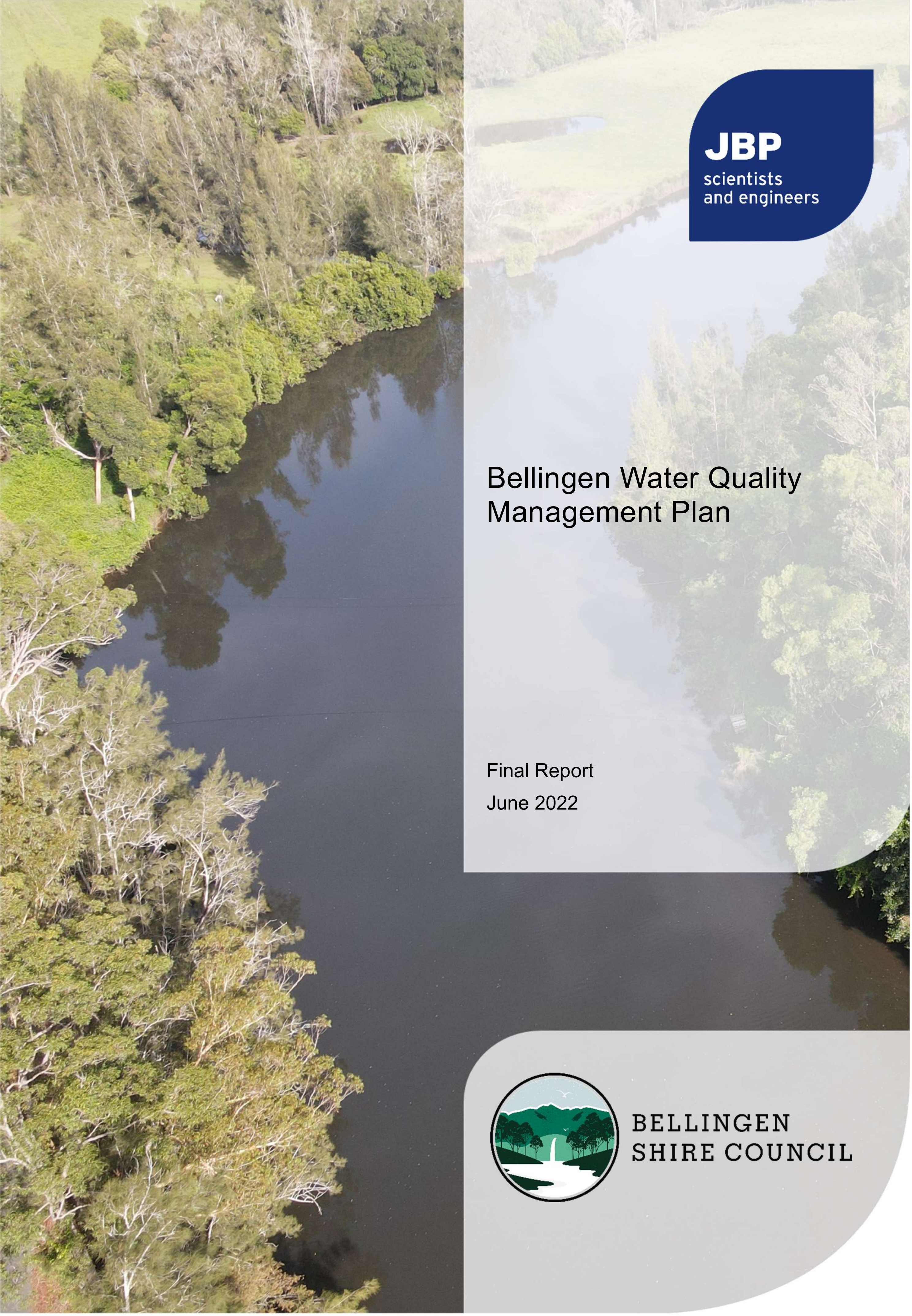

Bellingen Water Quality Management Plan

Final Report

June 2022

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Revision History

Revision Ref / Date Issued	Amendments	Issued to
P01-S3/ INTERNAL DRAFT 18 Oct 2021		JE, JS
P02-S3 Draft Report 31 Jan 2022		JE, JS, TD
P03-S3 Draft Report 09 Jun 2022	Review comments addressed	JE
A1-C1 Final Report 30 Jun 2022	Updates on governance and funding	JE

Contract

This report describes work commissioned by Lucy Menzies, on behalf of the Bellingen Shire Council, by a letter dated 11/08/2021. Bellingen Shire Council's representative for the contract was Justine Elder. Emma Walker, Clare Yang, Daniel Rodger, and Zoe Nehring of JBP carried out this work.

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Disclaimer

Acknowledgements

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Executive Summary

This report was undertaken by JBPacific on behalf of the Bellingen Shire Council (BSC) to develop a Water Quality Management Plan (WQMP) for the Bellinger-Kalang Catchment. This Plan has been developed as an outcome of the Bellingen Coastal Management Programme (CMP) which sets the long-term strategy for the coordinated management of the Bellingen Shire coastline and estuaries. The development of this WQMP continues Councils management of the upstream catchments and estuary regions, which has included a review of water quality monitoring and development of management actions.

Several monitoring programmes have been implemented, including Bellingen Riverwatch, comprehensive bi-annual water quality surveys undertaken by the state government, and two seasons of historic monitoring in 2010 and 2016 under the Ecohealth Program. Monitoring programmes show that elevated turbidity levels can occur throughout the catchment, with the potential for site-specific hotspots for primary water quality, Nitrogen, Phosphate and Faecal Coliforms.

New management actions have been proposed under four broad goals:

Goal 1: Improve poor water quality and control faecal coliforms

- WQ1: Continue and expand the Sewering Coastal Villages programme
- WQ2: Unsealed road management and buffers
- WQ3: Update Stormwater Management Plans and implement previous recommendations
- WQ4: Introduce a stormwater levy

Goal 2: Continue a high standard of water quality monitoring and data collection

- MON1: Continue support for the Riverwatch programme
- MON2: Permanent water quality monitoring station
- MON3: Join the Beach Watch programme
- MON4: Expand public water quality website
- MON5: Investigate the need for metal monitoring

Goal 3: Increase biodiversity and ecosystem services

- BIO1: Managing grazing/stock exclusion on riparian land.
- BIO2: Reinstatement and reforestation of riparian buffers
- BIO3: Refresh the Bellinger Landcare Manual
- BIO4: Protect and restore areas of intertidal saltmarsh, lagoons, and mangroves on Council managed land

Goal 4: Mitigate erosion and improve bank stability

- ERO1: Site-specific erosion investigations
- ERO2: Advocate and educate for private land restoration and erosion protection works
- ERO3: Bank stabilisation and revegetation works on Council managed land
- ERO4: Minimise impacts of boating

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Abbreviations

AEP	Annual Exceedance Probability
ANZECC	Australian and New Zealand Environment and Conservation Council
ASQAP	Australian Shellfish Quality Assurance Programme
BSC	Bellingen Shire Council
DEM	Digital Elevation Model
DO	Dissolved Oxygen
DPE	Department of Planning and Environment (Previously DPIE)
ELVIS	Geoscience Australia Elevation Information System
FRP	Filterable Reactive Phosphate
HRU	Hydrologic Response Unit
JBP	Jeremy Benn Pacific or JBPacific
MER	Monitoring Evaluation and Reporting
MUSLE	Modified Universal Soil Loss Equation
N	Nitrogen metric (considers Ammonia, NOx and TN)
NoV	Norovirus
NRCMA	Northern Rivers Catchment Management Authority
OSMS	On-site Wastewater Management Systems
P	Phosphate metric (considers FRP and TP)
PMF	Probable Maximum Flood
REF	Review of Environmental Factors
Q	Primary water quality metric (considers pH, EC and DO% saturation)
SEPP	State Environmental Planning Policies
SWAT	Soil and Water Assessment Tool
T	Water clarity and sediment load metric (considers Turbidity and TSS)
TP	Total Phosphorus
TN	Total Nitrogen
TSS	Total Suspended Solids
UNE	University of New England
USLE	Universal Soil Loss Equation
WQMP	Water Quality Management Plan
WWTP	Wastewater Treatment Plant

1 Introduction

The Bellinger-Kalang catchment is located on Gumbaynggirr Country in the Bellingen Shire on the Mid North Coast of NSW. It includes the towns of Bellingen, Thora, Fernmount, Mylestom, and Urunga, with a population of approximately 10,000. The catchment spans approximately 1,110km^2 with major tributaries including the Bellinger River, Kalang River, Never Never River, Rosewood River, Hydes Creek, Manarm Creek, Spicketts Creek, and Pickett Hill Creek, and includes a coastline of approximately 10km.

Over half of the catchment is forested as part of a State Forest, National Park, or Nature Reserve. The local community values their local waterways as their cultural heritage, drinking water resource, recreational services, aquaculture, irrigation, biodiversity, and ecosystem services. Visual amenity is highly valued, and popular recreational activities include boating, walking, hiking, camping, swimming, picnicking, and fishing. The Bellinger-Kalang catchment is under pressure from increased population, tourism, and conflicts of usage. Water quality within the catchment is monitored frequently and has previously identified water quality parameter values outside of recommended water quality guideline values.

To help guide the future management of the catchment, the Bellingen Shire Council (BSC) has engaged JBPacific to develop this regional Water Quality Management Plan (WQMP), to inform the Bellingen Coastal Management Programme (CMP). The CMP sets the long-term strategy for the coordinated management of the Bellingen Shire coastline and estuaries. This WQMP will continue BSC's management of the upstream catchments as they impact the coastal zone, and will integrate water quality monitoring, new analysis, options appraisals, and the development of management actions. The structure of this WQMP consists of the following sections:

- **Section 2. Existing Catchment:** This section details the existing catchment water quality, monitoring, and modelling of the catchment with a detailed review of current water quality management within the Bellinger-Kalang Catchment.
- **Section 3. Catchment Goals:** This section details the community values and management goals, water quality indicators and guidelines, and water quality objectives.
- **Section 4. Catchment Management Actions:** This section details a water quality monitoring plan, a snapshot of current issues, catchment management options, and an implementation plan to manage water quality, biodiversity, and bank erosion.

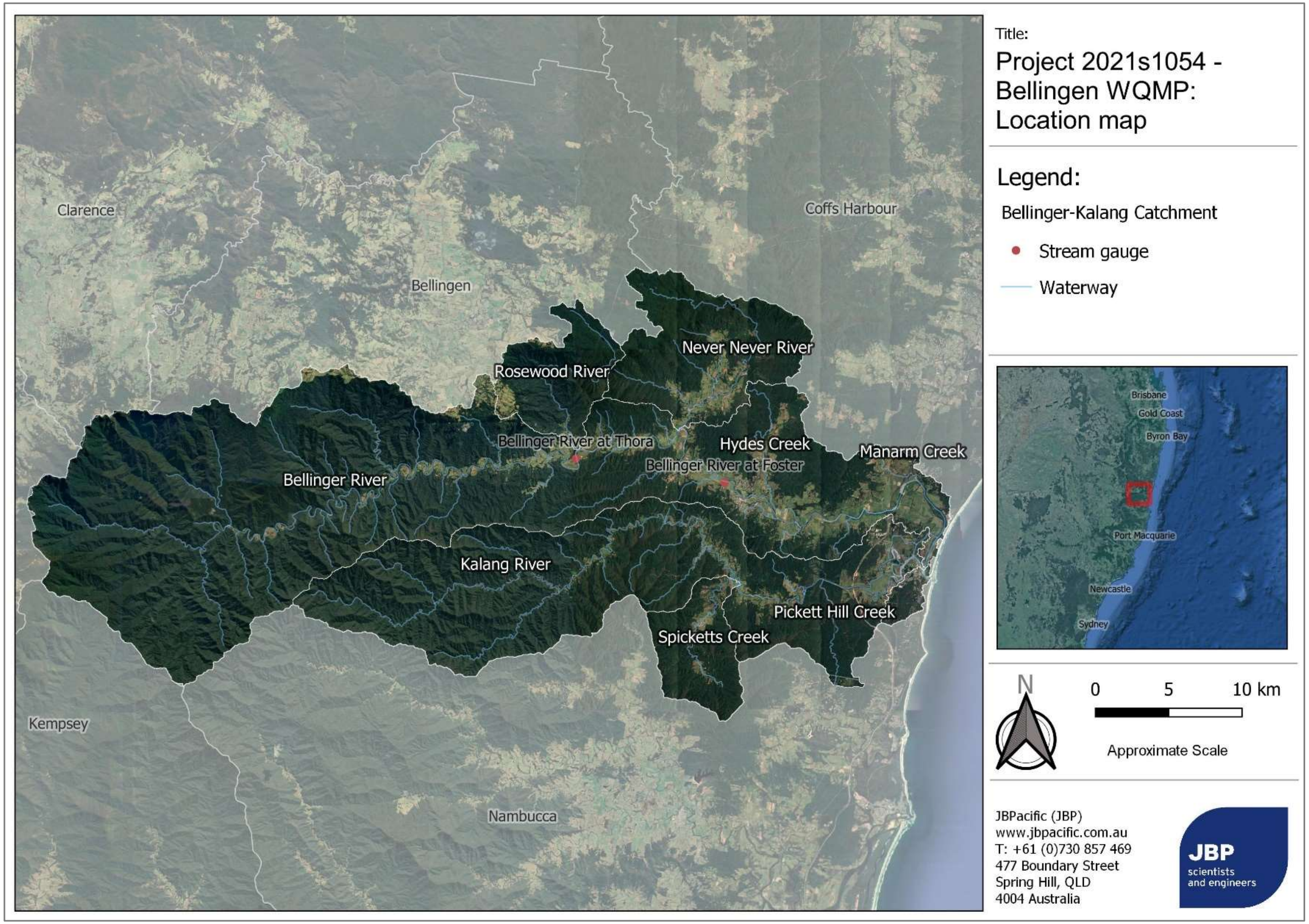


Figure 1-1: Bellingen Local Government Area

2 Existing Catchment

2.1 Catchment Description and Processes

The Bellinger-Kalang Catchment is approximately 1,114km^2 in size and consists of the northernmost Bellinger River and the Kalang River to its south. The confluence of the Bellinger and Kalang Rivers is approximately 700m upstream of the coastline at the northern point of the Urunga Lagoon. The area is characterised by high rainfall and surface runoff with annual rainfall between 650mm and 2,895mm within the catchment[1].

Landuse spatial mapping within the Bellinger-Kalang Catchment was undertaken based on DPE NSW Landuse (2017)[2] and the Australian Land Use and Management Classification Version 8 (2016)[3]. Landuse within the catchment is described in Table 2-1 and shown in Figure 2-1. This data shows that over half (53.7%) of the catchment is labelled as conservation and natural environments (as of 2017) which a large proportion of this (35.5%) is labelled national parks. Approximately 40.4% of the catchment is used for production from relatively natural environments, 2.4% for production from dryland agriculture and plantations, less than 1.0% for production from irrigated agriculture and plantations, and Intensive uses take up around 1.5% of the catchment.

Soil landscape maps were obtained from the NSW DPE eSPADE version 2.2 soil and land information system[4]. The accompanying soil landscape reports for the Bellinger-Kalang Catchment describe soil qualities in the upper and mid catchment as generally stony soils with organic topsoil containing acidity and aluminium toxicity potential. Very steep slopes with extreme mass movement hazard, rock outcrop, rockfall hazard, high water erosion risk, shallow soils, complex soils, and engineering hazards were all limitations of the upper catchment which are subject to debris avalanches, landslips, and rotational slumping, particularly following heavy rainfall. Sheet and gully erosion is common, especially where the soil surface has been disturbed by roads and forestry activities due to erodible soils on steep slopes with high rainfall erosivity. There has been evidence of in-stream sedimentation from runoff associated with forestry operations. Sheet and rill erosion occurs on, and around existing forestry operations caused by runoff from roads, snig tracks, and log dumps. Logging operations and roading can also cause increased soil erosion, slope instability, new mass movements or reactivation of existing landslides[4].

The estuary and lower catchment soil landscape reports describe strongly acid soils with low fertility, acid sulfate potential, and low permeability. High water erosion hazard (localised, along banks of major rivers), flood hazards, and seasonal waterlogging were also described. Localised severe stream bank erosion along river channels, particularly that of the Bellinger River itself, as a result of periodically high stream discharges caused by storms in the upper Bellinger catchment. Such bank erosion may significantly affect the integrity of adjacent agricultural land or buildings[4].

No spatial datasets were identified showing riparian zone statistics, which had to be generated for this project. This was created as a 40m buffer around rivers and streams, and land use split into vegetated or unvegetated zones. These zones have been mapped using aerial imagery, with any areas of tree cover considered vegetated, and any bare earth, pervious surfaces or areas of grass cover considered unvegetated. Throughout the entire Bellinger-Kalang catchment, 84% of riparian zones are vegetated, as shown in Figure 2-2. The unvegetated areas are primarily dryland agriculture and intensive use zones.

1 BCMC (2000). Bellinger Catchment Management Committee Water Quality Monitoring Project Final Report.

2 Department of Planning and Environment (DPE). NSW Landuse 2017.

3 Department of Agriculture, Water, and the Environment (ABARES) (2016). Australian Land Use and Management Classification Version 8 (October 2016).

4 NSW Department of Planning and Environment (2022). eSPADE V2.2 first published April 2022.

Table 2-1. Landuse in the Bellinger-Kalang Catchment.

Land Use	Cover (%)	Description	Environmental effects
Conservation and natural environments	53.7	- Nature conservation - Managed resource protection - Other minimal use	Little to no adverse effects on water quality within the catchment and provide many ecosystem services and benefits.
Production from relatively natural environments	40.4	- Grazing native vegetation - Production native forests	Increase erosion through vegetation clearing, exposing soils, and the clearing of forest-derived leaf litter[5]. Heavy machinery used can alter the natural contour of the land and cause soil compaction reducing forest productivity. Anthropogenic soil erosion removes nutrient-rich topsoil attributing to degraded soil quality and ecosystem function and decreased soil porosity and water filtration. Logging and intensive forestry activities can also produce significant nonpoint source pollution to the waterways, cause a significant loss to wildlife and habitat, reduce riparian buffer width, and contribute total suspended solids to the waterway[6]
Production from irrigated agriculture and plantations	<1.0	- Irrigated plantation forests - Grazing irrigated modified pastures - Irrigated cropping - Irrigated perennial horticulture - Irrigated seasonal horticulture - Irrigated land in transition	Implications of irrigated cropping include land degradation, habitat loss, riparian vegetation loss, loss of biodiversity, high erodibility, and more. These effects can contribute turbidity to the catchment, runoff of farming effluent, and a loss of biodiversity. Logging from plantation forests have impacts on water and soil quality due to the use of fertilisers, pesticides, and herbicides, and their initial deforestation which causes long-lasting adverse effects.
Production from dryland agriculture and plantations	2.4	- Plantation forests - Grazing modified pastures - Cropping - Perennial horticulture - Seasonal horticulture - Land in transition	Implications of dryland cropping include land degradation, habitat loss, riparian vegetation loss, loss of biodiversity, high erodibility, and more. These effects can contribute turbidity to the catchment, runoff of farming effluent, and a loss of biodiversity. Logging from plantation forests have impacts on water and soil quality due to the use of fertilisers, pesticides, and herbicides, and their initial deforestation which causes long-lasting adverse effects.
Intensive Uses	1.5	- Intensive horticulture - Intensive animal production - Manufacturing and industrial - Residential and farm infrastructure - Services - Utilities - Transport and communication - Mining - Waste treatment and disposal	Potential risk to riparian and instream values and the downstream oyster industry through erosion, turbidity, and habitat loss. Animal industries such as farming may degrade water quality through faecal and nutrient contamination, loss of riparian vegetation through trampling and grazing, runoff from pesticides, fertilisers, and nutrients, and turbidity and erosion through bank trampling if stock access is unmanaged. Runoff from intensive landuse use may also contribute pollutants, nutrients, toxicants, and turbidity.
Water	2.0	- Lake - Reservoir or dam - River - Channel or aqueduct - Marsh or wetland - Estuary or coastal waters.	N/A

5 Wenger, A. S., Atkinson, S., Santini, T., Falinski, K., Hutley, N., Albert, S., Horning, N., Watson, J.E., Mumby, P.J., and Jupiter, S.D. (2018). Predicting the impact of logging activities on soil erosion and water quality in stepp, forested, tropical islands. Environmental research letters, 13(4), 044035.

6 Eco Logical Australia (2019). Bellingen Shire Biodiversity Strategy. Prepared for Bellingen Shire Council.

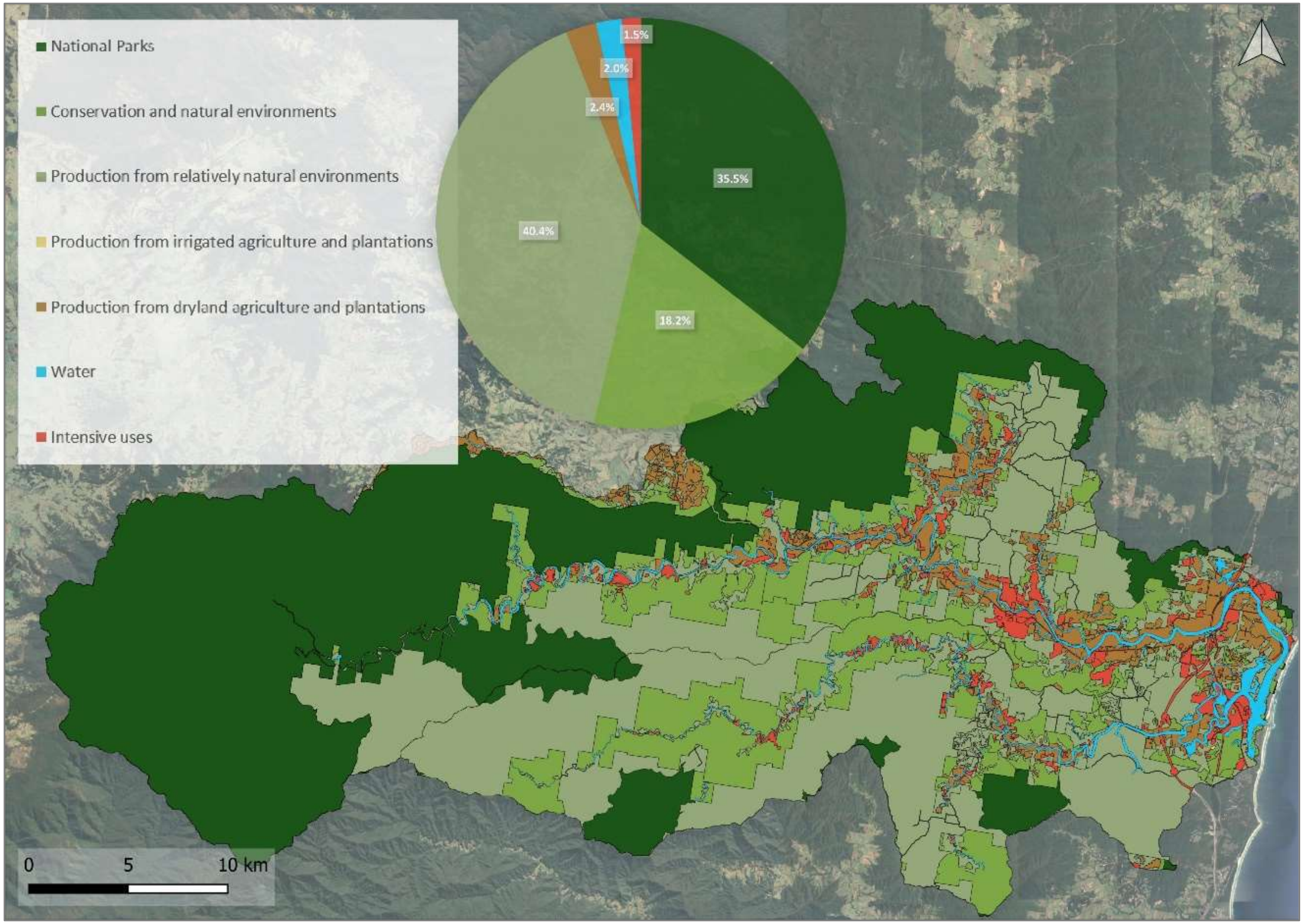


Figure 2-1: Bellinger-Kalang Catchment land use

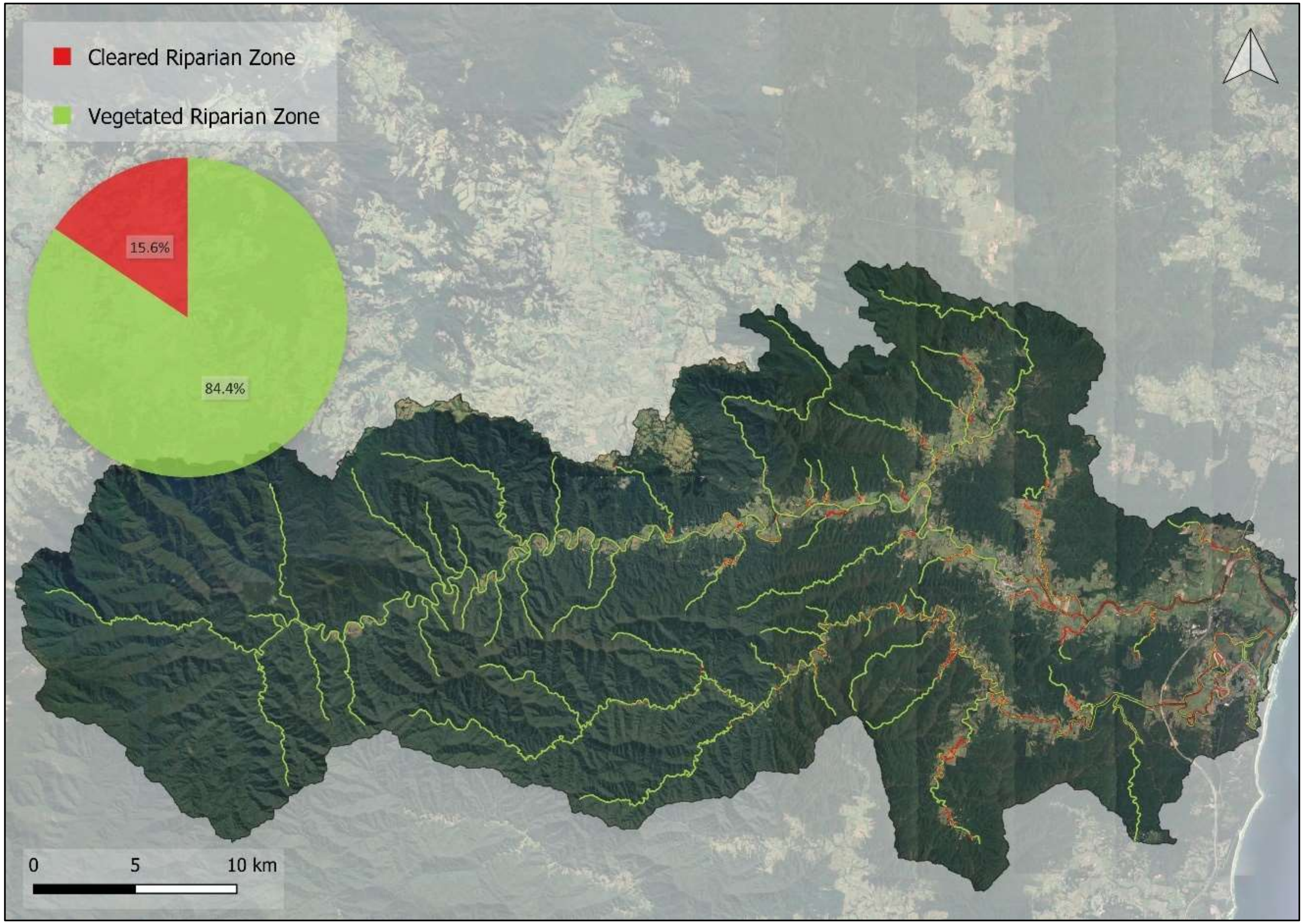


Figure 2-2: Bellinger-Kalang Catchment riparian vegetation condition

2.1.1 Bellinger River

The Bellinger River flows east through Darkwood, Thora, Bellingen, Fernmount, and Mylestom, and discharges at Urunga into the Pacific Ocean. The Bellinger River has a catchment area of approximately 773km^2 with a river length of ~70km with tidal limit approximately 26.1km from the ocean. Its major tributaries include the Never Never River, Rosewood River, Hydes Creek, Manarm Creek, and Boggy Creek as shown in Figure 2-4. The Never Never and Rosewood Rivers are beyond the tidal limit. The tidal limit reaches approximately 22km from the ocean up the North arm to ~900m upstream of Lavenders Bridge, approximately 22.3km from the ocean up the west arm of Hydes Creek to ~150m upstream of Constables Bridge, and approximately 10.3km from the ocean up Manarm Creek near old timber bridge (2km upstream from Bellinger River).

The Bellinger River Catchment is composed of sedimentary, igneous, and metamorphic rocks. The upper Bellinger River is predominantly composed of stable bedrock and boulders within the riffles, and fine sands and silts in the deeper pools. The mid-catchment floodplain consists of mobile cobble bedrock and shallow pools, and the lower estuarine regions consisting of mostly coarse sands and gravel[7]. The dominant lithology consists of sand, clastic sediment, and gravel. The upper reaches of the Bellinger River also contain some gabbro, sandstone, slate, phyllite, and basalt from the Ebor extinct volcano to the west[7].

Soil landscape maps were obtained from the NSW DPE eSPADE version 2.2 soil and land information system[8] for the Bellinger River. The soil limitations of the Bellinger River riparian zone were described as having low to very low wet bearing strength, low permeability, and low subsoil fertility with a high water erosion hazard, high run-on, high foundation hazard, flood hazard, and seasonal waterlogging[8]. Existing land degradation along the riparian zone includes localised severe stream bank erosion along river channels, and localised gully erosion along tributary streams particularly in the upper western Bellinger Valley. A moderate soil structure decline was observed in many areas resulting from compaction and trampling by cattle[8]. The upper Bellinger Valley landscape includes very steep to precipitous mountains with narrow crests and long rectilinear slopes on Nambucca Block metasediments in the Horseshoe Ranges and along the western Dorrigo escarpment. The upper catchment is mostly uncleared tall open forest with distinctive high-altitude vegetation, including shallow soils with a moderate to severe mass movement hazard[8]. The mid to lower catchment landscape includes rolling low hills to hills on Permian metasediments in the Gleniffer Hills, and as lower slopes in valleys draining the Horseshoe Ranges. These landscapes contain strongly acid, stony soils with low fertility, high erodibility, high aluminium toxicity potential, low subsoil permeability and low subsoil available water capacity. Limitations also include high water erosion hazard, high run-on, and steep slopes.

The Bellinger River has steeper fluvially-dominated upper tidal reaches that have eroded at a faster rate than the lower gradient fluvial-transition reaches[9]. Estuary erosion studies show that erosion rates were highest at the right riverbank upstream of the Hydes Creek confluence, opposite Fernmount on the left bank of the river, and on the left bank approximately 500m downstream of Carlill's Wharf. These areas are particularly susceptible to erosion due to their low cohesion of bank soils, lack of riparian vegetation, and poorly managed stock access[3]. Telfer (2010) revealed that 54% of the estuary was stable, while the remaining 46% showed either minor erosion, or areas protected by erosion control works.

Around 73% of the Bellinger River Catchment landuse is classed as 'conservation and natural environment' and a further 21% as a 'production area from relatively natural environments'. Minor landuses include dryland agriculture (4%), water (1.5%), and intensive uses (1%), as shown in Figure 2-5[10]. Analysis of the riparian zone indicates the majority is vegetated (87%) as shown in Figure 2-6. The riparian zone in upper reaches beyond Darkwood is mostly vegetated, with an increasing proportion of clearing when moving towards the lower estuary.

7 Leitch E.C., Neilson M.J. and Hobson E., 1971, Dorrigo - Coffs Harbour 1:250 000 Geological Sheet SH/56-10 & part SH/56-11, 1st edition, Geological Survey of New South Wales, Sydney.

8 NSW Department of Planning and Environment (2022). eSPADE V2.2 first published April 2022.

9 Telfer, D. (2010). Bellinger and Kalang River Estuaries Erosion Study.

10 Based on NSW landuse (2017) datasets, using the Australian Land Use and Management Classification (2016)

Figure 2-3: Bellingen River (JBP 2022)

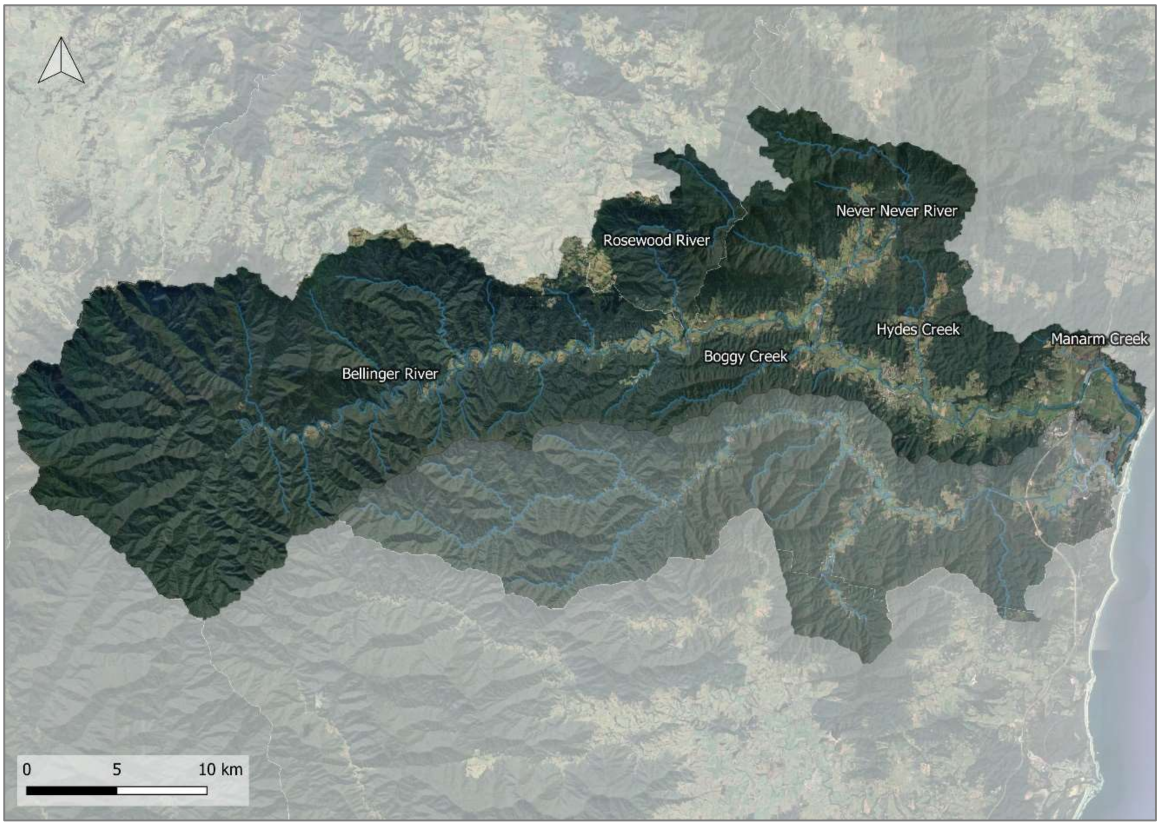


Figure 2-4: Bellinger River main tributaries.

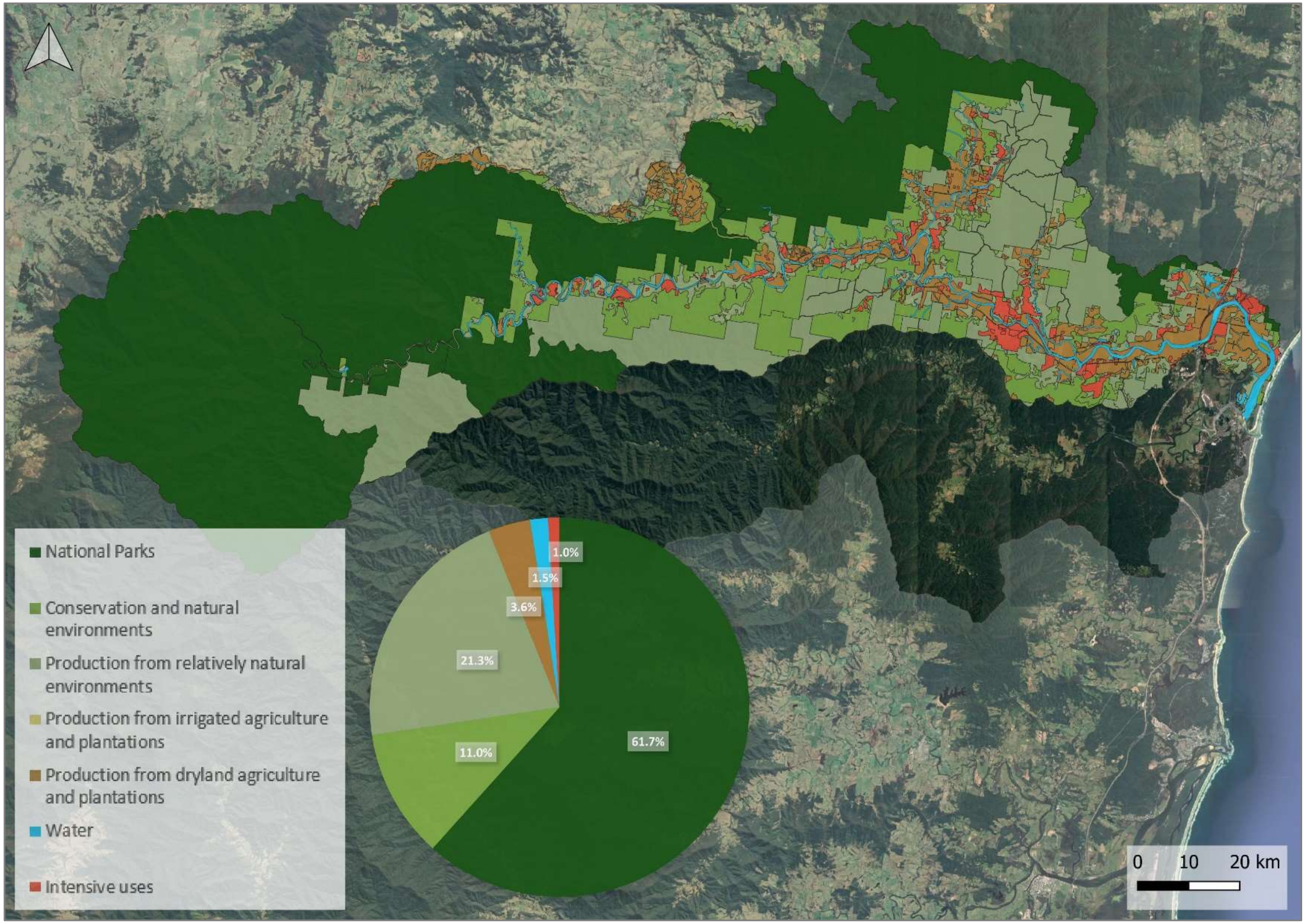


Figure 2-5: Bellinger River Catchment land use

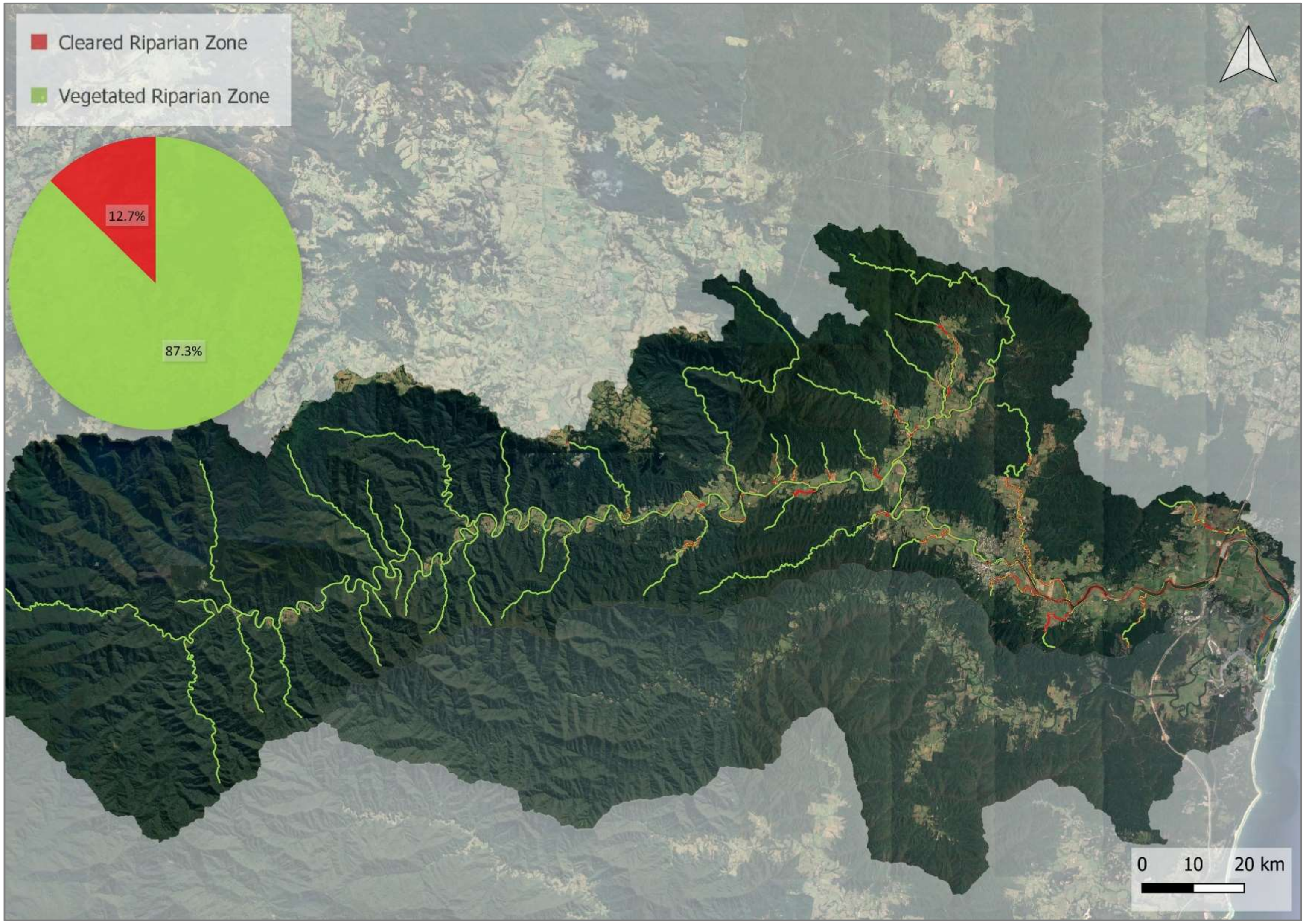


Figure 2-6: Bellinger River Catchment riparian vegetation condition

2.1.2 Never Never River

The Never Never River is a perennial stream of the Bellinger River catchment which spans approximately 26km with headwaters in Dorrigo National Park. The Never Never sub catchment is approximately 95km^2 in size. It is located to the north of the Bellinger River and meanders south-east and south-westward through densely forested national park and forestry areas for 17km before reaching the Angel Gabriel Capararo Reserve and joins the Bellinger River approximately 500m south of Gordonville. Its main tributaries include Little Promised Land Creek, Promised Land Creek, Sweetwater Creek, Stony Gully, and Stony Creek/Buffer Creek.

The river consists of a series of short shallow pools and longer riffle runs. The composition of the stream is a mix of bedrock and cobble/gravel with small amounts of coarse sands with a dominant lithology of granite, sand, and clastic sediments. There is very little fine sediment in this river which results in high clarity and low turbidity. Many of its shallow pools are formed of dynamic cobble beds which can reshape following high flow events, although riffles in the upper sections are considered stable[11].

Soil landscape maps were obtained from the NSW DPE eSPADE version 2.2 soil and land information system[12] for the Never Never Catchment. Soil landscape reports describe stony, strongly acid, slowly permeable soils of low fertility and high aluminium toxicity potential with very high erodibility. The Never Never Catchment contains steep to very steep slopes, high to severe water erosion hazard, high to severe foundation hazard, high mass movement hazard and rock fall hazard. Localised soil compaction and mixing, plus sheet and rill erosion, on and adjacent to forest roads and other logging works are degrading soils in this region[12].

Using the Australian Land Use and Management Classification (2016), the land use within the catchment includes national parks (64%), production from relatively natural environments (24%), conservation and natural environments (6%), water (4.5%), dryland agriculture (1.5%), and intensive uses (~0.5%), which is shown in Figure 2-8.

Analysis of the riparian zone shows approximately 87% is vegetated, as shown in Figure 2-9. The greatest areas of clearing have occurred at the downstream end of Youngers Creek at the Gordonville Road crossing, at the confluence of Buffer Creek and Never Never River, and the downstream and the midsection of Promised Land Creek. The riparian zone in the lower catchment includes exotic species such as camphor laurel, which has resulted in the development of large, deep leaf packs forming adjacent to waterway pools. These areas are typically surrounded by cleared farmland with a mix of dense exotic and native vegetation along the riparian zone.

