Hedgehog Grass										Y				Y												Y				Y			Y	Y							Y		Y	
Grasses	E	*Poaceae*	*Ehrharta*	*erecta*	Panic Veldtgrass																		Y		Y			Y					Y														Y		
Grasses	E	*Poaceae*	*Eleusine*	*tristachya*	Goose Grass																																						Y						
Grasses	N	*Poaceae*	*Eragrostis*	*sp.*	Lovegrass				Y					Y		Y		Y															Y									Y							
Grasses	N	*Poaceae*	*Eriochloa*	*procera*	Spring Grass																		Y																										
Grasses	E	*Poaceae*	*Festuca*	*arundinaceae*	Tall Fescue	Y		Y	Y	Y		Y		Y		Y	Y																																
Grasses	N	*Poaceae*	*Hemarthria*	*uncinata*	Matgrass						Y								Y		Y																												
Grasses	E	*Poaceae*	*Holcus*	*lanatus*	Yorshire Fog			Y					Y	Y		Y	Y																										Y						
Grasses	N	*Poaceae*	*Imperata*	*cylindrica*	Blady Grass			Y	Y	Y					Y																		Y		Y	Y		Y											Y
Grasses	N	*Poaceae*	*Lachnagrostis*	*filiformis*	Blown Grass	Y	Y	Y			Y		Y	Y			Y	Y	Y		Y							Y																					
Grasses	E	*Poaceae*	*Lolium*	*rigidum*	Wimmera Ryegrass				Y				Y				Y		Y																														
Grasses	E	*Poaceae*	*Megathyrsus*	*maximus var. pubiglumis*	Green Panic																						Y																						
Grasses	E	*Poaceae*	*Melinis*	*repens*	Red Natal Grass															Y	Y		Y					Y																					
Grasses	N	*Poaceae*	*Microlaena*	*stipoides*	Rice Grass								Y				Y	Y	Y	Y		Y						Y										Y	Y	Y	Y	Y		Y	Y	Y		Y	Y
Grasses	N	*Poaceae*	*Oplismenus*	*aemulus*	Australian Basket Grass		Y								Y				Y	Y	Y	Y	Y					Y								Y	Y	Y	Y	Y	Y	Y	Y	Y		Y	Y		Y
Grasses	N	*Poaceae*	*Oplismenus*	*imbecillis*	Creeping Beard Grass																														Y										Y				
Grasses	N	*Poaceae*	*Ottochloa*	*gracillima*	Ottochloa																																		Y										
Grasses	N	*Poaceae*	*Panicum*	*bisulcatum*	Black-seeded Panic																				Y																								
Grasses	N	*Poaceae*	*Panicum*	*decompositum*	Native Millet																																						Y		Y		Y		
Grasses	N	*Poaceae*	*Panicum*	*effusum*	Hairy Panic																																											Y	
Grasses	E	*Poaceae*	*Paspalum*	*dilatatum*	Paspalum								Y							Y	Y	Y						Y							Y	Y				Y	Y	Y	Y	Y		Y			Y
Grasses	N	*Poaceae*	*Paspalum*	*distichum*	Water Couch								Y				Y				Y	Y															Y			Y	Y	Y	Y		Y				
Grasses	E	*Poaceae*	*Paspalum*	*longifolium*	Paspalum																																											Y	
Grasses	E	*Poaceae*	*Paspalum*	*mandiocanum*	Broadleaf Paspalum																		Y							Y							Y	Y						Y	Y	Y	Y		
Grasses	E	*Poaceae*	*Paspalum*	*orbiculare*	Ditch Millet																																			Y	Y	Y					Y		
Grasses	E	*Poaceae*	*Paspalum*	*urvillei*	Vasey Grass																				Y								Y																
Grasses	E	*Poaceae*	*Pennisetum*	*clandestinum*	Kikuyu																			Y	Y	Y					Y			Y															
Grasses	E	*Poaceae*	*Phalaris*	*aquatica*	Phalaris	Y			Y					Y		Y	Y										Y								Y														
Grasses	N	*Poaceae*	*Poa*	*labillardierrei*	Tussock							Y		Y																								Y											
Grasses	N	*Poaceae*	*Poa*	*siebriana*	Snow Grass	Y		Y	Y	Y			Y	Y	Y		Y	Y																															
Grasses	N	*Poaceae*	*Rytidosperma*	*spp.*	Wallaby Grass						Y																																						
Grasses	E	*Poaceae*	*Setaria*	*sp.*	Pigeon Grasses			Y											Y	Y	Y	Y		Y	Y		Y	Y							Y	Y		Y	Y			Y			Y	Y	Y	Y	
Grasses	N	*Poaceae*	*Sorghum*	*leiocladum*	Native Sorghum									Y			Y																																
Grasses	E	*Poaceae*	*Sporobolus*	*africanus*	Parramatta Grass																			Y									Y	Y															
Grasses	N	*Poaceae*	*Sporobolus*	*crebra*	Slender Rat's Tail Grass			Y			Y						Y	Y					Y															Y		Y	Y	Y							Y
Grasses	E	*Poaceae*	*Stenotaphrum*	*secundatum*	Buffalo Grass																Y			Y	Y	Y					Y		Y	Y	Y								Y		Y	Y			
Grasses	N	*Poaceae*	*Themeda*	*australis*	Kangaroo Grass	Y								Y			Y																																
Grasses	N	*Poaceae*	*Urochloa*	*foliosa*	Leafy Panic																																											Y	
Grasses	E	*Poaceae*	*Vulpia*	*bromoides*	Squirrel Tail Fescue						Y					Y	Y																																
Herbs/Forbs	N	*Rosaceae*	*Acaena*	*novae-zelandiae*	Bidgee-widgee				Y					Y																																			
Herbs/Forbs	E	*Polygonaceae*	*Acetosella*	*vulgaris*	Sheep Sorrel			Y		Y							Y	Y							Y																								
Herbs/Forbs	N	*Pteridaceae*	*Adiantum*	*aethiopicum*	Common Maidenhair					Y					Y			Y																	Y	Y		Y	Y										
Herbs/Forbs	E	*Asteraceae*	*Ageratina*	*adenophora*	Crofton Weed																Y									Y												Y		Y	Y	Y			
Herbs/Forbs	E	*Asteraceae*	*Ageratina*	*riparia*	Mistflower																																	Y				Y			Y				
Herbs/Forbs	E	*Asteraceae*	*Ageratum*	*houstonianum*	Blue Billy Goat Weed														Y		Y			Y			Y	Y		Y	Y												Y	Y	Y	Y	Y		Y
Herbs/Forbs	N	*Lamiaceae*	*Ajuga*	*australis*	Austral Bugle					Y																																							
Herbs/Forbs	N	*Amaranthaceae*	*Alternanthera*	*denticulata*	Lesser Joyweed														Y	Y	Y	Y						Y		Y					Y				Y								Y		
Herbs/Forbs	N	*Asteraceae*	*Ammobium*	*alatum*	Winged Everlasting		Y		Y	Y		Y		Y		Y	Y	Y																															
Herbs/Forbs	E	*Asteraceae*	*Anagallis*	*arvensis*	Scarlet Pimpernel	Y	Y	Y					Y			Y	Y						Y												Y		Y	Y	Y			Y			Y			Y	
Herbs/Forbs	E	*Papaveraceae*	*Argemone*	*ochroleuca/mexicana*	Mexican Poppy			Y			Y								Y	Y	Y	Y															Y			Y	Y		Y		Y	Y			
Herbs/Forbs	E	*Asparagaceae*	*Asparagus*	*aethiopicus*	Asparagus Fern																												Y																
