Sydney Drinking Water Catchment Audit 2019-22

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In the spirit of reconciliation Eco Logical Australia acknowledges the Traditional Custodians of Country throughout the Sydney Drinking Water Catchment and their connections to land, rivers, creeks, other waterbodies, and the community. We pay our respects to their Elders past and present, and extend that respect to all Aboriginal and Torres Strait Islander peoples.

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To the NSW Minister for Water

Dear Minister

On behalf of the audit team, I am pleased to present the 2019-22 Sydney Drinking Water Catchment Audit report. This report is intended for tabling in Parliament, as required under section 42 of the *Water NSW Act 2014*.

The audit provides information about the health of the Sydney Drinking Water Catchment during the period 1 July 2019 to 30 June 2022. The audit team has assessed the state of the declared Catchment, having regard to the 18 Catchment health indicators approved under section 41 of the *Water NSW Act 2014*. The indicators relate to water quality, water availability, biodiversity and habitats, and land use and human settlements.

The audit report has been developed in consultation with the community, industry, local councils and NSW Government agencies. The audit team has collected, reviewed and analysed data and information available for the audit period and longer term, and conducted site inspections to determine:

- How healthy was the Catchment during the audit period in the context of longer-term trends?
- What were the main adverse impacts (pressures) on Catchment health and have these been decreasing, increasing or similar?
- What responses are needed to address the main threats to Catchment health?

The audit has formed 24 recommendations under the themes of climate change, land management and pollution. The responses have been developed in consultation with the relevant public authorities. Progress on implementation of audit recommendations will be documented by WaterNSW in publicly available annual catchment management reports.

We commend this audit report to you for tabling in the NSW Parliament and thank all contributors for their cooperation and assistance during the audit.

Beth Medway RPIA
Lead Auditor

Executive summary

Audit process

This audit assessed the health of the Sydney Drinking Water Catchment ('the Catchment') having regard to 18 indicators approved under section 41 of the *Water NSW Act 2014*. The audit used the state-pressure-response framework consistent with NSW state of environment reporting to identify the main risks to Catchment health. The state of the Catchment was assessed for the period 1 July 2019 to 30 June 2022 and compared to long-term conditions based on available data and studies. The audit was prepared by Eco Logical Australia and Restore Environmental Consultants in consultation with government and non-government stakeholders. WaterNSW was the lead agency for the audit on behalf of the NSW Minister for Water.

Key findings

Sydney's Drinking Water Catchment is a vital natural asset that supports our health, economy and natural environment. Actions taken by government, industry and the community since 1999, when the first audit was conducted, have reduced many hazards to Catchment health. These positive actions have included implementation of pollution controls, restoration and rehabilitation, and evidence-based decision-making. Examples of measures taken during the 2019-22 audit period to protect or improve Catchment health included:

- Refinement of the strategic planning and policy context, with a focus on climate change adaption and mitigation, water management and land use planning.
- Tightening regulatory requirements for mining and coal-fired power stations in the Catchment.
- Shifts to more sustainable land uses, including regenerative agriculture[1], renewable energy and water sensitive urban design.
- Establishment of the 30,000 ha Gardens of Stone State Conservation Area, with funds and resources assigned to pest and weed control, conservation of threatened species, swamp restoration and erosion control.

However, the 2022 audit also found climate-driven events and cumulative impacts have had a negative influence on Catchment health. Examples included:

- Reduced availability of suitable raw water due to severe drought, bushfires and subsequent heavy rainfall.
- Deteriorating wetlands due to the combined effects of bushfire and longwall mining.
- Declining macroinvertebrate communities due to instream and riparian habitat degradation associated with changes to water flows, water quality and vegetation.
- Amenity and environmental quality affected by illegal waste dumping.

[1] NSW Agriculture defines regenerative agriculture as 'a diverse range of approaches that sustain financially viable farming enterprises, restore and enhance ecosystem function on farms and landscapes, and help farmers achieve their social and lifestyle objectives'.

Climate change is predicted to drive more frequent and extreme natural disasters in coming years. This will threaten the resilience or capacity of the Catchment to maintain essential ecosystem services such as the provision of adequate, good quality source water. The evidence from the 2022 audit underscores the important role of climate in Catchment health and suggests that it is unlikely that good land management practices and pollution regulation will maintain Catchment health in future unless substantial effort is also made to reduce greenhouse gas emissions and limit climate change impacts.

Catchment state and trends

The overall state or condition of each Catchment health indicator during the 2022 audit period was assessed as good, moderate, poor or unknown, as summarised in the table below. Trends were categorised as improving, stable or worsening, and determined by comparing findings from the audit period against available long-term datasets and information, including findings from the first audit (CSIRO 1999). The overall suitability of information available for the assessment of each indicator is noted in the following table.

Summary of the overall state and trend for each indicator of Catchment health

Catchment health indicator	State during the audit period	Trend – current audit period compared to long-term	Suitability of information
Community attitudes, aspirations and engagement	Moderate	Stable	✓✓
Cyanobacterial blooms	Moderate	Stable	✓✓✓
Ecosystem and raw water quality	Moderate	Worsening	✓✓✓
Environmental flows	Good	Stable	✓✓✓
Fire	Poor	Worsening	✓✓✓
Fish	Moderate	Stable	✓
Groundwater availability	Good	Stable	✓✓
Land use	Moderate	Stable	✓✓
Macroinvertebrates	Moderate	Worsening	✓✓
Native vegetation	Moderate	Stable	✓✓
Nutrient load	Poor	Worsening	✓✓
Physical form	Moderate	Stable	✓✓✓
Population settlements and patterns	Moderate	Stable	✓✓✓
Riparian vegetation	Moderate	Stable	✓
Sites of pollution and potential contamination	Moderate	Stable	✓✓✓
Soil erosion	Moderate	Worsening	✓✓
Surface water flow	Good	Worsening	✓✓✓
Wetlands	Moderate	Worsening	✓✓

Further to the overall findings on Catchment health by indicator, this audit considered the state and trends for broad geographic areas within the Catchment. The 2019-22 audit found that the Special Areas continued to be the healthiest and most resilient parts of the Catchment, despite much of these areas having been severely burnt in 2019-20 and subsequently affected by heavy rain and hillslope erosion. The Special Areas generally had better ecological health than other areas of the Catchment, as indicated by good native vegetation cover, riparian vegetation condition and connectivity, and diversity of macroinvertebrates and fish. Water quality in the Special Areas was generally better than in more disturbed areas, and the physical form of watercourses in the Special Areas were mostly intact. The relatively good health of the Special Areas and their important role in the multiple barrier approach to protecting Sydney's drinking water continues to be supported by joint managers WaterNSW and National Parks and Wildlife Service through restricting access and controlling pests, weeds and erosion.

Compared to conditions in the Special Areas, many other parts of the Catchment continued to feature more degraded landscapes. Areas of poor health within the Catchment during the audit period were characterised by low or no native vegetation, poor water quality, severely impacted macroinvertebrate populations, presence of polluting activities and disengaged communities. These areas included:

- Agricultural properties with poor land management practices and poorly managed waterways (e.g., no native riparian vegetation, uncontrolled stock access, erosion)
- Watercourses in poor condition with moderate or low recovery potential
- Wetlands that have been degraded and are deteriorating
- Sites subject to pollution or contamination
- Poorly designed and/or maintained stormwater and on-site sewage management systems
- Sites affected by illegal activities e.g., rubbish dumping, unauthorised tracks
- Areas subject to unsustainable surface water or groundwater extraction volumes.

Risks and desired outcomes to be addressed by the audit recommendations

The overarching risks to Catchment health and desired outcomes to be addressed by the 24 audit recommendations are as follows and have been developed in consultation with government agencies under three themes:

Theme	Risks	Desired outcomes
Climate change	Catchment health and the security of Sydney's drinking water are increasingly threatened by climate-driven events, including severe drought, floods, heatwaves, storms and bushfires.	Greenhouse gas emissions in the Catchment are reduced to help meet the NSW Government net zero emissions targets (mitigation). Disruptions to Catchment management and monitoring caused by extreme climate-driven events are minimised (adaptation).
Land management	Ineffective and/or unsustainable land management practices are applied in the Catchment.	Sustainable land use practices, including water sensitive design and regenerative agriculture, are adopted more widely across the Catchment to improve ecosystem services and support communities.
Pollution	Pollution degrades Catchment health.	Less pollution in the Catchment.

Progress against the audit recommendations will be presented to the Minister and community annually and reviewed during the next Catchment audit in 2025.

Contents

List of Figures

Photos on audit report cover and title pages:

Main report cover page: Cordeaux Dam (photo provided by WaterNSW)
Appendix report cover page: Lake Burragorang during March 2021 wet weather event (photo provided by WaterNSW)
Audit Framework: Stormwater management by Blue Mountains City Council at Central Park, Wentworth Falls (November 2022)
Pressures on the Catchment: Landscape rehydration and restoration in the Mulloon Creek catchment (November 2022)
State of the Catchment – Biodiversity and Habitats: Stormwater management by Blue Mountains City Council at Leura Park (November 2022)
State of the Catchment – Water Availability and Quality: View south from Burragorang lookout (November 2022)
Responses and Recommendations: Rural Landscapes Program site near Braidwood (November 2022)

List of Tables

Abbreviations

Abbreviation	Description
ABS	Australian Bureau of Statistics
ACMR	Annual Catchment Management Report
ANWQMS	Australian and New Zealand Water Quality Management Strategy
ANZECC	Australian and New Zealand Environment and Conservation Council
ARRC	Australian River Restoration Centre
AUSRIVAS	Australian River Assessment System
BC Act	NSW *Biodiversity Conservation Act 2016*
BLR	Basic Landholder Rights
BMCC	Blue Mountains City Council
BoM	Bureau of Meteorology
CARM	Catchment and river modelling
CLUM	Catchment Scale Land Use Mapping
DPE	NSW Department of Planning and Environment
BCSD	Biodiversity, Conservation and Science Directorate (within the Environment and Heritage Group of DPE)
DPI	NSW Department of Primary Industries
DPIE	NSW Department of Planning, Infrastructure and Environment
EPA	NSW Environment Protection Authority
GDE	Groundwater Dependent Ecosystems
ha	Hectares
km	Kilometres
LGA	Local Government Area
LLS	Local Land Services
LTAAEL	Long term average annual extraction limit
ML	Mega litres
NHMRC	National Health and Medical Research Council
NorBE	Neutral or beneficial effect
NOW	NSW Office of Water
NPWS	National Parks and Wildlife Service
NRAR	NSW Natural Resources Access Regulator
OECC	Office of Energy and Climate Change
OECD	Organisation for Economic Co-operation and Development
OEH	NSW Office of Environment and Heritage
RFS	Rural Fire Service

Abbreviation	Description
RID	Regional Illegal Dumping
ROC	Rivers of Carbon
SASPoM	Special Areas Strategic Plan of Management
SEED	Sharing and Enabling Environmental Data
SELLS	South East Local Land Service
SEPP	State Environmental Planning Policy
WAL	Water access licence
WSP	Water Sharing Plan

Audit Framework

1. About this audit

This independent audit draws on multiple sources of evidence to assess the health of the declared Sydney Drinking Water Catchment ('the Catchment'; Figure 1-1). The audit has been prepared in consultation with government and non-government stakeholders using the pressure-state-response framework. Recommendations are provided to inform future management of the Catchment.

1.1. Audit purpose and scope

1.1.1. Statutory requirement to undertake the audit

This audit satisfies statutory obligations under section 42 of the *Water NSW Act 2014* to assess the health of the Catchment, as indicated in Table 1-1.

Table 1-1: Statutory audit requirements

Requirements	Response
'(1) The Minister:	NSW Minister for Water.
(a) must appoint a public authority or other person to be the appointed auditor to carry out functions under this section in relation to the Sydney catchment area, and	An independent expert team was engaged by WaterNSW on behalf of the Minister to conduct the 2022 Catchment audit. (Appendix A)
(b) may appoint a public authority or other person to be the appointed auditor to carry out functions under this section in relation any other declared catchment area.	There are no other declared catchment areas at this time.
(2) The appointed auditor must:	
(a) conduct an audit (a catchment audit) of the catchment health of the declared catchment area, and	Completed.
(b) present a report on that audit to the Minister.	Report to be presented to the Minister by 30 June 2023
(3) The catchment audit must assess the state of the declared catchment area having regard to the catchment health indicators approved under section 41 for the area, as in force at the time of the assessment.	The state of the Catchment was assessed in this audit report; refer to Table 1-2 for indicators.
(4) A catchment audit for the Sydney catchment area must be conducted, and a report presented to the Minister on that audit (the initial report), no more than 3 years after the day on which section 4 commences. Subsequent audits must be conducted, and reports must be presented to the Minister on those audits, at intervals of no more than 3 years calculated from the day the initial report is presented.	Audit report to be presented to the Minister by 30 June 2023, which is three years after the 2019 audit report was submitted.
(6) The Minister is to table the report (or cause it to be tabled) in both Houses of Parliament within one month after the Minister receives the report.	Pending at the time of writing this report.
(7) The Minister is to forward a copy of the report of a catchment audit to WaterNSW as soon as practicable after the report is received.'	Pending at the time of writing this report.

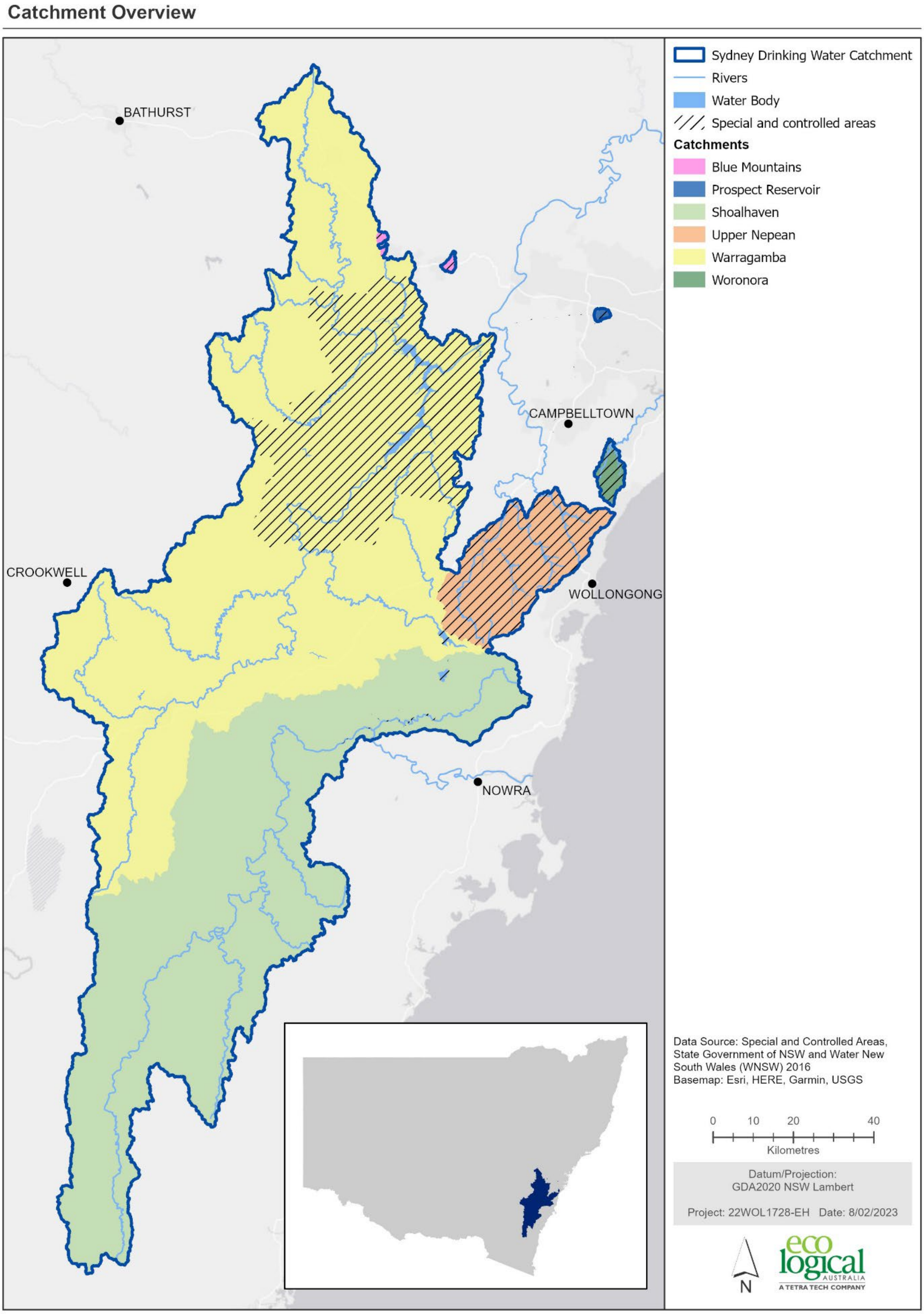

Figure 1-1: Major sub-catchments and Special Areas within the Sydney Drinking Water Catchment

1.1.2. Terms of reference

The terms of reference for the 2022 Catchment audit were defined by WaterNSW in the brief to the audit team as follows:

- 'The Catchment audit is required to assess the state of the Catchment having regard to the health indicators approved under section 41 of the *Water NSW Act 2014* and in force at the time of assessment.
- The Catchment audit is to be conducted having regard to the current methodology used in the state of environment reporting for NSW.
- Consultation must be undertaken with stakeholders inside and outside the Catchment to seek information and data that may assist with the audit and to seek comments relating to the state of the Catchment.
- The audit is to cover the period from 1 July 2019 to 30 June 2022.

The 2022 Catchment audit is required to assess:

- The change in Catchment pressure indicators from the 2019-22 audit period against the 1999 baseline (when the first audit was published (CSIRO 1999)).
- The temporal trend in Catchment state indicators from 1999 to 2022, where sufficient data are available to support this. A clear description of the data preparation and trend analysis methodology should be provided, including an explanation of how the analysis has considered the effects of variability in climate, streamflow conditions and sampling effort on trend detection.'

1.1.3. Catchment health definition and indicators

Section 3 of the *Water NSW Act 2014* defines Catchment health as follows:

> 'Catchment health, in relation to the catchment area, means the condition of ecosystems and systems of management (such as sewerage and stormwater systems) in that catchment that protect water quality'.

The audit is required to assess the state of the Catchment having regard to 18 indicators of Catchment health approved under section 41 of the *Water NSW Act 2014* and listed in the NSW Government Gazette No.158 (19 December 2008). The 18 health indicators are catalogued in Table 1-2. A 2009 Technical Report by the NSW Office of Water (NOW) explained how the indicators were selected. It also recommended methods for collection of data for each indicator and identified which government agencies have responsibility for data collection. These methods are summarised in Appendix B with updated information for this audit.

Table 1-2: Catchment health indicators

Catchment health indicator	Where addressed in this report
Community attitudes, aspirations and engagement	Sections 4.3, 8.3 and 12.4
Cyanobacterial blooms	Section 19.6
Ecosystem and raw water quality	Section 19
Environmental flows	Section 17.2
Fire	Section 6
Fish	Section 11
Groundwater availability	Section 18
Land use	Section 7
Macroinvertebrates	Section 10
Native vegetation	Section 13
Nutrient load	Section 9.2
Physical form	Section 15
Population settlements and patterns	Section 7.1
Riparian vegetation	Section 12
Sites of pollution and potential contamination	Section 9
Soil erosion	Section 16
Surface water flow	Section 17.1
Wetlands	Section 14

Source: NSW Office of Water 2009 Technical Report

1.2. Audit method

1.2.1. Audit standard

The audit method was designed to satisfy Australian Audit Standard ASAE 3500 'Performance Engagements' and other professional standards. The standards require the audit team to comply with relevant ethical requirements, and plan and perform the audit to obtain reasonable assurance and draw conclusions on the audit objectives.

1.2.2. Information used in the audit

Available information was reviewed and analysed by the auditor to determine the status of each indicator during the audit period (1 July 2019 to 30 June 2022). Longer term trends were identified where there were available, comparative data. Baseline conditions from the first audit (CSIRO 1999) were considered.

Many data types and collection methods have changed since the first audit report was prepared (CSIRO 1999) or since the Catchment health indicators were nominated in the Technical Report (NOW 2009). The spatial and temporal scale of datasets relevant to Catchment health varies widely, which was also noted in the first Catchment audit (CSIRO 1999); ‘The data for many attributes is not always presented on a catchment basis’. The 2022 audit team therefore sought, obtained, analysed and reviewed information relevant to the indicators, including but not limited to the sources recommended in the 2009 Technical Report.

The following criteria were considered when selecting information for this audit and are consistent with the 2009 Technical Report:

- Relevance to the Catchment and the formal definition of Catchment health under the *Water NSW Act 2014*
- Has an agreed scientifically or socio-economically sound meaning
- Representative of environmental conditions within the Catchment, pressures on the environment, or society's responses
- Measurable
- Ease of interpretation and ability to show trends over time
- Responsive to environmental changes and related human activity
- Assists management decision making and policy development
- Aligns with state of environment reporting and with WaterNSW's environmental reporting responsibilities (such as reporting required under its operating licence).

Information gathered for the audit included raw monitoring data, analysis reports, strategies, plans and policy documents, stakeholder submissions and consultation, and site inspections by the auditor. Appendix B summarises the main types of information used in this audit for each approved indicator.

1.2.3. Pressure-State-Response framework

The audit method was based on the pressure-state-response framework, developed by the Organisation for Economic Cooperation and Development (OECD 1993) and used for state of environment reporting in NSW. The pressure-state-response model provides a structure that links environmental policies to environmental monitoring and reporting. The model considers that human activities exert pressures[2] or impacts on the environment that affect the quality and quantity of natural resources ('state'); and society responds to these changes through environmental, general economic and sectoral policies and through changes in awareness and behaviour ('response'). The framework highlights cause-effect relationships, and helps decision makers and the public see environmental, economic, and social issues as inter-connected.

In this audit, the 'state' of a Catchment health indicator was categorised as:

- Good – the data generally show a positive or healthy condition
- Moderate – the data show that the condition was neither good nor poor, or results may be mixed across the Catchment
- Poor – the data generally indicate poor condition or condition under stress.

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[2] The 2018 National Water Quality Management Strategy defines a pressure as 'any human activity or biophysical pattern of change that has the potential to impact on the natural environment'.

The response part of the model refers to the extent to which society responds to the state and pressures. Response refers to individual and collective actions intended to:

- Mitigate, adapt to or prevent human-induced negative effects on the environment
- Halt or reverse environmental damage already inflicted
- Preserve and conserve nature and natural resources.

Responses aim to achieve behavioural changes or actions focussed on damage control and rehabilitation. Examples include education programs, grants and incentive schemes, planning controls, policies and legislation. In general, a greater response or change will be required if the state is poor, the trend is worsening, and pressures are increasing.

Trends (improving, stable or worsening) describe the direction of change in condition (pressure or state) between the current audit period and previous timeframes, as determined by available datasets.

The terms of reference for this audit (section 1.1.2) require 'an explanation of how the analysis has considered the effects of variability in climate, streamflow conditions and sampling effort on trend detection'. Climate and weather patterns are discussed in section 5 as context for this audit and streamflow conditions are reviewed in section 17. These are also considered where relevant to analysis of Catchment health indicators.

The main limitation of the pressure-state-response framework is that it tends to 'average' results of multi-criteria analysis rather than focus on key risks or issues. For example, across the Catchment landscape there will be areas in poor condition and areas in good condition, but the outcome of the assessment will present as an overall moderate condition. For this reason, the audit has applied the pressure-state-response framework to identify broad trends across the Catchment and identified key risks and issues at finer scale. This approach is similar to the first Catchment audit (CSIRO 1999) (see section 2.3), which provided comment about the overall health of the Catchment with more detail on specific issues that required a management response.

1.2.4. Consultation

Stakeholder consultation was an important part of this audit and consultation methods are summarised in Appendix C. Stakeholders invited to participate in this audit included representatives from government agencies, industry and the community. Stakeholders were asked to:

- Provide data and information relevant to the audit, including information requested by the audit team
- Highlight issues, concerns and opportunities for improvement
- Discuss potential responses and recommendations.

We gratefully acknowledge the cooperation and assistance of WaterNSW as the lead agency for the audit. We also thank the other government and non-government stakeholders who provided information to the audit team and/or participated in meetings or field visits.

2. Catchment overview

The Catchment covers diverse landscapes and communities, with multiple agencies involved in its management. It collects and stores up to 2.6 million ML of water from private and public land to supply Sydney, the Blue Mountains, the Illawarra, Southern Highlands, Goulburn and parts of the Shoalhaven.

2.1. Catchment features

Sydney's Drinking Water Catchment or 'hydrological catchment' was first referred to in the *Sydney Water Catchment Management Act 1998* (now repealed) and declared in Gazette 175 (page 9268) on 16 November 2001. The declared Catchment (Figure 1-1) is defined in clause 17 of schedule 2 of the *Water NSW Act 2014.* It extends over 16,000 km^2 and covers parts of the hydrologic catchments of the Hawkesbury–Nepean, Shoalhaven and Woronora Rivers from:

- North of Lithgow on the Coxs River, including Prospect Reservoir in western Sydney
- The head of the Shoalhaven River in the south near Cooma
- Woronora River in the east
- The source of the Wollondilly River west of Goulburn.

The Catchment forms part of the Great Dividing Range and its rivers eventually flow to the east coast. Its topography (Figure 2-1) is characterised by undulating hills in the south-western parts of the Catchment and steeply incised gorges near the storages in the northern parts of the Catchment. Elevations are lower than 1500 m above sea level.

The Catchment is characterised by six major river systems - Blue Mountains, Shoalhaven, Upper Nepean, Warragamba, Woronora and Prospect Reservoir (Figure 1-1). The Shoalhaven and Warragamba are the largest river systems, with 12 sub-catchments each, whereas the Blue Mountains, Prospect Reservoir, Upper Nepean and Woronora have one sub-catchment each (Table 2-1).

The sub-catchments drain into reservoirs that have been created by dams to store 'raw water', which has not yet been treated for drinking water purposes. Table 2-1 lists the raw water storages in the Catchment and indicates if they are managed by WaterNSW or a local council. Raw water is extracted directly from the Shoalhaven River by Queanbeyan-Palerang Regional Council to supply Braidwood, Wollondilly River by Goulburn Mulwaree Council to supply Goulburn and Marulan, Farmers Creek by Lithgow City Council to supply Lithgow, and Bundanoon Creek by Wingecarribee Council. The transfer routes for water around the system are shown in the water supply system schematic (Figure 2-2).

For management purposes, the Catchment comprises inner and outer catchment areas:

- The inner catchment comprises the Special Areas (Warragamba, Metropolitan, Woronora, Blue Mountains (Blackheath, Katoomba and Woodford), Shoalhaven, Fitzroy Falls and Wingecarribee) (Section 3.12) and the hydrological catchment of Prospect Reservoir.
- The outer catchment comprises the hydrological catchments of the Warragamba River and its tributaries which drain to Lake Burragorang; the Shoalhaven River and its tributaries which drain to Lake Yarrunga; and Greaves, Whipcord, Woodford and Cascades Creeks in the Blue Mountains, but excluding the inner catchment area described above.

Table 2-1: Major rivers, sub-catchments and storages

ID#	Sub-catchment	Major river system	Raw water storage*
1	Back & Round Mountain Creek	Shoalhaven	
2	Boro Creek	Shoalhaven	
3	Braidwood	Shoalhaven	
4	Bungonia Creek	Shoalhaven	Lake Yarrunga
5	Endrick River	Shoalhaven	
6	Grose River	Blue Mountains	
7	Jerrabattagulla Creek	Shoalhaven	
8	Kangaroo River	Shoalhaven	Fitzroy Falls Dam, Lake Yarrunga *Bundanoon Creek Dam*
9	Kowmung River	Warragamba	
10	Lake Burragorang	Warragamba	Lake Burragorang
11	Little River	Warragamba	Lake Burragorang
12	Lower Coxs River	Warragamba	Lake Burragorang
13	Mid Coxs River	Warragamba	
14	Mid Shoalhaven River	Shoalhaven	
15	Mongarlowe River	Shoalhaven	
16	Mulwaree River	Shoalhaven	
17	Nattai River	Warragamba	
18	Nerrimunga River	Warragamba	
19	Prospect Reservoir	Prospect Reservoir	Prospect Reservoir
20	Reedy Creek	Shoalhaven	
21	Upper Coxs River	Warragamba	*Farmers Creek Dam*
22	Upper Nepean River	Warragamba	Avon Dam, Cataract Dam, Cordeaux Dam, Nepean Dam, Upper Cordeaux Dam, Wingecarribee Dam
23	Upper Shoalhaven River	Upper Nepean	
24	Upper Wollondilly River	Shoalhaven	*Pejar Dam* *Sooley Dam*
25	Werri Berri Creek	Warragamba	Lake Burragorang
26	Wingecarribee River	Warragamba	Wingecarribee Dam
27	Wollondilly River	Warragamba	Lake Burragorang
28	Woronora River	Woronora (also referred to as Metropolitan)	Woronora Dam

Identification for sub-catchments used in maps throughout this audit report

*Italicised raw water storages are managed by local councils rather than WaterNSW

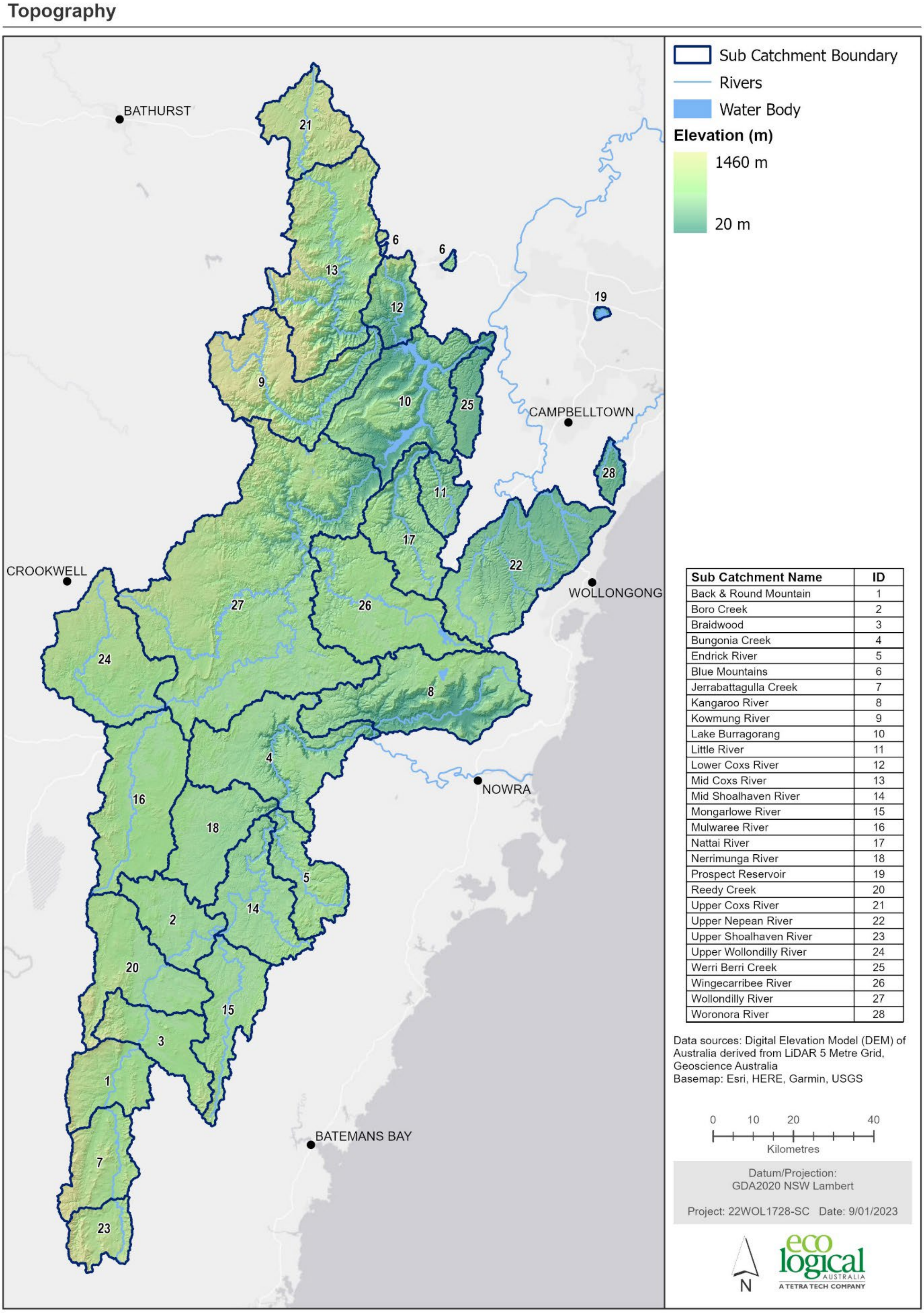


Figure 2-1: Catchment topography

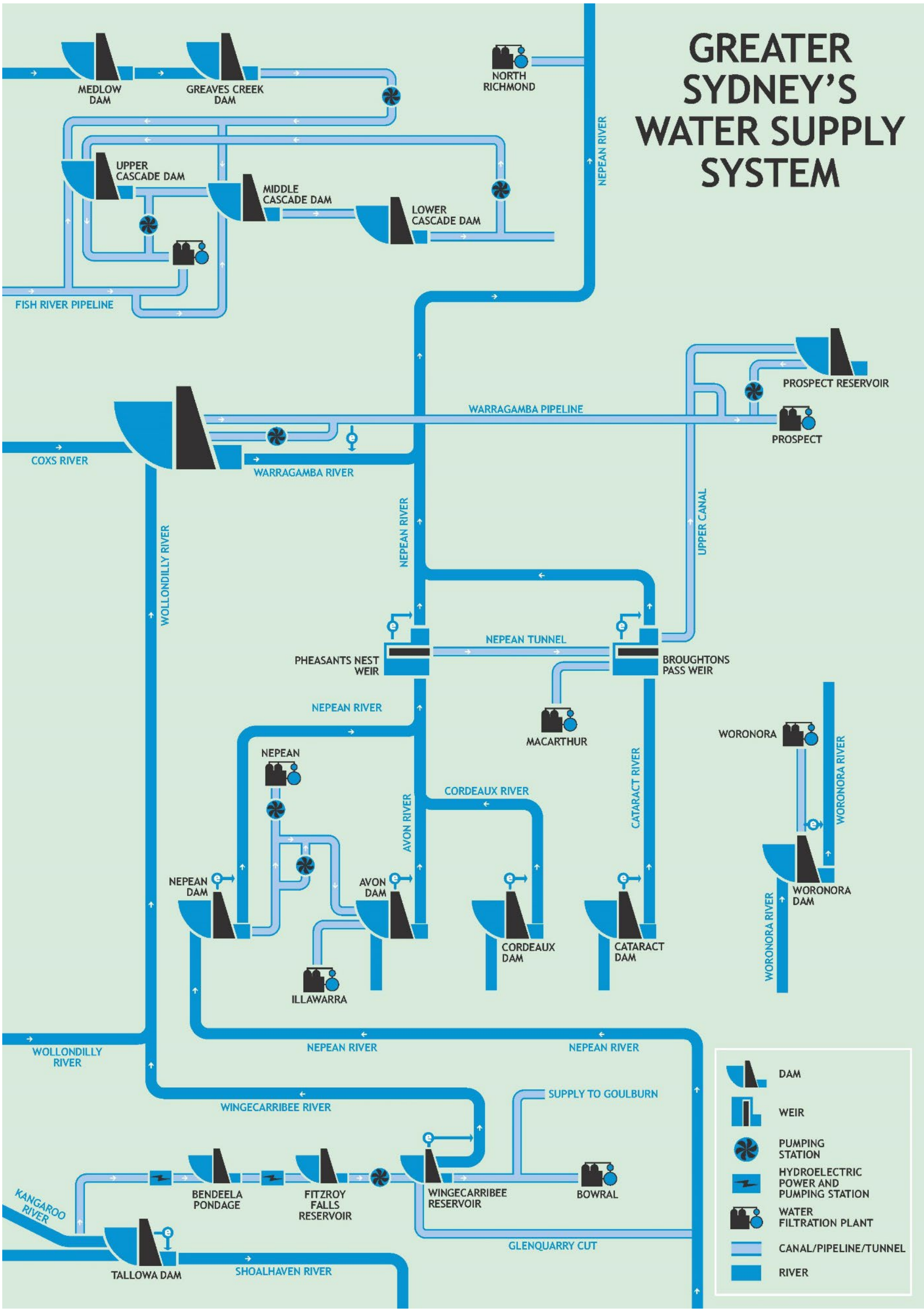


Figure 2-2: Greater Sydney's Water Supply System (WaterNSW 2019a)

2.2. Catchment management

More than five million people in Sydney, the Illawarra, Blue Mountains, Southern Highlands, Goulburn and Shoalhaven regions rely on access to good quality drinking water. Water quality management follows a multiple barrier approach consistent with the Australian Drinking Water Guidelines (National Health and Medical Research Council 2011[3]). Elements of the multiple barrier approach are illustrated in Figure 2-3 and include:

1. Monitoring and influencing land use, development and activities across the Catchment
2. Establishing, maintaining and managing Special Areas and Controlled Areas around water storages and water supply infrastructure, where human access or certain activities are restricted (refer to section 3.12 for further information)
3. Reservoir management
4. Water treatment and distribution.

Catchment management is the first barrier for the protection of water quality and availability. By decreasing contamination of the source water, the level of water treatment required (and associated costs and risks) can be reduced. Catchment management includes applying nature-based solutions such as increasing native vegetation cover and connectivity, protecting and rehabilitating wetlands, and rehydrating landscapes. The benefits of nature-based solutions for catchment and water management are summarised by UN Environment (2018).

Filtration plants cannot treat raw water for drinking water supply if the raw water is not of suitable quality or quantity. There is some flexibility in where the raw water is taken from, but the offtake system has limits. To demonstrate this, Sydney Water's 'Save it with me' campaign in 2022-23 encouraged the community to conserve water despite the dams in the Catchment being full or overflowing. The campaign explained to the community that only 15 m of the 60 m deep Warragamba Dam storage was treatable at that time due to consecutive floods and other impacts in the Catchment.

2.3. Baseline conditions

The terms of reference for this audit defined 'baseline' conditions in the Catchment as those in 1999, when the first audit was conducted by CSIRO. However, the 'base-line data set' assembled by the Sydney Catchment Authority (CSIRO 1999) was not available for the current audit. To provide a more complete analysis of Catchment health, the current audit supplemented descriptive information from the CSIRO (1999) audit report with long-term quantitative datasets and other information for the purposes of determining long-term changes in pressures, state and responses. Some datasets used in the current audit to help define baseline conditions extended prior to 1999.

Table 2-2 provides the key findings of the 1999 audit with links to updated information in the current audit.

[3] This publication is subject to rolling updates

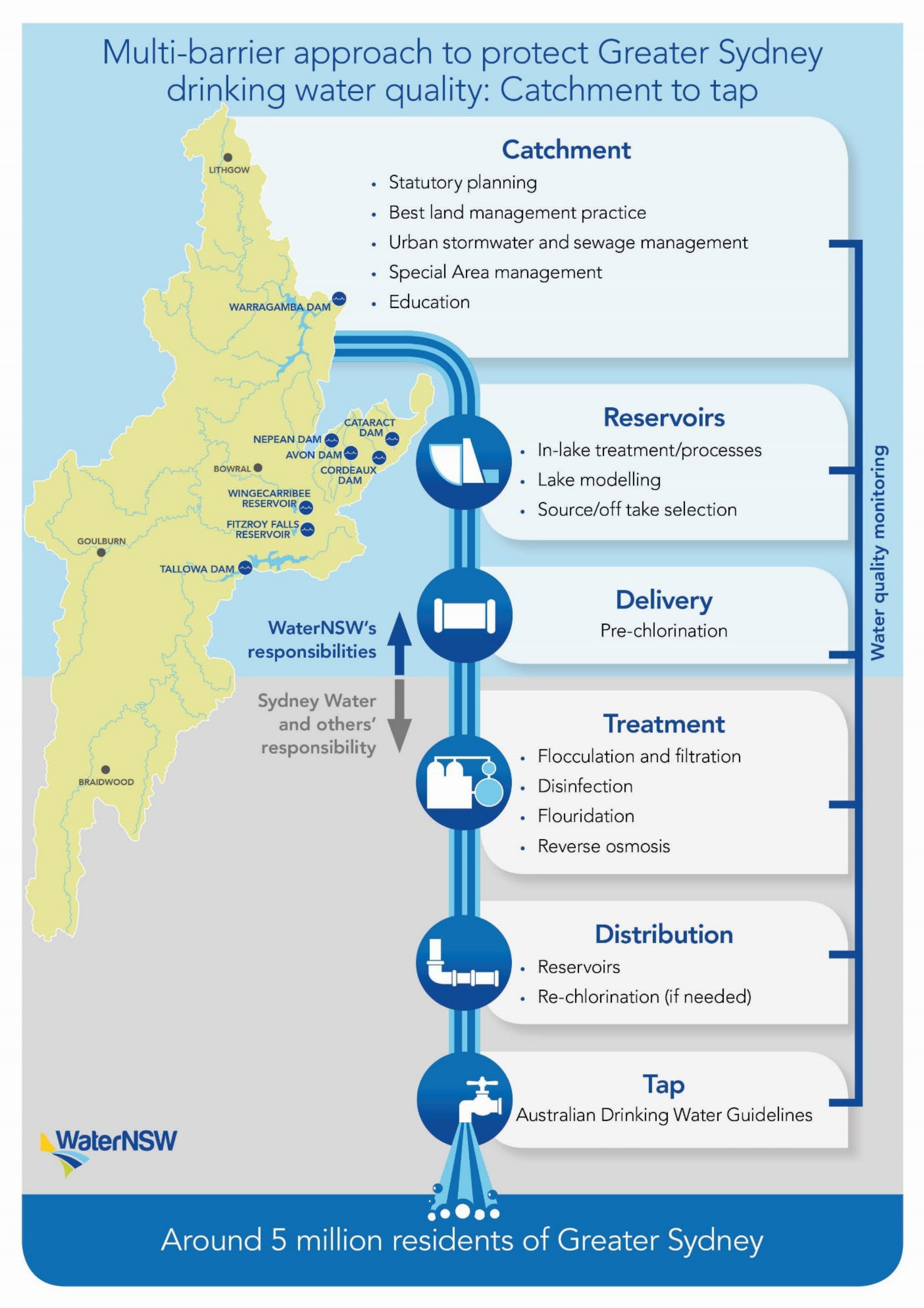


Figure 2-3: The multi-barrier approach - Catchment to tap (WaterNSW)

Table 2-2: Key findings of the baseline audit (CSIRO 1999)

Key finding in baseline audit (CSIRO 1999)	Information in 2019-22 audit
'A range of land uses within the headwater and upper catchments of the Coxs, Nepean, Nattai, Wingecarribee, Mulwarree, Wollondilly, Kangaroo and Shoalhaven River systems are increasing the hazards for both water quality and catchment health. These hazards derive from the extraction of water from the catchment and river systems and most importantly, the management of wastes and effluents. The specific pollution hazards to be managed are sewage effluent and biosolids from sewage treatment plants, unsewered villages, and unsewered peri-urban and rural smallholdings.'	Land uses (section 7) Pollution (section 9)
'Many of these same headwater catchments are under high levels of hydrological stress, particularly during periods of low flow and high demand. This stress, in concert with other impacts of land use and management, has degraded many headwater and upper catchment aquatic ecosystems to the extent that their ability to ameliorate and assimilate pollutants and toxins has been seriously compromised.'	Water flow (section 17) Macroinvertebrates (section 10)
'Hazards to water quality and catchment health in the Mulwarree, Wollondilly, Kangaroo and Shoalhaven catchments include urban and peri-urban development. However, the primary hazards in these catchments derive from the impact of animal grazing with stock access to streams, the large number of unsealed roads and tracks, intensive pig and poultry enterprises, meat and wool processing, and damaged riparian zone, coupled with extensive gully and sheet erosion.'	Land uses (section 7) Pollution (section 9) Soil erosion (section 16)
'It is clear that many of the risks to water quality within the catchment come from existing development. However, current legislation outside the mandate of the Sydney Catchment Authority can override catchment management regulation. Thus land uses that are inconsistent with drinking water quality and catchment health can be expected to flourish in the Sydney Water Supply catchments unless the Sydney Catchment authority has the legislative capacity and institutional arrangements to deal with existing and future development. This is the primary threat to both water quality and catchment health.'	Land uses (section 7) Water quality (section 19)
'The behaviour of microbial pathogens, in particular viral pathogens, in the continuum from source(s) to treatment plant within the Sydney catchments, is not well understood. While there has been work detecting Cryptosporidium and Giardia in the catchments, there is minimal information on the behaviour and survival of the different pathogens in the catchments under different environmental conditions. It is essential that any existing or future data used to improve the understanding of pathogen behaviour in the Sydney catchments is relevant to the environmental and climatic conditions of these catchments. Until these facts are properly understood, risk assessment and management decisions about pathogens in the catchments cannot be undertaken properly.'	Pathogens were not reviewed in this audit as they are not recognised as an indicator of Catchment health. Annual water quality reports by WaterNSW provide information about pathogens.
'There are large gaps in data on mines, both old and new, the status of their rehabilitation and their impact on the environment. This is largely due to poor collaboration between Government departments with different priorities and will need to receive attention.'	Mines (section 8)
'Diffuse sources of sediment and nutrients in the outer catchments, especially degraded riparian zones, unsealed roads and stock watering points, gully and sheet erosion, are a high priority for mitigation.'	Soil erosion (section 16) Riparian vegetation (section 12) Water quality (section 19)

3. Strategic planning and policy context

The strategic planning and policy context has matured since the previous Catchment audit, providing a more robust and consistent framework for decision-making.

3.1. Climate change

Climate is the greatest driver of the overall health of the Catchment and the climate is changing (see section 5). The direct and indirect impacts of a changing climate are evidenced in indicator trends throughout this audit report. Impacts can be event-driven, such as the bushfires in the summer of 2019-20, or longer-term shifts. The urgent need to mitigate and adapt to climate change is reflected in various policies, strategies and targets, including:

- The United Nations Emissions Gap Report 2022: The Closing Window – Climate crisis calls for rapid transformation of societies (UNEP 2022a). This report states that the international community is falling far short of the Paris Agreement goals, with no credible pathway to 1.5°C in place. It concludes that only an urgent system-wide transformation can avoid climate disaster.
- The National Climate Resilience and Adaptation Strategy 2021-2025, which assigns responsibility for major adaptation initiatives (e.g., land use planning, environmental protection, public infrastructure and service delivery for emergencies) to the states and territories.
- The 2022 NSW Climate Change Adaptation Strategy, which aims to make consideration of climate change risk part of standard organisational risk management processes for NSW Government agencies.
- The NSW Treasury Internal Audit and Risk Management Policy (TPP20-08), which requires NSW Government organisations to consider emerging risks such as climate change.
- The NSW Government guide for agencies to be 'climate risk ready' (DPIE 2020a) and prepare climate risk assessments by December 2023. This guide nominates three types of climate risk:
    - Physical risk – which result from the direct impacts of rising global temperatures
    - Transition risks or opportunities – resulting from the move to a lower-carbon economy
    - Liability risks – are those associated with people or businesses seeking compensation for losses suffered due to climate change, including physical or transition risks.
- Emissions targets and associated plans, such as the NSW Government's Climate Change Policy Framework and Net Zero Plan Stage 1: 2020-2030. The NSW Government aims to reduce NSW emissions by 50% by 2030 on 2005 levels, achieve a 70% cut in emissions by 2035 and net zero emissions by 2050.
- The EPA's Climate Change Policy and Action Plan 2023-26, which aims to support licenced industry holders and sectors reduce emissions to meet NSW Government emissions targets.
- Electricity Infrastructure Roadmap, which is enabled by the *Electricity Infrastructure Investment Act 2020* and comprises a 20-year plan to coordinate renewable energy investment and infrastructure as aging coal-fired power plants are retired from 2023.

The auditor was shown evidence of how organisations are embracing this strategic framework, through executive leadership, multi-agency collaboration and community engagement. However, the findings from this 2022 Drinking Water Catchment Audit also support the NSW Auditor-General's (2021) conclusion that:

> 'More work is needed to embed, sustain and lead effective climate risk management across the NSW public sector, especially for the State's critical infrastructure and essential services that may be exposed to climate change impacts.'

This will include development of a NSW Disaster Resilience Plan by the newly formed NSW Reconstruction Authority and preparation of more detailed, local disaster resilience plans by councils and other agencies.

Climate change is also increasingly influencing plans and actions by non-government organisations and individuals in the Catchment. This includes decisions to bring forward closure of coal mines and coal-fired power stations, and uptake of renewable energy technologies as part of the transition to a lower-carbon economy.

3.2. UN Sustainable Development Goals

In 2015, Australia and other United Nations member states adopted the 2030 Agenda for Sustainable Development. It has 17 sustainable development goals, which are further expanded by 169 targets and 232 indicators. These include United Nations Goal 13 to take urgent action to combat climate change and its impacts, and United Nations Goal 6 to ensure availability and sustainable management of water and sanitation for all. Targets and indicators for United Nations Goal 6 Clean Water and Sanitation that are most relevant to Catchment management and this audit are tabulated below.

Table 3-1: Selected targets and indicators for United Nations Sustainable Development Goal 6 Clean Water and Sanitation

Target	Indicators
Target 6.3: By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally	Indicator 6.3.1: Proportion of domestic and industrial wastewater flows safely treated Indicator 6.3.2: Proportion of bodies of water with good ambient water quality
Target 6.4: By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity	Indicator 6.4.1: Change in water-use efficiency over time Indicator 6.4.2: Level of water stress: freshwater withdrawal as a proportion of available freshwater resources
Target 6.5: By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate	Indicator 6.5.1: Degree of integrated water resources management Indicator 6.5.2: Proportion of transboundary basin area with an operational arrangement for water cooperation
Target 6.6: By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes	Indicator 6.6.1: Change in the extent of water-related ecosystems over time
Target 6.b: Support and strengthen the participation of local communities in improving water and sanitation management	Indicator 6.b.1: Proportion of local administrative units with established and operational policies and procedures for participation of local communities in water and sanitation management

3.3. National Water Initiative

The Intergovernmental Agreement on a National Water Initiative was established in 2004 to provide an overarching framework and principles for managing Australia's water resources. Under the Initiative, the NSW Government committed to:

- Prepare comprehensive water plans
- Achieve sustainable water use in overallocated or stressed water systems
- Introduce registers of water rights and standards for water accounting
- Expand trade in water rights
- Improve pricing for water storage and delivery
- Better manage urban water demands.

The Productivity Commission assesses progress implementing the National Water Initiative every three years in accordance with the Commonwealth *Water Act 2007*. Recommendations from the 2020 National Water Reform public inquiry by the Productivity Commission included strengthening capacity to deal with droughts, floods and shocks; adaptability to a changing climate; improved fit-for-purpose regulatory, governance and management arrangements; and use of the best available information in decision making. These recommendations were considered during development of the NSW Water Strategy (section 3.5).

3.4. National Water Quality Management Strategy

The National Water Quality Management Strategy was introduced in 1992 and incorporated into the Council of Australian Governments Water Reform Framework in 1994. It contributed to the development of a national policy to sustainably manage Australia's water resources by protecting and enhancing their quality while maintaining economic and social development. The 2018 National Water Quality Management Strategy features nationally agreed policies, guidelines and tools to assist governments and other organisations manage water quality, taking account of local conditions and community values. It provides context for development of state-based strategies and plans such as the NSW Water Strategy (DPIE 2021; see below) and the current NSW Government review of water quality objectives.

3.5. NSW Water Strategy

The NSW Water Strategy (DPIE 2021) is part of a suite of long-term strategies being developed by the NSW Government to improve the security, reliability, quality and resilience of water resources over the next 20 to 40 years. It provides updated operational and strategic guidance for management of the Catchment over the next audit period and longer-term. The NSW Water Strategy and the regional and metropolitan water strategies are designed to contribute to water management outcomes aligned with the objectives and principles of the *Water Management Act 2000,* the NSW Government's priorities and the National Water Initiative. The NSW Water Strategy and the regional and metropolitan water strategies do not replace statutory instruments, such as water sharing plans.

The NSW Water Strategy indicates the following high-level approaches to make water resources go further in a future with a changing climate:

- Drive changes in water use and behaviour to make NSW more water efficient and ensure water is supporting the highest value uses
- Improve capacity across NSW to cope with climate variability and change
- Invest in appropriate and affordable infrastructure.

The NSW Water Strategy 2050 vision is: 'Sustainable water resources for thriving people, places and ecosystems, both now and for future generations'. The Strategy has seven priorities:

- Build community confidence and capacity through engagement, transparency and accountability
- Recognise First Nations/Aboriginal People's rights and values and increase access to and ownership of water for cultural and economic purposes
- Improve river, floodplain and aquifer ecosystem health, and system connectivity
- Increase resilience to changes in water availability (variability and climate change)
- Support economic growth and resilient industries within a capped system
- Support resilient, prosperous and liveable cities and towns
- Enable a future focused, capable and innovative water sector.

Development of an Aboriginal Water Strategy and Groundwater Strategy are key actions from the NSW Water Strategy that will apply state-wide.

3.6. NSW Groundwater Strategy

The NSW Groundwater Strategy (DPE 2022e) was published in December 2022. It identifies three strategic priorities:

- Protect groundwater resources and the ecosystems that depend on them
- Build community and industry resilience through sustainable groundwater use
- Improve groundwater management decisions with better information.

The strategy indicates that regional water strategies will be developed to better manage groundwater issues including:

- Groundwater extraction limits
- Groundwater data collection, storage and access to information
- Declining groundwater quality and levels in some locations
- Declining health of groundwater dependent ecosystems

The Groundwater Strategy is supported by guides for groundwater management and groundwater resources (DPE 2022c and d).

3.7. Water Sharing Plans

Water sharing plans are statutory plans made and updated every ten years under the *Water Management Act 2000*. They set the priorities and rules for sharing surface water and groundwater between environmental and extractive needs, and between different types of extractive use for towns, domestic and stock and Native Title use, and other industrial and agricultural uses. There are two water sharing plans relevant to the Catchment:

- Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011
- Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources 2011.

A review by the Natural Resources Commission (NRC 2021) found the water sharing plans for the Greater Metropolitan region to be 'flawed' and 'not appropriate to manage the region's water given the significance of the region to the state and national economy, and the criticality of the water supply for maintaining this demographic and economic growth'. The NRC recommended, for example, that sustainable, numeric extraction limits should be set and rules for groundwater access and environmental flows should be defined based on ecosystem requirements.

Updates to the two water sharing plans are underway in consultation with stakeholders. The updated draft plans released for public comment during preparation of this audit feature new visions, objectives, strategies and performance indicators as well as specific requirements and rules. The revised water sharing plans are expected to apply from 1 July 2023, so the 2011 plans apply to the entire current audit period.

3.8. Greater Sydney Water Strategy

The Greater Sydney Water Strategy (DPE 2022b) replaced the 2017 Metropolitan Water Plan and is centred around improving the resilience of Greater Sydney's urban water cycle, including water supply, wastewater and stormwater systems. It was developed during the audit period and aims to respond to the challenges of population growth and climate change. It has a short-term implementation plan for 2022-2025 and its priorities and actions for the long term (20-40 years) are tabulated below.