Figure 2-7: Never Never River (JBP, 2022)

11 Leitch E.C., Neilson M.J. and Hobson E., 1971, Dorrigo - Coffs Harbour 1:250 000 Geological Sheet SH/56-10 & part SH/56-11, 1st edition, Geological Survey of New South Wales, Sydney.

12 NSW Department of Planning and Environment (2022). eSPADE V2.2 first published April 2022.

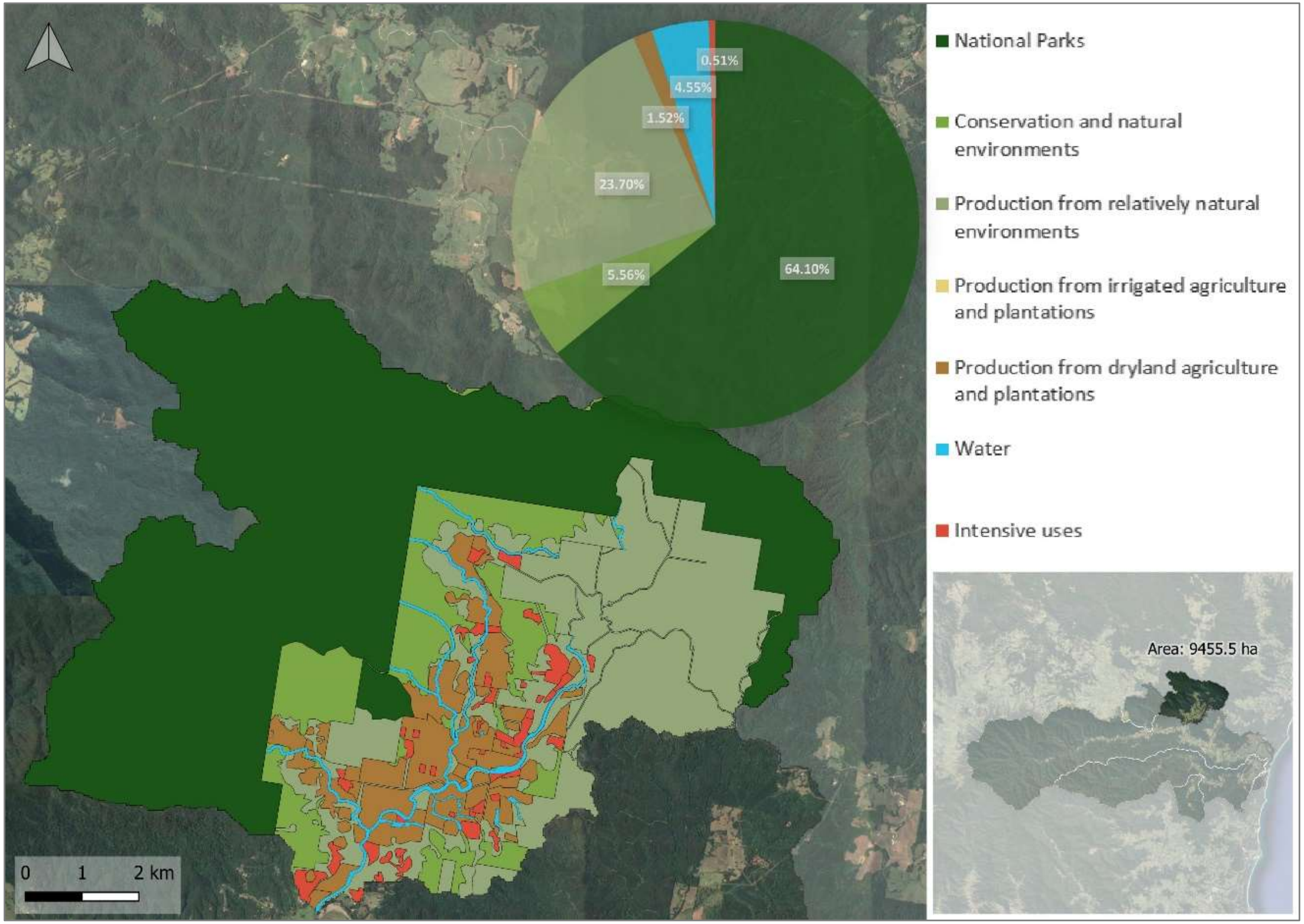


Figure 2-8: Never Never River Catchment land use

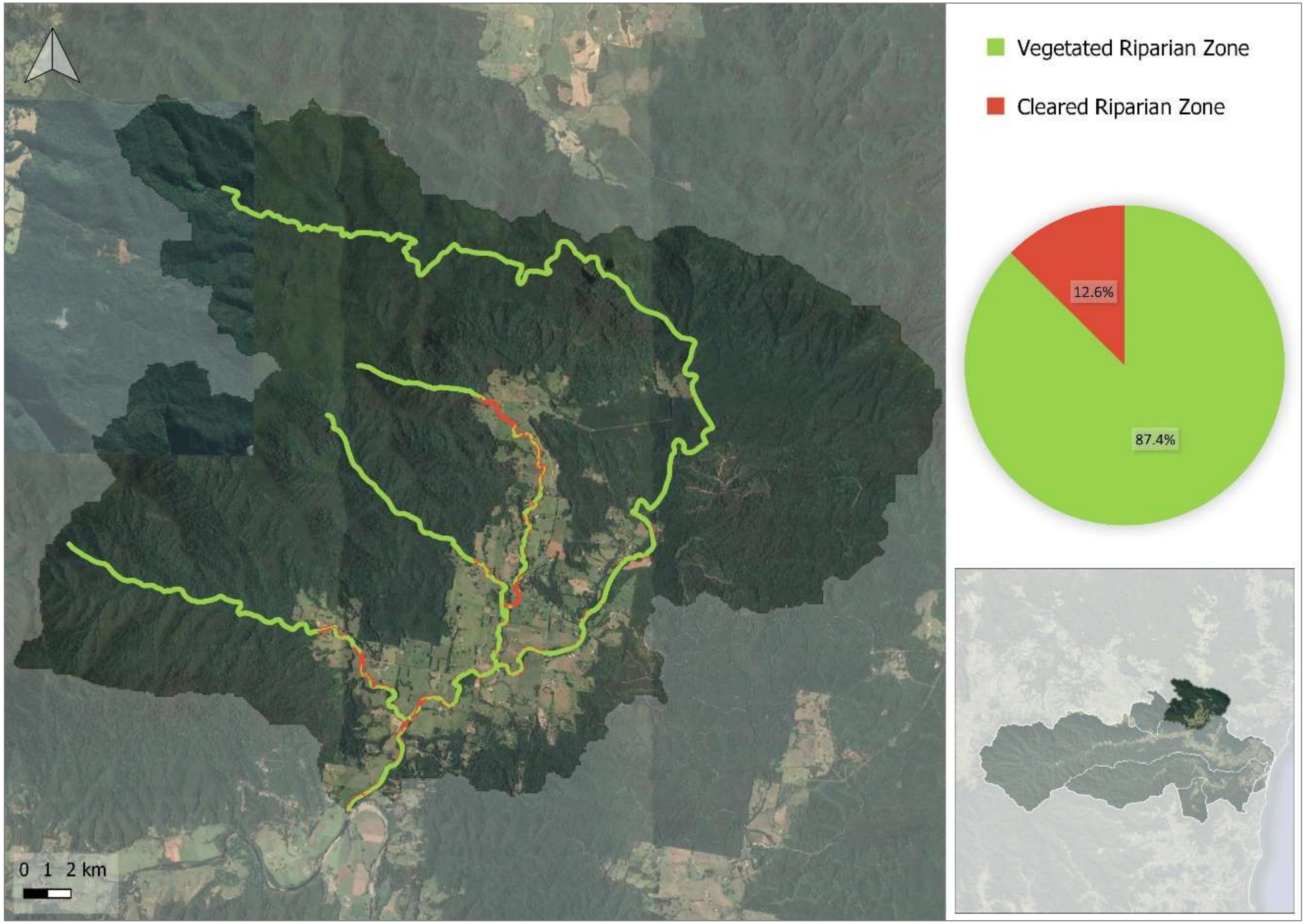


Figure 2-9: Never Never River Catchment riparian vegetation condition

2.1.3 Rosewood River

The Rosewood River is a perennial river tributary of the Bellinger River approximately 21km long with its headwaters in Dorrigo National Park. The Rosewood River sub catchment is approximately 50km^2 in size. It is located to the north of the catchment, meandering southerly and joining the Bellinger River at Thora.

The upper catchment is highly vegetated with predominantly dense native vegetation. The river runs through a narrow, steep sided valley with little floodplain development and an extensive riparian zone consisting of predominantly native vegetation with some exotic species. The riffles are stepped, short, and composed of large boulders and bedrock. The dominant lithology of the Rosewood River is clastic sediment, slate, gabbro, and basalt. Water turbidity is typically very low even during periods of high flow[13]. The riverbanks in the Rosewood River are stable with little to no erosion observed. The limited data available shows very good water quality and excellent clarity.

Soil landscape maps were obtained from the NSW DPE eSPADE version 2.2 soil and land information system[14] for the Rosewood River Catchment. Soil landscape reports describe strongly acid stony soils with high aluminium toxicity potential, low wet bearing strength, high to very high subsoil erodibility and low fertility. The Rosewood River Valley contains steep slopes, high water erosion hazard, foundation hazard, mass movement hazard (localised), and high run on (localised)[14].

Land use in the Rosewood River Catchment includes national park (96%), conservation and natural environments (1.5%), production from relatively natural environments (~1%), water (1.5%) and production from dryland agriculture (~0.4%), as shown in Figure 2-10)

The Rosewood River riparian zone is the most vegetated within the Bellinger-Kalang catchment, with only 0.6% unvegetated land (see Figure 2-11).

13 Leitch E.C., Neilson M.J. and Hobson E., 1971, Dorrigo - Coffs Harbour 1:250 000 Geological Sheet SH/56-10 & part SH/56-11, 1st edition, Geological Survey of New South Wales, Sydney.

14 NSW Department of Planning and Environment (2022). eSPADE V2.2 first published April 2022.

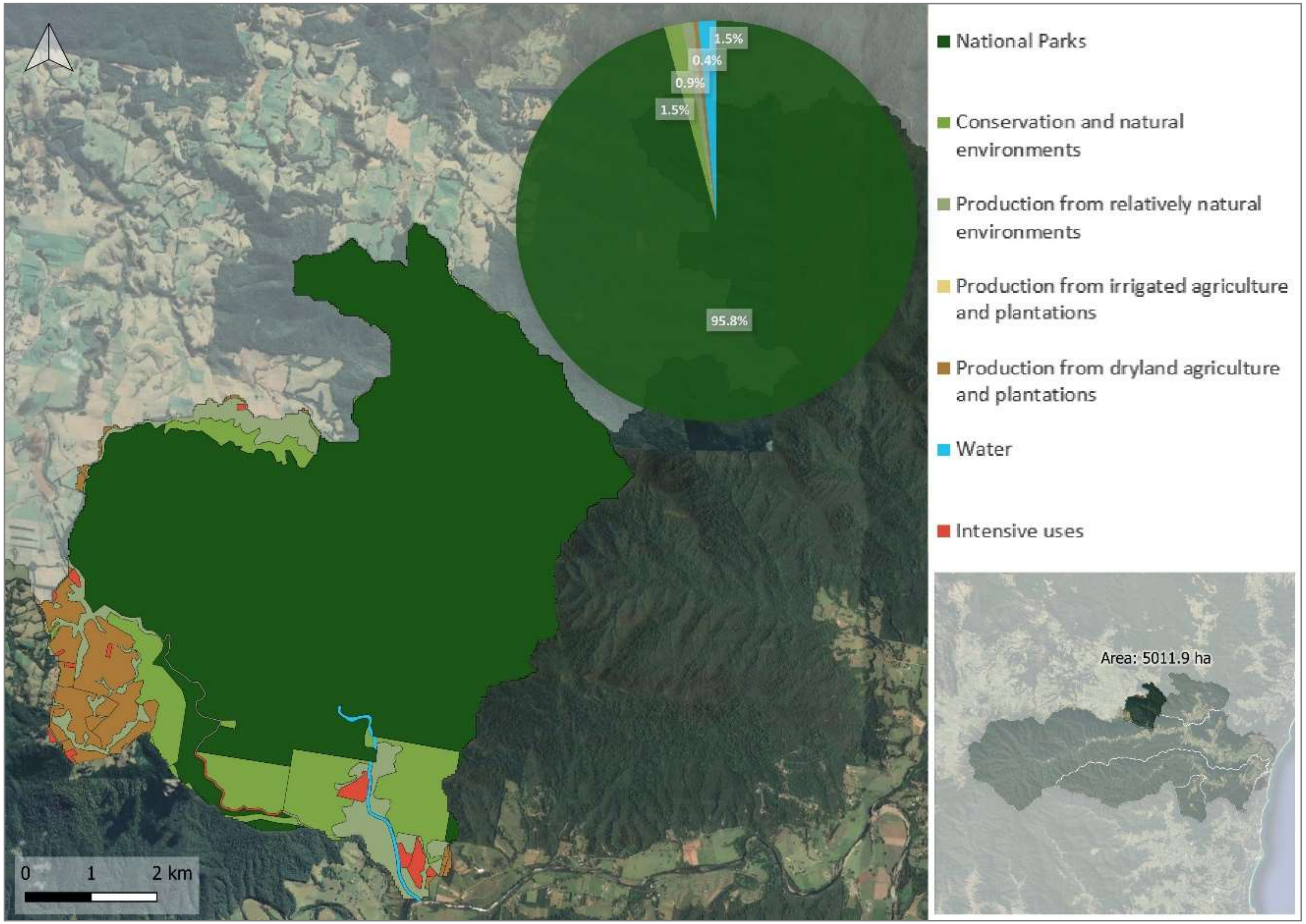


Figure 2-10: Rosewood River Catchment land use

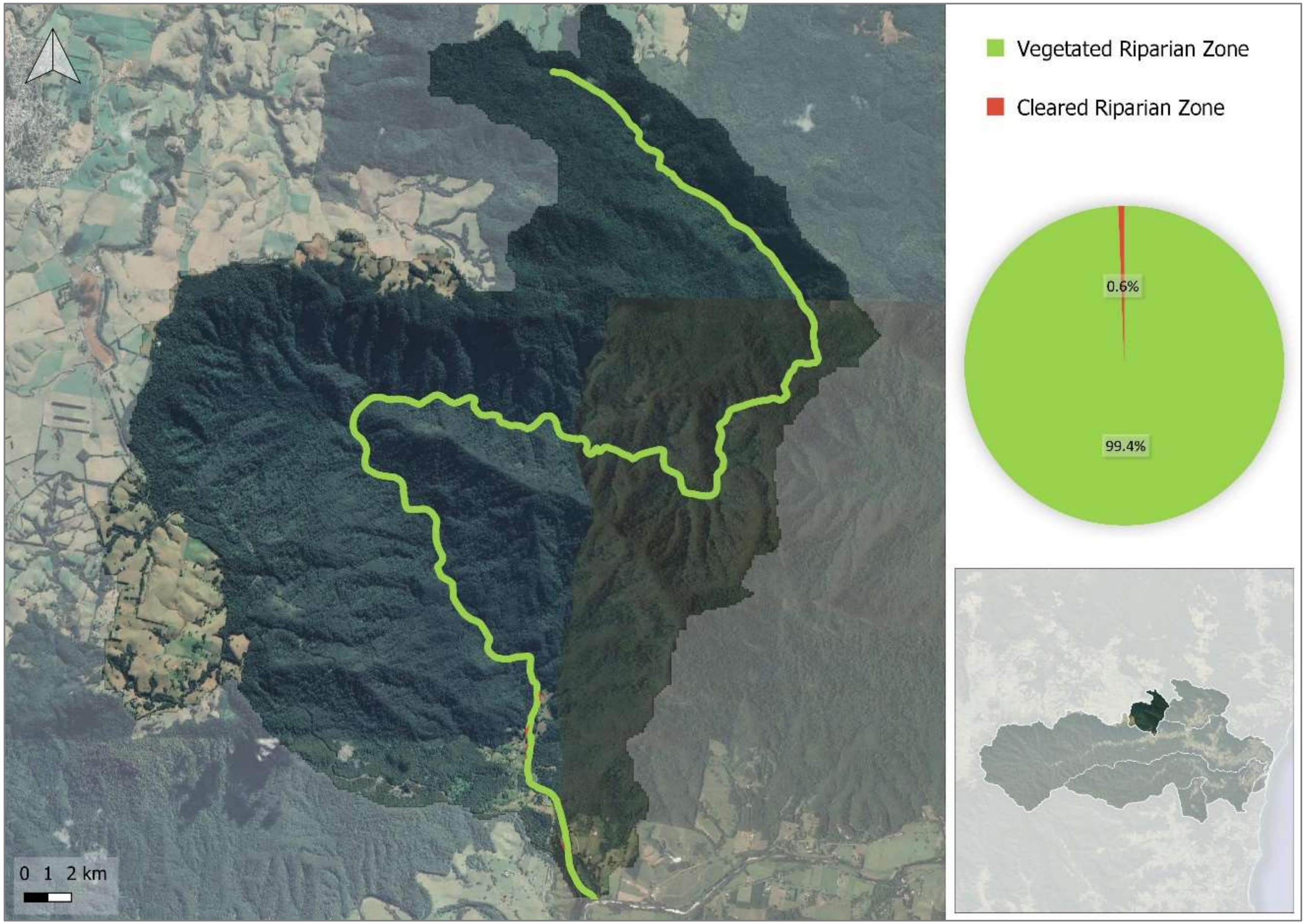


Figure 2-11: Rosewood River Catchment riparian vegetation condition

2.1.4 Kalang River

The Kalang River is the second largest river within the Bellingen region, with a length of approximately 77km with a catchment area of 341km^2. Major tributaries of the Kalang River include Picket Hill Creek and Spicketts Creek as shown in Figure 2-13. The tidal limit reaches approximately 25.1km from the ocean up the Kalang River ~700m upstream from the bridge at Brierfield. The Kalang estuary is characterised by discontinuous pocketed alluvial floodplains interspersed with more bedrock control than Bellingen estuary which meanders through a more expansive alluvial floodplain.

The downstream extent of the river is a short, low energy watercourse with long, shallow pools and short riffles. The riverbed consists of fine to coarse sands and silts in the pools and riffles intermixed with bedrock. The riffles are short and composed of either low relief runs of sand/gravel and minor large cobble/boulders or stepped bedrock[15]. The lower section of the Kalang River has larger low-energy pools with sand, silt, and clay substrates. The dominant lithology in the estuary and lower Kalang River is sand, clastic sediment, gravel, and slate. The mid Kalang River consists of clastic sediment, phyllite, sand, and slate, and the upper Kalang River lithology is dominant in clastic sediment, slate, and basalt from the Ebor volcano. Water turbidity recorded in the lower section was typically low although this has proven to increase during periods of high flow and to greater extents in the lower sections of the river. At the uppermost section and the Pearns Road Bridge section of the Kalang River, the stream is moderately sized with very good water quality and high visibility[15].

Soil landscape maps were obtained from the NSW DPE eSPADE version 2.2 soil and land information system[16] for the Kalang River Catchment. Stony soils with organic topsoils, acidity and aluminium toxicity potential were described for this catchment. The upper Kalang is comprised of localised steep slopes with moderate to high mass movement risk, localised high run-on, high sheet erosion risk, moderate gully erosion risk, and localised shallow soils. There is evidence of sheet erosion associated with roads and forestry activities. Landslips and road batter failures are common following heavy rainfall. There has been evidence of in-stream sedimentation from runoff associated with forestry operations[16]. The Kalang Catchment riparian zone is described as extensively cleared riverine forests containing gravelly soils with low wet bearing strength, organic topsoils, high erodibility, high permeability (floodplains; low terraces), low permeability (high terraces), low available water holding capacity and high topsoil fertility. Soil and land qualities include localised flood hazard, localised poor drainage, seasonal waterlogging, groundwater pollution hazard, and streambank erosion hazard. Streambank erosion is locally severe, especially where riparian vegetation has been removed. Localised gully erosion is present along tributary streams on floodplain and terrace surfaces, with localised moderate to severe fluted rill erosion on exposed terrace faces. Moderate soil structure decline is present in many areas from compaction by machinery and cattle[16].

Data collected by Telfer (2010) indicates that the Bellinger River erodes/migrates at a faster rate than the Kalang River possibly due to the more cohesive bank material and riparian vegetation condition in the Kalang River[17]. Erosion rates were higher on the Kalang River in the upper estuary, and on Newry Island opposite Urunga due to a lack of riparian vegetation, unmanaged stock access, and wind and boat wash[6]. Telfer (2010) also revealed that 68% of the estuary banks surveyed were stable, 21% had minor erosion, 6% had moderate erosion, and 4% was classed as severe erosion.

The Kalang River valley has varying riparian condition, with cleared farmland, exotic species, and remnants of native vegetation. Extensive macrophyte beds consisting of native and introduced species are a significant feature along the length of the river although to a lesser extent in the riffles due to mobile sand substrate. The valley is quite narrow with steep sides and dense, predominantly native vegetation in the riparian zone that provides heavy shading of the waterway. Downstream of the Pearns Road Bridge the valley is wider with predominantly exotic vegetation in the riparian zone.

The creek at this site is not influenced by the estuary in terms of water levels and salinity. However, the proximity to the estuary may be influencing aquatic biodiversity. The valley is wider than previous sites with almost entirely exotic vegetation making up the riparian zone. The dense riparian

15 Leitch E.C., Neilson M.J. and Hobson E., 1971, Dorrigo - Coffs Harbour 1:250 000 Geological Sheet SH/56-10 & part SH/56-11, 1st edition, Geological Survey of New South Wales, Sydney.

16 NSW Department of Planning and Environment (2022). eSPADE V2.2 first published April 2022.

17 Telfer, D. (2010). Bellinger and Kalang River Estuaries Erosion Study.

vegetation does provide an almost complete canopy cover to the waterway. Land use is predominantly cattle grazing properties[18].

Land use within the Kalang River Catchment includes production zones from relatively natural environments (59%), conservation and natural environments (25%), national parks (10%), water (2.5%), intensive uses (2%) and irrigated agriculture and plantation zones (~1.3%), which is shown in Figure 2-14.

Using the new riparian zone maps, approximately 81% of the catchment is considered to be vegetated, as shown in Figure 2-15. However, this is influenced by the large areas of conservation in the upper catchment, with the riparian zone in the lower catchment frequently cleared. Significant riparian clearing is observed at the Woods Creek confluence bordering Sunny Corner Road, the confluence of Moodys Creek and downstream Moodys Creek, the Spicketts Creek confluence, the midsection of Spicketts Creek from the upstream end of Simmons Road to 1091 Bowraville Road, a large patch of clearing upstream of Spicketts Creek at 1399 Bellingen Road, downstream of the Spicketts Creek confluence to Pine Creek, the downstream portion of Pine Creek, and from the Pacific Highway bridge through to the estuarine regions of the Kalang River mouth.

Figure 2-12: Kalang River (JBP, 2022)

18 Dickson, A., Belmer, N., and Serov, P., (2021). DRAFT - Water Quality and Macroinvertebrate Monitoring of the Bellinger Catchment Providing a scientific foundation to inform the Bellinger Riverwatch citizen science monitoring program. Published by NSW DPE.

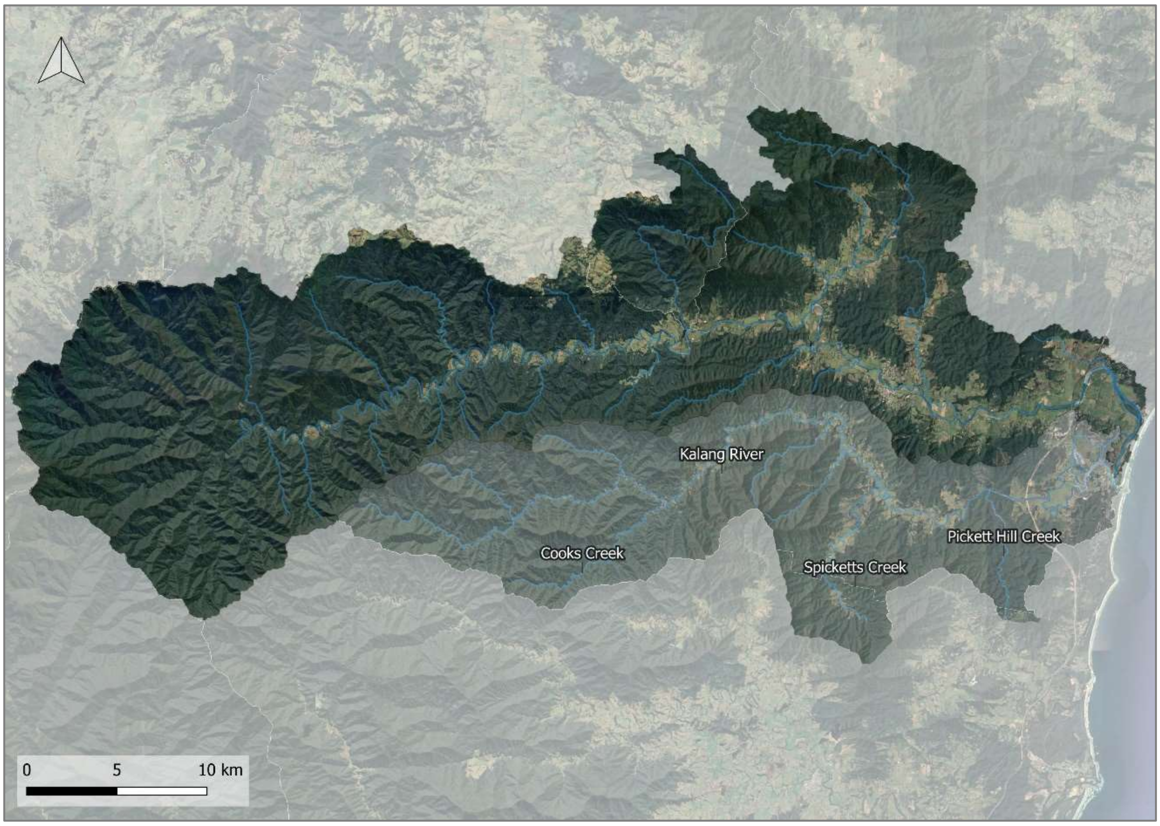


Figure 2-13: Kalang River major tributaries

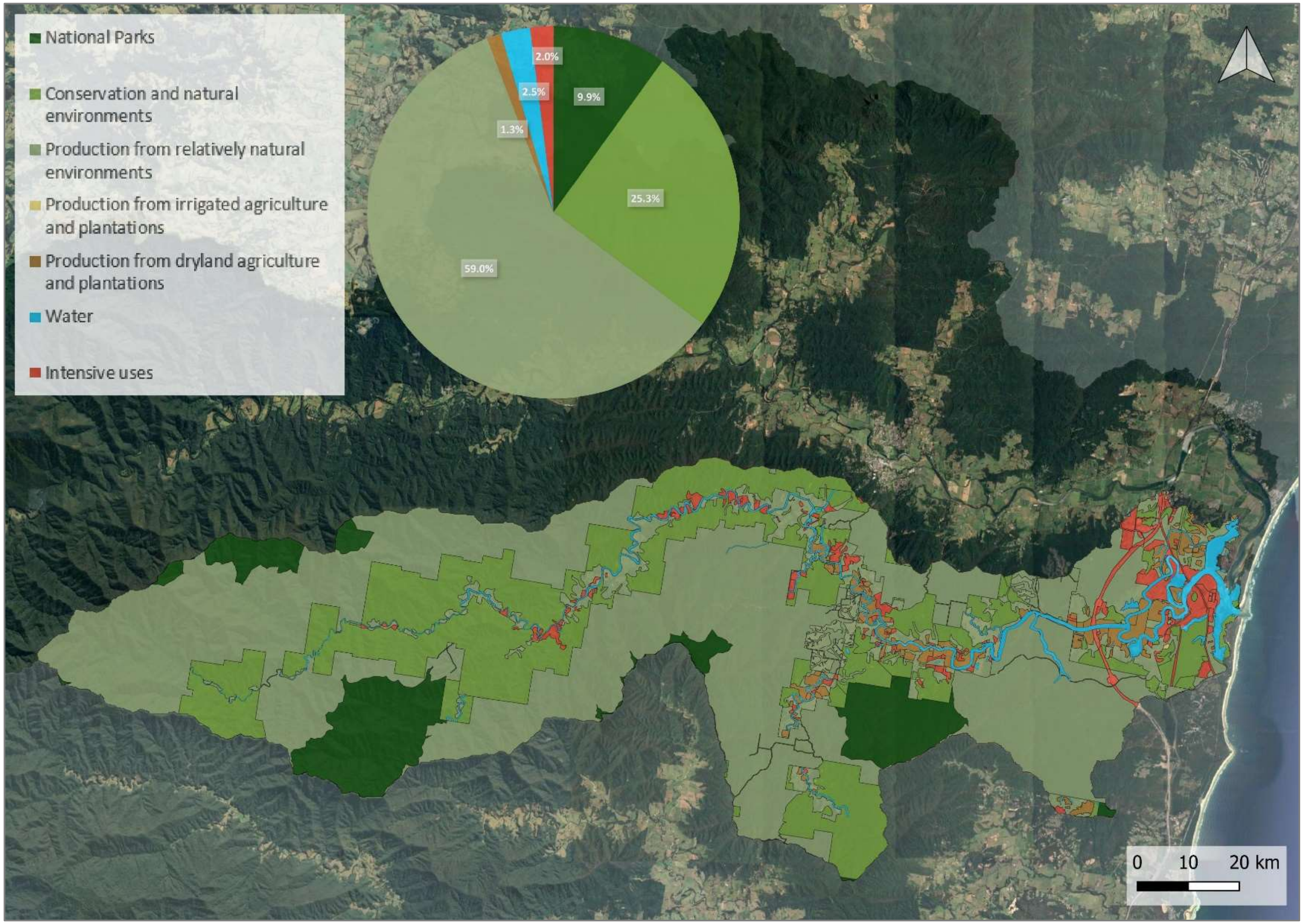


Figure 2-14: Kalang River Catchment land use

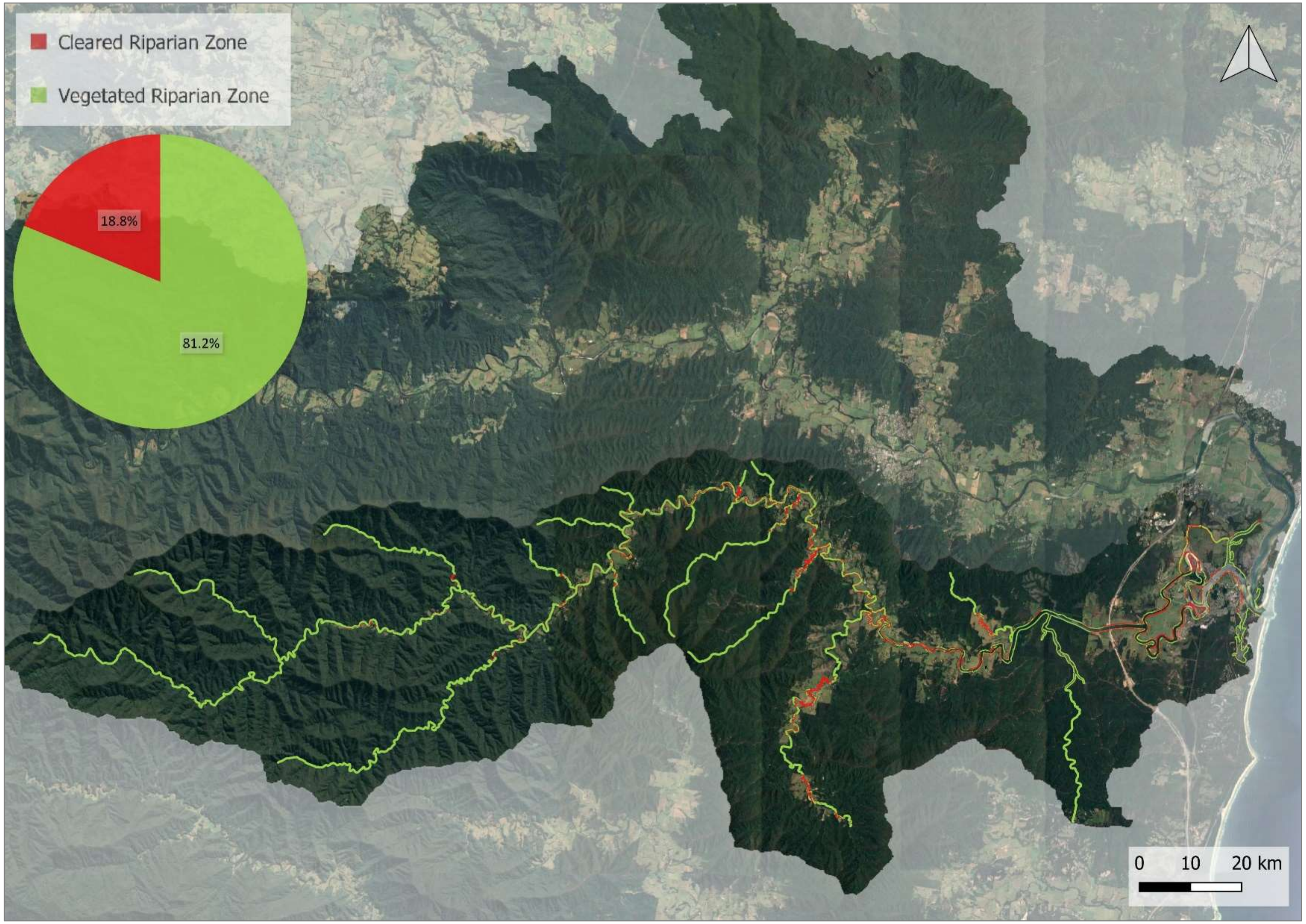


Figure 2-15: Kalang River Catchment riparian vegetation condition

2.1.5 Spicketts Creek

The confluence of Spicketts Creek with the Kalang River is situated within the tidal limit of the estuary. The creek at this site is not influenced by the estuary in terms of water levels and salinity, however the proximity to the estuary may be influencing the aquatic biodiversity. The valley is wider than previous sites with almost entirely exotic vegetation making up the riparian zone. The dense riparian vegetation does provide an almost complete canopy cover with heavy shading of the waterway. Land use is predominantly cattle grazing properties.

Soil landscape maps were obtained from the NSW DPE eSPADE version 2.2 soil and land information system[19] for the Spicketts Creek Catchment. This catchment shares a similar soil landscape to the Kalang containing gravelly soils with low wet bearing strength, organic topsoils, high erodibility, high permeability (floodplains; low terraces), low permeability (high terraces), low available water holding capacity and high topsoil fertility. Soil and land qualities include localised flood hazard, localised poor drainage, seasonal waterlogging, groundwater pollution hazard, and streambank erosion hazard. Streambank erosion is locally severe, especially where riparian vegetation has been removed. Localised gully erosion is present along tributary streams on floodplain and terrace surfaces, with localised moderate to severe fluted rill erosion on exposed terrace faces. Moderate soil structure decline is present in many areas from compaction by machinery and cattle[19].

Land use in the catchment includes production from relatively natural environments (75%), conservation and natural environments (10%), national parks (9%) and water (5%), with the residual land used as dryland agriculture or intensive uses.

Approximately 66% of the riparian corridor is vegetated; however, this is influenced by the natural areas in the upper catchment. As shown in Figure 2-17, significant clearing has occurred at the Spicketts Creek and Kalang River confluence, through the midsection of Spicketts Creek from the upstream end of Simmons Road to 1091 Bowraville Road, and throughout a large patch of clearing upstream of Spicketts Creek surrounding 1399 Bellingen Road.

19 NSW Department of Planning and Environment (2022). eSPADE V2.2 first published April 2022.

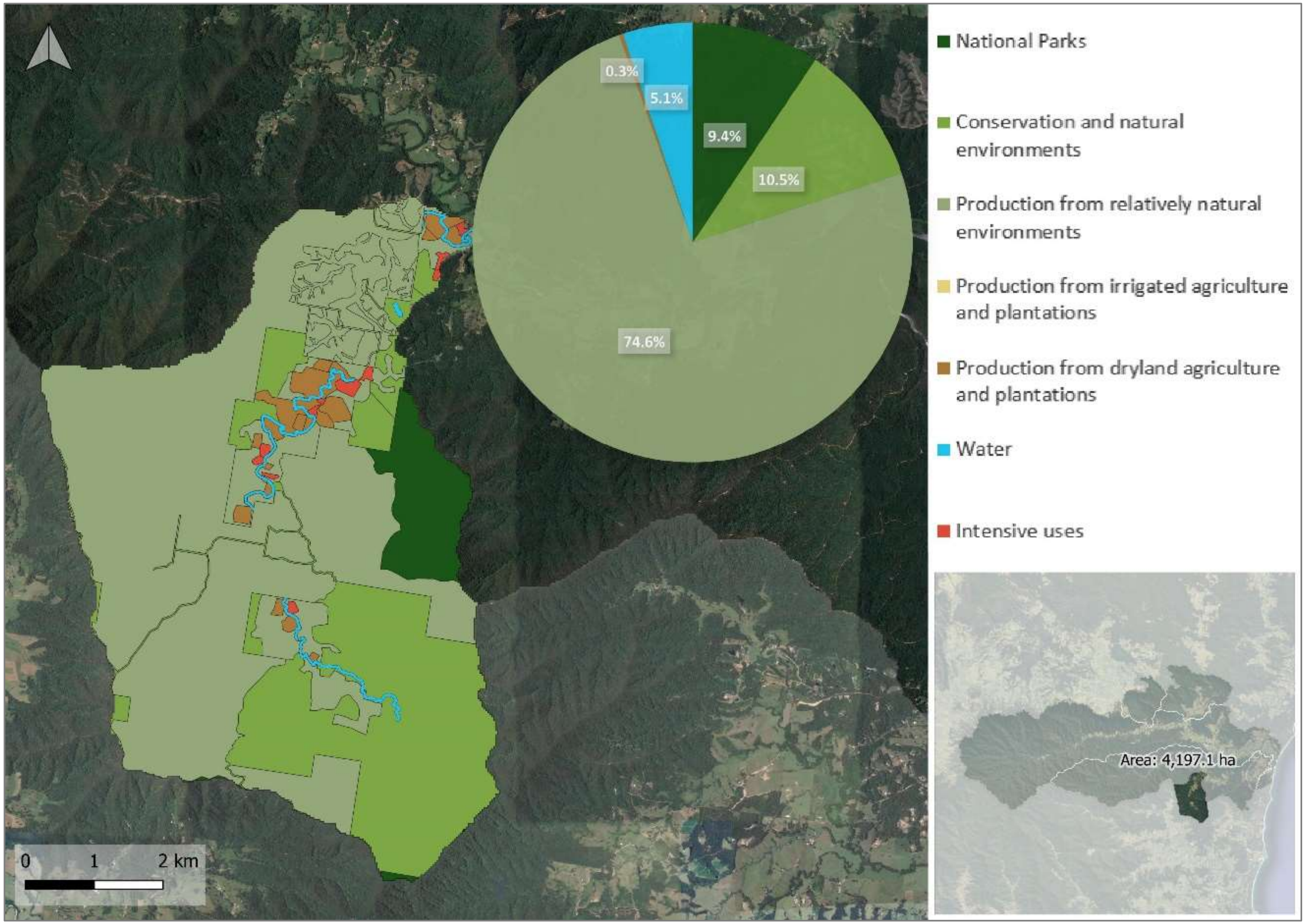


Figure 2-16: Spicketts Creek Catchment land use

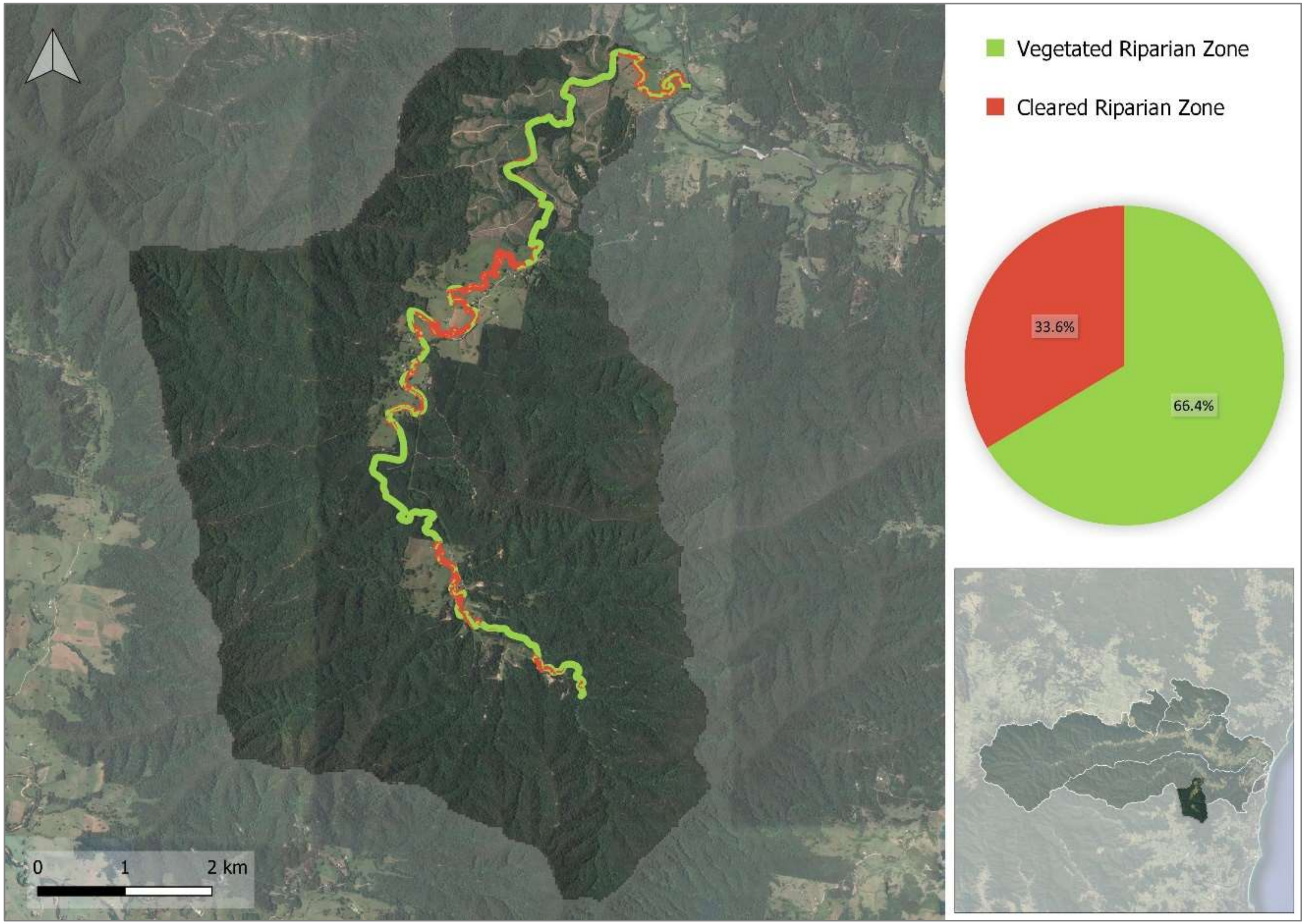


Figure 2-17: Spicketts Creek Catchment riparian vegetation condition

2.2 Water Quality

2.2.1 Available Literature

A large number of studies have been undertaken throughout the Bellingen coastline, estuaries, and catchments, or have been developed for other NSW locations which can be used to support this WQMP. These have been developed by Council, government agencies and a range of external groups. The reports and datasets listed blow have been summarised in Appendix A.

- River styles in Bellinger-Kalang catchment (NSW Department of Land and Water Conservation, 1998)
- Bellinger Water Quality Monitoring Project (Dickinson, 2000)
- Bellinger and Kalang Rivers Estuary Processes Study (Lawson and Treloar Pty, 2003)
- Kalang Strategic Plan (2008)
- Bellinger and Kalang River Estuaries Erosion Study (Telfer and Cohen, 2010)
- Bellinger-Kalang Rivers Ecohealth Project Assessment of River and Estuarine Condition (UNE, 2010)
- Bellinger River Estuary Action Plan Reach Plan (NRCMA, 2010)
- Bellinger River Health Plan (Bellingen Shire Council, 2010)
- Report on Preliminary Domestic Wastewater Survey of Nominated Systems on Newry Island (Whitehead & Associates, 2010)
- Bellingen Island Bank Protection Works – Stage 2 (Andrew Rickert, 2011)
- Bellinger River Estuary revegetation guide
- Bellingen and Urunga Stormwater Management Plans DRAFT (BMT WBM, 2011)
- Heritage Assessment (Bellingen Shire Council, 2011)
- Review of River and Drain Water Quality Nearby Yellow Rock Road Dairy, Raleigh (Whitehead & Associates, 2012)
- River Styles assessment and mapping in the Northern Rivers CMA area (Alluvium, 2012)
- Friesians & Fish – Bellinger River floodplain and estuary water quality improvement (OEH, 2016)
- Sanitary Survey Report for the Kalang River Harvest Area (SARDI, 2016)
- Water Quality Monitoring of the Bellinger and Kalang Rivers (UNE, 2016)
- Measuring riparian and instream responses to two riverbank stabilisation methods in the Kalang estuary, NSW (UNE, 2018)
- Bellingen Shire Biodiversity Strategy (Eco Logical Australia, 2019)
- Urunga Wetlands Post-Remediation Water Quality Monitoring Completion Report (Aquatic Science and Management, 2019)
- Lower Bellinger and Kalang Rivers floodplain risk management plan (WMA Water, 2021)
- Protocol for the prevention, detection, and management of sewage contamination in Oyster growing areas in the Bellingen Shire (Bellingen Shire Council)
- Urunga Wetland Water Quality Monitoring Report (Soil Conservation Service, 2021)
- Water Quality and Macroinvertebrate Monitoring of the Bellinger Catchment (Draft) (DPE, 2021).