Herbs/Forbs	N	*Rubiaceae*	*Asperula*	*conferta*	Common Woodruff						Y	Y																																	Y				
Herbs/Forbs	N	*Chenopodiaceae*	*Atriplex*	*sp.*	Saltbush sp.																		Y																										
Herbs/Forbs	E	*Asteraceae*	*Bidens*	*pilosa*	Coblers Pegs	Y	Y	Y		Y					Y			Y	Y	Y	Y	Y	Y		Y		Y	Y					Y		Y		Y		Y	Y	Y		Y		Y	Y	Y		Y
Herbs/Forbs	N	*Blechnaceae*	*Blechnum*	*cartilagineum*	Gristle Fern																										Y					Y		Y	Y					Y					Y
Herbs/Forbs	N	*Blechnaceae*	*Blechnum*	*wattsii*	Hard Water Fern		Y			Y					Y																																		
Herbs/Forbs	E	*Crassulaceae*	*Bryophyllum*	*delagoense*	Mother of Millions															Y			Y																										
Herbs/Forbs	N	*Asphodelaceae*	*Bulbine*	*bulbosa*	Native Leek	Y																																											
Herbs/Forbs	N	*Dicksoniaceae*	*Calochlaena*	*dubia*	Rainbow Fern																																	Y				Y							Y
Herbs/Forbs	N	*Asteraceae*	*Calotis*	*cuneifolia*	Purple Burr-daisy	Y		Y										Y																															
Herbs/Forbs	E	*Brassicaceae*	*Capsella*	*bursa-pastoris*	Shepherds Purse			Y												Y																													
Herbs/Forbs	E	*Brassicaceae*	*Cardamine*	*hirsuta*	Common Bittercress							Y		Y																																Y			

APPENDIX 2 *Dominant plant species recorded at the 44 Ecohealth sites assessed in the 2015 survey. Rows in red indicate exotic species.*

						Tableland sites													Macleay River - freshwater sites				Macleay River - esturine sites						Coastal tributary sites						Freshwater tributary sites														
Growth Form	Native/Exotic	Family	Genus	Species	Common Name	APSR 1	BACK 1	CHAR 1	COMM 1	GARR 1	GARR 2	GARR 3	OAKC 1	SALW 1	STYX 1	TIAR 1	YARR 1	WOLR 1	MACR 7	MACR 8	MACR 9	MACR 10	MACR 1	MACR 2	MACR 3	MACR 4	MACR 5	MACR 6	CLYR 1	BELR 1	KINC 1	NAMR 1	NAMR 2	SPEC 1	COLC 1	DEEC 1	DUNC 1	DUNC 2	DUNC 3	FIVC 1	FIVC 2	FIVC 3	GEOC 1	HICC 1	NULC 1	TOOC 1	TOOC 2	TOOC 3	WARB 1
Herbs/Forbs	N	Aizoaceae	Carpobrotus	glaucescens	Pigface																		Y																										
Herbs/Forbs	E	Apiaceae	Centella	asiatica	Indian Pennywort																			Y																			Y						
Herbs/Forbs	E	Caryophyllaceae	Cerastium	glomeratum	Mouse-ear Chickweed		Y			Y							Y	Y												Y								Y	Y		Y		Y		Y				Y
Herbs/Forbs	N	Pteridaceae	Cheilanthes	sieberi	Rock Fern	Y					Y																																					Y	
Herbs/Forbs	N	Asteraceae	Chrysocephalum	apiculatum	Common Everlasting		Y								Y			Y																															
Herbs/Forbs	E	Asteraceae	Cirsium	vulgare	Spear Thistle	Y	Y			Y		Y		Y		Y	Y	Y		Y		Y									Y				Y		Y	Y		Y	Y	Y	Y		Y	Y	Y	Y	Y
Herbs/Forbs	E	Apiaceae	Conium	maculatum	Hemlock	Y																																											
Herbs/Forbs	E	Commelinaceae	Commelina	benghalensis	Benghal Dayflower																		Y		Y					Y	Y																		
Herbs/Forbs	N	Commelinaceae	Commelina	cyanea	Scurvy Weed		Y			Y					Y					Y	Y	Y					Y	Y							Y	Y					Y	Y	Y	Y				Y	
Herbs/Forbs	E	Asteraceae	Conyza	bonariensis	Fleabane	Y	Y		Y	Y			Y		Y	Y	Y	Y					Y		Y		Y				Y		Y					Y			Y		Y			Y			Y
Herbs/Forbs	N	Asteraceae	Craspedia	variabilis	Common Billy Buttons								Y		Y																																		
Herbs/Forbs	N	Crassulaceae	Crassula	spp.	Stonecrop						Y																																						
Herbs/Forbs	N	Amaryllidaceae	Crinum	pedunculatum	Swamp Lily																		Y			Y				Y	Y				Y														
Herbs/Forbs	E	Apiaceae	Cyclospermum	leptophyllum	Slender Celery													Y	Y	Y	Y	Y	Y	Y											Y	Y	Y	Y							Y	Y	Y		Y
Herbs/Forbs	E	Solanaceae	Datura	stramonium	Common Thornapple			Y										Y																															
Herbs/Forbs	E	Asteraceae	Daucus	carota	Wild Carrot			Y	Y							Y	Y																																
Herbs/Forbs	N	Orchidaceae	Dendrobium	teretifolium	Rat's Tail Orchid																													Y															
Herbs/Forbs	N	Phormaceae	Dianella	caerulea	Blue Flax-lily	Y								Y																																			
Herbs/Forbs	N	Phormaceae	Dianella	revoluta	Blueberry Lily										Y																																		
Herbs/Forbs	E	Caryophyllaceae	Dianthus	armeria	Deptford Pink				Y	Y																																							
Herbs/Forbs	N	Convolvulaceae	Dichondra	repens	Kidney Weed		Y		Y																																	Y							
Herbs/Forbs	N	Blechnaceae	Doodia	aspera	Prickly rasp fern				Y			Y																																					
Herbs/Forbs	N	Chenopodiaceae	Einadia	hastata	Berry Saltbush																		Y																										
Herbs/Forbs	N	Asteraceae	Euchiton	involucratus	Star Cudweed										Y																																		
Herbs/Forbs	E	Apiaceae	Foeniculum	vulgare	Fennel																					Y																							
Herbs/Forbs	E	Asteraceae	Gamochaeta	spp.	Cudweed			Y	Y		Y						Y																																
Herbs/Forbs	N	Geraniaceae	Geranium	solanderi	Native Geranium	Y	Y		Y	Y		Y		Y			Y																																
Herbs/Forbs	N	Haloragaceae	Gonocarpus	micranthus	Creeping Raspwort																			Y																									
Herbs/Forbs	N	Fabaceae	Hovea	heterophylla	Common Hovea										Y																																		
Herbs/Forbs	N	Apiaceae	Hydrocotyle	laxiflora	Stinking Pennywort								Y		Y			Y		Y		Y																	Y	Y					Y				
Herbs/Forbs	E	Clusiaceae	Hypericum	perforatum	St. Johns Wort												Y																																
Herbs/Forbs	E	Asteraceae	Hypochaeris	radicata	Cat's Ear		Y		Y	Y			Y					Y					Y																							Y			
Herbs/Forbs	N	Dennstaedtiaceae	Hypolepis	muelleri	Harsh Ground Fern		Y															Y																		Y					Y				
Herbs/Forbs	E	Asteraceae	Lactuca	serriola	Prickly Lettuce					Y																																							