Table 3-2: Greater Sydney Water Strategy priorities and actions (DPE 2022b)

Priorities	Actions
Priority 1: We understand how much water we need and when	1.1 Change the way we think about future water needs (enduring supply) 1.2 Consider future drought and climate risks
Priority 2: Our water systems are sustainable for the long term and resilient to extreme events	2.1 A concentrated focus on water conservation and efficiency 2.2 Make best use of the assets we have by optimising use of the Sydney Desalination Plant 2.3 Plan for new infrastructure with a focus on rainfall-independent supply 2.4 Managing drought 2.5 Manage location specific or asset-specific risks 2.6 Respond to the impacts of flood mitigation decisions on the system
Priority 3: Our city is green and liveable	3.1 Integrate water cycle and land use planning 3.2 Support the design principles for Greater Sydney 3.3 Prioritise alternative water sources for greening and cooling 3.4 Progress a circular economy approach for water services

Priorities	Actions
Priority 4: Our waterways and landscapes are healthy	4.1 Maintain and improve ecosystem health 4.2 Invest in wastewater management 4.3 Improve stormwater management 4.4 Protect water for recreation
Priority 5: Water management and services meet community needs	5.1 Recognise and protect Aboriginal rights, interests and access to water 5.2 Enhance community confidence through engagement and transparency 5.3 Manage price impacts for customers

3.9. Source Water Protection Strategy

The *Water NSW Act 2014* requires WaterNSW 'to protect and enhance the quality and quantity of water in declared catchment areas'. WaterNSW has developed a Source Water Protection Strategy 2040 for the Sydney Drinking Water Catchment with a vision to have 'a healthy catchment that delivers safe, clean water through world class source water protection and shared responsibility across the community'.

Priorities and goals of the Source Water Protection Strategy are tabulated below and implemented by WaterNSW through the Catchment Protection Work Program. Annual catchment management reports published on the WaterNSW website[4] refer to performance measures that have been used consistently since 2016. The annual catchment management reports also indicate progress against the previous Catchment audit recommendations.

Table 3-3: Priorities and goals of the WaterNSW Source Water Protection Strategy 2040

Priority	Goal
Scientific approach	Undertake scientific research into water quality risks and emerging issues in the Catchment
Creating water sensitive towns	Improve the urban water practices of 5 major councils to a 'water sensitive city' score of 70%
Ensuring water quality compatible development	All new developments have a neutral or beneficial effect on water quality
Integrating water quality policy and practice	All councils and major developers formally commit to source water protection
Increasing regenerative agriculture	50% increase in regenerative agriculture practices across the Catchment [refer to additional information below this table]
Fulfilling land management responsibilities	30% reduction in water quality risks from fire, pests and weeds in the Special Areas
Enforcing catchment protection laws	Halve unauthorised activities in Special Areas and pollution incidents in Catchment

[4] Management - WaterNSW

The goal to achieve '50% increase in regenerative agricultural practices' refers to half (50%) of 2000 properties that were identified by WaterNSW in 2015 as 'high risk' grazing properties using a pollution source assessment tool. The annual performance measures (outputs) relevant to this goal are:

- Riparian length fenced
- Head cuts treated (and size)
- Streambank erosion length treated
- Sustainable grazing area (ha) introduced
- Riparian area (ha) protected/revegetated

WaterNSW also conducts less frequent, strategic evaluations to address this goal. For example:

- MODIS satellite imagery to investigate pasture cover after introducing rotational grazing fencing
- A comprehensive review of the status and effectiveness of projects under the Rural Landscape Program was underway at the time of this audit.

3.10. State Environmental Planning Policy

The following state environmental planning policies (SEPPs) contained Catchment protection provisions during the audit period:

- SEPP (Sydney Drinking Water Catchment) 2011 – from 1 July 2019 to 28 February 2022
- SEPP (Biodiversity and Conservation) 2021 – from 1 March 2022 to 30 June 2022.

The provisions of the former Sydney Drinking Water Catchment SEPP were initially carried across and incorporated under Chapter 8 of the Biodiversity and Conservation SEPP (effective 1 March 2022). Additional amendments commencing on 21 November 2022 have further consolidated the Sydney Drinking Water Catchment provisions under Part 6.5 of a new Chapter 6 (Water Catchments) of the SEPP. Broader water-related provisions have also been introduced under Part 6.2 for 'regulated catchments' which includes the Sydney Drinking Water Catchment.

Part 6.5 has two objectives:

- 'To provide for healthy water catchments that will deliver high quality water to the Sydney area while also permitting compatible development, and
- To provide for development in the Sydney Drinking Water Catchment to have a neutral or beneficial effect on water quality.'

Part 6.5 requires that development consent must not be granted to development in any part of the Catchment unless the consent authority is satisfied the carrying out of the development would have a neutral or beneficial effect (NorBE) on water quality. Part 6.5 also requires development to be consistent with the NorBE Guideline (see section 3.11). The NorBE Guideline calls up the current recommended practices and standards endorsed by WaterNSW that should be used in the design and preparation of new development proposals in the Catchment. Where alternative management practices are incorporated, the proponent must adopt approaches that achieve the same or better water quality outcomes. Current recommended practices are listed in Appendix D with their status during the audit period, and it is understood that WaterNSW is planning further promotion of these resources.

WaterNSW regularly reviews the current recommended practices to ensure they are contemporary and relevant.

New provisions under Part 6.2 of the Biodiversity and Conservation SEPP strengthen the protection of the Catchment and include new considerations and requirements for consent authorities to address before issuing development consent. These include:

- Water quality and quantity (including water flow, stormwater, water table, cumulative impacts and groundwater considerations)
- Aquatic ecology
- Flooding
- Recreation and public access (except for Special Areas)
- Total catchment management
- Land within 100 m of a waterbody.

New controls have also been introduced for specific purposes such as aquaculture, artificial waterbodies, heavy and hazardous industries, on-site domestic sewerage systems, and waste or resource management facilities.

The changes to the Biodiversity and Conservation SEPP were accompanied by amendments to the Environmental Planning and Assessment Regulation 2021 (section 171A) which specify the scope to be considered by determining authorities when assessing the likely environmental impact of their activities. For the Catchment, this includes whether the activity will maintain or improve water quality and whether the activity is consistent with the NorBE Guideline. For ‘declared catchments’ such as the Sydney Drinking Water Catchment, determining authorities are also required to consider the water quality and quantity, aquatic ecology, flooding, and recreation and public access considerations and requirements provided under the Biodiversity and Conservation SEPP.

3.11. NorBE Guideline

Section 6.61 of the SEPP (Biodiversity and Conservation) 2021 establishes the NorBE requirements for new development in the Catchment, including application of the NorBE Tool. The Neutral or Beneficial Effect on Water Quality Assessment Guideline (WaterNSW 2022c) states that NorBE is satisfied if the development:

- ‘Has no identifiable potential impact on water quality, or
- Will contain any water quality impact on the development site and prevent it from reaching any watercourse, waterbody or drainage depression on the site, or
- Will transfer any water quality impact outside the site where it is treated and disposed of, to standards approved by the consent authority’.

The type of NorBE assessment required relates to the risks associated with the type of development proposed and the site conditions (e.g., soils, rainfall, slope, existing systems). The NorBE Tool must be used for all types of local development assessment, although in some cases the outcome may be ‘WaterNSW concurrence required’. It refers to (but does not link to) supporting tools such as the wastewater effluent model, MUSIC stormwater model, and S3QM stormwater model for developments under the MUSIC threshold.

The 2019 Catchment audit recommended that a review be undertaken of NorBE related consent and approval conditions for a range of development types. The NorBE Tool underwent a comprehensive upgrade during 2020-21 to address issues raised by users, contemporise the referenced legislation and policy, apply WaterNSW mapping services, modify the logic to make it more intuitive and prevent common logic flow user errors, provide several enhancements to elevate the user experience, update the Standard Conditions, update the water balance data underpinning the wastewater effluent model, add new Development Classes, introduce ReCaptcha security technology, and move the application to WaterNSW's preferred technology architecture platform. The upgrade went 'live' in early April 2021. Further minor amendments to the NorBE Tool have occurred subsequently, including some in response to feedback from users. WaterNSW provided 22 training sessions to councils and consultants on the upgraded Tool between July 2019 and June 2022.

Discussions with engineers and environmental scientists from various organisations during the 2022 Catchment audit revealed concerns about the long-term effectiveness of some stormwater management systems associated with larger urban residential developments to achieve NorBE goals. Funding for maintenance of a public stormwater asset for an initial period (e.g., 20 years) after handover to council is typically covered by a voluntary planning agreement between the developer and council. However, council rates fund longer-term maintenance (including replacement of filters) and may have competing expenditure priorities. If development is permitted in the Catchment based on the assumption that it will meet NorBE criteria, it is critical that this can be achieved in the long-term.

To better understand the potential risks to Catchment health, it is recommended that stormwater management assets dedicated to council be audited to determine if they are maintained to achieve NorBE objectives. Key findings and recommendations of the review to be led by WaterNSW should be shared with councils to inform future development consent conditions, funding arrangements and maintenance regimes.

3.12. Special Areas Strategic Plan of Management

The Special Areas within the Catchment cover approximately 3,640 km^2 (Figure 3-1) and comprise mostly bushland and natural landscapes around the water storages and water supply infrastructure. As indicated in Table 3-4, most of the Blue Mountains, Upper Nepean and Woronora sub-catchments are categorised as Special Areas. However, less than one third of the Warragamba catchment is a Special Area and less than 1% of the Shoalhaven sub-catchment is a Special Area.

Table 3-4: Proportion of Special Areas within each major catchment system (30 June 2022)

Sub-catchment	Sub-catchment area (ha)	Special Areas (ha)	Proportion (%) of Special Areas in sub-catchment
Blue Mountains	2120	2033	96%
Shoalhaven	676,598	2126	0.3%
Upper Nepean	88,924	88,924	100%
Warragamba	902,619	259,644	29%
Woronora	7380	7380	100%

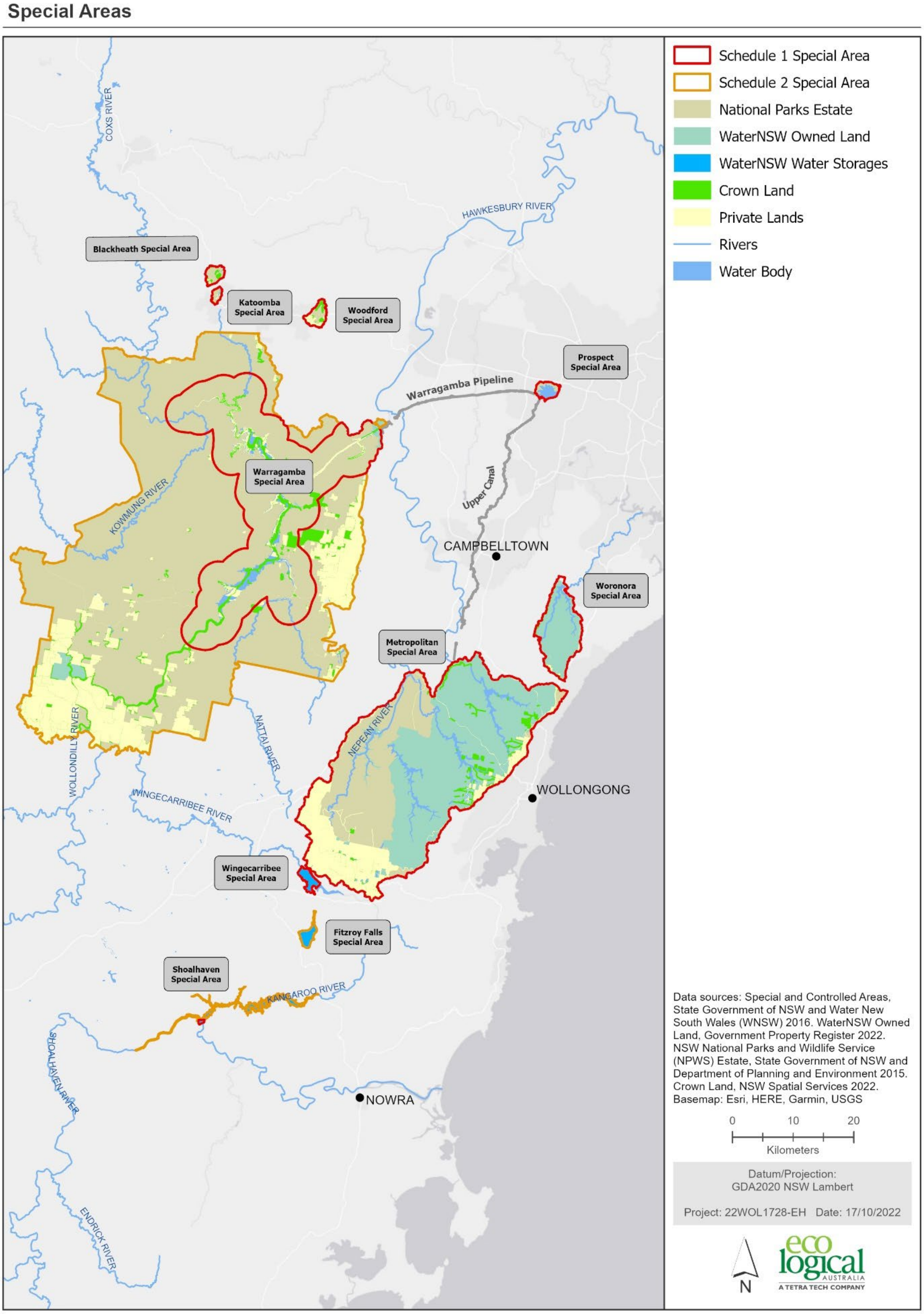


Figure 3-1: Special Areas (June 2022)

Table 3-5 shows there are three categories of access in the Special Areas. Public access and activities are either prohibited or restricted in the Special Areas, although most prohibitions and restrictions do not apply to privately owned land and public roads. The Water NSW Regulation 2020 specifies prohibitions and restrictions. WaterNSW has the authority to grant consent to individuals, companies or groups to carry out an otherwise prohibited or restricted activity provided specified criteria are met. There are expired and active coal mining leases in the Special Areas.

Table 3-5: Special Areas and Controlled Areas

Category	Description
Schedule 1 Special Areas – no entry	These areas include the water storages and surrounding land except Fitzroy Falls Reservoir and part of Lake Yarrunga, which are classed as restricted entry.
Schedule 1 Controlled Areas – no entry	These areas include the land at Warragamba protecting the water supply infrastructure and the land along the Warragamba Pipelines and Upper Canal.
Schedule 2 Special Areas – restricted access	These areas include the water storages and surrounding land of Fitzroy Falls Reservoir and part of Lake Yarrunga, and the second protection zone around Lake Burragorang. Vehicles (including motorcycles and bicycles), horses, pets, powered watercraft and firearms are not allowed.

The Special Areas Strategic Plan of Management 2015 (SASPoM) was prepared in accordance with section 52 of the *Water NSW Act 2014* and adopted by the 'joint sponsors', the Minister for the Environment and the Minister for Water, represented through the agencies of WaterNSW and the National Parks and Wildlife Service (NPWS). The SASPoM is scheduled for review every five years and was reviewed during the audit period, with no changes recommended.

Land management priorities under the SASPoM are developed by the joint sponsors using statutory instruments, operations plans and policies within the joint sponsor organisations, external research, subject matter expertise, information on emerging issues and field observations. Agreed priorities for the Special Areas are presented in a four-year land management priorities document and reviewed by the joint managers annually to allow for change in priority issues or land management interventions. This includes surveillance of the Special Areas to deter and act against unauthorised activities. Works carried out under the SASPoM are approved individually by the joint sponsor agencies and can be approved for any period depending on the agency. The four-year land management priorities are considered by the agencies when developing their individual annual work programs.

3.13. Local land use planning

3.13.1. Local Strategic Planning Statements

Each council in the Catchment is required to prepare a local strategic planning statement to set out its 20-year vision for land use, the special character and values that are to be preserved and how change will be managed into the future. The statements complement relevant State and Regional planning policies and plans (including Ministerial Directions issued under section 9.1 of the *Environmental Planning and Assessment Act 1979)*, which continue to guide planning decisions and the preparation of development controls in local environmental plans. All local strategic planning statements prepared by councils in the Catchment were published in 2020.

3.13.2. Local Planning Directions

The Minister for Planning issues directions to planning authorities under section 9.1(2) of the *Environmental Planning and Assessment Act 1979.* These directions apply to planning proposals lodged with the Department of Planning and Environment (DPE) on or after the date the direction was issued and commenced. Ministerial directions address a range of issues such as employment, environment, heritage, housing, infrastructure and urban development. The directions provide principles, aims, objectives or policies that must be achieved, or given effect to, in the preparation of local environmental plans.

The Sydney Drinking Water Catchment Ministerial Direction was updated on 21 November 2022 (previously numbered 5.2, now 3.3 of section 9.1 Ministerial Directions) as part of the Biodiversity and Conservation SEPP amendments. It helps address water quality risks and land and water capability issues at the earliest stages of planning and before areas are rezoned for more intensive uses such as residential development. This includes a broader objective recognising the need to provide healthy catchments as well as protect water quality. It also includes a new requirement for planning proposal authorities to identify any water quality risks (including groundwater) to any waterway occurring on or adjacent to the site.

3.13.3. Local housing strategies

Local housing strategies guide where new residential areas should and should not occur. They consider projected population growth, environmental values and constraints, servicing constraints and other factors. Examples of housing strategies relevant to the Catchment that were prepared during the audit period include:

- Blue Mountains Local Housing Strategy (Blue Mountains City Council 2020)
- Campbelltown Local Housing Strategy (HillPDA Consulting 2020)
- Goulburn and Marulan Urban and Fringe Housing Strategy (Elton Consulting 2020)
- Tarago Village Housing Strategy (Goulburn Mulwaree Council 2022)
- Wingecarribee Local Housing Strategy (Wingecarribee Shire Council 2021)
- Wollondilly Local Housing Strategy (Arup 2021).

Local housing strategies that have been endorsed by council are forwarded to DPE for consideration and approval. DPE may make the approval conditional.

4. Catchment stakeholders

Effective Catchment management requires shared effort by community, industry and government stakeholders.

4.1. Traditional owners

Aboriginal people are the enduring Custodians of the land, waters and sky of the Catchment. The health of the natural environment, wellbeing and culture are intimately connected. Representatives of the following groups were consulted as part of this audit, as recommended by the WaterNSW Aboriginal Engagement Manager:

- Bathurst Local Aboriginal Land Council
- Batemans Bay Local Aboriginal Land Council
- Cubbitch Barta Native Title Claimant Aboriginal Corporation
- Coomaditchie United Aboriginal Corporation
- Darug Custodian Aboriginal Corporation
- Deerubbin Local Aboriginal Land Council
- Gundungarra Aboriginal Heritage Association Inc.
- Gundungurra Tribal Council Aboriginal Corporation
- Illawarra Local Aboriginal Land Council
- Nowra Local Aboriginal Land Council
- Pejar Local Aboriginal Land Council
- Tharawal Local Aboriginal Land Council
- Mogo Local Aboriginal Land Council
- Ngambri Local Aboriginal Land Council
- South Coast People
- Ulladulla Local Aboriginal Land Council.

The only issue raised with the auditor by Traditional owners during the audit period was the desire to access certain areas within the Catchment for cultural purposes. A memorandum of understanding is being developed with WaterNSW for access to the Special Areas by Traditional owners.

4.2. Local councils

Local councils and their communities are at the front-line of managing Catchment health. They act and make decisions regarding changes in land use; management of pollutants; control of pests, weeds and disease; and respond to crises such as floods, droughts and fires. All councils within the Catchment (see locations in Figure 4-1) were consulted for this audit. Matters raised by councils included:

- Appreciation of support (funds and expertise) provided by WaterNSW and Local Land Services to councils and the community
- The importance of community programs such as Bushcare and Rivercare in protecting and improving environmental conditions and enhancing community interactions
- Biosecurity concerns (pests, weeds and disease)

- Need for additional resources and up-to-date spatial database showing the locations and compliance of on-site sewage management systems
- Need to integrate councils' environmental monitoring programs with state agency datasets for water quality, vegetation, macroinvertebrates, crayfish and E-DNA
- Concern about long-term maintenance and performance of approved water sensitive urban design development
- Concern about illegal activities affecting Catchment health e.g., illegal dumping, vegetation clearing, 4WD activity causing erosion, unauthorised rebuilding over creeks where crossings have been damaged in floods, large groups camping without adequate sewage management
- Concern about waste management on private landholdings that don't have a council waste service; and increasing concern about builders and waste removal contractors purchasing vacant land to illegally dispose of waste instead of using a licenced facility
- Benefits of council staff being on joint committees such as for mine closure or bushfire risk
- Interest in potential stewardship payments (or similar incentives) for riparian management instead of mandatory or voluntary requirements to manage stock along waterways.

4.3. The community

Community attitudes towards maintaining and improving Catchment health, and the level of engagement within the community to bring this about, are indicators that were considered in this audit. Community attitudes were revealed in:

- Community submissions to the audit, including consultation with environmental and Indigenous organisations and commercial entities (e.g., mining companies, energy providers)
- Community Strategic Plans prepared by local councils in consultation with their communities
- Community submissions on proposed developments in the Catchment e.g., mining, urban development, water and energy infrastructure
- Social and traditional media
- Community organisation websites and activities.

The available evidence suggests a stable trend in community engagement within the Catchment. In summary, there continues to be strong community support for protection of Catchment environmental and cultural values. Mining in the Special Areas continues to be a focus of community interest (see section 8.3). Concerns about sewage pollution, particularly from on-site sewage management systems, were also expressed to this auditor in written submissions and during interviews.

Many opportunities exist for landholders and members of the general community to volunteer or jointly fund activities that aim to improve Catchment health. Some records on community involvement are kept by organisations for their own programs (refer to examples in section 12.4). However, it is currently not possible to ascertain all the sites, activities and numbers of people involved in community volunteering and participation across the Catchment. This makes it difficult to assess patterns and effectiveness of community Catchment management programs.

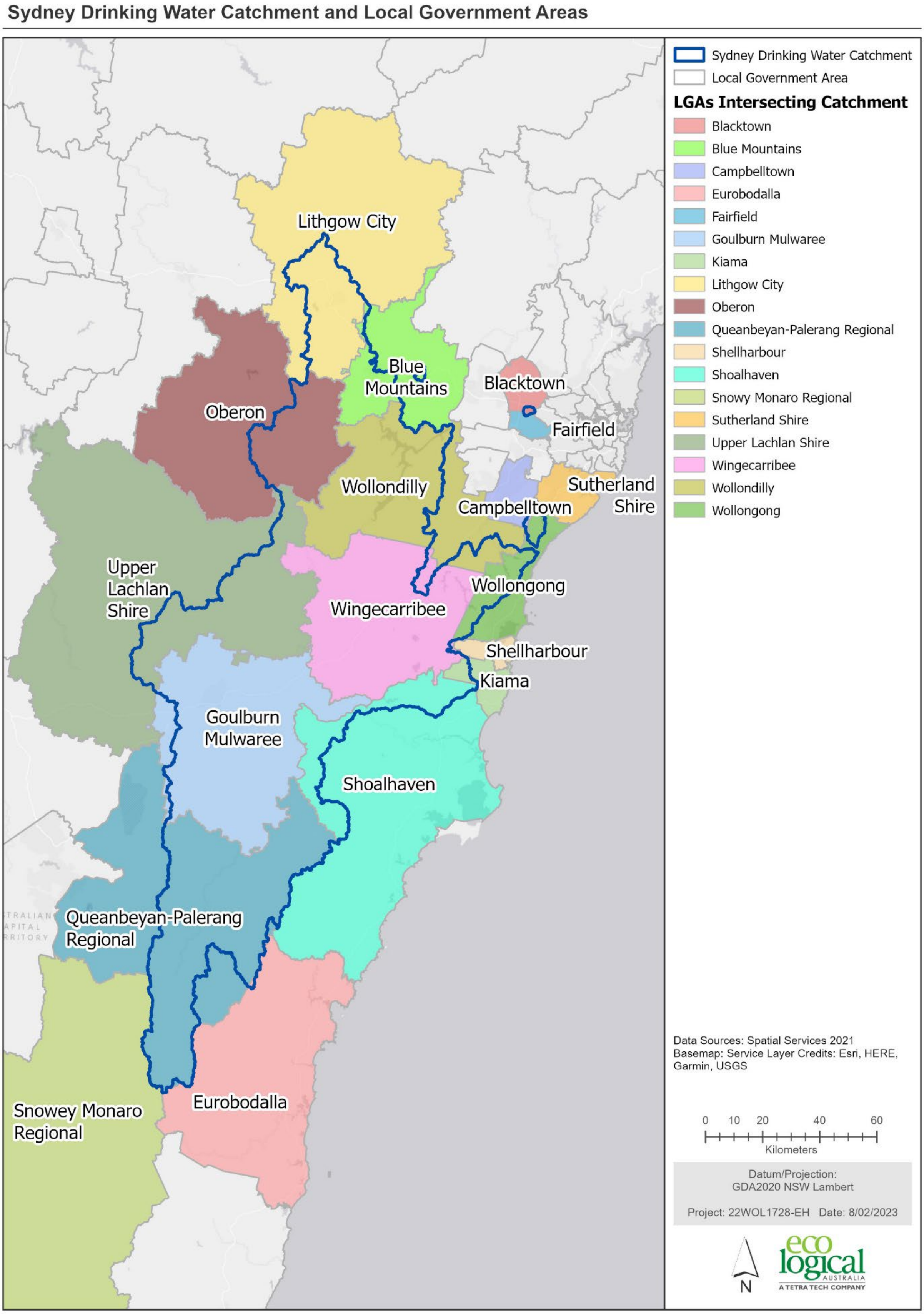


Figure 4-1: LGA and Catchment boundaries

4.4. Water management agencies

Responsibilities for water management in the Catchment continue to evolve and Figure 4-2 shows that multiple agencies have a role. A Roles and Responsibilities Agreement between WaterNSW, the Department of Planning and Environment (DPE)—Water, and the Natural Resources Access Regulator (NRAR) came into effect on 30 June 2021 to clarify each agency's water management functions. The Agreement provides a framework for resolving interagency issues and monitoring the performance of agencies against their responsibilities.

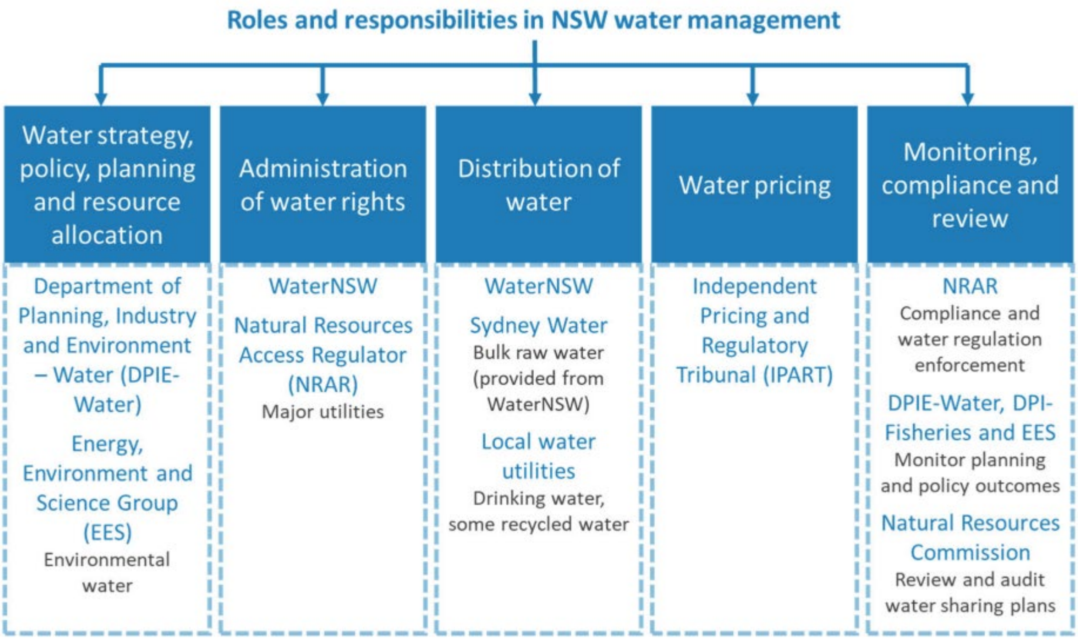


Figure 4-2: Overview of agency roles in water management (NRC 2021)

4.4.1. WaterNSW

WaterNSW is a state-owned corporation established under the *Water NSW Act 2014.* Its operating licence is issued and monitored by the Independent Pricing and Regulatory Tribunal (IPART). WaterNSW operates the rivers and water supply systems in accordance with the requirements set by the regulators. It supplies water from its dams and owns and operates surface and groundwater monitoring stations.

WaterNSW is subject to the following statutory requirements and standards that set requirements for its water monitoring program:

- Water NSW Act 2014
- Operating Licence (Part 2), *Water NSW Act 2014* (Division 4)
- Water Licences and Approvals Package under *Water Management Act 2000*
- Memorandum of Understanding between NSW Health and WaterNSW (2016) (Parts 5-8)
- Raw Water Supply Arrangements
- Water Quality Incident Response Protocol
- Private Water Supply Guidelines and *Public Health Act 2010*
- Commonwealth Water Act 2007.

A principal objective of WaterNSW under the *Water NSW Act 2014* is 'to ensure that declared catchment areas and water management works in such areas are managed and protected so as to promote water quality, the protection of public health and public safety, and the protection of the environment'. Functions of WaterNSW stated in section 7 of the Act that are relevant to the Catchment include to:

- 'Protect and enhance the quality and quantity of water in declared catchment areas
- Manage and protect declared catchment areas and water management works vested in or under the control of WaterNSW that are used within or for the purposes of such areas
- Undertake research on catchments generally, and in particular on the health of declared catchment areas'.

WaterNSW promotes protection of water quality across the Catchment through its statutory role in development and land use planning instruments, as well as through its compliance functions established under the *Water NSW Act 2014*, the *Protection of the Environment Operations Act 1997* and the Water NSW Regulation 2020 in relation to potentially polluting activities and incidents.

Section 43 of the *Water NSW Act 2014* states that WaterNSW must evaluate the findings of the Catchment audit to the extent to which they relate to the activities of WaterNSW and risks to water quality in the Catchment. It also states that WaterNSW must incorporate the findings of the Catchment audit, to the extent to which they relate to the activities of WaterNSW and water quality, into WaterNSW's risk framework, programs and activities relating to Catchment management. Section 44 of the Act states that WaterNSW must report to the Minister on WaterNSW's progress on the findings of the audit.

4.4.2. Natural Resources Access Regulator

The Natural Resources Access Regulator (NRAR) is part of the DPE. NRAR performs compliance and enforcement functions under the *Water Management Act 2000* using data from DPE Water and WaterNSW. It provides feedback to DPE Water on the on-ground effectiveness and efficiency of the legislative and policy framework, and to WaterNSW about implementation of the framework. It provides feedback to DPE Water and WaterNSW about the effectiveness and efficiency of policies and procedures from a compliance perspective. NRAR has a memorandum of understanding with WaterNSW.

4.4.3. DPE Water

DPE Water sets the legislation, policy and long-term plans for sharing, use and management of water resources in NSW. It relies on data from WaterNSW and NRAR to perform its resource management functions. It is responsible for development, review, audit and, where applicable, implementation of water policies and management plans across NSW. It provides groundwater advice and assessment for applications under the *Water Act 1912* and *Water Management Act 2000*, and manages groundwater and reports on groundwater variations, availability and management.

4.5. Other agencies

Roles and responsibilities for other key agencies and stakeholders involved in Catchment management are summarised in Table 4-1.

Table 4-1: Selected agency stakeholders

Agency	Role in the Catchment
DPE Environment and Heritage	The Environment and Heritage Group of DPE includes the National Parks and Wildlife Service (NPWS) and the Biodiversity, Conservation and Science Directorate (BCSD). NPWS jointly manages the Special Areas with WaterNSW in accordance with the 2015 Special Areas Strategic Plan of Management (SASPoM) and associated joint management arrangements. Under the SASPoM, the NPWS is responsible for the management of lands reserved under the *National Parks and Wildlife Act 1974*, including national parks, state conservation areas, regional parks, nature reserves, karst reserves and Aboriginal areas.
DPE Environment Protection Authority (EPA)	The EPA regulates activities scheduled under the *Protection of Environment Operations Act 1997* and enforces environmental regulations through licensing, monitoring and auditing. The EPA applies a risk-based approach to help manage potential water pollution impacts associated with development. The EPA responds to major pollution incidents and can impose fines, stricter operating conditions, or clean up orders. The EPA shares information and partners with other authorities to regulate activities impacting on water quality in the Catchment. It contributes to the planning process through the provision of advice and conditions for the development approval process. It considers water quality data to identify possible sources of pollution (e.g., salinity) and the relative contributions from licensed premises to further refine where regulatory effort can be focused. WaterNSW and the EPA have a memorandum of understanding to work together in carrying out their respective functions to prevent, avoid, reduce or mitigate the effects of pollution events in the Catchment and on water quality. The purpose is to encourage effective interaction between the parties, the exchange of information, and to form the basis for effective and cooperative relationships to further the objectives of each organisation in catchment protection. WaterNSW and the EPA maintain a strategic liaison group comprising senior representatives of each agency to ensure strategic matters relating to the memorandum of understanding are dealt with.
DPE Major Projects	DPE's Planning and Assessment group is responsible for environmental planning and assessment, and compliance monitoring and enforcement in accordance with the *Environmental Planning and Assessment Act 1979.* This includes management of the policies and approvals processes for developments such as mining, agricultural enterprises and major urban areas.
NSW Health	NSW Health is the public health regulator of drinking water quality. NSW Health contributed to the development of the water quality monitoring program which is implemented by WaterNSW. NSW Health has a memorandum of understanding with WaterNSW.
Department of Primary Industries (DPI) Fisheries	DPI Fisheries regulates recreational and commercial fishing, sets policies on fisheries resources and provides guidance on aquatic habitat management.
DPI – Local Land Services (LLS)	There are three LLS regions within the Catchment (Greater Sydney, Central Tablelands and South East) and these connect people with groups, information, support and funding to improve agricultural productivity and better manage natural resources.
DPI – Resources Regulator	The Resources Regulator was established in 2016 and is responsible for regulation, compliance and enforcement for mining and mining exploration activities. The Resources Regulator has an important role in overseeing mine rehabilitation.
Independent Pricing and Regulatory Tribunal (IPART)	IPART is an independent authority established under the *Independent Pricing and Regulatory Tribunal Act 1992* that reports each year to the NSW Parliament. IPART is the independent regulator that determines the prices that can be charged for certain retail water services in New South Wales. IPART also serves as the NSW Government's economic advisor. IPART oversees compliance with the operating licence for WaterNSW.

Agency	Role in the Catchment
NSW Reconstruction Authority	The NSW Reconstruction Authority was established in line with recommendations of the 2022 NSW Flood Inquiry to facilitate disaster prevention, preparedness, recovery, reconstruction and adaptation to the effects of natural disasters in NSW. Functions and powers are established by the NSW Reconstruction Authority Act 2022 and NSW Reconstruction Authority Regulation 2023, and include responsibility for creating and implementing the State disaster mitigation plan to: • Identify potential strategies and actions for reducing the impact of disasters • Assess and consider the impacts of climate change on disasters • Determine priority projects for regions to mitigate the impact of disasters.
Office of Energy and Climate Change	The Office of Energy and Climate Change (OECC) was established in the Treasury Cluster in April 2022. It supports the NSW Government with the transformation to a new low-cost, clean energy economy.
Rural Fire Service	The Rural Fire Service is the lead bushfire combat agency and sets bushfire risk management policies. It does not own land.

Pressures on the Catchment

5. Climate and weather

Catchment health indicators such as surface water flow, groundwater availability, aquatic ecology, bushfire, wetlands and erosion were affected by severe drought in the initial months of the audit period followed by intense rainfall and floods throughout 2020-22. Extreme weather, natural disasters and associated threats to Catchment health are predicted to become more frequent and severe as the climate changes.

5.1. Rainfall

Rainfall has a major influence on Catchment health. Figure 5-1 and Figure 5-2 are gridded data maps produced by the Bureau of Meteorology (BoM) that indicate the current audit period 1 July 2019 to 30 June 2022 was wetter than the previous audit period 1 July 2016 to 30 June 2019. The maps below show rainfall anomaly and total rainfall for the previous and current audit periods. This data reflects the dominance of La Nina conditions during the current audit period compared to El Nino (drought) conditions prevalent in the previous period.

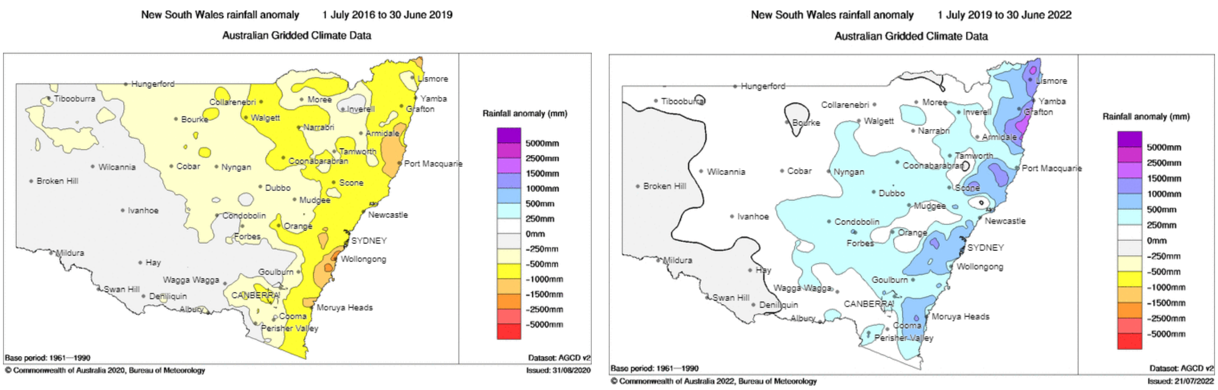


Figure 5-1: Comparison of rainfall anomaly previous audit period to the current audit period

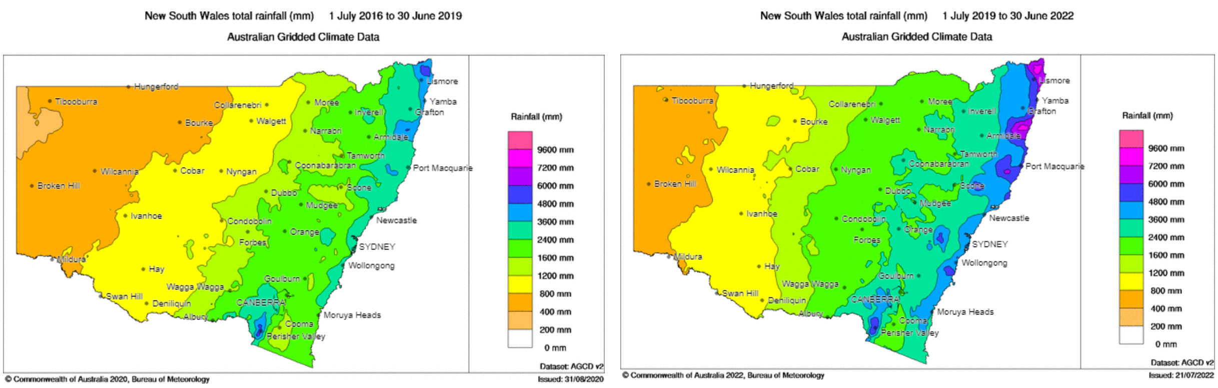


Figure 5-2: Comparison of total rainfall previous audit period to current audit period

Annual rainfall decile maps in Figure 5-3 show that rainfall across the Catchment during the last two years of the current audit period was above average (in 2020-21) or very much above average (in 2021-22).

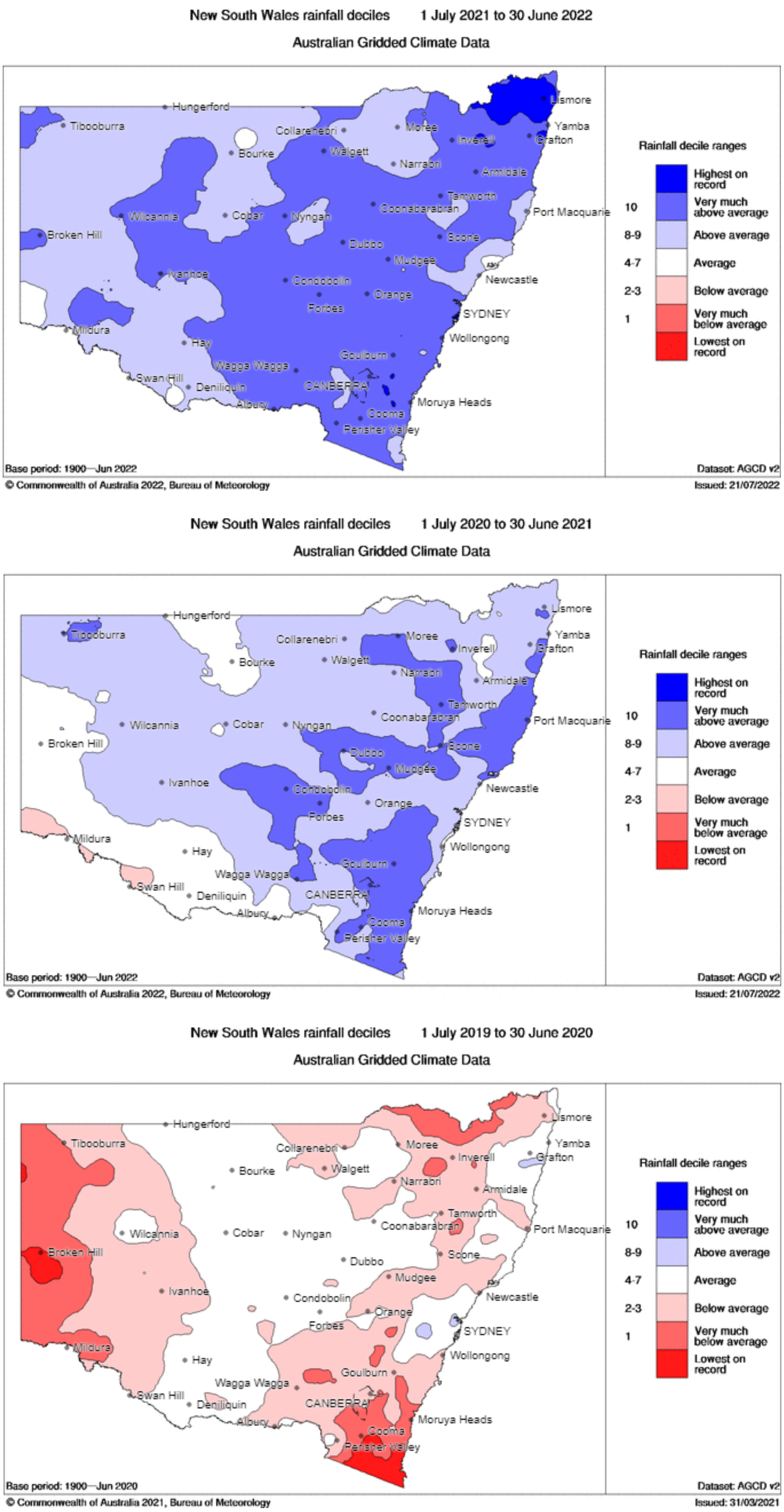


Figure 5-3: Comparison of annual rainfall deciles during the audit period

Figure 5-4 shows that rainfall deficiencies across the Catchment during the final months of the drought (October – December 2019) were either severely deficient or the lowest on record. Lack of rainfall resulted in low surface water flows, as described in section 17.1, and low levels of moisture in soils and vegetation. These factors all contributed to the widespread extent and severe intensity of the bushfires in the summer of 2019-20 (see section 6 for more details about bushfires in the Catchment).

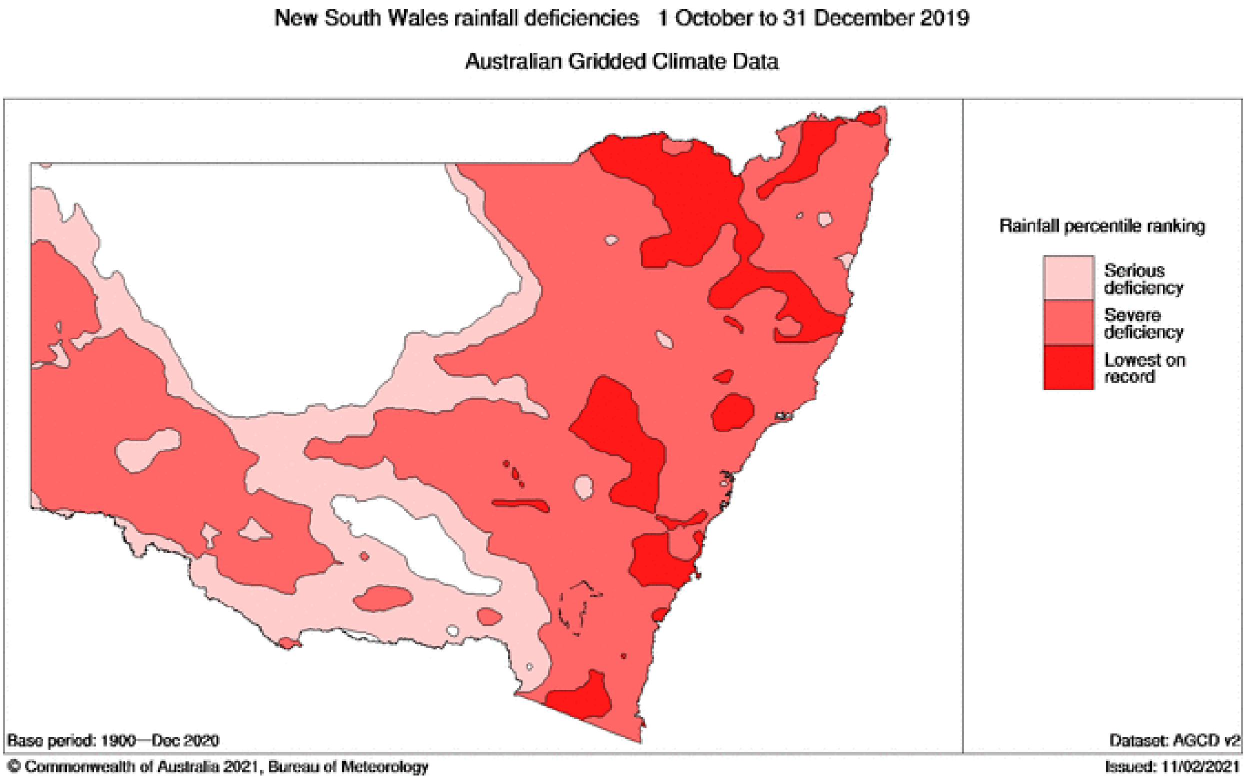


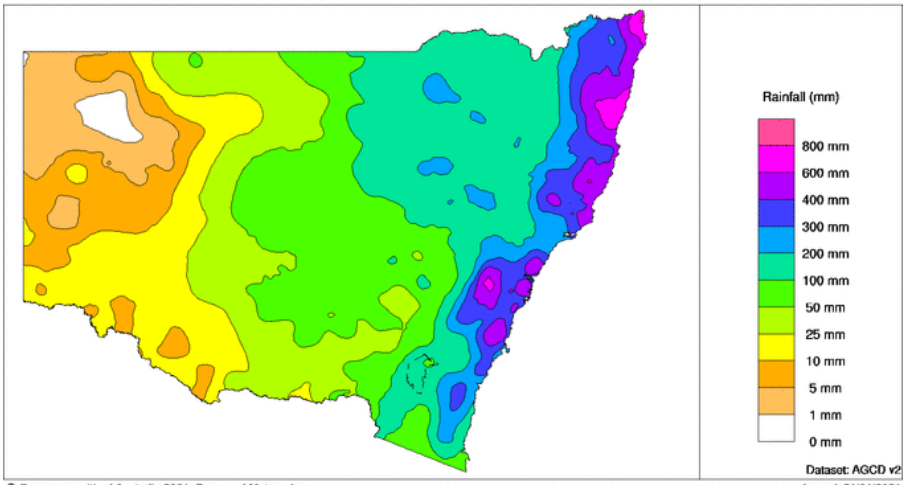
Figure 5-4: Drought conditions due to rainfall deficiency Oct-Dec 2019

The drought and bushfires in the Catchment were extinguished by heavy rainfall in February 2020. Figure 5-5 compares total rainfall distribution for the months of December 2019 to February 2020. Flooding and landslips occurred in the Catchment during 2020-22 as higher than average rainfall conditions persisted (Figure 5-3).

Figure 5-6 presents long-term annual rainfall data for four sites in the Catchment up to 2021. The four sites were selected because they have long data records and are geographically widespread. They represent different landscapes and microclimates within the Catchment. These graphs have been created using BoM data to provide further context to records in recent years. They indicate that total annual rainfall in the calendar years of 2020 and 2021 was much higher than the long-term median (and 2022 is expected to be even higher), whereas rainfall in the previous three years (2017-19) was much lower than median (drought conditions).

New South Wales total rainfall (mm) February 2020

Australian Gridded Climate Data



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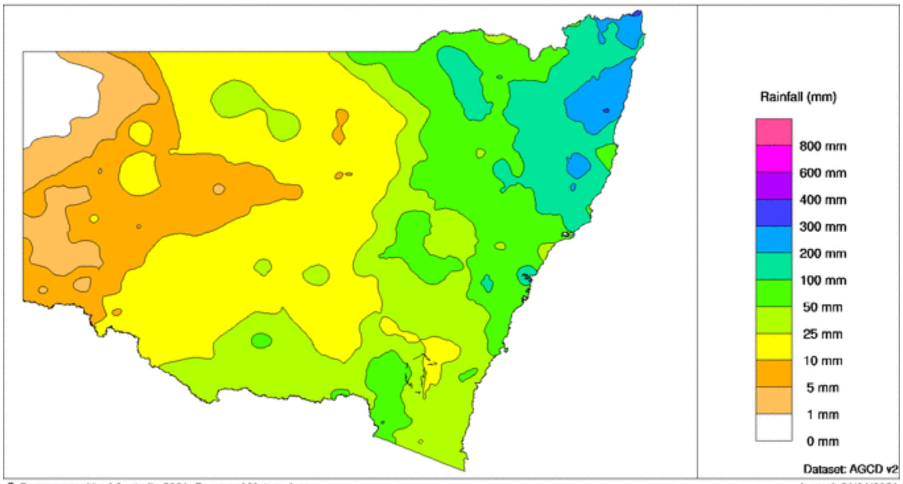
New South Wales total rainfall (mm) January 2020

Australian Gridded Climate Data



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New South Wales total rainfall (mm) December 2019

Australian Gridded Climate Data

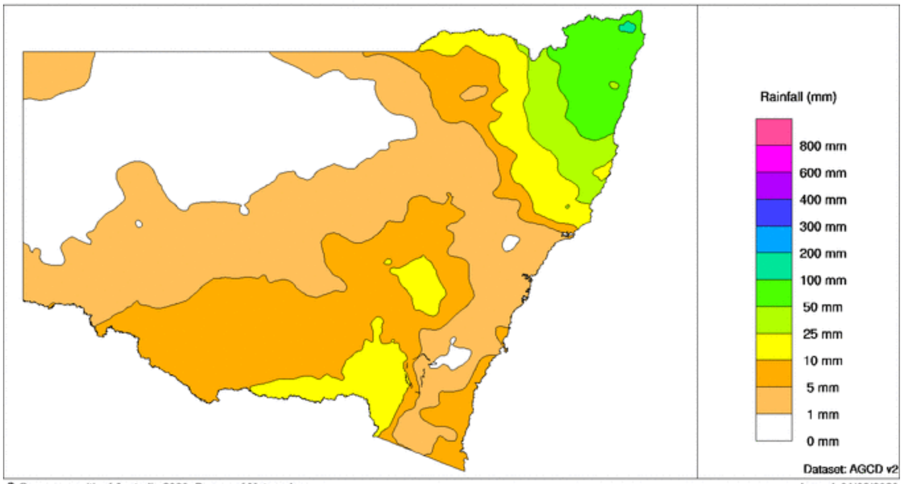

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Figure 5-5: Monthly rainfall totals showing end of the drought – Dec 2019, Jan 2020 and Feb 2020

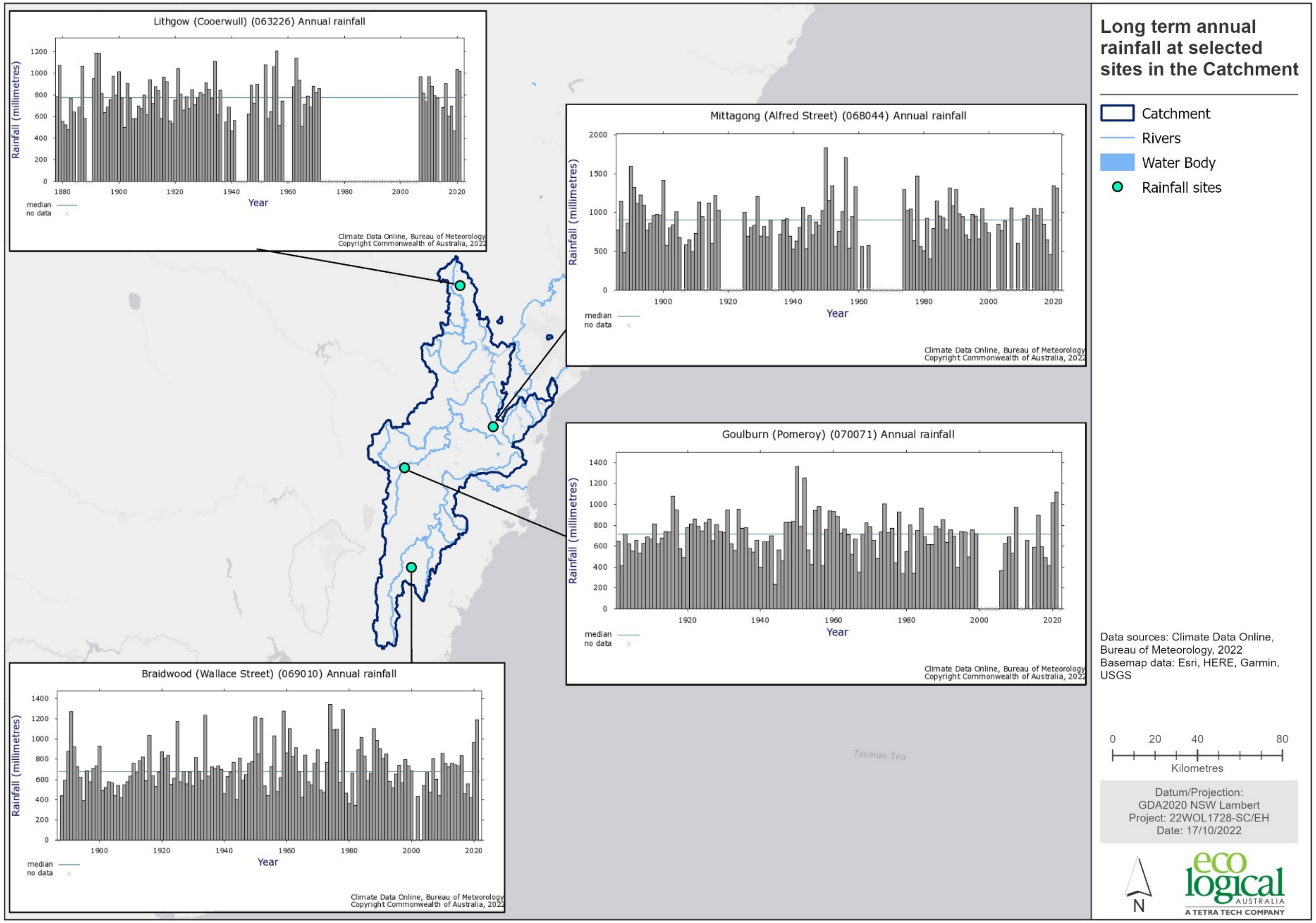


Figure 5-6: Long-term annual rainfall at selected locations in the Catchment

5.2. Temperature

The 2022 State of the Climate Report (BoM 2022) noted that changes in El Nino and La Nina temperatures since the 1950s have an overall increasing trend (Figure 5-7), with average global surface temperatures during La Nina years in the audit period warmer than those experienced during an El Nino year in the 1980s (BoM 2022). This type of analysis is not available at the Catchment-scale.