2.2.2 Water Quality Monitoring

Water quality monitoring has previously been undertaken throughout the catchment under the programmes listed in Table 2-3.

Table 2-2. Previous water quality monitoring in the Bellinger-Kalang catchment

Programme	Dates and frequency	Parameters and locations measured	Method	Available data	Water Quality Guidelines
DPE Monitoring River Health Program	1994-2000.	Bellinger River (7 sites), Kalang River (4 sites), Never Never (2 sites), Rosewood River (1 site) and Spicketts Creek (1 site).		Available from data NSW website: https://data.nsw.gov.au/data/dataset/aquatic-macroinvertebrates-of-nsw-1994-ongoingc357e/resource/6ac56aaa-7a7e-46ad-b258-1e605bf90aba	ANZECC (2000) guidelines for slightly disturbed ecosystems in South-east Australia.
The Bellinger Water Quality Management Project.	1998-2000. Monthly physiochemical and bacteriological analysis of water samples, and bi-annual macroinvertebrate samples taken between March 1998-March 2000.	Temperature, turbidity, depth, faecal coliform, TN, TP, Nitrate, TSS, and pH. 20 sites for physio-chemical samples, 6 sites for macroinvertebrate samples.	Volunteers collected monthly samples which were sent to the Environmental Analysis Laboratory in Lismore. Macroinvertebrates were collected via a 250 µm sweep net.	Dickinson, M.D. Bellinger Water Quality Monitoring Project Final Report.	The ANZECC (1992) Australian Water Quality Guidelines for primary recreation.
DPE sampling for the NSW Natural Resources Monitoring Evaluation and Reporting (MER)	2004 - 2012. Six sampling occasions between mid-September to end of January.	pH, EC, temperature, DO, turbidity, TSS, N and P, chlorophyll a, macroinvertebrates, zooplankton, fish, riparian condition, mangrove condition, seagrass condition, saltmarsh condition, and geomorphology.	MER guidelines.		NSW MER trigger values developed, and ANZECC and ARMCANZ (2000).
Ecohealth Project.	2009-2010. Monthly data collected for 12-month period between October 2009 and September 2010 for water chemistry, bi-annual sampling for freshwater macroinvertebrates, and one assessment of riparian condition.	pH, EC & salinity, DO, temperature, turbidity, TN, TP, SRP, NOx. 10 freshwater sites (5 on the Bellinger and 5 on the Kalang), 12 estuarine sites (5 on Bellinger and 7 on the Kalang).	Sampling follows MER guidelines. Water chemistry sampling over 3-day event to ensure consistency in sampling with tidal regime. The estuarine sites sampled on incoming high tide. BR4-BR8, and KR5-KR11 were sampled by boat, all other sites via road.	Ryder, D., Sbrocchi, C., Schmidt, J., Veal, R. (2011). Bellinger-Kalang Rivers Ecohealth Project: Assessment of River and Estuarine Conditions 2009-2010. Final Technical Report to the Bellingen Shire Council. University of New England, Armidale.	The ANZECC Australian Water Quality Guidelines for Fresh and Marine Waters.
SARDI (2016)	2011-2016. Between 1/1/2011 and 1/6/2016	Faecal coliforms in the Kalang River harvest area at 6 sites.		Turnbull, A., Malhi, N. (2016) Sanitary Survey Report for the Kalang River Harvest Area.	ASQAP guidelines. The ASQAP manual describes food safety requirements for the production, harvest, and storage of bivalve molluscs (e.g., oysters, scallops, mussels and pippis) for compliance with the Australia New Zealand Food Standards

					Code.
Whitehead & Associates (2012). This report reviews water quality data provided by Mr Pearce.		8 sample sites along Yellow Rock Road, Raleigh. Alongside dairy milking shed.		Duerinckx, S. (2012). Review of River and Drain Water Quality Nearby Yellow Rock Road Dairy, Raleigh. Whitehead & Associates Environmental Consultants Pty Ltd	ASQAP guidelines. The ASQAP manual describes food safety requirements for the production, harvest and storage of bivalve molluscs (e.g., oysters, scallops, mussels and pippis) for compliance with the Australia New Zealand Food Standards Code.
Ecohealth Project.	2016.	pH, EC, temperature, DO, turbidity, TSS, N and P, chlorophyll a, macroinvertebrates, zooplankton, fish, riparian condition, mangrove condition, seagrass condition, saltmarsh condition, and geomorphology.	Sampling follows MER protocols for rivers and estuaries.	Ryder, D, Mika, S and Vincent, B. (2016). Ecohealth: A health check for our waterways. Design, methods and reporting of waterway health in coastal NSW, Australia. University of New England, Armidale.	A combination of ANZECC (2000, 2006) and NSW MER water quality guidelines for freshwater (above and below 150m elevation) and estuarine systems of south-east Australia.
DPE Water Quality and Macroinvertebrate Monitoring of the Bellinger Catchment.	2017-2020. Biannually sampling (autumn and spring) in 2017, 2018, and 2019, and autumn 2020.	TSS, temperature, pH, EC, turbidity, DO, TN, TP, NH_3-N (ammonia), NOx, FRP. 15 monitoring sites. Bellinger River (7 sites), Kalang River (4 sites), Never Never (2 sites), Rosewood River (1 site) and Spicketts Creek (1 site).	pH using field titration, Aquatic macroinvertebrates in accordance with AUSRIVAS protocols, photographs of stream reach, visible condition of stream habitat and geomorphology. In-situ water quality meters Horiba U50, YSI EXO2, and YSI ProDSS.	Dickson, A., Belmer, N., Serov, P (2021). DRAFT - Water Quality and Macroinvertebrate Monitoring of the Bellinger Catchment. NSW Department of Planning, Industry and Environment	Water quality guidelines applied to the Bellinger River project data are taken from the ANZECC guidelines for lowland east flowing rivers (default 95 % protection level trigger values for slightly disturbed lowland rivers of south-east Australia unless otherwise indicated)
Urunga Wetlands Post-Remediation Water Quality Monitoring Completion Report – June 2019	2013-2019. Pre-construction monitoring occurred monthly from January 2013-February 2014, then fortnightly until August 2015 at sites SW01, 02, and 03. Weekly sampling during construction at sites SW01, 02, 03, 07, GW01, 02, and 03 from September 2015-September 2016. Weekly post-construction sampling between October 2016-December 2016, then monthly until April 2019 at sites SW01, 02, 03, 05, 16, 18, and 21, and GW01 and 02.	pH, EC, TDS, TSS, cyanide, silver, aluminium, arsenic, cadmium, chromium, copper, iron, manganese, nickel, lead, selenium, zinc, mercury, and antimony.	Samples collected and sent to Envirolab Group, Chatswood Sydney for analysis. Surface water samples were collected at 0.1-0.2m depth. Samples to be analysed for total metal concentrations have been acid fixed in the field since January 2016. Groundwater was sampled from the top 1m of water with a piezometer and peristaltic pump, bailer, or electric pump.	Luffman, B. (2019) Urunga Wetlands Post-Remediation Water Quality Monitoring Completion Report – June 2019. Aquatic Science and Management	This report compares the results against the ANZECC (2020) Guidelines for Water Quality for moderately disturbed freshwater at sites SW01, 02, 04, 05, 06, 07, 08, 09, & 10, the ANZECC guidelines for moderately disturbed marine water at site SW03, The Australian Drinking Water Guidelines (2011) for sites GW01-GW03, the NHMRC (2004) guidelines for sites SW01-SW03, and project water quality objectives (33% value of pre-construction concentrations) for sites SW07, 05, and 05.

Urunga Wetland Water Quality Monitoring Report	2020-2021. Samples were collected from 5/11/2020 to 27/05/2021.	Monthly sampling and after rainfall events (>40mm) for total arsenic, total antimony, pH, salinity, and turbidity at sites SW01, SW02, SW03, SW05, SW18, and SW21. Quarterly samples were taken at sites GW01 and GW02 for dissolved arsenic, dissolved antimony, pH, salinity, and turbidity. SW16 (leachate sump) was measured monthly for depth, and quarterly for total arsenic, total antimony, methyl phenols (cresylic acid), pH, salinity, and TSS.	Samples collected and sent to Envirolab Group, Chatswood Sydney for analysis. Surface water was sampled at depth of 0.1-0.2m. Groundwater was sampled from piezometers using electric pump. The leachate sump was sampled from the mono cell sump using electric pump.	Donner, T. (2021) Urunga Wetland- Water Quality Monitoring Report November 2020 to June 2021.	Australian and New Zealand Guidelines for Marine and Freshwater Quality ANZECC/ARMCANZ (ANZECC, 2000) for freshwater 'slightly to moderately disturbed system' with a 95% level of protection and the Guidelines for Managing Risks in Recreational Water (NHMRC, 2008) being 10 times the concentration stipulated in the drinking water guidelines (ADWG, 2011). The groundwater guidelines used are the Australian Drinking Water Guidelines 2011 (ADWG 2011).
Riverwatch citizen science water quality monitoring	2017- ongoing.	Temperature, pH, EC, turbidity, Phosphate, DO, faecal coliform.	Volunteers collect monthly data.	Data available via SEED portal (https://datasets.seed.nsw.gov.au/dataset/bellingen-riverwatch), and the OzGreen website (https://sites.google.com/ozgreen.org.au/2021-br-data-portal).	OZGreen uses DPE water quality scores and trigger values.
Private oyster monitoring	Ongoing monthly sampling. Anecdotally 20 years of data.	Parameters required for oyster harvesting. E.g., Faecal coliforms and E. coli	Collected within three hours of low tide by private oyster farmer.	Data issued to NSW food authority	NSW shellfish programme standards Food Regulation 2015 under the Seafood Food Safety Scheme
Bellingen, Urunga, and Dorrigo WWTP monitoring	The EPA licence for these sewage treatment plants requires the collection of samples for each parameter at least once a fortnight and at a minimum of ten day intervals.	BOD5, faecal coliforms, oil and grease, ammonia, pH, total suspended solids, total nitrogen, and total phosphorous. These measurements are taken at the Bellingen, Urunga, and Dorrigo wastewater treatment plants.		Data available from the BSC Water and Wastewater Public Data Portal https://www.bellingenwaterdata.sgautomation.com.au/wastewater	

Figure 2-18: Bellingen Riverwatch (https://www.ozgreen.org/br)

Each monitoring dataset has various strengths and limitations due to sampling methods, frequency, and coverage. In order to best review the catchment water quality, the biannual sampling and analysis undertaken by DPE was combined with data from the ongoing Bellinger Riverwatch programme and the Ecohealth lower estuary datasets. These combined datasets offer the best reflection of water quality throughout the region. Each sampling programme used different methods and was undertaken at a different frequency. However, when merged these datasets provide a holistic view of the catchment. These datasets have been separately analysed using a report card style assessment to provide an overview of the catchment health.

Commentary around sampling sites have used the 24 site names shown in Figure 2-19. These sites are established monitoring locations within the existing Riverwatch programme and are referenced in many water quality reports for the catchment. The location of these sites are a result of previous monitoring locations and ongoing sampling by volunteers in collaboration with Council and state government. Sampling sites and site names adopted by DPE and Ecohealth monitoring are shown in Figure 2-20 and Figure 2-21, respectively.

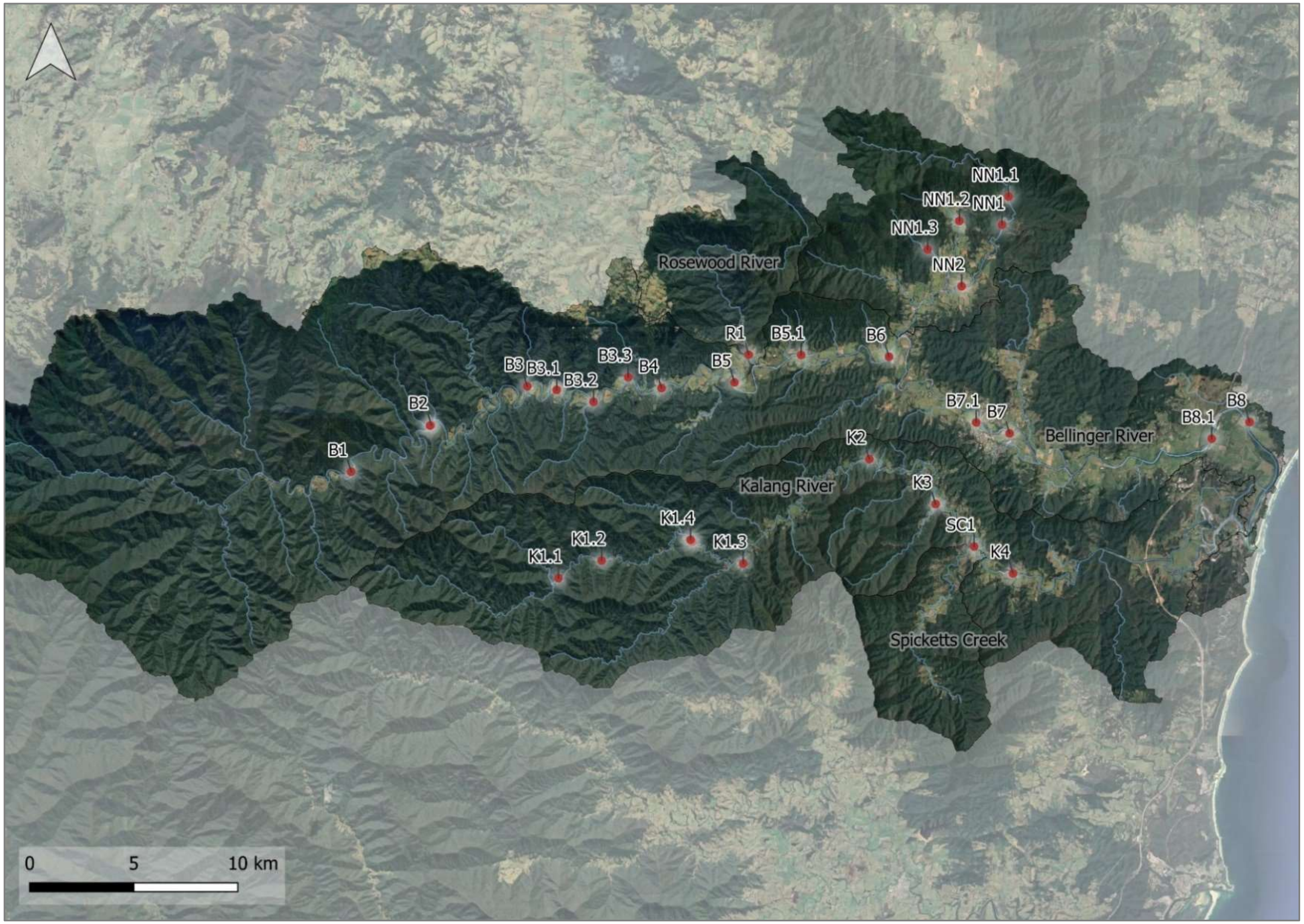


Figure 2-19: Map of the 24 monthly sampling sites within Bellingen Shire as part of the Riverwatch water quality monitoring

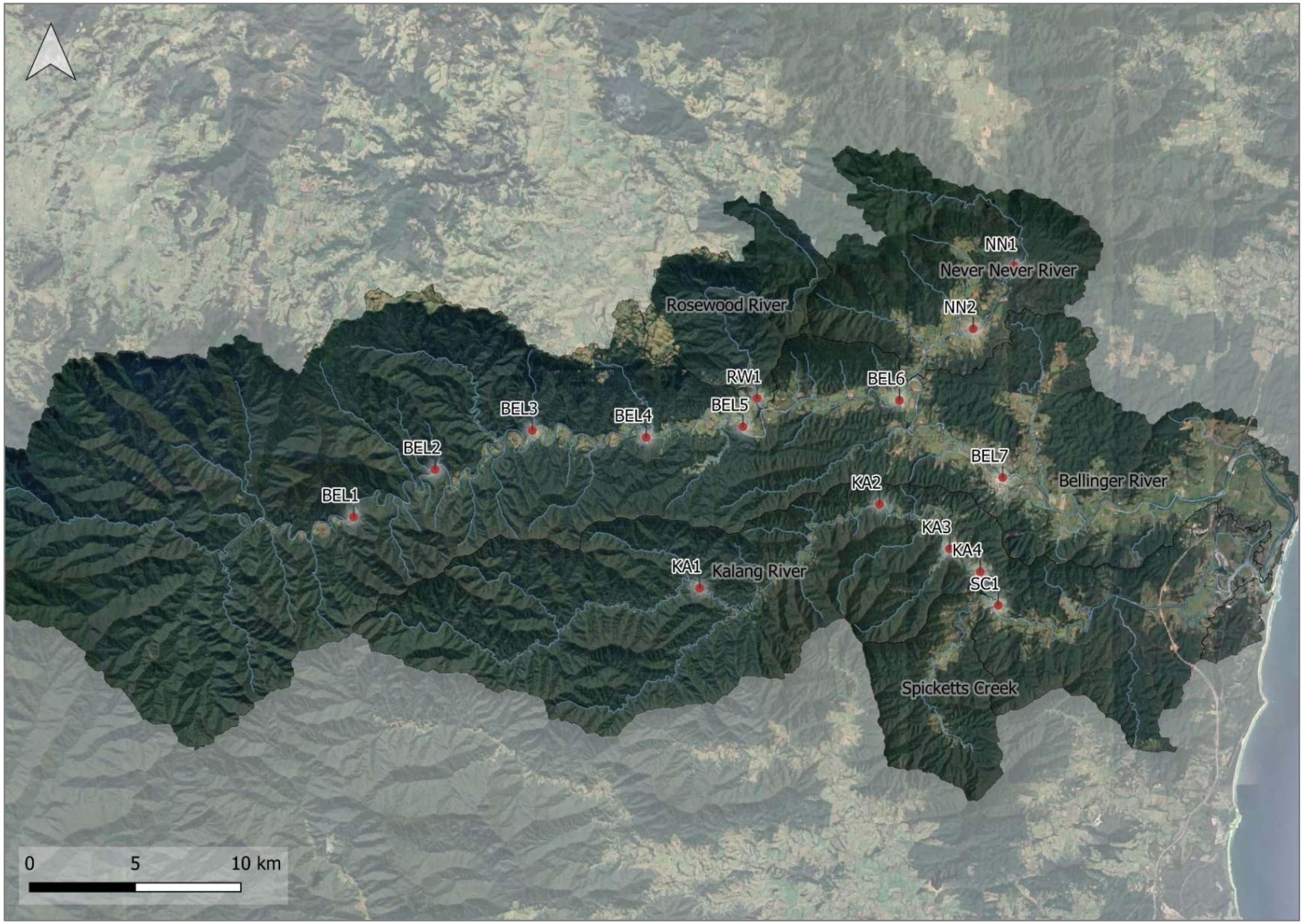


Figure 2-20: Map of the sampling sites within Bellingen Shire as part of the DPE water quality monitoring

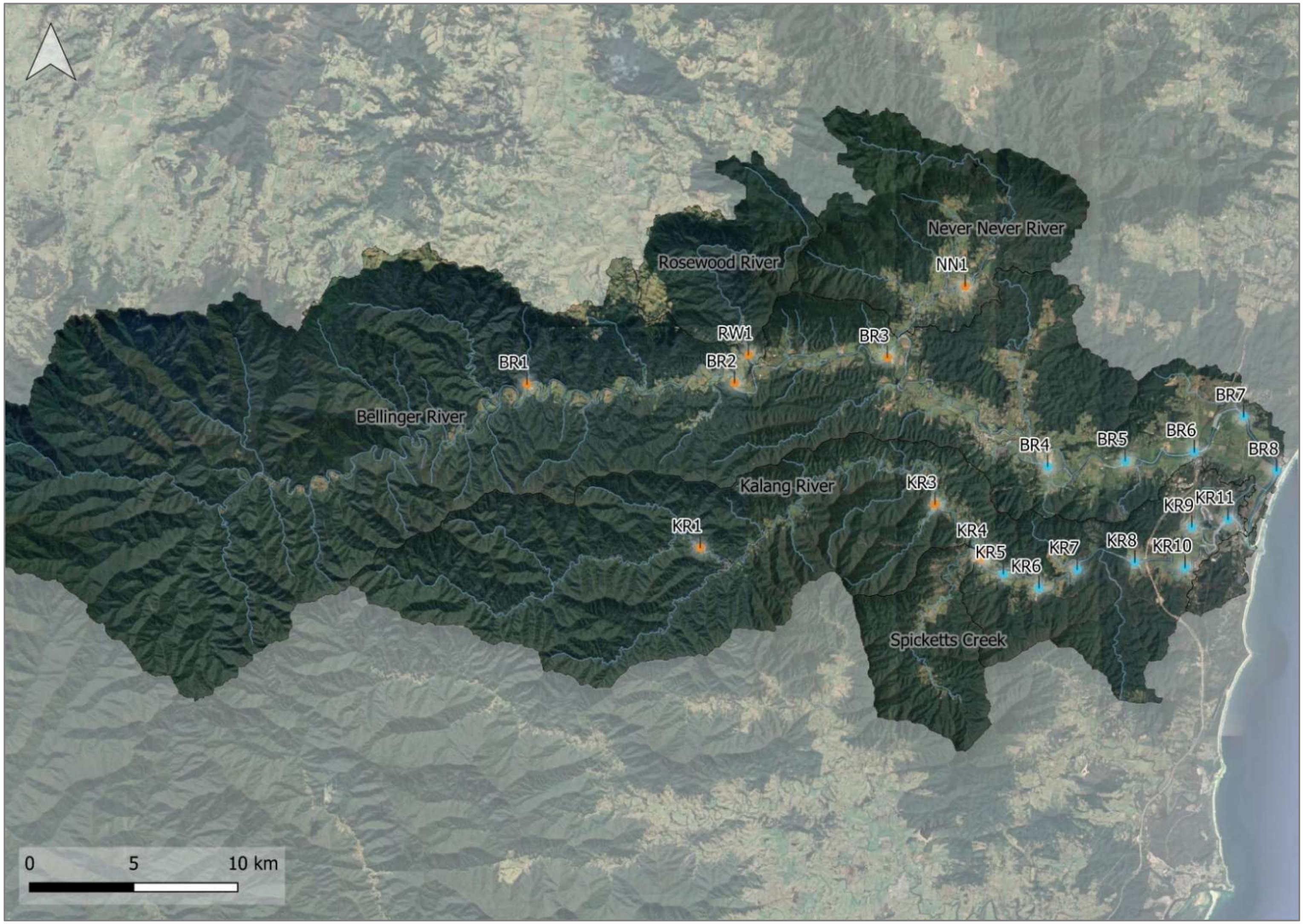


Figure 2-21: Map of 2009 Ecohealth sampling sites within Bellingen Shire. Blue represent estuary sites, orange represent freshwater sites.

2.2.3 Water Quality Indicators and Guidelines

Water quality guideline values provide a metric to evaluate the quality of the Bellinger-Kalang Rivers. There are a variety of guidelines available for the comparison and assessment of water quality results. Choosing appropriate guidelines depends on the environmental values of the site, human uses, the objectives for water quality, the level of protection required for the site and the issues and associated risks present.

Water quality guidelines and thresholds for fresh and marine water quality have traditionally been assessed under Australian and New Zealand Environment and Conservation Council (ANZECC) and NSW Monitoring Evaluation and Reporting (MER) guidance. However, new regional freshwater-specific water quality guideline values have recently been developed by NSW Department of Planning, Industry and Environment (DPE) for the Bellinger-Kalang Catchment which have been provided for this study. New estuary-specific water quality guideline values are also being prepared, which consider the uses and values within the catchment; however, they were not released in time for this study. Together, these new water quality thresholds set the new standard for all future analysis undertaken in the Bellinger-Kalang Estuary. These targets were developed based on a review of available water quality data and catchment uses and were designed to reflect community contemporary values and expectations. These updated objectives have been developed in state-cased consultation and are used to underpin the application of a Risk-Based Framework for water quality. The review of the NSW water quality objectives include:

- Long term goals for how communities use and value their waterways
- Requirements under the National Water Quality Management Strategy and Australian Water Quality Guidelines
- Guidance for assessments of land use impacts
- Guidelines for achieving objectives of Coastal Environment Area, under SEPP (Coastal Management) 2018.

Guidelines values appropriate for each indicator, calculated in accordance with the Australian Water Quality Guidelines for Bellinger River Catchment are shown in Table 2-3.

Table 2-3. New Trigger Values provided by DPE for the Bellinger-Kalang Rivers

	pH pHu	EC µS/cm	DO % sat	T NTU	NOx µg/L	Ammonia µg/L	TP µg/L	TN µg/L
20th Percentile	6.49	103.96	76.7	0.5	7.51	2.8	7.4	106
80th Percentile	7.47	404.4	97.4	1.74	36.2	6.0	14.22	179.72
Guideline Value	6.49-7.47	404.4	76.7	1.74	36.2	6.0	14.22	179.72

A catchment-wide water quality review was undertaken using the new guideline values and results have been fit into a scorecard framework. The updated regional guideline values were provided for freshwater sites, while default Australian and New Zealand Guideline values for Fresh and Marine Water Quality (ANZECC, 2000) for NSW lowland, east flowing coastal rivers, and NSW MER guideline values were utilised for estuarine sites for this report. Thresholds for TSS and EC are not available within the ANZECC guidelines for the lower estuary, with the analysis instead using thresholds described in the DPE (2021) report, which is calculated as 80th percentile value of all TSS results[7]. Water quality indicators and their units analysed in this report are shown in Table 2-4. Thresholds for freshwater rivers are shown in Table 2-5 and lower estuary thresholds are shown in

Table 2-6. The results have been summarised using report-card style maps which considers the following key metrics:

- Q = primary water quality (considers pH, EC and DO% saturation)
- T = Water clarity and sediment load (considers Turbidity and TSS)
- N = Nitrogen (considers Ammonia, NOx and TN)
- P = Phosphate (considers FRP and TP)
- WQ = Overall water quality (Considers all of the above parameters)
-

Each metric has been scored using an Excellent (X), Very Good (A), Fair (B), Poor (C) or Very Poor (D) grading system, based on the scoring shown in Figure 2-22. Results are shown in Figure 2-23 to Figure 2-29.

Table 2-4. Water quality parameters and units

Water Quality Parameter	Unit
Filterable Reactive Phosphate (FRP or P)	µg/L
Nitrogen Oxide (NOx)	µg/L
Toral Phosphorus (TP)	µg/L
Total Nitrogen (TN)	µg/L
Dissolved Oxygen (DO%)	% saturation
Electrical Conductivity (EC)	µS/cm
Turbidity	NTU
Total Suspended Solids (TSS)	(mg/L)
pH	pH Units
Temperature (Temp)	ºC

Table 2-5. Scores and trigger values/thresholds applied to the Bellinger River for lowland freshwater rivers for this report

Score	pH pHu	EC µS/cm	DO % sat	T NTU	NOx µg/L	FRP µg/L	TP µg/L	TN µg/L
1 = Excellent	6.5 - 7.5	404.4	85 - 110	1.74	36.22	20	14.22	179.72
2 = Very good	N/A	505.5	63.75 - 85 or 110 - 137.5	2.18	45.28	25	17.77	224.65
3 = Fair	N/A	606.6	42.5 - 63.7 or 137.5 - 165	2.61	54.33	30	21.33	269.57
4 = Poor	N/A	707.7	21.25 - 42.5 or 165 - 192.5	3.05	63.39	35	24.88	314.5
5 = Very poor	<6.5 or >7.5	>707.7	<21.25 or >192.5	> 3.05	>63.39	>35	>24.88	>314.5

Table 2-6. Scores and trigger values/thresholds applied to the Bellinger River for estuaries for this report

Score	pH pHu	EC µS/cm	DO % sat	T NTU	NOx µg/L	FRP µg/L	TP µg/L	TN µg/L
1 = Excellent	7 - 8.5	N/A	80 - 110	2.8	15	5	30	300
2 = Very good	N/A	N/A	60 - 80 or 110 - 137.5	3.5	18.75	6.25	37.5	375
3 = Fair	N/A	N/A	40 - 60 or 137.5 - 165	4.2	22.5	7.5	45	450
4 = Poor	N/A	N/A	20 - 40 or 165 - 192.5	5.6	26.25	8.75	52.5	525
5 = Very poor	<7 >8.5	N/A	< 20 or > 192.5	> 5.6	>26.25	>35	>52.5	>525

Excellent	1	X
Very Good	1-2	A
Fair	2-3	B
Poor	3-4	C
Very poor	4-5	D

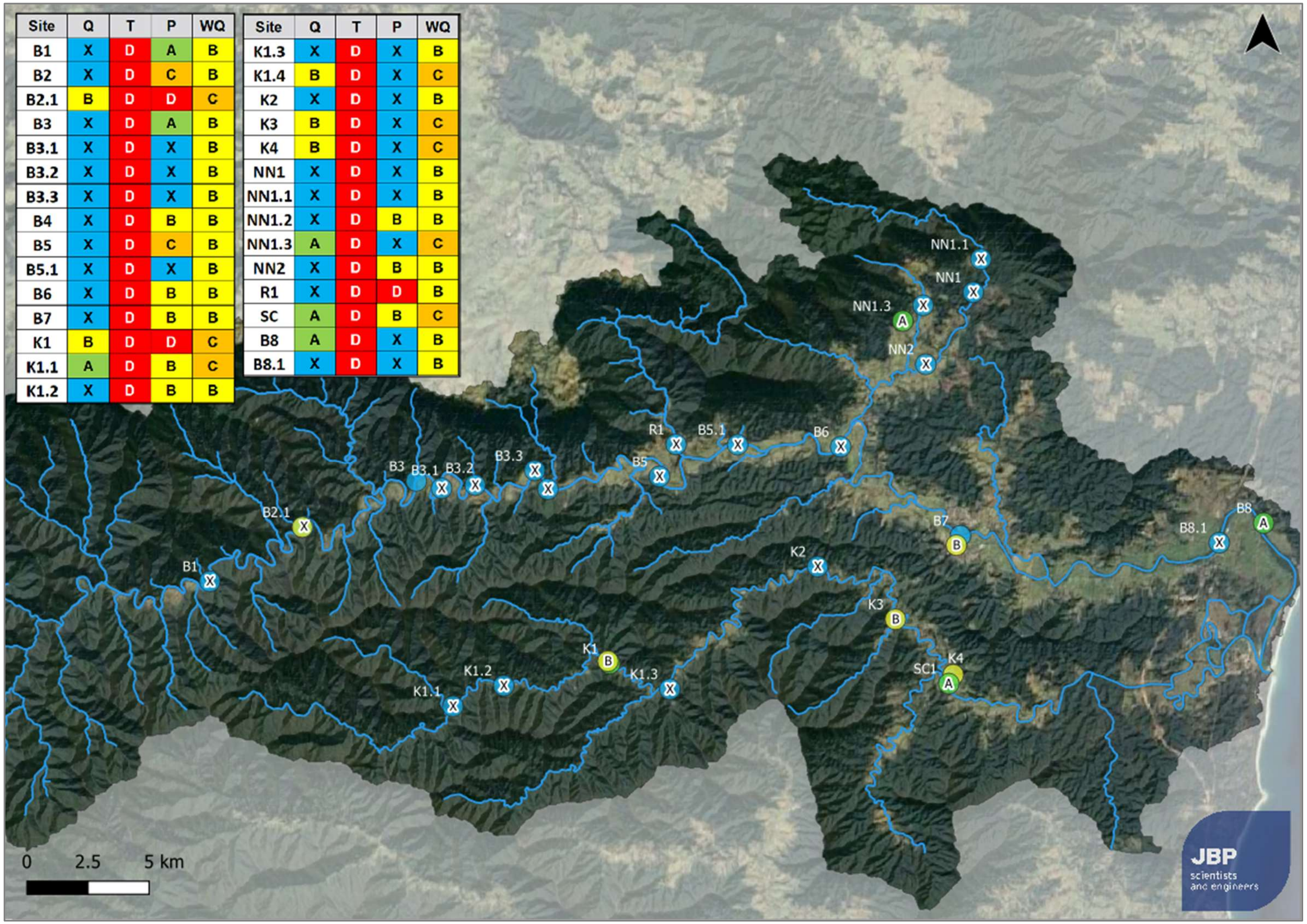
Figure 2-22. Water quality scorecard grading system

2.2.4 Water Quality Analysis

A review of the water quality sampling results, datasets and reports produced by the Bellingen Riverwatch, DPE, and Ecohealth has been undertaken. The Riverwatch programme is led through a local community environmental group who have supplied raw water quality data for review since 2017. This data has been compared with the water quality analysis report prepared by DPE (2021)[20], and data provided by the Ecohealth project (2009-2010). Further comparisons were made against other site-specific sampling, e.g., for faecal coliforms.

Catchment-wide water quality scores are displayed in Figure 2-23 to Figure 2-29, with Figure 2-30 to Figure 2-34 presenting combined water quality results and land-use maps.

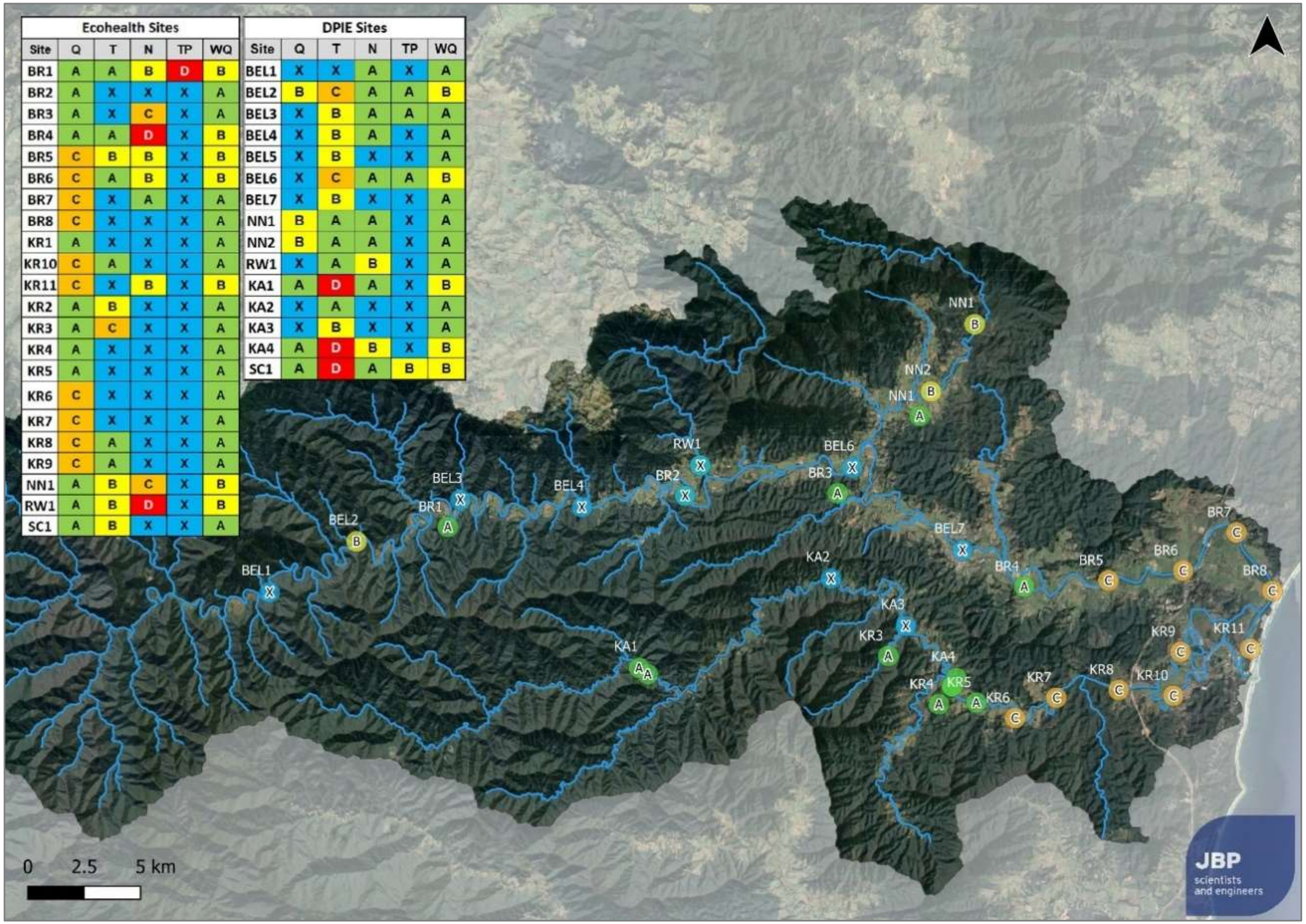
20 Dickson, A., Belmer, N., and Serov, P., (2021). DRAFT - Water Quality and Macroinvertebrate Monitoring of the Bellinger Catchment Providing a scientific foundation to inform the Bellinger Riverwatch citizen science monitoring program. Published by NSW Department of Planning, Industry and Environment.



Site	Q	T	P	WQ
B1	X	D	A	B
B2	X	D	C	B
B2.1	B	D	D	C
B3	X	D	A	B
B3.1	X	D	X	B
B3.2	X	D	X	B
B3.3	X	D	X	B
B4	X	D	B	B
B5	X	D	C	B
B5.1	X	D	X	B
B6	X	D	B	B
B7	X	D	B	B
K1	B	D	D	C
K1.1	A	D	B	C
K1.2	X	D	B	B

Site	Q	T	P	WQ
K1.3	X	D	X	B
K1.4	B	D	X	C
K2	X	D	X	B
K3	B	D	X	C
K4	B	D	X	C
NN1	X	D	X	B
NN1.1	X	D	X	B
NN1.2	X	D	B	B
NN1.3	A	D	X	C
NN2	X	D	B	B
R1	X	D	D	B
SC	A	D	B	C
B8	A	D	X	B
B8.1	X	D	X	B

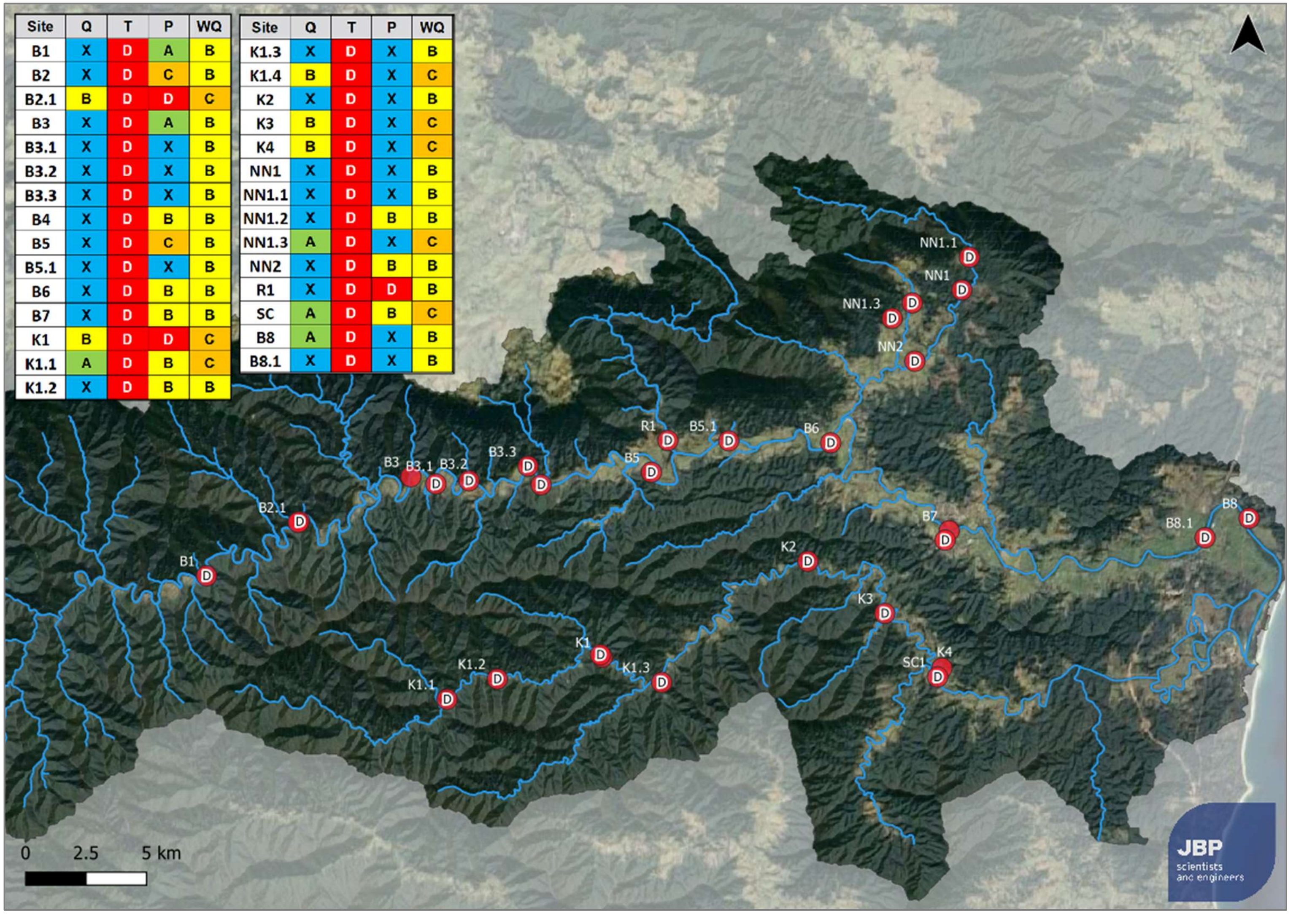
Figure 2-23. Primary water quality (Q) based on Riverwatch monitoring records



Ecohealth Sites					
Site	Q	T	N	TP	WQ
BR1	A	A	B	D	B
BR2	A	X	X	X	A
BR3	A	X	C	X	A
BR4	A	A	D	X	B
BR5	C	B	B	X	B
BR6	C	A	B	X	B
BR7	C	X	A	X	A
BR8	C	X	X	X	A
KR1	A	X	X	X	A
KR10	C	A	X	X	A
KR11	C	X	B	X	B
KR2	A	B	X	X	A
KR3	A	C	X	X	A
KR4	A	X	X	X	A
KR5	A	X	X	X	A
KR6	C	X	X	X	A
KR7	C	X	X	X	A
KR8	C	A	X	X	A
KR9	C	A	X	X	A
NN1	A	B	C	X	B
RW1	A	B	D	X	B
SC1	A	B	X	X	A

DPIE Sites					
Site	Q	T	N	TP	WQ
BEL1	X	X	A	X	A
BEL2	B	C	A	A	B
BEL3	X	B	A	A	A
BEL4	X	B	A	X	A
BEL5	X	B	X	X	A
BEL6	X	C	A	A	B
BEL7	X	B	X	X	A
NN1	B	A	A	X	A
NN2	B	A	A	X	A
RW1	X	A	B	X	A
KA1	A	D	A	X	B
KA2	X	A	X	X	A
KA3	X	B	X	X	A
KA4	A	D	B	X	B
SC1	A	D	A	B	B

Figure 2-24. Primary water quality (Q) based on DPE/Ecohealth monitoring records.



Site	Q	T	P	WQ
B1	X	D	A	B
B2	X	D	C	B
B2.1	B	D	D	C
B3	X	D	A	B
B3.1	X	D	X	B
B3.2	X	D	X	B
B3.3	X	D	X	B
B4	X	D	B	B
B5	X	D	C	B
B5.1	X	D	X	B
B6	X	D	B	B
B7	X	D	B	B
K1	B	D	D	C
K1.1	A	D	B	C
K1.2	X	D	B	B
K1.3	X	D	X	B
K1.4	B	D	X	C
K2	X	D	X	B
K3	B	D	X	C
K4	B	D	X	C
NN1	X	D	X	B
NN1.1	X	D	X	B
NN1.2	X	D	B	B
NN1.3	A	D	X	C
NN2	X	D	B	B
R1	X	D	D	B
SC	A	D	B	C
B8	A	D	X	B
B8.1	X	D	X	B

Figure 2-25. Turbidity (T) based on Riverwatch monitoring records.