Herbs/Forbs	E	Lamiaceae	Leonurus	japonicus	Japanese Lionstail														Y		Y							Y		Y																	Y		
Herbs/Forbs	N	Fabaceae	Lespedeza	juncea	Native Clover				Y					Y				Y																															
Herbs/Forbs	E	Asteraceae	Leucanthemum	vulgare	Ox-eye Daisy	Y			Y	Y		Y	Y	Y		Y	Y																																
Herbs/Forbs	N	Lobeliaceae	Lobelia	trigonocaulis	Forest Lobelia																															Y													
Herbs/Forbs	E	Lamiaceae	Marrubium	vulgare	White horehound	Y						Y																																					
Herbs/Forbs	E	Fabaceae	Medicago	polymorpha	Burr Medic				Y	Y																																							
Herbs/Forbs	N	Amaranthaceae	Nyssanthes	diffusa	Barbwire Weed		Y																																				Y						
Herbs/Forbs	N	Polygonaceae	Persicaria	decipiens	Slender Knotweed		Y						Y						Y	Y	Y	Y			Y										Y				Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Herbs/Forbs	N	Polygonaceae	Persicaria	hydropiper	Knotweed			Y		Y			Y		Y			Y	Y	Y	Y	Y					Y	Y			Y				Y		Y		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Herbs/Forbs	N	Polygonaceae	Persicaria	orientalis	Princes Feathers																														Y														
Herbs/Forbs	N	Polygonaceae	Persicaria	sp.	Knotweed	Y						Y			Y		Y																																
Herbs/Forbs	N	Polygonaceae	Persicaria	strigosa	Hairy Knotweed			Y										Y				Y						Y		Y					Y		Y	Y	Y				Y				Y		
Herbs/Forbs	E	Caryophyllaceae	Petrorhagia	nanteuilii	Proliferous Pink	Y		Y					Y					Y																															
Herbs/Forbs	E	Plantaginaceae	Plantago	lanceolata	Plantain	Y	Y		Y	Y	Y	Y	Y	Y		Y	Y	Y					Y												Y														
Herbs/Forbs	N	Asteraceae	Pseudognaphalium	luteoalbum	Jersey Cudweed	Y																																											
Herbs/Forbs	N	Dennstaedtiaceae	Pteridium	esculentum	Common Bracken										Y													Y					Y			Y		Y		Y		Y	Y						
Herbs/Forbs	N	Ranunculaceae	Ranunculus	inundatus	Stream side						Y						Y											Y											Y									Y	
Herbs/Forbs	N	Ranunculaceae	Ranunculus	plebeius	Forest Buttercup																																					Y							Y
Herbs/Forbs	E	Brassicaceae	Rapistrum	rugosum	Turnip Weed			Y		Y								Y	Y	Y	Y	Y					Y																						
Herbs/Forbs	E	Rubiaceae	Richardia	brassiliensis	White Eye																																						Y						
Herbs/Forbs	E	Brassicaceae	Rorippa	sp.	Watercress													Y																															
Herbs/Forbs	N	Polygonaceae	Rumex	brownii	Swamp Dock	Y	Y	Y	Y			Y	Y		Y		Y	Y	Y																					Y		Y	Y	Y	Y				
Herbs/Forbs	E	Polygonaceae	Rumex	crispus	Curled Dock									Y						Y	Y																Y												
Herbs/Forbs	E	Asteraceae	Senecio	madagascariensis	Fireweed														Y	Y	Y	Y		Y	Y			Y			Y							Y	Y	Y	Y		Y	Y	Y	Y		Y	Y
Herbs/Forbs	E	Lamiaceae	Sida	rhombifolia	Sidratusa				Y	Y								Y	Y	Y			Y					Y		Y			Y		Y		Y	Y	Y		Y		Y			Y	Y	Y	Y
Herbs/Forbs	E	Solanaceae	Solanum	nigrum	Black-berry Nightshade														Y		Y	Y																									Y		
Herbs/Forbs	N	Solanaceae	Solanum	prinophyllum	Forest Nightshade		Y											Y				Y																		Y									
Herbs/Forbs	E	Solanaceae	Solanum	sp.	Silver nightshade			Y																									Y		Y														
Herbs/Forbs	E	Solanaceae	Solanum	viarum	Tropical Soda Apple																																			Y									
Herbs/Forbs	E	Asteraceae	Sonchus	asper	Prickly Sowthistle		Y		Y	Y								Y			Y				Y				Y							Y									Y		Y		
Herbs/Forbs	N	Stackhousiaceae	Stackhousia	monogyna	Creamy Candles										Y																																		
Herbs/Forbs	N	Caryophyllaceae	Stellaria	pungens	Prickly Starwort		Y								Y																																		
Herbs/Forbs	E	Asteraceae	Taraxacum	officinale	Dandelion			Y						Y																																			
Herbs/Forbs	N	Aizoaceae	Tetragonia	tetragonioides	New Zealand Spinach																		Y						Y			Y	Y																
Herbs/Forbs	E	Commelinaceae	Tradescantia	fluminensis	Wandering Jew														Y						Y			Y		Y	Y						Y	Y		Y	Y	Y		Y	Y	Y			Y
Herbs/Forbs	E	Fabaceae	Trifolium	arvense	Haresfoot Clover						Y			Y		Y																																	
Herbs/Forbs	E	Fabaceae	Trifolium	glomeratum	Clustered Clover													Y																															
Herbs/Forbs	E	Fabaceae	Trifolium	repens	White Clover	Y		Y			Y	Y	Y									Y											Y								Y	Y				Y			
Herbs/Forbs	E	Fabaceae	Trifolium	spp.	Clover spp.				Y			Y		Y																																			
Herbs/Forbs	E	Tropaeolaceae	Tropaeolum	majus	Nasturtium																					Y																							
Herbs/Forbs	N	Urticaceae	Urtica	incisa	Stinging Nettle		Y											Y	Y			Y																		Y		Y						Y	
Herbs/Forbs	E	Scrophulariaceae	Verbascum	thapsus	Great Mullein			Y								Y																																	
Herbs/Forbs	E	Scrophulariaceae	Verbascum	virgatum	Green Mullein	Y								Y			Y		Y		Y																												
Herbs/Forbs	E	Verbenaceae	Verbena	bonariensis	Purpletop	Y	Y	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y		Y	Y	Y	Y		Y		Y										Y				Y	Y	Y		Y	Y	Y	Y	Y
Herbs/Forbs	E	Plantaginaceae	Veronica	anagallis-aquatica	Blue Water Speedwell					Y				Y				Y				Y																											
Herbs/Forbs	E	Fabaceae	Vicia	sp.	Vetch	Y		Y	Y	Y		Y		Y																																			
Herbs/Forbs	N	Violaceae	Viola	banksii	Wild Violet										Y																				Y	Y			Y	Y		Y						Y	Y
Herbs/Forbs	N	Campanulaceae	Wahlenbergia	spp.	Bluebell						Y			Y						Y		Y	Y																										
Herbs/Forbs	E	Asteraceae	Xanthium	occidentale	Noogoora Burr																	Y																											
Herbs/Forbs	N	Asteraceae	Xerochrysum	bracteatum	Golden Everlasting							Y	Y																																				