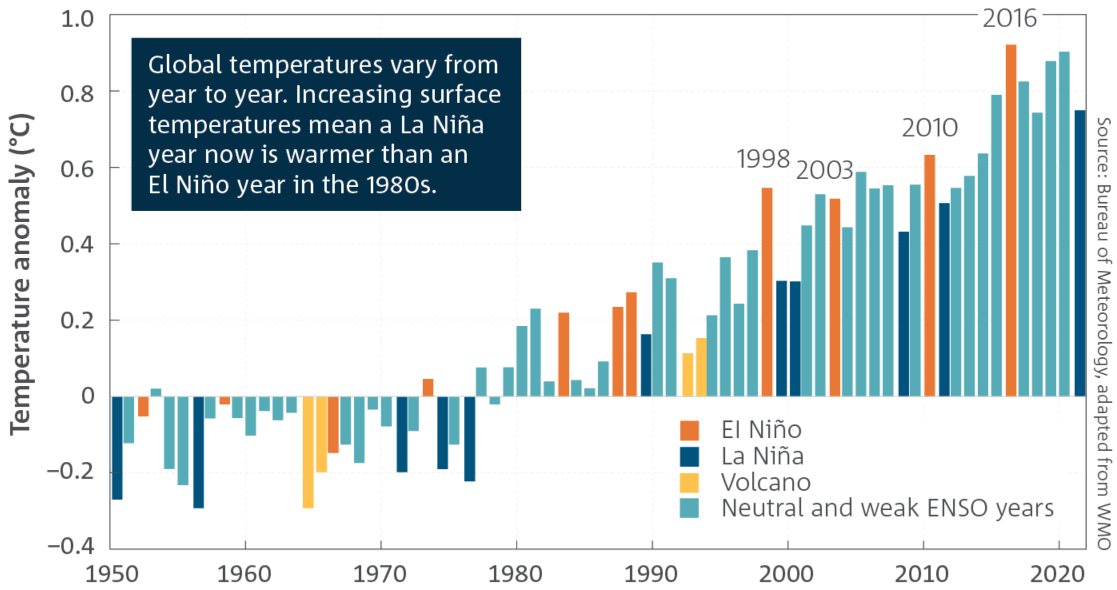
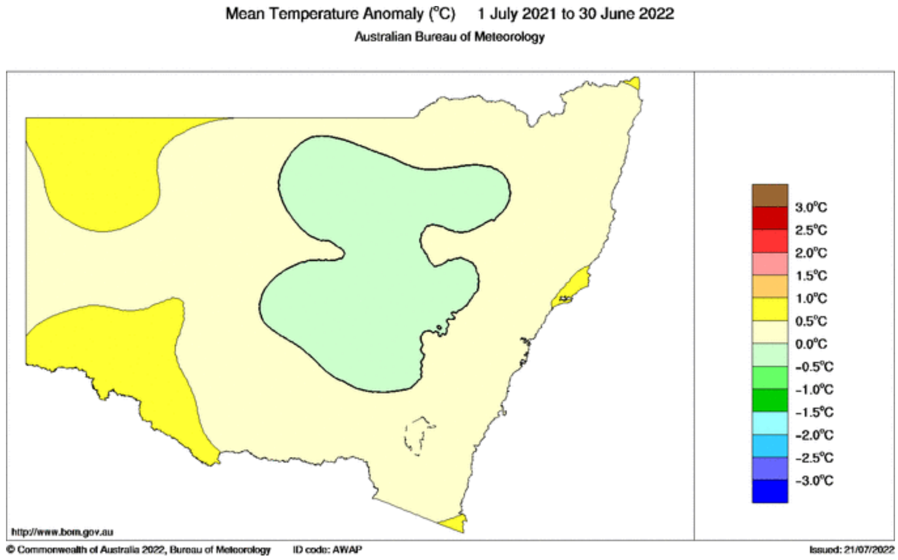
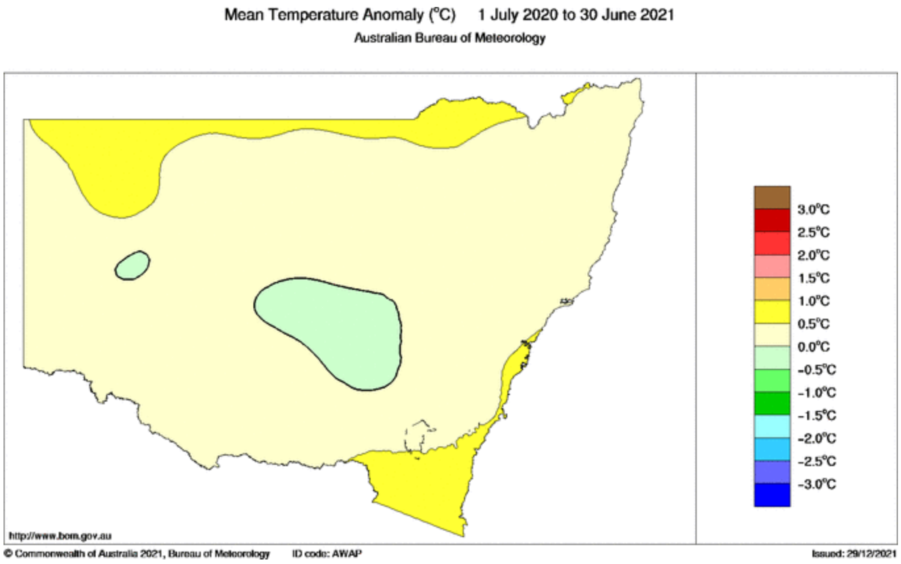


Figure 5-7: Annual global surface temperature anomalies of the Earth (land and ocean) 1950-2021 (BoM 2022)

The 2022 State of the Climate Report (BoM 2022) found that Australia's climate has warmed by an average of 1.47 ± 0.24 °C since national records began in 1910. Figure 5-8 compares BoM maps of the annual mean temperature anomalies experienced in NSW for each year of the current audit period. Temperature anomalies were calculated by the BoM with respect to the average over the 1961 to 1990 reference period. The last two years of the current audit period (2020-22) had similar conditions to the reference period, whereas mean temperatures in 2019-20 were higher than the reference period. Higher temperatures contributed to drought conditions and bushfires in 2019-20. Higher temperature and lower rainfall resulted in the lowest total runoff for the period 2018-2019 within 100 years for the Warragamba sub-catchment.





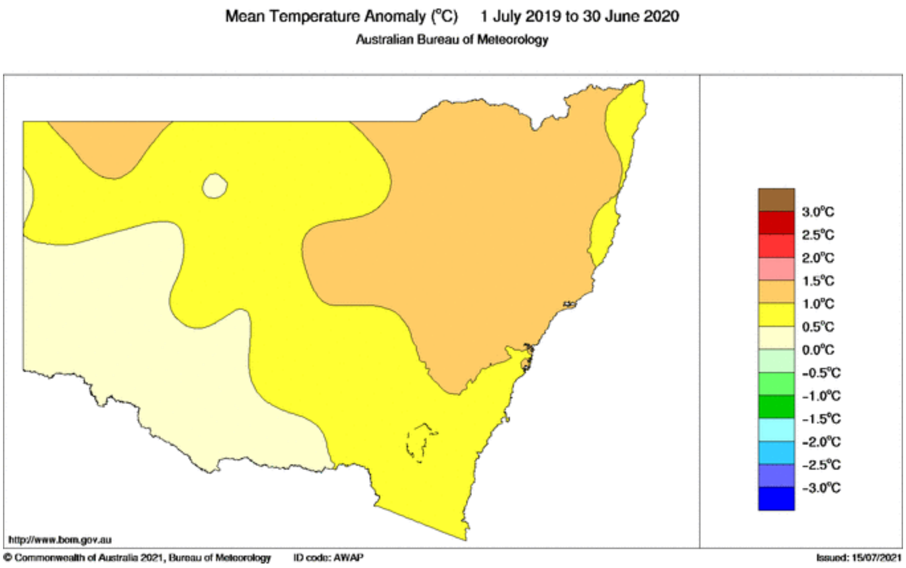


Figure 5-8: Comparison of annual mean temperature anomalies for the audit period

5.3. Climate change and sources of greenhouse gas emissions

Climate change is an existential global problem that is driven by greenhouse gas emissions (Intergovernmental Panel on Climate Change (IPCC) synthesis report 2023). The IPCC states that 'continued greenhouse gas emissions will lead to increasing global warming' and 'every increment of global warming will intensify multiple and concurrent hazards'. It further states that 'deep, rapid, and sustained reductions in greenhouse gas emissions would lead to a discernible slowdown in global warming within around two decades, and also to discernible changes in atmospheric composition within a few years'.

The Australian Government tracks the nation's greenhouse gas emissions each quarter through the National Greenhouse Gas Inventory, with sectorial analysis provided for:

- Energy – electricity (the largest source of emissions in the national inventory)
- Energy – stationary energy excluding electricity
- Energy – transport
- Energy – fugitive emissions
- Industrial processes and product use
- Agriculture
- Waste
- Land use, land use change and forestry.

Data for the quarterly reports are compiled in accordance with emissions estimation rules adopted under the Paris Agreement. Australia's emissions in the year to September 2022 were 21.0% below emissions in the year to June 2005 (the baseline year for Australia's 2030 target under the Paris Agreement) (DCCEEW 2023).

There were no data or studies available for this audit on sources and quantities of emissions from the Catchment. Compared to global values, emissions from the Catchment are negligible, however, every bit counts. Likely major sources of emissions from the Catchment include:

- Mt Piper coal-fired power station
- Coal mines: thermal and metallurgical coal extracted to be burnt as well as fugitive emissions from the mines
- Waste management centres such as at Woodlawn in the Mulwaree River sub-catchment
- Other industrial sources such as cement works
- Transport
- Agricultural activities such as from livestock.

5.4. Conclusion and recommendations

Long-term rainfall and temperature records for the Catchment reveal a pattern of increasingly frequent extreme weather, and climate models predict this worsening trend will continue. Adverse impacts from climate-driven events are already observable in the Catchment although the thresholds to avoid serious and irreversible harm to Catchment health from a changing climate are unclear. It is recommended that future Catchment audits review climate data and the influence of climate on indicators of Catchment health. Future audits should also review NSW Government climate change mitigation policies, strategies and activities relevant to Catchment health to inform future audit findings and recommendations.

There are global efforts underway to mitigate and adapt to a changing climate. To help reach NSW Government net zero targets, it is recommended that:

- The major sources of greenhouse gas emissions in the Catchment are confirmed and ranked to inform mitigation priorities.
- Major sources of greenhouse gas emissions in the Catchment need to demonstrate how they are reducing or eliminating greenhouse gas emissions. Initial plans for major regulated sources of greenhouse gases in the Catchment are to be complete in accordance with Action 5 of the EPA's Climate Change Action Plan 2023-26 and these should be made publicly available by June 2025.
- The EPA partners with DPE to ensure that development applications and post-approvals plans for proposed major projects in the Catchment provide evidence on how greenhouse gas emissions will be avoided or minimised. Proposed projects that would become a major contributor to greenhouse gas emissions in the Catchment should not be supported as this would counter global efforts to reach net zero and increase risks to Catchment health.

6. Bushfire

Severe, widespread bushfires were experienced in the Catchment during the summer of 2019-20. Climate change increases bushfire risks, which is a worsening trend for Catchment health.

6.1. Background

The State of the Climate Report (BoM 2022) found that parts of Australia, including the Catchment, have experienced an increase in extreme fire weather and a longer fire season since the 1950s. Poor water quality can result from large amounts of sediment, nutrients, ash and other pollutants being washed or leached into waterways and stored waters following significant fire activity. This is particularly a problem where heavy rain occurs in areas that have been severely burnt and there is no protective vegetation cover remaining.

Bushfire occurrences across the Catchment for the audit period and longer term were analysed in this audit by considering:

- Incidence of fire: which varies greatly from year to year, with the number of fires closely linked to prevailing weather patterns.
- Fire ecology: Fire shapes the structure, composition and ecological function – including soil and nutrient cycles of most plant communities, creating the specific habitats required by a range of species. Differing patterns of fire history will favour some species and associations, while suppressing others.
- Impacts of 2019-20 fire season (Black Summer bushfires): unprecedented in its intensity and scale.
- Fire intervals for vegetation communities: The minimum fire intervals needed to maintain a full complement of biodiversity within vegetation communities have been developed for NSW vegetation formations. These allow sufficient time between fires for species to complete the crucial stages of their life cycles essential for regeneration, such as plants being able to reach an age where they can produce seed. A key component of long-term monitoring of the effects of fire on ecological systems is matching fire history to vegetation formations.
- Hazard reduction: burning to reduce fuel loads is a key control strategy practised widely across NSW.
- Cultural burning: Cultural burning forms part of a broader cultural practice of caring for Country in traditional Aboriginal land management (DPC 2020). Cultural fire management protects, maintains, heals and enhances ecosystems and cultural values, while also reducing fuel loads (DPC 2020).

6.2. Categories of fire

There are two main categories of fire:

- Uncontrolled bushfire or wildfire – which can be caused by natural and human activities. Arson and accidental fires are more common where access to bushland areas is relatively easy. Natural fires started by lightning are also common, with dry thunderstorms a regular occurrence in late spring and summer. These fires have the potential to burn large areas of bushland, as they often originate where access is difficult and may burn for some time before suppression commences, by which time they are of considerable size. Under hot, dry weather conditions fire can spread rapidly and threaten life, property, assets and other values of the wider region. Suppression within the Catchment is often difficult due to remoteness, access and rugged terrain and if fires are not controlled while small, they typically require a significant and extended commitment of firefighting resources. During the bushfire season, WaterNSW runs an early detection and rapid response suppression program, where fire towers, surveillance flights and satellite tools are used to detect fires and fire fighters are deployed to ignitions in remote terrain by helicopter. This program is in addition to RFS and NPWS fire suppression capabilities and has a specific focus on the protection of Special Areas and water quality.

- Prescribed burns – also known as hazard reduction burns or planned burns. These are carefully planned and implemented by agencies in consultation with the community. They aim to achieve a mosaic of differing burn ages, contributing to the retention of natural landscape and biodiversity values by implementing appropriate fire intervals and thresholds for the vegetation types. Prescribed burning on public land within the Catchment is undertaken by the NPWS, RFS, NSW Fire and Rescue, Forestry Corporation, and WaterNSW (including contractors). The RFS and private land managers (or contractors) undertake prescribed burning in areas of native vegetation on private lands within the Catchment, at a smaller scale than burning of public land. An emphasis is placed by these agencies on managing vegetation at the urban/bushland interface to reduce fire risk to life and property.

6.3. Fire management

The principal aim of fire management is to reduce the risk that fires pose to human life, property, environment and cultural heritage while maintaining benefits to natural ecosystems and biodiversity. Fire management tools include bush fire risk management plans and the Bushfire Environmental Assessment Code. Key changes to the fire management planning framework that occurred during the audit period included:

- The 'next generation' bush fire risk management plan process was triggered by the 2020 NSW Bushfire Inquiry.
- Next generation bush fire risk management plans commenced preparation (but have not yet been finalised) for Sutherland, Lake George and Macarthur, with notification of Blue Mountains, Southern Highlands and Illawarra Bush Fire Risk Management Committees to commence.
- The Bush Fire Environmental Assessment Code was issued in 2021. See section 6.3.3 below.

The interim Bush Fire Coordinating Committee Policy was released in July 2022 and included changes to fire management zones, with specific zones to protect drinking water quality. For example, WaterNSW recommended a 'buffer zone' such as larger riparian areas to protect water quality and a 'fire advantage zone' to incorporate additional planned burns to keep fuel loads low and protect the Catchment from catastrophic burns.

6.3.1. Bush Fire Risk Management Plans

All land managers are required under the *Rural Fires Act 1997* to prevent the occurrence of bushfire, minimise the danger of a bushfire spreading from their land and undertake prevention works in line with bush fire risk management plans applicable to their properties. Plans are prepared by local multi-agency bushfire management committees in accordance with NSW Government policies and guidelines.

A bush fire risk management plan is a strategic document that identifies community assets at risk and sets out a five-year program of coordinated multi-agency treatments to reduce the risk of bush fire to life, property and other assets. Treatments include hazard reduction burning, grazing, community education, fire trail maintenance and establishing community fire units. Annual implementation programs are undertaken by the relevant land managers and fire-fighting authorities.

Bush fire risk management plans must be reviewed every five years in accordance with section 52 of the *Rural Fires Act 1997*. The current plans approved by each bush fire management committee across the Catchment are as follows:

- Blue Mountains – May 2016
- Chifley – February 2021
- Cumberland – October 2021
- Illawarra – March 2017
- Lake George – November 2018
- Lithgow – February 2021
- Macarthur – June 2012
- Southern Tablelands – March 2019
- Sutherland – 2015-2020
- Wollondilly – Wingecarribee – May 2017

The NSW Bushfire Inquiry 2020 Progress Report for the April to June 2022 stated that all bush fire management committees have a valid bush fire risk management plan and section 52 operations plan, with next generation plans currently in development. The next generation planning process will incorporate new modelling and methods of quantifying risk. The RFS is facilitating workshops and volunteer engagement on the next generation bush fire risk management plans.

6.3.2. Fire Access and Fire Trail Plans

Sections 51 and 52 of the *Rural Fires Act 1997* and clause 15 of the Rural Fires Regulation 2013 require fire access and fire trail plans to be prepared, monitored and maintained by bush fire management committees. Recommendation 33 of the 2020 Bushfire Inquiry stated that as a matter of urgency, the RFS Commissioner and Bush Fire Coordinating Committee need to accelerate and finalise a State-wide strategic fire trail network by 2029, with the RFS to lead acceleration of a strategic fire trail network. The NSW Bushfire Inquiry 2020 Progress Report for April to June 2022 stated that all bush fire management committees have prepared draft fire access and fire trail plans. At the time of this audit, no trails in the Catchment have been certified and registered by the RFS.

6.3.3. Bush Fire Environmental Assessment Code 2021

The Bush Fire Environmental Assessment Code July 2021 specifies the environmental assessment and approval process for bush fire hazard reduction work by identifying the conditions that are to be applied to minimise the potential environmental impact, including consideration of riparian buffers and watercourses. Authorities issue bush fire hazard reduction certificates for identified works in accordance with section 100C of the *Rural Fires Act 1997*. Bush fire hazard reduction works carried out in accordance with a bush fire hazard reduction certificate issued under this Code do not require approval under any other NSW environmental regulatory legislation.

The Code also identifies circumstances for which a certificate may not be issued based on the potential environmental impact. In these cases, a more comprehensive assessment of the potential impact is required under the relevant environmental legislation.

The Code sets fire interval requirements for vegetation communities. The fire intervals have been informed by the 'Guidelines for Ecologically Sustainable Fire Management' (Kenny et al 2004). The intervals are identified at the vegetation formation and vegetation class level, following the state-wide vegetation classification hierarchy by Keith (2004).

6.3.4. Bushfire management in the Special Areas

Land tenure within the Special Areas is 67% NPWS, 19% WaterNSW (inclusive of water storages) and 14% other. Active bushfire management is a core strategy for WaterNSW and NPWS under the SASPoM. The SASPoM does not direct actions on private lands within the Special Areas.

Under the *Rural Fires Act 1997*, the NPWS has primary responsibility for fire management on NPWS lands and WaterNSW has primary fire management responsibility on WaterNSW lands. This includes early detection, rapid response and fire suppression capabilities. NPWS is a statutory firefighting authority as defined by the *Rural Fires Act 1997* whereas WaterNSW is not. The joint sponsors have detailed fire management strategies and plans for the Special Areas that are regularly updated in consultation with the RFS and bush fire management committees.

NPWS and WaterNSW co-ordinate bush fire management planning at the operational level. In 2021-22, NPWS undertook 902 ha of hazard reduction burns within the Special Areas and 25 ha were burnt by WaterNSW.

NPWS

Key publications and programs for the NPWS are as follows:

- Fire management practices are guided by Living with Fire in NSW National Parks – A strategy for managing bushfires in national parks and reserves 2012-2021.
- Specific policies and procedures for managing fire in NSW national parks are included in the Fire Management Manual (2021-2022).
- Each reserve has a fire management plan used by NPWS in fire management planning and fire operations.
- The Enhanced Bushfire Management Program is a state-wide program that addresses bushfire risk through improved bushfire response capability, increased hazard reduction on parks and reserves, and enhanced bushfire research capacity.

The NPWS Fire Management Manual 2021-2022 details the policies and procedures for all fire management planning and fire operations on lands reserved under the *National Parks and Wildlife Act 1974* and any land managed by NPWS. This includes requirements regarding access (section 2.9.7), protection of waterways from firefighting chemicals (section 4.12.2) and the recognition that different management objectives apply in various places within the reserve system (e.g., the Catchment). There is a section for additional considerations regarding access to Schedule 1 and 2 Special Areas.

The NPWS Fire Management Manual lists the Cultural Fire Management Policy, Aboriginal Partnerships Policy and Guidelines for community (low risk) cultural burning on NPWS-managed land. It includes the following definitions:

- **Cultural fire management** is the involvement of Aboriginal people in fire management. The term cultural fire management is a broad term, which can cover the full spectrum of Aboriginal community involvement in fire management from consultation with communities about their needs and values in NPWS fire management activities to community presence on the fire ground for a low-risk cultural burn.
- **Culturally informed burning** is any burn with cultural burning objectives and Aboriginal community partnership in planning and approval. Culturally informed burning may not always have Aboriginal people involved on the fire ground.
- **Community (low risk) cultural burning** has the objective to enable Aboriginal community participation in culturally informed burning activities with NPWS. It is any cultural informed burn that would not normally meet the competency, personal protective equipment or other provisions of the Fire Management Manual but can be safely undertaken within the community led (low risk) cultural burn guidelines.

The Bushfire Research Hub has been set up by DPE to draw on the capabilities of partner research institutions to share fire management strategic knowledge. The Hub provides information needed to better understand how climate change will affect bushfire mitigation activities, and to evaluate the effectiveness, efficiency and impacts of the Enhanced Bushfire Management Program. The research will directly inform how fire is managed within parks leading to improved conservation of natural and cultural values both on- and off-reserves.

WaterNSW

WaterNSW manages fire on its land according to its:

- Bushfire Management Framework
- Bushfire Operational Protocol
- Procedure on Fire Management Principles for Water Quality and Quantity Protection in the Declared Catchment, which include:
    - Minimise the catchment area burned by unplanned and high-intensity fire
    - Protect riparian areas from mechanical and fire impact
    - Manage fire regimes within ecological thresholds where possible
    - Minimise impact of fire management activities on water quality
    - Suppress unplanned fire within important catchment areas
    - Apply recovery techniques to mitigate impacts in areas severely disturbed by fire and suppression activities
    - Promote fire management policies for water quality and quantity, and educate the community and stakeholders

   - Fire management for water quality outcomes based on best available science, monitoring and practice

- Type 2 Fire Strategies 2022-27 (Greater Sydney Sites) (Figure 6-1).

WaterNSW has identified its desired objective for fire in its Source Water Protection Strategy 2040. Fire management is planned on a five-year cycle through the Fire Management Plans for each bush fire management committee in Greater Sydney (Figure 6-1), and activities planned each year in WaterNSW's Catchment Protection Work Program and reported in the Annual Catchment Management Report.

WaterNSW has developed a dashboard to collate and track fire management information for the Catchment. The WaterNSW Bushfire Portal (dashboard) provides access to the planning, preparation and response phases of fire management. There is a fire map within the dashboard that gives the user an up-to-date interface. The entry point of the dashboard and an example of a mapping interface are shown in Figure 6-2 and Figure 6-3.

WaterNSW conducts a post burn assessment after hazard reduction activities to determine the outcomes and effectiveness. The science team samples the ash bed and the field team measures scorch height and load reduction measures. All post fire assessment results are reported to the relevant bush fire management committee.

6.4. Fire type and extent

The mapped record of wildfires and prescribed burns across the Catchment was prepared for this audit using datasets published by the RFS and NPWS on the SEED portal dating back to 1963. Whilst the compiled dataset does not contain all bushfire occurrences, it provided an indicative record of the location, extent and frequency of bushfires impacting the Catchment, especially larger landscape scale events. Results are graphed in Figure 6-4, with fire extent and type during the audit period mapped in Figure 6-5. Details of areas burnt by fire type and sub-catchment are in Table 6-1.

Wildfires were the dominant fire type across most of the Catchment during the audit period (and long-term), with 537,573 ha burnt by uncontrolled fires compared to 5,693 ha for prescribed fires. Most of the area burnt by wildfires during the audit period was during the 2019-20 fire season and it led to a substantial increase in the total area burnt by wildfire compared to previous audit periods.

In contrast, the total area of prescribed burning (5,693 ha) during the audit period was the lowest for all audit periods, with the largest extent being 46,488 ha in 2013-16. The Blue Mountains (12.9%), Upper Nepean (3.9%) and Wingecarribee (1.1%) sub-catchments were subject to prescribed burns during the audit period. The area burnt by prescribed burns after the 2019-20 fires was substantially reduced, which is likely a reflection of the wet weather conditions and the reduced need for prescribed burning given the extent of the Catchment burnt by wildfire in the 2019-20 fire season.

Table 6-1 shows that 17 of the 28 sub-catchments experienced wildfires across more than 25% of their total area during the current audit period. In contrast, no sub-catchments had more than 25% of their total area burnt during any previous audit period since 2007. The Lake Burragorang, Little River and Endrick River sub-catchments were the most extensively burnt (>80%) during the audit period.

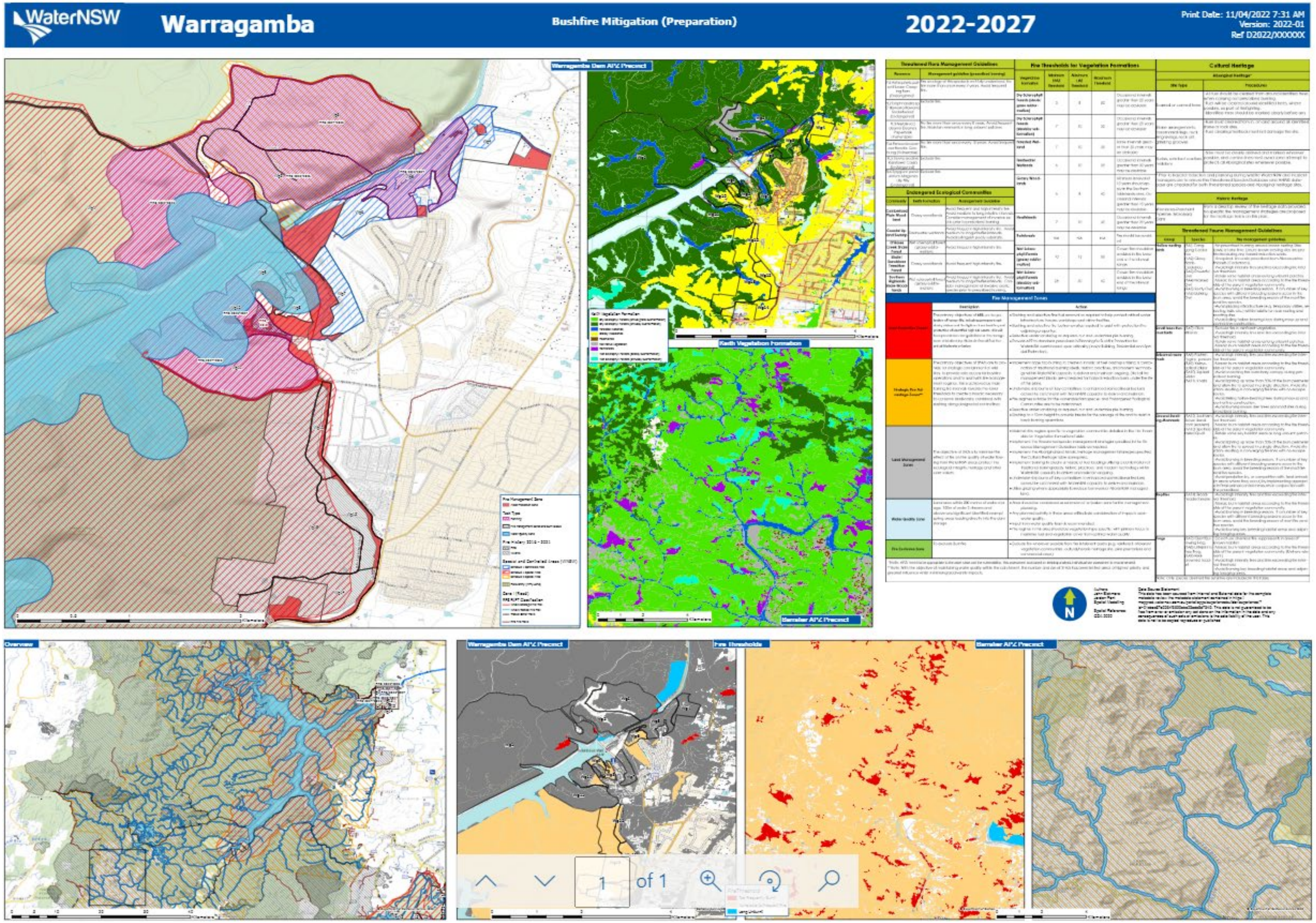


Figure 6-1: Warragamba Type 2 Bushfire Management Plan

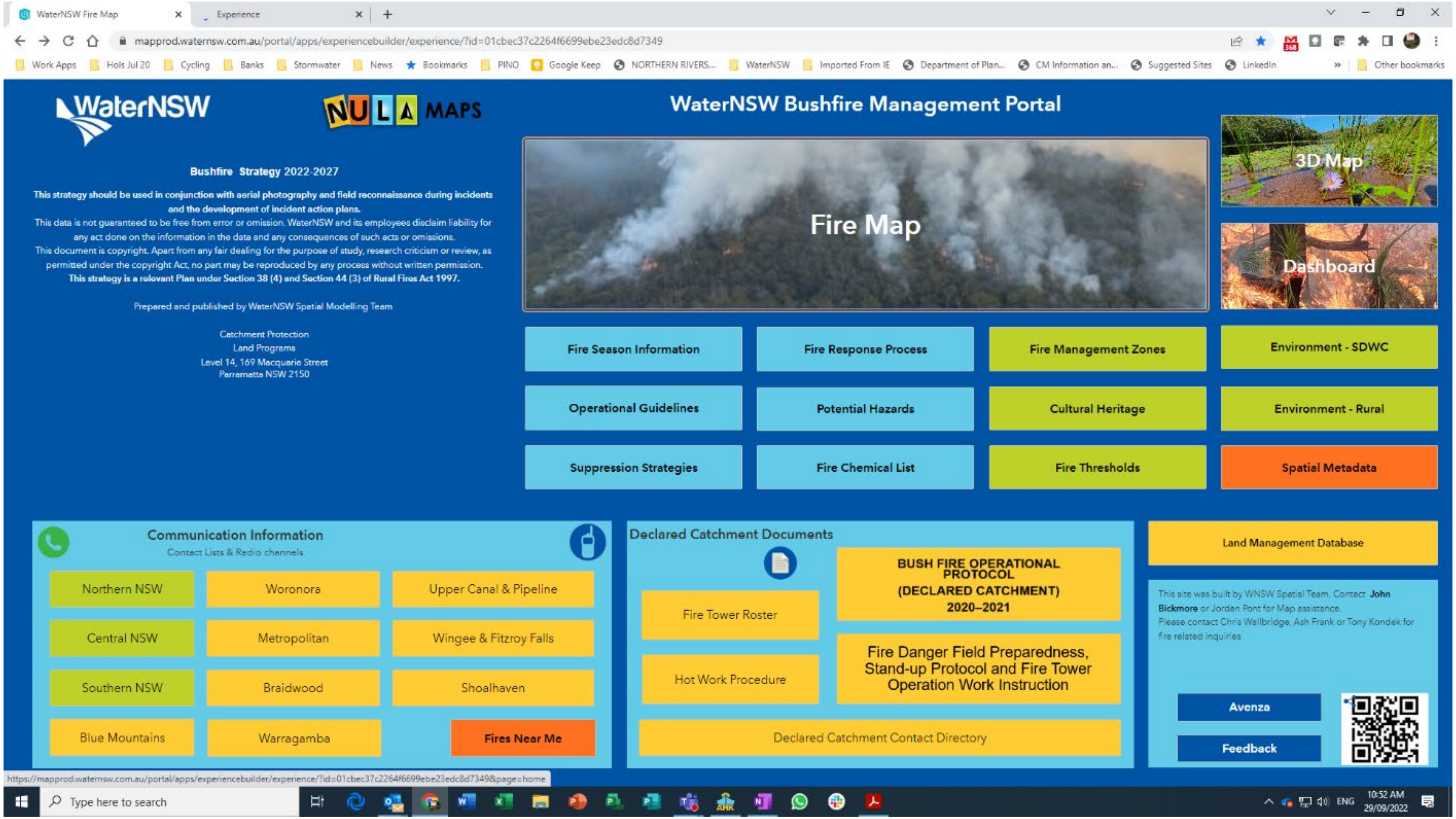


Figure 6-2: WaterNSW bushfire dashboard interface

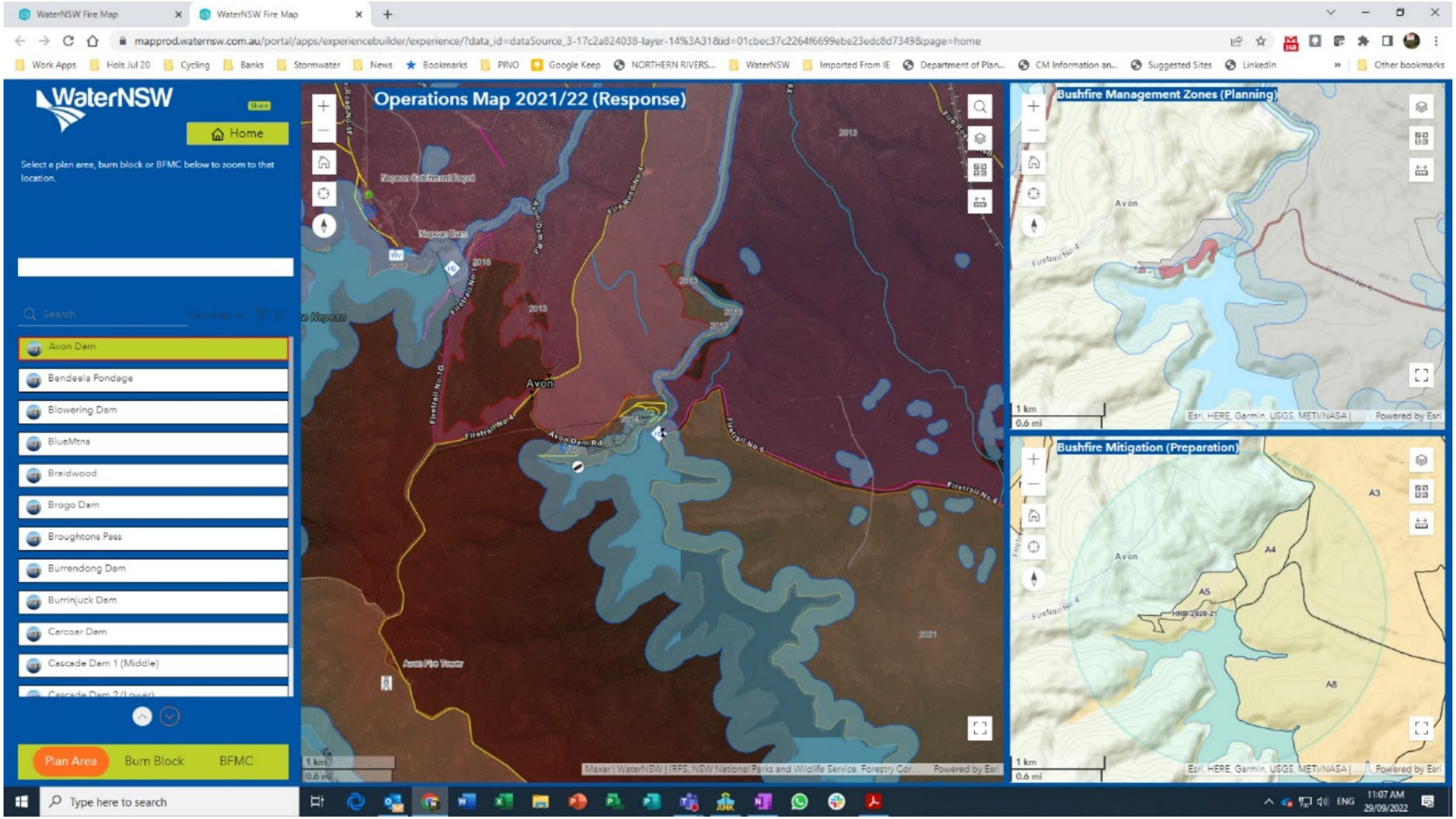


Figure 6-3: WaterNSW bushfire dashboard mapping interface snapshot

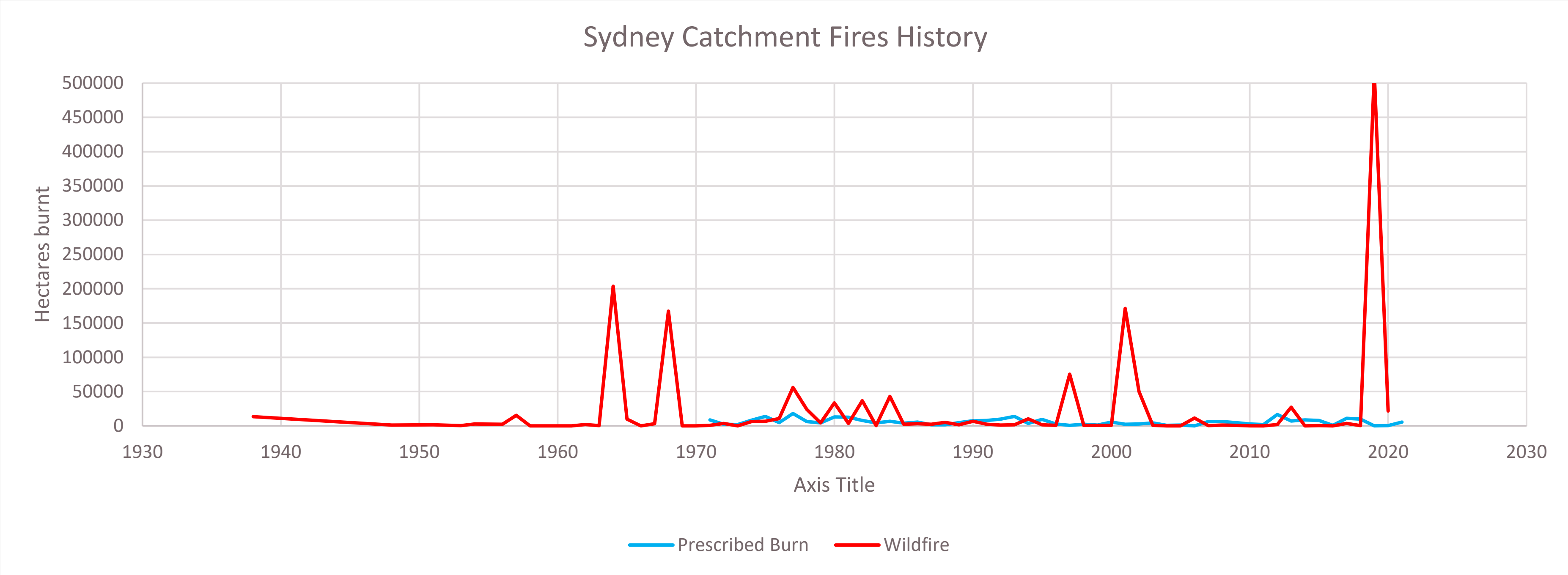


Figure 6-4: Long term patterns in fire extent in the Catchment

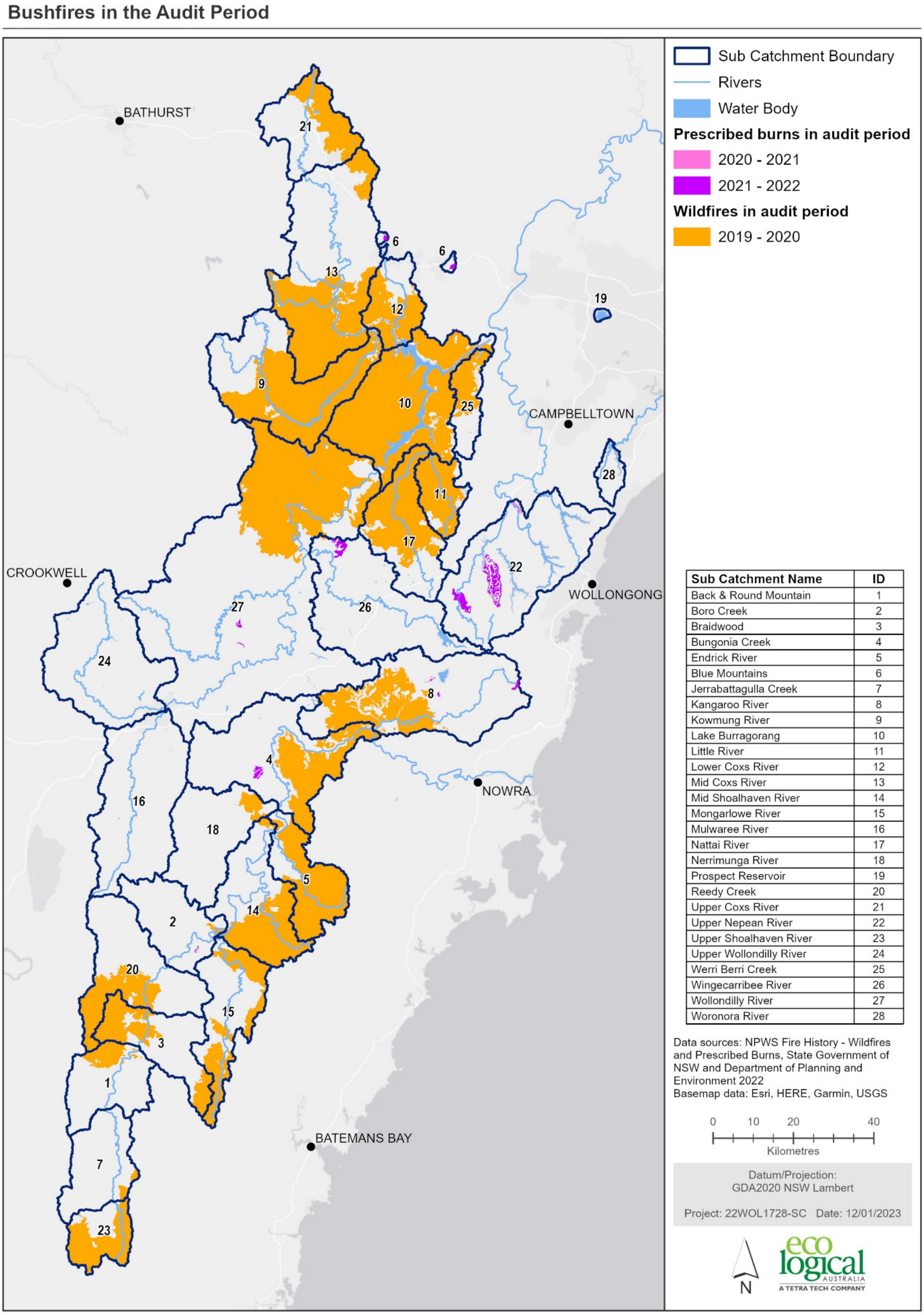


Figure 6-5: Bushfire and prescribed burn areas during the audit period

Table 6-1: Area (%) of prescribed and uncontrolled fires in each sub-catchment during five audit periods

Sub-catchment	Prescribed burns - % of total sub-catchment area						Uncontrolled burns - % of total sub-catchment area						Total
	2007-10	2010-13	2013-16	2016-19	2019-21	Total	2007-10	2010-13	2013-16	2016-19	2019-21	Total	
Back & Round Mountain Creeks						*0.0%*	0.0%				14.3%	*14.3%*	***14.3%***
Boro Creek			0.7%		0.2%	*0.9%*	0.4%		0.8%	0.6%	1.8%	*3.6%*	***4.5%***
Braidwood	1.4%		1.7%			*3.1%*			0.1%	0.0%	41.9%	*42.0%*	***45.1%***
Bungonia Creek		2.5%	0.8%	0.0%	0.6%	*3.9%*	0.0%	0.1%	0.0%		30.1%	*30.2%*	***34.1%***
Endrick River			6.0%	0.5%		*6.5%*					80.0%	*80.0%*	***86.5%***
Blue Mountains	13.1%	2.9%	5.7%	0.3%	12.9%	*34.9%*						*0.0%*	***34.9%***
Jerrabattagulla Creek				1.5%		*1.5%*					3.4%	*3.4%*	***4.9%***
Kangaroo River	1.4%	2.9%	1.7%	2.1%	0.4%	*8.5%*	1.3%	0.0%	0.0%	0.3%	28.6%	*30.2%*	***38.7%***
Kowmung River	4.7%	5.5%	0.3%	4.7%		*15.2%*			0.1%	0.0%	65.6%	*65.7%*	***80.9%***
Lake Burragorang	0.4%	0.0%	7.6%	5.6%	0.0%	*13.6%*	0.5%	0.0%	0.0%	0.0%	87.7%	*88.2%*	***101.8%***
Little River	0.1%	2.5%	5.8%	19.5%		*27.9%*	0.0%	0.0%	0.1%		86.1%	*86.2%*	***114.1%***
Lower Coxs River	1.1%	3.5%	3.5%	11.0%	0.0%	*19.1%*	0.5%	2.3%	0.7%	0.0%	64.9%	*68.4%*	***87.5%***
Mid Coxs River	3.0%	5.9%				*8.9%*	0.0%	0.0%	4.5%	0.0%	46.3%	*50.8%*	***59.7%***
Mid Shoalhaven River			1.3%	0.6%		*1.9%*		0.0%	1.1%	0.0%	48.6%	*49.7%*	***51.6%***
Mongarlowe River		0.5%	3.8%			*4.3%*	0.1%		2.9%	0.2%	42.7%	*45.9%*	***50.2%***
Mulwaree River			0.0%			*0.0%*						*0.0%*	***0.0%***
Nattai River	10.2%	3.8%	6.0%	1.8%		*21.8%*	0.0%	0.0%			64.9%	*64.9%*	***86.7%***
Nerrimunga River		1.2%	2.1%			*3.3%*			0.0%		5.7%	*5.7%*	***9.0%***
Prospect Reservoir		0.1%				*0.1%*			0.0%			*0.0%*	***0.1%***
Reedy Creek	0.0%		0.6%			*0.6%*				0.1%	29.5%	*29.6%*	***30.2%***

Sub-catchment	Prescribed burns - % of total sub-catchment area						Uncontrolled burns - % of total sub-catchment area						Total
	2007-10	2010-13	2013-16	2016-19	2019-21	Total	2007-10	2010-13	2013-16	2016-19	2019-21	Total	
Upper Coxs River						*0.0%*	0.0%		17.6%	0.0%	40.2%	*57.8%*	***57.8%***
Upper Nepean River	0.2%	1.0%	1.0%	0.8%	3.9%	*6.9%*	0.0%	1.2%	15.2%	0.1%	0.0%	*16.5%*	***23.4%***
Upper Shoalhaven River			4.7%	1.2%		*5.9%*	0.4%	0.0%		0.0%	70.6%	*71.0%*	***76.9%***
Upper Wollondilly River						*0.0%*						*0.0%*	***0.0%***
Werri Berri Creek	1.6%	2.8%	1.4%	3.2%		*9.0%*		0.4%			51.5%	*51.9%*	***60.9%***
Wingecarribee River	0.0%	1.0%	0.1%		1.1%	*2.2%*	0.0%		0.0%	0.0%	0.2%	*0.2%*	***2.4%***
Wollondilly River	1.0%	0.0%	0.7%	0.7%	0.1%	*2.5%*	0.0%	0.0%	0.0%	1.1%	25.2%	*26.3%*	***28.8%***
Woronora River				0.2%		*0.2%*		0.3%				*0.3%*	***0.5%***

6.5. Fire frequency

Long term fire frequency mapping is shown in Figure 6-7. Fire frequency is not a direct measure of impact on Catchment health and needs to be considered in conjunction with fire severity (section 6.6) and fire interval thresholds (section 6.7). The pattern emerging in the long-term fire frequency across the Catchment is a matrix resulting from proximity to urban areas, rates of arson, wildfires resulting from lightning, remote areas where fire suppression was difficult and prescribed burn history. An example of this is within the Upper Nepean, Little River and Nattai River sub catchments which contain at-risk towns and are therefore subject to more frequent prescribed burning regimes that are geared towards reducing risk to public safety and urban assets.

The Lake Burragorang sub-catchment fire frequency reflects its management and land ownership profile and is a combination of prescribed burning regimes and wildfire ignitions in remote areas. Most of the area in the photo below was burnt in 2019-20. Vegetation was recovering well at the time of the audit site inspection in November 2022.

Figure 6-6: Lake Burragorang looking north from Burragorang lookout (November 2022)

Fire Frequency – Complete Mapped Record

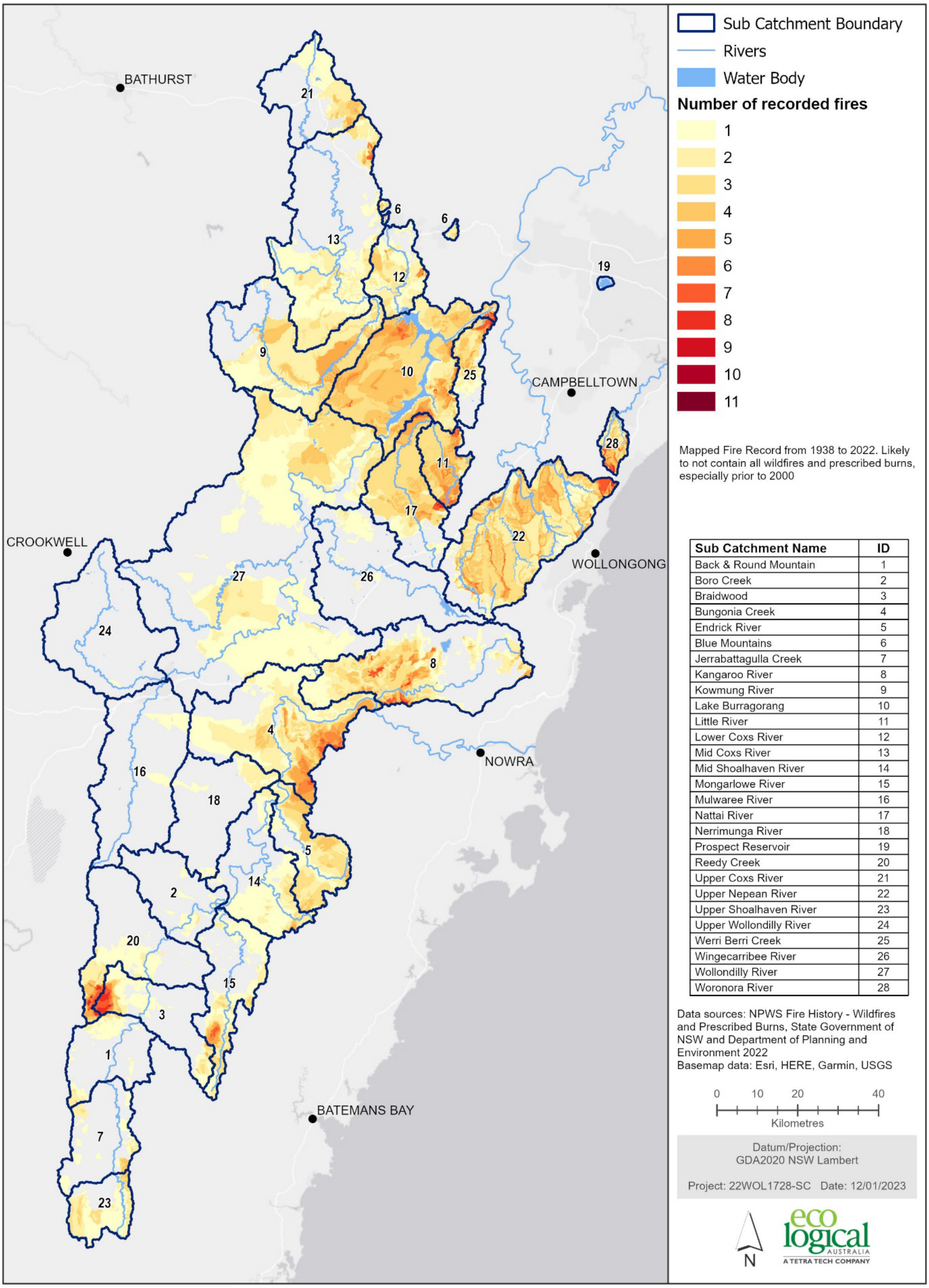


Figure 6-7: Long term fire frequency (1938-2022)

6.6. Fire extent and severity

Fire extent and severity mapping uses Sentinel 2 satellite imagery and machine learning to assess vegetation consumption by fire across NSW. This semi-automated approach to fire mapping was developed by DPIE and RFS and launched in July 2020, with a prototype system deployed in December 2019. Fire extent and severity mapping has standardised severity classes to allow comparison of different fires across the landscape (Figure 6-8).

Severity class	Description	Percentage foliage fire affected
Unburnt	Unburnt surface with green canopy	0% canopy and understorey burnt
Low	Burnt understorey with unburnt canopy	>10% burnt understorey >90% green canopy
Moderate	Partial canopy scorch	20–90% canopy scorch
High	Complete canopy scorch / partial canopy consumption	>90% canopy scorched <50% canopy biomass consumed
Extreme	Complete canopy consumption	>50% canopy biomass consumed

Figure 6-8: Fire extent and severity classification (DPE 2020)

Figure 6-9 shows the severity of the fires across the Catchment in 2019-20 and Table 6-2 details the percentage extent and severity burnt by sub-catchment. Eight sub-catchments had over 50% of their area burnt, and 17 had over 25% burnt. Furthermore, the fire severity for more burnt sub-catchments often also experienced elevated fire severity, being moderate, high or extreme. Sub-catchments with a notable severely burnt area include:

- Endrick River with 56% burnt at extreme severity (full canopy consumption)
- Mid Shoalhaven River with 32% burnt at extreme severity
- Little River with 14% burnt at extreme severity and an additional 23% burnt at high severity (full canopy scorch +/- partial canopy consumption) plus 26% burnt at moderate severity (partial canopy scorch)
- Lake Burragorang with 9% burnt at extreme severity and an additional 20% burnt at high severity plus 34% burnt at moderate severity
- Upper Shoalhaven River with 19% burnt at extreme severity and an additional 18% burnt at high severity
- Nattai River with 15% burnt at extreme severity and an additional 19% burnt at high severity plus 19% burnt at moderate severity
- Kowmung River with 16% burnt at extreme severity and an additional 17% burnt at high severity plus 23% burnt at moderate severity.