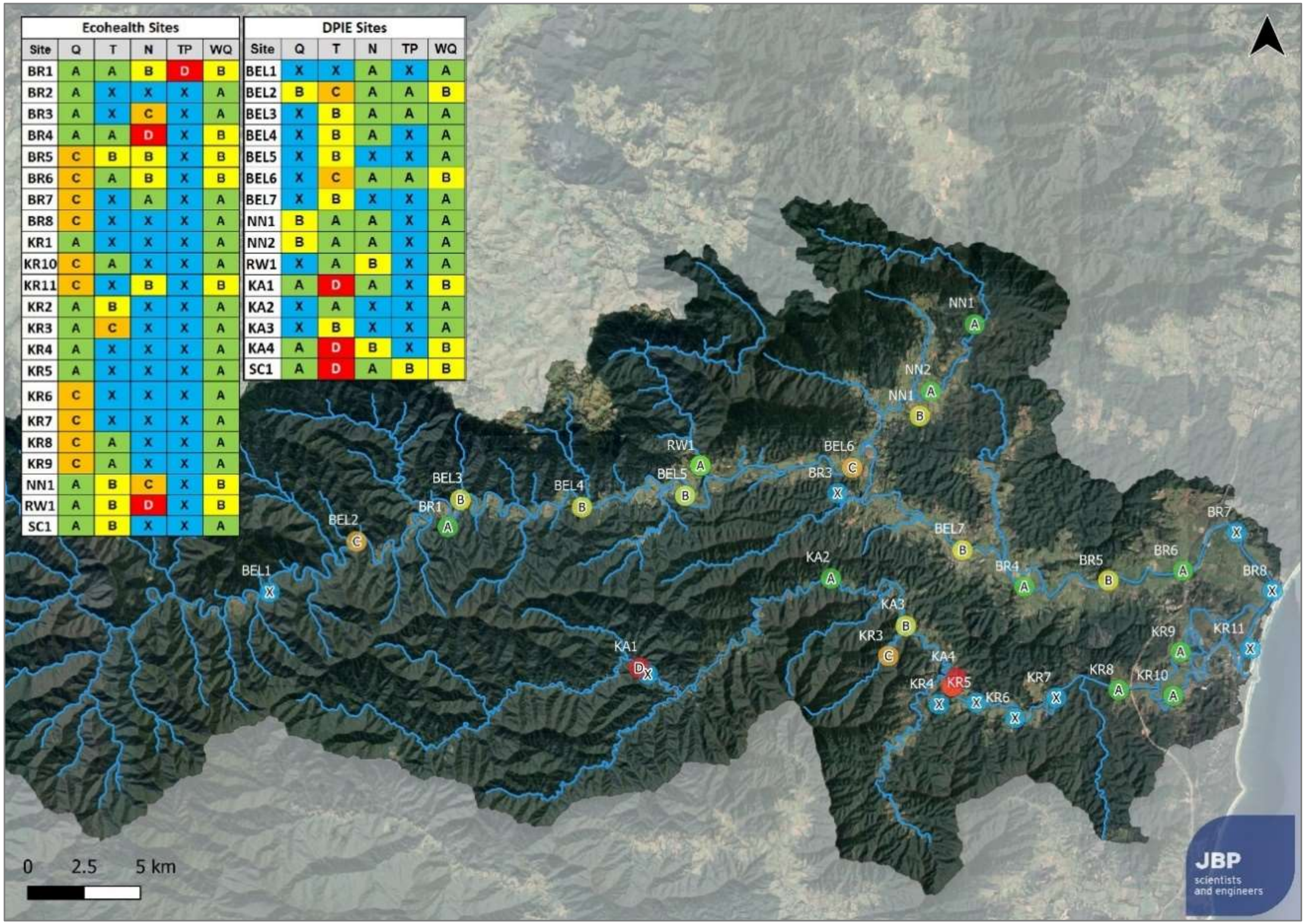
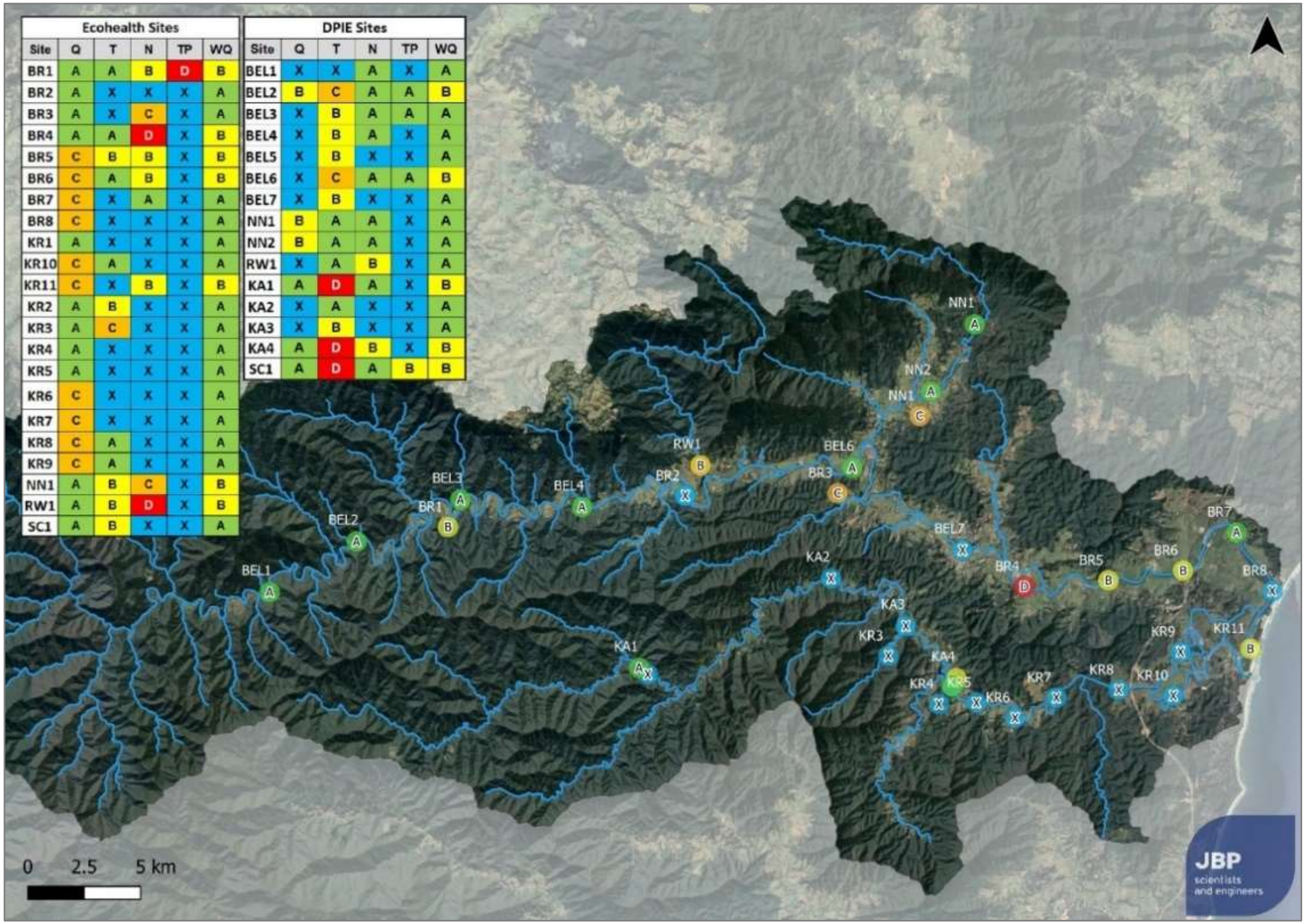


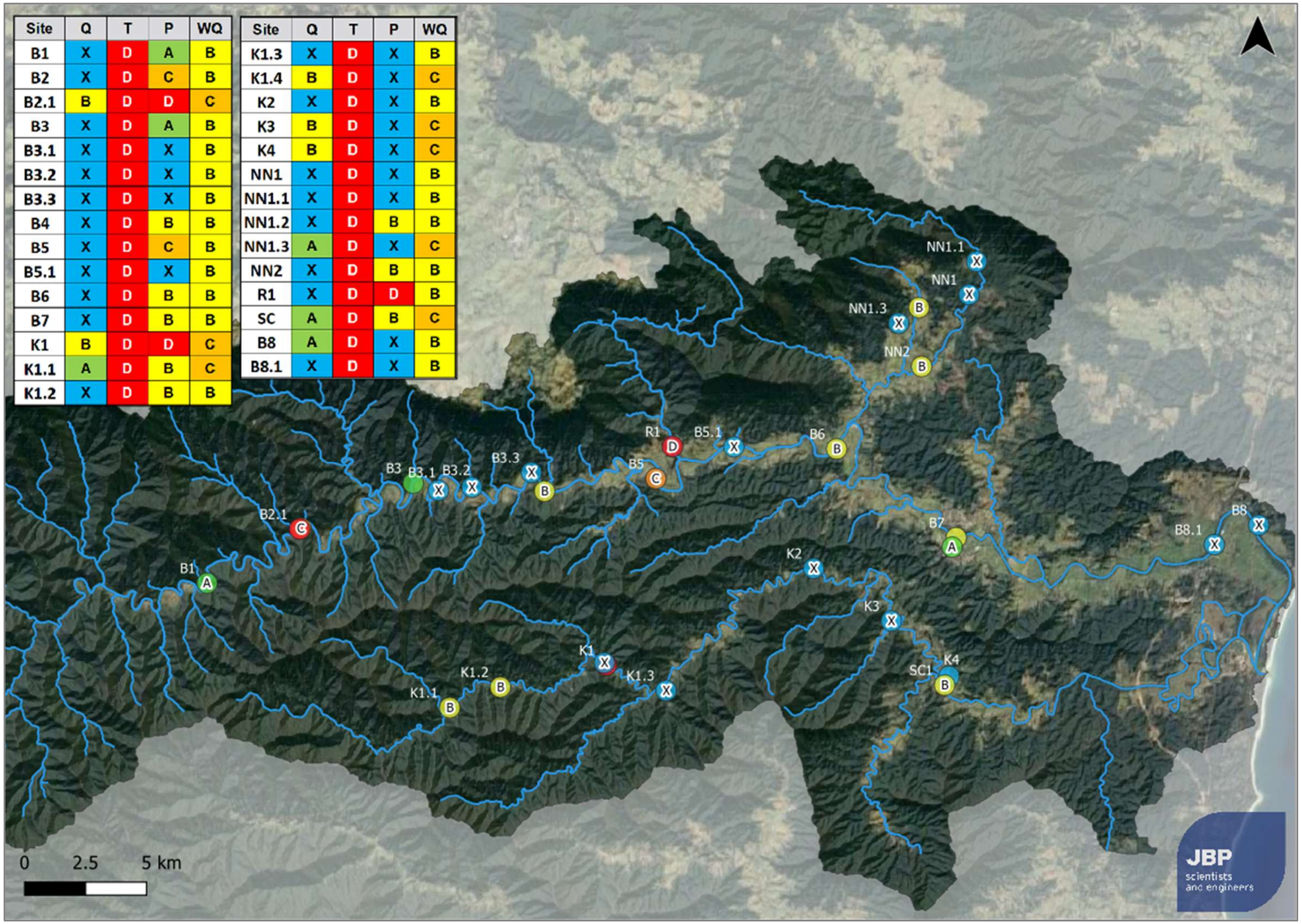
Figure 2-26. Turbidity (T) based on DPE and Ecohealth monitoring records



Ecohealth Sites					
Site	Q	T	N	TP	WQ
BR1	A	A	B	D	B
BR2	A	X	X	X	A
BR3	A	X	C	X	A
BR4	A	A	D	X	B
BR5	C	B	B	X	B
BR6	C	A	B	X	B
BR7	C	X	A	X	A
BR8	C	X	X	X	A
KR1	A	X	X	X	A
KR10	C	A	X	X	A
KR11	C	X	B	X	B
KR2	A	B	X	X	A
KR3	A	C	X	X	A
KR4	A	X	X	X	A
KR5	A	X	X	X	A
KR6	C	X	X	X	A
KR7	C	X	X	X	A
KR8	C	A	X	X	A
KR9	C	A	X	X	A
NN1	A	B	C	X	B
RW1	A	B	D	X	B
SC1	A	B	X	X	A

DPIE Sites					
Site	Q	T	N	TP	WQ
BEL1	X	X	A	X	A
BEL2	B	C	A	A	B
BEL3	X	B	A	A	A
BEL4	X	B	A	X	A
BEL5	X	B	X	X	A
BEL6	X	C	A	A	B
BEL7	X	B	X	X	A
NN1	B	A	A	X	A
NN2	B	A	A	X	A
RW1	X	A	B	X	A
KA1	A	D	A	X	B
KA2	X	A	X	X	A
KA3	X	B	X	X	A
KA4	A	D	B	X	B
SC1	A	D	A	B	B

Figure 2-27. Nitrogen (N) based on DPE and Ecohealth monitoring records



Site	Q	T	P	WQ
B1	X	D	A	B
B2	X	D	C	B
B2.1	B	D	D	C
B3	X	D	A	B
B3.1	X	D	X	B
B3.2	X	D	X	B
B3.3	X	D	X	B
B4	X	D	B	B
B5	X	D	C	B
B5.1	X	D	X	B
B6	X	D	B	B
B7	X	D	B	B
K1	B	D	D	C
K1.1	A	D	B	C
K1.2	X	D	B	B
K1.3	X	D	X	B
K1.4	B	D	X	C
K2	X	D	X	B
K3	B	D	X	C
K4	B	D	X	C
NN1	X	D	X	B
NN1.1	X	D	X	B
NN1.2	X	D	B	B
NN1.3	A	D	X	C
NN2	X	D	B	B
R1	X	D	D	B
SC	A	D	B	C
B8	A	D	X	B
B8.1	X	D	X	B

Figure 2-28. Phosphorous (P) based on Riverwatch monitoring records

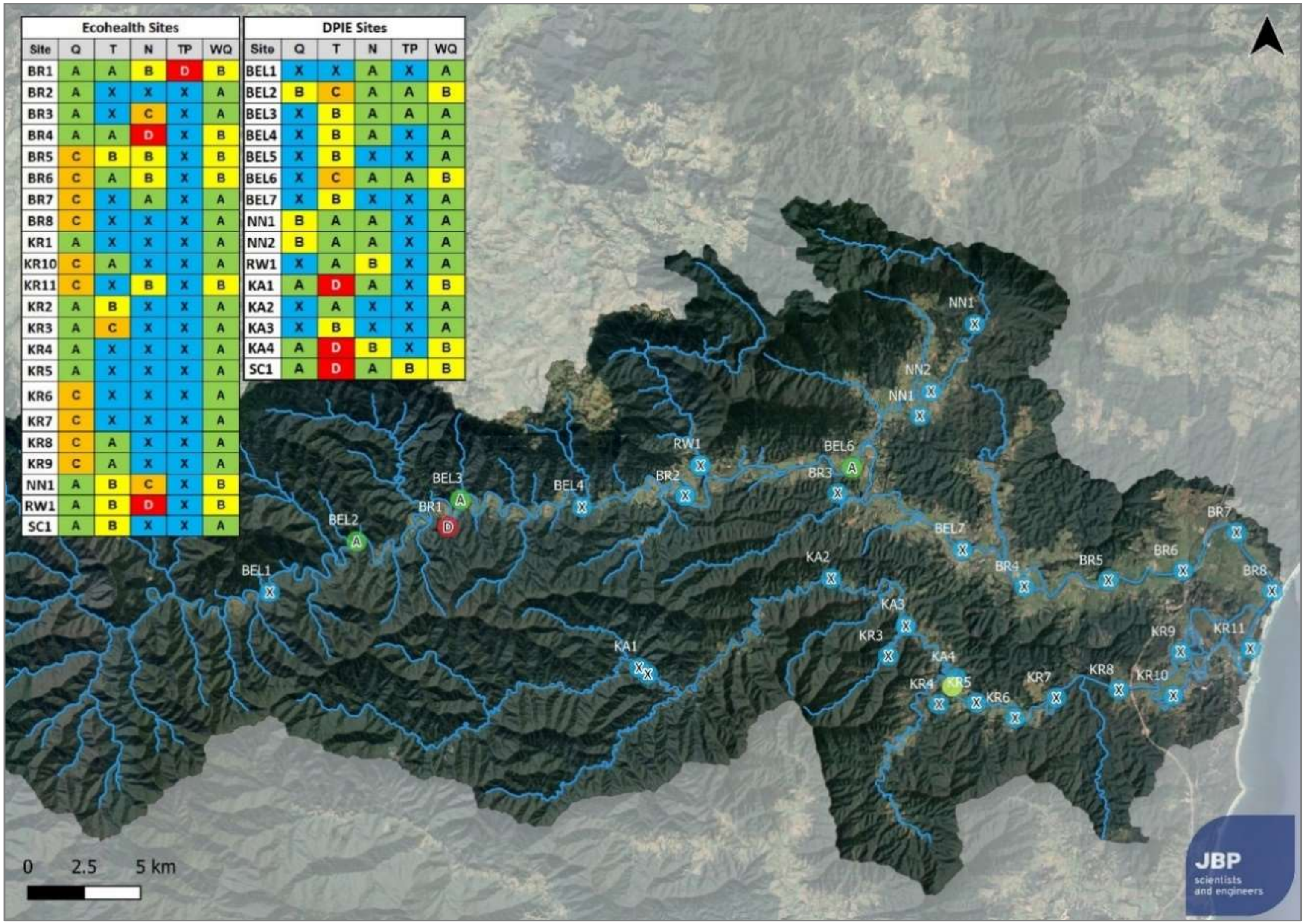


Figure 2-29. Phosphorus (P) based on DPE and Ecohealth monitoring records

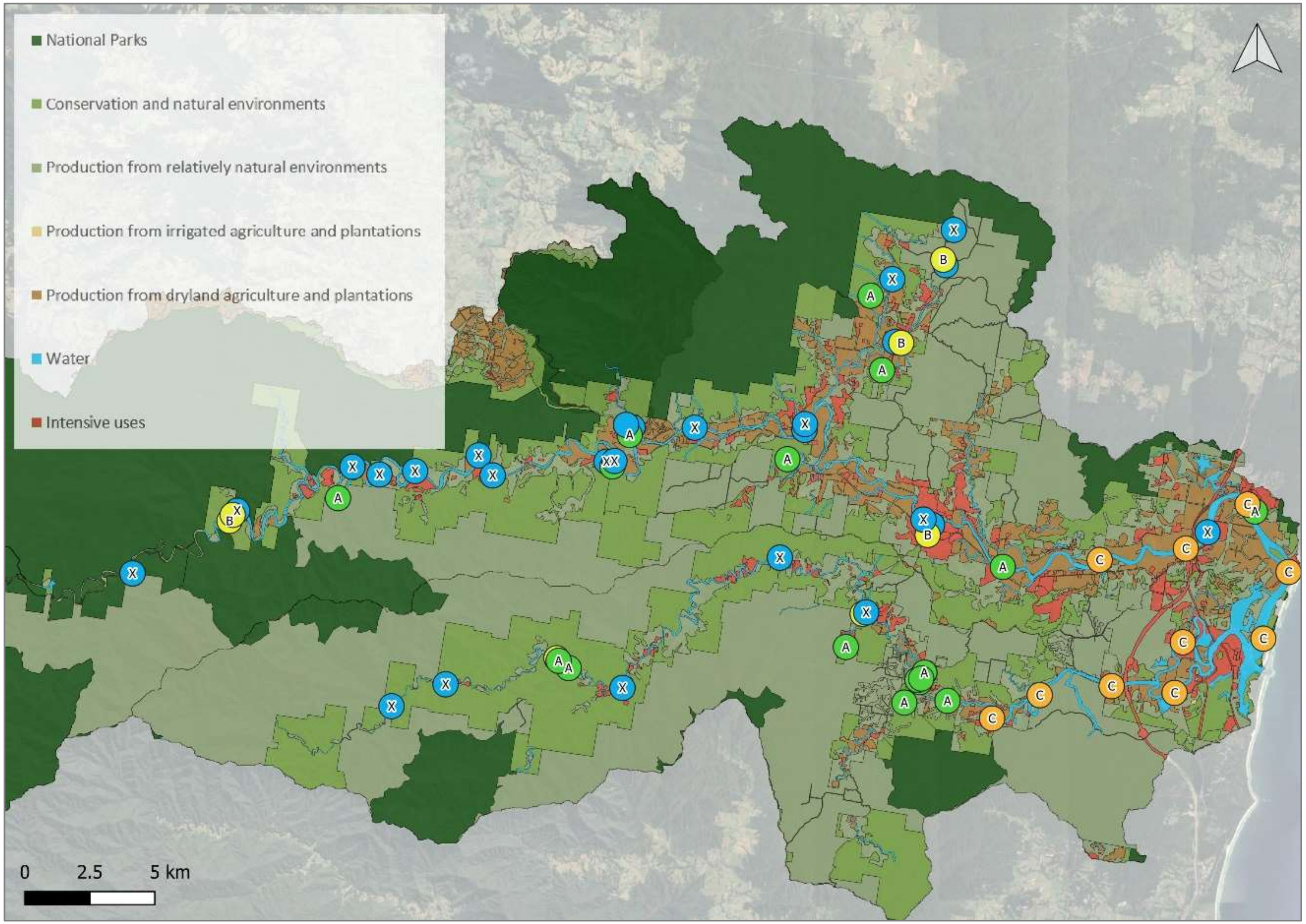


Figure 2-30. Primary water quality (Q) scores and land use in the Bellinger-Kalang Catchment.

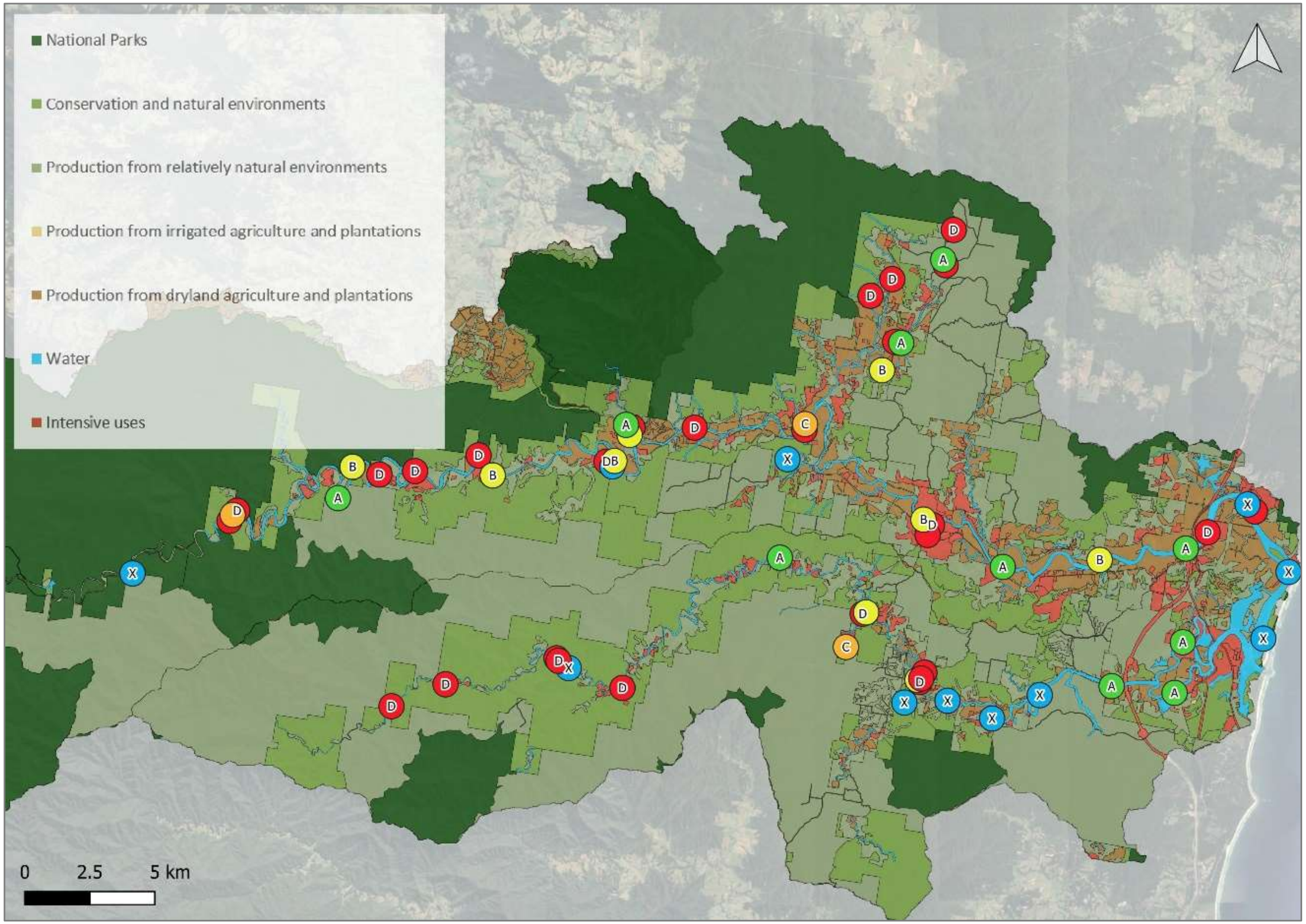


Figure 2-31. Turbidity (T) scores and land use in the Bellinger-Kalang Catchment.

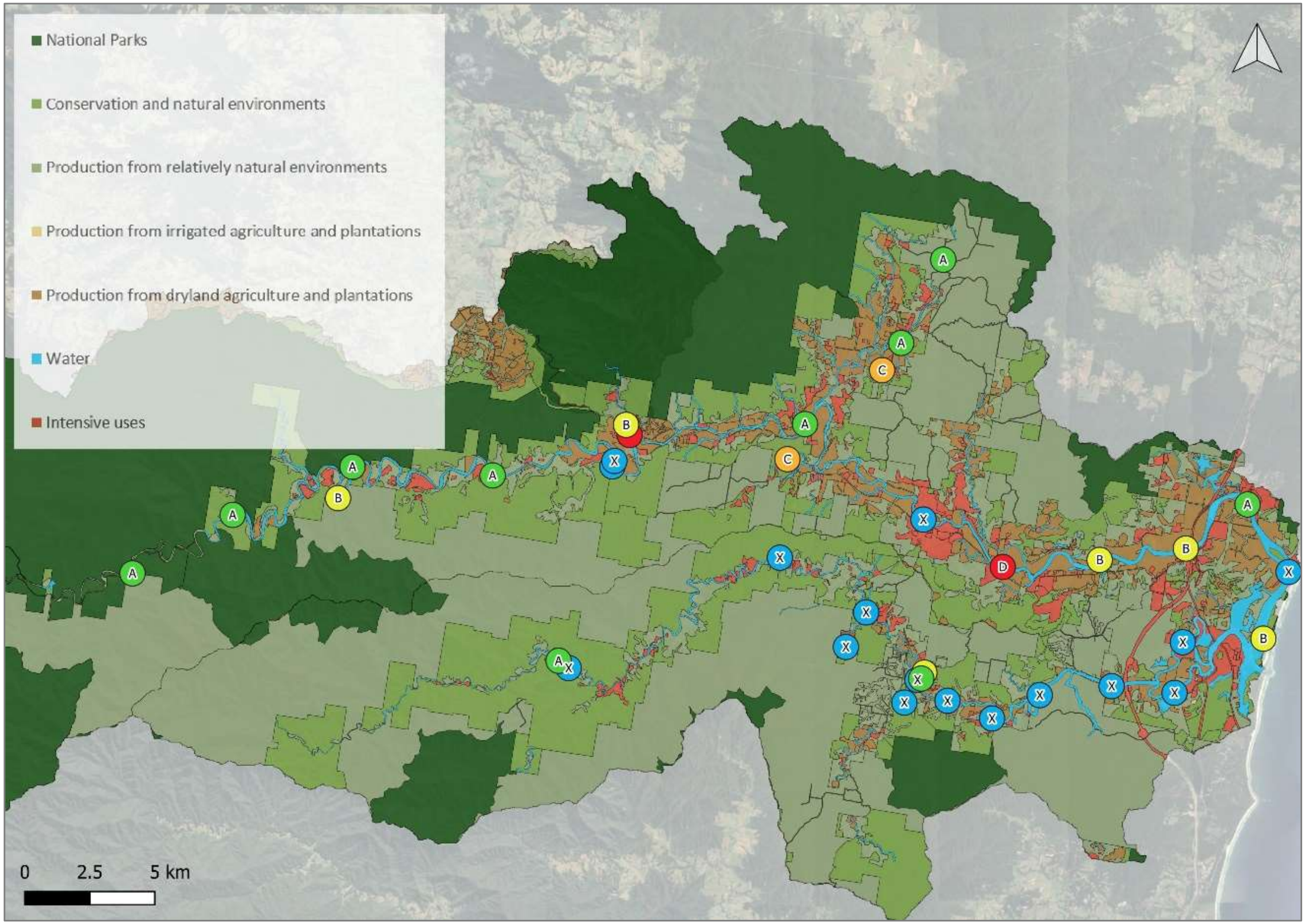


Figure 2-32. Nitrogen (N) scores and land use in the Bellinger-Kalang Catchment.

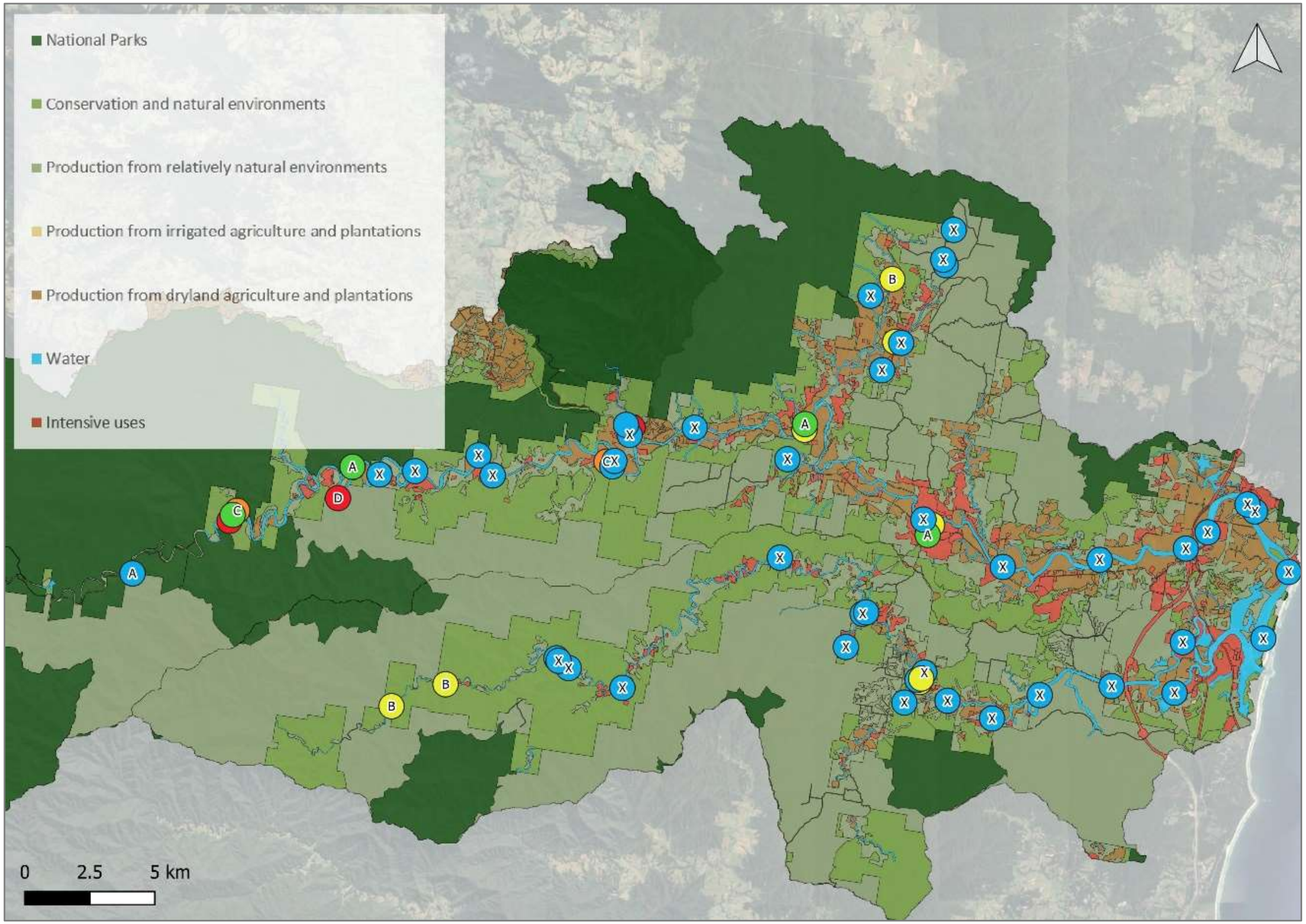


Figure 2-33. Phosphorous (P) scores and land use in the Bellinger-Kalang Catchment.

2.2.4.1 Upper Bellinger River

Water quality results from the Riverwatch, DPE and Ecohealth programmes indicate that the majority of the upper Bellinger River sites have 'excellent' to 'very good' primary water quality (Q). Exceptions are at Cool Creek near Darkwood (site B2.1/BEL2) which returned a 'fair' result due to low pH recordings. Additionally, DPE data showed two 'fair' scores within the Never Never River catchment (NN1/NN2), however both were scored 'Excellent' by Riverwatch.

Turbidity results also show a discrepancy between Riverwatch and DPE data. Whilst Riverwatch monitoring shows 'very poor' turbidity throughout all upper Bellinger River sampling sites, DPE and Ecohealth present a wider range of values ranging between 'excellent' and 'poor'. Sites considered 'poor' by Riverwatch and DPE were Cool Creek near Darkwood (B2) and the Gordonville Road causeway (B6).

Only the DPE and Ecohealth programmes have collected parameters to review Nitrogen (N) levels. The majority of sites scored 'very good', with 'poor' scores limited to the lower Never Never River (NN1) and Little Boggy Creek (BR3).

Total phosphorus (TP) results have some discrepancies between programmes. Riverwatch is more highly varied, ranging from 'excellent' to 'very poor', whilst DPE and Ecohealth show the majority of sites having 'excellent' scores. Both Riverwatch and Ecohealth show localised 'very poor' results at two locations in Darkwood - Cool Creek (B2.1) and the smaller southern tributary (BR1). Discrepancies occur at Rosewood (R1) and Thora (B5) which is scored 'very poor' and 'poor' by Riverwatch, however both 'Excellent' by DPE.

Based on these results, sites with the greatest potential for water quality issues are:

- Darkwood (B2) - pH, Turbidity, Phosphorus.
- Land uses adjacent to the waterway and upstream of site B2 are production from relatively natural environments, conservation and natural environments, and national parks.
- Never Never (NN1, NN2) - Nitrogen.
- Land uses adjacent to these monitoring sites and upstream are predominantly production from dryland agriculture and plantation, intensive uses, and production from relatively natural environments.
- Gordonville Causeway (B6) - Turbidity.
- Land uses adjacent to the waterway at site B6 and upstream are intensive uses, production from dryland agriculture and plantation, and production from relatively natural environments.
- Little Boggy Creek (BR3) - Nitrogen.
- Land use adjacent to the waterway at site BR3 and upstream include conservation and natural environment, production from relatively natural environments, and intensive uses.

2.2.4.2 Upper Kalang River

The majority of the upper Kalang River has 'excellent' or 'very good' for primary water quality (Q). There were three exceptions for Riverwatch program, which scored 'fair', Kalang Firetrail (K1), Woods Creek (K3) and Kalang River Bridge (K4). Ecohealth data also showed 'Poor' values between Spicketts Creek and the highway.

Riverwatch data considers all sites as having 'very poor' turbidity. This was only supported by three Ecohealth locations, Kalang Firetrail (K1), Kalang River Bridge (K4) and downstream Spicketts Creek (SC1).

Using the DPE and Ecohealth monitoring data, the majority of the catchment scored between 'excellent' and 'very good' for Nitrogen (N). A single 'fair' value was recorded at the Kalang River Bridge (K4).

The majority of Phosphorus values were considered 'excellent' within all datasets. Spicketts Creek (SC1) was considered 'fair' by Riverwatch and DPE, in addition to the upper Kalang River at the Roses Creek confluence (K1.1), and Wyembah Road (K1.2), by Riverwatch only.

Based on these results, sites with the greatest potential for water quality issues are:

- Kalang Firetrail (K1) - Primary water quality, Turbidity

- Land use adjacent to the waterway at K1 and upstream are production from relatively natural environments, and conservation and natural environments. There is a small amount of intensive land uses upstream at K1.2.
- Kalang River Bridge (K4) - Primary water quality, Nitrogen, Turbidity
- This site is among intensive uses and production from dryland agriculture and plantation land uses, with production from relatively natural environments and conservation and natural environment land uses upstream.
- Spicketts Creek (SC1) - Phosphorus, Turbidity.
- Site SC1 is adjacent to intensive uses, production from dryland agriculture and plantations, and production from relatively natural environments. Upstream of SC1 is predominantly production from relatively natural environments with patches of intensive uses and production from dryland agriculture and plantations. High turbidity found at site SC1 is likely due to the extensive riparian vegetation clearing along Spicketts Creek.

2.2.4.3 Lower Bellinger-Kalang Estuary

Ecohealth data provides the greatest coverage within the lower estuary, which classifies the majority of sites as 'poor' for primary water quality (Q). Riverwatch is limited to two sampling points on the Bellinger Main Arm near the Raleigh Winery and Repton which are scored 'excellent' and 'very good' respectively.

Ecohealth data shows varying turbidity values, ranging from 'excellent' between the Bellinger-Kalang confluence (KR11) and Repton, where it then transitions to 'very good' near to the highway. A single 'fair' value was given upstream of Connels Creek (BR5). In contrast, all Riverwatch data showed all sites as having 'very poor' turbidity.

DPE and Ecohealth data classify the lower Kalang arm (downstream of Spicketts Creek) as 'excellent' for Nitrogen (N). On the Bellinger River, a 'Very Poor' value is returned upstream of the Nicholson Street river access (BR4), and several 'fair' values returned upstream of Connels Creek (BR5), upstream of the highway (BR6) and at the lower confluence (KR11).

All Ecohealth and Riverwatch shows 'excellent' scores for Phosphorus (P) in the lower catchment.

Based on these results, sites with the greatest potential for water quality issues are:

- All sites - each has the potential for poor primary water quality and turbidity.
- Land use in the estuary is heavily contributed to intensive uses, production from dryland agriculture and plantations, and production from relatively natural environments with patches of conservation and natural environments.
- Upstream of the Nicholson Street river access (BR4) - Nitrogen.
- Land uses adjacent to the waterway at site BR4 and upstream are production from dryland agriculture and plantations, intensive uses, and production from relatively natural environments.

2.2.4.4 Lower Estuary - Faecal Coliforms Summary

The assessment of faecal coliforms is not part of the Riverwatch, DPE or Ecohealth data collection programmes, however an assessment can be made based on several studies conducted over the last 10 years. The SARDI (2016)[21] surveys collected monthly faecal coliform data from the Kalang River harvest area from 21/07/2011 and 7/04/2016 at six sites. Whitehead & Associates (2012)[22] reviewed water quality data in the Bellinger River alongside a dairy milking shed complex at Yellow Rock Road, Raleigh. The lower reaches of the Bellinger River adjacent to the 'Dairy' was a Priority Oyster Aquaculture Area, therefore, the maintenance of a sustainable oyster aquaculture in the Bellinger River was a state priority. Faecal coliforms were measured at five sites on several occasions during March, April, and May of 2012. Faecal coliform values were also available at Bellingen Wastewater Treatment Plant (WWTP) (Jarret Park and Doepel Park sites) and Urunga WWTP (Sea Lido site) from 02/01/2019 to 17/06/2020 on a monthly basis.

21 South Australian Research & Development Institute, SARDI, (2016). Sanitary survey report for the Kalang River harvest area. Prepared by Turnbull, A., and Malhi, N. Published by

22 Whitehead & Associates (2012). Review of river and drain water quality nearby Yellow Rock road dairy, Raleigh. Prepared by Duerinckx, S.

The faecal coliform data was analysed based on the Australian Shellfish Quality Assurance Programme (ASQAP) operational manual (2016). As presented in the SARDI (2016) report, the water quality was consistently poor across the Kalang River harvest area. The harvesting criteria was defined as:

- Approved (A): Median value < 14 faecal coliforms / 100 m, and not more than 10% samples with faecal coliforms > 21/100 ml
- Unconditionally Restricted (UR): Median value < 70 faecal coliforms / 100 m, and not more than 10% samples with faecal coliforms > 85/100 ml
- Conditionally Restricted (CR): Median value < 70 faecal coliforms / 100 m, and more than 10% samples with faecal coliforms > 85/100 ml.

The analysis within SARDI (2016) shows that no sites complied with the ASQAP "Approved" criteria for harvesting as shown in Table 2-7. Three sites complied with "Unconditionally Restricted" classification requirements, with the remaining three meeting the restricted classification, as more than 10% of the samples were above 85 faecal coliforms per 100 ml and classified "Conditionally Restricted". Results from Whitehead & Associates (2012) revealed that all sites were classified as "Conditionally Restricted", with some showing very high faecal coliform measurements which exceed all threshold criteria. The faecal coliform results obtained at Jarrett Park and Doepel Park from the Bellingen WWTP also classified these areas as "Conditionally Restricted", however the faecal coliform recorder at Sea Lido in Urunga WWTP in 2020 classified it "Unconditionally Restricted". Based on these results, all sampled sites contained some level of faecal contamination which led to no approved sites for harvesting. These conditions are snapshots in time, and for future analysis, it is recommended that a data sharing arrangement is implemented with the local oyster growers for inclusion in any Riverwatch analysis. Private water quality monitoring is undertaken for parameters required for oyster harvesting. E.g., Faecal coliforms and E. coli. This is collected within three hours of low tide by private oyster farmers, with data issued to NSW food authority, in order to demonstrate water quality meets harvesting criteria.

Table 2-7. Summary of faecal coliforms data

Report	Site	Number of Sample	Median	Min	Max	samples with FC > 21 cfu/100 ml (%)	samples with FC > 85 cfu/100 ml (%)	Category
SARDI (2011-2016)	6	33	17	-	150	42.4	6.1	UR
	7	33	15	-	165	57.6	9.1	UR
	8	33	31	-	230	69.7	15.2	CR
	10	33	21	1	148	72.7	15.2	CR
	11	33	23	1	192	69.7	6.1	UR
	12	33	18	-	270	51.5	15.2	CR
Whitehead & Associates (2012)	4(D)	3	54	54	54	33.3	0	CR
	S1	7	32	9	108	71.4	28.6	CR
	S2	7	22	2	138	57.1	14.3	CR
	S3	7	53	12	560	57.1	42.9	CR
	S4	7	29	0	102	57.1	14.3	CR
	S5	7	30	6	86	57.1	14.3	CR
Bellingen WWTP (2019)	Jarrett Park	22	172.5	33	1030	100	90.9	CR
Bellingen WWTP (2020)	Jarrett Park	13	130	50	880	100	92.3	CR
Bellingen WWTP (2019)	Doepel Park	24	185	64	660	100	91.7	CR
Bellingen WWTP (2020)	Doepel Park	13	120	30	690	100	76.9	CR
Urunga WWTP (2019)	Sea Lido	26	28.5	0	280	61.5	23.1	CR
Urunga WWTP (2020)	Sea Lido	13	10	0	980	30.8	7.7	UR

2.2.4.5 Summary of Water Quality Analysis

The review of catchment water quality has revealed a large quantity of data available for analysis within the catchment. This includes monthly water quality monitoring from the community-led Riverwatch programme since 2017, data from the state government-led DPE monitoring which is available in autumn and spring between 2017 and 2020, data from Ecohealth 2009 water quality monitoring in the estuary and upper catchment, and data of faecal contamination from SAUDI (2016), Whitehead & Associates (2012), and WWTP data from 2019-2020. Each dataset and their water quality scores are shown in Table 2-8. This table shows where monitoring sites overlap and the varying scores of each site between monitoring programmes. Each dataset varies in terms of recorded parameters, spatial coverage, and sampling sites, and can often have conflicting information due to the sampling approach. Variation of scores between programmes at the same sites may be due to differing monitoring techniques, equipment, and/or the varying frequencies in data collection. However, based on this data the following sites have the greatest potential to experience water quality issues:

Bellinger

- Darkwood (B2) - pH, Turbidity, Phosphorus
- Never Never River (NN1, NN2) - Nitrogen
- Gordonville Causeway (B6) - Turbidity
- Little Boggy Creek (BR3) - Nitrogen.

Kalang

- Kalang Firetrail (K1) - Primary water quality, Turbidity
- Kalang River Bridge (K4) - Primary water quality, Nitrogen, Turbidity
- Spicketts Creek (SC1) - Phosphorus, Turbidity.

Lower estuary

- All sites - each have the potential for poor primary water quality and turbidity.
- Upstream of the Nicholson Street river access (BR4) - Nitrogen
- Kalang River estuary (KR10 & KR11) - Faecal coliforms
- Bellingen River estuary (BR8) - Faecal coliforms

Table 2-8. Overall Water Quality score for Riverwatch, DPE and Ecohealth monitoring sites.