Macrophytes	N	Salviniaceae	Azolla	filiculoides/pinata	Duck Weed			Y			Y					Y	Y				Y	Y					Y	Y							Y									Y					
Macrophytes	N	Cyperaceae	Bolboschoenus	fluviatilis	Marsh Club-rush										Y		Y		Y						Y		Y			Y	Y				Y														
Macrophytes	E	Callitrichaceae	Callitriche	stagnalis	Common Starwort										Y																Y						Y			Y	Y	Y							
Macrophytes	N	Cyperaceae	Carex	appressa	Tall Sedge						Y	Y			Y		Y																Y																
Macrophytes	N	Characeae	Chara	cera	Stonewort		Y										Y																						Y				Y			Y			
Macrophytes	E	Cyperaceae	Cyperus	papyrus	Papyrus																					Y																							
Macrophytes	E	Hydrocharitaceae	Egeria	densa	Egeria										Y							Y					Y	Y																					
Macrophytes	N	Elatinaceae	Elatine	gratioloides	Waterwort	Y																																								Y			
Macrophytes	N	Cyperaceae	Eleocharis	acuta	Pinrush	Y					Y	Y																							Y														
Macrophytes	N	Cyperaceae	Eleocharis	sphacelata	Tall Spikerush				Y								Y																																
Macrophytes	E	Hydrocharitaceae	Elodea	canadensis	Canadian Waterweed					Y	Y								Y	Y	Y	Y					Y	Y												Y	Y	Y	Y		Y	Y	Y		Y
Macrophytes	N	Hydrocharitaceae	Hydrilla	verticillata	Water Thyme																Y	Y				Y	Y	Y							Y														
Macrophytes	N	Apiaceae	Hydrocotyle	tripartita	Pennywort	Y		Y		Y	Y																															Y		Y	Y	Y			
Macrophytes	N	Cyperaceae	Isolepis	sp.	Club Rush	Y				Y												Y																Y	Y	Y	Y		Y	Y	Y	Y		Y	
Macrophytes	N	Lemnaceae	Lemna	trisulca	Ivy Leaf Duckweed																																				Y	Y							
Macrophytes	N	Onagraceae	Ludwigia	peploides	Water Primrose	Y		Y		Y			Y	Y					Y		Y	Y													Y									Y				Y	
Macrophytes	N	Haloragaceae	Myriophyllum	crispatum	Upright Water Milfoil																																											Y	
Macrophytes	N	Haloragaceae	Myriophyllum	gracile	Water-milfoil																														Y			Y	Y										Y
Macrophytes	N	Haloragaceae	Myriophyllum	sp.	Water-milfoil								Y		Y	Y	Y																					Y								Y			

APPENDIX 2 *Dominant plant species recorded at the 44 Ecohealth sites assessed in the 2015 survey. Rows in red indicate exotic species.*

						Tableland sites													Macleay River - freshwater sites				Macleay River - esturine sites						Coastal tributary sites						Freshwater tributary sites														
Growth Form	Native/Exotic	Family	Genus	Species	Common Name	APSR 1	BACK 1	CHAR 1	COMM 1	GARR 1	GARR 2	GARR 3	OAKC 1	SALW 1	STYX 1	TIAR 1	YARR 1	WOLR 1	MACR 7	MACR 8	MACR 9	MACR 10	MACR 1	MACR 2	MACR 3	MACR 4	MACR 5	MACR 6	CLYR 1	BELR 1	KINC 1	NAMR 1	NAMR 2	SPEC 1	COLC 1	DEEC 1	DUNC 1	DUNC 2	DUNC 3	FIVC 1	FIVC 2	FIVC 3	GEOC 1	HICC 1	NUJC 1	TOOC 1	TOOC 2	TOOC 3	WARB 1
Macrophytes	N	*Haloragaceae*	*Myriophyllum*	*variifolium*	Varied Water-milfoil			Y		Y	Y	Y		Y				Y				Y					Y	Y																					
Macrophytes	N	*Haloragaceae*	*Myriophyllum*	*verrucosum*	Red Water-milfoil	Y		Y			Y								Y	Y	Y																						Y		Y				
Macrophytes	N	*Najadaceae*	*Najas*	*tenuifolia*	Waternymph														Y								Y																						
Macrophytes	N	*Nymphaeaceae*	*Nymphaea*	*gigantea*	Giant Waterlily																														Y														
Macrophytes	N	*Nymphaeaceae*	*Nymphoides*	*indica*	Water Snowflake														Y																Y														
Macrophytes	N	*Hydrocharitaceae*	*Ottelia*	*ovalifolia*	Swamp Lily								Y																															Y					
Macrophytes	N	*Poaceae*	*Phragmites*	*australis*	Common Reed	Y											Y	Y					Y		Y	Y	Y			Y	Y																		
Macrophytes	N	*Potamogetonaceae*	*Potomogeton*	*crispus*	Curly Pondweed			Y		Y		Y	Y	Y							Y					Y				Y									Y	Y									
Macrophytes	N	*Potamogetonaceae*	*Potomogeton*	*ochreatus*	Blunt Pondweed	Y		Y		Y			Y				Y											Y																Y					
Macrophytes	N	*Potamogetonaceae*	*Potomogeton*	*octandrus*	Old Javanicus																Y						Y								Y		Y												
Macrophytes	N	*Potamogetonaceae*	*Potomogeton*	*perfoliatus*	Clasped Pondweed												Y			Y	Y	Y					Y	Y												Y		Y	Y					Y	Y
Macrophytes	N	*Potamogetonaceae*	*Potomogeton*	*sulcatus*	Pondweed	Y								Y		Y	Y																						Y										
Macrophytes	N	*Poaceae*	*Potamophila*	*parviflora*	Hastings River Reed														Y			Y																	Y				Y				Y		
Macrophytes	N	*Cyperaceae*	*Schoenoplectiella*	*mucronata*	Triangular Club Rush													Y			Y	Y						Y												Y	Y		Y			Y	Y	Y	
Macrophytes	N	*Cyperaceae*	*Schoenoplectus*	*validus*	River Club Rush	Y					Y	Y		Y			Y						Y		Y				Y		Y			Y															
Macrophytes	N	*Juncaginaceae*	*Triglochin*	*sp.*	Water Ribbons						Y	Y		Y																																			
Macrophytes	N	*Typhaceae*	*Typha*	*orientalis*	Broadleaf Cumbungi	Y											Y											Y																					
Macrophytes	N	*Hydrocharitaceae*	*Vallisneria*	*australis*	Ribbonweed	Y			Y					Y		Y																																	
Macrophytes	N	*Hydrocharitaceae*	*Vallisneria*	*nana*	Freshwater Eelgrass	Y								Y			Y		Y	Y	Y	Y					Y	Y		Y										Y			Y		Y				Y
Saltmarsh/Mangro	N	*Myrsinaceae*	*Aegiceras*	*corniculatum*	River Mangrove																		Y		Y				Y			Y	Y	Y															
Saltmarsh/Mangro	N	*Acanthaceae*	*Avicennia*	*marina subsp. Australasica*	Grey Mangrove																		Y						Y			Y	Y	Y															
Saltmarsh/Mangro	N	*Apocynaceae*	*Cynanchum*	*carnosum*	Mangrove Vine																								Y			Y																	
Saltmarsh/Mangro	N	*Cyperaceae*	*Gahnia*	*filum*	Chaffy Saw Sedge																											Y																	
Saltmarsh/Mangro	N	*Hydrocharitaceae*	*Halophila*	*ovalis*	Paddle Weed																												Y																