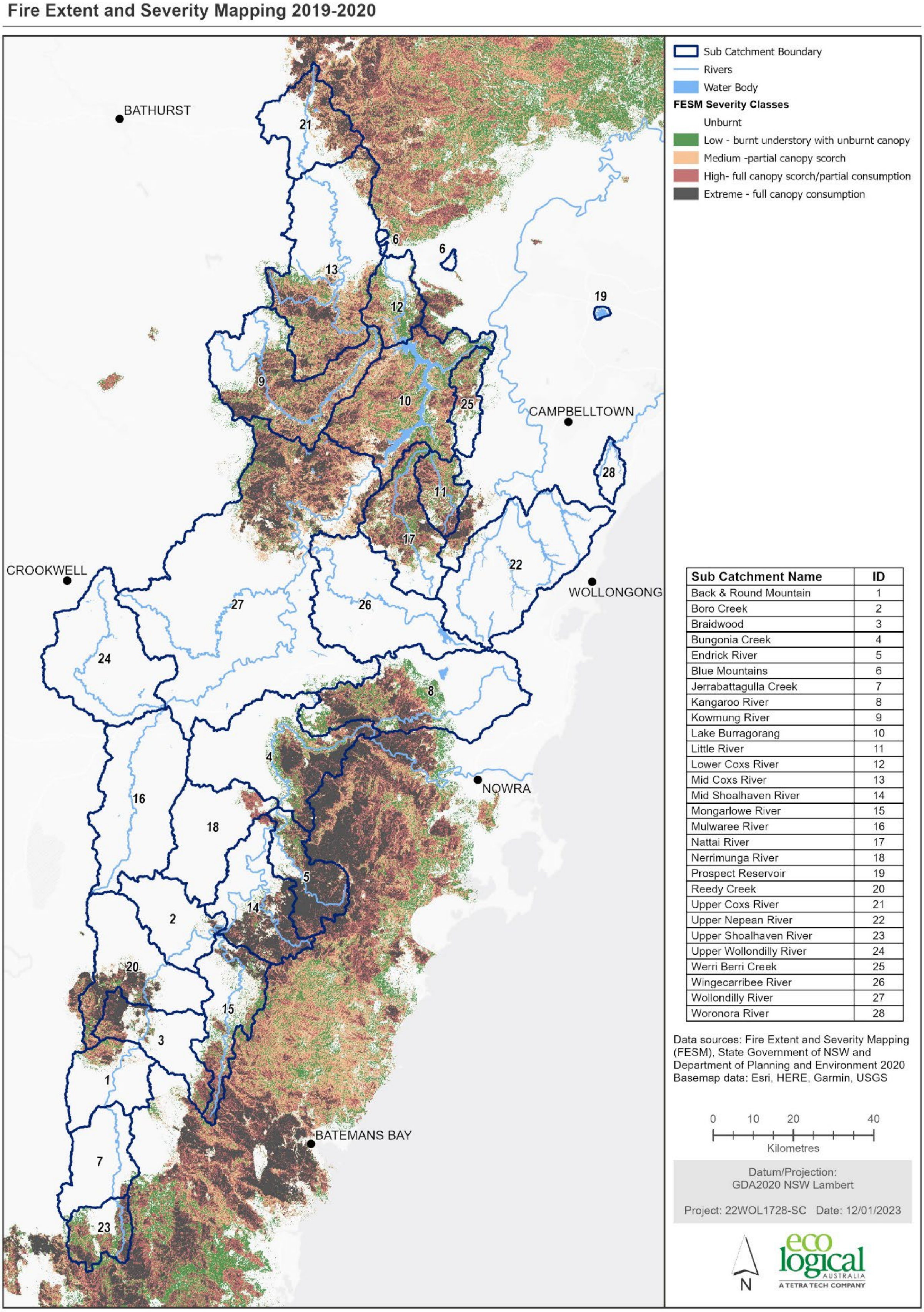


Figure 6-9: Fire extent and severity - 2019-20 fire season

Table 6-2: Fire extent and severity results 2019-2020

Sub-catchment	Low	Moderate	High	Extreme	Total extent burnt
Little River	21%	26%	23%	14%	84%
Lake Burragorang	21%	34%	20%	9%	83%
Endrick River	6%	7%	13%	56%	82%
Upper Shoalhaven River	21%	13%	18%	19%	70%
Nattai River	14%	19%	19%	15%	68%
Kowmung River	12%	23%	17%	16%	67%
Lower Coxs River	23%	24%	11%	8%	65%
Werri Berri Creek	17%	18%	12%	5%	52%
Mongarlowe River	12%	11%	12%	15%	50%
Mid Shoalhaven River	3%	5%	9%	32%	48%
Mid Coxs River	8%	19%	11%	9%	47%
Kangaroo River	11%	9%	9%	12%	41%
Upper Coxs River	3%	13%	11%	13%	39%
Bungonia Creek	8%	7%	6%	19%	39%
Braidwood	4%	7%	10%	16%	37%
Reedy Creek	3%	5%	6%	14%	29%
Wollondilly River	3%	7%	6%	8%	25%
Back & Round Mountain Creeks	3%	5%	3%	2%	14%
Nerrimunga River	1%	1%	3%	1%	6%
Jerrabattagulla Creek	1%	0%	1%	1%	3%
Boro Creek	1%	1%	0%	1%	3%
Blue Mountains	1%	0%	0%	0%	1%
Wingecarribee River	0%	1%	0%	0%	1%
Upper Nepean River	0%	0%	0%	0%	0%
Mulwaree River	0%	0%	0%	0%	0%
Prospect Reservoir	0%	0%	0%	0%	0%
Upper Wollondilly River	0%	0%	0%	0%	0%
Woronora River	0%	0%	0%	0%	0%

Low – Burnt surface with unburnt canopy. Moderate – Partial canopy scorch. High severity – Full canopy scorch (+/- partial canopy consumption). Extreme – Full canopy consumption.

It is at these higher burn severities where surface fuel was consumed and the canopy was scorched or consumed to varying degrees (Figure 6-9) where impacts on water quality were greater and additional measures (e.g., ash containment booms) were needed to manage risks to drinking water. This was especially the case for more severely burnt sub-catchments within the Special Areas (e.g., Lake Burragorang, Nattai, Kowmung, Little River) or in other areas proximal to water storages (e.g., Lower Coxs River, Mid Coxs River, Wollondilly River, Kangaroo Creek, Bungonia Creek) where there was less opportunity to capture and mitigate the products of fire combustion.

6.7. Vegetation fire interval

The vegetation fire regime threshold analysis for this audit was sourced from FireTools (Williamson 2021), an initiative of the NSW Bushfire Hub. It examined the annual fire history record from 1990 to 2022 against the fire regimes for vegetation formations (Keith 2004). The analysis identified where vegetation had been too frequently burnt, vulnerable to being over-burnt, within threshold, or too long unburnt as per Table 6-3.

The fire interval analysis for the audit period was potentially skewed by the fires during the 2019-20 season. Therefore, the vegetation fire interval status immediately prior to the audit period was explored using 2018 data and presented in Figure 6-10 and Table 6-4 to provide a base case scenario to give context to the audit period data.

Table 6-3: Vegetation fire regime threshold status definitions (Firetools Cloud User Guide v1.1)

Category Name	Guidelines for interpreting fire regime threshold status
Too Frequently Burnt (Consecutive fire intervals shorter than recommended minimum interval)	These areas have experienced sustained (two or more) consecutive intervals between fires shorter than the recommended minimum interval for this vegetation type. Any Rainforest / Mangrove/ fire exclusion vegetation that has been burnt will be in this category. Areas of vegetation that are repeatedly burnt at intervals shorter than recommended for the vegetation type may experience a decline in the abundance of plant species sensitive to frequent fire. If inter- fire intervals shorter than the recommended minimum continue, these sensitive species are at risk of local extinction. Attempts should be made to minimise fire occurrence in these areas.
Vulnerable to Frequent Fire (Most recent fire interval shorter than recommended minimum interval)	These areas have already experienced one inter-fire interval less than the minimum interval recommended for this vegetation type and/or the current time-since-fire is less than the minimum recommended interval. All unburnt Rainforest/ Mangrove/ fire exclusion vegetation is in this category.
Within Threshold	The time-since-fire age of the vegetation is greater than the minimum recommended inter-fire interval and less than the maximum recommended inter-fire interval. If a fire occurs before the number of years specified as the minimum interval has been reached it will move into the 'Vulnerable to Frequent Fire' category. If three or more fires occur in close succession the area will move into the 'Too Frequently Burnt' category.
Long Unburnt (One or more fire intervals longer than longest recommended interval)	The post-fire age of the vegetation is greater that the recommended maximum inter-fire interval for this vegetation type. If fire continues to be absent from the vegetation for a prolonged time, it is anticipated that plant species that require fire to stimulate flowering or seed production (and their seed banks) may begin to senescence. Long unburnt areas in some vegetation types are very rare and therefore significant. Long unburnt vegetation may also have other ecological values that make it important habitat for certain species in a given area. Careful consideration should be given before burning these areas, and wherever possible the decision should be based on a scientific assessment and/or recommendation prior to burning.
Unknown	There has been no fire mapped for this area and the maximum recommended fire interval for the vegetation type is longer than the length of time for which fire records are available in the study area. It is not possible to determine if the vegetation is in the 'Within Threshold' or 'Long Unburnt' category.
No Regime Assigned	Areas which do not have recommended fire intervals assigned to them e.g., cleared land, rock.

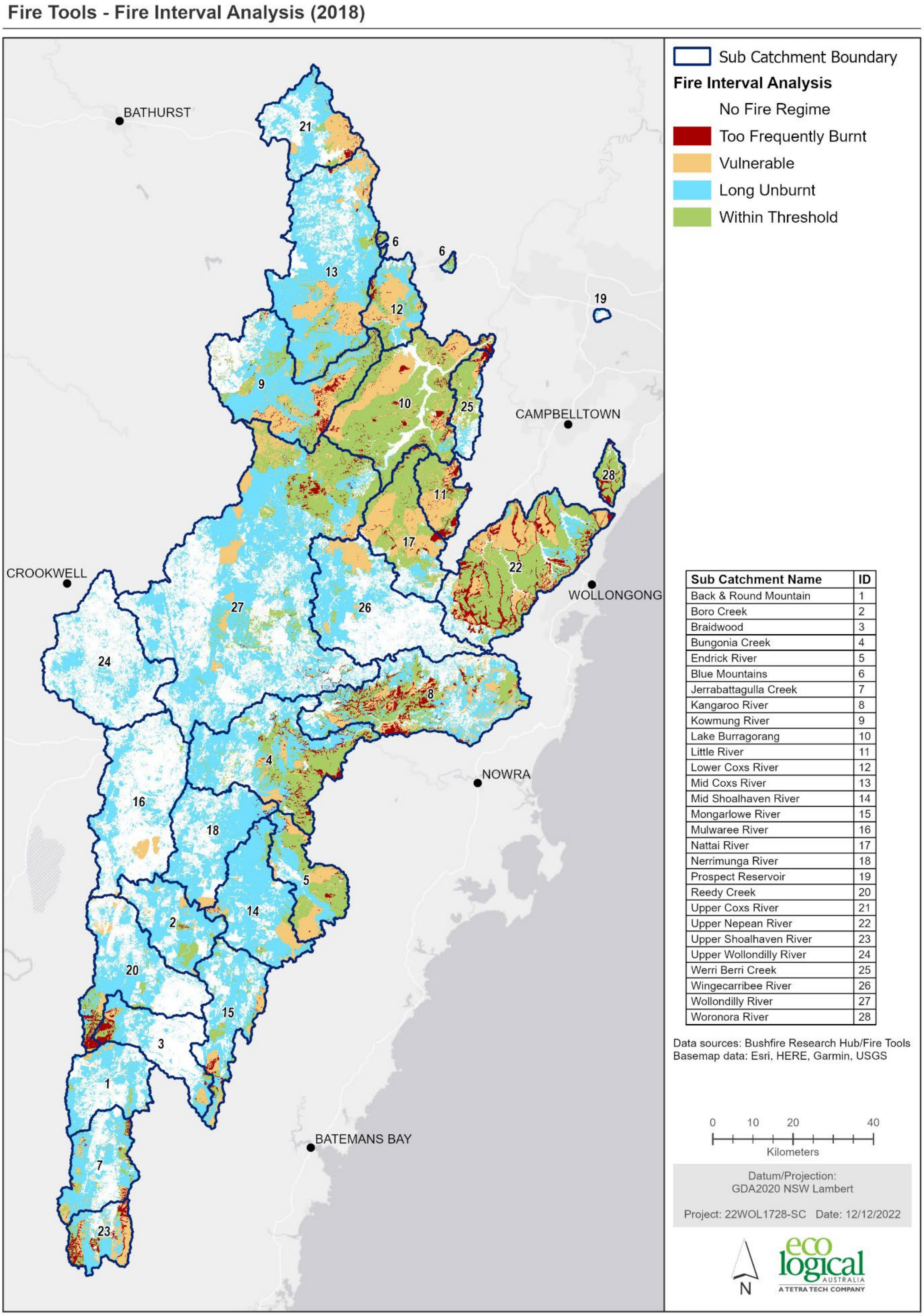


Figure 6-10: Fire interval analysis 2018

Table 6-4: 2018 Fire interval analysis proportion (%) of sub-catchment area in fire regime category

Sub-catchment	No Regime	Overburnt	Vulnerable	Vulnerable	Within Threshold
Back & Round Mountain Creeks	45%	0%	3%	49%	2%
Boro Creek	31%	0%	4%	57%	7%
Braidwood	57%	5%	4%	29%	5%
Bungonia Creek	19%	5%	5%	41%	30%
Endrick River	7%	2%	26%	26%	39%
Blue Mountains	14%	7%	9%	13%	57%
Jerrabattagulla Creek	32%	2%	8%	51%	7%
Kangaroo River	24%	9%	15%	31%	22%
Kowmung River	17%	4%	19%	40%	19%
Lake Burragorang	9%	5%	25%	2%	59%
Little River	3%	11%	42%	0%	43%
Lower Coxs River	7%	3%	35%	31%	24%
Mid Coxs River	20%	1%	17%	55%	7%
Mid Shoalhaven River	14%	0%	9%	72%	5%
Mongarlowe River	29%	2%	9%	51%	8%
Mulwaree River	73%	0%	3%	24%	0%
Nattai River	14%	3%	33%	9%	41%
Nerrimunga River	36%	0%	4%	60%	0%
Reedy Creek	48%	3%	3%	39%	7%
Upper Coxs River	36%	1%	18%	41%	3%
Upper Nepean River	12%	13%	21%	8%	46%
Upper Shoalhaven River	13%	12%	28%	37%	9%
Upper Wollondilly River	76%	0%	0%	24%	0%
Werri Berri Creek	28%	5%	10%	12%	45%
Wingecarribee River	57%	0%	8%	33%	1%
Wollondilly River	38%	1%	6%	42%	13%
Woronora River	8%	18%	1%	0%	72%
Prospect Reservoir	67%	0%	0%	26%	7%
TOTAL	32%	3%	12%	35%	17%

Fire Tools - Fire Interval Analysis (2022)

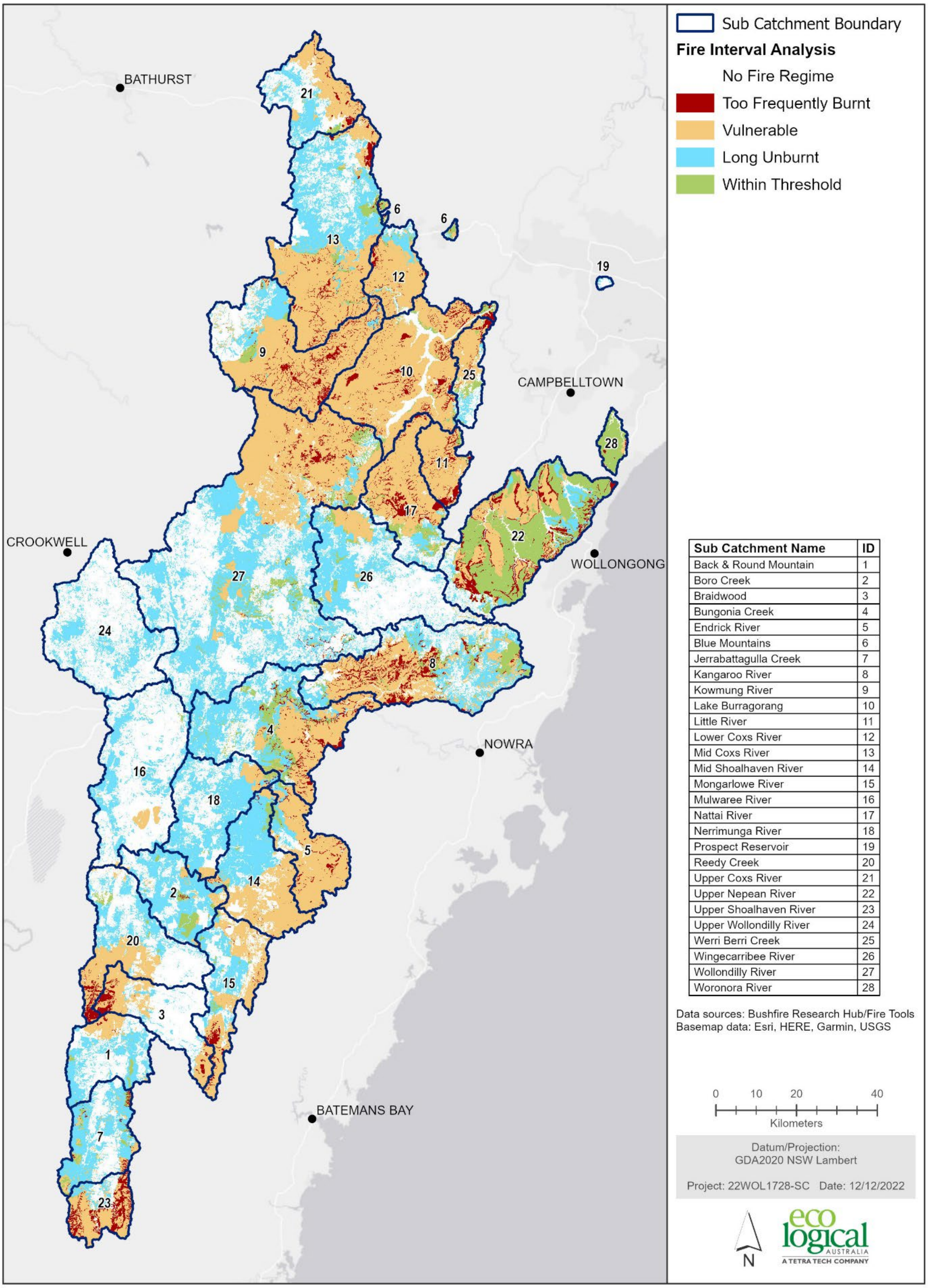


Figure 6-11: Fire interval analysis 2022

Table 6-5: 2022 Fire Tools Analysis proportion (%) of sub-catchment area in fire regime category

Sub catchment	No Regime	Overburnt	Vulnerable	Long Unburnt	Within Threshold
Back & Round Mountain Creeks	45%	1%	12%	40%	2%
Boro Creek	31%	0%	7%	55%	7%
Braidwood	57%	5%	31%	6%	0%
Bungonia Creek	19%	5%	31%	34%	11%
Endrick River	7%	4%	79%	8%	3%
Blue Mountains	14%	7%	18%	9%	52%
Jerrabattagulla Creek	32%	2%	9%	51%	6%
Kangaroo River	24%	9%	35%	25%	8%
Kowmung River	17%	7%	62%	12%	2%
Lake Burragorang	9%	8%	80%	1%	2%
Little River	3%	12%	82%	0%	3%
Lower Coxs River	7%	4%	75%	12%	2%
Mid Coxs River	20%	3%	44%	30%	3%
Mid Shoalhaven River	14%	1%	44%	40%	2%
Mongarlowe River	29%	4%	43%	23%	2%
Mulwaree River	73%	0%	3%	24%	0%
Nattai River	14%	9%	61%	9%	7%
Nerrimunga River	36%	0%	9%	54%	1%
Reedy Creek	48%	3%	25%	22%	1%
Upper Coxs River	36%	3%	38%	22%	2%
Upper Nepean River	12%	11%	22%	8%	47%
Upper Shoalhaven River	13%	22%	53%	11%	0%
Upper Wollondilly River	76%	0%	0%	24%	0%
Werri Berri Creek	28%	6%	48%	10%	8%
Wingecarribee River	57%	0%	8%	33%	2%
Wollondilly River	38%	2%	25%	32%	3%
Woronora River	8%	3%	5%	0%	85%
Prospect Reservoir	67%	0%	0%	26%	7%
TOTAL	32%	4%	33%	25%	6%

Comparison of results for 2018 and 2022 (Table 6-6) shows there was a substantial increase in the 'vulnerable' category during the audit period and corresponding decreases in the 'within threshold' and 'long unburnt' categories.

Table 6-6: Summary of Fire Tools Analysis results for 2018 and 2022

Category	2018 results	2022 results
Overburnt	3%	4%
Vulnerable	12%	33%
Within threshold	17%	6%
Long unburnt	53%	25%
No fire regime	32%	32%

Understanding the processes operating in the regularly overburnt areas of the catchment is critical to effective management in those sub-catchments. Consistently overburnt vegetation can increase risks to water quality via reduced vegetative cover and soil stability, as well as mobilising combustion products into the water cycle. Sub catchments with a notable negative change from 2018 to 2022 were those affected by the 2019-20 fires, including:

- Upper Shoalhaven
    - 12% overburnt in 2018 increasing to 20% overburnt in 2022
    - 28% vulnerable in 2018 increasing to 53% vulnerable in 2022
    - 72% within threshold in 2018 decreasing to 0% within threshold in 2022
- Little River
    - Vulnerable increased from 42% in 2018 to 82% in 2022
    - 43% was within threshold in 2018 decreasing to 3% in 2022
- Nattai River
    - Vulnerable rose from 33% in 2018 to 61% in 2022
    - Within threshold dropped from 41% in 2018 to 7% in 2022
- Lake Burragorang
    - Overburnt rose from 5% in 2018 to 8% in 2022
    - Vulnerable rose from 25% in 2018 to 80% in 2022
    - Within threshold dropped from 59% in 2018 to 2% in 2022
- Kowmung River
    - Vulnerable increased from 19% in 2018 to 62% in 2022
    - Within threshold decreased from 19% in 2018 to 2% in 2022

- The two largest sub catchments displayed comparable results despite only being partially impacted by fire in the 2019-20 season:
  - Wollondilly River
    - Vulnerable rose from 6% in 2018 to 25% in 2022
    - Long unburnt dropped from 42% in 2018 to 32% in 2022
    - Within threshold subsequently changed from 13% in 2018 to 3% in 2022
  - Mid Coxs River
    - Overburnt saw a minor increase from 1% in 2018 to 3% in 2022
    - Vulnerable rose from 17% in 2018 to 44% in 2022
    - Long unburnt decreased from 55% in 2018 to 30% in 2022
    - Within threshold dropped from 7% in 2018 to 3% in 2022

To further explore results of the fire interval analysis for this audit, two locations were mapped in more detail. The 2018 vegetation fire interval status of Tallaganda State Conservation Area is shown in Figure 6-12 and Tallowa Dam in Figure 6-13. In these cases, the 'too frequently burnt' areas closely align with the extent of previous prescribed burns. These case studies indicate that in some areas, fire management activities (in this case prescribed burning) may be leading to vegetation becoming overburnt, which could result in soil instability, mobilisation of nutrients during rain events and harm to ecosystems. Discussions with relevant agencies during this audit indicated that they are aware of these risks and regularly undertake fire interval analysis using FireTools and other methods.

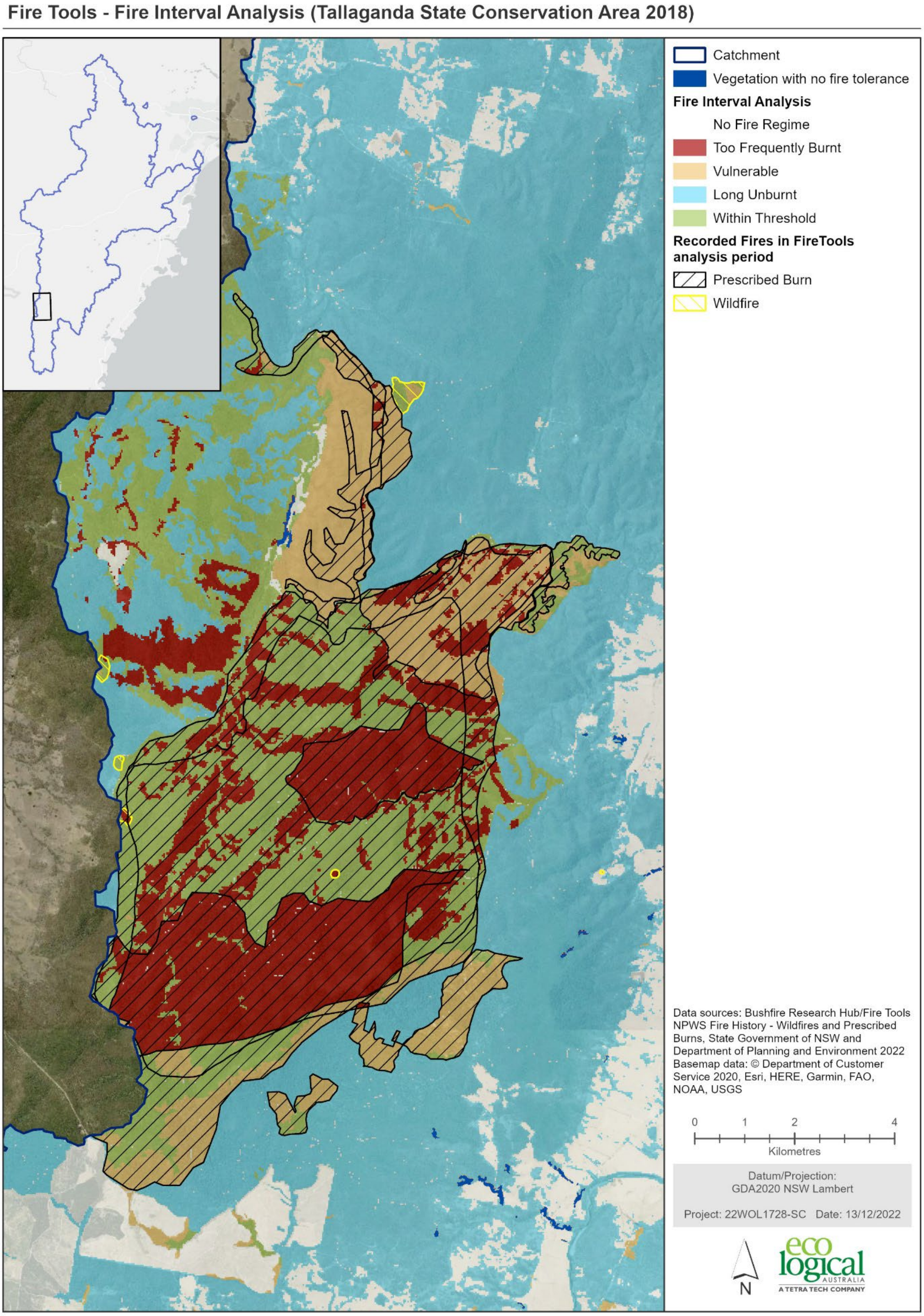


Figure 6-12: Tallaganda fire interval analysis

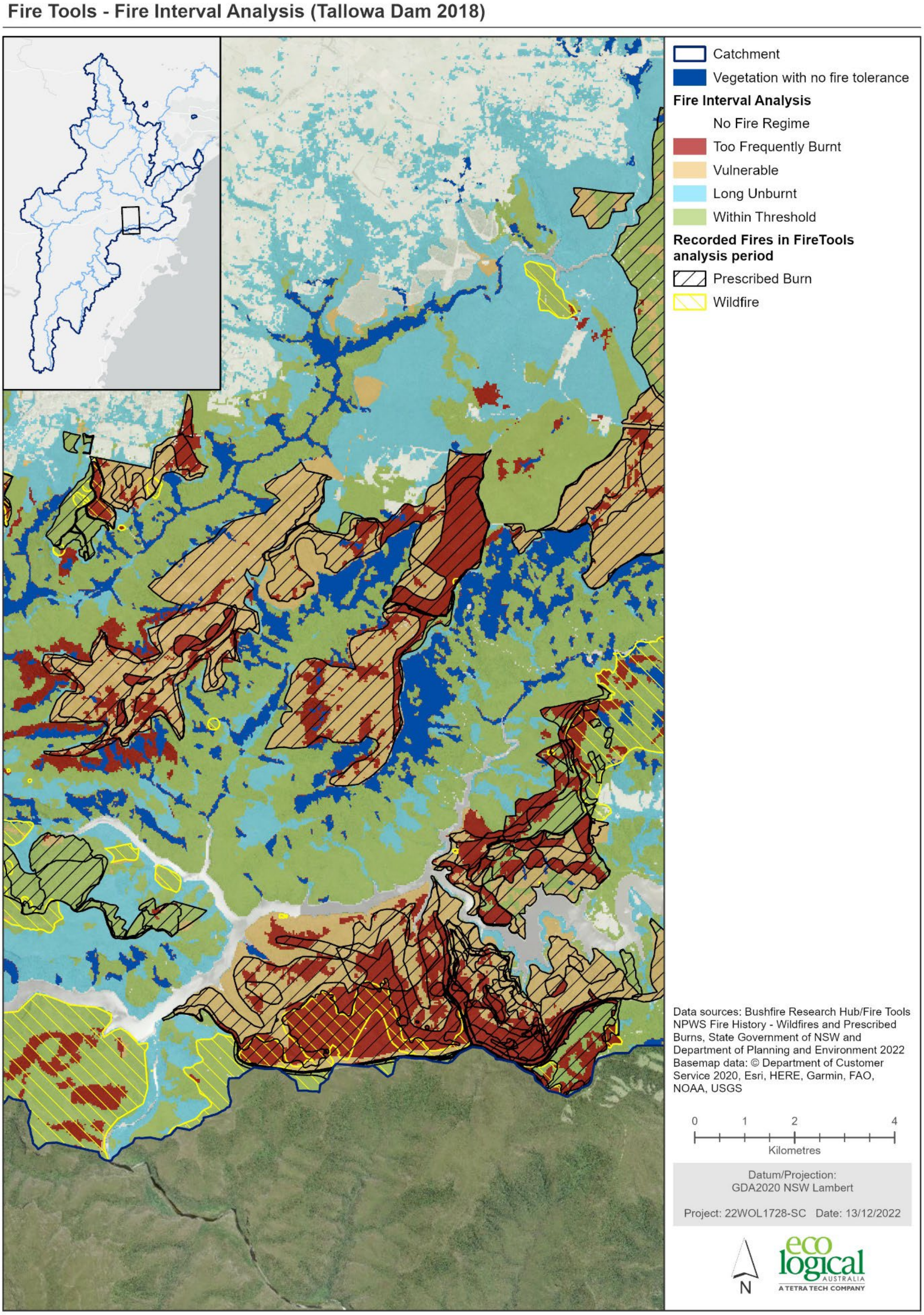


Figure 6-13: Tallawa Dam fire interval analysis

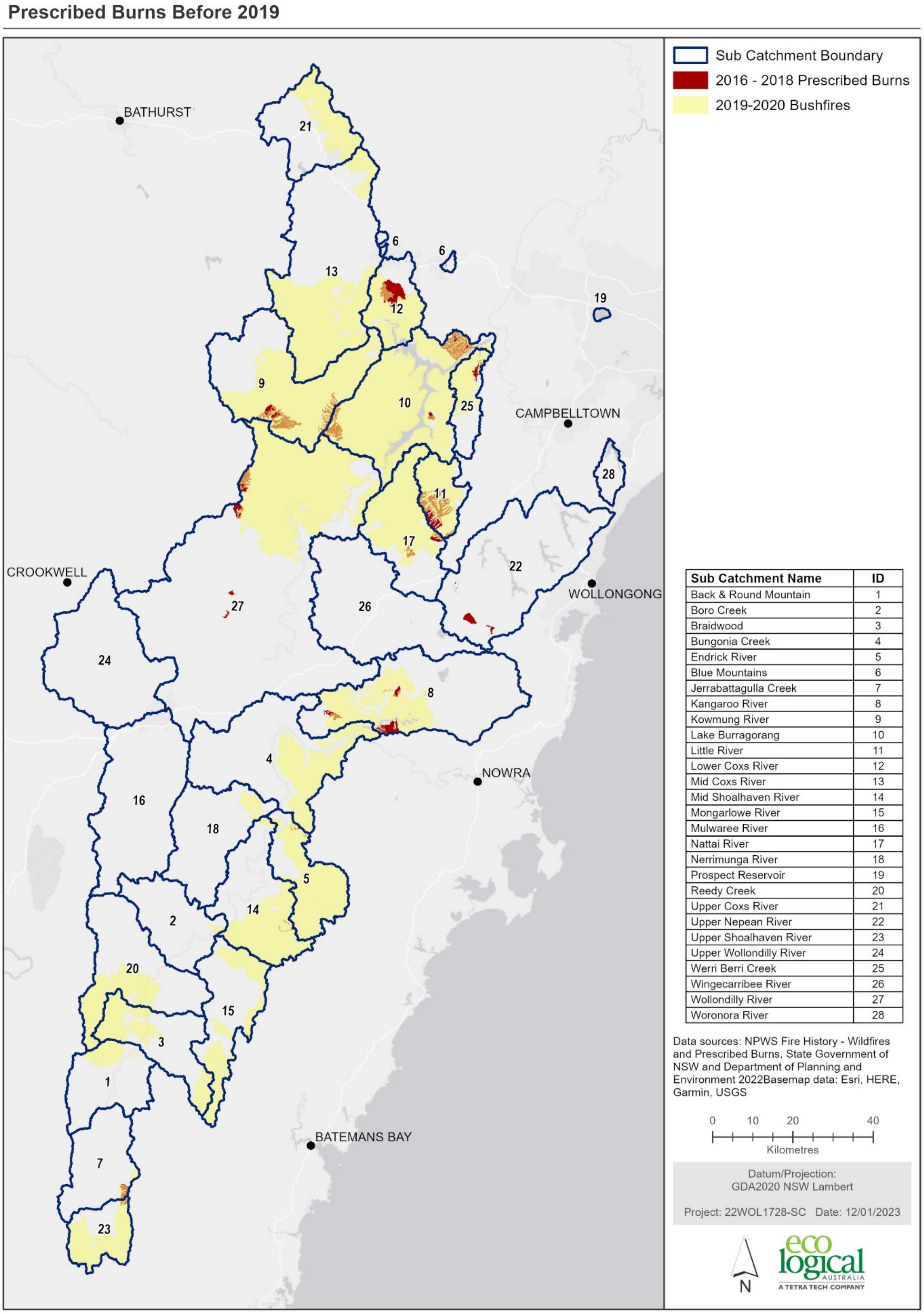


Figure 6-14: Areas subject to prescribed burns prior to 2019 compared with 2019-20 bushfire extent

6.8. 2019-20 fire season

The 2019-20 fire season is often referred to as the 'Black Summer' bushfires and about one third of the Catchment was burnt. Factors that contributed to the extent and severity of the fires included (Department of Premier and Cabinet (DPC) 2020):

- Spatially continuous fuel
- Dryness of the fuel and its availability to burn
- Weather conducive to fire spread (high temperatures, low humidity and wind)
- Ignition sources e.g., lightning strikes.

Previous prescribed burning and hazard reduction activity appear to have reduced fire severity and spread in some instances across NSW, but in others it seems to have had no effect (DPC 2020). This finding is consistent with the experience in the Catchment. Figure 6-14 demonstrates many (but not all) areas in the Catchment that were subject to prescribed burns in the three years prior to 2019 were re-burnt during the 2019-20 bushfires.

Figure 6-15: Butchers and Green Wattle bushfire 2019-20 (photo provided by WaterNSW)

6.8.1. Action taken

Action taken by WaterNSW in response to the Black Summer bushfires included:

- Ash booms were deployed 1 km, 2 km and 10 km from the Warragamba Dam wall in Lake Burragorang to limit the amount of ash and debris near the water supply off-take point

- Monitoring and modelling of risks of ash and nutrient inflow into the lake
- Erosion risk modelling based on slope and fire intensity
- Lake ecology risk analysis
- Contingency water sampling program
- Analysis of retardant use and potential water quality impacts
- Condition assessment and repair of fire trails and fire breaks damage by fires
- Repair and replacement to Water Monitoring and SCADA sites damaged by fire.

In addition to the actions taken by WaterNSW are the actions taken by NPWS, RFS, councils and other organisations to rehabilitate and repair fire breaks and fire trails as part of make safe and recovery efforts.

Research actions after the 2019-20 fires included:

- WaterNSW engaged the Soil Conservation Service to undertake a post-fire investigation to identify areas of high risk to raw water quality in the Warragamba sub-catchment and assess the performance of erosion mitigation works.
    - Erosion mitigation works were completed in September 2021 and included installation of 250 coir logs and 13 in-channel structures. Monitoring included watercourse condition, erosion and sedimentation rates, sediment capture rates, vegetation condition and soil/sediment composition analysis. Baseline monitoring was completed in September 2021, followed by two rounds of monitoring in May/June 2022 and November 2022.
    - Erosion monitoring on hillslopes determined that, by May/June 2022, two out of three sites were no longer eroding and had shifted to accumulating sediment/leaf litter. The vegetation at two sites responded well post-fire, however vegetation at the third site responded more slowly, likely due to the different vegetation community and steeper slopes more prone to erosion.
    - In future, greater erosion mitigation outcomes would be expected if the works are completed prior to any post-fire rain events.
- Green Wattle Creek Fire Research: collaboration with Swansea University and DPE.
    - Radionuclide analysis showed most fire related sediments settled out at the junction, suggesting that there is minimal risk of mobilisation
    - Leachate assessment of floating debris and water quality surrounding ash control boom
    - Mass balance model developed to estimate post-turnover water quality from event samples
    - Erosion modelling to support catchment risk assessment.
- Fire Research Strategy developed under the WaterNSW 2021-2025 Science Program include:
    - In-house ash and erosion data collection from hazard reduction burns
    - Water industry collaboration to develop modelling software plugin for burned sub-catchments
    - Australian Research Council linkage project on ecological effects of firefighting chemicals
    - Liaising with researchers at DPE and the Bushfire Natural Hazards Research Hub.
    - New hazard reduction techniques investigations e.g., drone ignition.

6.8.2. 2020 Bushfire Inquiry

The Inquiry into the Black Summer bushfires (DPC 2020) concluded, ‘it is clear that we should expect fire seasons like 2019-20, or potentially worse, to happen again’. The Inquiry made 76 recommendations, including some of relevance to the Catchment. For example:

> ‘That the NSW Government, along with other Australian governments, ask AFAC [Australasian Fire and Emergency Service Authorities Council] to establish a national bush fire database. This database would enable:
>
> - Monitoring of trends in bush fire activity and impacts, including timing, cause, extent and intensity across all land tenures and vegetation types
> - Tracking trends and identifying patterns in associated weather and climate signals that contribute to severe bush fires
> - Evaluation of the cost and effectiveness of risk mitigation efforts, including hazard reduction, and fire suppression activities so we have a better understanding of what works.’

As a result of the Inquiry, the NSW Government has (amongst other things) committed $2 million over three years to support DPE projects to examine the effect bushfires have on NSW water quality objectives and assess and mitigate the risk to soil health during hazard reduction activities.

6.9. Conclusion and recommendations

Long-term records indicate the 2019-20 bushfires significantly increased the total area burnt within the Catchment. Ash and debris from the fires affected water quality, and many ecological communities and constructed assets were burnt or damaged. Heavy rain following the fires assisted vegetation recovery in many areas, but also triggered soil erosion and landslips. This event was consistent with the research findings of Touma et al (2022), which suggested that there is increased likelihood of compounding effects of extreme rainfall following significant fire seasons due to climate change.

Implementation of recommendations from the 2020 Bushfire Inquiry will better prepare agencies and the community for increasingly frequent and severe bushfires as the climate changes. Application of emerging fire analysis techniques by agencies such as the NPWS, WaterNSW and RFS will inform the required burn regime to maintain healthy ecosystems in the Catchment.

7. Land use change

The Catchment continues to be broadly characterised by conservation and agricultural land uses, with changes in population densities concentrated in the urban and peri-urban areas. The Catchment health indictors of population settlements and patterns, and land use were assessed as having an overall moderate state and a stable trend.

7.1. Population

The first Catchment audit (CSIRO 1999) stated the 'major growth areas of Robertson, Hill Top, Colo Vale, Kangaroo Valley and Buxton represent threats to water quality'. A growing population can increase the loads of pollutants and volume of stormwater and wastewater entering waterways unless accompanied by enhanced wastewater, water supply and waste management capacity. Services need to be in place to support the growing population and avoid significant environmental harm.

The estimated resident population is the official estimate by the Australian Bureau of Statistics based on the census every five years. It links people to a usual place of residence within Australia. The latest available population dataset is from the 2021 census. The data are available in spatial 'mesh blocks' as a measurement unit.

Quantitative evidence of a steadily growing total population in the Catchment was provided for this audit by census data since 2006:

- 2006: 108,463
- 2011: 113,146
- 2016: 120,677
- 2021: 129,250.

Figure 7-1 maps the population across the Catchment at the 2021 census. Presentation of the data is affected by the size of the mesh blocks, with smaller mesh blocks and higher populations concentrated in urban and peri-urban areas. In 2021, there was an average of approximately 0.08 persons per hectare across the Catchment. This was consistent with the findings of CSIRO (1999) that the Catchment as a whole was 'sparsely populated', and the human population was 'low by world standards'.

Recent changes in population density were derived for this audit by comparing the 2016 and 2021 census data, which were derived from the same spatial mesh blocks. Most of the Catchment experienced little or no change in population density (±0.5 persons per hectare) between 2016 and 2021, with changes more evident in the townships of Lithgow, the Blue Mountains, the Southern Highlands and Goulburn (Figure 7-2). As indicated in Table 7-2, townships in Goulburn and the Southern Highlands experienced the largest population growth in the Catchment since 2006. Population growth was mainly associated with new urban release areas (see examples from the Southern Highlands in Figure 7-3), infill development and changes to higher density housing forms.

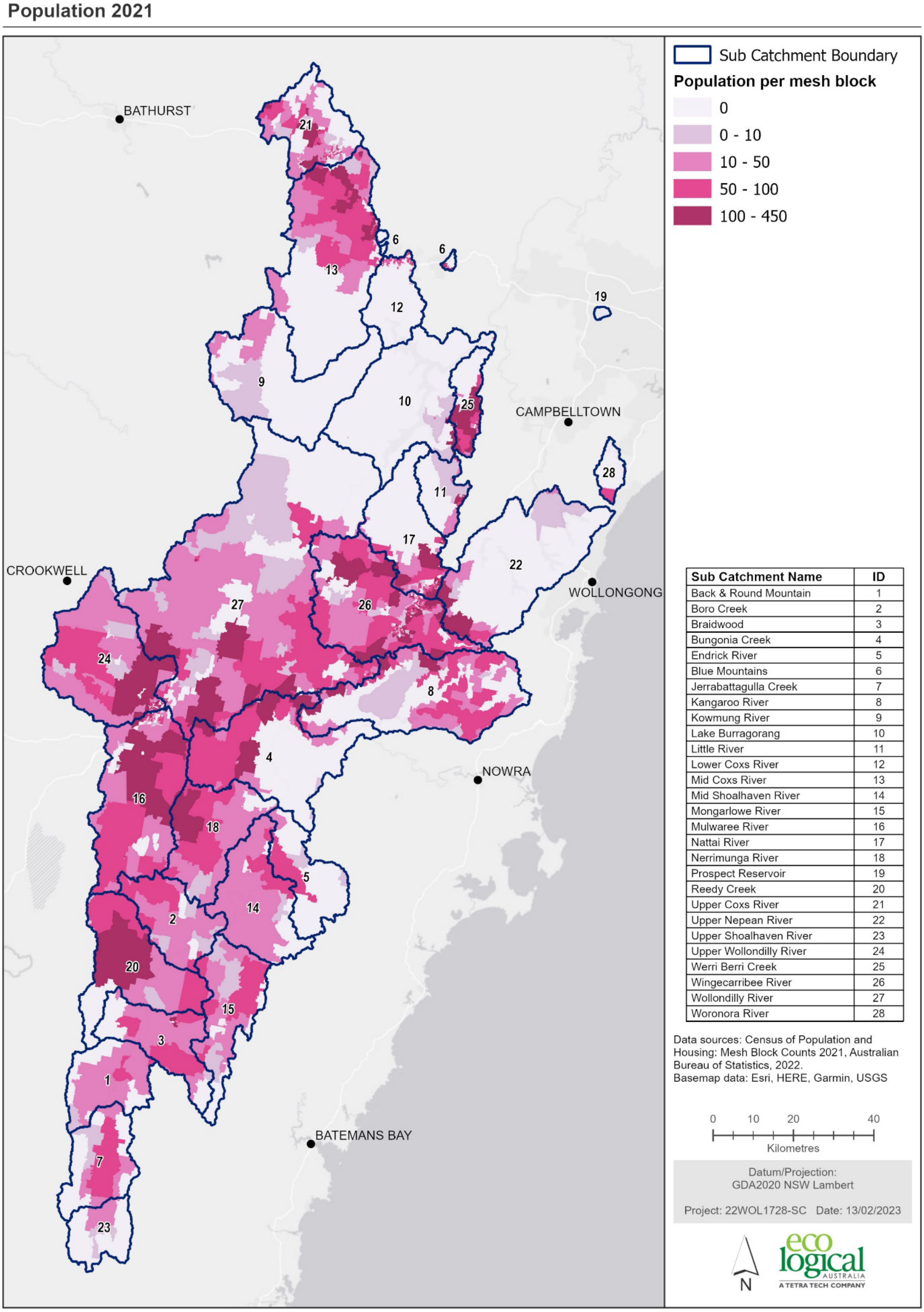


Figure 7-1: Population per mesh block (Census 2021)

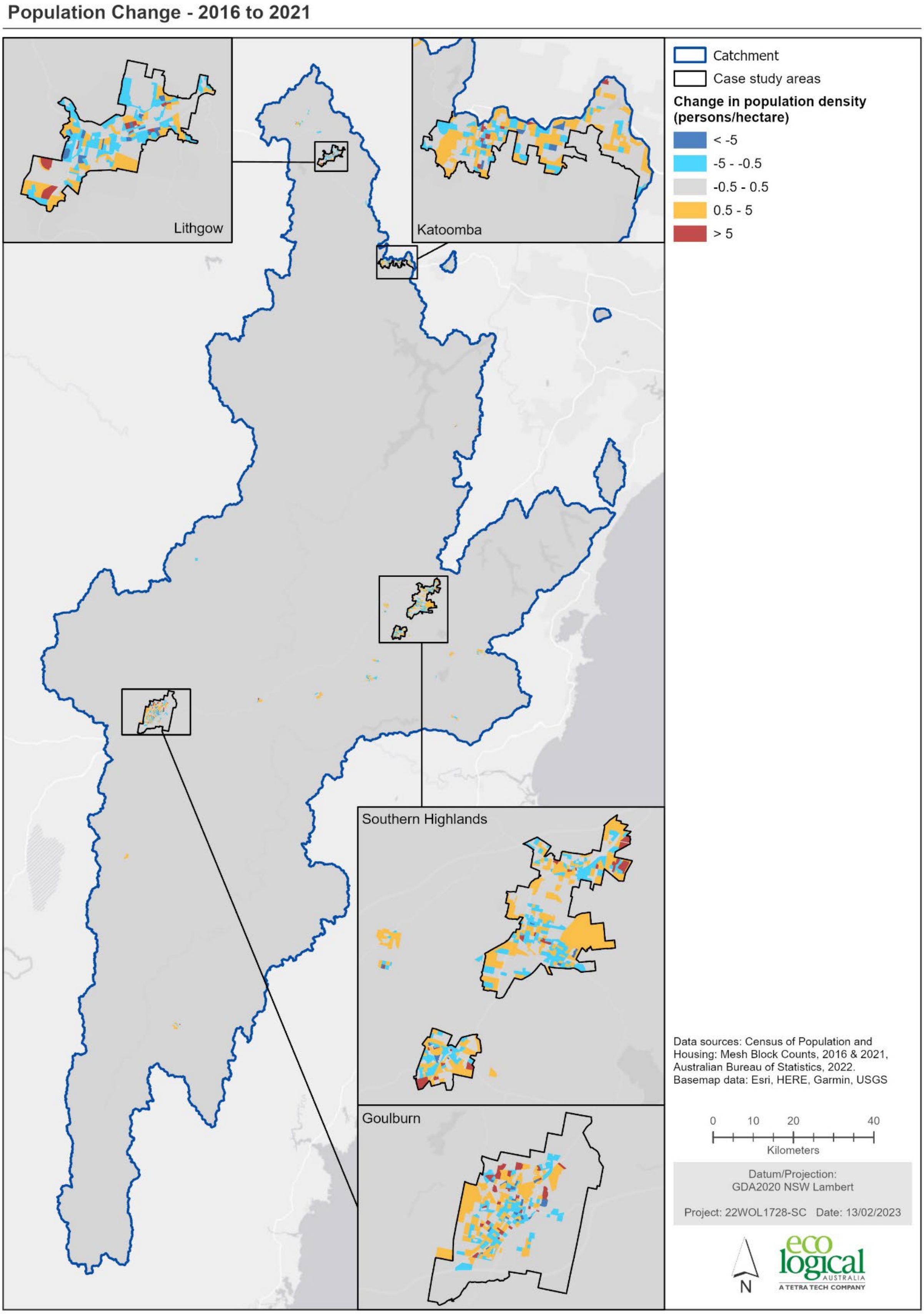


Figure 7-2: Population density changes 2016-2021 using Census data

Table 7-1: Increasing population case studies 2016-21

Mesh blocks from Figure 7-2	Aerial photo 2016	Aerial photo 2021
Braemer, Mittagong		
		
South Moss Vale		
		
East Moss Vale		
		

Local strategic plans for most councils in the Catchment predict the population will continue to steadily grow. This includes the Lithgow Strategic Planning Statement 2040 which states Council will ‘reconfirm a growth target of 25,000 by 2040 to underpin our decision making’. However, Table 7-2 indicates Lithgow’s population slightly decreased following the 2016 census. This was consistent with the ‘projected population stagnation to decline to 2031’ stated in the Lithgow Land Use Strategy 2010-2030.

Table 7-2: Population change in urban and peri-urban areas of the Catchment

Urban area (see Figure 7-1)	2006	2016	2021	Trend
Goulburn	20,158	22,436	23,864	Increasing
Katoomba	10,662	11,378	11,731	Increasing (growth rate reduced 2016-21)
Lithgow	10,634	11,422	11,071	Increase 2006-16, then slight decline
Southern Highlands	24,542	27,739	30,802	Increasing
Total	**65,996**	**72,975**	**77,468**	**Increasing**

7.2. Land ownership and use

Land ownership mapping (Figure 7-3) was compiled from NSW Government Property Register (2022), DPI (2022), Spatial Services (2022), and NSW Government and Forestry Corporation of NSW (2023) datasets. It includes the updated tenure for the recently listed Gardens of Stone State Conservation Area.

The most recent spatial land use data for the Catchment is the 2017 Catchment Scale Land Use Mapping (CLUM) by the Commonwealth Department of Agriculture and Water Resources (Figure 7-4). It is a seamless raster dataset that combines land use data at a resolution of 50 m by 50 m, produced by combining land tenure and other types of land use information, fine-scale satellite data and information collected in the field. The date of mapping (2008 to 2019) and scale of mapping (1:5,000 to 1:250,000) vary, reflecting the source data, capture date and scale. Date and scale of mapping are provided in a supporting dataset.

CLUM was adopted by WaterNSW as the preferred land use dataset to improve consistency across government agencies following a recommendation of the 2019 audit. However, land use changes since the previous audit period are difficult to discern without updated[5] CLUM mapping as other potential datasets (e.g., for local government areas) do not align with Catchment boundaries.

The auditor has been advised that BCSD is preparing a business case for ongoing land use mapping updates.

Land ownership and use across the Catchment can be broadly categorised as follows:

- More than half (55%) of the Catchment is under private ownership characterised by:
  - Grazing, cropping and horticultural land uses
  - Intensive urban land uses at Lithgow, the Blue Mountains (Katoomba, Leura, Wentworth Falls), the Southern Highlands (Bowral, Mittagong, Moss Vale), Goulburn and Braidwood.

[5] CLUM was updated in December 2020 but the updated areas did not cover any part of the Catchment.