Region	Riverwatch					DPIE						Ecohealth					
	Site	Q	T	P	WQ	Site	Q	T	P	N	WQ	Site	Q	T	P	N	WQ
Upper Bellinger	B1	X	D	A	B	BEL1	X	X	X	A	A	BR1	A	A	D	B	B
	B2	X	D	C	B	BEL2	B	C	A	A	B	-	-	-	-	-	-
	B2.1	B	D	D	C	-	-	-	-	-	-	-	-	-	-	-	-
	B3	X	D	A	B	BEL3	X	B	A	A	A	-	-	-	-	-	-
	B3.1	X	D	X	B	-	-	-	-	-	-	-	-	-	-	-	-
	B3.2	X	D	X	B	-	-	-	-	-	-	-	-	-	-	-	-
	B3.3	X	D	X	B	-	-	-	-	-	-	-	-	-	-	-	-
	B4	X	D	B	B	BEL4	X	B	X	A	A	-	-	-	-	-	-
	B5	X	D	C	B	BEL5	X	B	X	X	A	BR2	A	X	X	X	A
	B5.1	X	D	X	B	-	-	-	-	-	-	-	-	-	-	-	-
	B6	X	D	B	B	BEL6	X	C	A	A	B	BR3	A	X	X	C	A
	B7	X	D	B	B	BEL7	X	B	X	X	A	-	-	-	-	-	-
Lower Bellinger	-	-	-	-	-	-	-	-	-	-	-	BR4	A	A	X	D	B
	-	-	-	-	-	-	-	-	-	-	-	BR5	C	B	X	B	B
	B8	A	D	X	B	-	-	-	-	-	-	BR7	C	X	X	A	A
	B8.1	X	D	X	B	-	-	-	-	-	-	BR6	C	A	X	B	B
	-	-	-	-	-	-	-	-	-	-	-	BR8		X	X	X	A
Kalang	K1	B	D	D	C	KA1	A	D	X	A	B	KR1	A	X	X	X	A
	K1.1	A	D	B	C	-	-	-	-	-	-	-	-	-	-	-	-
	K1.2	X	D	B	B	-	-	-	-	-	-	-	-	-	-	-	-
	K1.3	X	D	X	B	-	-	-	-	-	-	-	-	-	-	-	-
	K1.4	B	D	X	C	-	-	-	-	-	-	-	-	-	-	-	-
	K2	X	D	X	B	KA2	X	A	X	X	A	-	-	-	-	-	-
	K3	B	D	X	C	KA3	X	B	X	X	A	KR3	A	C	X	X	A
	K4	B	D	X	C	KA4	A	D	X	B	B	KR4	A	X	X	X	A
	-	-	-	-	-	-	-	-	-	-	-	KR5	A	X	X	X	A
	-	-	-	-	-	-	-	-	-	-	-	KR6	C	X	X	X	A
	-	-	-	-	-	-	-	-	-	-	-	KR7	C	X	X	X	A
	-	-	-	-	-	-	-	-	-	-	-	KR8	C	A	X	X	A
	-	-	-	-	-	-	-	-	-	-	-	KR9	C	A	X	X	A
	-	-	-	-	-	-	-	-	-	-	-	KR10	C	A	X	X	A
	-	-	-	-	-	-	-	-	-	-	-	KR11	C	X	X	B	B
Never Never River	NN1	X	D	X	B	NN1	B	A	X	A	A	-	-	-	-	-	-
	NN1.1	X	D	X	B	-	-	-	-	-	-	-	-	-	-	-	-
	NN1.2	X	D	B	B	-	-	-	-	-	-	-	-	-	-	-	-
	NN1.3	A	D	X	C	-	-	-	-	-	-	-	-	-	-	-	-
	NN2	X	D	B	B	NN2	B	A	X	A	A	NN1	A	B	X	C	B
Rosewood River	R1	X	D	D	B	RW1	X	A	X	B	B	RW1	A	B	X	D	B
Spicketts Creek	SC1	A	D	B	C	SC1	A	D	B	A	B	SC1	A	B	X	X	A

2.3 Catchment Modelling

The analysis of water quality monitoring alone does not identify the source of poor water quality, only downstream results. The top locations exceeding water quality targets were therefore subject to new analysis and catchment modelling to identify source catchments, which may be subject to new management actions. Numerical modelling was undertaken to support the water quality review throughout the upper Bellinger River Catchment. The Soil and Water Assessment Tool (SWAT) was utilised, which is a time-continuous, semi-distributed, process-based river catchment model developed to assess the impacts of land use and land management on soil and streams.

The model inputs included:

- A Digital Elevation Model (DEM).
- A soil map and a database table of soil texture, available water content, hydraulic conductivity, bulk density, and organic carbon content.
- Land use data was categorised into six types: horticulture land (HORT), mixed forest (FRST), water body and wetlands (WATR), pasture (PAST), mixed dryland/irrigated cropland (MIXC), and high density urban (URHD).
- Observed meteorological data of rainfall, temperature, relative humidity, solar radiation, and wind speed.

The SWAT model was setup by dividing the watershed into sub catchments based on topography, soil, land use, and slope. The model was used to track particle size distribution of eroded sediments which are routed through ponds, channels, and surface waterbodies. The sediment yield from the landscape is lagged and routed through grassed waterway, vegetative filter strips, and ponds, before reaching the stream channel. By combining both components, the model can simulate areas of high sediment yield from the upper catchment into categories shown in Table 2-9.

Table 2-9. SWAT average annual sediment yield rating.

Rating	Average suspended load (tonnes/year)
Very Low	0.3 - 117645
Low	117645 - 303470
Medium	303470 - 537400
High	537400 - 820540
Very High	820540 - 1313510

Figure 2-34 to Figure 2-35 show the spatial distribution of sediment yield in the watershed, based on suspended sediment load and deposition in waterways. The results show that sediment yield varies spatially throughout the catchment. However, there are small areas of high sediment yield in two tributaries upstream of Brinerville (B1) and Darkwood B4. The area of greatest sediment deposition occurs upstream of Thora between sites B4 and B5. High rates of sediment deposition were also observed in the Rosewood River from the Endiandra Creek confluence to ~2.5km west, along Endiandra Creek to its Sassafras Creek confluence, and Bellingen River from its Fishers Creek confluence west to and upstream of Woods Creek.

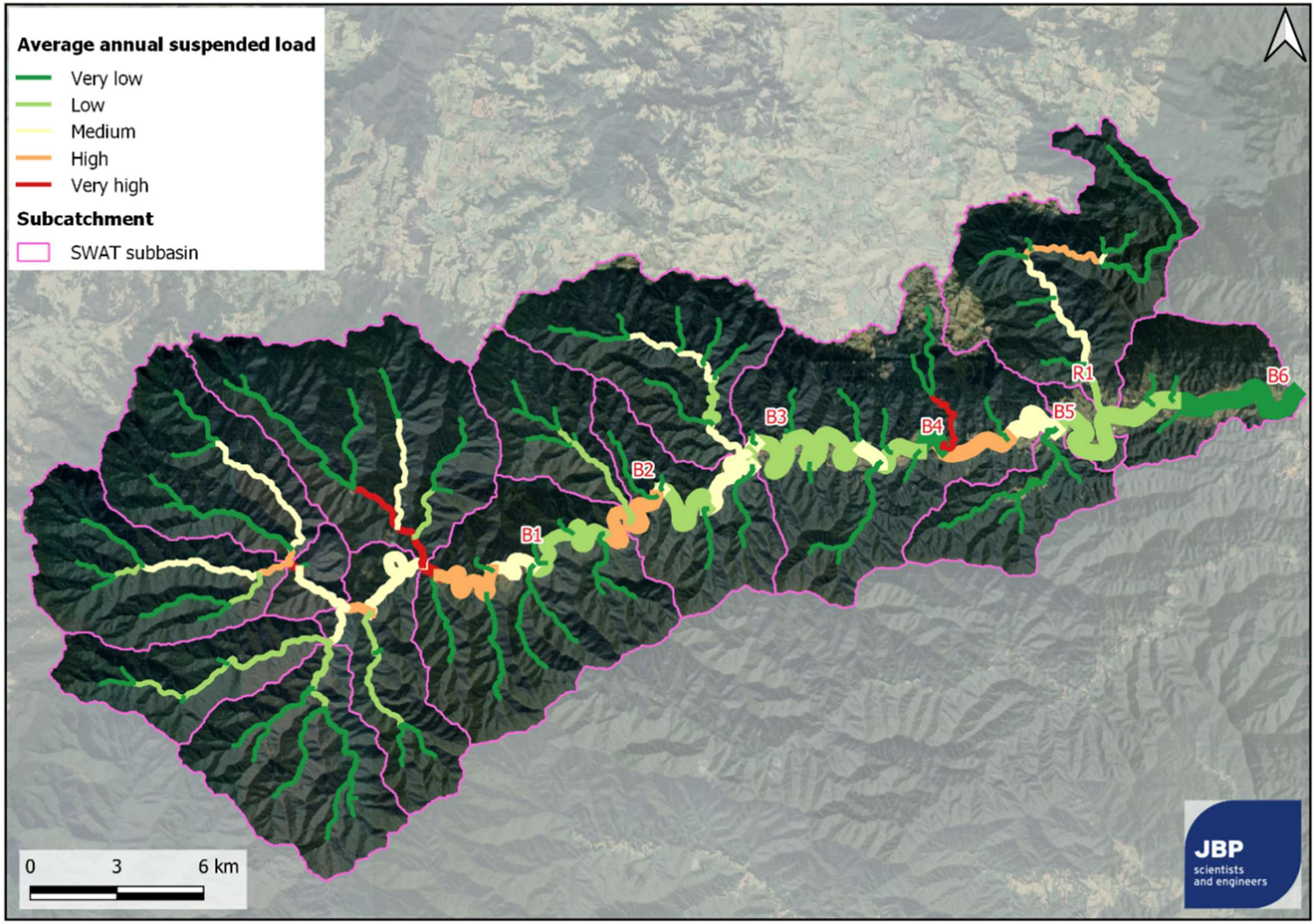


Figure 2-34. Annual average of suspended sediment load in Upper Bellinger River

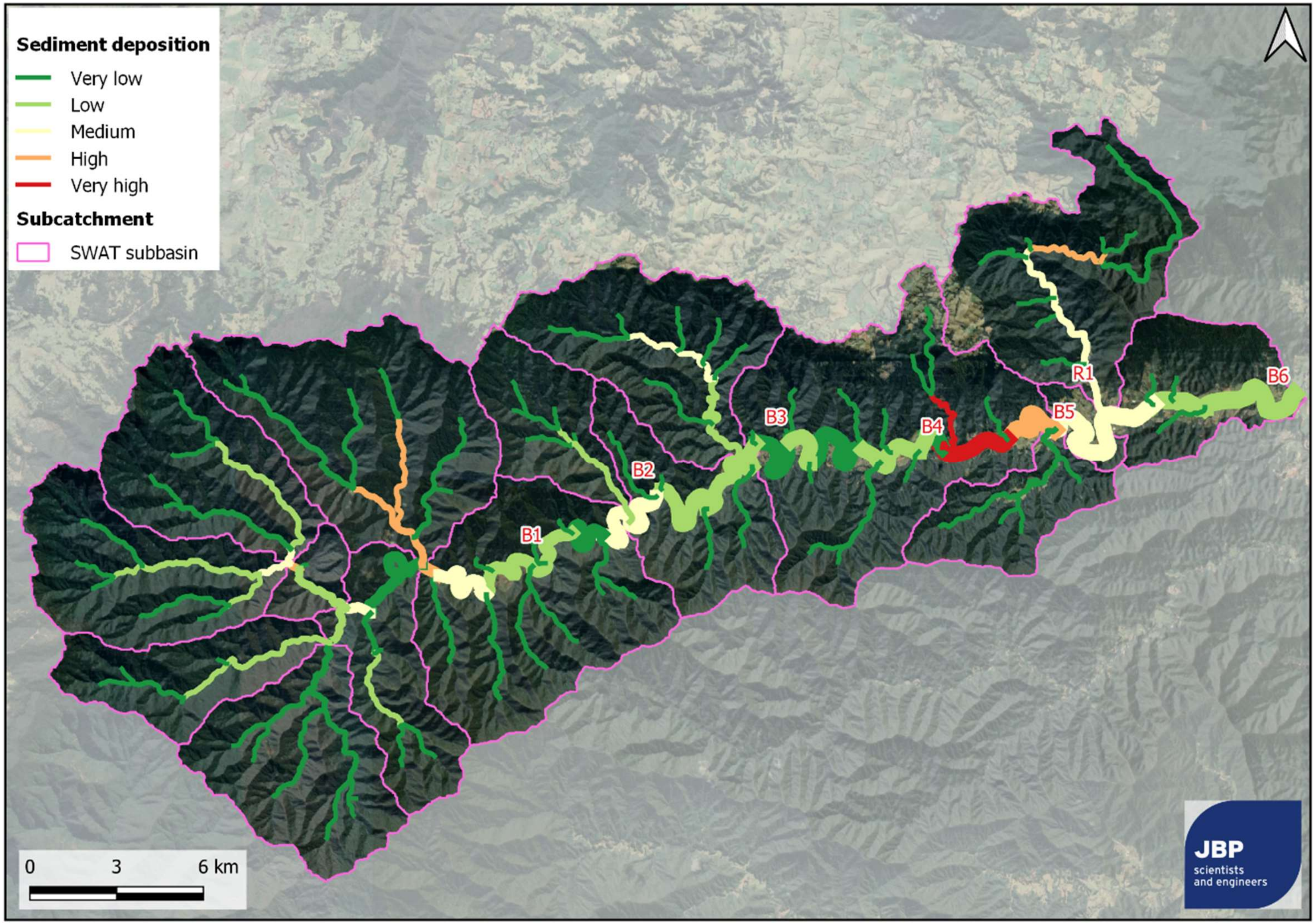


Figure 2-35. Annual average sediment deposition rate in Upper Bellinger River

3 Catchment Goals

3.1 Community Values and Management Goals

The management of water quality throughout the Bellinger-Kalang Catchment needs to consider the values of the local community. These have been reviewed based on previous surveys, community questionnaire responses from the CMP Stage 1 study and the Bellingen Shire Biodiversity Strategy (2020), in addition to a new Water Quality community survey undertaken by JBPacific for this WQMP.

3.1.1 CMP Phase 1 Study

The CMP Phase 1 study included community surveys relating to the coastal zone. This data showed that the most valued aspect of the Bellingen coast was the natural ecosystems and wildlife. Additionally, recreational opportunities, the unique landscape and the natural beauty were also highly valued. Residents felt that riverbank erosion and loss of vegetation along waterways were among the top threats to the coast.

3.1.2 Bellingen Shire Biodiversity Strategy (Eco Logical Australia, 2019) Community Consultation Summary

Based on community consultation responses collected by the Bellingen Shire Biodiversity Strategy, participants identified walking, jogging and/or hiking as the most popular activity followed by swimming and family events. Actions within the Bellingen Shire that were identified as extremely important to participants included the enhancement and protection of biodiversity, providing natural areas for recreation, protecting threatened vegetation, and creating and enhancing river foreshore and bushland. Participants where short responses were available commented on their uses of natural areas being for rest and relaxation, forest bathing, connecting to culture, spiritual wellbeing, exploring, connecting with nature, photography, and admiration of natural landscapes. Participants also identified vegetation clearing, weed invasion, climate change, and pest animals as the biggest threat to Bellingen Shires natural environment. Short responses regarding threats to the Bellingen Shire natural environment also included logging, over-development, harmful farming practices, overgrazing, population increase, tourism, noise pollution, and disrespectful human activities.

3.1.3 Bellinger-Kalang River Catchments Water Quality Community Response Summary

A new water quality survey was distributed to stakeholders and public forums over a two-week period from 23 November to 7 December 2021 and received 53 responses. It was designed to collect community feedback regarding water quality, waterway values and uses in the Bellinger-Kalang River and its tributaries in alignment with current DPE NSW water quality objectives project. Responses are summarised here and provided in full within Appendix E, and findings have contributed to DPE's data for the Bellinger-Kalang Catchment.

3.1.3.1 Values

The survey had a high number of responses from local residents, with 69% of participants based in either Upper Bellinger River or the Bellinger River Estuary. Figure 3-1 shows the distribution of their local waterways, with the highest responses for the Bellinger River, Never Never River, and Kalang River. The survey revealed that most participants currently use their local waterways as a place to swim, enjoy scenery, walk, relax, picnic and camp. The waterways are valued as a habitat for flora and fauna, and for its culture and history (Figure 3-2).

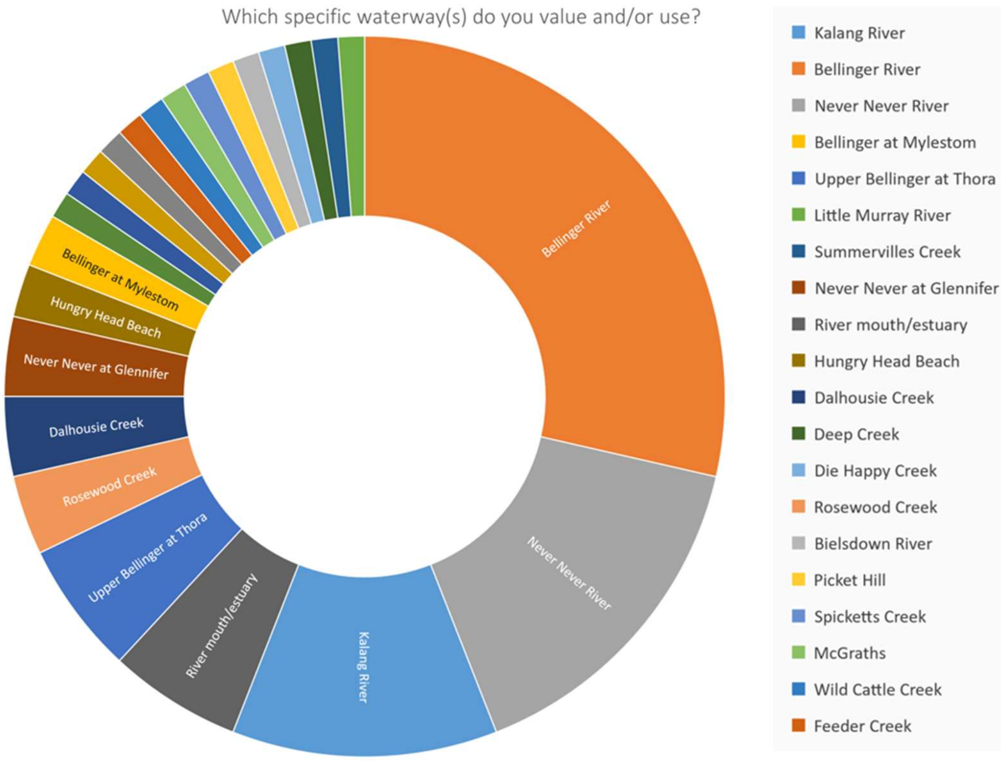


Figure 3-1. Community water quality survey responses to question 'Which specific waterway(s) do you value and/or use?'

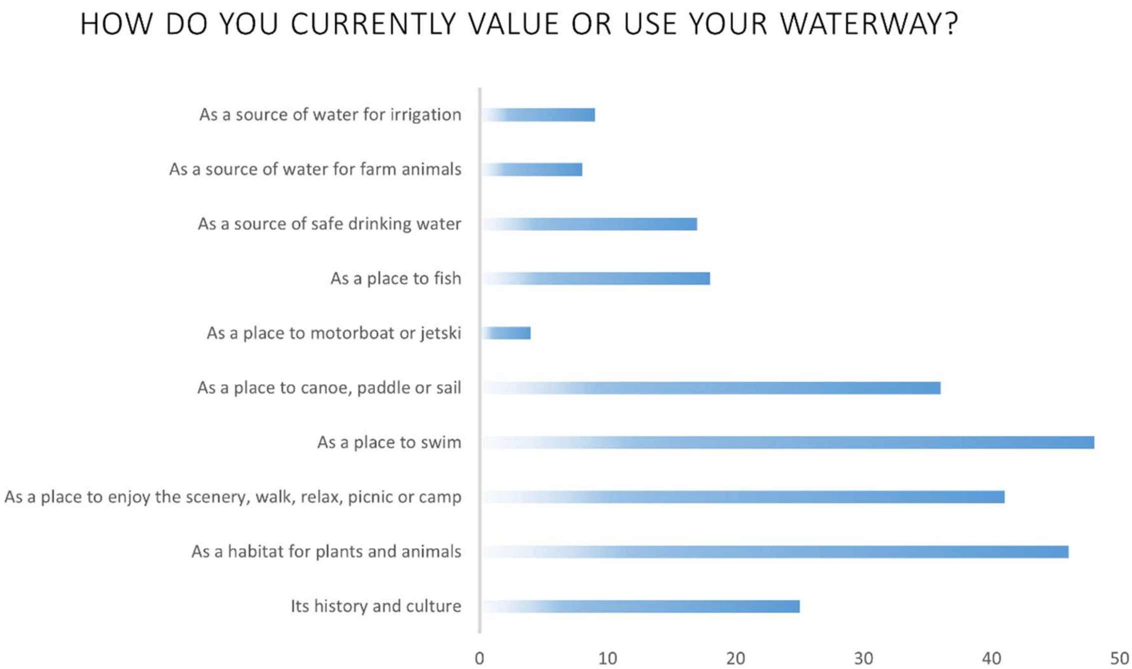


Figure 3-2. Community water quality survey responses to question 'How do you currently value or use your waterway?'

3.1.3.2 Water Quality

Responses regarding user satisfaction with the existing water quality and health are shown in Figure 3-3. This shows 30% were highly satisfied/satisfied and around 40% were very unsatisfied/unsatisfied.

The survey showed 52% of respondents identified problems that limited their use or enjoyment of the local waterways. This included limited access or parking, lack of amenities/infrastructure, sensitive area/cultural respect, areas being unsafe to use, conflict between uses, or a range of other responses (see Figure 3-4).

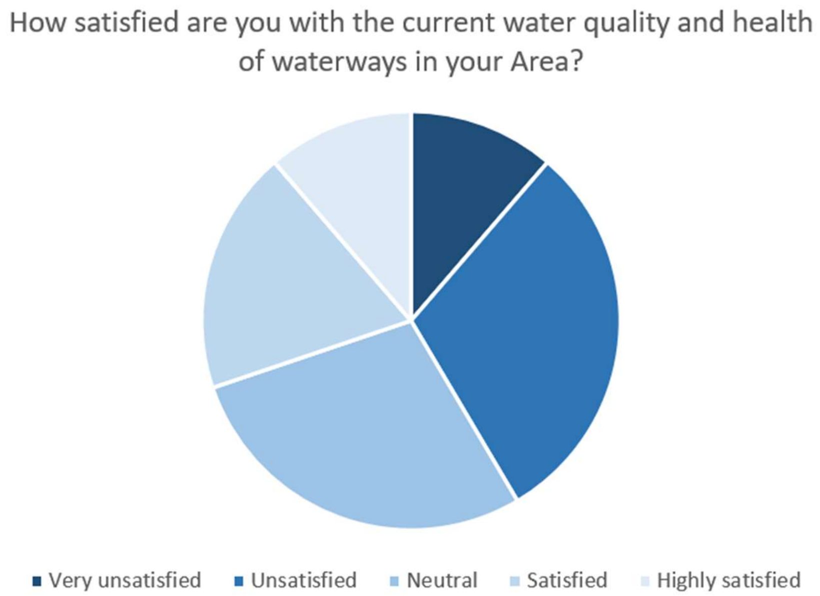


Figure 3-3. Community water quality survey responses to question 'How satisfied are you with the current water quality and health of waterways in your area?'

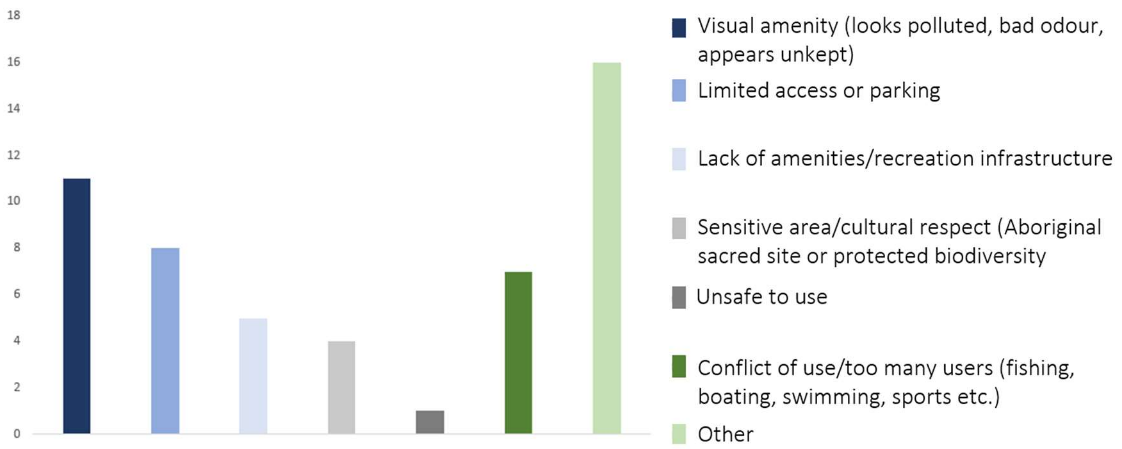


Figure 3-4. Community water quality survey responses to question regarding what problems or concerns are stopping participants from using or enjoying their local waterways.

3.1.3.3 Cultural Heritage

The survey showed 69% of participants were unsure whether cultural heritage sites exist in their local area. When asked about the incorporation of Aboriginal knowledge and practices into the Bellinger-Kalang River water quality objectives, the majority of participants supported the idea and provided input to how this could be implemented. Suggestions included cultural site identification, informative signage at cultural sites, improved consultation with Gumbaynggirr Aboriginal elders and local council, community education programmes and groups, and guided walks.

3.1.3.4 Future Use

The survey allowed participants to comment on how the waterways could be used in the future. The highest responses were for a place to *'enjoy scenery, walk, relax, picnic and camp'*, followed by '*a place for habitat for animals*', as a '*place for swimming*' and for '*safe drinking water supply*'.

A wide range of community recommendations were proposed to support future management. These suggested the need for increased funding, improved restrictions and regulations, improved water quality management, stricter enforcement, revegetation, improved weed/invasive species management, improved/increased community education for farmers and landowners, riparian restoration, reforestation, erosion control, stock exclusion, riparian fencing, more public bathrooms and rubbish bins, runoff control, a reduction in advertising swimming holes and tourism management, regulation of septic tanks, and the implementation of fish ladders, weirs, and off stream water storage.

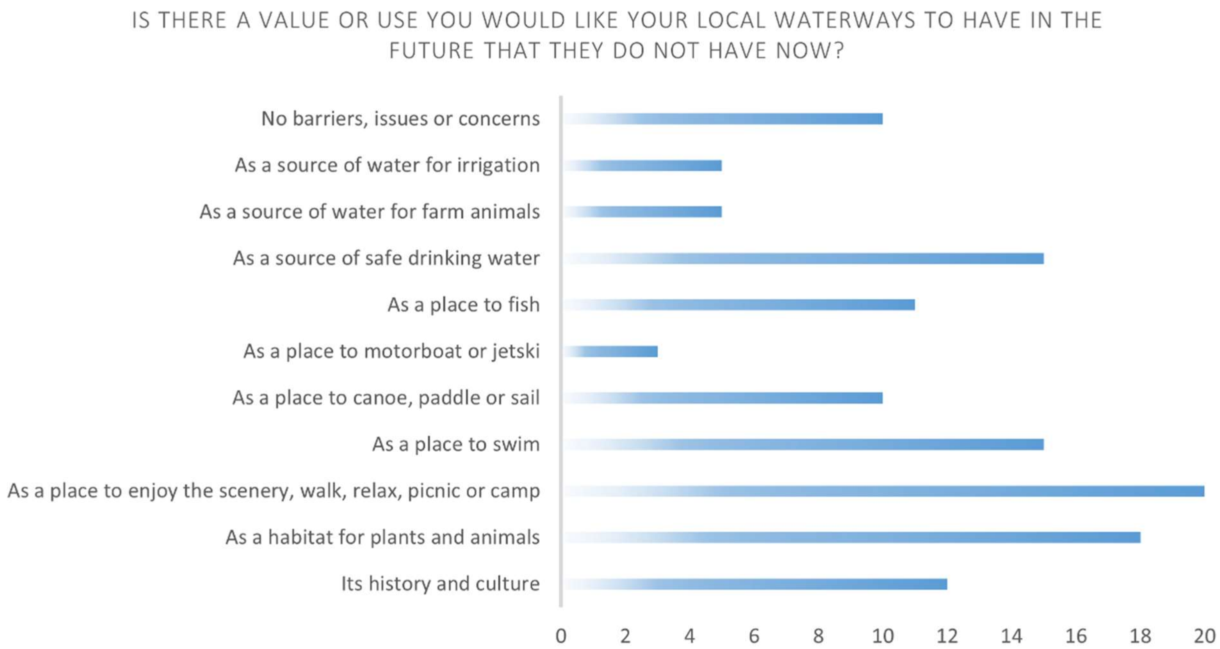


Figure 3-5. Community water quality survey responses to question regarding values and uses they would like introduced into their waterways.

3.2 Bellinger-Kalang Water Quality Objectives

NSW Water Quality Objectives have been set for the Bellinger River and have been outlined for specific regions including mainly forested areas, waterways affected by urban development, uncontrolled streams, and estuaries. These regions are shown in Figure 3-6 with their objectives shown in Table 3-2[23]. The key benefits and major threats identified in the Bellinger-Kalang Catchment are shown in Table 3-1.

Table 3-1 Key benefits and major threats identified in literature and community consultation.

Benefit category	Key benefits	Major threats to benefits
Economic benefits to the community	• Tourism • Fishing and fresh seafood	• Water pollution • Seafood contamination • Loss of natural areas • Declining levels of tourism
Social benefits to the community	• Enjoyment of natural beauty • Safe place for socialising • Encourages an active, healthy lifestyle • Cultural heritage for future generations • Source of scientific discoveries	• Anti-social behaviour and unsafe practices • Water pollution and littering • Overcrowding/congestion • Resource use conflicts • Excessive resource extraction (logging)
Environmental benefits to the community	• Clean waters • Habitats and Assemblages • Threatened and protected species • Abundant aquatic life • Unique biodiversity	• Littering and debris • Riparian degradation • Water pollution, including run-off, turbidity, and stormwater discharge • Urban development • Mining and logging • Farming practices • Climate change

23 Marine Estate Management Authority (2015) Threat and Risk Assessment Framework for the NSW Marine Estate

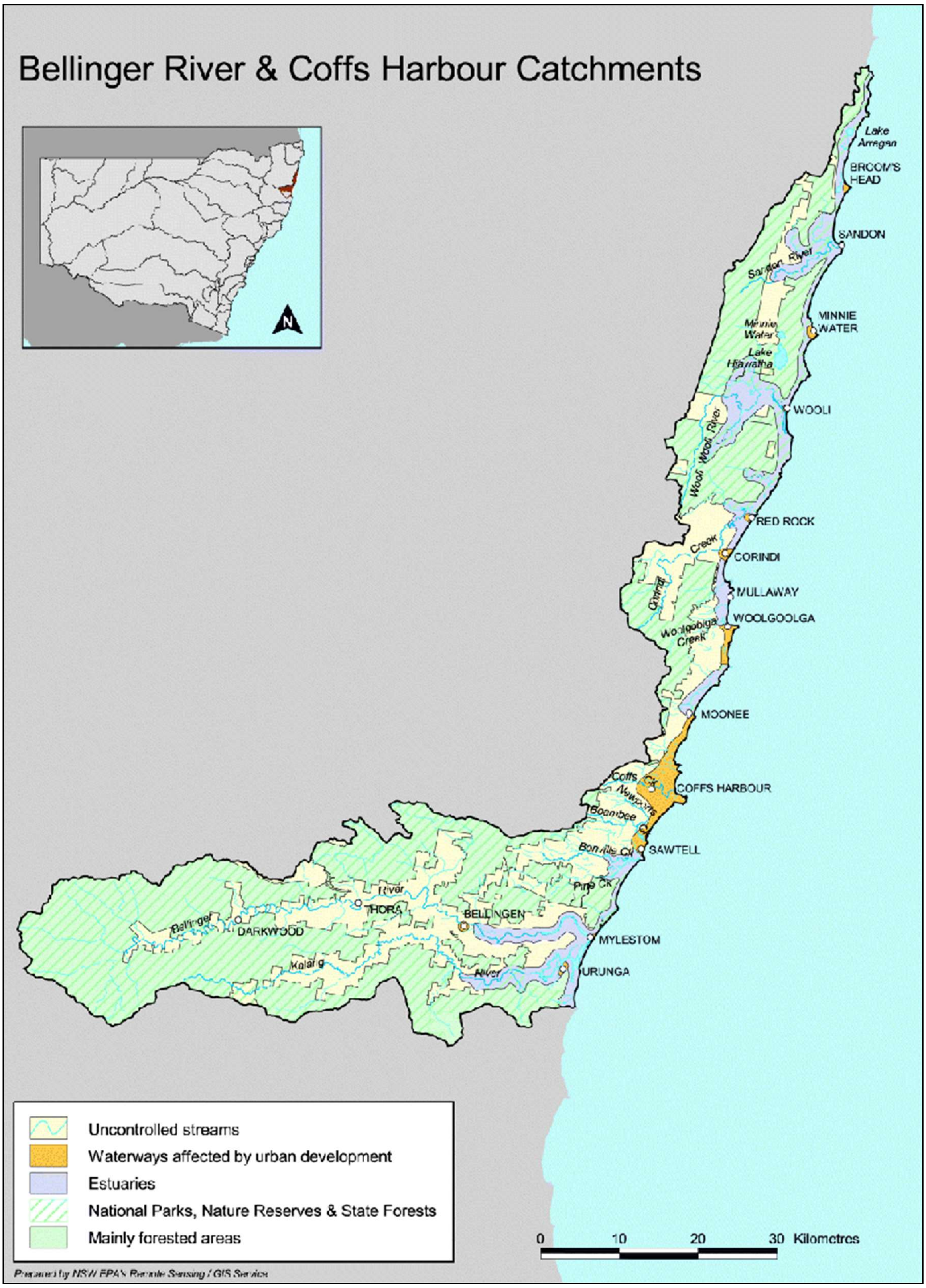


Figure 3-6: Bellinger River and Coffs Harbour Catchments (Source: NSW Water Quality and River Flow Objectives, NSW DPE)

Table 3-2 Water Quality Objectives for the Bellinger-Kalang Catchment

Regions	Water Quality Objectives. The protection of:
Mainly forested areas	Aquatic ecosystems Visual Amenity Secondary contact recreation Primary contact recreation Drinking water at point of supply-disinfection only Drinking water at point of supply-Clarification and disinfection Aquatic foods (cooked)
Waterways affected by urban development	Aquatic ecosystems Visual Amenity Secondary contact recreation Primary contact recreation
Uncontrolled streams	Aquatic ecosystems Visual Amenity Secondary contact recreation Primary contact recreation Livestock water supply Irrigation water supply Homestead water supply Drinking water at point of supply-disinfection only Drinking water at point of supply-Clarification and disinfection Drinking water at point of supply-Groundwater Aquatic foods (cooked)
Estuaries	Aquatic ecosystems Visual Amenity Secondary contact recreation Primary contact recreation Aquatic foods (cooked)

3.3 Water Quality Indicators and Guidelines

Combining the results of the survey with the known agricultural uses, the key values for the catchment are considered to be:

1. As a place for recreational swimming
2. As habitat for plants and animals
3. As an important region for agriculture and aquaculture.

Ongoing water quality monitoring should be reviewed against recreation, agriculture/aquaculture, and environmental thresholds.

- Recreation: Remain within the ANZECC (2020) guidelines for recreation and aesthetics
- Agriculture and aquaculture: Remain within the ANZECC (2020) guidelines for primary industries, aquaculture, and harvesting of aquatic foods, and any thresholds within the Australian Shellfish Quality Assurance Programme.
- Environmental: Remain within the new DPE Bellingen-Kalang Catchment water quality guideline values (including the new estuarine values which are in preparation) and the ANZECC (2020) guidelines for aquatic ecosystems.

4 Catchment Management Actions

4.1 Introduction

This section details a range of catchment management actions that can be implemented throughout the Bellinger-Kalang Catchment to improve water quality. These recommendations have been developed with the following goals:

- To improve poor water quality and control faecal coliforms.
- To improve the standard of water quality monitoring, and data collection and integration.
- To increase biodiversity and ecosystem services.
- To mitigate erosion and improve bank stability.

4.2 Framework

The Bellinger-Kalang Catchment is subject to a range of threats to water quality, erosion, and riparian biodiversity. The degree of risk experienced throughout the catchment varies, which requires an adaptable management response. A tailored framework has been developed using a risk-based framework that determines the most appropriate levels of consequence and likelihood following The Marine Estate Management Authority (MEMA) Threat and Risk Assessment (TARA) Framework for the NSW Marine Estate[24]. The risks to water quality have been identified from reviewing literature and community consultation within the catchment and has been scored from the ratings of consequence (levels of impact) and the likelihood (levels of probability) and grouped into four ratings (minimal, low, moderate, and high).

4.3 A snapshot of issues

Threats to water quality in the Bellinger-Kalang Catchment have been identified in the reviewed literature, through extensive community consultation, and in the NSW Marine Estate Threat and Risk Assessment Report[25]. Their risks have been calculated using the MEMA TARA framework as shown in Table 4-3. Additional threats have been added relating to unmonitored water quality and catchment clearing to including risks associated with unknown water quality and clearing works for forestry and agriculture.

A map of water quality issues has been developed using the water quality analysis, Council reports, and new field investigations. These are shown in Figure 4-1, with proposed management actions shown in Figure 4-2 which are described in the following sections.

24 Marine Estate Management Authority (MEMA) (2015), Threat and Risk Assessment (TARA) Framework for the NSW Marine Estate

25 NSW Marine Estate Management Authority (MEMA) (2017), New South Wales Marine Estate Threat and Risk Assessment Report - Final Report.

Table 4-1 Risk Assessment Matrix

Likelihood	Level of Risk				
Almost certain	Minimal	Low	Moderate	High	High
Likely	Minimal	Low	Moderate	High	High
Possible	Minimal	Minimal	Low	Moderate	High
Unlikely	Minimal	Minimal	Minimal	Low	Moderate
Rare	Minimal	Minimal	Minimal	Minimal	Low
Consequence Level	Insignificant	Minor	Moderate	Major	Catastrophic

Table 4-2 Risk Tolerance Table

Risk Levels	Description	Likely Management Action
Minimal	Risk currently acceptable but trend in the risk to be tracked over time.	Existing control measures (if any) are suitable. Monitoring of risk likelihood and consequence over time to identify if risk is increasing, decreasing, or staying the same.
Low	Risk likely to be acceptable but trend to be tracked over time.	Existing control measures (if any) are suitable. Monitoring of risk likelihood and consequence over time to identify if risk is increasing, decreasing, or staying the same.
Moderate	Risk may be acceptable with suitable risk control measures in place.	Review of existing management controls or activities for the risk. Increased or different management controls or activities may be needed.
High	Risk less likely to be acceptable. Additional risk control measures may need to be considered.	Review of existing management controls or activities for the risk. Increased or different management controls or activities are likely to be needed.

Table 4-3 Threats and risks to water quality in the Bellinger-Kalang Catchment.

Threat	Consequence	Likelihood	Risk
Clearing riparian and adjacent habitat	Major	Likely	High
Catchment clearing including forestry	Major	Likely	High
Agricultural diffuse source runoff	Major	Almost certain	High
Urban stormwater discharge	Major	Almost certain	High
Modified freshwater flows	Major	Almost certain	High
Stock grazing of riparian and aquatic vegetation	Major	Likely	High
Recreation and tourism	Moderate	Likely	Moderate
Riparian development	Moderate	Almost certain	Moderate
Sewage effluent and septic runoff	Moderate	Almost certain	Moderate
Climate and sea temperature rise (20 years)	Moderate	Likely	Moderate
Unmonitored water quality	Major	Possible	Moderate
Commercial aquaculture	Minor	Likely	Low
Recreational fishing	Minor	Likely	Low
Passive recreational use	Minor	Likely	Low
Invasive species	Minor	Likely	Low

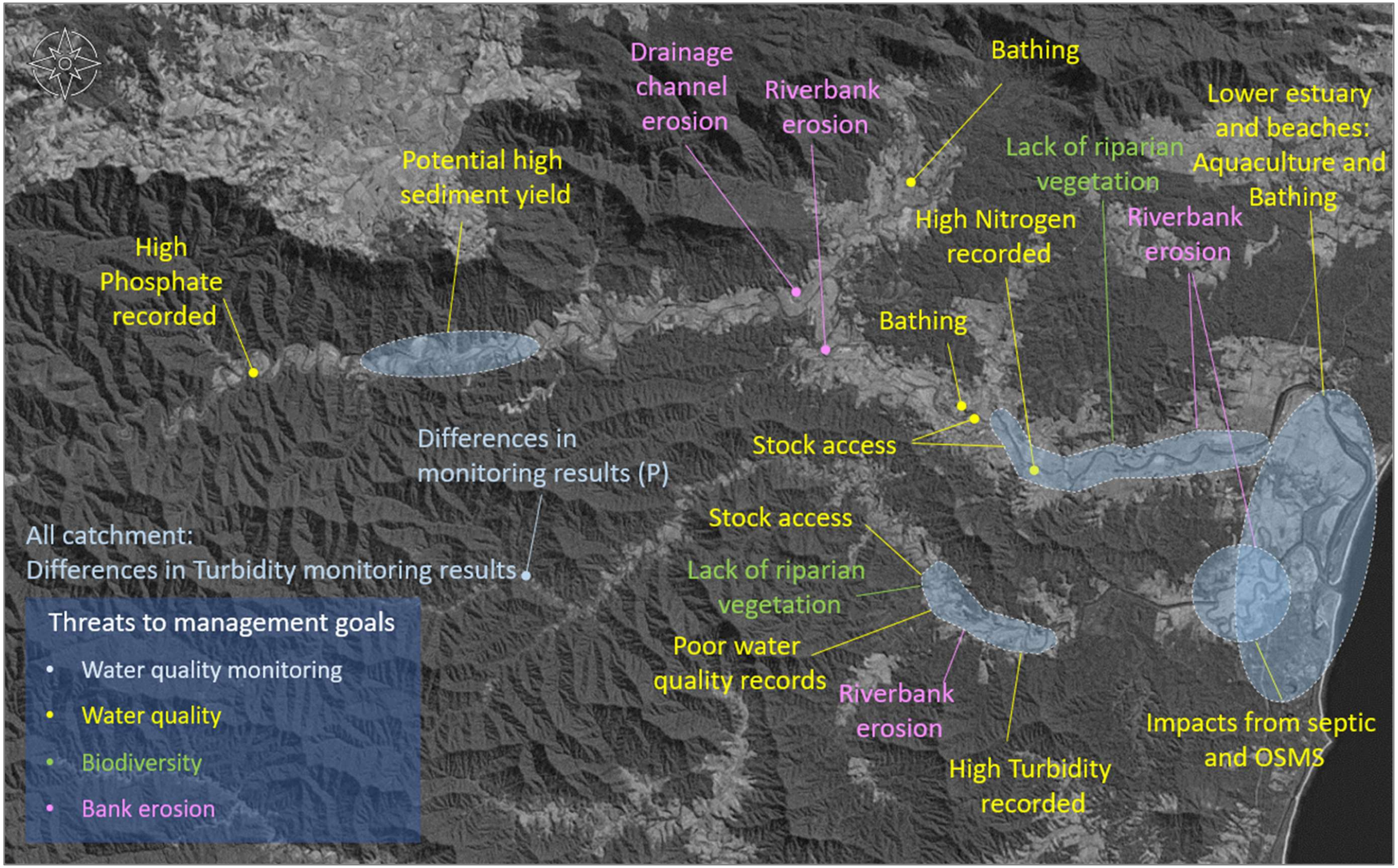


Figure 4-1: Catchment snapshot of issues.