Saltmarsh/Mangro	N	*Poaceae*	*Paspalum*	*vaginatum*	Saltwater Couch																		Y						Y			Y																	
Saltmarsh/Mangro	N	*Theophrastaceae*	*Samolus*	*repens*	Creeping Brookweed																		Y						Y			Y																	
Saltmarsh/Mangro	N	*Chenopodiaceae*	*Sarcocornia*	*quinqueflora*	Samphire																											Y																	
Saltmarsh/Mangro	N	*Poaceae*	*Sporobolus*	*virginicus var. minor*	Marine Couch																								Y			Y																	
Saltmarsh/Mangro	N	*Poaceae*	*Sporobolus*	*virginicus var. virginicus*	Sand Couch																		Y										Y	Y															
Saltmarsh/Mangro	N	*Chenopodiaceae*	*Suaeda*	*australis*	Austral Seablite																		Y						Y			Y	Y																
Saltmarsh/Mangro	N	*Zostereaceae*	*Zostera*	*muelleri subsp. capricorni*	Zostera																								Y			Y	Y	Y															
Shrubs	N	*Mimosoideae*	*Acacia*	*amoena*	Boomerang Wattle	Y																																											
Shrubs	N	*Mimosoideae*	*Acacia*	*filicifolia*	Fern-leaved Wattle			Y										Y																															
Shrubs	N	*Mimosoideae*	*Acacia*	*floribunda*	White Sally Wattle																																									Y	Y	Y	
Shrubs	N	*Mimosoideae*	*Acacia*	*ingramii*	Ingrams Wattle										Y																																		
Shrubs	N	*Fabaceae*	*Acacia*	*irrorata*	Green Wattle																															Y			Y										
Shrubs	N	*Mimosoideae*	*Acacia*	*longifolia subsp. longifolia*	Sydney Golden Wattle										Y																																		
Shrubs	N	*Mimosoideae*	*Acacia*	*longifolia subsp. sophorae*	Coastal Wattle																		Y						Y	Y																			
Shrubs	N	*Mimosoideae*	*Acacia*	*sp.*	Could be concurrens?																												Y																
Shrubs	N	*Fabaceae*	*Acacia*	*dealbata*	Silver Wattle		Y																																										
Shrubs	N	*Fabaceae*	*Acacia*	*leiocalyx*	Black Wattle		Y																																										
Shrubs	N	*Fabaceae*	*Acacia*	*rubida*	Red Wattle			Y					Y																																				
Shrubs	N	*Myrtaceae*	*Acmena*	*smithii*	Lilly Pilly																														Y	Y	Y	Y	Y		Y	Y		Y	Y				
Shrubs	N	*Loranthaceae*	*Amyema*	*cambagei*	She-oak Mistletoe																										Y		Y															
Shrubs	E	*Apocynaceae*	*Asclepias*	*curassavica*	Read Head Cotton Bush																						Y												Y	Y		Y						
Shrubs	E	*Asteraceae*	*Baccharis*	*halimifolia*	Groundsel Bush																										Y																	
Shrubs	N	*Myrtaceae*	*Backhousia*	*myrtifolia*	Ironwood																																	Y							Y	Y	Y	
Shrubs	N	*Proteacea*	*Banksia*	*integrifolia subsp. intergrifolia*	Coast Banksia																		Y										Y																
Shrubs	N	*Ericaceae*	*Brachyloma*	*daphnoides*	Daphne Heath										Y																																		
Shrubs	N	*Pittosporaceae*	*Bursaria*	*spinosa*	Blackthorn	Y									Y			Y																															
Shrubs	N	*Myrtaceae*	*Callistemon*	*salignus*	Willow Bottlebrush																														Y	Y													
Shrubs	N	*Myrtaceae*	*Callistemon*	*sieberi*	River Bottlebrush	Y		Y	Y	Y	Y		Y	Y	Y		Y	Y																															
Shrubs	N	*Myrtaceae*	*Callistemon*	*viminalis*	Weeping Bottlebrush														Y	Y	Y	Y					Y	Y		Y	Y						Y		Y	Y			Y	Y	Y	Y	Y	Y	Y
Shrubs	E	*Asteraceae*	*Chrysanthemoides*	*monilifera subsp. Rotundata*	Bitou Bush																	Y									Y	Y																
Shrubs	E	*Rutaceae*	*Citrus*	*x taitensis*	Rough Lemon																																						Y		Y		Y	
Shrubs	N	*Asteliaceae*	*Cordyline*	*stricta*	Narrow-leaved Palm Lily																															Y													
Shrubs	N	*Rutaceae*	*Correa*	*lawrenceana*	Mountain Correa										Y																																		
Shrubs	N	*Sapindaceae*	*Cupaniopsis*	*anacardioides*	Tuckeroo																		Y	Y		Y						Y	Y		Y														
Shrubs	N	*Rousseaceae*	*Cuttsia*	*virburnea*	Elderberry																																									Y			
Shrubs	N	*Sapindaceae*	*Dodonaea*	*rhombifolia*	Boroad-leaf Hop-bush												Y																																
Shrubs	N	*Moraceae*	*Ficus*	*coronata*	Sandpaper Fig		Y													Y	Y	Y						Y		Y					Y	Y	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y		Y
Shrubs	N	*Phyllanthaceae*	*Glochidion*	*fernandi*	Cheese Tree															Y		Y	Y			Y		Y		Y			Y		Y	Y	Y		Y					Y			Y		
Shrubs	E	*Apocynaceae*	*Gomphocarpus*	*fruiticosus*	Narrow-leaved Vetch																	Y																		Y	Y		Y			Y		Y	
Shrubs	N	*Proteacea*	*Hakea*	*microcarpa*	Small-fruit Hakea			Y					Y		Y																																		
Shrubs	N	*Malvaceae*	*Hibiscus*	*heterophyllus*	Native Rosella																															Y						Y							
Shrubs	N	*Euphorbiaceae*	*Homalanthus*	*populifolius*	Bleeding Heart																																					Y							
Shrubs	E	*Verbenaceae*	*Lantana*	*camara*	Lantana														Y	Y	Y	Y	Y		Y	Y	Y	Y		Y	Y	Y	Y		Y	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y	Y
Shrubs	N	*Myrtaceae*	*Leptospermum*	*brachyandrum*	Silver Weeping Tea-tree																					Y	Y							Y		Y	Y	Y										
Shrubs	N	*Myrtaceae*	*Leptospermum*	*gregarium*	Common Tea-tree										Y																																		
Shrubs	N	*Myrtaceae*	*Leptospermum*	*polygalifolium subsp. transmontan*	Tantoon	Y	Y	Y	Y	Y				Y	Y		Y	Y																															
Shrubs	E	*Oleaceae*	*Ligustrum*	*sinense*	Small-leaved Privet					Y												Y					Y	Y		Y	Y							Y		Y	Y	Y		Y	Y				
Shrubs	N	*Myrtaceae*	*Melaleuca*	*bracteata*	Black Tea-tree															Y	Y	Y								Y										Y									