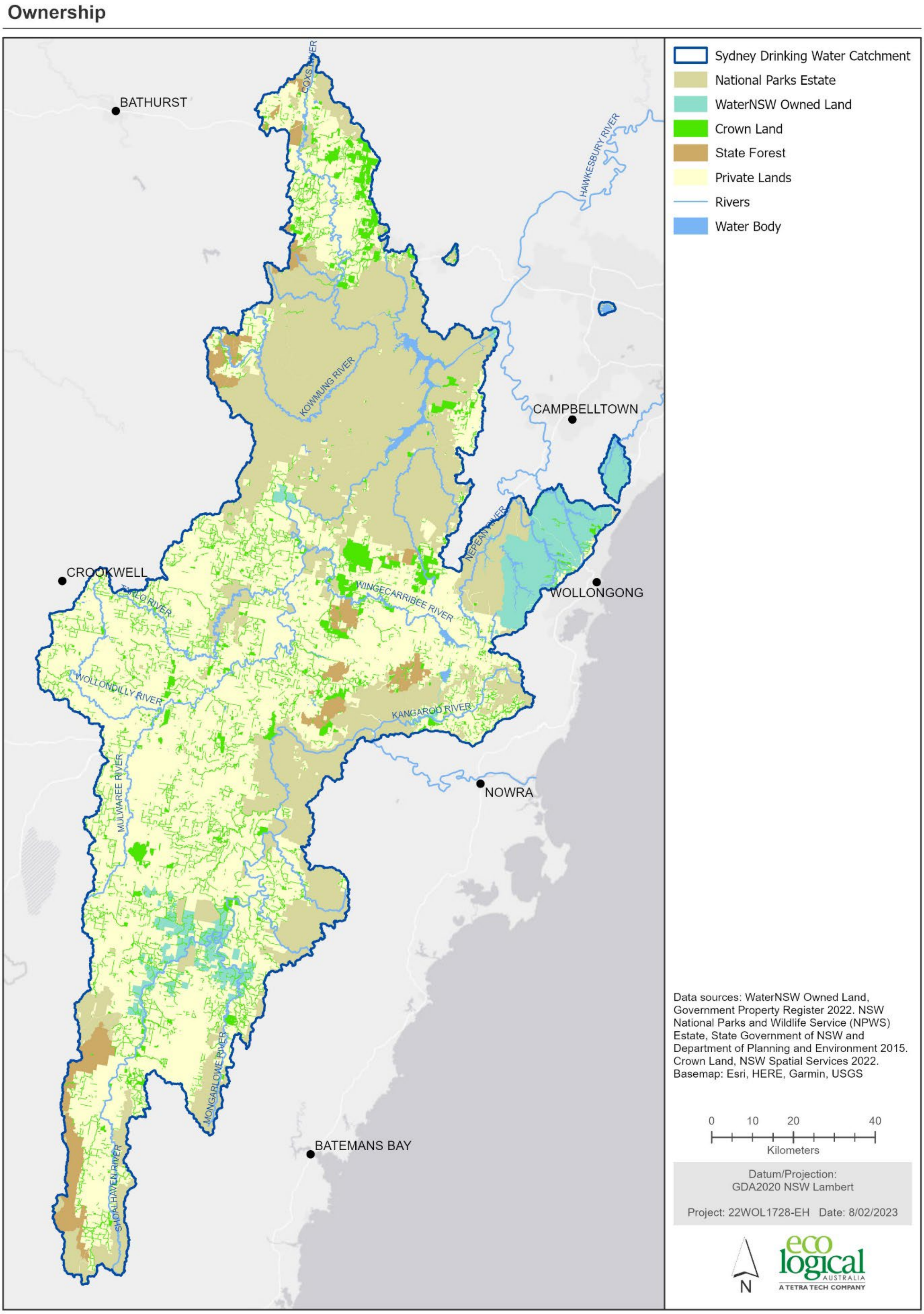


Figure 7-3: Land ownership

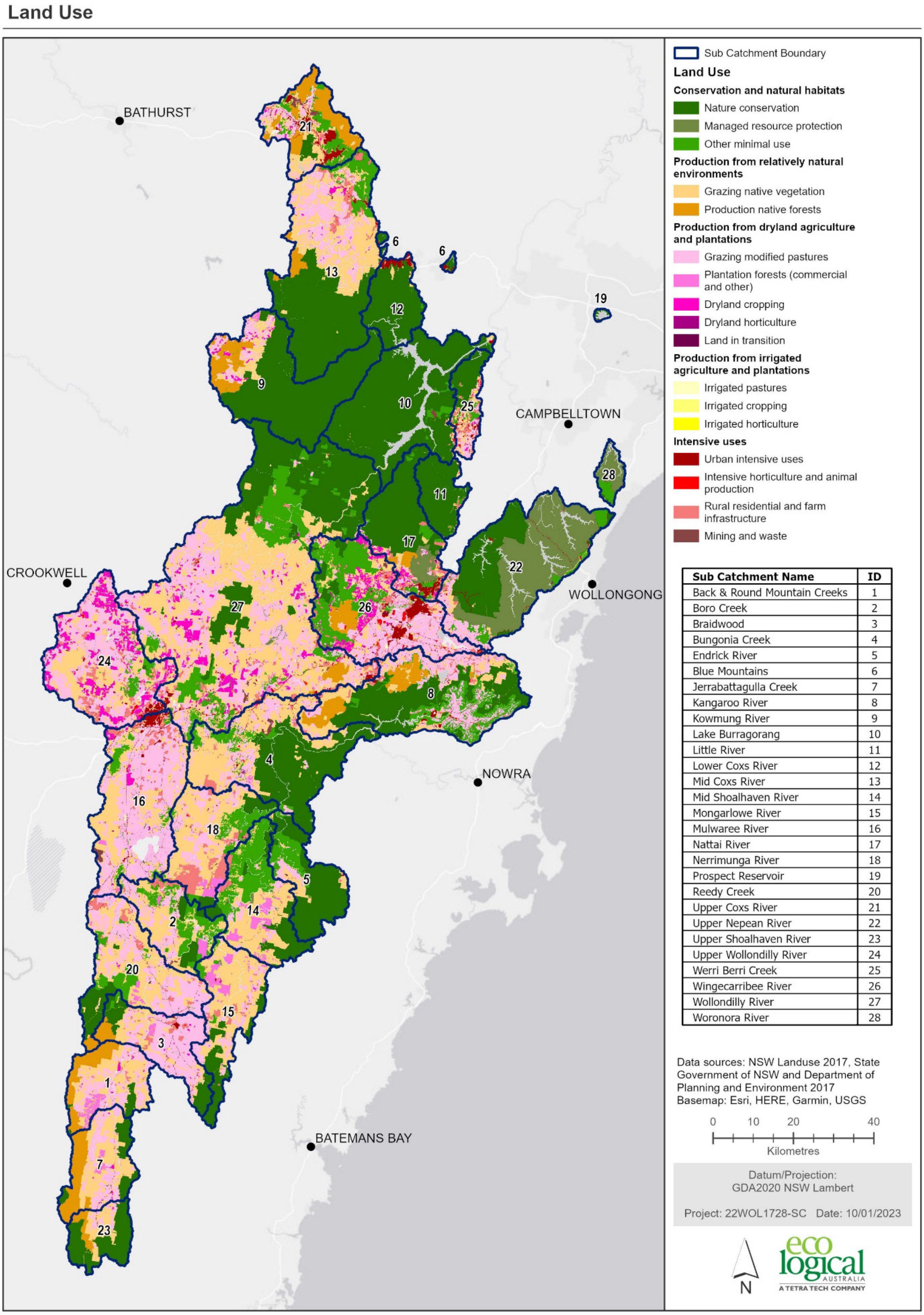


Figure 7-4: Land use (CLUM 2017)

- About a third of the Catchment (32%) is NPWS estate managed for conservation purposes. It includes all or parts of nature reserves, state conservation reserves (including the recently listed Gardens of Stone State Conservation Area – see section 7.3) and:
    - Blue Mountains National Park
    - Budderoo National Park
    - Deua National Park
    - Gourock National Park
    - Kanangra-Boyd National Park
    - Marrangaroo National Park
    - Monga National Park
    - Morton National Park
    - Nattai National Park
    - Thirlmere Lakes National Park
- About 6% of the Catchment is owned by WaterNSW. Most of these lands are in the Woronora and Upper Nepean sub-catchments, and around Braidwood (along the Shoalhaven and Mongarlowe Rivers).
- About 3% of the Catchment is State Forests (plantation forests and native forests used for production).
- The remaining 4% of the Catchment is owned by the Crown. This includes Crown reserves and public roads.

The Special Areas are mostly under NPWS or WaterNSW tenure, although some areas such as Kangaloon (Schedule 1) and the Oaks / Oakdale (Schedule 2) are privately owned land. Conservation lands and natural habitats dominate the Special Areas. Longwall coal mining leases exist in some of the Special Areas but mainly operate underground so are not indicated on Figure 7-4. Maps of mining lease areas in the Catchment are presented in section 8, with case studies of mining land use changes.

Protected areas of the Catchment that maintain good native vegetation cover and have minimal human disturbance are the most effective land uses for sustaining good water quality and ecological health. As shown in Figure 7-4 and Table 7-3, 'nature conservation', 'minimal use' and 'grazing native vegetation' are the dominant land uses across the Catchment. 'Grazing modified pasture' is another major land use in the Catchment, and this is the grazing CLUM class applied when there is greater than 50% dominant exotic species. Detail of land uses in each sub-catchment is given in Table 7-4 to Table 7-6.

Risks to Catchment health increase as disturbance increases. Land uses identified in the 1999 Catchment audit (CSIRO 1999) as 'providing increasing hazards for both water quality and catchment health' involved extraction of water and management of wastes and effluents. They included 'residential development, urban centres, peri-urban and rural subdivision, a range of intensive agricultural activities (predominantly livestock, vegetable growing, pig and poultry farming), mining and extractive industry, public roads, and utility easements'. These land uses do not cover a wide extent of the Catchment but have a substantive effect on Catchment health. The available data indicate that while some intensive uses in the Catchment have declined (e.g., the number of dairies), the number and extent of other intensive uses have increased (e.g., some urban and peri-urban areas – refer to Table 7-1).

Table 7-3: Extent (ha) of land uses in the Catchment (CLUM 2017)

Land Use	Total
Channel/aqueduct	13
Cropping	33165.75
Estuary/coastal waters	0
Grazing irrigated modified pastures	307.5
Grazing modified pastures	262452.8
Grazing native vegetation	441581.3
Intensive animal production	2186.25
Intensive horticulture	82
Irrigated cropping	52
Irrigated land in transition	0
Irrigated perennial horticulture	284.5
Irrigated plantation forests	0
Irrigated seasonal horticulture	102.5
Lake	19310.75
Land in transition	281.25
Managed resource protection	16416
Manufacturing and industrial	607.75
Marsh/wetland	1342.25
Minimal use	191435.3
Mining	2925.5
Nature conservation	508084.3
Perennial horticulture	1103.5
Plantation forests	15699.75
Production native forests	57408.5
Reservoir/dam	2079
River	11138
Seasonal horticulture	96.75
Services	4633.25
Transport and communication	5210.25
Urban residential	58977.25
Utilities	769.25
Waste treatment and disposal	201.25
Grand Total	1637947

Table 7-4: Extent (ha) of land uses in the Shoalhaven sub-catchments (CLUM 2017)

Land Use	Round Mountain Cr	Boro Ck	Braidwood	Bungonia Ck	Endrick R	Jerrabattagulla	Kangaroo R	Mid Shoalhaven R	Mongarlowe R	Mulwaree R	ReedyCk	Upper Wollondilly	Total
Channel/aqueduct	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Cropping	231	0	172.75	55.75	0	119.5	0	0	47	1050.75	70.75	13035.75	**14783.25**
Estuary/coastal waters	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Grazing irrigated modified pastures	0	0	0	0	0	0	0	0	0	83.25	0	0	**83.25**
Grazing modified pastures	9516.5	6543.25	18205.5	8791.75	1827.25	7736.75	9599	2256	5889.25	41252.75	20098.75	30104.5	**161821.25**
Grazing native vegetation	12522.25	12646.75	6904	24821	3061.75	12843.5	21331.75	16757.25	21237.25	22463.25	20508	19578.75	**194675.5**
Intensive animal production	0	1.25	13.75	90.25	0	0	141.5	0.25	11	94.25	2	181	**535.25**
Intensive horticulture	0	0	0	0	0	0	0.5	0	0	7.75	0	5.25	**13.5**
Irrigated cropping	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Irrigated land in transition	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Irrigated perennial horticulture	0	0	0	11.5	0	1.75	6	0	0	43.25	0	11.5	**74**
Irrigated plantation forests	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Irrigated seasonal horticulture	0	0	0	0	0	0	3.75	0	0	0	0	0	**3.75**
Lake	0	0	0	24.25	0	0	841.75	0	0	1965.75	2.25	337.75	**3171.75**
Land in transition	0	0	0	29.75	3.5	0	19.25	0	0	42.75	0	0	**95.25**
Managed resource protection	33.25	24.5	46.5	48.25	0	29.25	0	169.5	7.25	515.5	84	471	**1429**
Manufacturing and industrial	0	0	0	17	0	0	0	0	23.5	104	0	33.75	**178.25**
Marsh/wetland	2	101	2.25	29.75	0	0	0	11	0	426.75	7.75	31	**611.5**
Minimal use	0	9571.75	592	4984.75	5984	0	10906.5	14926.75	1514.5	3433.75	4854	2626.5	**59394.5**
Mining	6.75	134.25	2.75	433.25	26.5	0	6.75	28.25	4.5	520	49.75	41	**1253.75**
Nature conservation	1843	3320.75	6396	37238.75	22553.75	5348.25	31469.5	10209.25	9384.25	99	6620.5	104.75	**134587.75**
Perennial horticulture	0	0	6.75	87.5	47	2	47.5	5	20.25	58.5	25.75	47.5	**347.75**
Plantation forests	2033.75	1117.5	510.25	370.25	4	808	3	3465.25	2711.75	474.25	721	39	**12258**
Production native forests	7472	0	2214.5	0	0	8464.5	8574.75	0	0	0	1109	0	**27834.75**
Reservoir/dam	8.25	7	7.25	77.75	0	2.5	34	5.25	7	69.5	29.25	132.25	**380**
River	334.5	399.5	158.25	997.5	223.5	312	745.75	743.75	378.75	162	499.25	162.25	**5117**
Seasonal horticulture	0	0	0	0.5	0	0	25.5	0	0	0	1.25	3.25	**30.5**
Services	0	0	72.25	55	0	0	349.75	0	0	533.5	25.75	181.25	**1217.5**
Transport and communication	43.5	128.25	172.25	284.5	27	97.25	220.25	79.75	41.75	986	278	2.25	**2360.75**
Urban residential	427.75	1195.75	1817.25	1753.5	142	58.5	2112.75	1135.75	1629.5	4336	2454.5	6859.25	**23922.5**
Utilities	0	0	3.75	0	0	0	2.75	6.25	0	16.5	0	35.5	**64.75**
Waste treatment and disposal	0	0	12.25	0.75	0	0	0	0	0	22.5	0	10.75	**46.25**
Grand Total	**34474.5**	**35191.5**	**37310.25**	**80203.25**	**33900.25**	**35823.75**	**86442.25**	**49799.25**	**42907.5**	**78761.5**	**57441.5**	**74035.75**	**646291.25**

Table 7-5: Extent (ha) of land uses in the Warragamba sub-catchments (CLUM 2017)

Land Use	Kowmung R	Lake Burragorang	Little R	Lower Coxs R	Mid Coxs R	Nattai R	Nerrimunga R	Upper Coxs R	Upper Nepean R	Werri Berri Ck	Wingecarribee R	Wollondilly R	Total
Channel/aqueduct	0	0	0	0	0	6.75	0	0	1.5	0	3.25	0	**11.5**
Cropping	1128	5.5	0	0	582.25	1187.75	0	278	0.75	145.75	5243.25	9810.5	**18381.75**
Estuary/coastal waters	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Grazing irrigated modified pastures	0	0	0	0	0	0	0	0	0	10.25	71.75	142.25	**224.25**
Grazing modified pastures	4351.25	50.5	27.25	0	15623.75	1526.5	8794	4245.25	456.25	2491.25	7989.5	54619.75	**100175.25**
Grazing native vegetation	5760	624	435.75	842.75	27611	2299.75	20630	8276	28446.5	2330.5	23878.25	97173.75	**218365.25**
Intensive animal production	0	55	8.5	0	0	29.5	22.75	12	38.75	188.5	901.25	323.25	**1579.75**
Intensive horticulture	0	0	2	0	14	5.75	0	0.5	0	8.75	6.5	30.5	**68**
Irrigated cropping	0	0	0	0	0	0	0	0	0	0	28.5	23.5	**52**
Irrigated land in transition	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Irrigated perennial horticulture	0	11	0.75	0	12	0	0	0	0	37.5	60.25	58.5	**180**
Irrigated plantation forests	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Irrigated seasonal horticulture	0	12.25	0	0	0	0	0	0	0	86.5	0	0	**98.75**
Lake	0	7083	0	562.25	6	1.5	28.75	375	3529.25	111.25	731.25	120.5	**12579.25**
Land in transition	0	0	0	0	0	52.75	0	0	1.75	35.75	92.25	1.75	**184.25**
Managed resource protection	3	0	0	0	5	4297.75	25.75	4.5	1243.75	2.25	150.25	840.75	**6578.75**
Manufacturing and industrial	0	0	0	17.75	12	39.5	0	107.25	19.25	4.25	160.75	49.5	**410.25**
Marsh/wetland	1.75	4.25	16	24.75	9	0	0	247.75	0	16.5	305.5	105.25	**730.75**
Minimal use	130	1797.5	448.5	62.75	7362.75	2578.25	6271.25	5790.25	29083	1211.25	19291.25	28455.5	**102660**
Mining	0	159	5	0	51.5	15	53.25	694.75	19	5.5	151.75	494.75	**1649.5**
Nature conservation	57071.5	69853.5	16886.75	21664.75	47605	27177.25	3646.25	1668.25	25440	6997	3202.25	64034.75	**346646.5**
Perennial horticulture	0	16.25	9	0	2.5	80	60.5	4	82.25	33	195.25	190.75	**673.5**
Plantation forests	519.75	0	0	0	58.25	1.5	1760.25	222.5	0	2	73.25	804.25	**3441.75**
Production native forests	7347.5	0	0	0	2693	1377.75	0	12124.25	0	0	3923.75	2107.5	**29573.75**
Reservoir/dam	0	22.25	0	0	24	42.75	11.25	41	23	119.25	182.75	227.75	**748.5**
River	576.5	125.5	15	198.75	1503.25	108.25	334.25	270	18.75	174.75	473	2190.75	**5988.75**
Seasonal horticulture	0	0	0	0	14.5	0	0	0	4.5	12.5	30.25	0	**61.75**
Services	0	57	1.25	349	52.5	203	0.5	1323.75	6.25	38	700	465.25	**3283.25**
Transport and communication	0	38.25	0	33.25	182.75	230.75	64	306	275.5	166	663.75	446.75	**2462**
Urban residential	0	349.5	538.25	832.25	3411.75	3284.5	6575.5	1781.75	449.25	2235.5	7594.5	7037.25	**34342.75**
Utilities	0	51	0	0.25	1.5	2.75	29	369.25	93.75	0	5.5	44.25	**604**
Waste treatment and disposal	0	2	0	0	0.75	7.5	0	56.25	1	11.5	46.25	28.75	**154**
Grand Total	**76889.25**	**80317.25**	**18394**	**24588.5**	**106839**	**44556.75**	**48307.25**	**38198.25**	**89234**	**16475.25**	**76156**	**269828**	**891909.75**

Table 7-6: Extent (ha) of land uses in the Blue Mountains, Prospect, Upper Nepean and Woronora (CLUM 2017)

Land Use	Blue Mountains	Upper Nepean	Woronora	Prospect	Total
Channel/aqueduct	0	1.5	0	0	**1.5**
Cropping	0	0.75	0	0	**0.75**
Estuary/coastal waters	0	0	0	0	**0**
Grazing irrigated modified pastures	0	0	0	0	**0**
Grazing modified pastures	0	456.25	0	0	**456.25**
Grazing native vegetation	57	28446.5	36.25	0.75	**28540.5**
Intensive animal production	0.25	38.75	32.25	0	**71.25**
Intensive horticulture	0	0	0.5	0	**0.5**
Irrigated cropping	0	0	0	0	**0**
Irrigated land in transition	0	0	0	0	**0**
Irrigated perennial horticulture	0	0	30.5	0	**30.5**
Irrigated plantation forests	0	0	0	0	**0**
Irrigated seasonal horticulture	0	0	0	0	**0**
Lake	30.5	3529.25	0	0	**3559.75**
Land in transition	0	1.75	0	0	**1.75**
Managed resource protection	5.75	1243.75	6713.25	445.5	**8408.25**
Manufacturing and industrial	0	19.25	0	0	**19.25**
Marsh/wetland	0	0	0	0	**0**
Minimal use	177.75	29083	120	0	**29380.75**
Mining	0	19	3.25	0	**22.25**
Nature conservation	1399.25	25440	10.75	0	**26850**
Perennial horticulture	0	82.25	0	0	**82.25**
Plantation forests	0	0	0	0	**0**
Production native forests	0	0	0	0	**0**
Reservoir/dam	54.5	23	354.75	518.25	**950.5**
River	0	18.75	13.5	0	**32.25**
Seasonal horticulture	0	4.5	0	0	**4.5**
Services	86.75	6.25	36.25	3.25	**132.5**
Transport and communication	55	275.5	55.5	1.5	**387.5**
Urban residential	252.75	449.25	9.5	0.5	**712**
Utilities	6.75	93.75	0	0	**100.5**
Waste treatment and disposal	0	1	0	0	**1**
Grand Total	**2126.25**	**89234**	**7416.25**	**969.75**	**99746.25**

7.3. Case study – Gardens of Stone

Protected areas of the Catchment that maintain good native vegetation cover and have minimal human disturbance are the most effective land uses for sustaining good water quality and ecological health. Risks to Catchment health decrease as disturbance decreases. The recent change in land use at the Gardens of Stone State Conservation Area (Figure 7-5) is expected to improve Catchment health. This area falls partly within the Upper Coxs River sub-catchment. It comprises about 30,000 ha of three former state forests and Crown land transferred to NPWS and gazetted in May 2022. Additional funds and resources have been assigned to improve land management in accordance with a masterplan and plan of management for the reserve, including pest and weed control, conservation of threatened species, swamp restoration and erosion control.

Figure 7-5: Gardens of Stone State Conservation Area

7.4. Conclusion and recommendations

Land uses identified in the 1999 Catchment audit (CSIRO 1999) as 'providing increasing hazards for both water quality and catchment health' involved extraction of water and management of wastes and effluents. They included 'residential development, urban centres, peri-urban and rural subdivision, a range of intensive agricultural activities (predominantly livestock, vegetable growing, pig and poultry farming), mining and extractive industry, public roads, and utility easements'. All these land use types continue to exist in the Catchment.

The evidence available during the current audit indicates that increasing population density and intensive land use changes that are increasing pressure on the Catchment are mostly occurring in the urban and peri-urban areas of the Southern Highlands and Goulburn. In contrast, there was evidence of land use changes during the audit period that reduced pressure on Catchment health. These included increasing the extent of conservation land and rehabilitated land.

Recommendations relevant to changes in land use and population in the Catchment, such as annual vegetation change mapping, and sewage and stormwater pollution controls, are covered in elsewhere in this audit report.

8. Mines and power stations

Regulatory requirements for modification, operation, closure and rehabilitation of mines and coal-fired power stations in the Catchment were tightened during the audit period in response to concerns about environmental impacts, including impacts to Catchment health. Government, business organisations and communities in the Catchment provided evidence of the transition to a low-carbon economy.

8.1. Mining leases

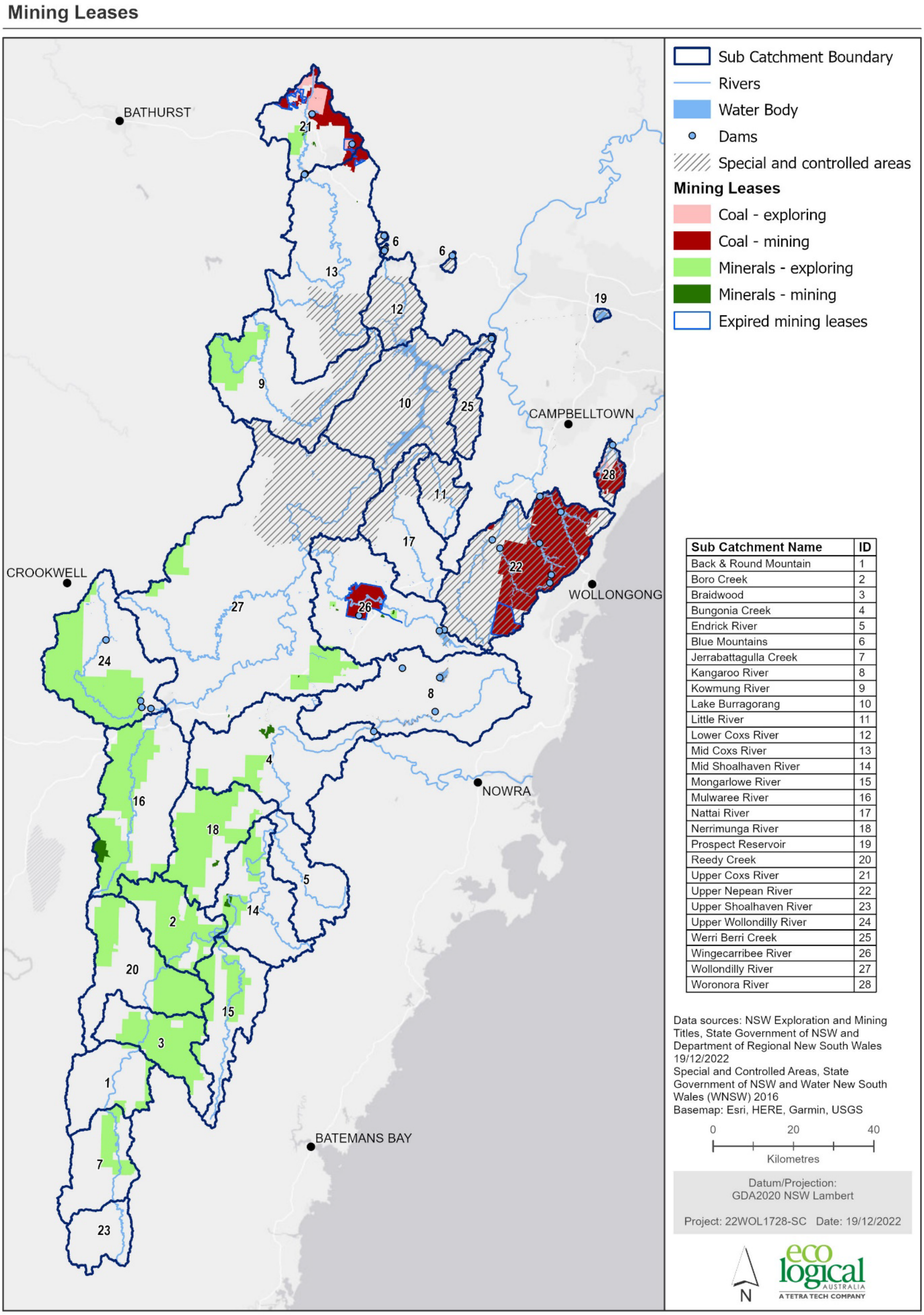
Mining for minerals and coal in some areas of the Catchment pre-dates the Catchment declaration for drinking water purposes. Current and expired leases for exploration and mining are mapped in Figure 8-1, with further detail in Figure 8-2 for the Woronora and Metropolitan Special Areas and Figure 8-3 for the Upper Coxs River sub-catchment. Mines around Lithgow in the Upper Coxs River sub-catchment supply thermal coal, some of which is used at the nearby Mt Piper power station. Mines in the Southern Coalfield mainly provide metallurgical coal used to produce steel at Port Kembla and overseas. Most coal mines are underground.

8.2. Mining impacts

Impacts to the Catchment from underground mining vary depending on site-specific environmental conditions, activities and management regimes, and have included:

- Surface impacts from exploration and monitoring establishment activities such as clearing for boreholes.
- Surface effects from ground movements related to subsidence[6], including vertical subsidence, cracking and fracturing of streambeds and swamp bases, and diversion of surface water underground.
- Permanent changes to the flow regimes of stream reaches that substantially decrease stream flows and increase the number of low-and no-flow days under different rainfall scenarios.
- Major changes to water regimes and increases in drying severity in swamps.
- Increased vulnerability of swamps and their surrounding vegetation to irreversible damage or loss following extreme bushfires in a drier landscape.
- Irreversible loss of near-pristine swamps, in-stream and riparian habitats (including threatened species, populations and ecological communities), and their water-dependent processes.
- Reduced water quality and inflows to Sydney's drinking water storages.
- Unquantified long-term alterations to groundwater levels and water quality post-mining.
- Increased mine water outflows through portal(s) after mine closure and groundwater level recovery when controlled by bulkheads within the mine, including in-perpetuity requirements for water treatment prior to discharge.

[6] Detailed information about subsidence effects, impacts and consequences on water supply is given in chapter 2 of the 2019 Report of the Independent Expert Panel for Mining in the Catchment: Part 2 – Coal Mining Impacts in the Special Areas of the Greater Sydney Water Catchment.



Sub Catchment Name	ID
Back & Round Mountain	1
Boro Creek	2
Braidwood	3
Bungonia Creek	4
Endrick River	5
Blue Mountains	6
Jerrabattagulla Creek	7
Kangaroo River	8
Kowmung River	9
Lake Burragorang	10
Little River	11
Lower Coxs River	12
Mid Coxs River	13
Mid Shoalhaven River	14
Mongarlowe River	15
Mulwaree River	16
Nattai River	17
Nerrimunga River	18
Prospect Reservoir	19
Reedy Creek	20
Upper Coxs River	21
Upper Nepean River	22
Upper Shoalhaven River	23
Upper Wollondilly River	24
Werri Berri Creek	25
Wingecarribee River	26
Wollondilly River	27
Woronora River	28

Figure 8-1: Mining leases

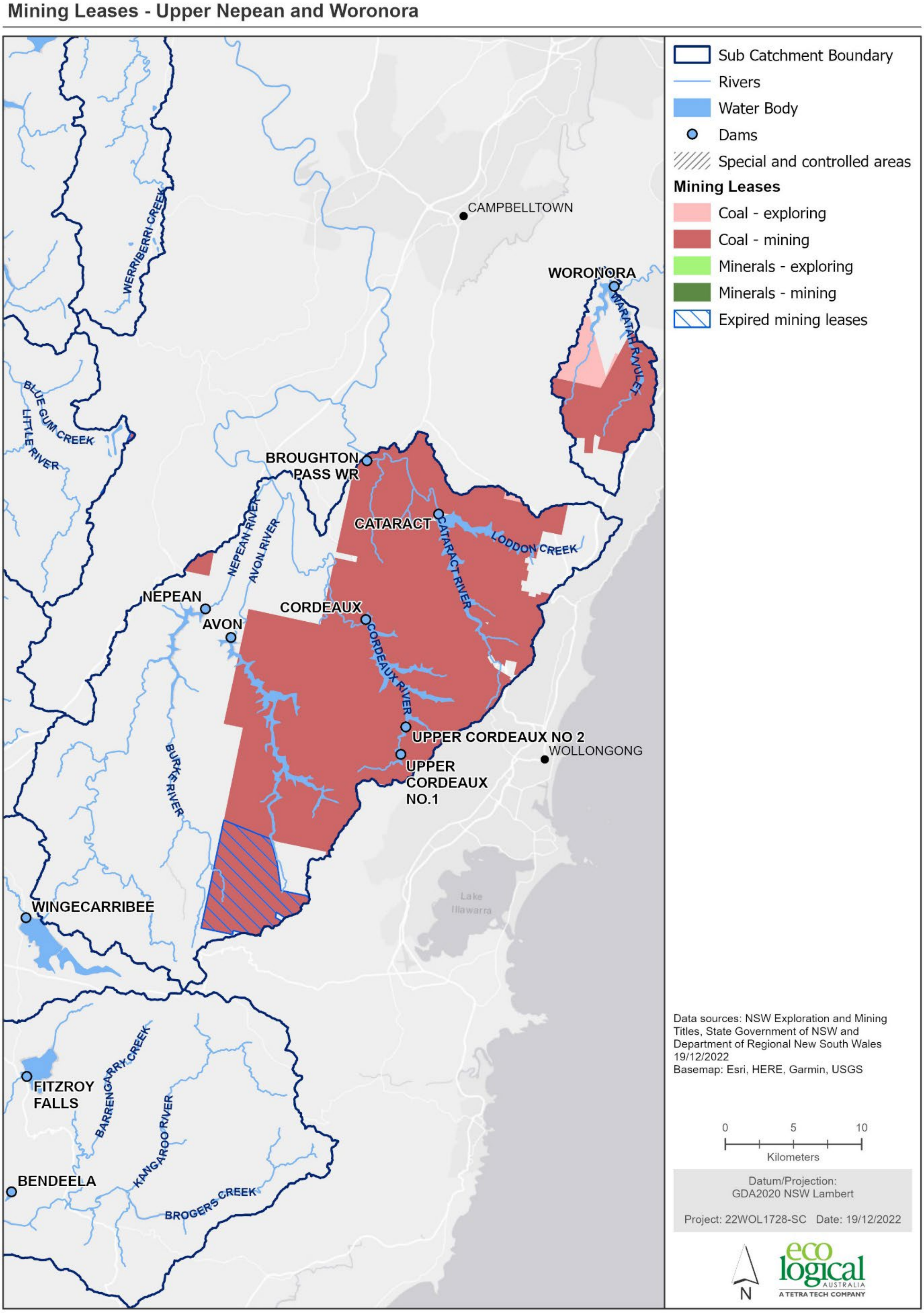


Figure 8-2: Mining leases in the Upper Nepean and Woronora sub-catchments

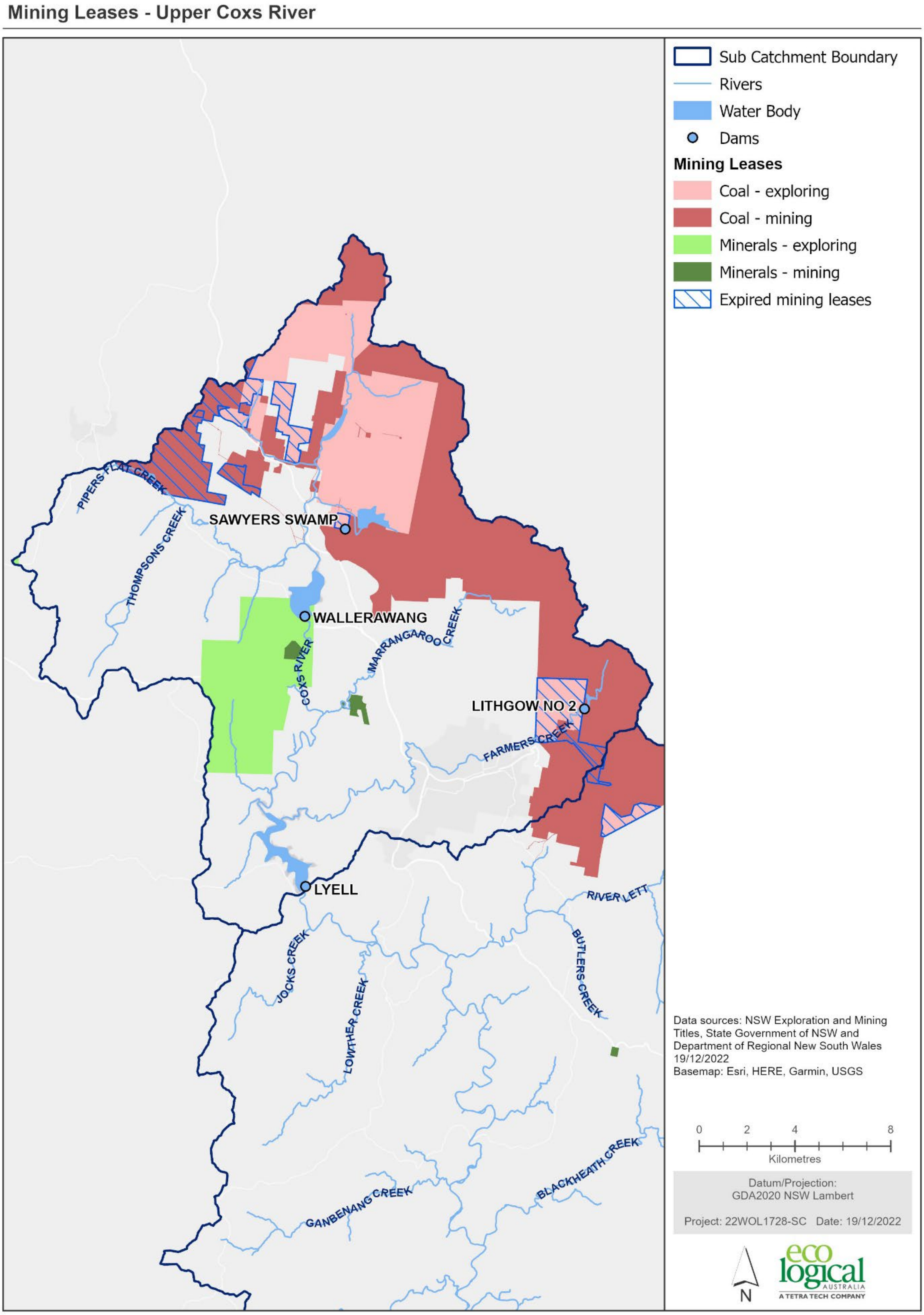


Figure 8-3: Mining leases in the Upper Coxs sub-catchment

8.3. Community attitudes

Community (non-government) attitudes are an indicator of Catchment health (Table 1-2). Petitions, submissions on development proposals, media articles and legal challenges indicate coal mining in the Catchment continues to provoke strong community attitudes both against and in favour of mining. Case studies to illustrate some of these views are provided below.

8.3.1. Submissions to this audit

Submissions were provided to this auditor from the following non-government organisations regarding mining in the Catchment:

- Lock the Gate – stated 'it's well past time to stop new coal mine development in the drinking water catchment (especially new longwall mining)' and provided the following links to submissions on the proposed Dendrobium Mine Extension Project to convey concerns in detail:
  - Independent Expert Scientific Committee submission 11 April 2022
  - WaterNSW submission 22 June 2022
- Metropolitan Coal – provided the link to Peabody's website with approvals, plans and reports for Metropolitan Mine
  - Peabody - Approvals, Plans & Reports (peabodyenergy.com)
- South32 Illawarra – indicated that it produces high-quality metallurgical coal used for steelmaking and it is an important contributor to local jobs and the economy. Detailed comments and links to additional information were provided in a letter submission dated 28 August 2022, which is replicated in Appendix C.
- Sutherland Shire Environment Centre – expressed 'concerns about damaging impacts from coal mining on our water supply' and provided links to the following detailed submissions on the DPE major projects website:
  - Metropolitan Longwalls 305-307
  - Wongawilli Mod2
  - Dendrobium extension - CR
  - Dendrobium extension SSD-8194
  - Russell Vale

The Sutherland Shire Environment Centre also provided examples of media articles regarding mine pollution escaping Peabody's Metropolitan Colliery surface facilities into the Royal National Park and the fine imposed by the EPA. The submission acknowledged that this incident occurred outside the Catchment but stated, 'if this company is so complacent about allowing pollution like this into the Royal National Park, what are they doing with our water catchment?'

8.3.2. Case study – proposed Hume coal mine

The Independent Planning Commission invited written submissions from the public between 8 June 2021 and 23 July 2021 in relation to a proposed new coal mine in the Wingecarribee River sub-catchment (Hume Coal owned by POSCO). The Commission received 432 unique written submissions, comprising 72 in support of the application for the new mine, 358 objecting to the application and two neutral submissions. A further 181 form submissions were provided to the Commission, all objecting to the new mine's application.

The proposed new Hume Coal Mine was refused by the Independent Planning Commission on 31 August 2021. The Commission gave the following reasons for rejection, stating that the project:

- 'Would result in unacceptable groundwater impacts
- Would pose an unacceptable risk to Sydney's drinking water catchment
- Would result in adverse social impacts
- Would be incompatible with surrounding land uses'.

The mine lease area was subsequently advertised for sale on the property market.

8.3.3. Case study – proposed Dendrobium coal mine expansion

The announcement by South32 in 2022 to discontinue plans for Dendrobium coal expansion demonstrated that coal mining is increasingly less feasible as a commercial proposition, in the context of more rigorous environmental impact assessment criteria, global markets and strong community sentiment. Significant concerns were also raised by agencies including WaterNSW and the Commonwealth Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development. The announcement by South32 regarding the proposed Dendrobium mine expansion project situated in the Metropolitan Special Area (Upper Nepean River sub-catchment) stated:

> 'While the Project demonstrated the potential to extend the life of the Dendrobium Mine, with the complexities involved the expected returns do not support investment by South32…While this decision provides clarity on the Dendrobium Mine Extension Project, we acknowledge it may be unexpected to our people and their families, the local community, local businesses, suppliers and our many other partners in various ways.' - South32 website 23 August 2022.

8.3.4. Case study – proposed Russell Vale underground coal mine expansion project

In 2009, two Russell Vale underground mine proposed expansion projects in the sub-catchment of Cataract Dam were determined unsuitable by Government. The proposed scope was subsequently amended by reducing the extent and changing the mining method from longwalls to bord and pillar. In December 2020, the Independent Planning Commission approved the Russell Vale Revised Preferred Underground Expansion Project. The Commission considered the bord and pillar method 'is unlikely to cause significant surface subsidence or significant interaction with the overlying coal seams.' Further, the Commission considered:

- Impacts to swamps would be negligible
- The project would have a neutral impact on water quality in the Catchment and would not contravene the aims of the (then) Sydney Drinking Water Catchment SEPP.

The project approval is limited to five years and contains 118 conditions designed to:

- Prevent, minimise and/or offset adverse environmental impacts
- Set standards and performance measures for acceptable environmental performance
- Require regular monitoring and reporting
- Provide for the on-going environmental management of the development.

8.4. Strategic planning

In 2020, the NSW Government released the Strategic Statement on Coal Exploration and Mining in NSW. Its objectives include to:

- ‘Improve certainty to explorers, investors, industry stakeholders and communities about where coal mining should not occur.
- Support responsible coal production.
- Reduce the impact of coal mining, including responses to the Independent Expert Panel for Mining in the Catchment report.
- Support diversification of coal-reliant regional economies to assist with the phase-out of thermal coal mining’.

In May 2022, a map[7] of available and excluded mining areas was released by Mining, Exploration and Geoscience to accompany the Strategic Statement on Coal Exploration and Mining in NSW (Department of Regional NSW 2020). The map covers the northern parts of the Catchment but most of the Southern Coalfield, including the Metropolitan and Woronora Special Areas, is not shown. The map identifies ‘areas where higher priority land uses mean that coal exploration and mining cannot occur’. None of the mapped high priority areas are within Sydney’s Drinking Water Catchment.

Other gaps in the strategic planning context that were raised by government and industry stakeholders during this audit include the need for improved coordination of planning and services to support the transition of coal mines, coal-fired power stations and associated businesses and communities (including those currently reliant on metallurgical coal) to more sustainable land uses. DPE is investigating how regions will transition away from coal mining. This includes investigating post mining and other infrastructure land uses which will be identified in its regional strategic plans.

8.5. Planning assessment and approval

The NSW DPE, Independent Planning Commission and the Division of Resources and Geosciences are responsible for assessing and approving state significant development mining activities and associated titles, including modifications to current operations. During the audit period, regulators have updated or introduced more rigorous guidelines for mining impact assessments based on scientific evidence. For example:

- In October 2019, the Independent Expert Panel for Mining in the Catchment released its Review reports:
    - Part 1 – Review of Specific Mining Activities at the Metropolitan and Dendrobium Coal Mines
    - Part 2 – Coal Mining Impacts in the Special Areas of the Greater Sydney Water Catchment.
- In March 2020, the NSW Government adopted all 50 recommendations of final report of the Independent Expert Panel for Mining in the Catchment. An interagency taskforce was created to implement the action plan and will continue to report progress.

[7] Areas in NSW coal regions available and excluded from future coal exploration and mining Accessed 13 December 2022

- In October 2020, DPE established the Independent Advisory Panel for Underground Mining. The panel provides the NSW Government independent expert advice on the assessment and management of underground coal mining proposals and post approval matters.
- DPE has strengthened and improved standard conditions of consent relating to the management, monitoring and mitigation of impacts to surface and groundwater for any new state significant underground mining proposals. This includes updates to the standard Groundwater Management Plan conditions to include more frequent reviews of the groundwater models for the development, incorporation of the Independent Advisory Panel for Underground Mining recommendations regarding surface and groundwater models and inclusion of a requirement to commission an independent peer review if requested by the Planning Secretary. These conditions would also require the applicant to consider and implement relevant recommendation of expert agencies, including DPE Water, the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development, and the Independent Advisory Panel for Underground Mining.
- DPE has developed new standard conditions relating to water quality and mine closure for any new underground mining proposals within the Special Areas.
- DPE will continue to consider the recommendations of the Panel and apply the new Standard Conditions to any new proposals for mining in the Catchment.
- DPE continually reviews the Trigger Action Response Plans applicable to various environmental performance measures during the extraction plan approvals process. This enables the department to monitor and review mine environmental performance standards.

In 2021, WaterNSW updated the principles to guide the environmental planning and approval process for all mining activities in the Catchment, including exploration, extraction, production, rehabilitation and closure[8], as follows:

- ‘The integrity of water supply infrastructure must not be compromised.
- Leakage from reservoirs as a result of mining activities must be avoided.
- Regional depressurisation and diversion of surface water flows must be avoided and minimised by adopting a precautionary approach to mine design.
- All mining activities must have a neutral or beneficial effect on water quality.
- The ecological integrity of the Special Areas must be maintained and protected’.

In 2023, a new trading rule was introduced to meet a commitment made by the NSW Government in its Mining in the Catchment Action Plan to establish a regulatory regime to license surface water losses (incidental water take) by mines within the Special Areas (DPE 2023a). There are currently four mines in the Special Areas that are covered by the new rule: South32’s Dendrobium Mine, Metropolitan Coal’s Metropolitan Mine, Wollongong Resource’s Russell Vale Mine (all currently operating) and Wollongong Resource’s Wongawilli Mine (not currently operating but has approval to recommence operations). The rule was introduced via an amendment to the Access Licence Dealing Principles Order 2004 (the Access Licence Dealing Principles (Special Areas) Amendment Order 2023) to allow WaterNSW to trade water

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[8] WaterNSW Mining Principles are publicly available at https://www.waternsw.com.au/__data/assets/pdf_file/0009/119889/Mining-Principles.pdf

allocation from water access licences it holds in the Upper Nepean and Upstream Warragamba Water Source and the Southern Sydney Rivers Water Source, to unregulated river access licences held in relation to coal mines in the Woronora and Metropolitan Special Areas. The mines are now required to account for and pay water management charges for the water they take, so that the incidental surface water take can be better quantified to inform water resource planning.

8.6. Monitoring and audits

Mines are required to conduct comprehensive environmental monitoring in accordance with approval conditions and submit monthly and annual reports to the regulators. Environmental parameters that are monitored typically include:

- Stream features
- Surface water flow
- Pool water levels
- Stream water quality
- Swamp groundwater levels
- Shallow and deep groundwater levels
- Groundwater quality
- Upland swamp vegetation
- Riparian vegetation
- Aquatic biota and their habitats
- Amphibians
- Land features (cliffs, overhangs, steep slopes)
- Heritage
- Noise
- Air quality
- Waste management
- Water management
- Rehabilitation measures.

In 2021, WaterNSW published the Water Monitoring Guidelines for Underground Mining Activities in the Special Areas. This document replaced the previous SCA (2009) monitoring guidelines, incorporated the relevant Independent Expert Panel for Mining in the Catchment (2019) recommendations and reflected recent advances in understanding and monitoring of subsidence impacts in the Special Areas. The guidelines specify where to monitor surface and groundwater, what to monitor, and how long and how often to monitor.

Mines are also subject to external audits by the NSW Resources Regulator to assess the level of compliance with regulatory instruments. The scope and results of each mines' compliance audit and a summary report for the whole audit program are made available on the NSW Resources Regulator website. Many mining companies also make their reports available to the community via their website.

Comments provided to this auditor from government and non-government sources indicate there is a need to better understand cumulative impacts of mining and other activities in the Catchment in a timely manner. Provision of mine monitoring datasets and mapping via the SEED open-source data sharing platform, together with other monitoring datasets from agencies, would better inform communities, consultants and agencies involved in reviewing and preparing impact assessments, post-approval plans and monitoring reports. As an initial step, it is recommended that formal data sharing agreements be established between mining companies operating in the Special Areas and BCSD (the department that hosts SEED), with a focus on datasets relevant to swamps and stream health.

8.7. Mine rehabilitation

Mine rehabilitation is overseen by the Resources Regulator in accordance with the Mining Amendment (Standard Conditions of Mining Leases – Rehabilitation) Regulation 2021. It includes a clause 'ensuring rehabilitation occurs promptly and achieves the final land use'. This applies to closed mining leases that have a security deposit with a land title holder and mines that have development consent conditions applied. Under the Regulation, all mine lease holders are required to demonstrate that the rehabilitation of land and water disturbed by mining is safe and stable and can support the future final land use(s) approved through the development consent. Lease holders are required to:

- Prevent or minimise harm to the environment
- Rehabilitate land and water as soon as reasonably practicable after disturbance occurs
- Achieve the approved final land use for the mining area as set out in the:
    - Rehabilitation objectives statement
    - Rehabilitation completion criteria statement
    - Final landform and rehabilitation spatial plan (large mines only)
- Undertake a rehabilitation risk assessment and implement measures to eliminate, minimise or mitigate risks to achieving the final land use
- Prepare and implement a rehabilitation management plan (large mines only)
- Prepare an annual rehabilitation report which describes the progress of rehabilitation over the annual reporting period
- Prepare a forward program which includes the schedule of mining and rehabilitation activities for the next three years demonstrating how rehabilitation will occur as soon as reasonably practicable after disturbance.

A series of guidelines and fact sheets are available on the Resource Regulators' website[9] to assist lease holders meet their mine rehabilitation obligations.

In 2021, the NSW Resources Regulator also released a policy on rehabilitation security deposits to ensure that the people of NSW do not incur a financial liability due to coal and mineral exploration and mining operations. All mining title holders are required to lodge a security deposit that covers the government's full costs in undertaking progressive rehabilitation in the event of default by the title holder. The title holder is required to provide an estimate of rehabilitation costs. The Resources Regulator will consider this estimate when determining the amount of the security deposit required for a title, or group of titles. The Resources Regulator is responsible for determining when rehabilitation has met the required

[9] Rehabilitation | NSW Resources Regulator

standard, considering the rehabilitation objectives and rehabilitation completion criteria, and compliance with the title conditions, before the title is relinquished and the security deposit released.

Some examples of mine rehabilitation activities undertaken during the audit period are outlined below.

8.7.1. Case study - Berrima mine

Berrima colliery in the Wingecarribee sub-catchment commenced operations in the 1880s and closed in 2013. The underground workings filled with groundwater in 2016 and discharged through the mine audit site into Wingecarribee River, resulting in water quality issues. The EPA regulates implementation of Boral's pollution reduction program at the closed mine, with support from the Resources Regulator.

Controls have been implemented since 2018 in accordance with the pollution reduction program to treat the groundwater and reduce pollutants discharging to the Wingecarribee River. Current controls include treatment with lime to reduce acidity and, subject to regulators' approval, Boral propose to construct infrastructure to redirect treated groundwater to its cement works instead of being discharged to the river. Further groundwater modelling is required to be submitted by Boral to the regulators in accordance with section 240 of the *Mining Act 1992*.

8.7.2. Case study - Metropolitan mine

Rehabilitation activities associated with the Metropolitan mine in the Woronora Special Area during the audit period include (Peabody 2021):

- Remediation of surface facilities areas (e.g., roads, stockpiles) by weed control
- Stream pool / rock bar remediation at Waratah Rivulet and the Eastern Tributary to restore surface flow and pool holding capacity [note that there are other pools upstream and downstream yet to be remediated]
- Catchment improvement works including rehabilitation of a former quarry and disused access track by supplementary brush matting in areas of low regeneration potential, direct seeding with native species and weed control.

8.7.3. Case study - Angus Place mine

Angus Place coal mine operated for about 70 years in the Upper Coxs River sub-catchment and has been in care and maintenance since 2015. An application for extension of the longwall mine was withdrawn by Centennial Coal in 2021 and a consolidated consent that included water management and rehabilitation reforms was issued by the DPE 'for information' in 2022. A new first workings mining proposal for Angus Place West is proposed and the Department of Planning Secretary's Environmental Assessment Requirements were issued in 2021.

The 2022 Rehabilitation Management Plan for Angus Place states that, following the cessation of mining operations at Angus Place, the Pit Top and all rehabilitated areas on the Newnes Plateau will be rehabilitated to woodland commensurate with the adjacent remnant vegetation. The final land use for these areas will be 'environmental protection works', which is consistent with the surrounding land use of forestry within the former Newnes State Forest. Additionally, the final land use aligns with the current Lithgow Local Environmental Plan 2014 and the Lithgow Land Use Strategy 2010 – 2030.

The water management structures at the Angus Place Pit Top will be retained in the post-mining landform to provide water resources for any fauna inhabiting the Pit Top. The zoning of this land changed to RU1 Rural Production, under the provisions of the Local Environmental Plan 2014, which aligns with the final land use.

8.7.4. Case study - Springvale mine

Progressive rehabilitation at Springvale mine has mainly been associated with infrastructure corridors following the trenching of services. No major rehabilitation of the pit top and Newnes Plateau infrastructure is anticipated until site closure (Centennial 2022a).

Consent conditions for the Springvale mine extension project required progressive reduction of salinity in mine water discharges to improve Catchment health. Springvale mine ceased discharging mine water into the Coxs River in July 2019. A water treatment plant was jointly developed by Springvale Mine (Centennial Coal) and EnergyAustralia to address the development consent condition and provide water treatment and reuse at Mt Piper power station (EnergyAustralia 2020). Partial operation of the Springvale mine water treatment plant commenced in December 2019, and it was fully commissioned by the end of 2021.

8.8. Coal-fired power station case studies

8.8.1. Wallerawang power station

The Wallerawang power station in the Upper Coxs sub-catchment is an example of a transitioning land use that affects Catchment health. The coal-fired power station closed in 2014 which meant a decrease in water demand in the Catchment as water was no longer needed for cooling, so Lake Lyell (Figure 8-4) and Lake Wallace maintained high water levels during the 2019 drought. Greenspot purchased the former power station site from EnergyAustralia in 2020, including Lake Wallace and the Sawyers Swamp Creek Ash Dam. The water access licence is retained by EnergyAustralia as it is attached to land use rather than ownership under the Greater Metropolitan Water Sharing Plan.

An indicative concept plan for the 620 ha site indicates there will be three zones in the redeveloped precinct; commercial, mixed use and green corridor. A battery energy storage system was approved for the site in 2022. Greenspot is aiming to establish a long-term governance framework for the site that includes an infrastructure and public domain company that landholders contribute to for management. Greenspot is seeking partnership opportunities for activities that provide 'exceptional' environmental outcomes to improve water quality and ecosystem health that may not be otherwise commercially viable.

8.8.2. Mt Piper power station

The Mt Piper power station is located 25 km north-west of Lithgow in the Upper Coxs River sub-catchment. The power station and associated infrastructure, including Lyell Dam and Thompsons Creek Dam, were constructed in the 1980s-1990s. The dams were designed to supply water to cooling towers at the Mt Piper power station, which is fuelled using coal sourced from local mines. The Springvale water filtration plant was built within the Mt Piper site (see section 8.7.4) and reduced the volume of water needed from Lake Lyell and Thompsons Creek Reservoir. NSW Water Access Licence 27428 and the Water Use Approval issued under the *Water Management Act 2000* allow Energy Australia to use up to

25,000 ML/year from the Coxs River, only once all available water from Springvale/Angus Place Mine[10] has been utilised. Further changes to water management in the Upper Coxs River sub-catchment are expected as the power station is scheduled to close in 2040; and this may include pumped hydro power.

Representatives from EnergyAustralia raised concern during this audit that the current 30-year water access licence prohibits transfer of water to uses other than for electricity generation. This inflexible approach limits potential adaptive management responses over the following decades when conditions may rapidly change. As part of the discussions on transitioning from coal-fired power to more sustainable land uses, it is anticipated that EnergyAustralia will seek more flexible water licence conditions where there is justification that it would improve Catchment health.

Figure 8-4: Lake Lyell

[10] Angus Place mine went into care and maintenance in 2015. The Angus Place water treatment project was approved in 2018 increasing mine water discharges under an environment protection licence. Discharge ceased in July 2019, coinciding with commencement of Springvale mine water treatment plant. In 2021, a new Angus Place water transfer system was approved (until 2024), allowing mine water to be transferred via pipe to Mt Piper power station.

8.9. Conclusions and recommendations

Strong community interest, a tighter regulatory environment and global market forces are driving the transition from coal mining and coal-fired power stations to alternative energy sources and more sustainable land use practices. Under the EPA's Climate Change Action Plan 2023-26, regulated sources of greenhouse gas emissions, such as Mt Piper power station and coal mines in the Catchment, will be required to develop and implement greenhouse gas mitigation plans. It is recommended that initial plans for major sources of greenhouse gas emissions in the Catchment should be complete and made publicly available by June 2025.

Some agencies have noted challenges accessing Catchment monitoring data from mining companies to make timely decisions and recommendations regarding proposed developments that may have cumulative impacts. It is therefore recommended that formal data sharing agreements be established between the NSW Government agencies and the mining companies operating in the Special Areas to improve timely access to data, with an initial focus on datasets relevant to swamps and stream health.

9. Pollution and contamination

Pollution and contamination continue to adversely affect the health of the Catchment but are generally well regulated, managed and monitored. This indicator was therefore assessed as having a moderate state and a stable trend.