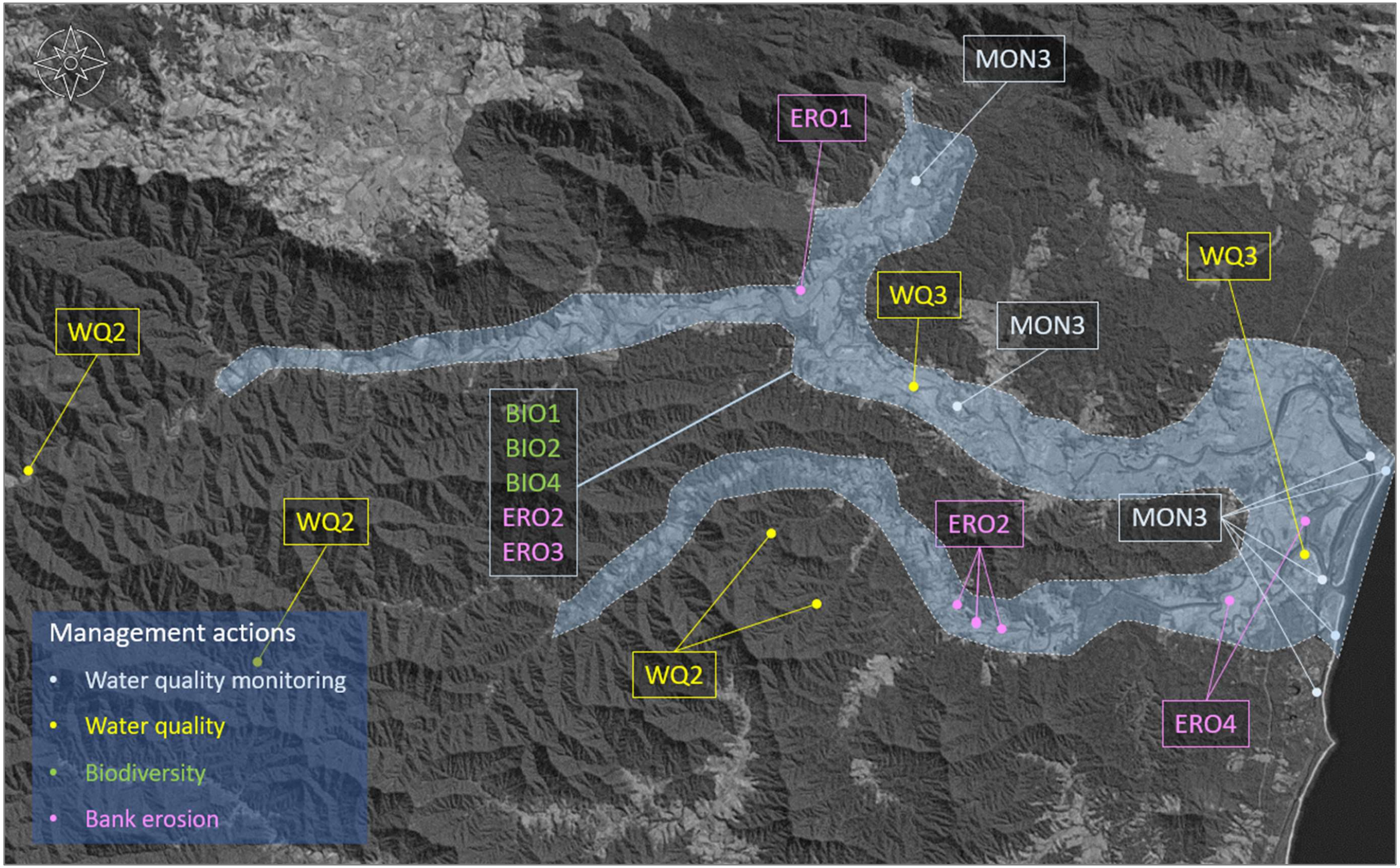


Figure 4-2. Map of management action sites

4.4 Review of Previous Plans

A review of previous plans and literature within the Bellinger-Kalang Catchment are available in Appendix 4.7.2. An additional description of management actions proposed by the following management plans are outlined in this section:

- Bellingen Shire Biodiversity Strategy (Eco Logical Australia, 2019)
- Bellinger and Kalang River Estuaries Erosion Study (Telfer and Cohen, 2010)
- Bellingen and Urunga Stormwater Management Plan (BMT, 2011)
- Bellinger and Kalang Rivers Estuary Action Plan (BSC, 2010)
- Bellingen Coastal Zone Management Plan (BMT, 2017)

4.4.1 Bellingen Shire Biodiversity Strategy (Eco Logical Australia, 2019)

This strategy aims to ensure ecosystem health and species richness within the Bellingen Shire for the purposes of prolonging ecosystem services for the community. It provides a framework and strategic plans that focus on habitat maintenance, preservation, and expansion, along with erosion, sedimentation, and pollution of aquatic habitats.

This report graded river water condition and found that extreme rainfall and flood events caused river and estuary health issues including poor water quality due to the high nutrient and sediment runoff. The overall health of the river systems is on a declining trend. The threatened and migratory species map of Bellingen LGA suggests that the threatened and endangered species are more condensed towards the coast.

The report recommends improving agricultural practices, riparian and wetland management, on-site sewage management systems, boating, tourism and recreational impacts, stormwater, rural roads and bridges, forestry, logging and clearing, oil, diesel and waste spills, wastewater treatment plants, and water quality monitoring. The management actions recommended by the Bellingen Shire Biodiversity Strategy for the improvement of waterways are outlined in Table 4-4.

Table 4-4 The Bellingen Shire Biodiversity Strategy (2020) action plan for waterways.

Name	Actions	Priority	Status
1. Measurable improvement in water quality across Bellinger-Kalang waterways.	- Continue water quality monitoring programmes. Include metals, microbiological and physiochemical parameters. - Reduce sediment inputs through bank stabilisation revegetation works. - Minimise impacts of boating and recreation on seagrass through 'no wash zones, buoy markers, education, and other controls. - Manage public access at environmentally sensitive foreshore locations. Priority areas may include key habitat and vegetation communities located in areas that are frequented by the public and require detailed design to achieve biodiversity protection - Reduce the unauthorised clearing of riparian and estuarine vegetation, impacts of agricultural runoff and use of unsuitable materials for bank stabilisation - Work with agencies and corporations, private landholders and Landcare groups to encourage and assist in the revegetation of riparian areas, and the protection, management and conservation of existing riparian vegetation and catchment headwaters. As a priority, target landholders with ecologically significant vegetation present on their land.	High	- Continued financial and in-kind support for Bellingen Riverwatch funded from Environmental Levy. - Completion of Restoring Reserves of the Never Never riparian restoration at Earl Preston reserve. - Support for Bellingen Urban Landcare for multiple riparian sites at O'Connell Park, Bellingen Park, The Point, Ringwood reserve through ELCF. - Work with LLS and Bellinger Landcare on riparian restoration project at Darkwood on Council reserve.
2. Protect foreshores, coastal lagoons, significant wetlands and coastal saltmarsh	- Validate and update mapping of all coastal, foreshore and wetland TECs and develop a management plan to control/remove any relevant threatening processes. - Identify opportunities for Council planning controls/ plans of management to provide greater provision for protection of wetlands, mangroves, saltmarsh, seagrasses and migratory and wader bird habitat (e.g. inclusion of core habitats, wetlands, priority areas and validated mapped HEVs as W2, E2, E3, E4 or Natural Resources Sensitivity in the LEP, and update clauses, maps or overlays within LEP and DCP) - Prepare a Council policy to conserve mangroves, mudflats, seagrass, coastal lagoons and shorebird habitat. - Identify site specific threats and implement appropriate management options in accordance with the Bellinger and Kalang Rivers Estuary Management Plan and the Bellingen Coastal Zone Management Plan - Participate in the preparation, implementation and review of Estuary and Coastal Management Plans and the NSW Marine Estate Management Strategy - Ensure that foreshore infrastructure masterplans and implementation protect wetlands, lagoons, saltmarsh, mangroves, seagrasses, and migratory bird habitat - Ensure that public and private projects protect foreshore vegetation, mudflats, and where rock revetment/ seawalls are required ensure they are designed as being biodiversity friendly.	High	Coastal, foreshore and wetland TEC's mapped and validated for council managed land
3. Restore the ecological function of high priority waterways and	- Protect and restore Council managed land where Key Fish Habitat mapped by NSW DPI Fisheries https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0003/634269/Bellingen.pdf - Prioritise and protect areas of intertidal saltmarsh, lagoons, coastal foreshore and mangrove to	High	Nil

wetlands	provide habitat for migratory waders - Identify opportunities for Council planning controls to provide greater provision for improving water quality and habitat value of waterways through reviewing planning controls/ clauses, maps or overlays within LEP and DCP - Retain and enhance in-stream woody debris and other riparian and aquatic habitat features (hollows, understorey) - Conduct regular targeted field surveys of threatened migratory bird species feeding and roosting sites - Restoration works to enhance aquatic habitat (e.g. feeding sites, and native fish habitats) on waterways / corridors - Educate internal stakeholders on the importance of coastal and estuarine wetlands and habitats - Consider use of constructed wetlands for new development growth areas to improve water quality and expand habitat diversity and foraging opportunities using native plants for biofiltration systems and raingardens - Continue river rehabilitation projects - Promote off leash dog beaches to draw this recreation activity away and protect sensitive (feeding and nesting) areas for migratory waders - Protect nesting, roosting, feeding sites from fox predation.		
4. Develop education workshops, programs and to engage schools, community groups and residents to establish a sense of ownership and participation and restoring the biodiversity along rivers and coastal foreshores.	- Target management of threats on coast, wetlands and lagoons e.g. continue and expand project to educate dog owners about protection of Beach Stone-curlew and nests at Urunga Reserve - 'A Dog's Breakfast' through 'Our Living Coast' and include other migratory species and foreshore habitats where there are similar issues - Consider creation of community education/ signage about mangrove and salt marsh protection/conservation - Educate the community on issues about protection of biodiversity, habitat and water quality and the impacts along river and coastal foreshores, including understanding of controlled activities on waterfront land and riparian corridors.	High	Thoughtful disposal of fishing debris bin sticker project with WIRES.

4.4.2 Bellinger and Kalang Estuaries Erosion Study (Telfer and Cohen, 2010)

This study has assessed the geomorphology and bank erosion of the Bellinger and Kalang Estuaries. A list of recommendations proposed within this study include:

- Protect existing infrastructure
- Protect important conservation values
- Protect existing works
- Utilise best practice erosion control techniques
- Improve riparian vegetation
- Manage recreational boat use

Site location specific recommendation are listed in Table 4-5 and erosion surveys have been categorised into three main priority groups:

- a) Highest Priority: The sites that threaten existing community infrastructure or property, or high value ecological systems including riparian and remnant vegetation
- b) High Priority: The sites where bank protection measures have already been implemented but where flooding or other identified factors are threatening the works and future stability of the banks
- c) Moderate Priority: The sites where erosion is considered to be serious but where significant and ongoing commitment is required by both landholders and responsible government agencies and funding bodies. Many moderate priority sites have very poor riparian vegetation and ongoing disturbance factors such as wind or boat wave wash or impacts from unmanaged stock access

Table 4-5: Problems or remediation areas identified within Bellinger and Kalang River Estuaries Erosion Study

Name	Description	Status
Site 10 (Highest priority)	260m of erosion adjacent to Yellow Rock Road. Wave wash causing undermining and subsequent bank collapse.	Some minor works undertaken (rock fillets)
Site 12/27 (Highest priority)	Ongoing disturbances associated with wave wash (primarily wind generated) and unmanaged stock access	Nil
Site 16 (Highest priority)	The deep water profile limits potential bank stabilisation methods. Further site investigation is recommended to determine appropriate methods of stabilisation and approximate costs	Nil
Site 21 (Highest priority)	The deep water profile limits potential bank stabilisation methods. Further site investigation is recommended to determine appropriate methods of stabilisation and approximate costs	Nil
Site 26 (Highest priority)	Erosion on the left bank (Pacific Highway side) upstream of the Newry Island bridge may threaten upstream eastern bridge abutment if not treated	Nil
Site 2 (High)	Flood damage to existing bank protection measures threatens the loss of a small alluvial flat	Nil
Site 5 (High)	Flood damage to existing protection works adjacent to the Bellingen Golf Club. The majority of works have survived the 2009 floods well, however, revegetation and weed control and some repair of mesh fencing on the site may assist in reducing scour at the site and on the adjacent golf course	Nil
Site 17 (High)	Flood damage to an existing riparian revegetation project should receive priority assistance to ensure the success of the works. Landholder commitment has already been demonstrated	Nil
Site 23 (High)	Works here should aim to stabilise the banks using best practice techniques, although the deep water profile adjacent to the site will complicate and increase the costs of construction. Remove of disturbance factors such as unmanaged stock access and wave wash	Nil

	(primarily from boats in this location) will also be important factors in long-term stability	
Site 1 (Moderate)	All adjacent sites listed here as Moderate Priority are in agricultural landscapes and would require a significant commitment from landholders, responsible government agencies, and funding bodies to actively remediate. All sites except Site 9 (which had fencing on the top bank) are subject to stock impacts with sites 7 and 11 also affected by wave wash	Nil
Site 3 (Moderate)		Nil
Site 4 (Moderate)		Nil
Site 6 (Moderate)		Nil
Site 7 (Moderate)		Nil
Site 8 (Moderate)		Nil
Site 9 (Moderate)		Nil
Site 11 (Moderate)		Nil
Site 13 (Moderate)	All adjacent sites listed here as Moderate Priority are in agricultural landscapes and would require a significant commitment from landholders, responsible government agencies, and funding bodies to actively remediate. All sites except Site 20 are subject to stock impacts with sites 22, 23, 24 and 25 also affected by wave wash. Sites 24 and 25 may be suitable for rock embayment construction due to their relatively shallow water profiles and proximity to the lower estuary and therefore mangrove seed sources	Nil
Site 14 (Moderate)		Nil
Site 15 (Moderate)		Nil
Site 18 (Moderate)		Nil
Site 19 (Moderate)		Nil
Site 20 (Moderate)		Nil
Site 22 (Moderate)		Bank restoration in 2017, and 2018/19.
Site 24 (Moderate)		Bank restoration in 2017, and 2018/19
Site 25 (Moderate)		Nil
Site 28 (Moderate)	This site covers two separate remnant vegetation communities which occur on outside bends in the lower Kalang estuary opposite Newry Island. The condition of the remnants has not been established and erosion is not currently occurring adjacent to the remnants. Further assessment and monitoring is recommended	Nil

4.4.3 Bellingen and Urunga Stormwater Management Plan (BMT, 2011)

Management actions for urban stormwater discharge have been proposed in the (Draft) Bellingen and Urunga Stormwater Management Plans (BMT 2011), which was not adopted by Council. Many of the recommendations are outdated and a more holistic approach to Water Sensitive Urban Design would be warranted in urban areas. It is therefore recommended that the draft Stormwater Management Plan be updated and adopted by Council.

During the plan update, the following priority actions should be reviewed, which include retrofitting stormwater quality controls, Stormwater Quality Improvement Devices (SQIDs) and Gross Pollutant Traps (GPTs).

4. Bio-retention basin along Tamarind Drive, North Bellingen including the maintenance of the adjacent existing sediment/detention basins.
5. Swales along James Eather Way and Dowle Street, North Bellingen.
6. Bio-retention basins and swales adjacent to existing sediment/detention basins along Mccristal Dr, North Bellingen.
7. Bio-retention basins between 22 and 26 Dowle Street, and on the east side of number 2 River Place, in North Bellingen. Status: This action has been completed.
8. Bio-retention basins with diversion pipes along Connell Creek, South Bellingen.
9. Bio-retention basin with diversion pipe along Park Street, and towards Connell Park.

The advocation and implementation of a Stormwater Levy was proposed within the (Draft) Bellingen and Urunga Stormwater Management Plans (BMT 2011) to assist in funding recommended actions. The Local Government Act 1993 was amended in 2005 to allow Councils to levy a stormwater management service charge (SMSC) for improved stormwater management. The annual SMSC is currently capped at $25 for a residential dwelling with an area-based pro-rata cap applying to commercial properties. If adopted, it would provide Council with an additional funding stream of ~$100,000 per year to tackle river health and water issues that could be further leveraged through a range of state and federal funding program sources including the NSW coastal and estuary grant, and NSW environmental trust grants.

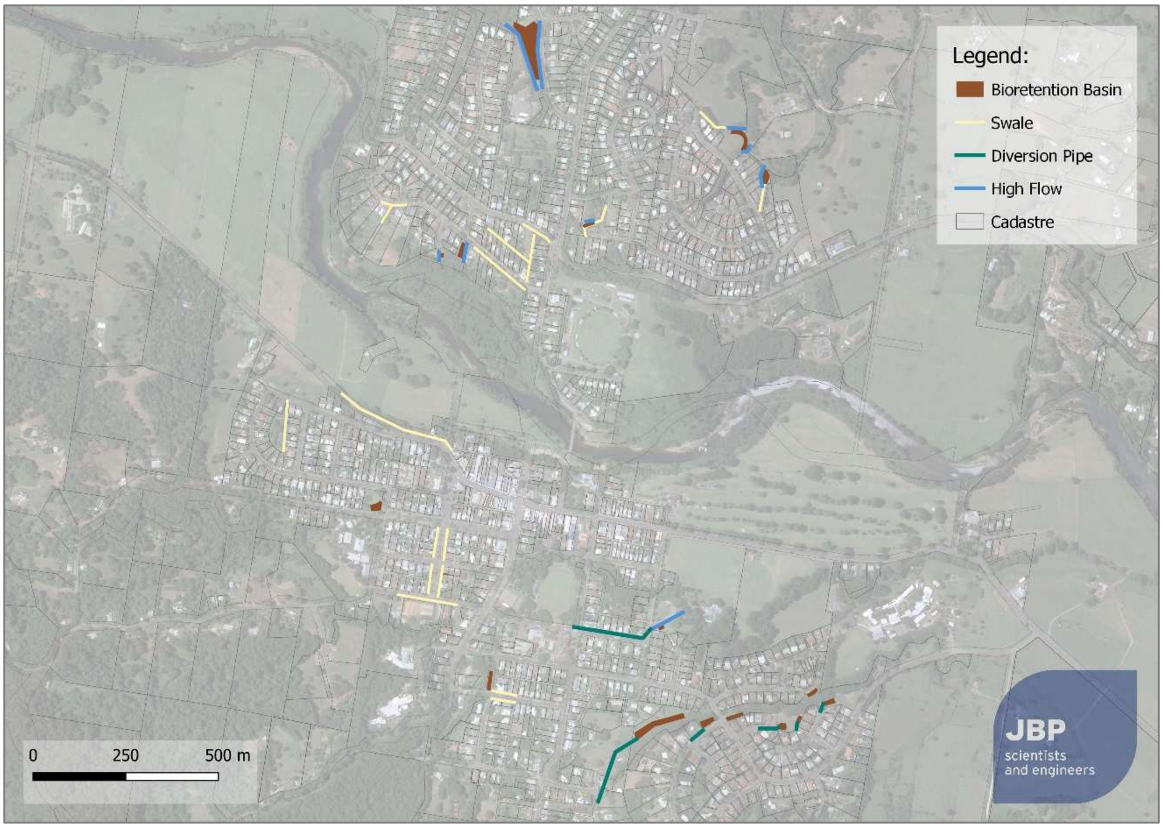


Figure 4-3. Potential sites for SQIDs in Bellingen outlined in the Bellingen and Urunga Stormwater Management Plans (BMT 2011).

Figure 4-4. Potential sites for SQIDs in Urunga outlines in the Bellingen and Urunga Stormwater Management Plans (BMT 2011).

4.4.4 Bellinger River Estuary Action Plan (BSC, 2010)

This action plan was prepared by BSC to identify key threats to the Bellinger River Estuary and make recommendations towards management actions. A baseline condition assessment of vegetation cover, weed infestation, erosion, stock access, riparian regrowth, riparian width, and riparian suitability. Table 4-6 outlines key management actions for the Bellinger River Estuary.

Table 4-6: Management actions recommended by the Bellinger River Estuary Action Plan

Action	Site
Riparian restoration: - Revegetation - Weed control - Tree removal - Structural works - Stock fencing - Maintenance	Lot 7001 Ford St, Bellingen
	Lot 3, Hammond Street, Bellingen
	Lot 42, 100 Wheatley St, Bellingen
	Lot 20, 1172 Waterfall Way, Bellingen
	Lot 1, North Bank Road, Bellingen
	Lot 7, 105 North Bank Road, Bellingen
	Lot 1, 17 Doepel Street, Bellingen
	Lot 1, Cahill Street & 1060 Waterfall Way, Bellingen
	Lot 21, 224 North Bank Rd, Bellingen
	Lot 1, 236 North Bank Rd, Bellingen
	Lot 2, 278 North Bank Road, Bellingen
	Lot A, 850 Waterfall Way, Fernmount
	Lot 1, 838 Waterfall Way, Fernmount
	Lot 12, 794 Waterfall Way, Fernmount
	Lot 212, 700 & 754 North Bank Road, Raleigh
	Lot 112, 534 Waterfall Way, Fernmount
	Lot 400, 516 Waterfall Way, Fernmount
	Lot 401, 461 Waterfall Way, Fernmount
	Lot 3, 935 North Bank Road, Raleigh
	Lot PTA, 383 Waterfall Way, Fernmount
	Lot 10, 182 Waterfall Way & 1018 North Bank Road, Raleigh
	Lot 32, 160 Waterfall Way, Raleigh
	Lot 1, 124 Waterfall Way, Raleigh
	Lot 2, 100 Waterfall Way, Raleigh
	Lot 4, 62 Waterfall Way, Raleigh
	Lot 16, 44 Waterfall Way, Raleigh

4.4.5 Bellingen Coastal Zone Management Plan (CZMP) (BMT WBM, 2017)

This management plan was prepared to preserve and protect the environmental, recreational, cultural, and economic values along the open coast of the Bellinger Shire. It provides practical actions for managing coastal hazards. Prioritised management actions proposed in the Bellingen Coastal Zone Management Plan (2017) are outlined in Table 4-7.

Table 4-7: Overview of priority coastal zone management actions from the Bellingen Coastal Zone Management Plan (2017)

Name	Action	Priority	Status
Asset Management	Update Council's Asset Management Plan with coastal hazard information, to ensure cost effective and appropriate asset management in coastal zone	High	Nil
	Provide hazard mapping to Australian Rail Track Corporation	High	Nil
Beach Access & Use Management	Ensure safe beach access is maintained, which may require accesses to be re-contoured following storm activity	High	- Hungry Head completed 2021. - North Beach to start 2022.
Dune and Habitat Management	Continue, improve, and extend dune rehabilitation and weed removal efforts	High	- Hungry Head works 2021 North Beach works 2022
	Manage sea level rise threat to high value natural habitats, including estuarine habitats	High	Nil
Further Studies Including Precinct Planning	Conduct geotechnical investigation to improve hazard definition at Hungry Head and Wenonah Head, as both areas have high value community assets located adjacent to (and potentially on) bedrock	High	Nil
	Conduct precinct planning for Hungry Head and Wenonah Head, following outcomes of the geotechnical investigation(s)	High	Nil
	Undertake an estuary foreshore erosion study at Mylestom Spit, to address long term risks associated with combined estuary and beach recession hazards	High	Nil
Monitoring	Conduct regular topographic beach surveys at targeted locations	High	Nil
	Collect LiDAR topographic data across all beach and estuary foreshore locations	High	Nil
	Monitor beach access conditions, particularly after storms	High	Nil
Planning and Development Controls	Prepare internal checklist, guideline or policy to guide Council officers to consider hazard zones and timeframes when building structures / facilities in the coastal zone (for which Council is the consent authority, REF required only).	High	Nil
	Conduct internal training to ensure that coastal zone management is properly integrated into Council's operations	High	Nil
	Incorporate coastal inundation into Council's Floodplain Risk Management Plan	High	Nil

4.5 Water Quality Monitoring Strategy

Water quality monitoring has been undertaken be a range of organisations throughout the catchment, as reviewed in in Section 2.2. The ongoing strategy for water quality monitoring aims to optimise the current program and propose new recommendations.

While past monitoring has been extensive, it has been undertaken through different organisations, and is inconsistent in timing, locations, and parameters. This limits the ability to compare results and poses a risk for future analysis. Most detailed monitoring programmes have been over restricted timeframes, making the Riverwatch volunteer program unique in its provision of near continuous data. This offers a valuable dataset to review water quality against established criteria. With some minor adjustments to this programme, a more consistent, wholistic, and accurate depiction of the catchments water quality can be achieved. The following recommendations are made following the data reviewed from Council, stakeholders, and the public through consultation. A complete set of new monitoring locations are shown in Figure 4-5.

Water Quality Monitoring Strategy recommendations:

1. Increase monitoring sites to include identified swimming and primary recreational locations.
    a. Relocate site NN1 to the Promised Land Swimming location approximately 1km downstream or adopt a new sample site here called NN1.4. This site is particularly important for swimming guideline values due to the hiking track containing several water holes.
2. Increase estuarine monitoring sites to provide data for the whole catchment by adopting previous Ecohealth estuary monitoring sites.
    a. Add new estuary sites at K4, K5, K6, K7, K8, B7.2, B7.3, and B9.
3. Adjust current sites for improved efficiency and optimisation:
    a. Remove site K4 due to its close proximity to SC1.
    b. Remove site K1.4 due to its close proximity to K1.
    c. Relocate site K3 to 100m downstream to cover Woods Creek.
    d. Remove site B2.1 due to its close proximity to B2.
    e. Relocate site B5.1 downstream of the Dairy Farm on Merricks Creek.
4. Acquire additional funding to include metal and microbial parameters as recommended by the Bellingen Shire Biodiversity Strategy (2020), SARDI (2016), and WWTP reports.
    a. This could be achieved by sending collected samples to Coffs Harbour Laboratory for metal and microbial analysis.
    b. Collaborate with oyster harvesters for microbial monitoring data.
    c. Alternatively, Join the NSW DPE Beach Watch programme. This would reduce pressure on the Riverwatch programme by monitoring bacteria and faecal pollution in the upstream swimming locations and along the coast at Hungry Head Beach, and North Beach.
5. Acquire funding to continue the Support Vols Programme. The 'Support Vols Programme' provides the volunteers in the Riverwatch programme with monthly visitors to offer training, observe techniques, and to calibrate water quality monitoring probes. They may also compare volunteer results with their own to verify accuracy.
6. Update Riverwatch techniques and equipment. This should include new testing approaches for Turbidity and Phosphorus.
7. Install a permanent water quality station in the catchment. This would require a mounted station with several water quality sensors and a remote terminal unit to collect data and apply to Councils public water quality website. This permanent station would collect high-frequency data on the natural variability within the system, provide a baseline dataset that can be used for training and validation, and provide consistent and precise monitoring of pH, EC, nutrients, turbidity, temperature, etc.

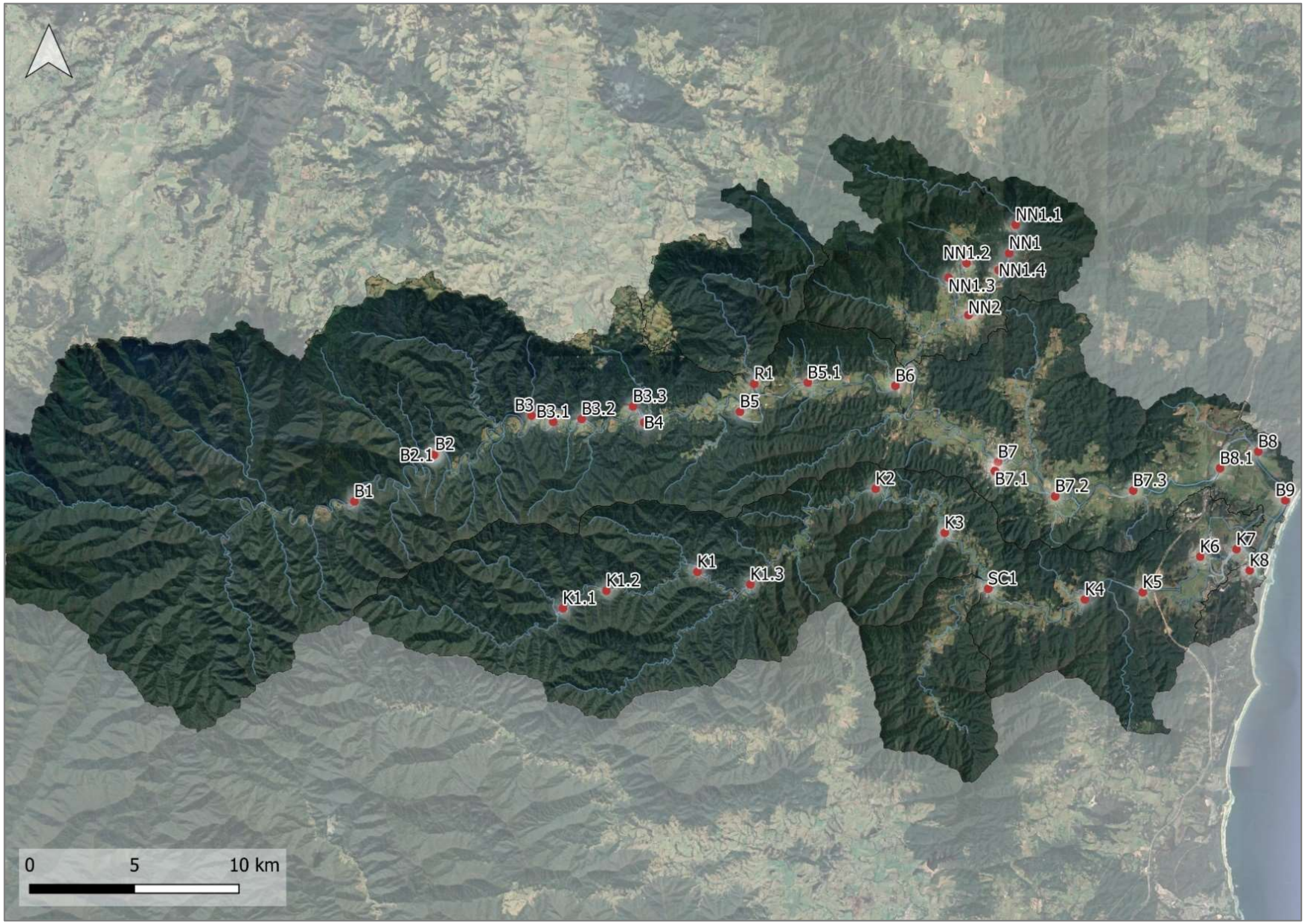


Figure 4-5. Existing and proposed new monitoring sites for the Riverwatch Programme

Upon the implementation of the above recommendations, future water quality monitoring in the Bellinger-Kalang Catchment would consist of:

- 35 monitoring sites for monthly data collection by the Riverwatch Programme of DO, EC, Phosphate, Turbidity, pH, and Temperature.
- Recruiting new Riverwatch volunteers for the additional estuarine sites.
- Updating the Riverwatch website to reflect the new changes.
- Training the Riverwatch volunteers to use new instrumentation and techniques by the 'Support Vols Programme'.
- Collecting, preparing, and shipping samples of water at each site seasonally to the Coffs Harbour Laboratory for metal and microbial pollutants by the Riverwatch volunteers during regular monitoring regime.
    - These samples could be increased or reduced according to initial results and necessity.
    - The alternative solution to this is to join Beachwatch for the collection of bacterial and microbial pollution.
- Assessing Riverwatch Programme water quality results against results obtained from the permanent monitoring station.
- Maintaining the permanent water quality monitoring station which could also be tasked to the Riverwatch Programme.
- Updating and maintaining the Council water quality website to receive daily permanent water quality station data, and to display Riverwatch, Coffs Harbour Laboratory and/or Beachwatch data, and oyster harvesting microbial monitoring data to the public.

Future monitoring efforts could be financially sustained through grants and funding available from the NSW Environmental Trust programs including:

- Environmental education: Supports projects that develop knowledge, skills, commitment to, and ongoing participation in protecting the environment.
- Protecting our places: Funds protection and rehabilitation for culturally important land and water.

4.6 Catchment Management Options

New management actions have been proposed under four broad goals. These are designed to enhance the existing catchment actions contained within the adopted management plans reviewed in Section 4.4

Goal 1: Improve poor water quality and control faecal coliforms

- WQ1: Continue and expand the Sewering Coastal Villages programme
- WQ2: Unsealed road management and buffers
- WQ3: Update Stormwater Management Plans and implementation of previous recommendations
- WQ4: Introduce a stormwater levy

Goal 2: Continue a high standard of water quality monitoring and data collection

- MON1: Continued support for the Riverwatch programme
- MON2: Permanent water quality monitoring station
- MON3: Join Beach Watch
- MON4: Expand public water quality website
- MON5: Investigate the need for metal monitoring

Goal 3: Increase biodiversity and ecosystem services

- BIO1: Managing grazing/stock exclusion on riparian land.
- BIO2: Reinstatement and reforestation of riparian buffers
- BIO3: Refresh the Bellinger Landcare Manual
- BIO4: Protect and restore areas of intertidal saltmarsh, lagoons, and mangroves on Council managed land

Goal 4: Mitigate erosion and improve bank stability

- ERO1: Site-specific erosion investigations
- ERO2: Advocate and educate for private land restoration and erosion protection works
- ERO3: Bank stabilisation and revegetation works on Council managed land
- ERO4: Minimise impacts of boating.

4.6.1 Goal 1: Improve poor water quality and control faecal coliforms

The Bellinger-Kalang system has shown varying water quality results. Whilst areas like the Never Never River are renowned for their pristine water, long-term monitoring shows high turbidity loads, low pH and low Dissolved Oxygen levels can be experienced at most catchment locations, particularly in the Kalang River and lower reaches of the Bellinger River. Previous monitoring campaigns show faecal coliform levels can exceed recreational and harvesting thresholds, potentially impacting waterway use and aquaculture. Increased nutrient loads can lead to excessive plant growth in receiving waters, whilst increased sediment loads (indicated by high turbidity values) have the potential to reduce photosynthesis and smother aquatic plants and animals. Generally, water pollutants are derived from either diffuse or point sources. Diffuse sources include catchment runoff from agricultural, residential, and rural lands, with much of the diffuse pollutant loads delivered to creeks and stormwater systems. Point sources generally refer to concentrated or singular points where significant loads of pollutants are delivered to the waterway (i.e., sediment loads from specific erosion sites or faecal loads from septics).	**Actions:** - WQ1 - WQ2 - WQ3 - WQ4

Figure 4-6. Oyster beds in the lower estuary - critical receptors for poor water quality

Four management actions have been proposed to improve poor water quality and control faecal coliforms in the Bellinger-Kalang Catchment:

- WQ1: Continue and expand the Sewering Coastal Villages programme
- WQ2: Unsealed road management and buffers
- WQ3: Update Stormwater Management Plans and implementation of previous recommendations
- WQ4: Introduce a stormwater levy

4.6.1.1 Sewering Coastal Villages Project (WQ1)

This large-scale project involves the connection of coastal villages in the lower estuary to a reticulated sewerage system. This would reduce the likelihood of local sewage overflows into the estuary, reducing faecal contamination and wastewater pollution which aligns with the Bellingen Shire Biodiversity Strategy (2020) for the measurable improvements in water quality across Bellinger-Kalang waterways, protect foreshores, coastal lagoons, significant wetlands, and coastal saltmarsh, and restore the ecological function of high priority waterways and wetlands. This action also reduces the moderate-risk threat of sewage effluent and septic runoff.

This project has bene designed and costed in collaboration between the BSC and the NSW Government and has received partial funding to improve wastewater treatment and infrastructure, including an upgrade of the Urunga Sewerage Treatment Plant and new pump stations. Continued funding should be investigated to allow the full scheme to be completed, which would connect 20.5 km of sewer mains to approximately 234 residential lots, commercial properties, and up to 100 industrial lots in Raleigh, and connect schools, farms and community infrastructure to the sewerage mains throughout Mylestom, Repton and Raleigh.

Further expansion could consider additional locations in Urunga where many private residences on Newry Island are reported to contain medium to very high-risk domestic on-site wastewater management systems that are likely to contribute contaminated surface or groundwater to the Kalang River[26].

4.6.1.2 Unsealed road and buffer management (WQ2)

BSC undertakes continuous road repairs and sealing activities throughout its LGA, supported by programmes such as the NSW Fixing Local Roads Programme. Recent estimates indicate Council has approximately 400km of sealed roads and 200km of unsealed roads remaining in the catchment.

The continuation of road sealing for any dirt road adjacent to a waterway will reduce sediment, runoff, and pollutants from discharging directly into Bellingen waterways. Actions could initially include the establishment of buffer strip vegetation adjacent to the road, restoration of riparian vegetation along adjacent banks, with road sealing then undertaken for high use unsealed roads. This action will reduce the amount of sediment runoff in urban stormwater discharge, a high-risk threat to water quality in the catchment.

Road sealing activities are limited by Council's infrastructure budget. Future budgets should consider leveraging coastal and other environmental grants to allow new waterway roads to be sealed. Initial actions should target areas aligning with poor water quality results, such as Darkwood Road in the upper catchment.

26 Whitehead and Associates, 2010. Report on Preliminary Domestic Wastewater Survey of Nominated Systems on Newry Island

4.6.2 Goal 2: Continue a high standard of water quality monitoring and data collection

The long-term water quality monitoring implemented across the Bellinger-Kalang River system provides well documented scientific evidence to help inform the long-term management of the catchment. Several monitoring programmes have been previously implemented, each using different methods. The most frequent is the Bellingen Riverwatch, which engages 43 local community volunteers and five schools to collect monthly water quality data at 30 sites every month across the Bellinger, Never Never, and Kalang Rivers. This is supported by a comprehensive bi-annual water quality and macroinvertebrate survey undertaken by the state government, which has been developed following the historic Ecohealth projects, conducted by government and academic groups where methods are consistent with the state approved methods in the MER strategy. The benefits of the community driven Riverwatch monitoring is its large extent and the frequency of monitoring, which allows the catchment water quality to be reviewed throughout the year without seasonal bias. The programme can be enhanced by reviewing data capture methods, the installation of new instruments to improve sampling accuracy, and the use of new techniques to help monitoring. Monitoring water quality in the catchment may also be enhanced by joining the DPE Beachwatch programme and implementing a continuous water quality monitoring station at a fixed location to understand natural variability within the system and to serve as a baseline for each sampling programme.	**Actions:** - MON1 - MON2 - MON3 - MON4 - MON5

Figure 4-7: Bellingen Riverwatch (https://www.ozgreen.org/br)

Five management actions have been proposed to improve the standard of water quality monitoring and data collection:

- MON1: Continued support for the Riverwatch programme
- MON2: Permanent water quality monitoring station
- MON3: Join Beach Watch
- MON4: Expand public water quality website
- MON5: Investigate the need for metal monitoring.

4.6.2.1 Continued support for the Riverwatch programme (MON1)

The value of the existing water quality monitoring programme cannot be understated, which has provided an excellent scientific basis for ongoing management actions. This action would reduce the moderate-risk threat of unmonitored water quality. The bi-annual monitoring undertaken by the state government meets a high standard of analysis, although it is sporadic and not guaranteed to continue. The Riverwatch programme is able to provide more regular data and analysis and should therefore become a priority to obtain ongoing funding. This has been identified and recommended in the Bellingen Shire Biodiversity Strategy (2020) through an action to continue water quality monitoring programmes for the measurable improvement in water quality across Bellinger-Kalang waterways. The Biodiversity Strategy also recommends including metals, microbiological and physiochemical parameters to future monitoring efforts. With the support of the BSC, Riverwatch monitoring efforts can be improved with volunteer training, updated techniques, upgraded equipment, and including more parameters in their monitoring efforts. These actions will minimise the need for additional monitoring programs and can provide a long term, consistent dataset of water quality throughout the catchment. The Riverwatch programme can be sustained through financial support from the following state government ongoing environmental trust programs:

- Environmental education: This funding programme supports projects that develop knowledge, skills, commitment to, and ongoing participation in protecting the environment through community groups, non-profit organisations, and state and local governments.
- Emergency pollution clean-up program: This trust programme funds emergency clean-ups of hazardous materials and could be applied for if and when high levels of pollutants are found during water quality monitoring efforts. This trust is managed by the NSW Environment Protection Authority.
- Protecting our Places: This grant funds protection and rehabilitation for culturally important land and water and is provided to NSW Aboriginal community organisations/groups.
- NSW Coastal and estuary grants: These grants are issued for the management of coastal risks, the restoration of degraded coastal habitats, and improvement of estuary, wetland, and littoral rainforest health.

Recommendations to improve and continue the Riverwatch programme include:

- Funding is secured to allow the Riverwatch programme to continue indefinitely
- All water quality monitoring analysis should implement the new Bellinger-Kalang Catchment specific freshwater guideline values presented in this report and apply the new upcoming estuary guideline values once completed and provided by DPE.
- A review should be conducted into the approach and equipment used within the Riverwatch programme to measure Turbidity and Phosphorus and gain consistency between the DPE and Riverwatch sampling.
- Continuing and/or funding for the Support Vols Program where experienced water quality experts occasionally attend Riverwatch monitoring to support volunteers and assess/validate monitoring techniques.
- Potential changes to sample site locations as discussed in 4.5

4.6.2.2 Permanent water quality monitoring station (MON2)

A continuous water quality monitoring station capable of measuring physiochemical parameters is recommended for the catchment. This management action aligns with the Bellingen Shire Biodiversity Strategy (2020) in their action to continue water quality monitoring programmes for the measurable improvement in water quality across Bellinger-Kalang waterways. The monitoring station could also potentially include metal and microbiological parameters as recommended by the Biodiversity Strategy and would reduce the moderate-risk threat of unmonitored water quality. The monitoring station could be configured to record a range of water quality parameters with the results shared in real-time through an online portal. This station would:

- Provide high-frequency data on the natural variability within the system.
- Provide a baseline dataset that can be used for training and validation.
- Provide consistent and precise monitoring of pH, EC, nutrients, turbidity, temperature, etc.
- Include metals, microbiological, and physiochemical parameters as recommended by the Bellingen Shire Biodiversity Strategy (2020).

4.6.2.3 Join Beachwatch programme (MON3)

By joining the DPE Beachwatch water quality programme, Council would gain additional information on bacteria and faecal coliforms at beachfront and upstream recreational swimming locations. This management action aligns with the Bellingen Shire Biodiversity Strategy (2020) in their action to monitor microbiological parameters and would reduce the moderate-risk threat of unmonitored water quality. The programme includes sampling, laboratory testing, and analysis of water quality, in addition to daily pollution forecasts, weekly star ratings, and annual beach grades. Recreational swimming locations that would benefit from the Beachwatch programme are the Never Never River, Lavenders Bridge in Bellingen, Mylestom swimming holes, North Beach, Hungry Head beach, Dalhousie Creek, and the Urunga Lido. Samples could be collected by Riverwatch volunteers during regular monitoring and sent to the Beachwatch programme for assessment. This management action aligns with the Bellingen Shire Biodiversity Strategy (2020) in their action to continue water quality monitoring programmes for the measurable improvement in water quality across Bellinger-Kalang waterways.

4.6.2.4 Expand public water quality website (MON4)

The Bellingen Shire Council currently have a Water and Wastewater Public Data Portal which displays information on wastewater quality and water usage, although includes additional information on upcoming weather and the Sewering Coastal Villages Project[27]. To avoid additional website maintenance, alternatively this data could be included in the BSC website. This website could be expanded to include the proposed continuous water quality monitoring station (Action MON2), Riverwatch data, oyster harvesting microbial monitoring data, and the proposed Beachwatch programme data (MON3). The site would display recent monitoring data against thresholds and could include score-card style reporting. The website would provide transparency of current water quality to the public and stakeholders and include frequent water quality forecasts to inform locals on areas safest for swimming.

4.6.2.5 Investigate the need for metal monitoring (MON5)

The ANZECC/ARMCANZ guidelines provide trigger values for trace metal concentrations in waterways and analytical methods for monitoring metals. A yearly metals analysis can be undertaken to compare with trigger values to assess the level of necessity of increased monitoring. If required, metal monitoring should be undertaken twice-yearly due to the significantly higher average rainfall in Summer and Autumn compared with Winter and Spring. The Coffs Harbour Laboratory has the capability to analyse Aluminium (Al), Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), Iron (Fe), Manganese (Mn), Nickel (Ni), Lead (Pb), and Zinc (Zn). Mercury (Hg) can also be analysed for additional fees which would require subcontracted analyses through a third-party laboratory. These analyses could be requested as an addition to Beachwatch monitoring samples already being received by the Coffs Harbour Laboratory to avoid extra administrative costs or collected and sent to the Coffs Harbour Laboratory by the Riverwatch programme during their regular monitoring times. This action aligns with recommended management actions outline in the Bellingen Shire Biodiversity Strategy (2020) and would reduce the moderate-risk threat of unmonitored water quality.

27 Council Water and Wastewater Public Data Portal accessible via: https://www.bellingenwaterdata.sgautomation.com.au/

4.6.3 Goal 3: Increase biodiversity and ecosystem services

Removal of riparian vegetation has well-publicised adverse effects on water quality and habitat. The introduction of weeds and invasive species has caused a shift in biodiversity in Australia, which can be managed by weed control and reforestation of cleared land.

Reforestation of native flora species along the riparian zone has great potential for improving visual amenity to the Bellingen Shire while providing natural filtration, habitat, bank stability, and shading of the waterway. Secondary benefits of these improvements include reduced bank erosion, natural filtration of agricultural effluent, increased fauna biodiversity, increased capacity for aquaculture and recreational fishing, improvements in water quality, improvements in visual amenity, increased tourism, and other ecosystem services.

Reinstating the riparian buffer zone and excluding stock access will provide significant benefits to the natural regrowth of vegetation and optimise the success of assisted reforestation efforts. Fencing to exclude stock from the riparian buffer zone and directly in waterways will benefit water quality by allowing natural regrowth and regeneration of bank vegetation, increase biodiversity, increase bank stabilisation, reduce bank erosion, reduce turbidity and TSS, reduce faecal contamination, and mitigate eutrophication in the waterways. Animal faecal matter is known to contain harmful pathogens which may contribute to degrading health in the community and conflicts with current waterway uses of drinking, swimming, fishing, and other recreational activities.

Advocating for the reforestation of privately owned riparian land will have major benefits to the waterway health throughout the entire catchment, especially on farmed land where agricultural effluent runoff has no natural filtration or buffer between the waterways.

Actions:

- BIO1
- BIO2
- BIO3
- BIO4
- ERO2
- ERO3
- ERO4

Figure 4-8. Cleared water way banks in the Kalang catchment

Four management actions have been proposed to increase biodiversity and ecosystem services:

- BIO1: Managing grazing/stock exclusion on riparian land
- BIO2: Reinstatement and reforestation of riparian buffers
- BIO3: Refresh the Bellinger Landcare Manual.
- BIO4: Protect and restore areas of intertidal saltmarsh, lagoons, and mangroves on Council managed land.