Shrubs	N	*Myrtaceae*	*Melaleuca*	*linariifolia*	Flax-leaved Paperbark																														Y												Y		
Shrubs	N	*Myrtaceae*	*Melaleuca*	*styphelioides*	Prickely-leaved Tea-tree																									Y					Y														
Shrubs	N	*Violaceae*	*Melicytus*	*dentatus*	Tree Violet		Y								Y																																		
Shrubs	N	*Oleaceae*	*Notelaea*	*longifolia*	Large mock olive																															Y		Y											
Shrubs	N	*Oleaceae*	*Notelaea*	*microcarpa*	Velvet Mock Olive	Y				Y																																							
Shrubs	N	*Asteraceae*	*Olearia*	*sp.*	Daisy Bush										Y			Y																															
Shrubs	E	*Cactaceae*	*Opuntia*	*stricta*	Spiny Pest Pear																	Y	Y																										
Shrubs	N	*Phyllanthaceae*	*Phyllanthus*	*gunnii*	Scrubby Spurge																														Y	Y													
Shrubs	E	*Phytolaccaceae*	*Phytolacca*	*octandra*	Ink Weed																																					Y	Y						
Shrubs	N	*Thymelaeaceae*	*Pimelea*	*neo-anglica*	Poison Pimelea		Y											Y																															
Shrubs	N	*Pittosporaceae*	*Pittosporum*	*multiflorum*	Orange Thorn																															Y		Y							Y				Y	
Shrubs	N	*Polypodiaceae*	*Platycerium*	*superbum*	Staghorn																																	Y									Y	
Shrubs	N	*Rhamnaceae*	*Pomaderris*	*sp.*	Pomaderris										Y																																		
Shrubs	E	*Amygdalaceae*	*Prunus*	*persica*	Peach																																										Y	
Shrubs	E	*Euphorbiaceae*	*Ricinus*	*communis*	Castor Oil Plant														Y	Y						Y	Y	Y		Y	Y						Y					Y							
Shrubs	E	*Rosaceae*	*Rosa*	*rubiginosa*	Sweet Briar												Y																																
Shrubs	E	*Caesalpinioideae*	*Senna*	*pendula var. glabrata*	Senna																						Y								Y							Y				Y				
Shrubs	E	*Caesalpinioideae*	*Senna*	*septemtrionalis*	Arsenic Bush														Y									Y										Y	Y			Y				Y	Y	Y	
Shrubs	N	*Solanaceae*	*Solanum*	*arviculare*	Kangaroo Apple																																			Y			Y						
Shrubs	E	*Solanaceae*	*Solanum*	*mauritianum*	Wild Tobacco														Y	Y	Y	Y				Y	Y			Y	Y				Y		Y			Y	Y	Y	Y	Y	Y	Y	Y		Y
Trees	N	*Rutaceae*	*Acronychia*	*pubescens*	Hairy Acronychia																																					Y							
Trees	N	*Sapindaceae*	*Alectryon*	*Alectryon subdentatus f. subdentat*	Hairy Birds Eye		Y																																										
Trees	N	*Rhamnaceae*	*Alphitonia*	*excelsa*	Red Ash																														Y	Y													
Trees	N	*Myrtaceae*	*Angophora*	*subvelutina*	Broad-leaved apple		Y																															Y										
Trees	N	*Ulmaceae*	*Aphananthe*	*philippinensis*	Rough-leaved Elm																						Y								Y		Y		Y	Y					Y			
Trees	N	*Casuarinaceae*	*Casuarina*	*cunninghamiana subsp. cunningha*	River Oak		Y		Y	Y			Y		Y			Y	Y	Y	Y	Y						Y									Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Trees	N	*Casuarinaceae*	*Casuarina*	*glauca*	Swamp Oak																	Y		Y	Y	Y		Y	Y	Y	Y	Y	Y	Y		Y												
Trees	E	*Lauraceae*	*Cinnamomum*	*camphora*	Camphor Laurel															Y						Y	Y		Y			Y		Y		Y								Y			
Trees	N	*Myrtaceae*	*Corymbia*	*intermedia*	Pink Bloodwood																														Y													
Trees	N	*Lauraceae*	*Cryptocarya*	*sp.*	Meisneriana																														Y													

APPENDIX 2 *Dominant plant species recorded at the 44 Ecohealth sites assessed in the 2015 survey. Rows in red indicate exotic species.*

						Tableland sites													Macleay River - freshwater sites				Macleay River - esturine sites						Coastal tributary sites						Freshwater tributary sites														
Growth Form	Native/Exotic	Family	Genus	Species	Common Name	APSR 1	BACK 1	CHAR 1	COMM 1	GARR 1	GARR 2	GARR 3	OAKC 1	SALW 1	STYX 1	TIAR 1	YARR 1	WOLR 1	MACR 7	MACR 8	MACR 9	MACR 10	MACR 1	MACR 2	MACR 3	MACR 4	MACR 5	MACR 6	CLYR 1	BELR 1	KINC 1	NAMR 1	NAMR 2	SPEC 1	COLC 1	DEEC 1	DUNC 1	DUNC 2	DUNC 3	FIVC 1	FIVC 2	FIVC 3	GEOC 1	HICC 1	NULC 1	TOOC 1	TOOC 2	TOOC 3	WARB 1
Trees	E	*Fabaceae*	*Erythrina*	*numerosa*	Pine Mountain Coral tree																												Y																
Trees	E	*Fabaceae*	*Erythrina*	*x sykesii*	Coral Tree																				Y	Y				Y	Y																		
Trees	N	*Myrtaceae*	*Eucalyptus*	*acaciiformis*	Wattle-leaved Peppermint										Y	Y	Y																																
Trees	N	*Myrtaceae*	*Eucalyptus*	*amplifolia*	Cabbage Gum																																Y				Y		Y						
Trees	N	*Myrtaceae*	*Eucalyptus*	*blakelyi*	Blakely's Red Gum		Y			Y																																							
Trees	N	*Myrtaceae*	*Eucalyptus*	*caliginosa*	Broad-leaved Stringybark	Y		Y									Y	Y																															
Trees	N	*Myrtaceae*	*Eucalyptus*	*dalrympleana subsp. heptantha*	Mountain Gum	Y																																											
Trees	N	*Myrtaceae*	*Eucalyptus*	*grandis*	Flooded Gum																															Y						Y							
Trees	N	*Myrtaceae*	*Eucalyptus*	*melliodora*	Yellow Box		Y																																										
Trees	N	*Myrtaceae*	*Eucalyptus*	*nobilis*	Ribbon Gum										Y																																		
Trees	N	*Myrtaceae*	*Eucalyptus*	*nova-anglica*	New England Peppermint			Y						Y	Y																																		
Trees	N	*Myrtaceae*	*Eucalyptus*	*pauciflora*	Snow Gum									Y			Y																																
Trees	N	*Myrtaceae*	*Eucalyptus*	*resinifera*	Red Mahogany																															Y													
Trees	N	*Myrtaceae*	*Eucalyptus*	*tereticornis*	Forest Red Gum																	Y													Y			Y	Y	Y						Y	Y		
Trees	N	*Myrtaceae*	*Eucalyptus*	*viminalis*	Manna Gum	Y				Y							Y																																