9.1. Sources of pollution and contamination

Pollution is the introduction of a harmful or poisonous substance into the environment. Pollutants can be natural (e.g., ash from a bushfire) or created by human activity. Pollutants can enter waterways via:

- Point sources – include sewage treatment plants, on-site sewage management systems, urban development stormwater infrastructure and intensive agriculture (e.g., dairies, piggeries). Some point sources are regulated by the EPA under an environment protection licence in accordance with the *Protection of the Environment Operations Act 1997* (see section 9.3.1).
- Diffuse sources – involve pollutants entering waterways via uncontrolled runoff from land uses such as grazing and forestry, or the atmosphere.

This audit reviewed changes that have occurred in environment protection licenced point sources of pollution since previous audits. It also noted concerns from councils, agencies and the community about unauthorised or poorly regulated pollution sources such as illegal dumping of waste.

9.2. Priority pollutants - nutrients

Nitrogen and phosphorus are nutrients that are regarded by WaterNSW as 'priority pollutants' because of the adverse impact they can have on waterways. Nutrients in waters, particularly the impounded waters of lakes and reservoirs, can accumulate over time in water and sediment. Waterways with high nutrient concentrations often experience excessive plant and algal growth, which can be damaging to aquatic ecosystems and adversely affect water quality (refer to section 19.6 for information about cyanobacteria).

9.2.1. Nutrient load

Before a nutrient enters the waterway, it is measured as a load value, which is often in mass (kilograms or tonnes per year) but can also be expressed in area terms (e.g., as kg per km^2). Nutrient load is an indicator of Catchment health (Table 1-2), but it is currently not possible to determine the total nutrient load to the Catchment due to the many unlicensed point and diffuse sources of pollution that are not monitored. Also, the publicly available data on the EPA's website is not in a format suitable for a strategic review of nutrient loads from all licenced premises in the Catchment. The EPA is working toward improving data search capabilities and access on the website while protecting privacy.

As discussed in section 9.3.1, some point sources of pollution are monitored and managed under an environment protection licence. Load-based licensing fees charged by the EPA are based on the amount of pollutant load, how harmful it is and where it is released. Fees can be reduced under voluntary load reduction agreements. As an example, Mittagong sewage treatment plant (licence 10362) was charged an annual fee of $11,403.12 in 2021-22 based on the following assessable pollutant loads:

- Total nitrogen 7211.600 kg

- Total phosphorus 353.300 kg
- Total suspended solids 12,691.600 kg
- Biochemical oxygen demand 4202.399 kg

The EPA and BCSD teams are researching the ecological carrying capacity of waterways within the Hawkesbury-Nepean catchment (which overlaps with parts of Sydney's Drinking Water Catchment) to determine thresholds for nutrient loads. This research will improve understanding of preferred requirements for environment protection licences at sewage treatment plants rather than their technological capability, which is currently the main consideration.

9.2.2. Nutrient concentration

Once nutrient enters a stream or storage, it can be measured and expressed as a concentration value (such as mg/L). As discussed in section 19, the WaterNSW water quality monitoring program seeks to provide a comprehensive picture of water quality in streams and storages across the Catchment, including various analytes related to nutrient concentrations. Other organisations (e.g., some local councils and EnergyAustralia) also monitor nutrient concentrations in selected Catchment waterways, for compliance or environmental health programs.

9.3. Pollution management

9.3.1. Environment Protection Licences

The EPA issues environment protection licences under the *Protection of the Environment Operations Act* 1997. There were 78 active licences in the Catchment[11] at the end of the audit period, with most in or near the urban centres of Lithgow, the Southern Highlands and Goulburn (Figure 9-1). This number includes licences that have multiple fee-based activities under the same reference. Compared to results of previous audits, the number of active licences in the Catchment is stable. Licence holders are required to publish environmental monitoring results (e.g., via a website) so the community is informed.

Most activities in the Catchment covered by active licences have surface and/or groundwater management, monitoring and reporting requirements. Details are given in each environment protection licence. Typically, the licence also states the responsibilities of the licensee as follows:

> 'Separate to the requirements of this licence, general obligations of licensees are set out in the *Protection of the Environment Operations Act 1997* ('the Act') and the Regulations made under the Act. These include obligations to:
>
> - Ensure persons associated with you comply with this licence, as set out in section 64 of the Act
> - Control the pollution of waters and the pollution of air (see for example sections 120 - 132 of the Act)
> - Report incidents causing or threatening material environmental harm to the environment, as set out in Part 5.7 of the Act.'

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[11] Locations on Figure 9-1 indicate the address for the licence rather than the extent of the operation. For example, some coal mining activities are located outside the Catchment (e.g., pit top of metro colliery is within the Hacking River sub-catchment) but the underground operational mine is within the Catchment (refer to maps of mine lease areas in section 8).

Environment Protection Licences

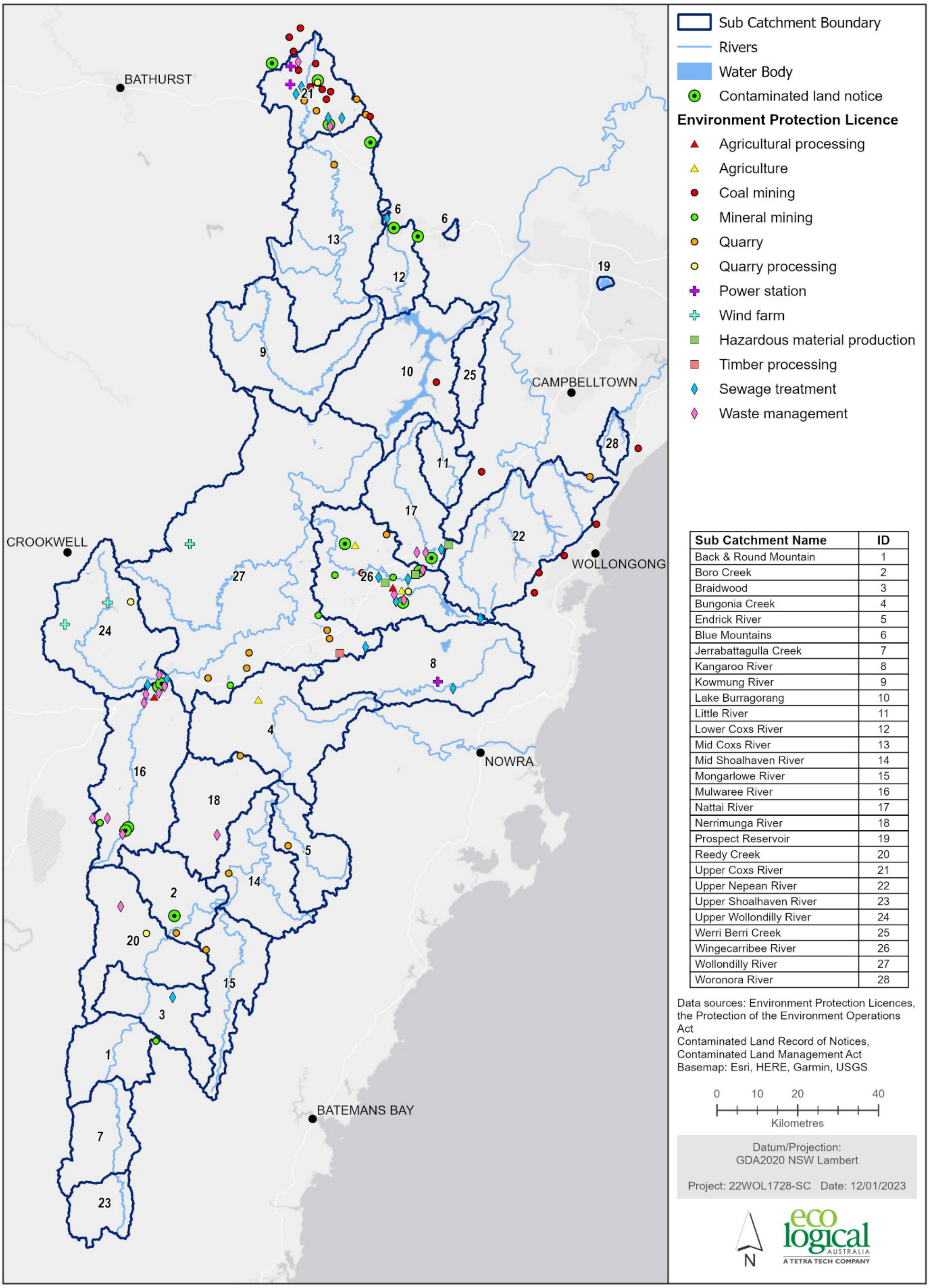


Figure 9-1: Sites of environment protection licences and known contamination (EPA 2022)

9.3.2. Contaminated land

Landowners are required to notify the EPA of contaminated land in accordance with the *Contaminated Land Management Act 1997*. The number (n=11) and locations of current and former contaminated sites in the Catchment remained steady since the 2019 audit (Figure 9-1). Contaminated sites include former gas works, shale oil refinery and waste disposal depot with asbestos. Remediation activities at some of these sites during the audit period included excavation of contaminated material and offsite disposal at an appropriate licenced facility, as well on-site testing and surface area restoration.

9.3.3. Collaborative pollution control programs

Regional Illegal Dumping (RID) program - Illegal dumping of waste adversely affects Catchment health and some councils raised concerns during this audit that illegal dumping is a growing problem. The EPA's Illegal Dumping Strategy supports RID squads to investigate illegal dumping incidents, educate the community and construction industry, and work with charities and local councils to prevent and manage illegally dumped waste. RID squads relevant to local government areas in the Catchment during the audit period are tabulated below.

Table 9-1: Regional Illegal Dumping squads in the Catchment (EPA)

RID squad / program	Local Government Area
Sydney RID squad:	Sutherland Shire Council
Western Sydney RID squad:	Blue Mountains City Council
Southern Councils Group RID program:	Wollondilly Shire Council Wollongong City Council Wingecarribee Shire Council Shellharbour City Council Kiama Municipal Council Shoalhaven City Council Eurobodalla Shire Council Snowy Monaro Regional Council
ACT-NSW Cross Border Program:	Goulburn-Mulwaree Council Queanbeyan-Palerang Regional Council
Not covered by the RID program	Oberon Council Upper Lachlan Shire Council Campbelltown City Council Lithgow City Council

The Urban Program - The Urban Program features projects that WaterNSW has funded and/or collaborated with five local councils to improve urban catchment condition and reduce threats to water quality during the audit period. Examples are provided in Table 9-2 below.

Get the Site Right campaign - In 2022, WaterNSW and five partner councils joined the 'Get the Site Right' campaign as part of the Urban Program. The 'Get the Site Right' campaign is a council and community-based education campaign targeting developers and the wider community to improve erosion and sediment control on construction and building sites. The education and pre-inspections campaign runs during the month prior to the inspection 'blitz day' each May and October.

Table 9-2: WaterNSW Urban Program stormwater management projects (2019-22)

Council	Project	Summary
All Councils	WaterNSW Water Sensitive Cities Rapid Benchmarking Tool Project, 2020	WaterNSW engaged the Cooperative Research Centre for Water Sensitive Cities (CRCWSC) to develop a framework and tool to support the identification and evaluation of water management projects in eight regional NSW councils located in the Sydney Drinking Water Catchment.
	Bioretention Workshop delivered online during COVID in March 2021	30 participants attended.
	Erosion and Sediment Control training, delivered 2022	Delivered as part of Get the Site Right Campaign, 14 Council participants and 2x WaterNSW staff attended training.
	Stormwater Maintenance and Operations Training, delivered 2022	2-3 participants from 5x Councils attended.
	‘Get the Site Right’ Campaign, May 2022	Education campaign focused on erosion and sediment control at new development sites.
	DCP, LSPS and LEP stormwater clause review	SW clauses reviewed and draft clauses created for strategic document updates and reviews.
	Stormwater Pollution Investigations	Wet weather sampling of stormwater drains to identify and fix ‘at risk’ stormwater watersheds within Council key urban areas. Preliminary studies in Lithgow and Goulburn conducted during audit period. Online Dashboard mapping stormwater drainage (pits, pipes, flow direction) were modelled and mapped. Project paused due to COVID, to be resumed in 2022/2023.
Blue Mountains City Council	Bioretention Workshop (Face to face delivery, delivered September 2019)	30 participants across Council attended. Practical component included.
	Recommendations for the Water Sensitive Blue Mountains Strategic Plan, 2019	The Cooperative Research Centre Water Sensitive Cities was engaged to make recommendations to Council to align the Strategic Plan with a broader community water vision. The review process involved three community engagement workshops over October,2018 and desktop analysis from research on water sensitive cities
	Shaping a Water Sensitive Blue Mountains Project, 2019.	The Cooperative Research Centre for Water Sensitive Cities (CRCWSC) was invited to apply the Water Sensitive Cities Transition Index with Council to identify water sensitive drivers and barriers. This involved desktop review of current policy documents, phone interviews with select council staff, and a one-day collaborative workshop with participants from Blue Mountains City Council, Sydney Water, and WaterNSW in December 2019.

Council	Project	Summary
	Jamison Catchment Streets to Creeks Project, 2015-2019.	Aims to protect Wentworth Falls Lake and Jamison Creek from stormwater pollution and other threats posed by urban runoff. Council constructed 12 stormwater biofiltration systems throughout the catchment, removing pollutants such as litter, sediment, nutrients and pathogens and increasing groundwater recharge. Local residents, schools and Bushcare groups contributed to the project by taking part in Waterways Festivals, catchment crawls, planting and weeding days and citizen science events.
	The "Gedumba Sweet Water Project"	Aims to improve the ongoing health of the upper Gedumba (Kedumba) Creek in Katoomba through stormwater mitigation and community engagement initiatives. Project Approved, June 2022.
Wollondilly Shire Council	The "Wollondilly Shire Council Water Sensitive Urban Design Education and Improvement Project".	Aims to improve the internal collaboration and technical knowledge of Council staff and broader community to support implementation of water sensitive stormwater management projects. The project will include Council, Developer and Community components and involve practical and capacity building initiatives. Project approved, June 2022.
	The "Onsite Solutions Project"	A digital 'onsite sewerage system management program' will be developed to replace current paper-based record systems in Council. Dependent data process and administration will be streamlined and integrated into councils' records management systems supporting effective long-term management of a key source of nutrient and pathogens. Project approved, June 2022.
Goulburn Mulwaree Council	Novel Urban Water Mass Balance Model Assessment of Goulburn Project, 2018	The water data for Goulburn Mulwaree Council (GMC) was used to determine the efficacy and usability of a novel water mass balance model and tool developed by the CRCWSC.
	'Shaping a Water Sensitive Goulburn Project', 2019	The Cooperative Research Centre for Water Sensitive Cities (CRCWSC) worked with the Goulburn Mulwaree community to develop a water management vision for the Goulburn Mulwaree Region through a series of three collaborative workshops.
	The "Wollondilly Walking Track, Mulwaree River Project"	Aims to complete the rehabilitation of a reach of the Mulwaree River adjacent to the river walking track and upgrade a stormwater treatment train. Project Approved, June 2022
Wingecarribee Shire Council	The "Stormwater Quality Improvement Devices Audit"	Aims to provide Council and WaterNSW with greater understanding of the SQIDs location, design and condition/performance assessment within Council's stormwater network. This will support the implementation and design of Council's updated maintenance plan, Engineering Design Guidelines and SQID Masterplan for more effective stormwater management. Project Approved, June 2022

Council	Project	Summary
Lithgow City Council	The "Review of Council Stormwater Management and Planning for Evolving Community Needs" project	Aims to support future stormwater treatment, planning, flood mitigation and pollution control across Council to be more streamlined and incorporate local community and cultural values. Alongside this project, Council is preparing a review of their DCP and Floodplain Risk Management Plan, so results of these projects will be immediately implemented within Council policy and practices going forward. Project Approved, June 2022

The Get the Site Right campaign was launched by the Parramatta River Catchment Group in 2016, and is supported by the Cooks River Alliance, Georges River Riverkeeper, Sydney Coastal Councils Group, Lake Macquarie City Council, EPA, DPE and more than 20 councils. The campaign aims to:

- Increase awareness of the impacts of runoff from construction sites and encourage developers, builders and home renovators to implement appropriate erosion and sediment controls
- Increase collaboration between WaterNSW and partner council compliance teams
- Assess scalability and repeatability for ongoing participation in future years.

WaterNSW has advised that results of the 2022 campaign are currently being analysed and will be released to the public.

9.4. Pollution case studies

9.4.1. Clean-up notices issued by WaterNSW

Clause 8 of the Water NSW Regulation 2020 requires WaterNSW to maintain a register that details each environment protection notice and penalty notice issued under the *Protection of the Environment Operations Act 1997*. The register is available to the public on the WaterNSW website. Table 9-3 identifies clean up notices issued by WaterNSW under section 91 of the *Protection of the Environment Operations Act 1997* during the audit period. The notices related to erosion and sediment control, illegal disposal of waste, or on-site sewage management.

Table 9-3: Register of s.91 clean up notices issued by WaterNSW during the audit period

Date	Recipient	Issue	Location	Reference
29/11/21	Daniel J DOGGETT	Illegal Disposal of Waste	Upper Nepean Special Area	#2021/114 D2021/124790
03/09/21	Wonderrock Pastoral Company Pty Ltd	Erosion / sediment	Outer Catchment Area	#2021/63 D2021/90792
11/03/21	Bernard JESSUP	Erosion / sediment	Outer Catchment Area	#2021/15 D2021/27064
16/10/20	Charles OLSSON	Erosion / sediment	Outer Catchment Area	#2020/188 D2020/110522
07/10/20	Peter BURROWS	Erosion / sediment	Upper Nepean Special Area	#2020/187 D2020/105105
13/10/20	Wonderrock Pastoral Company Pty Ltd	Erosion / sediment	Outer Catchment Area	#2020/186 D2020/104403
15/10/20	Roger FAGAN (Variation to Notice)	Onsite sewage management	Outer Catchment Area	#2020/185 D2020/112259
25/09/20	Roger FAGAN	Onsite sewage management	Outer Catchment Area	#2020/185 D2020/104282
18/09/20	Charles OLSSON	Erosion / sediment	Outer Catchment Area	#2020/175 D2020/101575
31/07/20	John Holland Pty Ltd	Erosion / sediment	Outer Catchment Area	#2020/154 D2020/78325
31/07/20	Wonderrock Pastoral Company Pty Ltd	Erosion / sediment	Outer Catchment Area	#2020/153 D2020/78313

9.4.2. Wallerawang pollution spill

In August 2019 a storage tank fitting failed at Wallerawang sewage treatment plant and 13,000 L of caustic soda spilled into a bund and subsequently escaped into an unnamed watercourse and onto adjoining land. The owner, Lithgow City Council, did not notify the EPA or implement a Pollution Incident Response Management Plan at the time of the spill. The incident gave rise to breaches of the *Protection of the Environment Operations Act 1997*, including pollution of waters, land pollution and breaches of Council's environment protection licence.

An Enforceable Undertaking by the Land and Environment Court required Lithgow City Council to spend $417,000 to drive improvements in Council's environmental performance including additional training and staff. Council was also required to contribute a further $100,000 to deliver benefits to the local environment and community and pay the EPA's legal and investigation costs totalling $26,759, with up to another $5,000 for EPA compliance monitoring.

9.4.3. On-site sewage management systems

In NSW, properties that are not connected to a centralised sewerage system require council approval to install and operate ('register') an on-site sewage management system and these systems are subject to regular compliance inspections by councils. The Designing and Installing On-site Wastewater Systems Current Recommended Practice (WaterNSW 2019b) states that there are more than 11,000 on-site systems in the Catchment. Existing standards and guidelines for design, installation and operation include:

- Designing and Installing On-Site Wastewater Systems (WaterNSW 2019b; currently under review)
- AS/NZS 1547:2012 On-site Domestic Wastewater Management (Standards Australia 2012)
- Environmental Guidelines - Use of Effluent by Irrigation (DEC 2004)
- On-site Sewage Management for Single Households (Silver Book) (NSW Department of Local Government 1998; currently under review).

Many councils in the Catchment provided the auditor with records of on-site systems in their local government area, including locations and types of systems and inspection details. However, some councils acknowledged they have insufficient resources (staff and information systems) to adequately undertake compliance monitoring or the results of monitoring are not available in a spatial database format that can be used to inform strategic environmental management. Without accurate records about the locations and conditions of on-site systems it is not possible to identify or manage areas at greatest risk from pathogens and nutrients. A 2014 IPART review found that 'the installation and operation of onsite systems are high risk activities, as systems which are not properly installed, maintained and operated can pose significant public health and environmental risks'.

9.4.4. New stormwater management in Werri Berri Creek sub-catchment

In November 2022, the auditor inspected three residential subdivisions in the Werri Berri Creek sub-catchment and observed gross pollutant traps, bioretention basins, scour protection, vegetated riparian buffers and swales, and a floating wetland (Figure 9-2 and Figure 9-3). The WaterNSW representative explained that the systems were designed and constructed in accordance with approved NorBE requirements. The design models included assumptions about the performance of proposed devices and pre-development site conditions.

The planning, design, construction and short-term maintenance of stormwater systems is tightly regulated to meet NorBE requirements. For example, as part of concurrence conditions WaterNSW requires performance monitoring and evaluation of new stormwater devices such as the floating wetland installed at Oakdale (Figure 9-3).

Figure 9-2: Bioretention to improve stormwater quality at The Oaks

Figure 9-3: Floating wetlands installed to improve water quality at Oakdale

Wollondilly Shire Council has responsibility for long-term maintenance of stormwater systems in the Werri Berri Creek sub-catchment. This includes checking and cleaning stormwater control devices and managing weeds. In reviewing the effectiveness of a stormwater system, compliance officers review conditions upstream, downstream and at the device, including drainage, vegetation health, erosion, litter and other evidence. Council also educates residents on how to protect local waterways and be 'stormwater smart'.

9.4.5. Retrofitting stormwater management in the Blue Mountains

Retrofitting stormwater management in urban catchments involves many challenges. As outlined in the 2019 Water Sensitive Blue Mountains Strategic Plan, Blue Mountains City Council has taken a long-term, innovative, landscape-scale approach that aims to have treatment systems installed at all its stormwater outlets, at a scale commensurate with the risk at each location. Council's 'grey - green - blue' stormwater systems are required to satisfy three design principles: be functional, aesthetic and provide habitat. Water quality and macroinvertebrate monitoring have demonstrated that these systems are more effective than traditional 'end-of-pipe' stormwater treatment approaches. Council also intends to increase householder education, so stormwater is better managed 'at the source'.

Figure 9-4: Stormwater management by Blue Mountains City Council at Leura Park

9.5. Conclusions and recommendations

Pollution adversely affects Catchment health. Technological advances, tighter regulations and environmental education programs reduced some pollution pressures during the audit period, however, further opportunities for improvement were identified. These involve improving compliance and collaboration, as follows (and reiterated in section 21.3):

- Updated NSW guidelines for on-site sewage management are scheduled for release in mid-2023. As part of the roll-out of the new guidelines, it is recommended that the Office of Local Government requests councils in the Catchment review integration of the new guidelines with councils' compliance and enforcement policies and programs and provide feedback that can be used to inform community and industry education programs and updates to the Local Government (General) Regulation 2015.
- It is recommended that collaborative pollution control programs such as, but not limited to, the Get the Site Right and RID squads are expanded or realigned in high-risk areas in the Catchment, as defined by councils in consultation with the EPA.
- It is recommended that stormwater management assets that are dedicated to council are audited to determine if they are maintained to achieve NorBE objectives.
- Consistent with the goal to transition to Water Sensitive Cities, it is recommended that educational material be developed by WaterNSW in consultation with councils based on experience in innovative stormwater management practices in the Catchment. The material should showcase successful initiatives in the Catchment (including on-ground outcomes) and provide information on what should be avoided. The material should be targeted to practitioners from councils and other organisations (e.g., WaterNSW, Transport for NSW, LLS) that include design engineers, construction and maintenance personnel, environmental scientists, bush regenerators and community volunteers.
- It is also recommended that sewage treatment plants in Wingecarribee LGA are upgraded no later than: Bowral July 2024, Moss Vale 2026 and Mittagong 2028. The EPA has advised that upgraded sewage treatment plants will have more stringent environment protection licence conditions than currently apply. Councils should not consent to developments that would result in sewage treatment plants being non-compliant with environment protection licences.

State of the Catchment – Biodiversity and Habitats

10. Macroinvertebrates

Macroinvertebrate monitoring indicates the overall health of waterways across the Catchment are in moderate condition, but there is a worsening trend.

10.1. What are macroinvertebrates

Aquatic macroinvertebrates are small aquatic organisms, mostly insects, that live in creeks and rivers, mainly on the stream bed. They are an indicator of Catchment health (NOW 2009) as they perform several ecological functions, such as processing organic matter, and making nutrients and energy available for other organisms in river food webs (such as fish, birds, lizards and platypus). Abundant macroinvertebrates present in complex assemblages of different species and higher groupings (genera, families and orders) represent healthy aquatic ecosystems.

Macroinvertebrate data is complementary to water chemistry data (section 19). Whilst water chemistry represents a series of 'snap-shots' of water quality, macroinvertebrates represent a cumulative measure of water quality and habitat conditions over their life cycles that range from weeks to years (Cairns and Pratt 1993).

10.2. AUSRIVAS method

The Australian River Assessment System (AUSRIVAS) is the recommended measure of macroinvertebrates for the Catchment (NOW 2009, ANZECC & ARMCANZ 2000). It compares actual (observed) macroinvertebrate results collected from sampling sites with predicted results (expected) modelled from undisturbed regional reference sites (Turak and Waddel 2000). The AUSRIVAS ratio of observed to expected macroinvertebrates is used to classify the samples into results bands (Table 10-1). Band X and Band A represent healthy macroinvertebrate assemblages, whereas Bands B, C and D represent moderate to severe biological impairment, respectively. The cause of the impairment is not revealed, however, and can be due to water pollution, disturbance of river habitat and/or climatic conditions.

Table 10-1: AUSRIVAS criteria

Band Label	Band Name	Comments
Band X	More biologically diverse than reference sites	More families found than expected. Indicative of a potential biodiversity hot spot.
Band A	Reference condition	Most or all of the expected families found. Indicative that water quality and/or habitat condition is roughly equivalent to reference sites.
Band B	Significantly impacted	Fewer families than expected. Potential impact on water quality and/or habitat, or both.
Band C	Severely impacted	Many fewer families than expected. Loss of macroinvertebrate biodiversity due to substantial water quality and/or habitat quality.
Band D	Extremely impacted	Few of the expected families remain. Extremely poor water quality and /or habitat quality.
OEM	Outside experience of model	

10.3. Macroinvertebrate monitoring programs

Macroinvertebrate monitoring sites across the Catchment are mapped in Figure 10-1, dominated by WaterNSW macroinvertebrate program sites, plus localised clusters near mines, flow monitoring points and council stream health monitoring.

10.3.1. WaterNSW

Macroinvertebrates in the Catchment are monitored annually by WaterNSW, at both routine sites and a selection of other water monitoring locations covering 27 of the 28 sub-catchments. Across the audit period, WaterNSW sampled 80 sites in Spring 2019, 86 sites in Spring 2020 and 82 sites in Spring 2021. The number of sites is an increase from 63 following a review of WaterNSW's macroinvertebrate monitoring program in 2018 (WaterNSW 2020c). Overall, a total of 493 samples (edge and riffle) were collected over three seasons.

10.3.2. Blue Mountains City Council

Blue Mountains City Council surveys macroinvertebrates as part of their annual aquatic health monitoring program. A total of 22 sites were surveyed across the audit period. Additionally, 12 sites were surveyed for Freshwater Crayfish, expanding their monitoring program since a pollution event in 2012 (McCormack 2022). Crayfish results are also included in section 11.

10.3.3. EnergyAustralia NSW

EnergyAustralia uses water from the Upper Coxs River sub-catchment as a primary source of cooling water for Mt Piper power station, and until 2014 for Wallerawang power station. EnergyAustralia's use of water resources in the sub-catchment is defined in its Water Access Licence, Water Supply Work and Water Use Approval issued under the *Water Management Act 2000*. The Water Use Approval requires EnergyAustralia to implement a river health monitoring program to assess biophysical impacts on the Coxs River downstream of Lake Lyell arising from the environmental flow regime, focusing on benthic macroinvertebrate communities, periphyton and fish. The monitoring program includes ten sites with controlled and natural flow regimes across the Mid Coxs River, Upper Coxs River and Wollondilly River sub-catchments, plus an eleventh site out of the Catchment (Cardno 2021).

10.3.4. Mines

Aquatic ecology monitoring programs and impact assessments take place near longwall coal mines in the Woronora River and Upper Nepean River sub-catchments (e.g., Bio-Analysis 2020 and Cardno 2022). Those studies investigated changes or potential impacts to biological communities from mining activities at a small number of long-term monitoring sites and compared to nearby control sites.

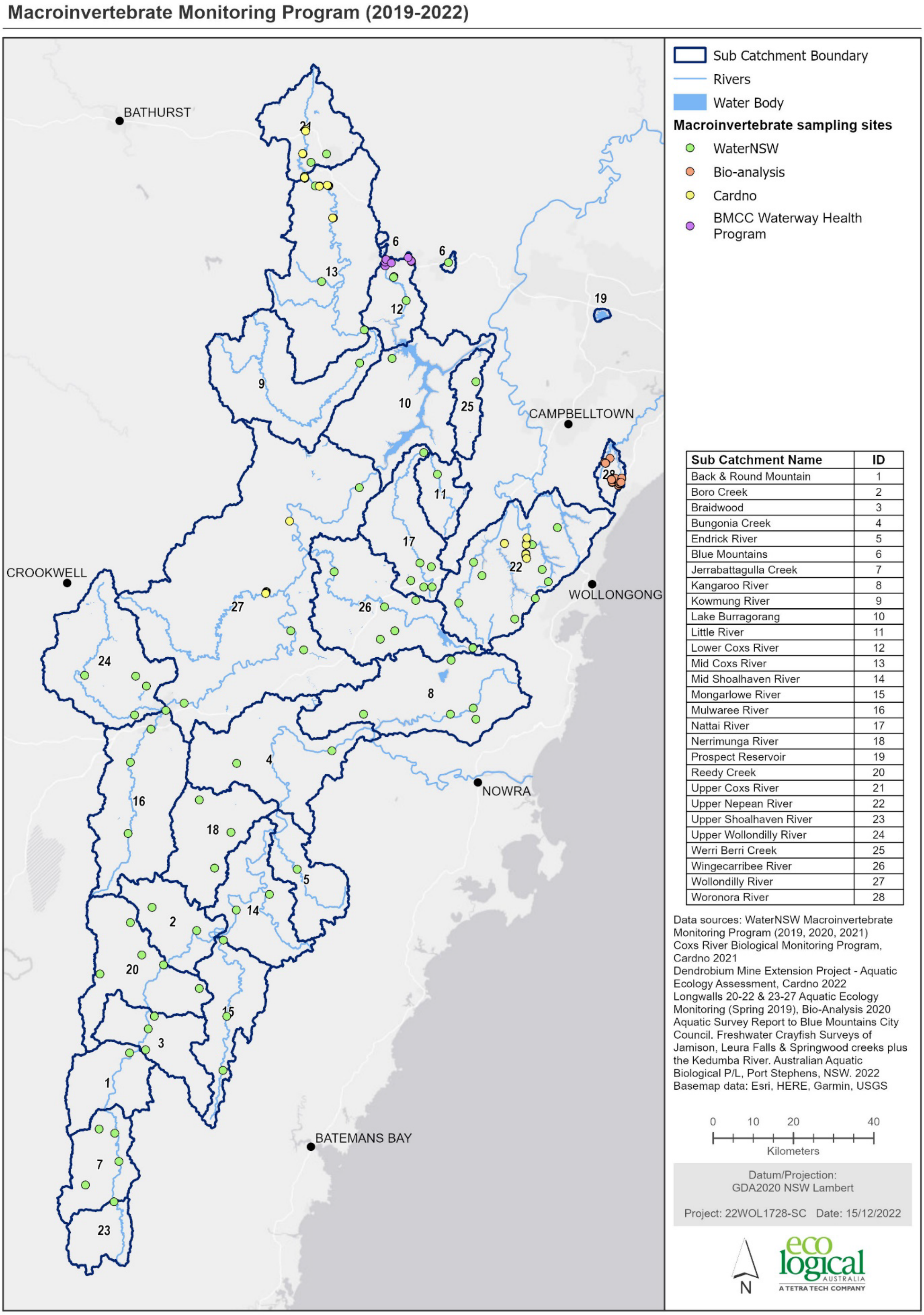


Figure 10-1: Macroinvertebrate monitoring sites

10.4. Trends

From the 493 samples taken in the audit period by WaterNSW, the majority (54%) fell within Band B – significantly impacted (Table 10-2), followed by 27% severely impacted (Band C). Only 16% of the samples were equal to or better than reference condition. When compared to historical records from previous audits, there was a notable decline in condition since 2017 (Figure 10-2), with fewer Band X and A (no impact), and more Band B, C and D combined (impacted). This analysis of decline is consistent with the observations of the macroinvertebrate monitoring program results described in the 2020-21 Annual Water Quality Monitoring Report (WaterNSW 2021c).

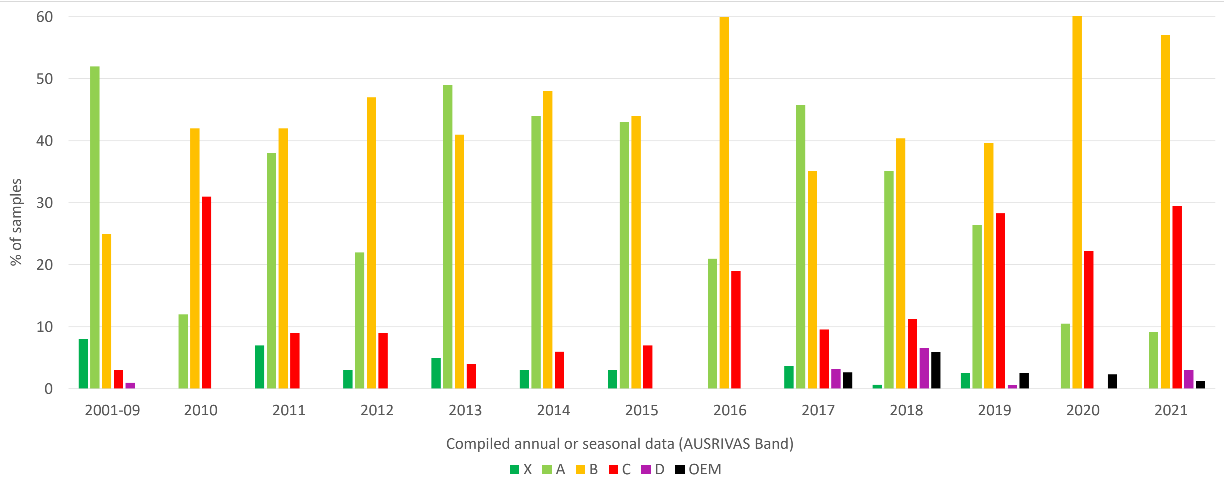


Figure 10-2: Average annual AUSRIVAS categories for macroinvertebrates across all catchment sites

In 2019, Blue Mountains City Council observed a decline in the proportion of healthy watercourses compared to 2018. This result improved in 2020 and again in 2022, with 68% of sites in excellent to good condition (Figure 10-3). The 2021 Freshwater Crayfish survey found two sites with excellent results (Jamison Creek and Kedumba River), one site with poor results (Springwood Creek) and one site with extremely poor results (Leura Creek). Of the 160 individuals captured, nine were recaptures (from 86 tagged between 2017-2020). The low number of recaptures may indicate the population is larger or more mobile than the surveys can identify at this stage.

EnergyAustralia found that from 2017 to 2020 the macroinvertebrate community just downstream of Lake Lyell has become more similar to that expected under natural flow conditions, following implementation of the environmental flow regime. However, given there have been coincidental increases in rainfall and other water inputs since 2011 that would also have contributed to greater flow variability in the Coxs River, the specific influence of the environmental flow regime could not be determined (Cardno 2021).

At a local mine-monitoring scale, Cardno (2022) recorded Bands A and B at two sites in the Upper Nepean River (Spring 2019). Bio-Analysis (2020) recorded Band B at three sites and Band C at one site in the Woronora River sub-catchment (Spring 2019).

Table 10-2: Percentage of macroinvertebrate samples collected in the MMP 2019-2021

Sub-catchment	Number of samples	% of Band X	% of Band A	% of Band B	% of Band C	% of Band D	% of OEM
Back & Round Mountain Creeks	6	0	33	33	33	0	0
Blue Mountains	6	0	17	50	33	0	0
Boro Creek	12	0	25	50	25	0	0
Braidwood	18	0	11	56	22	0	11
Bungonia Creek	10	0	10	50	20	0	20
Endrick River	6	17	0	50	33	0	0
Jerrabattagulla Creek	24	0	8	67	25	0	0
Kangaroo River	28	0	29	46	21	0	4
Kowmung River	6	0	50	17	33	0	0
Lake Burragorang	4	0	25	50	25	0	0
Little River	4	0	0	25	75	0	0
Lower Coxs River	12	0	17	50	33	0	0
Mid Coxs River	24	4	38	29	17	0	13
Mid Shoalhaven River	12	0	8	83	8	0	0
Mongarlowe River	18	6	11	67	17	0	0
Mulwaree River	18	0	11	78	11	0	0
Nattai River	36	0	6	56	31	8	0
Nerrimunga River	16	0	6	81	13	0	0
Reedy Creek	23	0	17	52	30	0	0
Upper Coxs River	30	3	23	43	30	0	0
Upper Nepean River	60	0	15	55	30	0	0
Upper Shoalhaven River	6	0	17	67	17	0	0
Upper Wollondilly River	24	0	17	63	21	0	0
Werri Berri Creek	5	0	0	80	20	0	0
Wingecarribee River	35	0	9	34	49	9	0
Wollondilly River	38	0	8	58	29	0	5
Woronora River	12	0	17	67	17	0	0
% of total		**1**	**15**	**54**	**27**	**1**	**2**
Total number of sites	**493**	**4**	**75**	**267**	**131**	**6**	**10**

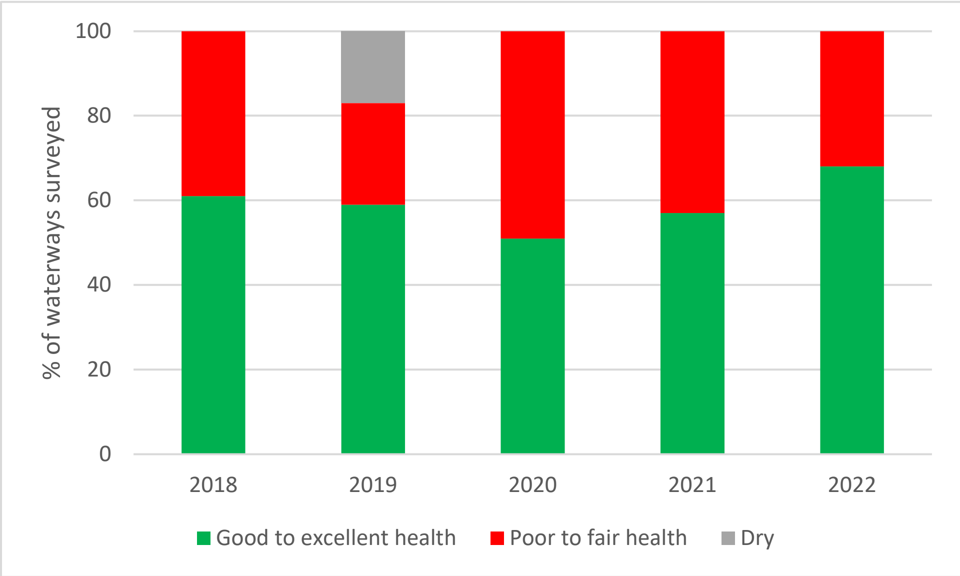


Figure 10-3: Five-year trend of ecological waterway health (macroinvertebrates) in the Blue Mountains LGA

The first audit (CSIRO 1999) referenced a report by Thomson and Norris (1999) that included AUSRIVAS models, although no quantitative data or results were provided by CSIRO (1999). It was therefore not possible to compare recent results to baseline 1999 conditions. CSIRO (1999) discussed limitations of the 1999 AUSRIVAS analysis and stated:

> 'As the balance between local and catchment causes of degradation is unknown, it is difficult and potentially misleading to interpret AUSRIVAS assessments. While results may reflect some aspects of catchment condition, the small number of sites, and the small number of sample dates means the results may either mask or exaggerate spatial and temporal variations in macroinvertebrate communities. It would be unwise to interpret any spatial or temporal patterns in these data. In general, the assessments for the Warragamba and Shoalhaven catchments correlate in an expected manner with the land use and riparian vegetation condition categories. That is, the poorest sites are generally associated with poor riparian vegetation condition and land cleared and grazed. However, the occurrence of several 'below reference' and one 'well below reference' sites in association with Special Areas in the Warragamba catchment supports the above reservations about these assessments. It also indicates that the Special Areas, while a most important component of catchment management, cannot be relied on to protect the water quality and health of the Sydney water catchments.'

10.5. Conclusion and recommendations

Results of macroinvertebrate monitoring across the Catchment by WaterNSW indicate an overall worsening trend since 2017. The timing aligns with the drought, then 2019-2020 bushfires, followed by heavy rainfall in the Warragamba Special Area and Shoalhaven sub-catchment. However, results of macroinvertebrate monitoring by Blue Mountains City Council indicate the health of some waterways has improved since the end of the drought. Macroinvertebrate monitoring provides a more complete picture of Catchment health than results of water quality monitoring alone and therefore will continue to be an important tool in evaluating Catchment health.

11. Fish

Surveys found 21 native and 8 introduced species of fish across the Catchment during the audit period, but variable survey methods across audit periods means it is difficult to determine the state or trends of populations of threatened fish species, fish communities or diversity of fish species.

11.1. What are fish

The *Fisheries Management Act 1994* defines a ‘fish’ as any marine, estuarine or freshwater fish or other aquatic animal life at any stage of their life history (whether alive or dead). It excludes whales, mammals, reptiles, birds and amphibians which are managed under other legislation. Therefore, a ‘fish’ includes not only fin fish (including sharks), but also crustaceans, molluscs, worms, insects and other invertebrates with an aquatic life stage.

The numbers and proportions of native fish and exotic species present within each sampled water body are the recommended measurements for the Catchment audit (NOW 2009). The total number of native species is often used as a measure of the general health of aquatic ecosystems because it has been shown that the number of native species declines with increasing environmental stress. The potential impacts of pest fish include competition with native species for food and habitat, predation, physical damage to habitat and introduction of disease (DPI 2017). The presence of introduced species also reflects the general condition of the aquatic ecosystem and may represent both a symptom and a cause of declines in stream health and disturbance (Harris 1995). The distribution of threatened fish species is also considered below.

11.2. Fish surveys

Results of fish surveys by DPI Fisheries are presented in Table 11-1 and Table 11-2 for the current and previous audit periods. DPI Fisheries surveyed eight sub-catchments in 2019-22 compared to four in 2016-19 (Figure 11-1). The surveys were designed for routine monitoring and specific research goals, notably:

- Macquarie Perch Surveys – 2019
- Recreational Fishing Assessments in NSW: Trout Stocking Assessment – 2019
- Fitzroy Falls Spiny Crayfish Survey – 2020 and 2021
- Blue Mountains Perch Survey – 2021.

With the inclusion of public observations reported via the Atlas of Living Australia, a total of 2907 individual fish were recorded in 13 sub-catchments during the audit period. These records were from 29 species (21 native and 8 introduced).

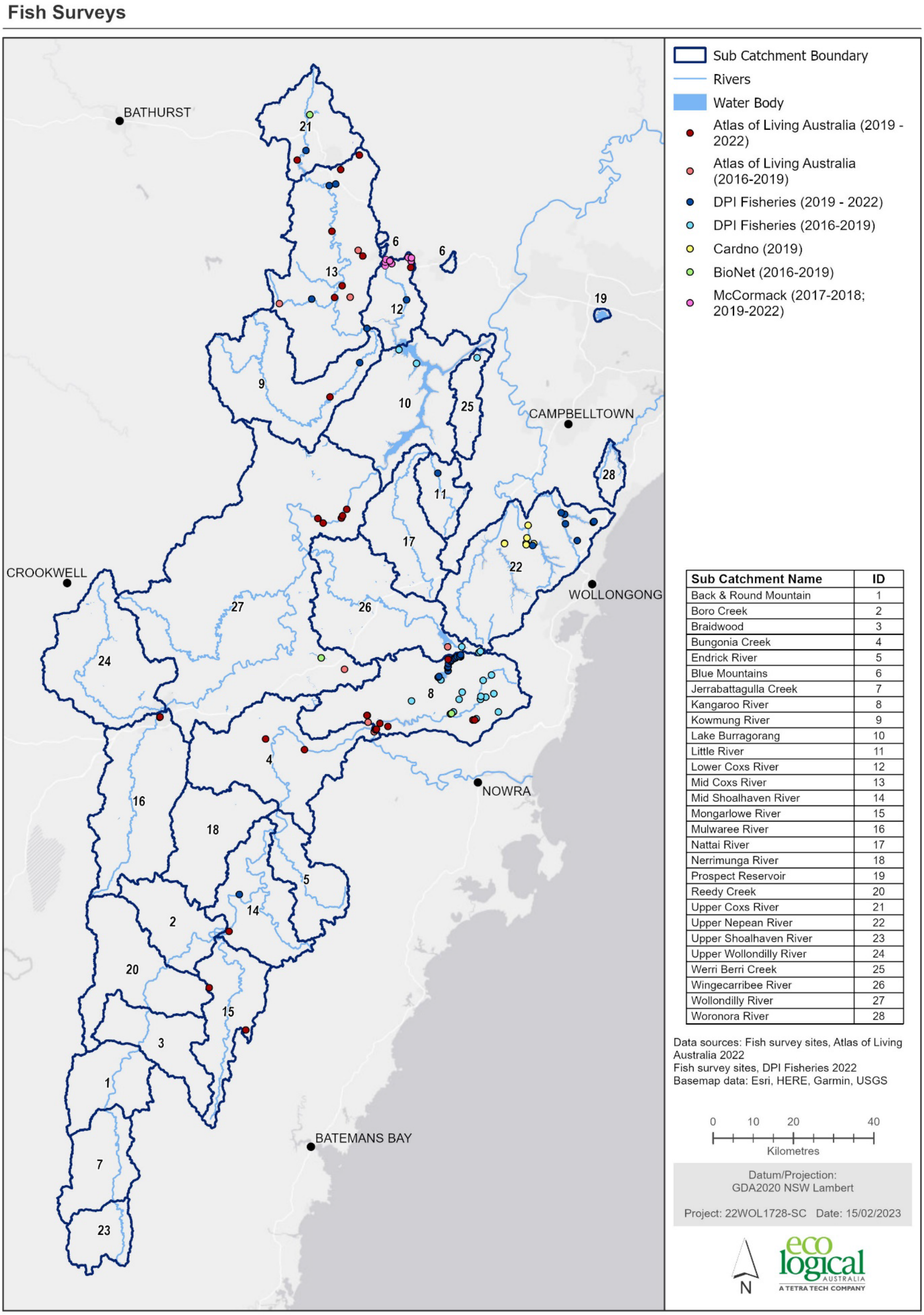


Figure 11-1: Location of fish surveys conducted June 2016 to June 2022

Table 11-1: Fish species expected to occur (pre-1930s) and collected between June 2005 and June 2022 in the Catchment

Species	Common name	Status	Expected to occur (pre-1930s)	June 2005 - June 2007	July 2007 - June 2010	July 2010 - June 2013	July 2013 - June 2016	July 2016 - June 2019	July 2019 - June 2022
Anguilla australis	Short-finned Eel	Native	x	x	x	x			
Anguilla reinhardtii	Long-finned Eel	Native	x	x	x	x		x	x
Anguilla sp.	Unidentified Eel	Native						x	
Bidyanus bidyanus	Silver Perch	Native		x		x		x	x
Carassius auratus	Goldfish	Introduced		x	x	x		x	x
Cherax destructor	Yabby	Native	x				x	x	x
Cyprinus carpio	Common Carp	Introduced		x	x	x		x	x
Euastacus australasiensis	Sydney Crayfish	Native					x	x	
Euastacus dharawalus	Fitzroy Falls Spiny Crayfish	Native	x				x	x	x
Euastacus spinifer	Giant Spiny Crayfish	Native					x	x	x
Euastacus yanga	Southern Lobster	Native						x	
Euastacus sp.	Unidentified Crayfish	Native						x	x
Galaxias brevipinnis	Climbing Galaxias	Native	x	x		x			x
Galaxias maculatus	Common Jollytail	Native	x			x		x	
Galaxias olidus	Mountain Galaxias	Native	x	x	x	x	x	x	x
Galaxias sp.	Unidentified Galaxid	Native						x	x
Gambusia holbrooki	Eastern Gambusia	Introduced		x	x	x	x	x	x
Gobiomorphus australis	Striped Gudgeon	Native	x	x	x	x			
Gobiomorphus coxii	Cox's Gudgeon	Native	x	x	x	x		x	x
Hypseleotris compressa	Empire Gudgeon	Native	x			x			
Hypseleotris gaii	Firetail Gudgeon	Native	x		x	x		x	x

Species	Common name	Status	Expected to occur (pre-1930s)	June 2005 - June 2007	July 2007 - June 2010	July 2010 - June 2013	July 2013 - June 2016	July 2016 - June 2019	July 2019 - June 2022
Hypseleotris klunzingeri	Western Carp-gudgeon	Native		x	x	x			
Hypseleotris sp.	Unidentified Carp-gudgeon	Native		x		x		x	x
Maccullochella hybrid	Trout Cod-Murray Cod hybrid	Native				x			
Maccullochella macquariensis	Trout Cod	Native				x			x
Maccullochella peelii	Murray Cod	Native		x				x	x
Macquaria australasica	Macquarie Perch	Native	x	x	x	x			x
Macquaria colonorum	Estuary Perch	Native	x						
Macquaria novemaculeata	Australian Bass	Native	x	x	x	x		x	x
Misgurnus anguillicaudatus	Oriental Weatherloach	Introduced		x	x	x	x		x
Mordacia mordax	Shortheaded Lamprey	Native	x						
Mordacia praecox	Lamprey	Native			x				
Mugil cephalus	Sea Mullet	Native	x			x			
Notesthes robusta	Bullrout	Native	x			x			
Oncorhynchus mykiss	Rainbow Trout	Introduced		x	x	x		x	x
Perca fluviatilis	Redfin Perch	Introduced		x	x				x
Philypnodon grandiceps	Flat-headed Gudgeon	Native	x	x	x	x	x	x	x
Philypnodon macrostomus	Dwarf Flat-headed Gudgeon	Native	x	x	x	x	x	x	x
Potamalosa richmondia	Freshwater Herring	Native	x			x			
Prototroctes maraena	Australian Grayling	Native	x						
Pseudomugil signifer	Southern Blue Eye	Native	x						
Retropinna semoni	Australian Smelt	Native	x	x	x	x		x	x
Salmo trutta	Brown Trout	Introduced		x	x	x		x	x

Species	Common name	Status	Expected to occur (pre-1930s)	June 2005 - June 2007	July 2007 - June 2010	July 2010 - June 2013	July 2013 - June 2016	July 2016 - June 2019	July 2019 - June 2022
Salvelinus fontinalis	Brook Trout	Introduced							x
Tandanus tandanus	Freshwater Catfish	Native		x	x	x		x	x
Trachystoma petardi	Freshwater Mullet	Native	x			x			
Total Native Richness			**24**	**16**	**14**	**24**	**7**	**21**	**21**
Total Introduced Richness			**0**	**7**	**7**	**6**	**2**	**5**	**8**
Total Richness			**24**	**23**	**21**	**30**	**9**	**26**	**29**

Table 11-2: Number of native and introduced fish species collected in the Catchment between June 2005 and June 2022

Sub-catchment		Blue Mountains	Boro Creek	Bungonia Creek	Endrick Creek	Kangaroo River	Kowmung River	Lake Burragorang	Little River	Lower Coxs River	Mid Coxs River	Mid Shoalhaven River	Mongarlowe River	Mulwaree River	Nattai River	Prospect Reservoir	Reedy Creek	Upper Coxs River	Upper Nepean River	Upper Shoalhaven River	Upper Wollondilly River	Werri Berri Creek	Wingecarribee River	Wollondilly River	Woronora River
June 2005 - June 2007	Sites sampled			4		5		4	1	2	2	1	3	1	2				12		3	1	2	6	
	Native			7		7		7	1	5	1	2	5	0	3				12		2	2	2	6	
	Introduced			2		2		1	0	2	2	0	0	2	1				1		2	2	0	5	
	Species richness			9		9		8	1	7	3	2	5	2	4				13		4	4	2	11	
July 2007 - June 2010	Sites sampled		2	5	1	8	3	3	4	1	4		1	1					17	1			3	11	2
	Native		0	8	3	7	0	10	4	4	2		4	2					11	1			2	6	2
	Introduced		3	3	0	3	3	3	2	1	3		3	1					2	1			3	4	1
	Species richness		3	11	3	10	3	13	6	5	5		7	3					13	2			5	10	3
July 2010 - June 2013	Sites sampled			7	1	24	3	1	4		4	1	2	1			1	7	16	1	2		1	2	1
	Native			17	2	9	1	3	6		2	2	5	0			2	3	13	2	3		2	4	1
	Introduced			4	0	2	1	2	2		3	1	3	2			0	4	2	2	3		1	2	0
	Species richness			21	2	11	2	5	8		5	3	8	2			2	7	15	4	6		3	6	1
July 2013 -	Sites sampled	3				7																			
	Native	2				5																			

Sub-catchment		Blue Mountains	Boro Creek	Bungonia Creek	Endrick Creek	Kangaroo River	Kowmung River	Lake Burragorang	Little River	Lower Coxs River	Mid Coxs River	Mid Shoalhaven River	Mongarlowe River	Mulwaree River	Nattai River	Prospect Reservoir	Reedy Creek	Upper Coxs River	Upper Nepean River	Upper Shoalhaven River	Upper Wollondilly River	Werri Berri Creek	Wingecarribee River	Wollondilly River	Woronora River
June 2016	Introduced	0				2																			
	Species richness	2				7																			
July 2016 - June 2019	Sites sampled	4		2		28		2		8	3							1	7			1	4	2	
	Native	2		2		9		4		4	2							1	4			4	5	2	
	Introduced	1		0		2		3		0	0							0	0			0	0	0	
	Species richness	3		2		11		7		4	2							1	4			4	5	2	
July 2019 - June 2022	Native	9		2		22	2		1	2	10	2	2	2				2	7					5	
	Introduced	3		2		8	4		6	7	6	2	1	0				1	12					0	
	Species richness	3		1		3	2		1	3	5	0	1	2				4	2					2	

In comparison, records from NSW Fisheries and the Australian Museum identified 24 native fish species predicted to be in the Catchment pre-1930s (DEC 2003). Occurrence of several species pre-1930s was dependent on unobstructed passage between fresh and marine waters, such as Australian Grayling, Estuary Perch, Shortheaded Lamprey and Southern Blue Eye that migrate across both habitat types during their life cycle or can tolerate both conditions. There are no records of these migratory species since DPI Fisheries commenced routine surveys within the Catchment potentially because of large impoundments are an obstruction to fish passage, even with fish lifts or ladders, and/or habitat loss and predation by introduced species has impacted the freshwater population, and/or those species are not in an abundance to be recorded at the limited survey sites.

Additional native species compared to the pre-1930s conditions were found in this audit period but were either not identified to species level (were of the same genus as expected) or have been recorded since 2005 and are presumed translocated (Silver Perch, Freshwater Catfish, Murray Cod and Trout Cod).

All known introduced species in the Catchment were recorded during this audit period.