4.6.3.1 Managing grazing/stock exclusion on riparian land (BIO1)

The management of grazing on riparian land involves stock exclusion and fencing which would optimise the capacity for vegetation recovery and reduce turbidity, bank erosion, and faecal contamination downstream. Therefore, this action aligns with the Bellingen Shire Biodiversity Strategy (2020) for the measurable improvement in water quality across Bellinger-Kalang waterways, protect foreshores, coastal lagoons, significant wetlands, and coastal saltmarsh, and restore the ecological function of high priority waterways and wetlands. This action would reduce the high-risk threat to water quality of stock grazing of riparian and aquatic vegetation. Areas suitable for stock exclusion are primarily on freehold, private land, where Council is not in a management position. In these areas Council should advocate for the riparian management, supporting any opportunities to work with landholders or other government departments. Opportunities will be dependent on the landholder agreement, which may not occur in areas of highest priority, for example initial landholders interested in applying riparian exclusions may be within medium-erosion risk areas. However, support should be given for any area where stock have direct access to the waterway in order to mitigate future issues.

Management actions would be based on the Bellinger Landcare Manual[28]. Fences are required to be at least 5 metres from the top of the bank, and ideally further (e.g., 20m or greater) where possible, or in areas where the bank is higher, and erosion is actively occurring. Along freshwater reaches of a watercourse fencing should be coupled with revegetation activities, including active weed control and periodic monitoring.

Project costs will depend on the extent of the riparian corridor; however, they could be supported by available grants such as the NSW Habitat Action Grant Programme, Protecting our Places NSW environmental trust programme, and the Restoration and Rehabilitation NSW environmental trust programme. Costs of riparian stock exclusion in the estuary may be eligible for the NSW coastal and estuary grants which fund the management of coastal risks including erosion, the restoration of degraded coastal habitats, and the improvement of estuarine, wetland, and littoral rainforest health.

4.6.3.2 Reinstatement and reforestation of riparian buffers (BIO2)

Restoration of riparian zones includes reinstating vegetation to offer resilience against bank erosion and provide bank stabilisation, natural filtration of agricultural effluent, filtration of sediment and nutrients, shading of the waterways and improved biodiversity. This action should be implemented by the BSC for any locally managed land adjacent to watercourses, with Council also advocating for reinstatement of riparian vegetation on privately-owned land, supporting any opportunities to work with landholders or other government departments. This management action was also discussed and recommended in the Bellingen Shire Biodiversity Strategy (2020) and the Bellinger and Kalang Estuaries Erosion Study (2010).

Future opportunities for riparian restoration works will be dependent on the landholder agreement. Support should be given for any area where stock is excluded from the waterway in order to mitigate future issues. Current grants for funding include the Restoration and Rehabilitation environmental trust programme, and the NSW coastal and estuary grants. The Restoration and Rehabilitation environmental trust programme grant funds the rehabilitation of degraded areas to state and local government and community groups. Areas where proven degraded land such as those outlined in the Spicketts Creek Catchment may qualify for this grant programme. The NSW coastal and estuary grants fund the management of coastal risks including erosion, the restoration of degraded coastal habitats, and the improvement of estuarine, wetland, and littoral rainforest health.

28 Bellinger Landcare Inc., Managing Erosion in the Bellinger and Kalang River System

4.6.3.3 Refresh and distribute the Bellinger Landcare Manual (BIO3)

The existing Bellinger Landcare Manual "Managing Erosion in the Bellinger and Kalang River System" is an information leaflet designed to guide landowners with bank restoration. It provides education on the benefits of bank restoration, details of flora species to plant or remove, and instructions on how and where to plant each species along the bank. This leaflet could be refreshed and redistributed to provide guidance on and advocate for bank restoration on private land. This could be implemented alongside action ERO2.

4.6.3.4 Protect and restore areas of intertidal saltmarsh, lagoons, and mangroves on Council managed lands (BIO4)

A Council policy and action plan should be undertaken to identify steps to conserve ecologically important wetlands from future development, changes in land use, pollution, and degradation. This would involve identification of wetland areas, mapping of adjacent threats, and development of management actions.

This action would be supported under the Marine Estate Management Strategy 2018-2028 and has been discussed and recommended in the Bellingen Shire Biodiversity Strategy (2020).

4.6.4 Goal 4: Mitigate erosion and improve bank stability

The Bellinger-Kalang system is a dynamic river with complex morphologic processes. The upper catchment fluvial processes (ie. high runoff and floods) tend to dominate and drive long term meandering and channel changes. In middle to lower reaches, the tidal influence creates new sedimentation patterns, flow dynamics, and erosion effects. Whilst these processes lead to a naturally dynamic watercourse, sustained bank erosion is being experienced throughout the catchment which is not able to naturally recover. Ongoing riverbank erosion can reduce land size, damage infrastructure, wash sediment into the lower waterways, and will increase turbidity and nutrient loads causing a decrease in water quality. Previous bank surveys have indicated that up to one third of riverbanks are experiencing some type of erosion. This erosion is caused by a range of factors, including inundation and slumping, scour during high flows at the bank toe, undercutting due to wave action, erosion due to unrestricted stock access, boat wash, and deforestation of riparian vegetation. In practise, these processes are interrelated, and once the erosion process begins it can be difficult to manage without intervention. A range of options may be implemented to mitigate erosion and improve bank stability, which should first implement simple bank revegetation works, leading into nature-based options and finally hard mitigation options (e.g., toe armour) if required.	**Actions:** - WQ2 - BIO1 - BIO2 - ERO1 - ERO2 - ERO3 - ERO4

Figure 4-9. Bank Erosion within the Kalang River (JBP, 2021)

Four management actions have been proposed to mitigate erosion and improve bank stability:

- ERO1: Site-specific erosion investigations.
- ERO2: Advocate and educate for private land restoration and erosion protection works.
- ERO3: Bank stabilisation and revegetation works on Council managed land.
- ERO4: Minimise impacts of boating.

4.6.4.1 Site-specific erosion investigations and works (ERO1)

The Bellingen Shire Biodiversity Strategy (2020), Bellinger River Estuary Action Plan (2010), and the Bellinger and Kalang Estuaries Erosion Study (2010) identify a range of areas with erosion problems. This action would aim to rehabilitate two sites to serve as demonstration projects. Each project would require a review of topography, geotechnical analysis, hydraulic assessment, design, and costing to produce engineering plans and technical specifications for bank works and revegetation. Initial designs could be packaged into a single project to reduce costs, with the construction then undertaken by Council works teams or externally by contractors. The sites sites are:

- Drain restoration at Gordonville Road
- Mylestom reserve bank stabilisation

Drain restoration at Gordonville Road

The crossroad drainage system at Gordonville Road is a cause of adjacent erosion due to the concentration of water through the culvert and its high velocity discharge. The site requires additional scour protection works and drain restoration incorporating natural-design features. This will require collaboration between Council and the adjacent landholder. Restoration will include:

- Stock exclusion fencing.
- Construction of energy dissipation scour protection.
- Grade level control and rock ramps where necessary to prevent additional head cuts forming from the downstream area.
- Reprofiling of the system and revegetation to reduce velocities and reinforce the bed and banks.
- Ensuring major storm flows (above pipe capacity) can adequately enter the channel and not cause lateral erosion around the culver outlet.

In order to progress this project forward the following elements would generally be required:

- Flood modelling to provide an understanding of velocities, depths, bed shear stress and stream power.
- An assessment of any potential flood afflux as a result of changes to the drain
- Conceptual and/or detailed design and a schedule of costs and specifications for construction.

The downstream restoration is expected to be returned to a naturally meandering channel, which could feature revegetation and pool/riffles. Example conceptual designs are shown in Figure 4-10, and an example completed system from northern NSW.

Figure 4-10. Bank erosion adjacent to Gordonville Road (JBP, 2021).

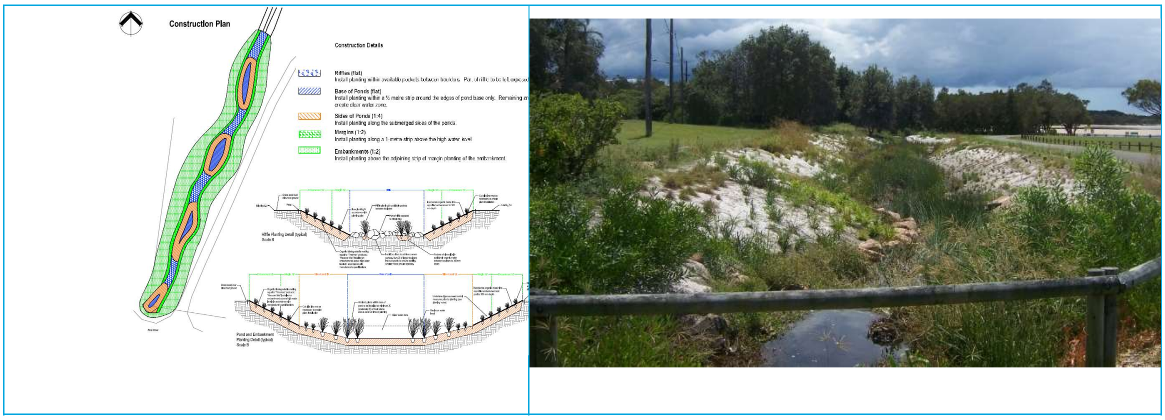


Figure 4-11. Left: Example concept design for a pool and riffle system for channel restoration, Right: Constructed waterway at Red Rock, NSW

Mylestom reserve bank stabilisation

The riverbank at Mylestom has a long history of stabilisation works to facilitate public jetty's, boat mooring, public access and swimming. Original works along the foreshore has consisted of a revetment made from concrete half-pipe and columns, constructed circa 1960s. Given their age the structures are starting to fail and releasing sediment into the waterway.

Several areas have been reinstated by replacing the half-pipes with pre-cast concrete panels, or through a new rock revetment placed against the batters. Whilst effective, more contemporary designs could now be incorporated to the remaining restoration to incorporate the principles of nature-based resilience.

Restoration should include:

- Removal of historic half-pipes
- Toe protection
- Reprofiling of the system
- Bank revegetation to reduce velocities and reinforce stabilisation.

To progress this project it would require additional geotechnical analysis, hydraulic assessment, design, and costing to produce engineering plans and technical specifications for the bank works.

Based on site inspections, the bank restoration would include toe armour, reprofiling, and the development of several vegetation zones along the bank. The nearshore zone could also consider reef balls or habitat-creation piles/logjams.

Figure 4-12. Top: Mylestom bank failures (JBP 2021).

4.6.4.2 Advocate for private land restoration (ERO2)

The advocation for the management of erosion sites on private property should be implemented, supporting any opportunities to work with landholders or other government departments. Opportunities will be dependent on the landholder agreement, which may not occur in areas of highest priority, for example initial landholders interested in applying riparian exclusions may be in lower-risk erosion zones. However, support should be given for any area where erosion is observed, and in particular any of the moderate or high-priority sites identified within the Environmental Bellinger-Kalang River Estuaries Erosion Study (2010)[29] as shown in Figure 4-13. This action would encourage the reduction of two high-level threats to water quality as identified in the TARA, including clearing riparian and adjacent habitat, and stock grazing of riparian and aquatic vegetation.

This management action aligns with the Bellingen Shire Biodiversity Strategy (2020) action to work with agencies and corporations, private landholders, and Landcare groups to encourage and assist in the revegetation of riparian areas, and the protection, management and conservation of existing riparian vegetation and catchment headwaters. As a priority, target landholders with ecologically significant vegetation present on their land. Funding for environmental education could be granted by the Environmental education NSW environmental trust programme.

Options for erosion mitigation can follow a similar approach as Action ERO3, incorporating nature-based approaches including those with engineering-influenced designs such as pool and riffle restoration, habitat-creating pile logs and rock fillets (see Table 4-8).

29 GECO Environmental (2010) Bellinger and Kalang River Estuaries Erosion Study. Produced for Bellingen Shire Council.

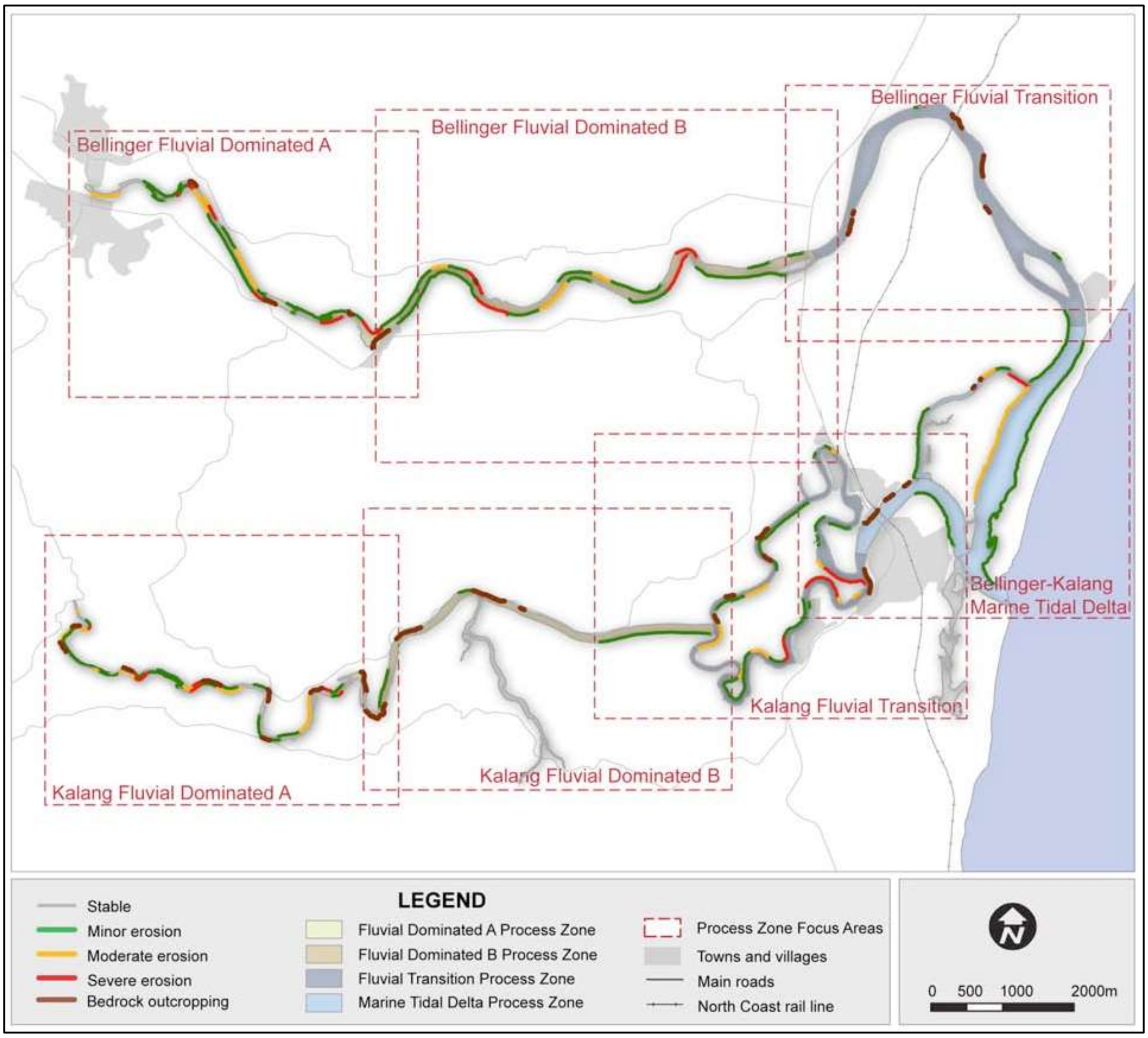


Figure 4-13. Active erosion mapped in the Bellinger and Kalang River estuaries (GECO, 2010)

4.6.4.3 Bank stabilisation and revegetation works on Council managed land (ERO3)

Council should continue to reduce sediment inputs through bank stabilisation and revegetation works on Council-managed land. Mitigation should begin using nature-based approaches including those with engineering-influenced designs such as pool and riffle restoration, habitat-creating pile logs and rock fillets. A range of management options with typical unit-rate costs are shown in Table 4-8.

4.6.4.4 Advocate for minimising impacts of boating (ERO4)

This management action was discussed and recommended in the Bellingen Shire Biodiversity Strategy (2020) and the Bellinger and Kalang Estuaries Erosion Study (2010) and was identified as having a moderate risk on water quality in the estuary while considering fuel spills and shoreline erosion. The impacts of boating could be minimised to prevent bank erosion which can be caused by excessive boat wash, and also to minimise the loss of seagrass habitat and aquatic biodiversity. These impacts could be minimised by advocating for enforced speed limits within the catchment where there are none enforced, reducing the speed of currently enforced areas, define 'no wash zones', and buoy markers. Appropriate signage should be applied to affected areas to educate boaters on the adverse effects of boat wash on the riparian zone, seagrass beds, and aquatic fauna. Affected areas currently include the southern branch of the Kalang around Newry Island and Back Creek[30]. An 8-knot speed limit is currently in place throughout the majority of the lower estuary which could be further reduced to 4 knots.

30 GECO Environmental (2010) Bellinger and Kalang River Estuaries Erosion Study. Produced for Bellingen Shire Council.

Table 4-8: Bank erosion mitigation options

Option	Description	
Bank reprofiling	Areas of steep, eroded riverbanks may require bank reprofiling prior to new stabilisation works. This involves reshaping the bank to a more gradual slope prior to further works. On the inside of channel bends, bank slopes can often be flatter than along the outside of the same bend. Typically bank slopes of 1:3 to 1:6 (vertical:horizontal) can be expected, which allows for safe working conditions during planting operations. Bank slopes on outside of bends are generally steep, typically around 1:1.5 to 1:2 (v:h), and may also require toe protection, usually involving woody debris, pile logs or rock. For straight sections of a waterway batters could range from 1:2 for moderately stable soils, 1:3 for less stable soils and 1:4 for unstable soils, with site specific assessments should be conducted prior to works.	
Pools and riffle systems	A pool and riffle system can be introduced within a degraded stream or a channalised drain to naturalise the system, increase stability by dissipating energy, and enhance the creek ecology and biodiversity. Pools and riffles can be created using rock, as well as introducing a meander back into the watercourse. The riffle is designed as a small rock chute, with a typical gradient of ~1:20 to reduce fish barriers. It is followed by a downstream pool to allow energy dissipation of flows.	
Pin groynes	Pin groynes are constructed using wooden piles installed perpendicular or at a large angle (typically 30º-45º) to the flow. It is an indirect method of reducing bank erosion by deflecting high velocity flow away from the vulnerable bank and encouraging sedimentation in areas between spurs as the flow aggressiveness decreases. The design life of a pin groyne depends on the log types, quality, treatment, and site location. Costs will vary depending on the availability of logs, which could be recycled in-situ from the nearby to the project site. Design considerations include the driveability of the logs, indicating whether they have sufficient strength to be pressed through the underlying material which also depends on the properties of underlying soil strata. Indicative costing should consider $500/m riverbank.	
Rock fillets	This consists of a low-level rock structure positioned parallel to the bank at a short distance from the shoreline. It is a common management approach to reduce bank erosion on outer bends and control channel alignment. Where there is sufficient bank toe, rock fillets can be placed mid-stream to deflect wave and current actions, encourage accretion, and promote the germination of local plants. Construction of rock fillets requires sufficient laydown area, space for plant movement, and vehicular site access which may limit their application. They have been installed along Newry island with good successes. Indicative costing should $1400 (no earthwork required) to $2800 (regrade of bank required) per metre.	
Log jams	A log jam is a nature-based groyne structure consisting of logs fixed along riverbank and interlocked together. They are inspired by natural log jams, which are observed to be stable in a dynamic alluvial environment and prevent bank erosion through altering flow path and deflecting flow away from eroding banks. Log jams also provides complex cover and scour pools to create fish habitats, potentially increases the sequestration of nutrients, and can improve water quality[31]. During construction placement of the structure will need to consider the waterway currents and potential erosion caused by altering the local flows. Designs would need to consider the jam geometry, including individual log dimensions, number of logs per layer, number of layers etc. Costs will vary depending on the availability of logs, which could be recycled in-situ from the nearby to the project site.	

31 Brooks, A. et al. 2006, Design guideline for the reintroduction of wood into Australian streams, Land & Water Australia, Canberra.

4.7 Catchment Management Implementation Plan

4.7.1 Prioritisation and costing

Each management action has been subject to high level costing and is presented in Table 4-9 with the following attributes:

- The threat it addresses and its relative risk (as presented in Table 4-3)
- Any links to other adopted plans
- Its priority for implementation
- High level costs

Actions proposed in this report that are also identified as high priority actions during the review of previous management plans and align with the water quality objectives for the Bellingen-Kalang catchment have been given high prioritisation.

Table 4-9: Management action prioritisation and costing

Goal	Management actions		Threat addressing	Threat Risk Level	Identified in other plans*	Priority	Cost	Funding
1	WQ1	Continue and expand the Sewering Coastal Villages programme	- Sewage effluent and septic runoff	Moderate	-	High	$22 million + extension	- Stormwater levy - NSW Coastal and Estuary Management Grants - Aus Gov Environment Restoration Fund
1	WQ2	Unsealed road management and buffers	- Urban stormwater discharge	High	-	Moderate	$450,000/km	- NSW Coastal and Estuary Management Grants - Aus Gov Environment Restoration Fund
1	WQ3	Update Stormwater Management Plans and implementation of previous recommendations.	- Urban stormwater discharge	High	3	High	$70,000 for updated plan	- Stormwater levy
1	WQ4	Introduce a stormwater levy	- Urban stormwater discharge	High	3	High	Nil (Council staff time only)	N/A
2	MON1	Continued support for the Riverwatch programme	- Unmonitored water quality	Moderate	1	High	Subject to further discussions	- NSW Environmental Trust - Environment levy
2	MON2	Permanent water quality monitoring station	- Unmonitored water quality	Moderate	-	Moderate	$15,500	- NSW Coastal and Estuary Management Grants - Environment levy
2	MON3	Join Beach Watch programme	- Unmonitored water quality	High	1	Moderate	$25,000/year	- NSW Coastal and Estuary Management Grants - Environment levy
2	MON4	Public WQ website	Indirectly addressing through public education: - Clearing riparian and adjacent habitat - Agricultural diffuse source runoff - Urban stormwater discharge - Stock grazing of riparian and aquatic vegetation - Riparian development - Sewage effluent and septic runoff - Commercial aquaculture - Recreational fishing - Passive recreational use	 High High High High Moderate Moderate Low Low Low	-	Moderate	$2,500	- NSW Environmental Trust - Environment levy

2	MON5	Investigate the need for metal monitoring	- Unmonitored water quality	High	1	High	$2000/year	- NSW Coastal and Estuary Management Grants - Environment levy
3	BIO1	Managing grazing/stock exclusion on riparian land	- Stock grazing of riparian and aquatic vegetation	High	2	High	$160 per m inc. labour, posts, concrete, and wire/mesh	- NSW Coastal and Estuary Management Grants - Aus Gov Environment Restoration Fund - NSW Recreational Fishing Trusts Fund - NAB Environmental Resilience Fund - Environment levy
3	BIO2	Reinstatement and reforestation of riparian buffers	- Clearing riparian and adjacent habitat	High	2	High	$20/m2	- NSW Coastal and Estuary Management Grants - Aus Gov Environment Restoration Fund - NSW Recreational Fishing Trusts Fund - NAB Environmental Resilience Fund - Environment levy
3	BIO3	Refresh the Bellinger Landcare Manual (based on 1000 prints)	Indirectly addressing through education: - Stock grazing of riparian and aquatic vegetation - Clearing riparian and adjacent habitat - Invasive species	 High High Low	-	Low	$10,000	- NSW Environmental Trust - NSW Recreational Fishing Trusts Fund - Environment levy
3	BIO4	Policy to protect and restore areas of intertidal saltmarsh, lagoons, and mangroves on Council managed land	- Clearing riparian and adjacent habitat - Stock grazing of riparian and aquatic vegetation - Modified freshwater flows - Riparian development - Commercial aquaculture - Invasive species - Recreation and tourism - Passive recreational use	High High High Moderate Low Low Low Low	1	High	$50,000	- NSW Environmental Restoration and Rehabilitation grants - Aus Gov Environment Restoration Fund - NSW Recreational Fishing Trusts Fund - NAB Environmental Resilience Fund - Environment levy
4	ERO1	Site -specific erosion investigations	Indirectly addressing through assessment of: - Clearing riparian and adjacent habitat - Modified freshwater flows - Stock grazing of riparian and aquatic vegetation	 High High	2	High	$150,000	- NSW Coastal and Estuary Management Grants - Aus Gov Environment Restoration Fund - NSW Recreational Fishing

			- Riparian development	High Moderate				Trusts Fund - NAB Environmental Resilience Fund - Environment levy
4	ERO2	Advocate and educate private land restoration and erosion protection works	- Clearing riparian and adjacent habitat - Stock grazing of riparian and aquatic vegetation	High High	2	High	Nil - Advocation	- NSW Coastal and Estuary Management Grants - Aus Gov Environment Restoration Fund - NSW Recreational Fishing Trusts Fund - NAB Environmental Resilience Fund - Environment levy
4	ERO3	Bank stabilisation and revegetation work on Council managed land	- Clearing riparian and adjacent habitat	High	1	High	$67/m^2	- NSW Coastal and Estuary Management Grants - Aus Gov Environment Restoration Fund - NSW Recreational Fishing Trusts Fund - NAB Environmental Resilience Fund - Environment levy
4	ERO4	Minimise impacts of boating	- Passive recreational use - Clearing riparian and adjacent habitat	Low High	1, 2	High	Nil - Advocation	N/A
* Plans: 1 Biodiversity Strategy (2020) 2 Bellinger River Estuary Action Plan (2010) and the Bellinger and Kalang Estuaries Erosion Study (2010) 3 Bellingen and Urunga Stormwater Management Plans DRAFT (BMT WBM, 2011)								

4.7.2 Funding and governance

This report provides many actions and recommendations for improving water quality in the Bellinger-Kalang Catchment that have also been recommended by previously adopted management plans. Previous management plans discussed throughout this report have seen little action towards implementation, mostly due to a lack of council staffing and unsuccessful grant funding. This section outlines recommended pathways for governing and funding these management actions.

Governance

These management actions range across disciplines and council departments and require a commitment from the whole of the Bellinger Shire Council for its implementation. Therefore, this management plan should be perceived as a whole of council plan.

Future implementation will be subject to available funding opportunities and require heavily on discontinuous streams of funding and one-off lump sums. In order to maximise grant funding opportunities, Council will need initial seed funding and in-kind contributions. It is recommended that levy funds are acquired through an environment levy and stormwater levy, which could then be used to leverage 1:1 or 2:1 funding through grants. Feedback during community consultation have highlighted the importance and high value of the environment and waterways to the local community, and therefore it is anticipated the community may be accepting of the introduction of new and revised levies funded by local ratepayers. This may entail introducing a new stormwater levy and/or a water supply catchment improvement levy, and an amendment to the existing environment levy to enable the implementation of water quality management actions. These levies will provide Council with an underlying base fund that need only be occasionally enhanced by outsourced grants and funding opportunities.

Funding opportunities

A range of environment specific funding opportunities are available for management actions through government grants and non-profit foundations. Funding opportunities frequently arise and expire and require research and applications for each action as they are implemented.

A list of current potential grants and funding opportunities include the following:

- NSW Coastal and Estuary Management Grants: The NSW Coastal and Estuary Grants Program supports planning and actions to manage risks from coastal hazards, restore and maintain coastal habitats and improve the health of estuaries, wetlands, and coastal rainforests. Grants are available for actions identified within a certified Coastal Management Program. This could include actions that reduce erosion, reduce risk from coastal hazards, restore habitat, or stabilisation bank and dune systems. This may be an opportunity to fund a wide range of actions from within this WQMP (e.g., ERO3: bank stabilisation and revegetation work on Council managed land).
- The NSW Environmental Trust provides funding to a range of community, government, and industry stakeholders to deliver projects that conserve, protect and rehabilitate the NSW environment, or that promote environmental education and sustainability. This includes the NSW Environmental Education program which supports projects that develop, broaden, and transform the community's knowledge, skills, and intrinsic motivation to undertake sustainable behaviour and encourage participation in protecting the environment. Funding proposals are expected to incorporate environmental benefit, community need, collaboration, and transformative learning approaches into their application. This may be an opportunity to fund action BIO3: Refresh the Bellinger Landcare Manual.
- The NSW Environmental Restoration and Rehabilitation grants are available for community and government groups. It is available to assist community and government organisations to contribute to the ongoing sustainable management and stewardship. Projects need to address two priority items: (i) support threatened species recovery, and (ii) address climate change impacts on the natural environment – both mitigation and adaptation. This may be an opportunity to fund rehabilitation on private or Council land, e.g., ERO2: Advocate and educate private land restoration and erosion protection works.
- The Australian Government Environment Restoration Fund has extended its 2022-23 budget to $200 million over three years as a part of the National Landcare Program to

protect Australia's water, soil, plants, and animals. Funding will be granted for actions to protect threatened and migratory species and their habitat, to protect Australia's coasts, oceans, and waterways by addressing erosion, improving water quality, and protecting coastal threatened and migratory species, and for the clean-up, recovery, and recycling of waste. The extension of this fund will run until 2025 and is being delivered through a mixture of grants, procurements, and specific purpose payments to the states. This may be an opportunity to fund actions WQ1, WQ2, BIO1, BIO2, BIO4, ERO1, and ERO3.

- The NAB Foundations Environmental Resilience Fund supports projects that build environmental resilience to natural disasters and climate change. This grant is available to regional and remote community organisations, research organisations, environmental organisations, and local governments. This could be an opportunity to fund new riparian restoration efforts and water quality monitoring actions.
- The NSW Recreational Fishing Trusts Fund provides funds for recreational fishing education, access and facilities, research, and habitat rehabilitation and protection. This fund is available for councils to apply for aquatic habitat rehabilitation projects including replanting and protecting riverbank vegetation, rehabilitation of riparian lands, re-snagging waterways with timber structure, and removal of exotic vegetation from waterways and replace with native species, and bank stabilisation works, and may be a suitable resource for funding for actions BIO1, BIO2, BIO3, BIO4, ERO1, ERO2, and ERO3.

A Appendix - Literature Review

- Bellinger River Estuary Revegetation Guide
- Protocol for the Prevention, Detection, and Management of Sewage Contamination in Oyster Growing Areas in the Bellingen Shire (Bellingen Shire Council)
- River styles in Bellinger-Kalang Catchment (NSW Department of Land and Water Conservation, 1998)
- Bellinger Water Quality Monitoring Project (Dickinson, 2000)
- Kalang Strategic Plan (2008)
- Bellinger River Health Plan (Bellingen Shire Council, 2010)
- Bellinger and Kalang River Estuaries Erosion Study (Telfer and Cohen, 2010)
- Report on Preliminary Domestic Wastewater Survey of Nominated Systems on Newry Island (Whitehead & Associates ,2010)
- Bellinger-Kalang Rivers Ecohealth Project Assessment of River and Estuarine Condition (UNE, 2011)
- Bellinger River Estuary Action Plan Reach Plan (NRCMA, 2011)
- Bellingen and Urunga Stormwater Management Plans DRAFT (BMT WBM, 2011)
- Bellingen Island Bank Protection Works – Stage 2 (Andrew Rickert, 2011)
- Heritage Assessment (Bellingen Shire Council, 2011)
- Review of River and Drain Water Quality Nearby Yellow Rock Road Dairy, Raleigh (Whitehead & Associates, 2012)
- Friesians & Fish – Bellinger River Floodplain and Estuary Water Quality Improvement (OEH, 2016)
- Sanitary Survey Report for the Kalang River Harvest Area (SARDI, 2016)
- Measuring riparian and instream responses to two riverbank stabilisation methods in the Kalang estuary, NSW (UNE, 2018)
- Bellingen Shire Biodiversity Strategy (Bellingen Shire Council, 2020)
- Water Quality and Macroinvertebrate Monitoring of the Bellinger Catchment DRAFT (DPE, 2021)
- Lower Bellinger and Kalang Rivers Floodplain Risk Management Plan (WWA Water, 2021)
- Urunga Wetland Water Quality Monitoring (2019)
- Urunga Wetland Water Quality Monitoring Report - Soil Conservation Service (SCS) (2021)

A.1 Bellinger River Estuary Revegetation Guide

This report serves as a revegetation guide for local landowners in estuarine areas. It provides education and information on the benefits of revegetating estuarine banks and lists native species suitable for revegetation. The leaflet also provides instruction on how to plant each native species.

A.2 Protocol for the Prevention, Detection, and Management of Sewage Contamination in Oyster Growing Areas in the Bellingen Shire (Bellingen Shire Council)

This protocol was developed to ensure and manage water quality in the Bellingen Shire for the consummation of NSW produced shellfish and fisheries. It outlines the relevant estuarine water quality policies, codes of practice and guidelines applicable for the protection of human consumers. The report provides instruction for water sampling, contamination detection, and response actions.

A.3 River styles in Bellinger-Kalang Catchment (NSW Department of Land and Water Conservation, 1998)

This study reviews aerial photography, survey data and gravel extraction files provided by the Department of Land and Water Conservation. It utilises catchment characterisation techniques developed by Brierley et al (1996), Brierley and Fryirs (1997), and Brierley (1998), to identify the river styles within the Bellinger-Kalang catchment. The paper assesses the catchment conditions and rehabilitation recommendations.

The report identified six primary river styles in the Bellinger-Kalang catchment. These include upland streams, mountainous headwater streams, mid-catchment gorges, confined bedrock rivers with discontinuous floodplains, alluvial rivers, and tidal rivers. The dominant influence on morphology throughout the catchment was identified to be bedrock controls, where few lower rivers are alluvial. The lower courses of the Bellinger and Kalang rivers are alluvial and experience net erosion and a stepped floodplain-terrace morphology. The Never Never River is subject to sediment accumulation from the upper catchment resulting in evulsion. The Bellinger Valley rivers have been degraded more than those in the Kalang Valley since the European settlement due to vegetation clearance and gravel extraction.

The following categories have been assigned to each region, which is the basis for rehabilitation priority groups.

Conservation sites: These are the least disturbed, with intact structure and vegetation that simply require maintenance and preservation and are listed as following:

- RW1. Rosewood River from the uplands to Thora.
- Land use may impact on the downstream national park.
- Never Never River (NN) (upstream of Copararo Bridge), Kalang River (Upstream of Cooks Creek) (K1.3), Cooks Creek.
- Weed and exotic vegetation management needed.
- Kalang River (Moodys Bridge to Sunny Corner Bridge) (K2)
- Very important remnant part of Kalang River. Stock exclusion and weed management needed.

Strategic Sites: These may be sensitive to disturbance:

- Rosewood River (Maynards Plain) (RW1)
- Stable vegetated channels with minimal bank or bed disturbance. Drainage line revegetation, stock exclusion recommended.
- Kalang River (Rosewood Creek to Moodys Creek)
- Unstable section undergoing bed lowering and localised lateral instability. Stock exclusion, vegetation and weed management recommended.
- Never Never River (NN), lower Buffer (B5.1), Stoney, and Promised Land (NN) Creeks.
- Bed level degradation and gravel extraction. Most likely avulsion occurring upstream of powerlines, downstream of Keoghs Park Bridge. Stock exclusion, monitoring bed-level degradation, weed management, and re-vegetation will reduce rates of sediment supply.

Connected sites with high recovery potential: These are sites that show natural recovery where only minimal management strategies may be needed such as weed management or stock exclusion.

Isolated sites with high recovery potential: These are reaches with high recovery potential but are isolated in the catchment. They may only require minimally invasive recovery techniques such as stock exclusion, and vegetation management. These should be assisted in their self-adjustment and natural rehabilitation:

- Rosewood River (RW1) to Never Never confluence (B5.1), Buffer Creek confluence to Bellinger River Confluence (B5.1)
- Least degraded. Minimal intervention needed. Stock exclusion and weed management.
- Spicketts Creek (Brooklands Reach) (SC1)
- Unstable, experiences high rates of bank erosion and lateral shifts in channel position. Recommends rehabilitation to reinstate a riparian zone to reduce sediment supply to lower Spicketts Creek and prevent sediment accumulation at the Kalang trunk stream.

Recommendations

Conservation and rehabilitation efforts should appreciate the natural variability of the Bellinger-Kalang catchment and its natural behaviours. These efforts must be reach-based rather than site-specific to avoid excessive rates of sediment transfer downstream. Management of bedload sediment budget with the use of structures where needed, although minimally invasive strategies are preferred. Riparian vegetation management and rehabilitation, weed management, and stock exclusion are advised to maintain ecology and geomorphology. This paper recommends allowing the most degraded sections of the catchment to self-adjust before invasive techniques are adapted, as the changes to many sections are considered to be irreversible.

Table 4-10: Identified problem or remediation areas identified within River styles in Bellinger-Kalang Catchment Report

Name	Description
Lower courses of Bellinger and Kalang Rivers	Net erosional landscape, stepped floodplain-terrace morphology
Never Never River	Large volumes of sediment from upper catchment resulting in sediment accumulation and evulsion.
Lower Bellinger river, downstream of Thora	Particularly degraded, bankfull width greatly enlarged, pools are indistinct and loss of habitat
Lower Kalang river - between Moody Bridge and Sunny Corner Bridge	Alluvial, Conservation priority, Prone to disturbance
Upland streams, especially in Rosewood catchment (RW1)	Transfer materials downstream into high conservation value reaches
Upstream of Moodys Bridge	Sediment transfer threatens downstream conservation reach
Unstable sections of Never Never catchment	Prone to incision and risk sediment release of high volumes of gravel
Middle to lower Never Never River	Channel has capacity to evolve
Head of floodplain immediately downstream of Copararo	Sediment accumulation zone
Boggy and Little Boggy creeks	Largest source of fine-grained sediment to the estuary
Tidal reach of lower Bellinger River	Largest sediment source in the Kalang Valley. Channel bed degradation extends upstream to Kalang community hall
Between Rosewood Creek and Woutis Bluff	Sediment source. Little to no vegetation. Extensive bank erosion. Sediment being trapped in State Forest downstream. Lateral shifts in channel position.
Brooklands Reach	Unstable section of Spicketts Creek

A.4 Bellinger Water Quality Monitoring Project (Dickinson, 2000)

The Bellinger Water Quality Monitoring Project was initiated to address a lack of information regarding water quality in the Bellinger catchment from 1998 to 2000. The aims of this project was monthly physico-chemical and bacteriological analysis of water samples and bi-annually collecting macro-invertebrate samples.

Due to the vegetation in the upper catchment, water quality was generally considered to be good although deterioration in water quality was recorded post rainfall which intensified downstream. Smaller streams including Hyde Creek, the Never Never River, and Spicketts Creek revealed poor water quality with high faecal contamination. Nutrient enrichment and occasionally severe faecal contamination were recorded at lower Bellinger and Kalang floodplain, particularly in the Never Never River and lower Bellinger River. Faecal contamination generally increased with distance from headwaters. During elevated flows, faecal contamination extended into estuaries.

Recommendations

Further assessment should be carried out to identify the sources of nutrients and faecal matter. Stock exclusion zones are recommended and a review of septic tank effectiveness in the areas affected. Regular water sampling should be analysed at Newry Island. Current riparian zone rehabilitation efforts should be extended and enhanced.

Table 4-11: Identified problem or remediation areas identified within Bellinger Water Quality Monitoring Project

Name	Description	Lat	Long
Never Never River at Gordonville (NN1.3)	Faecal contamination	-30.403286	152.859222
Hydes Creek at Northbank (H1)	Faecal contamination	-30.455558	152.919569
Spicketts Creek (S1)	Faecal contamination	-30.51917	152.87805
Bellinger estuary near Repton	Poor Water Quality	-30.491875	153.023776
Newry Island	Poor Water Quality	-30.491722	152.998745
Estuary at Urunga	Poor Water Quality	-30.454981	153.031384

A.5 Bellinger and Kalang Rivers Estuary Processes Study (Lawson and Treloar Pty, 2003)

Lawson and Treloar (2003) was conducted as one step of an eight-step process to implement an Estuary Management Plan in the Bellinger-Kalang Catchment. The plan aimed to provide a balanced long-term management framework for the ecologically sustainable use of the estuary and its catchment.

The following general findings were documented:

- Whilst the majority of the upper reaches of the catchment is forested, extensive areas of native vegetation have been cleared along the foreshores of both the Bellinger and Kalang Rivers since European settlement of the region. This has resulted in loss of native species, weed infestation and habitat reduction for endemic mammals and avifauna.
- The report identified that turbidity can be elevated during wet weather events resulting in a periodic decrease in water clarity and light penetration to the water column.
- Elevated levels of nutrients (both Nitrogen and Phosphorous) were observed, with ANZECC (2000) trigger levels exceeded at times.
- The lower reaches of the estuary are well flushed which results in a relatively low Chlorophyll-a level. However, the upper reaches of the estuary are not as well flushed and consequently, nutrient uptake by phytoplankton is greater resulting in higher Chlorophyll-a concentrations.
- Faecal contamination in the estuary is likely to be primarily from non-human sources (e.g., cattle).

- Limited sampling of sediment quality for this study was undertaken which indicates that sediment quality is reasonable and within the ANZECC (2000) guidelines for the estuary.
- Acid sulphate soils are a potential significant issue for the estuary. However, no data indicates acid sulphate soil issues and associated low pH of estuarine water, fish kills associated with low pH or Aluminium release from sediments.
- General findings related to the morphology of the river systems includes extensive riverbank erosion along the Bellinger and to a lesser extent, the Kalang River, sedimentation resulting from catchment clearing, some restoration works (e.g., Bellingen Golf Course), and a range of bank stability techniques used around Newry Island foreshore.
- Key human characteristics of the estuary: The broad range of active and passive recreational waterway activities conducted in the estuary, there are currently no mooring sites, however four sheltered locations have been identified by the Waterways Authority, commercial activities include oyster farming and sand extraction while commercial fishing has been prohibited, and private jetties are common.
- The main detrimental impacts that have occurred are a loss of habitat and biodiversity, reduction in soil and bank stability, reduction in water quality, and alterations to hydrological characteristics.
- Overall, the estuary is a modified system, but appears to be functioning well given the wide range of uses and the human impacts throughout the catchment. The interactions amongst the processes are complex and the ongoing recognition of these interactions through the management phase of the estuary management process will be vital to ensure that the value of the estuary is maintained and enhanced.

Recommendations included the following:

- Periodic compliance assessments are undertaken of the dredging operations at the Raleigh Shoal via the use of hydro survey
- Investigation into re-zoning of areas of riparian vegetation as environmental protection zones to provide specific protection for riparian vegetation
- Rehabilitation of degraded areas of riparian vegetation
- Mapping of noxious and environmental weeds
- Long term monitoring of faecal coliforms in recreational areas
- Catchment management and the creation of riparian buffer areas to filter catchment runoff before it enters the estuary to reduce nutrient inputs, particularly to the upper reaches of the estuary.

A.6 Kalang Strategic Plan (2008)

The Kalang Strategic identifies sources of contamination to the Kalang River. It details assessments and site inspections undertaken from 2008 to 2010. The report is incomplete and has not been upgraded since inspections were completed.

A.7 Bellinger River Health Plan (Bellingen Shire Council, 2010)

The purpose of this study is to determine river health issues from community and agency perspectives and priorities, and to assess how these currently impact on water quality and river health.

The following key issues were identified in this study that need further management to improve water quality:

- Agricultural practices
- Riparian and wetland management
- On-Site Sewage Management Systems (OSMS)
- Boating, tourism, and recreational impacts
- Stormwater
- Rural roads and bridges
- Forestry, logging and clearing

- Oil, diesel, and waste spills
- Wastewater treatment plants
- Water quality monitoring.

An overview was outlined for each of the above priority issues in this study which contains current status, a summary of the community and agency response, best practice management, and key considerations for change.

A.8 Bellinger and Kalang River Estuaries Erosion Study (Telfer and Cohen, 2010)

This study assessed the geomorphology and bank erosion of the Bellinger and Kalang estuaries.