Trees	N	*Moraceae*	*Ficus*	*macrophylla*	Morton Bay Fig																		Y	Y	Y												Y								Y				
Trees	N	*Moraceae*	*Ficus*	*rubiginosa*	Port Jackson Fig															Y	Y	Y																											
Trees	N	*Moraceae*	*Ficus*	*watkinsiana*	Strangling Fig																	Y																											
Trees	N	*Proteacea*	*Grevillea*	*robusta*	Silky Oak																Y						Y										Y	Y				Y	Y						
Trees	E	*Bignoniaceae*	*Jacaranda*	*mimosifolia*	Jacaranda																					Y	Y																						
Trees	E	*Oleaceae*	*Ligustrum*	*lucidum*	Broad-leaf Privet																									Y																			
Trees	N	*Myrtaceae*	*Lophostemon*	*confertus*	Brush Box																															Y													
Trees	N	*Euphorbiaceae*	*Mallotus*	*philippensis*	Red Kamala																	Y														Y			Y					Y	Y	Y			
Trees	N	*Meliaceae*	*Melia*	*azedarach*	White Cedar																	Y															Y	Y	Y			Y					Y	Y	
Trees	E	*Moraceae*	*Morus*	*alba*	White Mulberry																					Y	Y			Y	Y																		
Trees	N	*Scrophulariaceae*	*Myoporum*	*acuminatum*	Boobialla																											Y																	
Trees	E	*Salicaceae*	*Salix*	*sp.*	Willow	Y		Y	Y	Y	Y			Y	Y	Y	Y	Y				Y															Y	Y					Y						
Trees	E	*Araliaceae*	*Schefflera*	*actinophylla*	Umbrella Tree																												Y																
Trees	N	*Myrtaceae*	*Tristaniopsis*	*laurina*	Watergum		Y																					Y								Y	Y	Y	Y								Y	Y	
Trees	N	*Myrtaceae*	*Waterhousea*	*floribunda*	Weeping Lilly Pilly																															Y													
Vines	E	*Sapindaceae*	*Cardiospermum*	*grandiflorum*	Balloon Vine														Y							Y																							
Vines	N	*Vitaceae*	*Cayratia*	*clematidea*	Native Grape		Y																																										
Vines	N	*Vitaceae*	*Cissus*	*antarctica*	Kangaroo Vine																															Y			Y	Y		Y		Y			Y		
Vines	N	*Vitaceae*	*Cissus*	*hypoglauca*	Water Vine																																								Y		Y		
Vines	N	*Ranunculaceae*	*Clematis*	*sp.*	Clematis		Y																																										
Vines	E	*Bignoniaceae*	*Dolichandra*	*unguis-cati*	Cat's Claw Creeper														Y		Y																			Y		Y							Y
Vines	N	*Luzuriageae*	*Eustrephus*	*latifolius*	Wombat Berry		Y															Y	Y						Y						Y	Y		Y			Y		Y				Y		
Vines	N	*Fabaceae*	*Glycine*	*sp.*	Glycine										Y																							Y											
Vines	N	*Convolvulaceae*	*Ipomoea*	*brasiliensis*	Beach Morning Glory																		Y																										
Vines	E	*Convolvulaceae*	*Ipomoea*	*cairica*	Coastal Morning Glory																		Y		Y	Y	Y		Y	Y	Y	Y	Y																
Vines	E	*Convolvulaceae*	*Ipomoea*	*purpurea*	Common Morning Glory																						Y																						
Vines	N	*Oleaceae*	*Jasminum*	*volubile*	Stiff Jasmine																								Y																				
Vines	N	*Menispermaceae*	*Legnephora*	*moorei*	Round-leaf Vine																																									Y			
Vines	E	*Caprifoloaceae*	*Lonicera*	*japonica*	Japanese Honeysuckle											Y																	Y				Y												
Vines	N	*Moraceae*	*Maclura*	*cochinchinensis*	Cockspur Thorn																									Y							Y	Y	Y	Y	Y					Y		Y	Y
Vines	E	*Fabaceae*	*Macroptilium*	*atropurpureum*	Siratro																		Y																										
Vines	N	*Apocynaceae*	*Marsdenia*	*rostrata*	Milk Vine																	Y																					Y						
Vines	N	*Rubiaceae*	*Morinda*	*jasminoides*	Sweet Morinda																															Y													
Vines	N	*Bignoniaceae*	*Pandorea*	*pandorana*	Wonga Wonga Vine		Y																													Y													
Vines	N	*Aristolochiaceae*	*Pararistolochia*	*praevenosa*	Birdwing Vine																																							Y					
Vines	N	*Apocynaceae*	*Parsonsia*	*straminea*	Silkpod		Y													Y									Y	Y					Y	Y	Y	Y	Y	Y		Y		Y		Y		Y	
Vines	E	*Passifloraceae*	*Passiflora*	*sp.*	Common passionfruit														Y	Y		Y						Y													Y								Y
Vines	E	*Passifloraceae*	*Passiflora*	*subpeltata*	White Passionfruit																																									Y			
Vines	N	*Ripogonaceae*	*Ripogonum*	*album*	White Supplejack																															Y													
Vines	N	*Rosaceae*	*Rubus*	*parvifolius*	Native Raspberry		Y								Y			Y				Y															Y			Y	Y			Y			Y		
Vines	E	*Rosaceae*	*Rubus*	*sp.*	Blackberry	Y	Y	Y	Y	Y	Y	Y	Y	Y		Y	Y					Y																			Y		Y						
Vines	N	*Menispermaceae*	*Sarcopetalum*	*harveyanum*	Pearl Vine																															Y													
Vines	N	*Smilaceae*	*Smilax*	*australis*	Lawyer Vine																		Y													Y													
Vines	N	*Smilaceae*	*Smilax*	*glyciphylla*	Sweet Sarsaparilla																															Y	Y							Y					
Vines	E	*Solanaceae*	*Solanum*	*seaforthianum*	Climbing Nightshade																								Y																	Y			
Vines	N	*Menispermaceae*	*Stephania*	*japonica*	Snake Vine		Y																													Y						Y							
Vines	N	*Vitaceae*	*Tetrastigma*	*nitens*	Shining Grape		Y																																										
Vines	N	*Fabaceae*	*Vigna*	*marina*	Dune Bean																		Y																										

The tributary sites of Five Day Creek, Nulla Nulla Creek, Parrabel Creek, Hickeys Creek, Mungay Creek, Dungay Creek and Euroka Creek were typically cooler than the main stem of the Macleay River (Figure A3). In particular, Hickeys Creek and Mungay Creek had lower ranges and significantly lower mean water temperatures than any other site in the monitoring program. This does not appear to be related to differences in the sampling times at sites.