Due to the various survey methods, locations and research intent, comparison of sites, waterbodies or sub-catchments does not necessarily reflect actual change in condition. Table 11-2 lists the number of native and introduced fish species collected during each survey period per sub-catchment. Of note is the variable number of sites sampled over time and between sub-catchments. Using data from 2005 onwards, results from each audit period is plotted in Figure 11-2 as a logarithmic trendline of number of sites against native species richness. The long-term trend shows that in any given audit period:

- The dominant cluster of sampling events produced less than eight native species
- Sub-catchments with more than eight native species are Bungonia Creek, Kangaroo River, Lake Burragorang and Upper Nepean River
- There are few sub-catchments with more than ten sampling sites
- There is a positive correlation between sampling effort (number of sites) and number of native species (richness).

Missing from this analysis are details on the survey method, such as:

- Number of electrofishing ‘shots’ (e.g., 10 minutes at one site versus 15 x five minute shots at a sampling site will collect a different composition)
- Diversity of methods (e.g., traps only versus a site with a mix of methods including electrofishing, fyke nets, gill nets and unbaited traps)
- Season or flow (specific programs investigating success of fish ladders)
- Purpose (targeted threatened species versus overall composition)
- Emerging eDNA methods where a result does not provide temporal information on occurrence.

Given the diversity of methods, effort and location across the years, an evaluation of fish numbers or proportion of native versus introduced fish is not appropriate. The analysis plotted in Figure 11-2 does however demonstrate that survey effort (due to method and purpose) influences the number of species recorded. Without a full coverage of sub-catchments included and comparable methods, an overall change in condition is yet to be determined in the audit program.

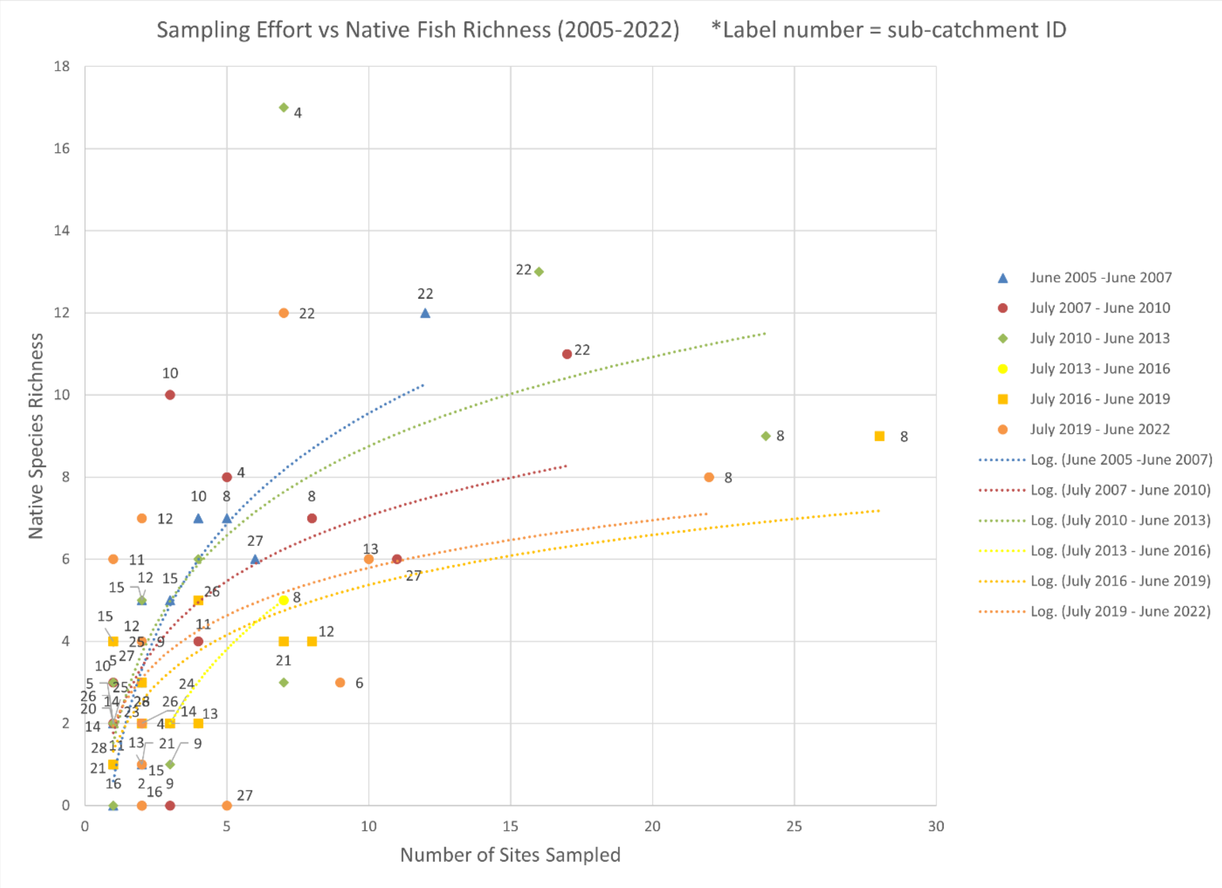


Figure 11-2: Correlation analysis of number of sampling sites with native species richness (2005-2022)

Sub-catchment ID: 1 Back & Round Mountain Creeks, 2 Boro Creek, 3 Braidwood, 4 Bungonia Creek, 5 Endrick River, 6 Grose River - Blue Mts Catchments, 7 Jerrabattagulla Creek, 8 Kangaroo River, 9 Kowmung River, 10 Lake Burragorang, 11 Little River, 12 Lower Coxs River, 13 Mid Coxs River, 14 Mid Shoalhaven River, 15 Mongarlowe River, 16 Mulwaree River, 17 Nattai River, 18 Nerrimunga River, 19 Prospect Reservoir, 20 Reedy Creek, 21 Upper Coxs River, 22 Upper Nepean River, 23 Upper Shoalhaven River, 24 Upper Wollondilly River, 25 Werri Berri Creek, 26 Wingecarribee River, 27 Wollondilly River, 28 Woronora River.

11.3. Fish community status

In 2016, DPI Fisheries created a map to show the status of fish communities using three indicators of condition (expectedness, nativeness and recruitment). The indicators were built from DPI Fisheries datasets, field sampling, environmental variables (National Hydrological Geospatial Fabric Version 2) and other modelling. The condition outcomes rate the fish communities as very good, good, fair, poor or very poor.

A total of 3547 km of stream length was assessed by DPI in the 2016 mapping project, which has not been revised since, and does not include unique areas that may provide refuge and isolation from invasive species and other catchment pressures (such as translocated threatened fishes in certain reservoirs). Of this, fish community status is comprised of fair (12%), poor (63%) and very poor (24%) (Figure 11-3). Sub-catchments that have waterways with a predominantly very poor fish community status are: Mulwaree River, Nerrimunga River, Upper Wollondilly River and Wollondilly River.

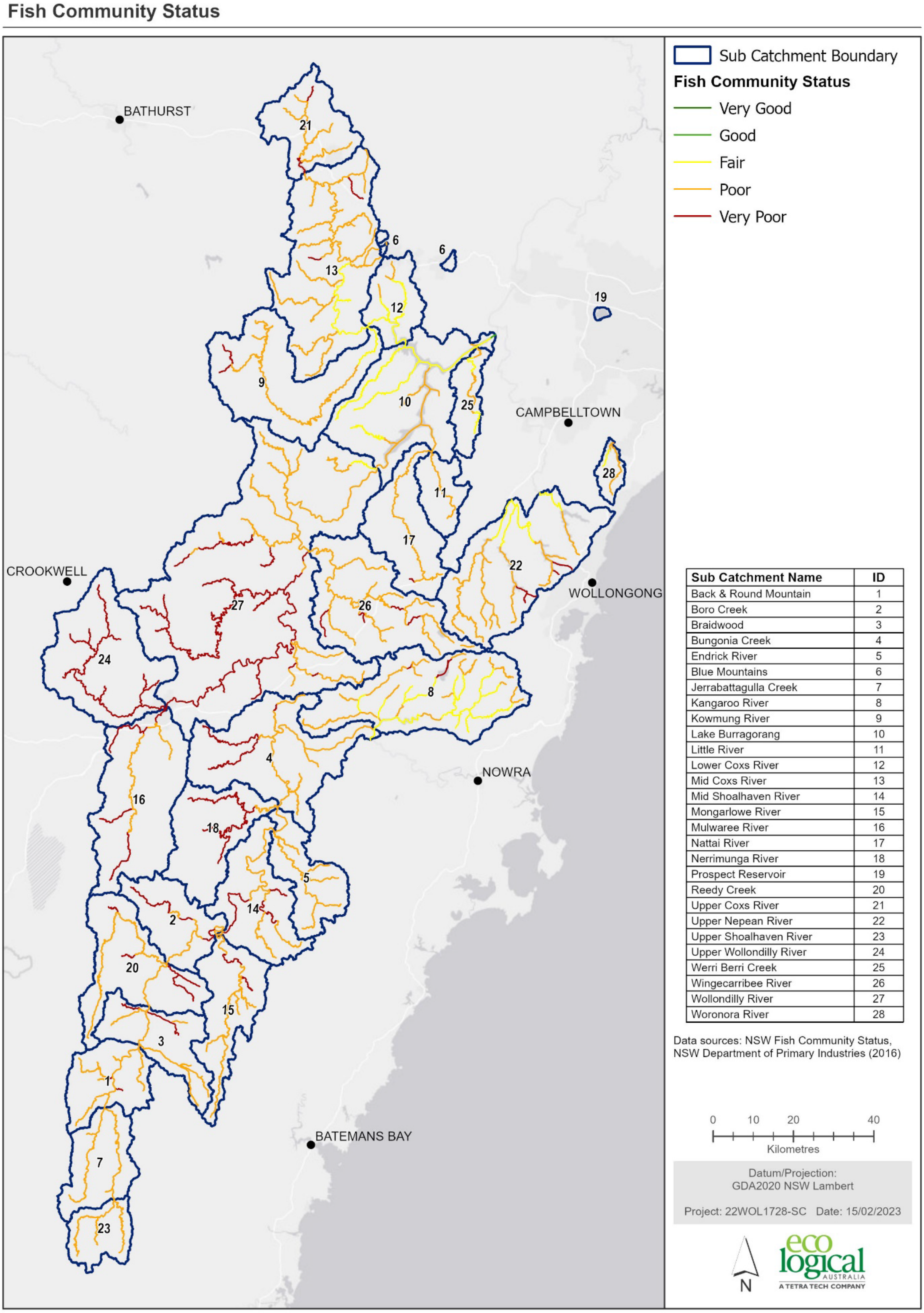


Figure 11-3: Freshwater fish community status (Riches et al 2016)

11.4. Threatened fish

DPI Fisheries used records collected since the late 1990s to model and map indicative distributions of threatened freshwater species (Figure 11-4). The 2016 model (Riches et al 2016) excluded translocated populations, such as stocked Macquarie Perch in the Mongarlowe River, which is considered likely to be the result of a translocation from the Murray-Darling Basin (Lintermans 2008) and where species occur but are outside their natural range. Several threatened species were data-deficient and could not be modelled to the required accuracy. This includes the Adams Emerald Dragonfly and Sydney Hawk Dragonfly, that have historically been recorded in the Catchment.

Two threatened fish species were modelled as likely or known to occur within the Catchment: Fitzroy Falls Spiny Crayfish (49 km in Kangaroo River and Wingecarribee River sub-catchments) and Macquarie Perch – east coast population (507 km in Lake Burragorang, Little River, Mid/Lower Coxs, Nattai River, Upper Nepean, Werri Berri Creek, Wollondilly River and Woronora River sub-catchments) (Figure 11-4). The Australian Grayling was also mapped in the Catchment, by mapping 'line work' over a barrier (i.e., Shoalhaven River downstream of the Tallowa Dam towards Nowra), although there is potential for the species to migrate upstream via the fish lift installed in 2009. Three threatened fish species outside of their natural range were also recorded during the audit period (Figure 11-4).

11.5. Fish passage

Structures such as dams, weirs and road crossings can prevent or inhibit fish passage and the cumulative effect of barriers to fish passage has been identified as a key threatening process to the continuing survival of several species of native fish. In addition to the dams and weirs operated by WaterNSW for water supply purposes, some weirs in the Catchment are privately managed for irrigation or amenity. NSW DPI is mapping and assessing barriers to fish passage across NSW with the aim to better understand and improve fish habitat. No recently published information or monitoring regarding weir management was available for this audit period.

11.6. Conclusion and recommendations

Lack of comparable methods and evenly distributed data across the audit periods means it is not possible to accurately determine the state or trends of populations of threatened fish species, fish communities or diversity of fish species. In its current form, surveys by DPI and others serve a purpose for individual study requirements and specific site monitoring but cannot be scaled-up to inform the health of the whole Catchment. Without extensive resources to perform Catchment-wide surveys and monitoring, integration with other indicators (e.g., macroinvertebrates) at targeted sites would help evaluate effectiveness of restoration efforts, impact from incidents and long-term trends. The eDNA library being developed by DPI Fisheries will address some of the current gaps. DPI Fisheries mapping and assessment of barriers to fish passage will provide information to better understand and improve fish habitat.

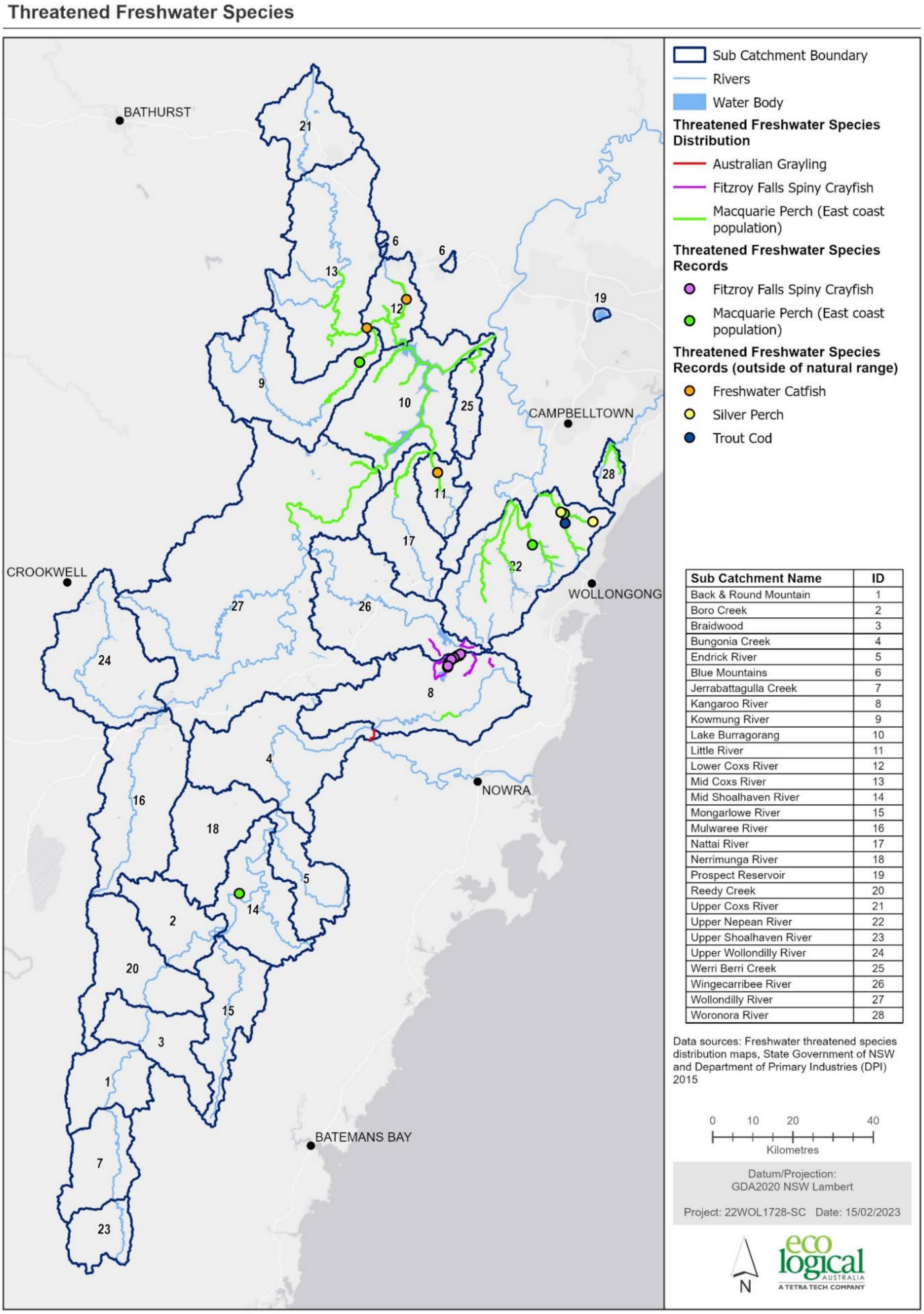


Figure 11-4: Threatened freshwater fish species distribution (based on 2016 model by Riches et al which excludes species outside natural range)

12. Riparian vegetation

There is insufficient data to determine the condition and connectivity of riparian vegetation across the Catchment during the audit period, or long-term changes resulting from removal, regeneration or revegetation.

12.1. Values and threats

The Biodiversity and Conservation SEPP 2021 defines riparian vegetation as 'hydrophilic vegetation, including submerged, emerging and fringing vegetation, that is within a waterway or the floodplain of a waterway'. Healthy riparian areas comprise a diversity of native species and habitats and are well-connected across the landscape. They assist in protecting water quality and bed and bank stability. In contrast, areas that have little or no native vegetation along waterways due to agriculture, urban development, severe bushfire or other degrading land uses may:

- Increase the amount of light and heat reaching waterways, which favours growth of nuisance algae and weeds
- Reduce habitat availability
- Increase delivery of sediment and nutrients to waterways
- Destabilise banks, often resulting in increases in channel width, channel incision and gully erosion
- Allow water to travel downstream at a faster rate, which can contribute to flooding and erosion
- Raise the water table and cause salinisation of land and waters (Lovett and Price 2007).

The impacts of disturbances are not just cumulative, they often exacerbate each other. The *Fisheries Management Act 1994* identifies 'the degradation of native riparian vegetation along New South Wales watercourses' as a key threatening process. Some riparian vegetation community types have been cleared so extensively that their status is now considered threatened. Clearing of riparian vegetation is regulated through mechanisms such as controlled activity approvals under the *Water Management Act 2000*.

Rehabilitation of riparian corridors includes erosion control, weed removal and revegetation with native species. NSW Government agency approvals may be needed for some rehabilitation or restoration activities including landscape rehydration infrastructure that involves natural materials, such as plants, logs, and rocks, slowing the stream and raising water levels so water is retained for longer periods, enabling it to seep into the soil. For example, section 2.165A of the Transport and Infrastructure SEPP states that a controlled activity approval under the *Water Management Act 2000* is required for landscape rehydration infrastructure works.

12.2. Extent

The Catchment contains 52,948 km of watercourses. This estimate is based on the drainage lines on 1:25,000 topographic maps which have a prescribed Strahler stream order classification between 1 and 11, comprising:

- 30,467 km of 1st order streams

- 11,044 km of 2nd order
- 5,549 km of 3rd order (Figure 12-1)
- 5,889 km of 4th order and above (Figure 12-1).

The width of a riparian zone varies depending on soil type, hydrology and topography. Under the *Water Management Act 2000* and the associated Guidelines for controlled activities on waterfront land – Riparian corridors (NRAR 2018), the expected width of the riparian zone is more prescriptive, with set riparian widths required for certain developments on waterfront land. Waterfront land includes the bed and bank of any river, lake or estuary and all land within 40 m of the highest bank of the river, lake or estuary. The prescribed riparian corridor widths are based Strahler stream order, where small headwater streams (1st order) have a 10 m riparian corridor on each side, up to the largest streams and watercourses requiring a 40 m zone on each side. Based on these criteria, there were an estimated 64,153 ha of riparian lands (or potential riparian lands) in the Catchment.

12.3. Condition and connectivity

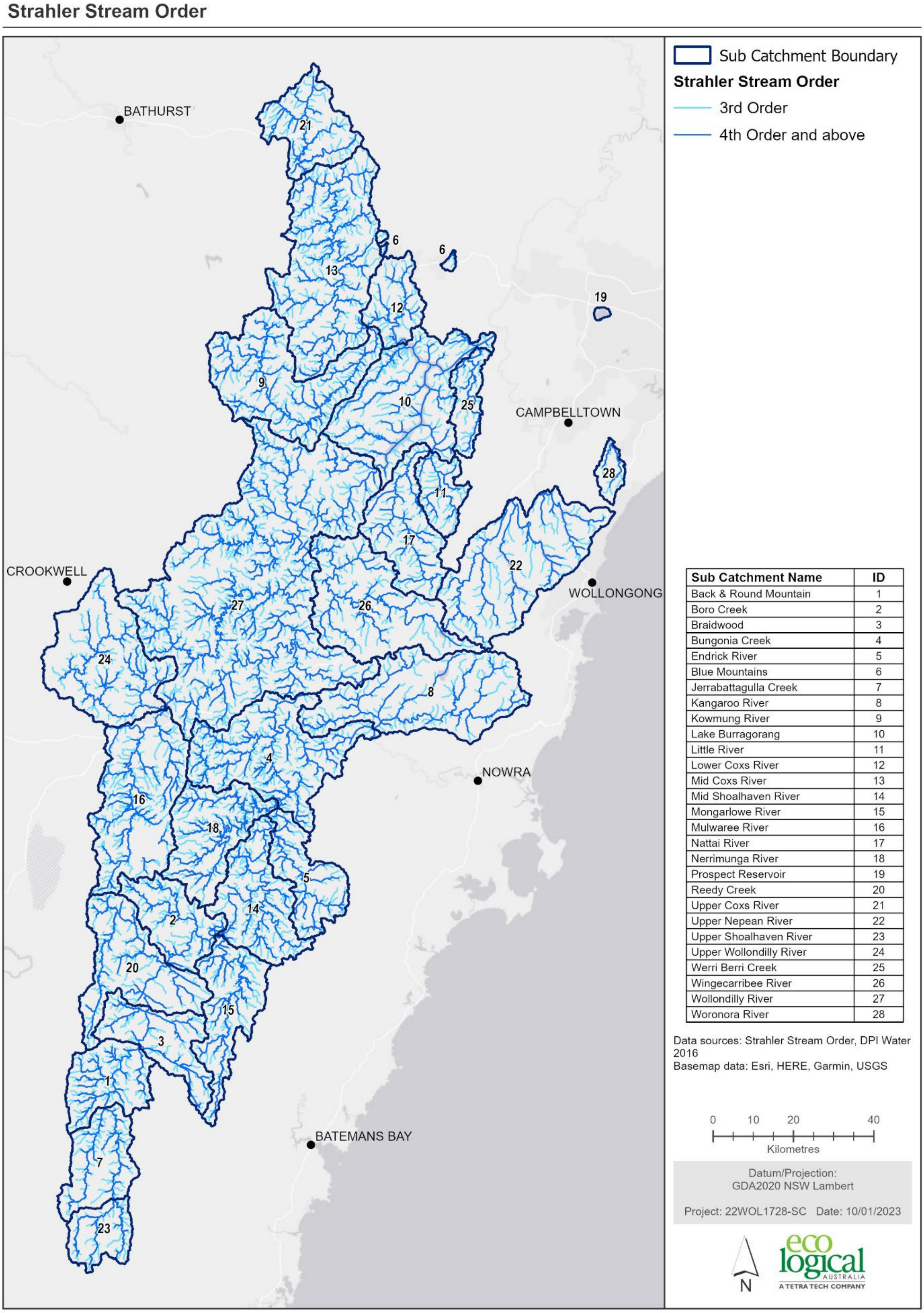
Many vegetated riparian areas across the Catchment feature weeds and exotic species. Weeds thrive in disturbed riparian corridors due to elevated nutrients and altered geomorphology. Weeds threaten human health, agricultural productivity, ecosystems and aesthetic values. There are statutory obligations to control priority weed species under the *Biosecurity Act 2015*.

In 2006, the former Sydney Catchment Authority created two methods to capture data on riparian vegetation across the Catchment: the riparian vegetation index and the riparian connection index. These methods revealed where riparian vegetation was connected and full, or fragmented or non-existent. They showed the relationship to land use (particularly the grazed landscape) and to landform (e.g., steep slopes, foothills, valley infills). Results were presented in the 2010 Catchment audit report and WaterNSW continues to use the data to inform program design.

DPE (2023b) released a riparian vegetation condition index map for NSW. This has been replicated for the Catchment in Figure 12-2. The categories for the riparian vegetation condition scores are defined as follows:

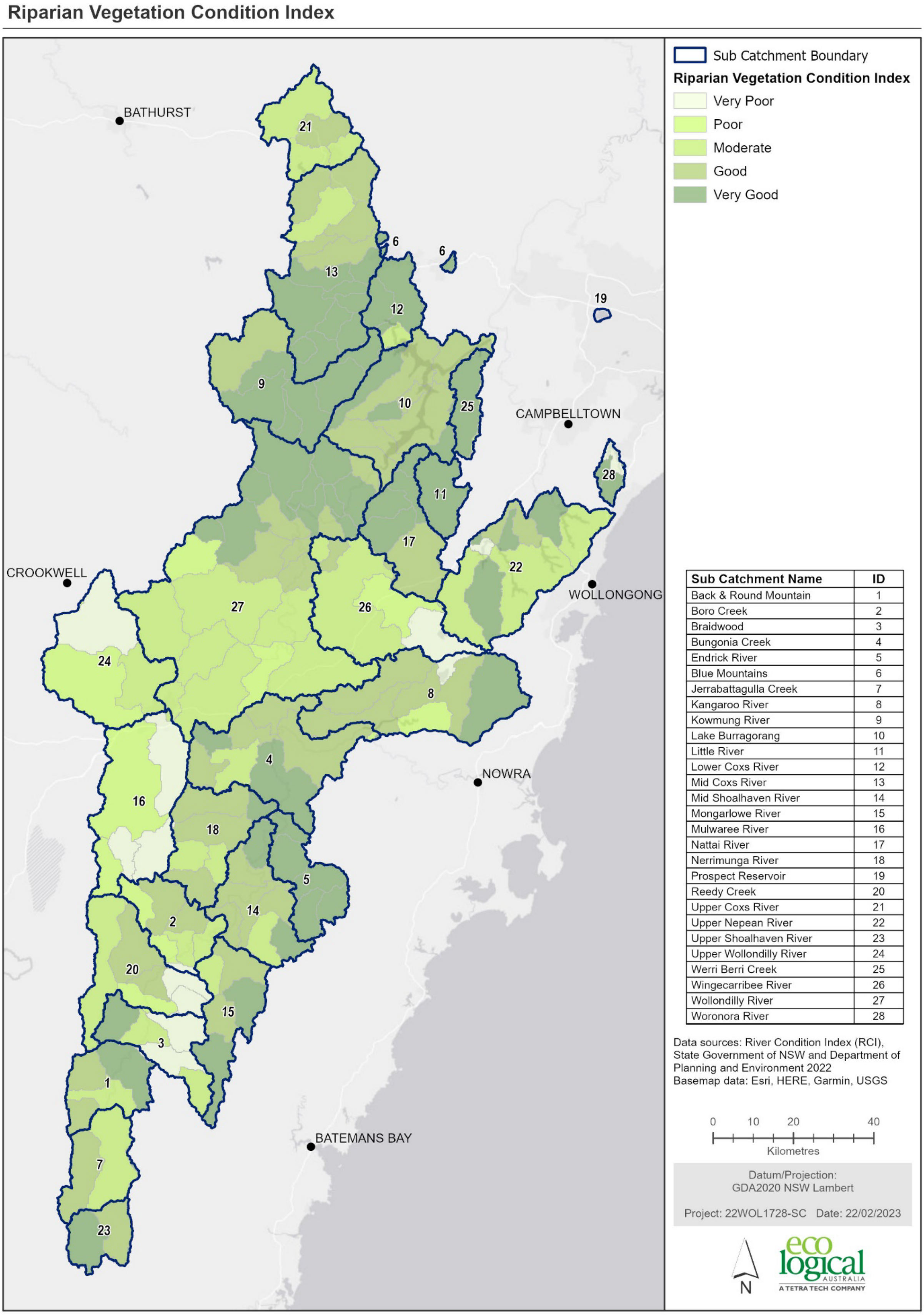
- Very poor ≤0.2
- Poor >0.2 – 0.4
- Moderate >0.4 – 0.6
- Good >0.6 – 0.8
- Very good >0.8 – 1.0

The extent of each riparian vegetation condition category in the Catchment is given in Table 12-1. The analysis indicates that most riparian areas in the Catchment are categorised good (27%), moderate (32%) or very poor (26%), rather than poor (14%) or very good (1%).



Sub Catchment Name	ID
Back & Round Mountain	1
Boro Creek	2
Braidwood	3
Bungonia Creek	4
Endrick River	5
Blue Mountains	6
Jerrabattagulla Creek	7
Kangaroo River	8
Kowmung River	9
Lake Burragorang	10
Little River	11
Lower Coxs River	12
Mid Coxs River	13
Mid Shoalhaven River	14
Mongarlowe River	15
Mulwaree River	16
Nattai River	17
Nerrimunga River	18
Prospect Reservoir	19
Reedy Creek	20
Upper Coxs River	21
Upper Nepean River	22
Upper Shoalhaven River	23
Upper Wollondilly River	24
Werri Berri Creek	25
Wingecarribee River	26
Wollondilly River	27
Woronora River	28

Figure 12-1: Waterways classified by Strahler stream order – 3rd order and above



Sub Catchment Name	ID
Back & Round Mountain	1
Boro Creek	2
Braidwood	3
Bungonia Creek	4
Endrick River	5
Blue Mountains	6
Jerrabattagulla Creek	7
Kangaroo River	8
Kowmung River	9
Lake Burragorang	10
Little River	11
Lower Coxs River	12
Mid Coxs River	13
Mid Shoalhaven River	14
Mongarlowe River	15
Mulwaree River	16
Nattai River	17
Nerrimunga River	18
Prospect Reservoir	19
Reedy Creek	20
Upper Coxs River	21
Upper Nepean River	22
Upper Shoalhaven River	23
Upper Wollondilly River	24
Werri Berri Creek	25
Wingecarribee River	26
Wollondilly River	27
Woronora River	28

Figure 12-2: Riparian vegetation condition index (DPE 2023b)

Table 12-1: Riparian vegetation condition index – area (ha) by sub-catchment

Row Labels	Very Good	Good	Moderate	Poor	Very Poor	Grand Total
Back & Round Mountain Creeks		480.02	25731.07	7943.28	311.80	34466.17
Blue Mountains	19.70	2045.84	55.68			2121.22
Boro Creek		389.49	9950.91	17966.11	6851.62	35158.14
Braidwood		8971.56	5948.45	6586.61	15792.61	37299.23
Bungonia Creek	117.99	42358.60	7043.85	20939.83	9651.44	80111.71
Endrick River	298.89	33307.10	132.16	136.14		33874.29
Jerrabattagulla Creek	134.28	666.08	14660.76	20366.18		35827.30
Kangaroo River	170.41	30329.50	44873.98	7957.56	2991.93	86323.38
Kowmung River	5138.15	48657.86	22832.19	119.01	7.30	76754.51
Lake Burragorang	3182.62	27194.77	32026.43	17780.33		80184.15
Little River		17888.36	427.09	47.03		18362.48
Lower Coxs River	210.23	24334.16				24544.39
Mid Coxs River	8544.03	31069.89	66977.38	50.29		106641.59
Mid Shoalhaven River	99.93	20440.34	28934.19	210.45	77.66	49762.56
Mongarlowe River	265.22	25444.69	16734.86	92.60	346.67	42884.05
Mulwaree River		3.27	50.16	55.70	78567.66	78676.79
Nattai River		529.96	24039.30	19802.73	116.67	44488.66
Nerrimunga River		8337.10	6451.49	3388.03	30087.39	48264.01
Prospect Reservoir					16.64	968.66
Reedy Creek		435.18	282.71	31925.44	24770.72	57414.05
Upper Coxs River		207.40	16012.34	21902.02		38121.76
Upper Nepean River		33092.24	54077.02	91.30	1837.38	89097.94
Upper Shoalhaven River	569.65	11354.50	9715.64	69.96		21709.76
Upper Wollondilly River					73936.44	73936.44
Werri Berri Creek			15494.36	955.06		16449.42
Wingecarribee River		3162.58	44702.21	1375.50	26809.20	76049.50
Wollondilly River		47635.89	51304.00	34923.80	135582.91	269446.60
Woronora River	148.40	4838.83	14.13		2406.28	7407.65
Grand Total	**18899.52**	**423175.23**	**498472.36**	**214684.97**	**410162.32**	**1566346.42**

Source: DPE (2023b); Prospect Reservoir had insufficient data (952.02 ha)

Riparian vegetation condition scores reflect the native non-woody vegetation mapping, native woody vegetation mapping, and patch size, fragmentation (non-native patch length) and connectivity for each river reach within a 30 m riparian buffer zone. Details of the method are given in DPE (2023b). This analysis draws on data from various dates, not limited to the audit period. Other limitations of the River Condition Index mapping by DPE (2023b) included:

> 'There are no regional benchmarks for riparian vegetation extent. It is assumed that a higher cover of native woody and native non-woody species is better than a lower cover. This assumption does not take into account different landscapes. For this reason, the development of riparian vegetation benchmarks for different landscapes would be beneficial to identify which areas have naturally higher cover of woody or non-woody species.'

DPE (2023b) also noted 'The lack of state-wide and fit-for-purpose data, collected at the appropriate scale, to enable a high level of confidence in the outputs is a limitation of the RCI. The development of the RCI was undertaken utilising existing, available datasets. State-wide datasets were used where possible to enable a consistent measure across all catchment areas. Further investment and improvement of data sets (the biodiversity index in particular) will improve the RCI product.'

Improved understanding of current riparian vegetation condition and connectivity in the Catchment could be provided by detailed satellite imagery analysis, including consideration of the findings, assumptions and limitations of the DPE (2023b) River Condition Index mapping methods.

12.4. Programs

Programs that aim to improve the condition and connectivity of riparian vegetation on public and private lands typically also target erosion, water quality and habitat. Many of these programs feature partnerships with community volunteers and/or not-for-profit organisations supported by government funding (e.g., grants[12], recurrent funds) and skilled personnel. Government-funded programs are subject to regular independent review.

Examples of some programs that aim to enhance the extent and condition of riparian vegetation are given below. Many of these programs rely heavily on grant funding and volunteer participation.

Rural Landscape Program - is a joint initiative between WaterNSW and South East LLS to increase diverse riparian vegetation, manage uncontrolled stock access to waterways, treat gully and streambank erosion, and implement sustainable grazing practices. As well as general educational material, the program supports action on individual properties. Landholders enter into a 10-year management agreement and undertake agreed management activities relevant to the funding they receive. All works associated with the project must be completed within an 18-month period. Landowner co-contributions for riparian and grazing projects are expected to match the level of public investment through a cash or labour contribution.

Data is collected on the riparian length and area influenced by fencing protection for regeneration and revegetation projects within Rural Landscape Program and Rivers of Carbon - Source Water Linkages

[12] Grants and funding | NSW Government

Program. There were 76 landholders that undertook projects during the audit period, which saw over 137 km of riparian length fenced and under agreed management and 475 ha of riparian area protected and regenerated with over 30,000 plants.

At the time of this audit, this program was subject to strategic review, with the following objectives:

- Assess the likely trajectory and potential of completed Rural Landscape Program projects to improve waterway health, groundcover, soil conditions, and water quality.
- Examine and understand the interaction between infrastructure, landscape condition (soil, groundcover, vegetation), seasonal conditions, and management actions (e.g., fence maintenance, strategic grazing) and provide a basis for promoting discussion, learning, and program improvement.
- Understand the impact of the project on each landholder and their property management objectives.

Figure 12-3: Auditor inspection of a Rural Landscape Program site near Goulburn in November 2022

Rivers of Carbon – Source Water Linkages - Rivers of Carbon is the on-ground component of the Australian River Restoration Centre, a not-for-profit organisation that works with landholders to protect and restore rivers, streams and wetlands. Rivers of Carbon supports landholders by providing funding for fencing, trees, small-scale erosion, off stream water and habitat rehabilitation. They aim to enable landholders achieve production and biodiversity goals, as well as potentially being able to gain carbon credits in the future.

Bushcare – Bushcare groups comprise community volunteers supported by local councils or NPWS to restore bushland by weed control and revegetation. Bushcare activities tend to be in bushland and riparian corridors close to urban areas.

Landcare – Landcare is a not-for-profit organisation with local community groups active across the Catchment. Landcare administers the $3 million Riparian Restoration Grants program (which is funded through the NSW Government's Regional Recovery Package), which enables Landcare and other natural resource management groups to seek funds for riverbank restoration. Individual Landcare groups also seek funds through applications to the Environmental Trust and other sources.

Wall to Wollondilly – This is a multi-organisation project involving conservation and restoration activities along the Wingecarribee River. Volunteers include Bushcare, Rivercare, Landcare and Birdlife Australia. It also involves private landholder conservation agreements.

Every Bit Counts project – This project is run by South East LLS with assistance from the NSW Environmental Trust and targets small landholdings and lifestyle blocks. It is delivered through the Small Farms Network which is a not-for-profit service run by small farmers for small farmers. They organise workshops on local farms, webinars and other events to provide practical information relevant to managing small rural properties.

The Mulloon Institute - The Mulloon Institute (TMI) is a not-for-profit, research, education and advocacy organisation. It is a demonstrator of regenerative agriculture land management practices through landscape rehydration and restoration across the Mulloon catchment, near Braidwood. The Mulloon Institute also provides consulting services.

Figure 12-4: Educational signage at the Mulloon Institute

12.5. Conclusions and recommendations

Riparian management projects are typically driven by motivated landholders and communities who observe local issues that need to be addressed (e.g., weeds, erosion) and apply for government program funding and support. Improvements to local riparian conditions are evident through project data, such as numbers of trees planted and length of fencing installed. Satisfaction with the process and outcomes leads participants to encourage others to be involved, which gradually expands the reach and benefits of these programs. Collectively, this benefits Catchment health.

To improve planning and evaluation of land management activities, it is recommended that agencies responsible for funding projects across the Catchment provide attributed spatial datasets (GIS maps) to BCSD. The land management datasets can then be collated and made available to other agencies and the community via SEED (hosted by BCSD). Attributes should include the general types of activities that have been performed (e.g., revegetation, weed control, erosion control). Matters relevant to landholder privacy must be protected. Historic records should be provided, where possible, to give a more complete picture of land management activities across the Catchment.

13. Native vegetation

About 68% of the Catchment comprises native vegetation. Loss of native vegetation from agriculture, forestry or infrastructure and increases from revegetation and regeneration were minor in comparison to the extent and condition of native vegetation affected by bushfires and subsequent regeneration across the Catchment during the audit period. The native vegetation indicator was assessed as having a moderate state and stable trend.

13.1. Vegetation management

Native vegetation is an indicator of Catchment health (Table 1-2). The NSW *Biodiversity Conservation Act 2016* and *Local Land Services Act 2013* define native vegetation as any species of trees, shrubs, understorey plants, groundcovers established in NSW before European settlement. It includes wetlands but not marine vegetation.

The extent and condition of native vegetation across the Catchment affects water quality and availability by helping to stabilise soils and filter nutrients and pathogens. Widespread healthy native vegetation supports good quality surface water, groundwater and biodiversity. An increase in the extent and/or condition of native vegetation would therefore be an improvement, whereas loss of native vegetation or decrease in condition indicates worsening.

Clearing of native vegetation on rural land is regulated under the *Local Land Services Act 2013.* This is administered by LLS, with DPE responsible for developing native vegetation regulatory mapping and compliance under the *Local Land Services Act 2013*. A Rural Boundary Clearing Code (RFS 2021) established under Section 100RA of the *Rural Fires Act 1997* facilitates a streamlined approval for the clearing of certain vegetation within 25 m of a rural property boundary.

Clearing of native vegetation in urban areas and land zoned for environmental protection is legislated by the SEPP (Biodiversity and Conservation) 2021 (formerly the SEPP (Vegetation in Non-Rural Areas) 2017), which is administered primarily by local councils. This legislation also allows councils to manage vegetation clearing in their local area through a permit system.

The Biodiversity Offsets Scheme provides a framework for offsetting the impacts of development on biodiversity and is administered by DPE. A Credit Supply Taskforce in DPE has managed the Biodiversity Stewardship Agreement application process since July 2022. The Biodiversity Conservation Trust continues to support landholders manage Stewardship sites.

The condition and extent of native vegetation are affected by weed control, bush regeneration, revegetation programs and adjacent land uses. These activities are undertaken by a variety of natural resource management groups within the Catchment including Bushcare and Landcare groups, with councils and LLS supporting community volunteers and contractors. Refer to section 12.4 for examples of these vegetation management activities.

13.2. Data

DPE monitors and reports on native vegetation in the following formats that were relevant to the audit:

- The Statewide Landcover and Tree Study (SLATS)[13], which reports on annualised rate (hectares/annum) of woody vegetation loss due to agriculture, forestry and infrastructure activities. DPE supplied SLATS data for the audit, showing the location and extent of change in woody vegetation for 2018-2019 and 2019-2020. SLATS data for 2020-2021 and 2021-22 were not available for the audit.

  The landcover classes in the SLATS program indicate the purpose for which the vegetation was cleared and include:

  - Agriculture, such as clearing for grazing, cropping or horticulture.
  - Infrastructure, such as residential, commercial, mining, public infrastructure and farm infrastructure.
  - Forestry, such as native and plantation harvesting, establishment, thinning, forestry infrastructure.
  - Natural processes, such as fire, landslide, storm, dieback.

  The SLATS program reports vegetation loss due to fire. However, fire is not considered a permanent loss of native vegetation (in most instances) and there are no legislative reporting requirements for it. Given this, it is distinguished in this audit from other vectors of vegetation loss.
- The woody and non woody vegetation landcover change method combines SLATS data with non woody vegetation change data for rural regulated land. DPE (2022i) summarised loss of native vegetation on rural regulated land across NSW for 2018-20.
- The NSW State Vegetation Type Map[14] (release C1.1.M1; 2022) provides a measure of vegetation type and extent across the Catchment based on remote sensing and composite mapping. It is a regional-scale map of each of the three levels of the NSW vegetation classification hierarchy. It maps the distribution of each plant community type, vegetation class and vegetation formation across all tenure in NSW. Older regional state vegetation maps have not all been incorporated into the new single map, so there are differences between the current and previous vegetation maps. It is important to note that:

  - The data does not give an indication of vegetation condition, including presence / abundance of exotic species, intactness of cover, structural naturalness, health and recruitment.
  - The data does not include non-native vegetation types.

[13] Woody vegetation change: Statewide Landcover and Tree Study method | NSW Environment and Heritage

[14] NSW State Vegetation Type Map | Dataset | SEED

- The 2018 DPIE datasets for ecological condition of terrestrial habitat[15] from the Biodiversity Indicator program[16] measures the intactness and naturalness of terrestrial vegetation and are thus relevant to Catchment health.

13.3. Native vegetation extent

Data from the NSW State Vegetation Type Map were used to map the extent of native vegetation across the Catchment (see Figure 13-1 and Figure 13-2). About 68% of the Catchment features native vegetation and Dry Sclerophyll Forest is the predominant vegetation formation across the Catchment. The area of native vegetation in each sub-catchment presented in Table 13-1 indicates that:

- The Enrick River, Blue Mountains, Lake Burragorang, Little River, Lower Coxs River, Nattai River, Upper Nepean River, Upper Shoalhaven River, Mid Shoalhaven River and Woronora River sub-catchments have greater than 85% native vegetation cover. These sub-catchments generally contain a large amount of NPWS estate, Crown Land or other lands containing extensive tracts of remnant native vegetation.
- The Mulwaree River and Upper Wollondilly River sub-catchments had relatively little (<35%) native vegetation cover as a proportion of their sub-catchment area. These sub-catchments are characterised by agricultural land uses.

13.4. Change in native vegetation extent

Temporary or permanent changes to the extent, condition or type of vegetation typically result from one or more of the following:

- Clearing native vegetation[17] by illegal activities or by approved land uses (e.g., infrastructure, forestry, mining, urban/rural development, agriculture)
- Dieback / disease[18] - exotic fungal infections (such as Phytophthora and Myrtle rust), viruses and other pathogens which can weaken and kill native vegetation species at a local or landscape scale
- Weed invasion[19] or control – weeds can out-compete native vegetation, and aquatic weeds can adversely impact water quality
- Anthropogenic climate change[20] directly impacting vegetation through changes to temperatures and rainfall, and intensifying threats such as weeds, natural hazards / disasters and disease.

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[15] Ecological condition of terrestrial habitat | Dataset | SEED (nsw.gov.au)

[16] A Biodiversity Indicator Program for NSW | NSW Environment and Heritage

[17] These are listed as ‘key threatening processes’ under Schedule 4 of the NSW *Biodiversity Conservation Act 2016* and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*.

[18] As above

[19] As above

[20] As above

- Bushfire or prescribed fire (about one third of the Catchment was burnt during the 2019-20 Black Summer fires; refer to section 6 for further details)
- Natural disasters such as flood, drought or windstorm
- Managed regeneration, revegetation and rehabilitation in accordance with biodiversity offsets, property vegetation plans, vegetation management plans etc.

No appropriate dataset is available to show changes in native vegetation for the Catchment across the three years of the audit period or allow direct comparison to previous audit periods due to changes in methods. An alternative approach is given here which refers to the woody vegetation change analysis mapping (SLATS) using data from 2019 and 2020. It is acknowledged that this may misrepresent changes in native vegetation extent but is presented as the best available source of information within the audit period.

Figure 13-3 and Figure 13-4 illustrate the location of the woody vegetation loss by type across the Catchment for 2019 and 2020, respectively. The woody vegetation change from natural processes has been excluded from this analysis because the reported areas in the natural processes category overwhelmingly appeared to be related to bushfire from the 2019-20 fire season. Bushfire is a temporal impact vector, thus it was excluded from the analysis.

Table 13-2 and Figure 13-5 show the hectares of woody vegetation loss during each calendar year back to the earliest SLATS dataset in 2015 (noting that there have been changes in the analysis methods over this period). Woody vegetation loss in 2020 was 43% greater in extent than the next highest year of 2016. Infrastructure related woody vegetation losses, which include residential land uses, have been increasing year on year, except 2017 when no loss was reported. The data indicates that less than 0.25% of total native vegetation is cleared as woody vegetation each year across the Catchment. This does not include non-woody vegetation or native vegetation removed due to bushfire (which is accounted for separately (see section 6.4) and expected to regrow).

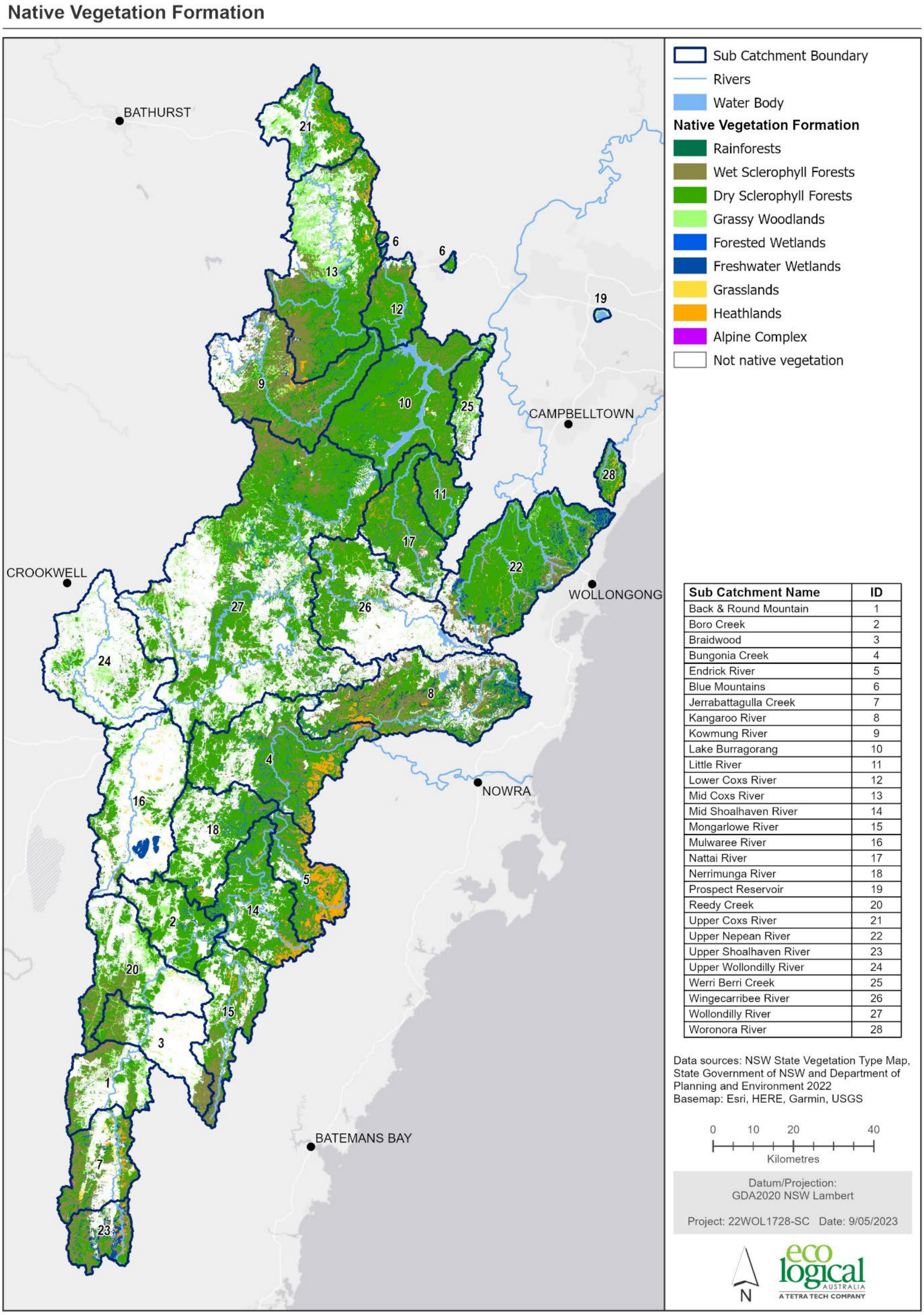


Figure 13-1: Native vegetation extent (SVTM 2022)

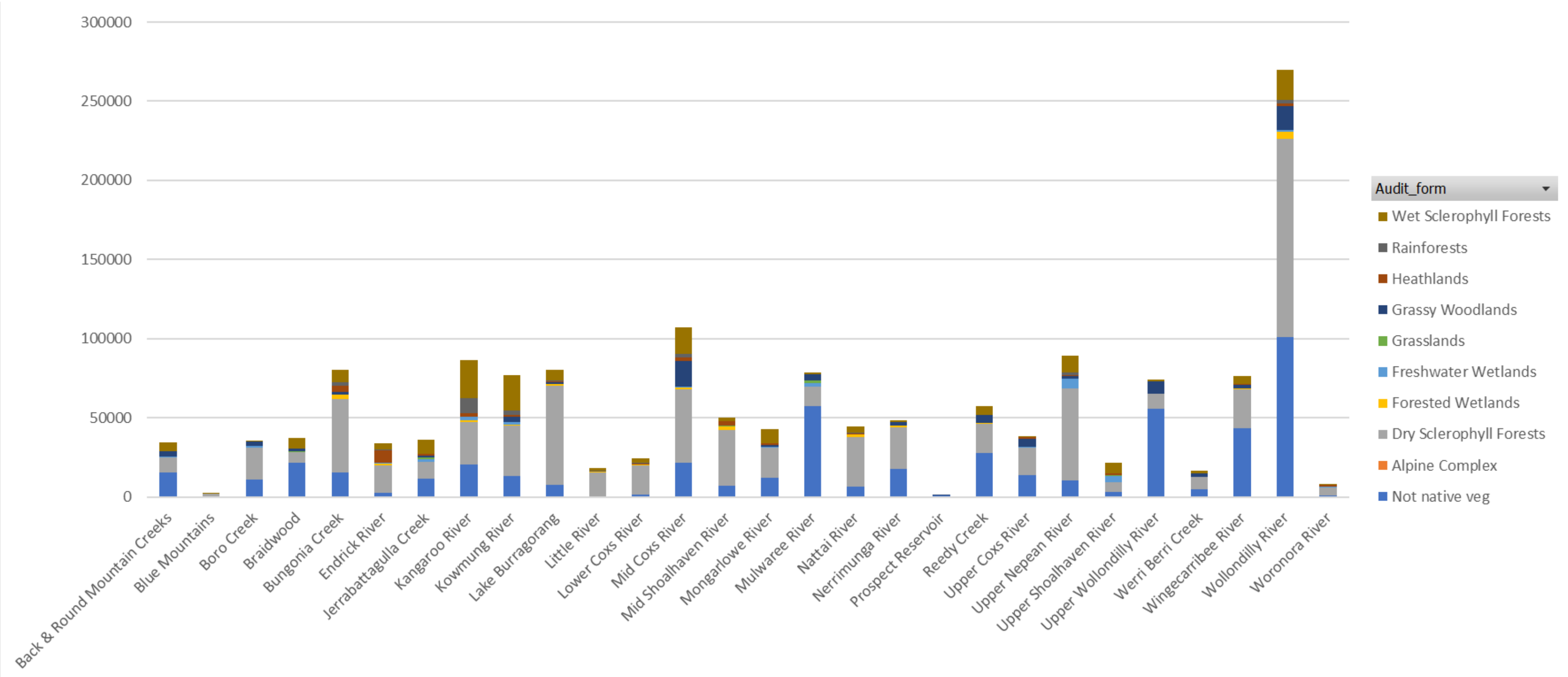


Figure 13-2: Area (ha) of native vegetation formations in each sub-catchment (SVTM 2022)

Table 13-1: Native vegetation extent within each sub-catchment (SVTM 2022)

Sub-catchment	Area (ha)	% of sub-catchment
Back & Round Mountain Creeks	18,931	54.91%
Blue Mountains	1842	86.70%
Boro Creek	24,376	69.28%
Braidwood	15,959	42.77%
Bungonia Creek	64,667	80.63%
Endrick River	31,636	93.31%
Jerrabattagulla Creek	24,428	68.18%
Kangaroo River	66,001	76.36%
Kowmung River	63,762	82.93%
Lake Burragorang	72,820	90.66%
Little River	17,862	97.12%
Lower Coxs River	22,917	93.20%
Mid Coxs River	85,320	79.86%
Mid Shoalhaven River	42,836	86.01%
Mongarlowe River	30,707	71.57%
Mulwaree River	21,263	27.00%
Nattai River	38,258	85.86%
Nerrimunga River	30,925	64.01%
Prospect Reservoir	322	33.23%
Reedy Creek	29,843	51.95%
Upper Coxs River	24,620	64.46%
Upper Nepean River	78,886	88.40%
Upper Shoalhaven River	18,866	86.92%
Upper Wollondilly River	18,374	24.82%
Werri Berri Creek	11,830	71.79%
Wingecarribee River	33,074	43.43%
Wollondilly River	168,635	62.49%
Woronora River	6832	92.08%
Total area of native vegetation	**1,065,791**	**~68% of total Catchment**