General findings:

- The Bellinger River at all sites erodes/migrates at a faster rate than the Kalang River due to more cohesive bank material and quality and extent of riparian vegetation in the Kalang River estuary.
- The bathymetric profile demonstrates the stability of macro-bedforms along the lower reaches of the tidal Bellinger River. Major changes in bed elevation are around Raleigh Shoal showing 1 – 1.5 m of net bed lowering and McGeary's Island showing the equivalent aggradation.
- Steeper fluvially-dominated upper tidal reaches of the Bellinger River have eroded at a faster rate than the lower gradient fluvial transition reaches on the Bellinger River.
- The June 2009 flood results showed that erosion rates were highest on the Bellinger River along the right bank upstream of Hydes Creek confluence, opposite Fernmount on left riverbank, and on the left riverbank approximately 500m downstream of Carlill's Wharf.
- Patterns of sedimentation on the Kalang estuary also show stability in the form of channel profile, where the only areas of demonstratable change occurred at the lower areas of the Kalang River around Newry Island. In this case, both the south and north branch show aggradation of 1 – 1.5 m
- On the Kalang River erosion rates were highest at the upper fluvial dominated reaches of the estuary, and at Newry Island opposite Urunga.
- In the Kalang River, bedrock outcropping (9% of banks recorded as stable) accounts for a greater proportion of stable banks than in the Bellinger River. In contrast to the Bellinger estuary, a lesser proportion of stable banks are stable due to bank protection works (13%), with the vast majority of works located in the lower estuary around Newry Island and Urunga. This suggests that in the Kalang River, approximately 53% of the alluvial riverbanks are naturally stable.
- The 2009 erosion study shows a very large increase in minor bank erosion but a net reduction in moderate and severe bank erosion (26% and 68% respectively) in both the Kalang and Bellinger estuaries. The high proportion of minor erosion recorded in this study is most likely a consequence of the proximity of the survey to the 2009 floods
- Riparian vegetation was generally poor throughout both estuaries, mostly as a consequence of historical land use but also influenced by contemporary management practices which continue to suppress native vegetation regeneration. Stock access and weed infestation were the two most common factors affecting native riparian vegetation recovery.
-

Recommendations

- Protect existing infrastructure
- Protect important conservation values
- Protect existing works
- Utilise best practice erosion control techniques
- Improve riparian vegetation
- Manage recreational boat use

Site location specific recommendations are listed in Table 4-12 and erosion survey have been categorised into three main priority groups:

- Highest Priority: The sites that threaten existing community infrastructure or property, or high value ecological systems including riparian and remnant vegetation
- High Priority: The sites where bank protection measures have already been implemented but where flooding or other identified factors are threatening the works and future stability of the banks
- Moderate Priority: The sites where erosion is considered to be serious but where significant and ongoing commitment is required by both landholders and responsible government agencies and funding bodies. Many moderate priority sites have very poor riparian vegetation and ongoing disturbance factors such as wind or boat wave wash or impacts from unmanaged stock access

Table 4-12: Problems or remediation areas identified within Bellinger and Kalang River Estuaries Erosion Study

Name	Description	Lat	Long
Site 10 (Highest priority)	Wave wash causing undermining and subsequent bank collapse.	-30.473635	153.028532
Site 12/27 (Highest priority)	Ongoing disturbances associated with wave wash (primarily wind generated) and unmanaged stock access	-30.480246	153.030483
Site 16 (Highest priority)	The deep water profile limits potential bank stabilisation methods. Further site investigation is recommended to determine appropriate methods of stabilisation and approximate costs	-30.519753	152.924443
Site 21 (Highest priority)	The deep water profile limits potential bank stabilisation methods. Further site investigation is recommended to determine appropriate methods of stabilisation and approximate costs	-30.452282	152.915456
Site 26 (Highest priority)	Erosion on the left bank (Pacific Highway side) upstream of the Newry Island bridge may threaten upstream eastern bridge abutment if not treated	-30.483338	153.006176
Site 2 (High)	Flood damage to existing bank protection measures threatens the loss of a small alluvial flat	-30.454418	152.916708
Site 5 (High)	Flood damage to existing protection works adjacent to the Bellingen Golf Club. The majority of works have survived the 2009 floods well, however, revegetation and weed control and some repair of mesh fencing on the site may assist in reducing scour at the site and on the adjacent golf course	-30.451241	152.900540
Site 17 (High)	Flood damage to an existing riparian revegetation project should receive priority assistance to ensure the success of the works. Landholder commitment has already been demonstrated	-30.511490	152.901226
Site 23 (High)	Works here should aim to stabilise the banks using best practice techniques, although the deep water profile adjacent to the site will complicate and increase the costs of construction. Remove of disturbance factors such as unmanaged stock access and wave wash (primarily from boats in this location) will also be important factors in long-term stability	-30.511285	152.992948
Site 1 (Moderate)	All adjacent sites listed here as Moderate Priority are in agricultural landscapes and would require a significant commitment from landholders, responsible government agencies, and funding bodies to actively remediate. All sites except Site 9 (which had fencing on the top bank) are subject to stock impacts with sites 7 and 11 also affected by wave wash	-30.468231	152.468231
Site 3 (Moderate)		-30.467185	152.932778
Site 4 (Moderate)		-30.450733	152.911536
Site 6 (Moderate)		-30.461392	152.953919
Site 7 (Moderate)		-30.465858	152.958644
Site 8 (Moderate)			
Site 9 (Moderate)		-30.458010	152.984417
Site 11 (Moderate)		-30.474784	153.033956
Site 13 (Moderate)	All adjacent sites listed here as Moderate Priority are in agricultural landscapes and would require a	-30.511882	152.905642
Site 14 (Moderate)		-30.505652	152.898067

Site 15 (Moderate)	significant commitment from landholders, responsible government agencies, and funding bodies to actively remediate. All sites except Site 20 are subject to stock impacts with sites 22, 23, 24 and 25 also affected by wave wash. Sites 24 and 25 may be suitable for rock embayment construction due to their relatively shallow water profiles and proximity to the lower estuary and therefore mangrove seed sources	-30.513433	152.913034
Site 18 (Moderate)		-30.511265	152.904815
Site 19 (Moderate)		-30.512423	152.913908
Site 20 (Moderate)		-30.513252	152.932567
Site 22 (Moderate)		-30.499775	153.002810
Site 24 (Moderate)		-30.499400	153.007279
Site 25 (Moderate)		-30.507946	153.000198
Site 28 (Moderate)	This site covers two separate remnant vegetation communities which occur on outside bends in the lower Kalang estuary opposite Newry Island. The condition of the remnants has not been established and erosion is not currently occurring adjacent to the remnants. Further assessment and monitoring is recommended	-30.515290 -30.510588	152.991979 152.986848

A.9 Report on Preliminary Domestic Wastewater Survey of Nominated Systems on Newry Island (Whitehead & Associates ,2010)

Whitehead & Associates compiled a wastewater assessment of 24 sites on Newry Island. The assessment was undertaken to assess the risk of On-Site Wastewater Management Systems (OSMS) contributing to virus pollution of the Kalang River oyster habitats.

General findings:

- Of the 24 properties required to be investigated, 22 contained working OSMS systems, one was disused (235 Newry Is. Drive) and one contained no dwelling (221 Newry Is. Drive).
- The 24 locations were grouped into categories of risk of likelihood to contribute contaminated surface or groundwater to the Kalang River as Very High, High, Medium, and Low (see Table 4-13). All properties investigated had at least one and typically three or more site and soil features of a High Limitation for on-site effluent disposal.

Recommendations

- A cost/benefit analysis should be used to consider the connection to council sewer versus upgrading OSMS on Newry Island.
- If sewer connections are undertaken, it is recommended that all properties currently containing OSMS, except the three systems located south of Hollis Close in the agricultural portion of Newry Island, be connected to BSC sewer. This would include those additional OSMS on Newry Island around Hollis Close, The Grove and Newry Island Drive not inspected during the current investigation.
- Further detailed studies should be undertaken on a select number of OSMS to monitor groundwater levels, groundwater quality and river water quality immediately downgradient of the selected application areas.

Table 4-13: Issues identified within Preliminary Domestic Wastewater Survey of Nominated Systems on Newry Island Study

Name	Description	Lat	Long
9 Hollis Cl	VH	-30.495424	153.001334
23 The Grove	VH	-30.496614	152.998299
28 The Grove	VH	-30.495079	152.995926
29 The Grove	VH	-30.496444	152.997788
32 The Grove	VH	-30.495776	152.996332
134 Newry Island Dr	VH	-30.492270	152.999520
189 Newry Island Dr.	VH	-30.499845	153.006457
219 Newry Island Dr.	VH	-30.501202	153.001475
235 Newry Island Dr	VH	-30.503341	152.989627
18 The Grove	H	-30.494172	152.996968
89 Newry Island Dr.	H	-30.491128	153.004663
108 Newry Island Dr.	H	-30.490829	153.002042
119 Newry Island Dr.	H	-30.493240	153.003146
124 Newry Island Dr.	H	-30.491791	153.001191
125 Newry Island Dr.	H	-30.494024	153.003399
126 Newry Island Dr.	H	-30.491693	153.000839
127 Newry Island Dr.	H	-30.494170	153.003069
130 Newry Island Dr.	H	-30.491727	153.000241
140 Newry Island Dr.	H	-30.492623	152.999099
142 Newry Island Dr.	H	-30.493032	152.998831
10 The Grove	M	-30.493721	152.997497
31 The Grove	M	-30.496466	152.997075
139 Newry Island Dr.	M	-30.493967	153.001398

Low Risk (L) = The system will only rarely contribute contaminated surface or groundwater to the Kalang River.
Medium (M) = The system is likely to contribute contaminated surface or groundwater to the Kalang River during occasional extreme weather periods.
High Risk (H) = The system is very likely to contribute contaminated surface or groundwater to the Kalang River on a seasonal basis.
Very High Risk (VH) = The system is expected to contribute contaminated surface or groundwater to the Kalang River on a daily and/or seasonal basis.

A.10 Bellinger-Kalang Rivers Ecohealth Project Assessment of River and Estuarine Condition (UNE, 2011)

This project was conducted over a 12-month period in the Bellinger and Kalang Rivers to contribute to the assessment of the ecological condition of the catchment. The project aimed to assess the health of coastal catchments using standardised indicators and reporting for estuaries, and upland and lowland river reaches using hydrology, water quality, riparian vegetation and habitat quality, and macroinvertebrates assemblages as indicators of ecosystem health in the Bellinger/Kalang system, and contribute scientific information to the development of a report card system for communicating the health of the estuarine and freshwater systems in the Bellingen Shire.

General findings:

- ANZECC trigger values for pH, dissolved oxygen, nitrogen (N) and phosphorus (P), and turbidity were exceeded in some months at sites within both river systems.
- Spicketts Creek in the Kalang catchment was particularly noteworthy as a freshwater site that exceeded the trigger values for nitrogen, phosphorus, DO and turbidity.
- Tributaries in both catchments had higher turbidity than the main stem of each river, suggesting these systems may be a source of suspended material.
- The Bellinger River supplies a disproportionate amount of N (460 tonnes/year), P (86 tonnes/year) and suspended solids (4320 tonnes/year) compared to the inputs from the

Kalang River. These differences arise from the higher discharge in the Bellinger River rather than higher concentrations.

- SIGNAL grades for macroinvertebrate Families for tributaries generally ranged from 2-8, with Spicketts Creek displaying a consistently low SIGNAL score, reinforcing the poor water quality and habitat condition documented in this study.
- The Bellinger catchment sites were identified as good riparian condition while the riparian condition of Kalang catchment were consistently low.
- The major disturbances to the riparian zone are weeds, reduced number of vertical strata and minimal riparian habitat in the form of organic litter and woody debris.
-

Recommendations

- Increasing number of tributaries in each catchment for future monitoring to identify sub-catchment level sources of poor water quality
- Develop long-term water quality sample sites at locations with active discharge measurements to determine load-based nutrient and sediment inputs to estuarine environments
- Continue to collect samples for macroinvertebrate community composition in Autumn and Spring on an annual basis
- Priority actions for riparian zones in all reaches should focus on weed management, improving riparian habitat in the form of organic litter and woody debris, and addressing undercutting, exposed roots and slumping of channel banks.
-

Table 4-14: Identified problem or remediation areas identified within the Bellinger-Kalang Rivers Ecohealth Project

Name	Description	Lat	Long
Spicketts Creek	Trigger values were exceeded for nitrogen, phosphorus, DO and turbidity	-30.505213	152.893608
Spicketts Creek	Riparian restoration	-30.505213	152.893608
Kalang River at Scotchman	Riparian restoration	-30.481556	152.870773
Kalang River at Briefield	Riparian restoration	-30.502375	152.895736
Never Never River	Riparian restoration	-30.387211	152.886018

A.11 Bellinger River Estuary Action Plan Reach Plan (NRCMA, 2011)

The Bellinger River Estuary Action Plan was compiled by the Bellingen Shire Council with the Northern River Catchment Management Authority (NRCMA). This Reach Plan utilises the Bellinger-Kalang Estuary Erosion Study (Cohen & Telfer, 2010) to reference the fluvial and geomorphological context and identify key threats. Recommendations to address the threats were made at the reach scale and developing Site Action Plan (SAP) at each property. The SAPs define an achievable goal that is defined based on the characteristics of the riparian vegetation, channel condition and fish passage.

General findings:

- The level of canopy cover within the reach was low with only 25% of properties showing between 76-100% canopy cover
- The riparian width of most properties within the reach was very low.
- Riverbanks that showed signs of significant erosion were mostly those properties that had little or no riparian width
- Riverbank condition in the upper-mid Bellinger River estuary is generally moderate to poor

Table 4-15: Identified problem or remediation areas within the Bellinger River Estuary Action Plan Reach Plan

Name	Description	Lat	Long
Ford Street	Active moderate erosion. Weed control required. Extending the riparian buffer already established in the upper section of the park along the entire riverbank to meet with the existing revegetation works established at site 2.	-30.451183	152.899397
1172 Waterfall Way	Moderate bank stability and minor erosion. Future targets for this site include extending the current riparian buffer a further 10-20m, ongoing weed management, further stabilizing the entry and exit points of the two flood chutes which span the site laterally.	-30.450619	152.908057
105 North Bank road	Reasonable bank stability with minor erosion occurring and small gully type erosion. Particular attention should be placed on revegetating the toe (lower third), extending the fences around the slump areas, ongoing weed management and exclusion of stock .	-30.450619	152.908057
Cahill Street, 1060 Waterfall Way	severe erosion has occurred immediately downstream of the rock revetment works. Erosion is considered to be moderate to severe. Rehabilitation strategies are constructing fence line around the riparian margin of the site, weed control, re-establishing riparian buffer, Off-stream water points.	-30.450911	152.911163
224 North Bank Rd	Moderate erosion is evident around the margin of the low-lying bank near the western edge of the property. Overall moderate active erosion. Recommended installation of rock revetment, revegetate bank from toe to a distance at least 5m back from bank crest edge and long term weed management.	-30.451400	152.914618
236 North Bank Rd	Severe active erosion. Recommended rock revetment wall and establishment of riparian zone.	-30.453882	152.916298
850 Waterfall Way	Minor active erosion. Rehabilitation strategy should focus on recreating a riparian buffer and additional structural works to increase hydraulic roughness and stabilize the bank upstream of the revetment wall.	-30.465650	152.927408
794 Waterfall Way	Due to lack of riparian vegetation, this section is vulnerable to undermining in future flood events. Severe active erosion along the outside bend. Cattle damage is a major issue to bank stability. Recommended construction of a new concreted laneway to a restricted river access point, construction of a restricted cattle access ramp at the river crossing.	-30.466649	152.934241
700 North Bank Road	overall severe active erosion. Recommended minimum fence line setback of ten metres from the crest of the bank, accompanying vegetation should be planted along the bank face and toe, Ongoing weed management and installation of a rock revetment wall along the toe of the bank.	-30.460727	152.952912
516 Waterfall Way	Minor bank erosion and channel was observed at the estuarine wetland entrance. Acid sulfate soil exposure in the bed of the drain which leads to negative effects on the immediate and downstream environment. Rehabilitation strategies are recommended as installation of 6 single pin sets (refer to site plan) to deflect flow away from right hand bank of backwater channel and re-establishment of a riparian corridor on the bank slope.	-30.466233	152.958865
461 Waterfall Way	Moderate active erosion. Recommended staged riparian fencing and revegetation program.	-30.465372	152.964018
182 Waterfall Way	Severe active erosion on the outside bend. Recommended minimum fence line setback of ten metres from the crest of the bank, being vegetated with a variety of deep-rooted plant species. Vegetation should be planted along the bank face and toe. Ongoing weed management and installation of a rock revetment wall along the toe of the bank are other strategies.	-30.459910	152.984164
44 Waterfall Way	Scour and mass failure along the adjacent bank. Rock revetment wall or rock fillet structures are recommended.	-30.459793	153.003014

A.12 Bellingen and Urunga Stormwater Management Plans DRAFT (BMT WBM, 2011)

This report presents the Stormwater Management Plan (SMP) for the urban centres of Bellingen and Urunga. The aim of this project is to provide a plan to systematically implement identified actions for the improvement of water quality within the Bellinger and Kalang Rivers. The study has identified only a few existing devices in the townships, most of which appear to require renewal and continued maintenance. This study has assessed the existing pollutant loadings from the urban areas of Urunga and Bellingen and then assessed the likely benefits of retrofitting in additional stormwater quality controls.

General findings:

- Water quality is generally acceptable in the Bellinger and Kalang river systems.
- Urban areas likely contribute to total suspended sediment, and both total and dissolved nitrogen and phosphorus loads to the estuary.
- Impacts of urban stormwater runoff are likely to be greater during periods of low and medium river flow which allows for urban derived pollutants to be retained in the estuary for a longer period of time.
- Update GIS based information specific to the existing stormwater system. The data needs to identify the full trunk drainage system and record salient details for the purposes of asset maintenance, drainage and also stormwater management.
- Develop an asset maintenance system for management of stormwater quality controls.
- Plans to upgrade city centres should be viewed as an opportunity to improve stormwater quality.

A.13 Bellingen Island Bank Protection Works – Stage 2 (Andrew Rickert, 2011)

Andrew Rickert (2011) conducted a Review of Environmental Factors (REF) to investigate the potential environmental impacts associated with proposed works adjacent to Bellingen Island, Bellingen. Proposed works included the construction of log deflector jams and pin groynes. The aim of this project was to improve bed and bank stability along a 200m stretch of the Bellinger River. The potential impact of the proposed works has been assessed in different categories such as environmental setting, water quality, flora and fauna, indigenous and non-indigenous heritage, noise, air quality, traffic, safety, and visual characteristics.

An assessment of environmental impacts has determined that the proposed works will be beneficial, both environmentally and socially. The proposed work will not adversely impact on the environment due to small scale of the proposal, the method of construction, and the control measures that will be implemented. It provides increased habitat opportunities for local native fish species and will results in bank and bed stability which leads to the recovery of the Bellinger River.

Following from this study, bank protection works were undertaken along a 200m stretch of river adjacent to Bellingen Island on the north bank of the Bellingen River (Lat: -30.447551, Long: 152.894618)

A.14 Heritage Assessment (Bellingen Shire Council, 2011)

BSC (2011) is a heritage assessment of numerous buildings on Atherton Drive, Urunga. Atherton Drive is located on the estuarine banks of the Kalang River at the northernmost tip of Urunga.

The site was found to be prone to flooding, and septic drainage systems are no longer considered appropriate. The Department of Lands have begun property reclamation efforts and were considering demolition of most buildings.

A.15 Review of River and Drain Water Quality Nearby Yellow Rock Road Dairy, Raleigh (Whitehead & Associates, 2012)

Whitehead & Associates (2012) provides an independent review of water quality data presented to BSC by Mr Pearce. Mr Pearce has indicated that data was obtained by collecting water quality samples from the Bellinger River alongside a dairy milking shed complex at 669 Yellow Rock Road, Raleigh. It shows that E. coli in oyster meat and Faecal coliforms in water were measured mostly between March and May of 2012. Measured data and locations are summarised in Table 4-16.

Table 4-16: Identified problem or remediation areas identified within River and Drain Water Quality Report

Name	Description	Lat	Long
T4	*E. coli* data in oyster meat was measured. The *E. coli* data indicates that the majority of concentrations exceed the Conditionally Restricted threshold criteria	-30.456506	153.044496
T5		-30.459401	153.039756
T6		-30.464058	153.045845
Drain 1	Faecal coliforms (FC) in water were measured. The drain sample data indicate that very high FC concentrations can be present in the drain exceeding all threshold criteria	-30.43983	153.02957
Drain 3		-30.453925	153.042596
Lease 4D		-30.458088	153.04402
S1	Faecal coliforms (FC) in water were measured. The majority of FC sample results in river water exceed the Conditionally Approved threshold criteria with some results exceeding the Conditionally Restricted threshold criteria	-30.457941	153.033222
S2		-30.461379	153.045444
S3		-30.461379	153.045444
S4		-30.461379	153.045444
S5		-30.461379	153.045444

A.16 Friesians & Fish – Bellinger River Floodplain and Estuary Water Quality Improvement (OEH, 2016)

OEH (2016) is a report of the improvement of water quality in the Bellinger River Estuary. The project aims were to improve effluent discharge from dairy farms, reduce erosion and sedimentation from livestock, reduce threats to endangered biodiversity, increase community awareness and council relationships with locals.

A.17 Sanitary Survey Report for the Kalang River Harvest Area (SARDI, 2016)

SARDI (2016) summarises oyster harvesting related water quality issues in the lower Bellinger-Kalang catchment. The initial sanitary survey of the Kalang River growing area in 2006 identified a number of domestic and agricultural pollution sources to the growing area, and resulted in a “Conditionally Restricted” classification, requiring oysters to be depurated before the sale to market. The harvest area was re-classified as “Prohibited” on the 24th of July 2008 following ongoing human enteric viral contamination of oysters. Two viral outbreaks of gastroenteritis were linked to oysters from the Kalang River in 2008. Follow up investigations, including viral surveys of the area for norovirus conducted in 2008 and 2009 suggested widespread contamination. Since 2009 significant remedial works have been undertaken by the BSC.

General findings:

- The shoreline survey identified that significant remedial work has occurred in the catchment for the Kalang River harvest area that has removed many potential viral sources to the growing area. Minor pollution risk still exists from private pump station overflows that are not notified to the NSW shellfish program, several OSMS, storm water drains, and agricultural waste.
- The shoreline survey identified that the growing area could, at best, be classified as "Restricted"
- The greatest concern is from domestic waste, both OSMS and the reticulated sewage system. Anchors Wharf restaurant and Brigalow Caravan Park are particularly notable in this case as they are close to the growing area and have a suggested history of failure.
- Stormwater runoff is likely to present a significant risk due to the proximity of harvest leases to the shoreline, the proximity of urban development, and the high rainfall in the area.

- Viral surveys have shown a significant reduction in norovirus (NoV) contamination of shellfish in the Kalang River following remediation. However, NoV was detected in one sample in the upstream section of the harvest area.
- One house with a failing OSMS at Urunga Caravan Park is connected to the reticulated sewage system and "Prohibited" classification should apply to the growing area.
- Heavy metal surveys have shown that oysters from the growing area comply with the Food Standards Code for heavy metal and pesticide residues.
- The data of this study supports a “Conditionally Restricted” classification where the conditions for being open for relay/depuration include a seven-day rainfall at Spicketts Creek < 45 mm, and salinity ≥ 22 PSU (practical salinity units) at site 10. Salinity should be taken on a mid to low falling tide.
- Following any remedial work required in relation to the investigation, and after decommissioning of the failing OSMS at house adjacent to Urunga Caravan Park, the growing area should be classified as “Conditionally Restricted”, and the public health risk managed using rainfall and salinity triggers.

Table 4-17: Identified problem or remediation areas identified within the Sanitary Survey Report

Name	Description	Lat	Long
Urunga Waters Caravan Park and House adjacent (PP039)	High Risk.	-30.48248	153.00451
Urunga "Boat Houses" (PPS011)	Medium-High Risk.	-30.489487	153.017069
Urunga Sewerage Treatment Plant (STP) (PPS001)	Medium Risk.	-30.50654	153.02013
Bellingen STW	Pollution: turbidity	-30.44819	152.90546
Raleigh Waste Management Facility	Limited information.	-30.47140	152.99338
Drainage network (PPS012)	Pollution: Nutrients, chemical, faecal, hydrocarbon, trace metals.	-30.490306	153.016003
Brigalow Caravan Park. (PPS028)	High Risk.	-30.50982	152.99010
Anchors Wharf Restaurant (PPS016)		-30.49263	153.01359
Livestock (PPS033)	Med-High risk.	-30.50817	152.98525
Livestock (PPS023)	Med-High risk.	-30.50058	153.00358
Stormwater drains (PPS024)	Medium Risk, faecal, nutrients and hydrocarbon.	-30.503827	153.002947
Stormwater drains (PPS025)	Medium Risk, faecal, nutrients and hydrocarbon.	-30.506385	153.00031
Housing development with discharge drain (PPS026)	Medium risk, faecal, nutrients and hydrocarbon.	-30.509273	153.000575
Private OSMS (PPS027)	Medium-High Risk, faecal and nutrients.	-30.508944	152.998788
Drainage system (PPS029)	Medium Risk. Faecal and nutrients.	-30.497337	153.01154
Railway bridge crossing Kalang River (PPS014)	Medium-high risk.	-30.49129	153.01332
Sewage pumping station (PPS052)	Med-High risk.	-30.48905	153.01372
Sewage pumping station (PPS049)	Med-High risk.	-30.48622	153.00846
Stan Mills Reserve (PPS040)	Med-High risk.	-30.48372	153.00584
Sewage pumping station (PPS021)	Medium Risk. Faecal and nutrients.	-30.505058	153.004537
Sewage pumping station (PPS041)	Medium risk. Faecal, nutrients and hydrocarbon.	-30.486465	153.007044
Natural Drain (PPS045)	Medium Risk. Faecal and nutrients.	-30.499711	153.009593
Private OSMS (PPS047)	High risk. Faecal and nutrients.	-30.50072	153.00172

Sewage pumping station (PPS050)	Medium risk. Faecal and nutrients.	-30.490924	153.011062
Sewage pumping station (PPS013)	Med-High risk pollution source. Faecal and nutrients.	-30.493018	153.017873

Recommendations

- Investigate the potential source of the positive NoV result at Site 11 and conduct a follow up virus survey during holiday periods prior to re-opening of the growing area.
- Following any remedial work required in relation to the investigation, and after decommissioning of the failing OSMS at house adjacent to Urunga Caravan Park, the growing area should be classified as “Conditionally Restricted” with, and the public health risk managed using rainfall and salinity triggers.
- Increase sampling over the next few years to follow elevated rainfall in 24 hours, 48 hours, and 7 days to improve the data set.
- Regular algal and biotoxin monitoring in line with the ASQAP Operations Manual 2016, and a biotoxin risk assessment is undertaken when data is available.
- Regular updates of the sanitary survey of the areas.
- Review data collected from the growing area annually and review the classification tri-annually, or sooner if more data becomes available.

A.18 Measuring riparian and instream responses to two riverbank stabilisation methods in the Kalang estuary, NSW (UNE, 2018)

This report serves as a post-construction assessment of estuarine erosion control measures and restoration efforts including rock revetments and fillets. They compared results to a pre-construction assessment of mangrove seedlings, leaf litter, and benthic macroinvertebrate and meiofaunal biodiversity. The bank stabilisation was implemented to address banks previously classified as severely eroded by Telfer and Cohen (2010)[32].

The port-construction review found that bank erosion completely ceased due to rock revetment, and significantly reduced due to rock and timber fillet installation. Six months after construction of fillets sediment accretion was observed and colonisation of mangrove seedlings. No colonisation was observed where the rock revetment was implemented. Rock and timber fillets were more successful in relation to flora and fauna improvement, whilst the rock revetment was a more successful approach to address erosion.

The report stated that Newry Island had previously been identified as having 'severely eroded' riverbanks, and that restoration works took place in 2017.

Recommendations

Rock and timber fillets were the recommended approach for other severely eroded banks along with native riparian vegetation regeneration and stock exclusion.

Table 4-18: Identified problem or remediation areas identified within the UNE riverbank stabilisation review

Description	Lat	Long
320m of rock and timber fillets, 250m of rock revetments, mangrove seedling establishment	-30.499053	153.006616
Similar bank stabilisation and revegetation	-30.499569	153.005861

32 D. Telfer, D. & Cohen, T. (2010) Bellinger and Kalang River estuaries erosion study

A.19 Bellingen Shire Biodiversity Strategy (Bellingen Shire Council, 2020)

This strategy aims to ensure ecosystem health and species richness within the Bellingen Shire for the purposes of prolonging ecosystem services for the community. It provides a framework and strategic plans that focus on habitat maintenance, preservation, and expansion, along with erosion, sedimentation, and pollution of aquatic habitats.

General findings:

- Extreme rainfall and flood events caused river and estuary health issues including poor water quality due to the high nutrient and sediment runoff.
- The overall health of the river systems is on a declining trend.
- The threatened and migratory species map of Bellingen LGA suggests that the threatened and endangered species are more condensed towards the coast.
- 87 threatened species of fauna and 27 threatened species of flora are found in the Bellingen Shire.
- Koala populations in the Bellingen Shire identified as being at risk from habitat fragmentation and reduced habitat connectivity.
- Key threats include invasive weed species, invasive and feral animal species, deforestation, urban development, pollution, eutrophication and nutrient runoff, disease, altered bushfire regimes, climate change effects, erosion, riparian clearing, bushrock removal, removal of dead wood and trees, logging,

Recommendations:

- Improve habitat connectivity for biodiversity, fauna corridors and habitat enhancement.
- Implement sustainable agriculture and forestry.
- Improve and increase the extent of riparian vegetation.
- Improve riverbank works and processes.
- Implement sustainable management of domestic sewage and wastewater.
- Improve stormwater management.
- Decrease impact from road runoff and scouring from rural roads and bridges.
- Improve logging and clearing practices.
- Improve management of oil spills.
- Enforce sediment measures in construction sites to reduce sediment and nutrient runoff.
- Support and encourage private native planting.
- Implement alternative lighting technology to reduce light pollution.
- Maintain and improve the condition of vegetation in council reserves.
- Continue to undertake water quality monitoring programmes including metals, microbiological, and physicochemical parameters.
- Minimise impacts of boating and recreation on seagrass.
- Work with agencies and corporations, private landholders and landcare groups to encourage and assist in the revegetation of riparian areas, and the protection, management and conservation of existing riparian vegetation and catchment headwaters.
- Protect foreshore, coastal lagoons, significant wetlands, and coastal saltmarsh.

A.20 Water Quality and Macroinvertebrate Monitoring of the Bellinger Catchment DRAFT (DPE, 2021)

This report provides an analysis of the DPE water quality and macroinvertebrate data collected between 2017 and 2020 in response to the significant mortality event of the endemic species of turtle within the Bellinger Catchment, the Bellinger River Snapping Turtle. DPE (2021) assessed the previous river health monitoring sites that were historically used by a number of agencies and groups. In general, the aim of the project was to provide environmental data that could be used to understand the conditions and variables of the environment that may affect the turtle population and the overall health of the river.

General findings:

- The Bellinger catchment is in a healthy condition with moderate impacts in the lower catchment, which is due to changes in land use, from natural forested areas in the upper catchment to open grazed and cropped areas with some rural and urban residential in the lower catchment.
- The analysis showed a lack of consistency in spatial coverage of monitoring sites and temporal coverage of monitoring events, differences in the historically assessment of water quality variables and the need for consistent long-term data collection program.
- The majority of Bellinger River sites were rated 'Excellent" except for BEL2, BEL5 and BEL6 which were rated 'Very good' due to elevated TSS, which indicates sedimentation could be an issue to consider at this site in the future.
- Most Bellinger River sites were rated "Very good" or "Fair" in terms of macroinvertebrate ecosystem response index with the exception of BEL7.
- There was an improvement in water quality across the Bellinger River. The system may be in recovery from a major stress event.
- The Never Never River was rated "Very good" for the water quality stressors and "Fair" for the macroinvertebrate response. The pH was slightly more acidic than other waterways and there were some instances of elevated NOx, suggesting some impacts from agricultural activity.
- Rosewood River displayed neutral pH values and there were several instances of very high NOx which suggests agricultural impacts leading into 2018. NOx levels recovered and was rated "Very good" in 2019 and 2020.
- Across the Kalang catchment the water quality stressors were generally rated "Excellent" except for DO, which was rated "Very good" at all Kalang sites. EC was outside the guideline value at K4 only.
- Spickets Creek was rated "Poor" for DO, and "Excellent" for all other water quality stressors. Macroinvertebrate response was rated "Fair" and made no improvements from 2018 to 2019.

Recommendations

- If the existing land use remains and the upper catchments maintain their natural forested condition, the Bellinger River catchment should be healthy and resilient into the future.
- The Bellingen Riverwatch citizen science monitoring program will provide valuable data and information to inform management of the catchment and should be continued.
- Water quality parameters currently measured by Riverwatch should continue, particularly for DO. Recently more precise monitoring equipment has been obtained and is currently being used in a Quality Assurance approach for the Riverwatch monitoring program and is a great step towards increasing the certainty of the citizen science data collection.
- The incorporation of the Waterbug Blitz into the Riverwatch will provide excellent data that, while it is not as scientifically accurate as the AUSRIVAS methods used by DPE Science, is a great step forward for citizen science in the catchment.
- Given the drought effect, ongoing monitoring should occur of macroinvertebrates particularly in the riffle habitats of the upper Bellinger River where the Turtles are being released through the breeding program.
- Ongoing monitoring should strongly consider moving the KA4 site to upstream to avoid the influence from estuarine water, or remove from the programme.
- To identify the factors impacting the macroinvertebrate community in Spickets Creek, more regular monitoring of water quality is recommended.
- Further investigation of the variability of DO over diurnal cycles is required in Kalang River to make a more complete assessment of DO conditions.

Table 4-19: Problem or remediation areas identified within the DRAFT DPE Water Quality and Macroinvertebrate Report

Name	Description	Lat	Long
BEL6	It was rated as "Very good" instead of "Excellent" due to elevated TSS which could be an issue in future due to vehicle crossing	-30.417670	152.847772
BEL2	Sedimentation could be an issue to consider at this site in future	-30.446730	152.618820
BEL5		-30.428770	152.770630
BEL7	This site was rated as poor in terms of macroinvertebrate ecosystem	-30.450713	152.898667
SC1	Spicket Creek was rated "poor" for DO (Dissolved Oxygen) and "Excellent" for all other water quality stressors. Macroinvertebrate was rated as "Fair". The large portion of agriculture and forestry of the catchment has strong influence on water and habitat quality.	-30.505280	152.893830
The riffle habitats of the upper Bellinger River	Given the drought effect, future monitoring should consider ongoing monitoring of macroinvertebrates particularly in the riffle habitats of the upper Bellinger River as it's the most sensitive habitat and where the Turtles are being released through the breeding program		
KA4	Ongoing monitoring should strongly consider moving the KA4 site to upstream to avoid the influence from estuarine water if access permits or removing it from the program.	-30.501990	152.895710
Spickets Creek	To identify the factors impacting the macroinvertebrate community in Spickets Creek, more regular monitoring of water quality is recommended, and it should remain a site of interest for future river health programs	-30.505280	152.893830

A.21 Lower Bellinger and Kalang Rivers Floodplain Risk Management Plan (WWA Water, 2021)

WWA Water (2021) assesses the current floodplain risk management plan of Lower Bellinger River and Kalang River catchments.

General findings:

- The low-lying floodplain downstream of Bellingen (Riverwatch site B7) is subject to flood depths greater than 2m, and long periods of inundation.
- During a 1% Annual Exceedance Probability (AEP) event, most of the floodplain between Bellingen (B7) and Urunga (KR11) are considered unsafe for residents and drivers.
- Cemetery Creek runs through Bellingen (B7.1). It experiences short duration flooding, drains to the Southeast, and connects with the Bellinger River (BR4).
- Flooding of Cemetery Creek caused inundation of properties in Bellingen during 1974 flood event.
- Recent inundation particularly effects low lying regions between Prince and Ford Streets.
- Hammond Rd and Dowle Street experience greater than 2m flood depths during 1% AEP events.
- Between Bellinger River (B7) and the Central Drainage Line connect during Probable Maximum Flood (PMF), isolating properties between Hobson Close and the Bellinger River.

Recommendations:

- The recommendations within this study generally relate to flooding, and not water quality.
- Flood awareness and preparedness of the community through flood awareness programs have been implemented to carry out the flood warning and evacuation process.
- Improvement of evacuation routes and appropriate warning is recommended.
- Council is considering raising North Bank Road and waterfall way for safer evacuation, and house raising has been implemented throughout the region.

A.22 Urunga Wetland Water Quality Monitoring (2019)

This report assessed surface, ground, and soil quality surrounding and downstream of the disused Antimony Processing Plant (APP) at Urunga. Analysis was undertaken between January 2013 and October 2016 prior to, during, and post contaminated land remediation project in 2016. The completion report analysed the data using the Australian and New Zealand Environment Conservation Council (ANZECC) Guidelines for Water Quality (ANZECC 2000), The Australian Drinking Water Guidelines, (National Health and Medical Research Council (NHMRC) 2004), The Guidelines for Managing Risks in Recreational Waters (NHMRC 2011) and the licensed discharge limits for the site, set by the NSW Environmental Protection Authority (EPA)[33]. Monitoring efforts tested for contaminants of concern including antimony, arsenic, copper, iron, manganese, nickel, zinc, pH, and total suspended solids (TSS), at sites shown in Figure 4-14. The sites include four surface water sites (SW01, SW05, SW18, and SW21), two groundwater sites (GW01 and GW02), and the monocell leachate sump (SW16) at the plant, and two surface water sites downgradient at the Station Creek Bridge on Hungry Head Road (SW02) and the footbridge at the Urunga Lagoon (SW03). The report describes the site as receiving high levels of historical pollution and heavily disturbed, while downstream at Station Creek and Urunga Lagoon was classified as moderately disturbed.

General findings

- The monitoring results of surface water quality revealed no compromise to swimming at the Sea Lido (SW03) as concentrations have remained below the NHMRC guidelines, and antimony and arsenic were rarely detected during monitoring.
- Antimony and arsenic concentrations at site SW01 showed a decline during remediation and post-remediation phases, although have not shown any significant decrease since and concentrations remain above NHMRC guideline values. Signs discouraging recreational use of this wetland area should remain in place until further monitoring can prove a decline of concentrations below the guideline values.
- Aluminium, iron, manganese, lead, and zinc remained present post remediation at Station Creek (SW02), although at levels suitable for swimming. Disturbances associated with the rehabilitation appear to have increased arsenic concentrations in Station Creek although concentrations remain below NHMRC recreational guidelines.
- The arsenic concentration at Station Creek appear to increase after rainfall, suggesting the source is upstream. Arsenic was shown to be mostly bound to sediment with only 25% dissolved, suggesting arsenic will only leave the site during high flow and disturbance only which may explain the increased concentrations in surface waters during remediation.
- Site SW05 in the S-shaped water storage channel showed no statistically significant increasing trend in the post-remediation dataset for iron and copper, and antimony, arsenic, aluminium, lead, and zinc, showed decreasing trends.
- Leachate monitoring at the monocell (SW16) showed decreasing trends of arsenic, aluminium, nickel, lead and zinc concentrations and the majority of samples indicate that the arsenic and antimony concentrations are within the project discharge guideline values.
- pH measurements at the site have remained within the normal range for the part of estuary throughout the project.
- Conductivity measurements showed an increase at SW01 and SW02 post remediation in comparison with pre remediation values which may be explained by wetter conditions during pre-remediation monitoring, although measurements remain within normal range for its environment.
- SW03 conductivity in measurements are influenced by tidal movements and have remained within the ranges measured during pre-rehabilitation monitoring.
- Total suspended solids increased at site SW05 in the post-remediation phase.
- There were notable increases in the groundwater post-remediation measurements of copper, manganese, iron, nickel, and zinc at GW02 when compared with measurements taken during the remediation phase.
- Groundwater quality results at GW01 showed an increase in pH, TSS, iron, manganese, and zinc during post-remediation measurements compared with pre remediation

33 Birch, M. (2019). Urunga Wetlands Post-Remediation Water Quality Monitoring Completion Report. Aquatic Science and Management. Prepared for NSW Soil Conservation Service and GHD.

measurements. GW01 is upgradient of the monocell, therefore these results are unlikely due to remediation efforts.

- Groundwater measurements all comply with guidelines for drinking water with the exception of pH and nickel. The good water quality results from downgradient of the monocell imply that the monocell is maintaining its integrity and that the treatment and storage of polluted materials has been successful.
- Groundwater dynamics have not been affected by remediation efforts.
- Overall remediation efforts have had a positive impact on water quality.

Figure 4-14. Monitoring sites for contaminated land remediation project at Urunga APP.

Table 4-20: Problem or remediation areas identified within the Urunga Wetlands post-remediation water quality monitoring complete report (2019).

Name	Description	Easting	Northing
SW01	Antimony and arsenic concentrations remain above NHMRC guideline values. Signs discouraging recreational use of this wetland area should remain in place until further monitoring can prove a decline of concentrations below the guideline values.	501099.6	6625245.2
SW05	Total suspended solids increased at site SW05 in the post-remediation phase.	501066.4	6625265.7
GW01	Groundwater quality results showed an increase in pH, TSS, iron, manganese, and zinc during post-remediation measurements compared with pre remediation measurements. GW01 is upgradient of the monocell, therefore these results are unlikely due to remediation efforts.	500861.5	6625298.8
GW02	There were notable increases in the groundwater post-remediation measurements of copper, manganese, iron, nickel, and zinc when compared with measurements taken during the remediation phase.	500932.8	6625254

A.23 Urunga Wetland Water Quality Monitoring Report - Soil Conservation Service (SCS) (2021)

SCS (2021) continues water quality monitoring efforts at the disused Antimony Processing Plant (APP) at Urunga, and monitors from the 5th of November 2020 to the 27th of May 2021 at the same sites as previously monitored (See A.22). Results are compared with those documented in Post remediation Water Quality Monitoring Completion Report- June 2019, prepared by Aquatic Science and Management.

General findings:

- As a direct consequence of contamination from the former antimony processing plant, antimony (Sb) and arsenic (As) remain the most prevalent contaminants of concern in the wetland system.
- Arsenic and Antimony varied from being below the ANZECC freshwater thresholds to being above the NHMRC thresholds at SW01.
- Of the 9 arsenic samples, 5 breached the ANZECC threshold and 1 the NHMRC with the highest result of 0.074mg/L being 6 times the ANZECC threshold but only marginally above the NHMRC.
- Of the 9 antimony samples, 5 breached the ANZECC threshold and 2 the NHMRC with the highest result of 0.088mg/L being 10 times and 3 times the ANZECC and NHMRC thresholds, respectively.
- Aluminium measurements showed a trend of increased concentrations with increased turbidity suggesting that mobilised sub-soil erosion within the catchment area is likely a source of this metal.
- Although mean concentrations for arsenic and antimony at SW01, SW18, and SW21 were equal to or below the NHMRC thresholds, may individual samples were not. Therefore, the wetland is not suitable for human recreational use, particularly during low rainfall periods.
- Comparison of the SW01 mean arsenic and antimony concentrations with those of previous monitoring periods shows a trend of continued notable reduction in these metals has occurred, suggesting contamination removed during remediation has resulted in continued water quality improvements in the upper wetland.
- Surface water quality at SW02 show that 1 individual arsenic sample breached NHMRC thresholds making this area unfit for human recreational use.
- Concentrations of arsenic and antimony have changed very little at SW02 across the three monitoring periods.
- Comparison of the upper and lower wetlands show that arsenic concentrations persist from the upper to the lower wetland whereas antimony concentrations decline marginally.
- Surface water results at the Urunga Sea Lido (SW03) show that contaminants remain below NHMRC thresholds, and the area remains fit for human recreational use.
- Surface water results at SW05 show that contaminants remain below NHMRC thresholds, and the area remains fit for human recreational use.
- ANZECC threshold breaches at SW03 are highly likely due to the former APP.
- Neither arsenic or antimony were detected in groundwater monitoring at GW02 downslope of the monocell suggesting it has maintained its integrity. GW02 complies with the ADWG aside from low levels of nickel and low pH breaching the thresholds.
- Results for GW01 upslope of the monocell show antimony and nickel above ADWG thresholds in all monitoring priods. Known sources of contaminated surface soil identified in Whitehead and Associates (2020)[34] on the adjoining property directly to the southwest are a potential source of this contamination.

34 Whitehead and Associates (2020), Detailed Environmental Site Assessment at 4114 & 4120 Giinagay Way, Urunga.

Recommendations

- On-going monitoring to capture a full 12-month period is recommended to establish long term water quality trends. Focus should be on SW01 and SW02 where the contamination is the most prevalent.
- A reduction in sampling frequency and or emission of sites from monitoring is recommended for negligible to low-risk sites (SW05, SW16, SW01), sites where long-term comparative data is unavailable (SW18 and SW21) and at duplicate sites (SW18 or SW21).
- Signs at SW01 discouraging recreational use of this wetland area should remain in place until further monitoring can prove a decline of concentrations below the guideline values.

Table 4-21: Problem or remediation areas identified within the Urunga Wetlands water quality monitoring report (2021)

Name	Description	Easting	Northing
SW01	Arsenic and Antimony varied from being below the ANZECC freshwater thresholds to being above the NHMRC thresholds. This wetland is not fit for human recreational use, particularly during low rainfall periods.	501099.6	6625245.2
SW02	Surface water quality at SW02 show that 1 individual arsenic sample breached NHMRC thresholds making this area unfit for human recreational use, particularly during low rainfall periods.	502048.3	6625563.7
SW18	Although mean concentrations for arsenic and antimony at SW01, SW18, and SW21 were equal to or below the NHMRC thresholds, may individual samples were not. Therefore, the wetland is not suitable for human recreational use, particularly during low rainfall periods.	500833.3	6625134.9
SW21		500949.4	6625192.5
GW01	Results upslope of the monocell show antimony and nickel above ADWG thresholds in all monitoring priods.	500861.5	6625298.8
GW02	GW02 complies with the ADWG aside from low levels of nickel and low pH breaching the thresholds.	500932.8	6625254

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