Mungay Creek also recorded the highest concentrations of dissolved oxygen (DO) of any freshwater site in the catchment (Figure A3). Peak concentrations of DO did not occur during lowest water temperatures and were not correlated with obvious algal growth in the water column. However, it is worth checking percent saturation of DO as well as or instead of concentration of DO (mg/L). There are six recorded DO concentrations greater than 15mg/L. It is likely that these are supersaturated given the water temperatures observed during measurements. Checking the DO calibration of the water meter would also be worthwhile.

Most sites experienced one or more events where DO was less than 2mg/L: Five Day Creek (2), Parrabel Creek (1), Dungay Creek (4) and Euroka Creek (5). This also occurred in the main stem of the Macleay River: Five Day bridge (2), Smithtown (1), Back Creek (3), Jerseyville (1), Rainbow Reach (7) and Clybucca Floodgates (9). DO concentrations below 2mg/L significantly impact the survival and health of aquatic biota. Low DO events can also lead to the release of nutrients and contaminants adsorped to sediments, increasing nutrient and contaminant concentrations in the water column.

pH was consistently alkaline across most sites (Figure A3). However, Clybucca Floodgates recorded a site minimum of 5.47 and Nulla Nulla Creek recorded a site minimum of 3.94. The site minimum pH at Clybucca was observed during the latter stages of a fresh, but the site minimum at Nulla Nulla Creek was observed during very low flows as the creek approached a cease-to-flow event. pH did not remain acidic at the following sampling occasion at either site.

Conductivity remained below ANZECC guidelines for all freshwater sites in the Macleay main stem and the tributaries (Figure A3). Of the freshwater sites, Mungay Creek followed by Hickeys Creek had consistently high conductivity. High conductivity during low flows may indicate natural groundwater inputs to stream baseflow.

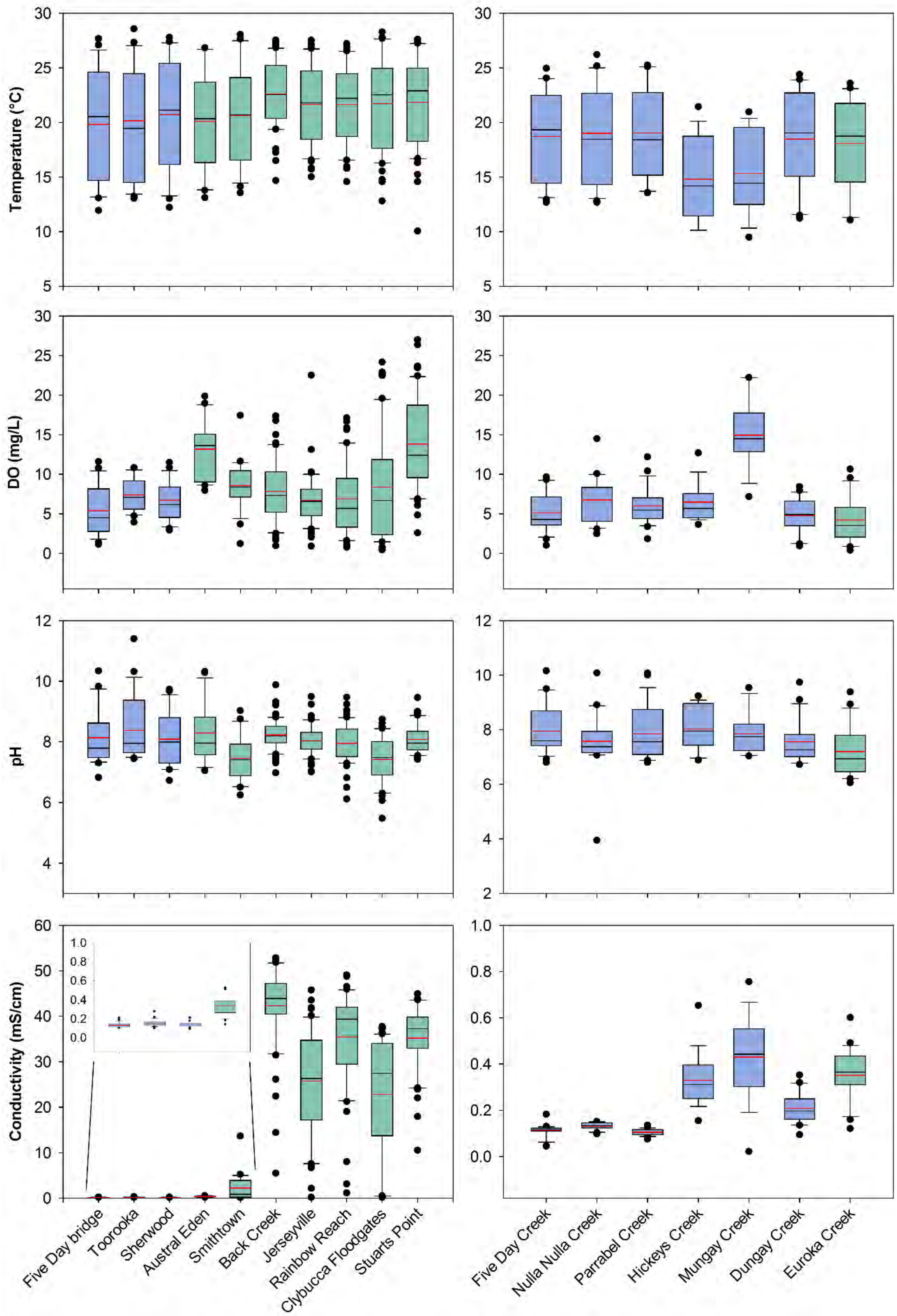

Figure A3. *Ranges of water quality variables from KSC field-based monitoring from 5 January 2015 to 22 March 2016. Freshwater and estuarine sites are represented by blue and green box fills, respectively. Red and black horizontal lines represent the mean and median values, respectively. Individual outliers are represented by black dots.*