SLATS - 2019

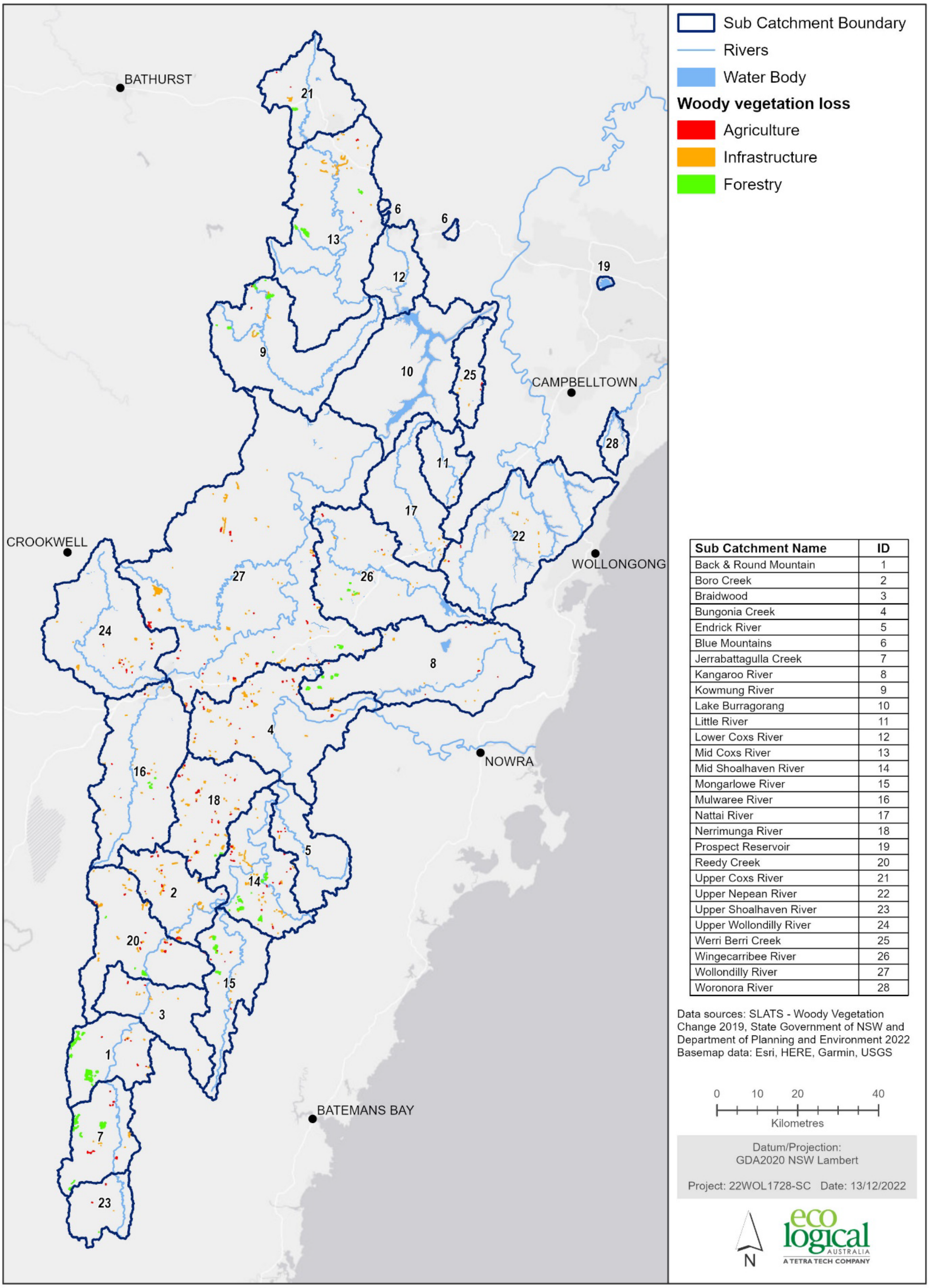


Figure 13-3: Woody vegetation loss in the Catchment (SLATS 2019)

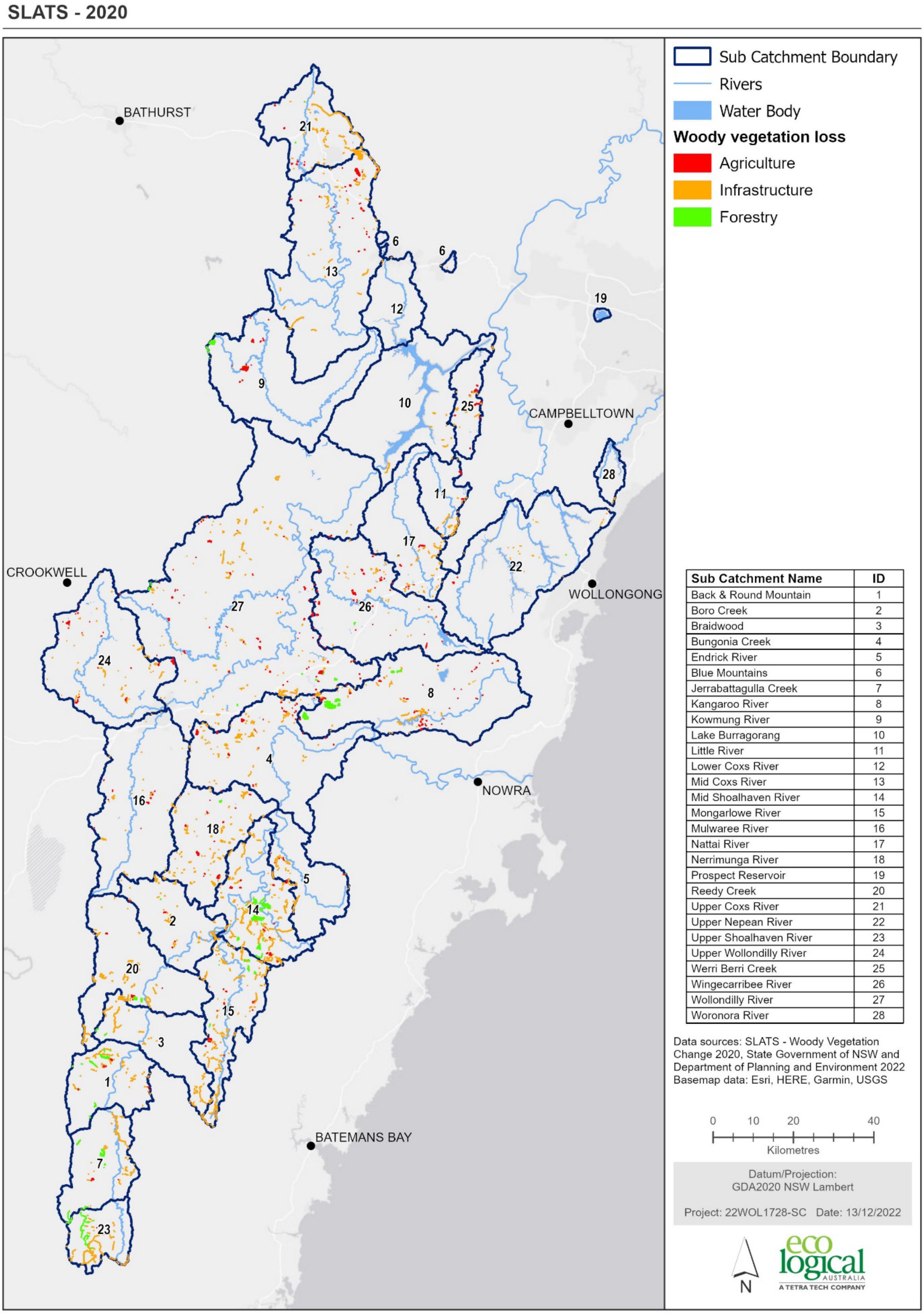


Figure 13-4: Woody vegetation loss in the Catchment (SLATS 2020)

Table 13-2: Area (ha) loss of woody vegetation (SLATS) 2015-2020

Cause of loss	2015	2016	2017	2018	2019	2020
Agriculture	44.46	138.04	0.00	271.89	165.68	358.74
Forestry	499.41	688.27	451.02	715.49	954.47	838.71
Infrastructure	61.15	218.93	0.00	279.73	326.36	1174.37
Total	605.03	1653.20	451.02	1559.90	1446.51	2371.82

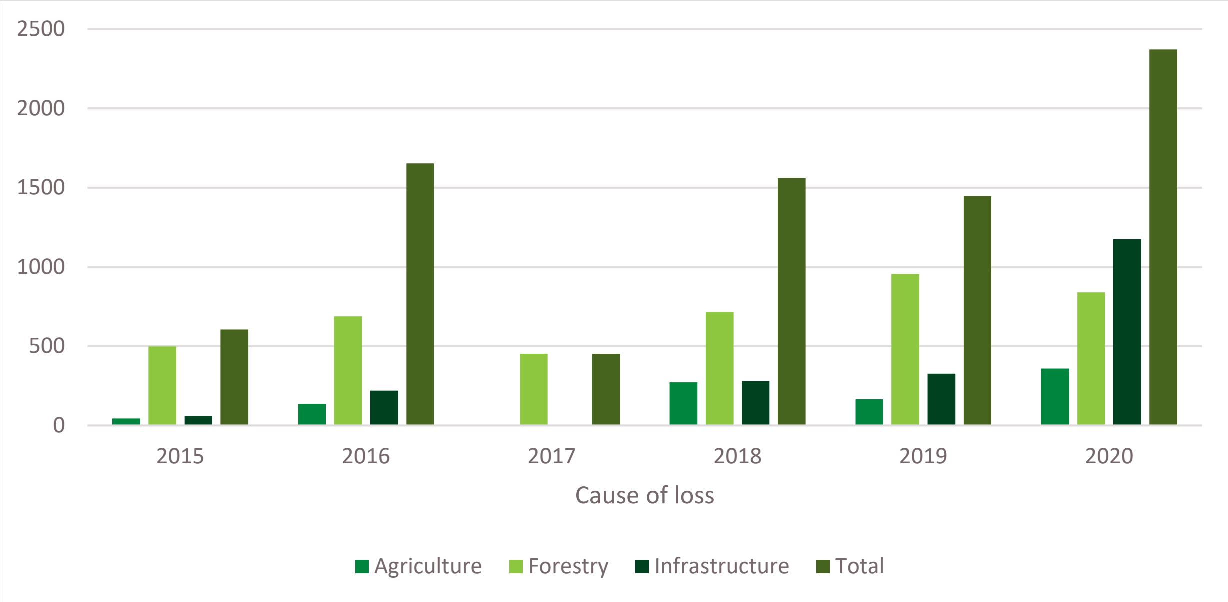


Figure 13-5: Area (ha) loss of woody vegetation (SLATS) 2015-20

There is currently no comprehensive dataset available that identifies areas where vegetation cover has increased. Remote sensing has limited capacity to detect young revegetation or regeneration until there is sufficient crown cover. The net loss recorded by remote sensing techniques may have been partially or fully offset through revegetation and/or restoration initiatives.

The public register of private land conservation agreements is published on the Biodiversity Conservation Trust website. However, the areas reported in this data do not directly correspond to vegetation cover, but rather the amount of land dedicated for in-perpetuity protection for conservation purposes. Formal biodiversity stewardship agreements contain agreed actions to improve vegetation condition and may include actions to increase extent of native vegetation. As the time required to effect change (in condition and extent) and the specific areas of management are property specific, the aggregate data is not a direct surrogate for potential increase in vegetation extent and condition for audit purposes.

The land area of conservation agreements approved during the audit period for each LGA in the Catchment is provided below in Table 13-3. The data is currently reported by LGA, so therefore can't be analysed by sub-catchment.

Table 13-3: Area (ha) of private land conservation agreements approved during the audit period

LGA	Biodiversity Stewardship Agreement	Funded Conservation Agreement	Unfunded Conservation Agreement	Wildlife Refuge Agreement	Total
Blue Mountains City Council			30.95		30.95
Goulburn Mulwaree Council	228.7	206	464.8	13.18	912.68
Oberon Council	141.1	652.2	536.7		1330
Queanbeyan-Palerang Regional Council	256.9	866.15	131.25	12.11	1266.41
Upper Lachlan Shire Council	423.52		112.6	230	766.12
Wingecarribee Shire Council		2580.25	24.5		2604.75
Wollondilly Shire Council	1929.2				1929.2
Wollongong City Council	258.25		23.42		281.67
Total	3237.67	4304.6	1324.22	255.29	9121.78

Source: Public register of private land conservation agreements | BCT (nsw.gov.au)

13.5. Ecological condition

The 2018 DPIE dataset for ecological condition of terrestrial habitat (Figure 13-6) measures the intactness and naturalness of terrestrial vegetation. It provides a surrogate for the presence / abundance of exotic species, the cover of vegetative canopy and other strata, structural form, function, health and recruitment ability. The dataset combines ground-based assessment with remotely sensed and other spatial data to classify the landscape in a range from benchmark (high) condition to maximum departure from benchmark (low) condition.

The ecological condition mapping in combination with the native vegetation extent mapping indicate:

- Areas of high ecological condition generally correspond to conservation or related land uses and areas with large tracts of undisturbed remnant natural vegetation.
- Areas of low ecological condition generally correspond to areas cleared of vegetation or where vegetation is heavily modified.

13.6. Conclusion and recommendations

Whilst the SLATS data identify changes in woody vegetation, it does not capture non-woody vegetation types and some open woodland formations. Therefore, there are data limitations to assessing the contemporary extent of all native vegetation across the Catchment and change over the audit period. Non-woody vegetation such as native grasslands influence Catchment health by providing erosion control, improved water infiltration, attenuate water velocity in flood, species diversity and should be considered in future audits.

As indicated in section 7, BCSD is preparing a business case for more frequent land use mapping updates. This will include information about vegetated and non-vegetated areas across NSW. It is further recommended that NSW spatial datasets are updated annually using satellite imagery to show the extent and formation classification of native and non-native vegetation. Datasets should be made publicly available via SEED to inform land management priorities and activities in a timely manner.

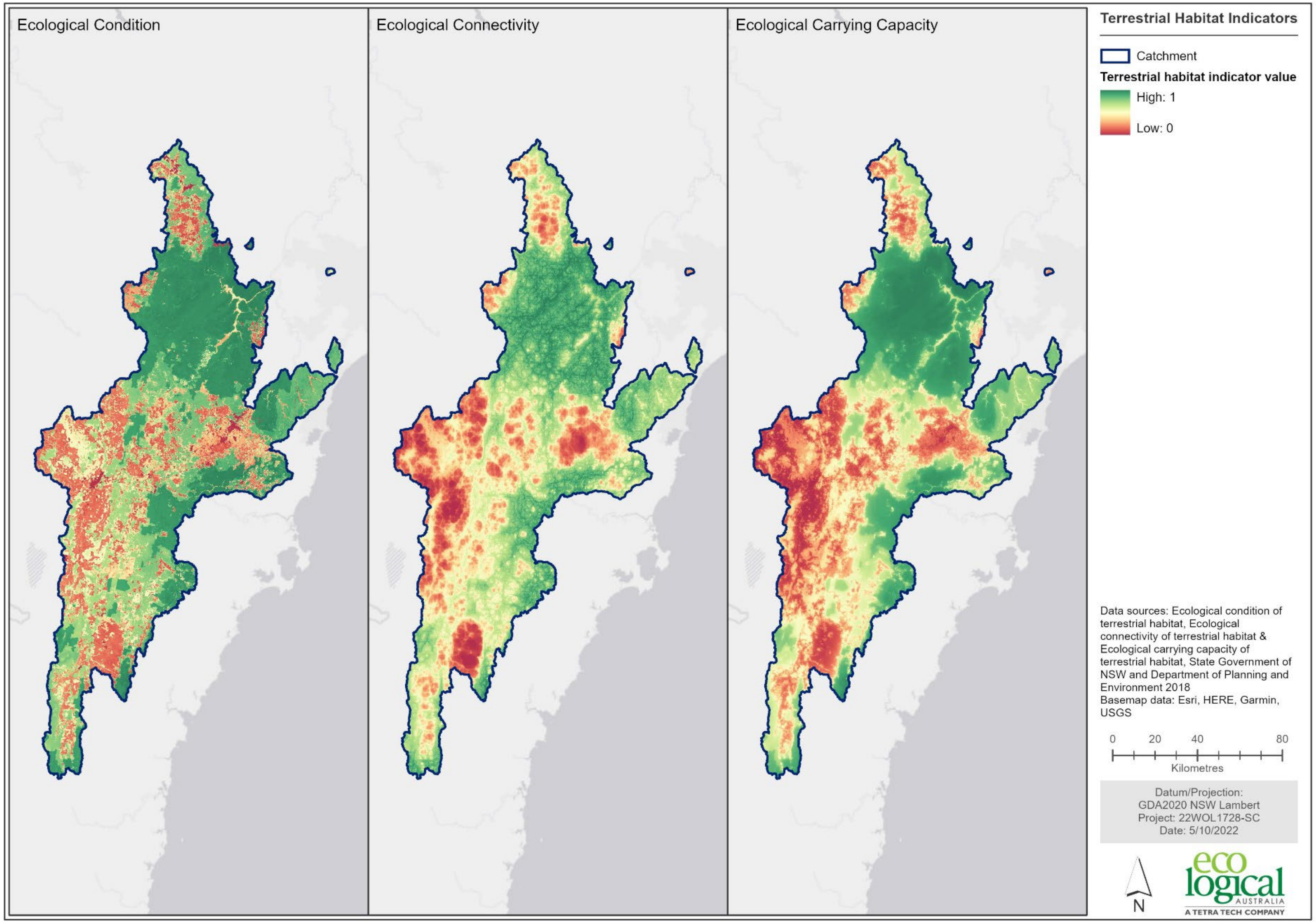


Figure 13-6: Terrestrial habitat indicators (DPIE 2018)

14. Wetlands

Statutory protections and rehabilitation programs have helped to protect and maintain the health of many wetlands in the Catchment. However, cumulative impacts from bushfire, longwall mining, weeds and urban runoff indicate an overall worsening trend.

14.1. What are wetlands

The 2021 NSW State of Environment Report defines wetlands as land covered or saturated with fresh, brackish or salt water that is generally still or slow-moving. Wetlands feature ecosystems that have adapted to or depend on wet conditions for at least part of their life cycles. They include groundwater dependent ecosystems and are often referred to as swamps.

Wetlands support high levels of biodiversity and have important cultural and economic values (Finlayson and Moser 1991). They provide essential ecosystem services and regulate hydrological cycles (DECCW 2010b). This includes improving water quality, storing water and carbon, and mitigating floods.

Types of wetlands found in the Catchment can be broadly categorised as follows according to the 2021 NSW State of Environment Report nomenclature:

- Riverine wetlands – are found around rivers, creeks, streams and other waterways. They include floodplains and marshes that are fed by these freshwater channels. They may be permanently wet or dry out during periods of low rainfall.
- Lacustrine wetlands – are inland freshwater lakes, constructed reservoirs and the areas around them. Like riverine wetlands, they may be permanently wet, or dry out during periods of low rainfall.
- Palustrine wetlands – are well vegetated inland areas of non-tidal fresh water. They include inland floodplain swamps, marshes, shrublands, bogs and fens. Some types of palustrine wetlands can be in a dry phase for several years before they receive enough water to change to their wet phase. They can exist adjacent or within lacustrine or riverine systems.

14.2. Wetlands in the Catchment

As outlined in the case studies below, detailed mapping of wetlands has been undertaken in some parts of the Catchment for specific purposes. The most recent consolidated mapping of wetlands in the Catchment was prepared by the Sydney Catchment Authority in 2012 (Figure 14-1). The probability of groundwater dependent ecosystems occurring was mapped by DPE in 2018 for each plant community type (Figure 14-2). Following a recommendation from the 2019 audit, BCSD commenced a review of wetland types, extent, condition and threats in the Woronora Plateau. Wetlands in the Newnes Plateau and Blue Mountains are subsequent priorities for investigation.

14.2.1. Important wetlands

Figure 14-1 identifies the location of Nationally Important Wetlands from the Protected Matters Search Tool. There are no sites within the Catchment that are recognised under the 1971 Ramsar Convention on Wetlands of International Importance. Seven wetland types present in the Catchment are listed as threatened under the legislation (Table 14-1) due to their significantly reduced extent since European settlement and ongoing threats.

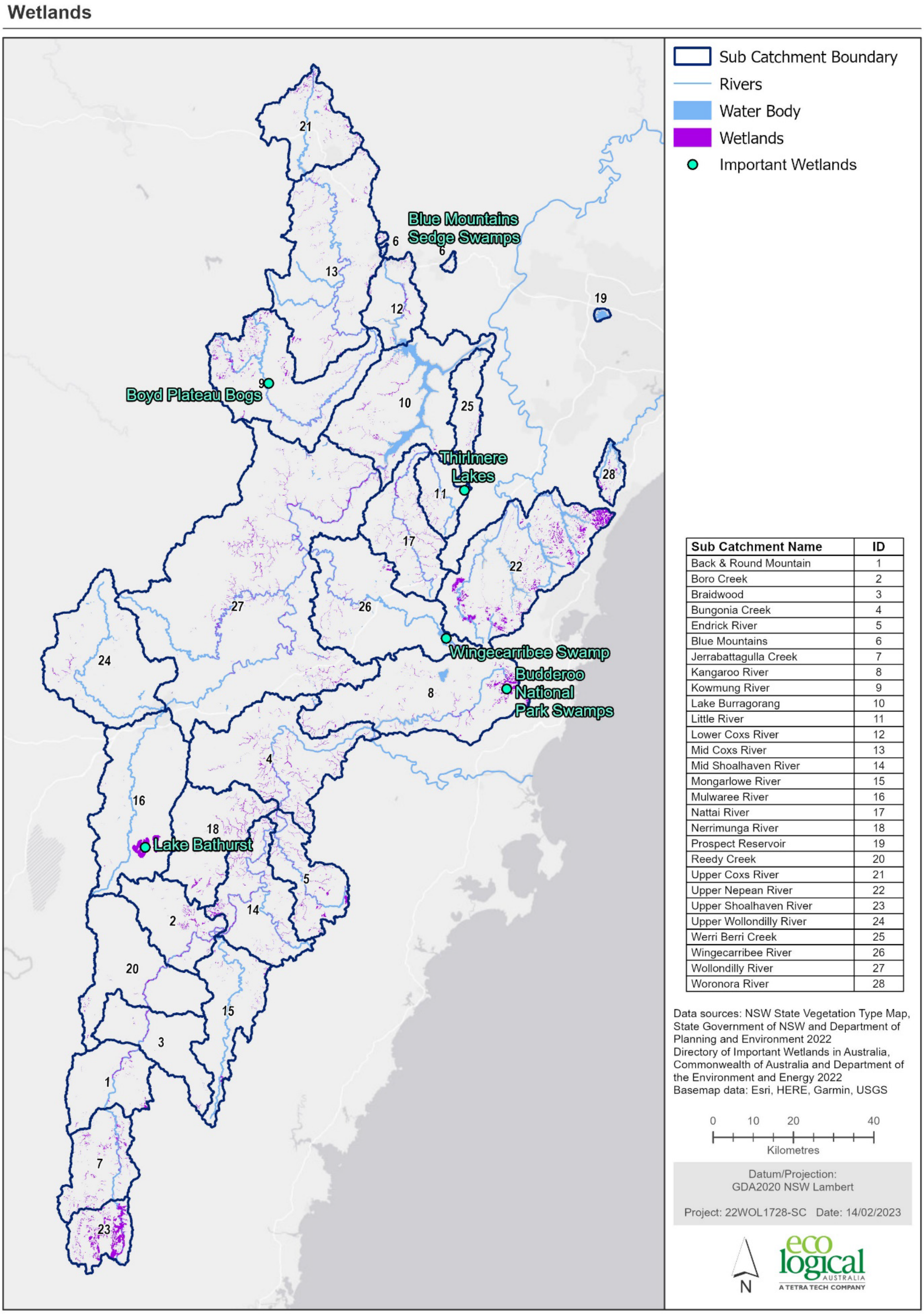


Figure 14-1: Wetlands

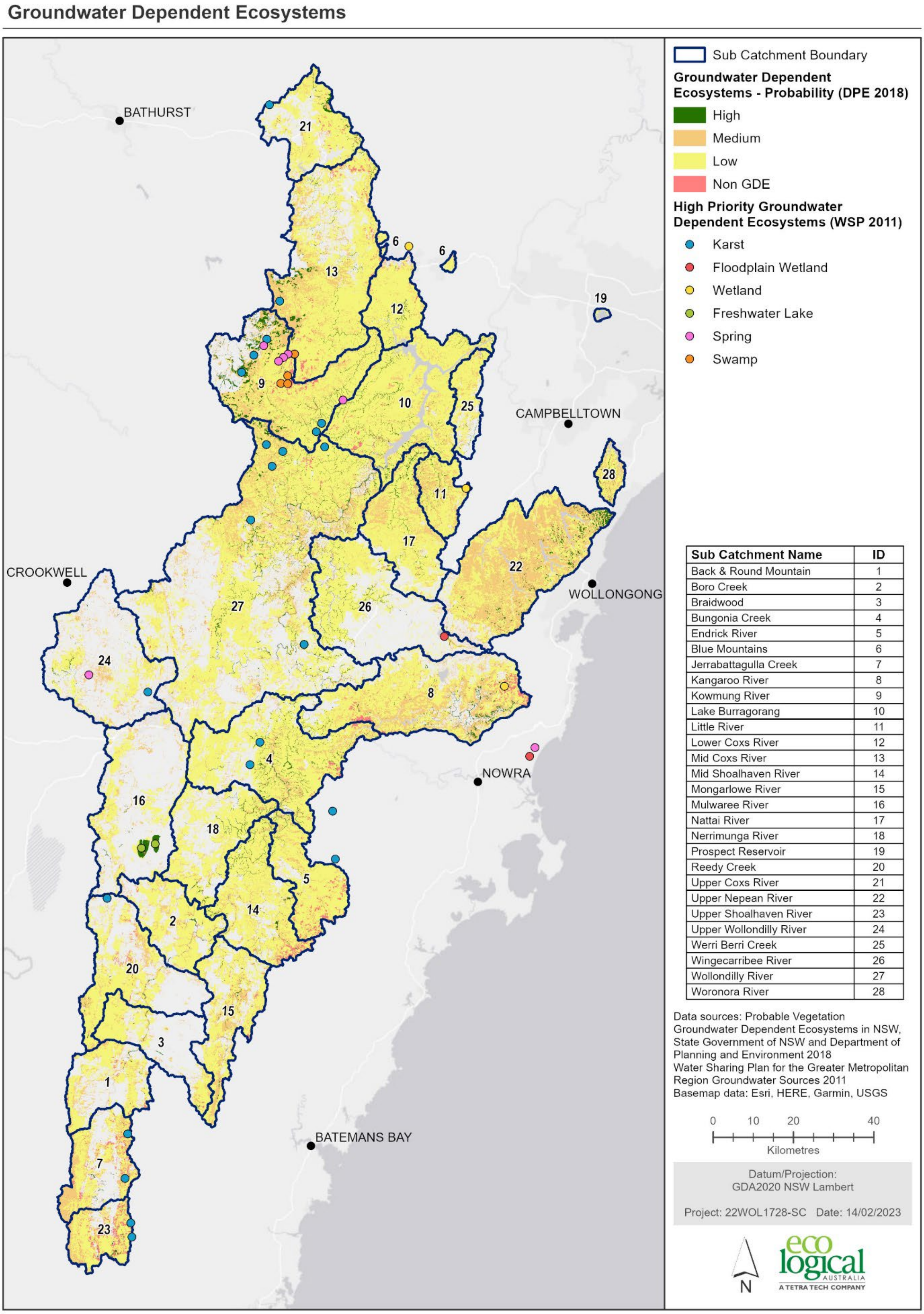


Figure 14-2: Probability of groundwater dependent ecosystems

Table 14-1: Threatened wetland ecological communities in the Catchment

Type	BC Act status	EPBC Act status
Blue Mountains Swamps in the Sydney Basin Bioregion	Vulnerable	-
Coastal Upland Swamp in the Sydney Basin Bioregion	Endangered	-
Montane Peatlands and Swamps of the New England Tableland, NSW North Coast, Sydney Basin, South East Corner, South Eastern Highlands and Australian Alps bioregions	Endangered	-
Newnes Plateau Shrub Swamp in the Sydney Basin Bioregion	Endangered	-
Swamp Oak Floodplain Forest of the NSW North Coast, Sydney Basin and South East Corner Bioregions	Endangered	-
Sydney Freshwater Wetlands in the Sydney Basin Bioregion	Endangered	-
Temperate Highland Peat Swamps on Sandstone – Sydney Basin	-	Endangered

14.2.2. Case studies

Wetlands in the Catchment have been assessed and mapped for multiple purposes, including:

- The Blue Mountains World Heritage Institute has surveyed some upland swamps in the Blue Mountains for research and management purposes (Upland Swamps — BMWHI)
- Wetlands in active mining lease areas have been monitored to comply with development consent conditions (e.g., Peabody Energy 2022)
- Wetlands have been assessed for potential environmental impacts for development applications (e.g., SMEC 2021)
- Monitoring associated with implementation of management actions (e.g., weed control at Wingecarribee Swamp)
- Research studies (e.g., Mason et al 2021).

Some case studies are summarised below:

- **Waterbird survey -** Results of the annual eastern Australian waterbird aerial surveys by UNSW Centre for Ecosystem Science suggests that the wetlands in the Catchment have low abundance of waterbirds compared to some other areas, such as in the Murray-Darling catchment. The survey has been conducted in October each year since 1983. The most recent report (Porter et al. 2020) describes long-term declines in abundance and breeding of waterbirds due to wetland habitat loss.
- **Upland swamps** - Spencer and Merson (2018) collated research on impacts of underground mining, urban development and climate change on upland swamps, also known as Temperate Highland Peat Swamps on Sandstone (THPSS). Upland swamps are groundwater dependent ecosystems that occur in the headwaters of streams on gentle sloping plateaus. These include shrub and sedge swamps found on the Blue Mountain, Newnes, Woronora and Illawarra plateaus. Key findings were that:
    - Longwall mining beneath swamps leads to erosion and subsidence which causes major changes in swamp structure, water retention characteristics, water quality, flow patterns, vegetation, and susceptibility to extreme weather events. Hydrograph measurements show

that after rainfall, water levels in swamps that have been undermined spike and decline much faster than non-mined swamps.
    - Urban development in the Blue Mountains damages swamps by altering their geomorphic structure, water chemistry, and overall function. The presence of impervious surfaces such as roads and roofs can block groundwater recharge and transport higher volumes of water to swamps, leading to the development of incised channels.

- **Longwall mining and swamps** - In 2019, the Independent Expert Panel for Mining in the Catchment made the following findings and recommendations relevant to swamps (refer to section 8 for further detail about mining in the Catchment):

    - 'It is now established that longwall mining directly under swamps in the Southern Coalfield can result in significant changes to swamp hydrology and redirection of surface runoff, which the Panel considers are very likely irreversible.
    - The understanding of the contribution that swamps make to baseflows continues to be limited, with no accurate water balance being available for any swamp in the Southern Coalfield and no strong evidence to date of consequences of swamp impacts on catchment-scale water supplies.
    - Despite decades of monitoring, mining-induced changes to upland swamp vegetation communities are still not able to be clearly differentiated from natural changes. [BCSD advised the auditor that the 2019 conclusion is not supported by recent data and observations.]
    - There is very limited, if any, scope for remediating fracture networks beneath swamps. Therefore, in circumstances where it is difficult, if not impossible, to design a viable mining layout that avoids impacting swamps and mining is to proceed, there is little option other than to consider offsets as compensation for the consequences of negative environmental impacts on swamps.
    - Remediation should not be relied upon for features, including watercourses and swamps, that are highly significant or of special significance.'

  Mine impact assessments and subsidence management plans are currently required to consider potential impacts within a 60 m buffer of swamps and streams. The 60 m setback is based on South32 interpretations of swamp monitoring data over the Dendrobium mine that there is high confidence that any swamp located within 60 m of the footprint will experience a quick and significant change in hydrology. Progressive and more subtle impacts can occur beyond 60 m. There are impacts to streams documented beyond a 60 m buffer zone.

- **Swampcare** - Wetland protection is much more effective than restoration. However, in some cases the natural hydrological conditions and biodiversity of desiccated wetlands can be enhanced or restored. For example, the 'Save our Swamps' and Swampcare programs were implemented by Blue Mountains City Council with support from community volunteers and other agencies over several decades to enhance the condition and extent of degraded swamps across the Blue Mountains and Lithgow local government areas. It also involved managing threats such as stormwater pollution (see section 9.4.5).
- **Wingecarribee Swamp** is over 5,000 years old and one the best examples of a montane peatland on mainland Australia. It features endangered ecological communities and threatened flora and

fauna species. It forms the headwaters of the Wingecarribee River and is located immediately upstream of the Wingecarribee Reservoir. Part of the swamp collapsed in 1998 following a large storm and years of peat mining. WaterNSW continues to undertake extensive weed control and operates the Wingecarribee Reservoir within a limited water level range to minimise the risk of further decline in the swamp's condition.

- **Bushfire and mining affected swamps** - Krogh et al (2022) assessed the condition of the Newnes Plateau Shrub Swamp following the 2019-20 Gospers Mountain Fire near Lithgow. All swamps on the Newnes Plateau were burnt, with some areas experiencing fire of very high severity. Despite this severity, the vegetation in all unmined reference swamps recovered relatively quickly, with substantial vegetation cover and biomass returning within ten weeks. In stark contrast, after the wildfire there was evidence of extensive combustion and oxidization of peat soils in swamps located above the footprint of prior longwall coal mining operations. Populations of endangered species, which were already in significant decline (due to longwall mining impacts on swamp hydrology), were found to be vulnerable to localised extinctions in undermined swamps.
- **Thirlmere Lakes** - Thirlmere Lakes is a group of five waterways in the Greater Blue Mountains World Heritage Area: Lake Gandangarra, Lake Werri Berri, Lake Couridjah, Lake Baraba and Lake Nerrigorang (approximately location shown in Figure 14-1). The lakes are about 15 million years old and have important ecological, cultural and recreational values. Community concerns about water fluctuations led to a series of scientific investigations. Key findings were presented in a Synthesis of Current Research (DPE 2022h), as follows:

    - 'Thirlmere Lakes behave like set of leaky bathtubs with water evaporating at the surface and leaking water into the ground beneath the lake sediments.
    - The lakes are quite shallow, so even minor changes in water levels can lead to the significant exposure of lakebed sediments.
    - Climate variability was the major driver of recent drying in Thirlmere Lakes and responsible for between 83% and 98% of water level fluctuations in recent times.
    - It is likely that the lakes will continue to oscillate between being dry and maintaining higher water levels depending on drought and the frequency, intensity, and duration of rainfall events.
    - The drying of Thirlmere Lakes increased in the recent drought, which began in mid-2017, and, before that, the Millennium drought (2001–2010), but investigations of sediment cores taken from the lakes also found that the lakes have dried before. There was a major drying period around 12,000 to 21,000 years ago. The last 120 years of historical records also indicate that the Lakes have dried intermittently.
    - Thirlmere Lakes are such dynamic systems that they are potentially vulnerable to future climate changes.
    - During periods of no or low water, the peat underlying the lakes is extremely vulnerable to desiccation and fire.
    - The research found no direct links between the drying of Thirlmere Lakes and the nearby coal mine but could not rule out a smaller (relative to climate) impact on water levels from mining.

  - In the longer-term, mining impacts on regional groundwater may affect lake water levels by reducing inflows to lakes and increasing the hydraulic gradient (water flow path) away from the lakes.'

14.3. Threats

Altered flows from water extraction, underground mining and the building of dams, levees and diversion structures have had long-term and ongoing negative effects on water availability in wetlands. In addition to hydrological change, climate change, floodplain development activities, and invasion by weeds and feral animals are recognised threats to wetland values. Some of these are nominated under environmental legislation as key threatening processes. Examples include:

- Alteration of fire regimes – wetland ecosystems should be infrequently or never burnt, however, bushfires in 2019-20 covered more than twice the area in the Catchment of any previous fire season since records began in 1940 (Figure 6-4); Figure 6-11 shows 'overburnt' areas of the Catchment in 2022, which include wetlands in the Upper Shoalhaven and Upper Nepean sub-catchments
- Changes in climatic moisture associated with climate change – as outlined in section 5, climate change is driving more extreme weather conditions and this was evident during the audit period, which was characterised by drought in 2019 followed by periods of intense rainfall
- Alteration to the natural flow regimes of rivers, streams, floodplains and wetlands – caused by activities such as urban development and mine water discharge, although water sensitive urban design and regenerative agricultural practices seek to maintain or improve waterway conditions
- Alteration of habitat following subsidence due to longwall mining – section 8.2 lists some of the impacts from longwall mining in the Catchment
- Browsing and soil disturbance by pest animals – deer, pigs, goats and other pest animal species are targeted for removal by landowners in accordance with the LLS Regional Strategic Pest Plan and *Biosecurity Act 2015;* refer to the WaterNSW Annual Catchment Management Report 2020-21 for examples of pest animal control activities.
- Localised disturbance associated with unauthorised recreational activities including access by vehicles, trail bikes and horses – surveillance and enforcement is ongoing in the Special Areas to minimise risks of harm from unauthorised activities.

Wetland resilience decreases where there are cumulative or multiple threats. For example, longwall mining and fire compared to fire only (Krogh et al 2022).

14.4. Protection mechanisms

Legislation, policies and programs that aim to protect or minimise impacts to wetlands include:

- Protection of areas with wetlands as part of the NSW reserve system under the *National Parks and Wildlife Act 1974* (e.g., Thirlmere Lakes National Park) or through conservation agreements with private landholders
- Protection of areas with wetlands within Special Areas (e.g., Wingecarribee Special Area, Metropolitan Special Area and Woronora Special Area)

- Listing of threatened species and ecological communities under the *Environment Protection and Biodiversity Conservation Act 1999, Biodiversity Conservation Act 2016* and NSW *Fisheries Management Act 1994*
- Requirements for riparian protection, water-sharing plans and floodplain management plans under the *Water Management Act 2000*
- Protection of underground water sources by the Aquifer Interference Policy
- The Independent Advisory Panel for Underground Mining to review and advise on management of subsidence impacts from mining in the Catchment
- NSW Wetlands Policy (DECCW 2010b) which sets guiding principles for sustainable management of wetlands, including:

    - 'Land management practices should maintain or improve wetland habitats, ecosystem services and cultural values
    - Degraded wetlands and their habitats should be rehabilitated and their ecological processes improved as far as is practicable
    - The potential impacts of climate change should be considered in planning for wetland conservation and management
    - Regular reporting of wetland extent and condition is vital to assess management performance and to understand wetland dynamics'

- NSW Government Saving Our Species program - which funded the 10-year Swamped by Threats multi-agency collaborative project addressing threats and improving the condition of over 40 swamps that are damaged on the Blue Mountains and Newnes Plateaus through activities such as stormwater and access management, erosion control, swamp rehydrating, weeding and bush regeneration over 40 swamps. The Blue Mountains City Council Bushcare group runs 'Swampcare' which includes educational workshops to increase awareness of threatened species like the giant dragonfly and practical workshops to help volunteers develop the skills to care for swamps. Central Tablelands Local Land Services and Forestry Corporation also run community education and bush regeneration events to protect the swamps on the Newnes Plateau.

14.5. Conclusions and recommendations

Many wetlands in the Catchment are declining in condition and extent despite protective instruments and measures. Further decline is likely due to climate change and increasing bushfires, especially in wetlands already under stress from impacts such as longwall mining or urban development. Countering this (to an unknown extent) is the increasing focus on wetland protection, rehabilitation, landscape rehydration and creating wetlands as part of water sensitive urban developments. Investigations underway by BCSD on priority wetlands in the Woronora Plateau, Newnes Plateau and Blue Mountains will be critical to informing Catchment health and management.

It is recommended that the assumption about mining impacts occurring within a 60 m buffer of swamps and streams is reviewed by investigation of reports and data pertaining to impacts on swamps and 1st, 2nd and 3rd order streams in historic and active mining leases in the Newnes Plateau and Woronora Plateau, including fracturing of rock bars, subsidence, upsidence, pollution, iron flocculant, draining of swamps and streams, and indirect impacts to threatened species. The assessment should include statistical analysis to determine probabilities of impacts in different size buffer zones. This should be an independent report by one or more expert scientists in the field of groundwater hydrology, water quality and statistics, with a peer review by two external scientists with sufficient expertise in the field and no conflict of interest.

15. Watercourse physical form

The River Styles assessment provides a consistent, scientifically robust method for prioritising protection and rehabilitation of watercourses in the Catchment. The state of the watercourse physical form indicator during the audit period was assessed as moderate. The River Styles dataset will provide a good baseline to determine trends in watercourse physical form in future audits.

15.1. River Styles

A River Style is a discrete river type, defined according to its valley setting, planform, bed material and assemblage of geomorphic units using the River Styles Framework (Brierley and Fryirs 2005). Each River Style has individual levels of sensitivity, groups of essential geomorphic features and degradation/recovery pathways, as defined by its:

- Valley setting (bedrock controls and levels of exposure) (Figure 15-1), which are categorised as:
    - Confined valley setting
    - Partly confined valley setting
    - Laterally unconfined valley setting – continuous channels
    - Laterally unconfined valley setting – discontinuous channels
- Geomorphic condition (Figure 15-2) – rivers may adjust away from a near-natural, intact state (e.g., in the Special Areas) towards a degraded condition (e.g., associated with agricultural or urban land uses) or may alter to become a different River Style.
- Geomorphic recovery potential (Figure 15-3) – which is an estimate of the river's capacity to return to a near-natural or realistic rehabilitated condition. This estimate is based on the controls on the reach and whether processes that enhance the rebuilding of geomorphic features are active. Classes of geomorphic recovery potential are:
    - Conservation
    - Rapid recovery
    - High recovery
    - Moderate recovery
    - Low recovery
    - None
- Fragility (Figure 15-4) is defined for each River Style and describes a river's likelihood to degrade if stressed by flood scour beyond a minimum threshold. This threshold may change, depending on the presence or absence of protective features such as exposed bedrock, vegetation and large wood. Generally, the greater level of exposed bedrock in a channel, the lower that channel's fragility will be. Fragility scores range from:
    - High = sensitive to change
    - Moderate
    - Low = more stable

DPE Water conducted an updated assessment of the River Styles of the Hawkesbury-Nepean catchment in 2022 (Figure 15-5). The results have been combined with the 2000 and 2013 River Styles mapping for the remainder of the Catchment throughout this section.

15.2. Updated analysis

The updated analysis by DPE (2022g) for areas within the Hawkesbury-Nepean catchment primarily aimed to assess all watercourses that are mapped as Strahler third order or higher using the River Styles framework. These changes are depicted in Figure 15-5. This meant, compared to the analysis in 2000 and 2013:

- An additional 2646 km of waterways in the Catchment have now been mapped and assessed
- 1579 km of waterways in the Catchment that were previously mapped have now been assessed
- River Styles assessments for approximately 300 km of waterways in the Catchment have been revised.

15.3. Priorities for action

The River Styles framework recommends priorities for action as follows:

- Protect rivers that are intact (good condition) or near-intact (moderate condition with rapid recovery potential) and identify and apply measures that improve geomorphic condition and 'work with the river' to promote and enhance recovery in high recovery potential rivers.
- Apply active or passive rehabilitation measures to moderate condition rivers with higher geomorphic recovery potential after rapid recovery reaches are assessed and rehabilitation measures are established. These rivers must be assessed for degrading processes and their connection to better condition reaches that will supply sediment and seed at rates that will enhance recovery processes.
- Only prioritise poor condition rivers with moderate recovery potential if they are threatening better condition reaches nearby, while poor condition, low recovery reaches should not be prioritised. Typically, expensive and high-risk intervention is required for these reaches to have realistic prospects for recovery.
- Prioritise strategic reaches by the type of threat they may pose to adjacent, vulnerable rivers or their propensity to large scale degradation that may impact on other, better condition, river reaches.

These criteria were applied to the available River Styles data to generate a composite map of priorities for the Catchment (Figure 15-6). Table 15-1 indicates the total lengths of reach for each priority level. The majority of intact or near intact reaches were in bushland areas, many of which are already protected in conservation reserves or the Special Areas. Reaches with moderate condition and high recovery potential are prevalent in the following locations, as shown in Figure 15-6:

- The northern half of the Mid Coxs River and Kowmung River sub-catchments
- Kangaroo Valley in the Kangaroo River sub-catchment
- The eastern half of the Wingecarribee River sub-catchment
- The central-western part of the Catchment.

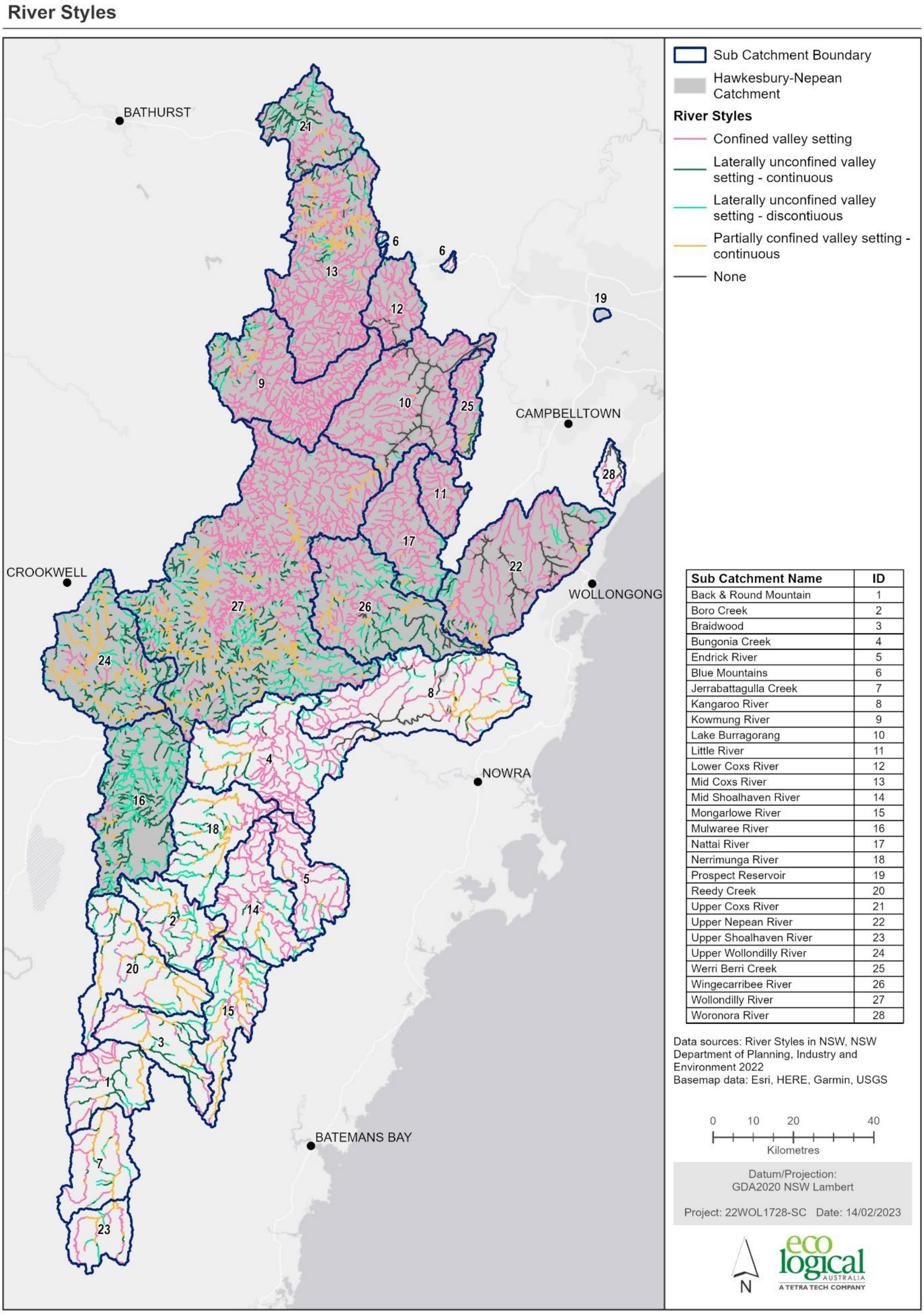


Figure 15-1: River Styles valley settings

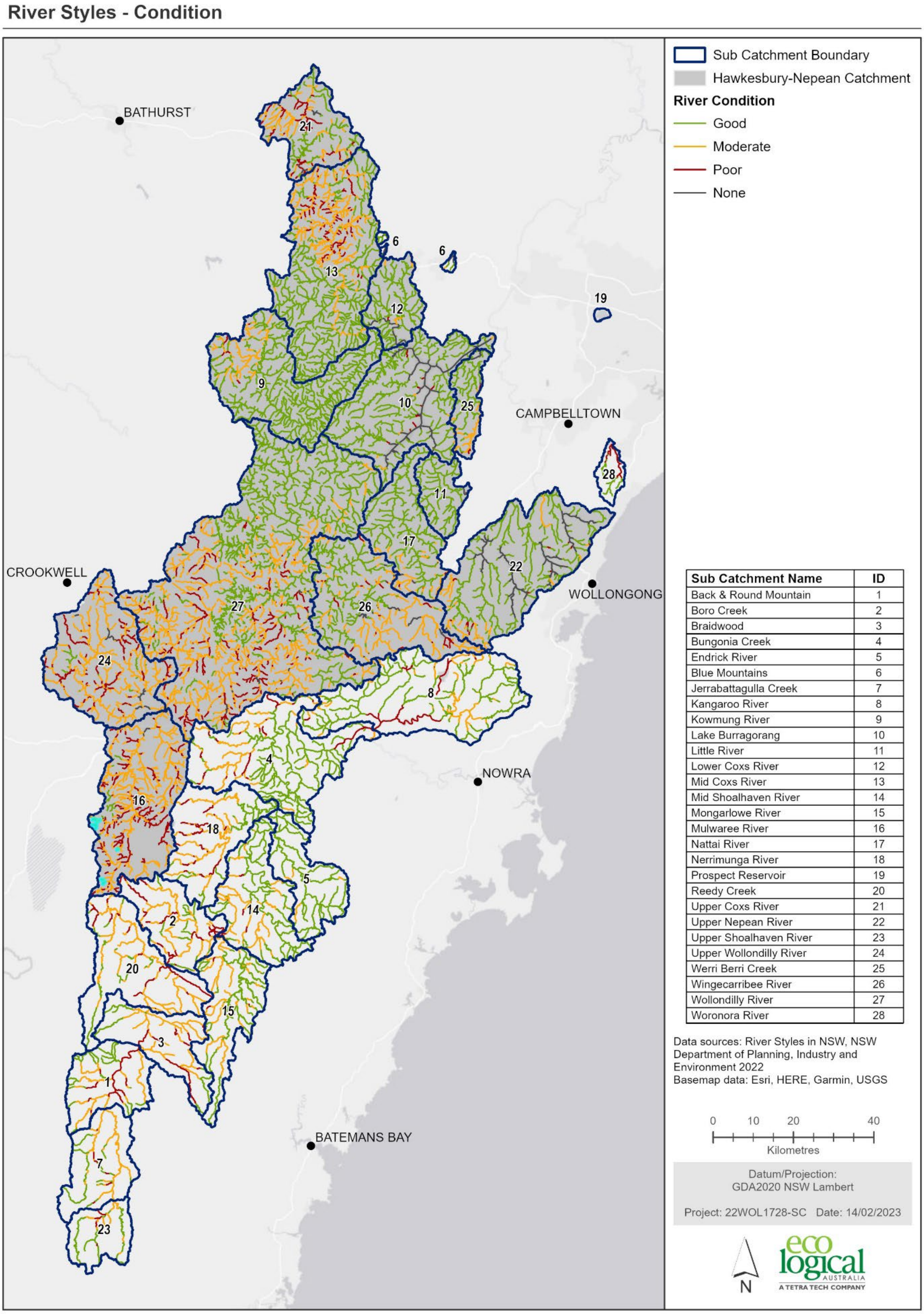


Figure 15-2: River Styles stream condition

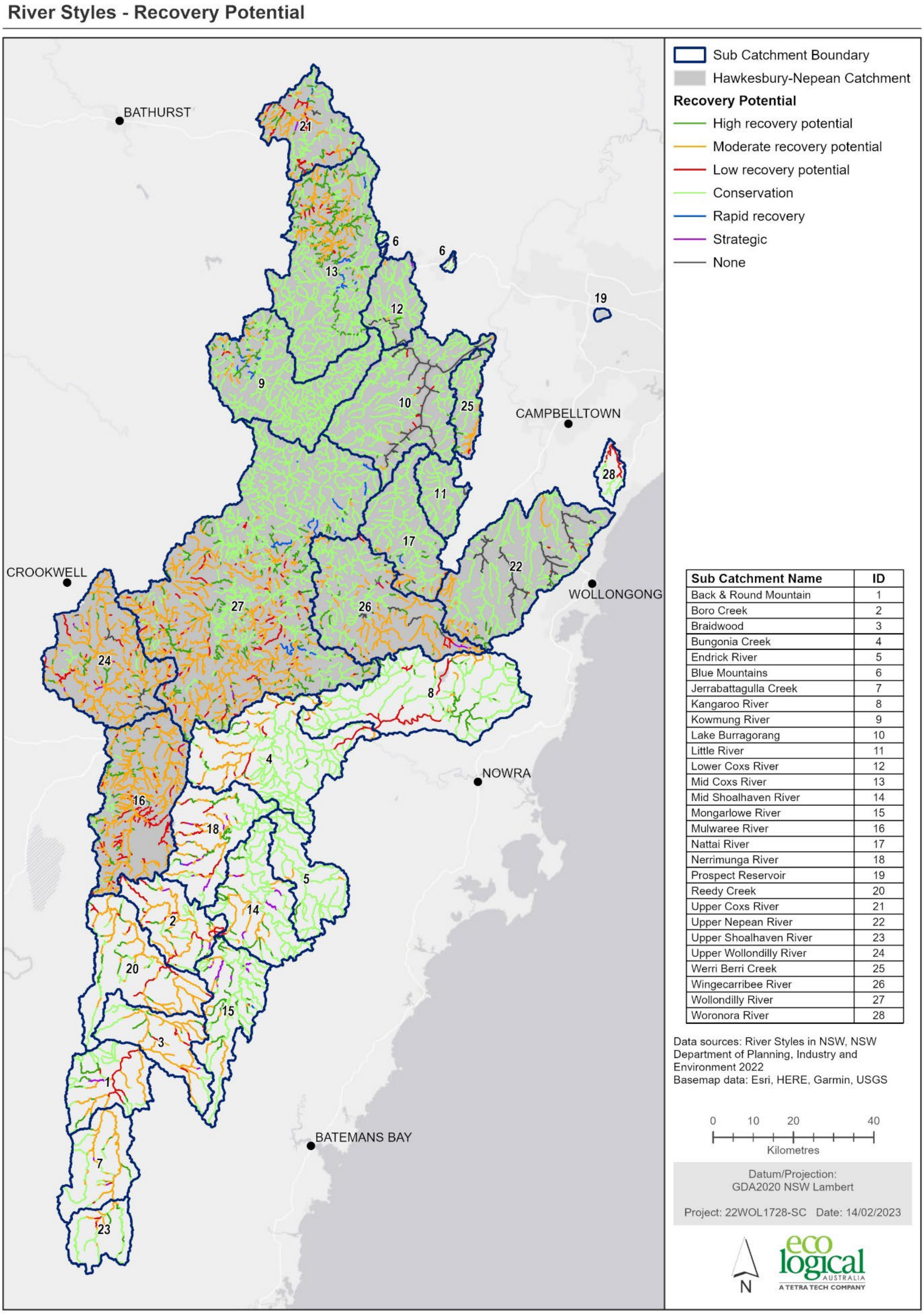


Figure 15-3: River Styles recovery potential

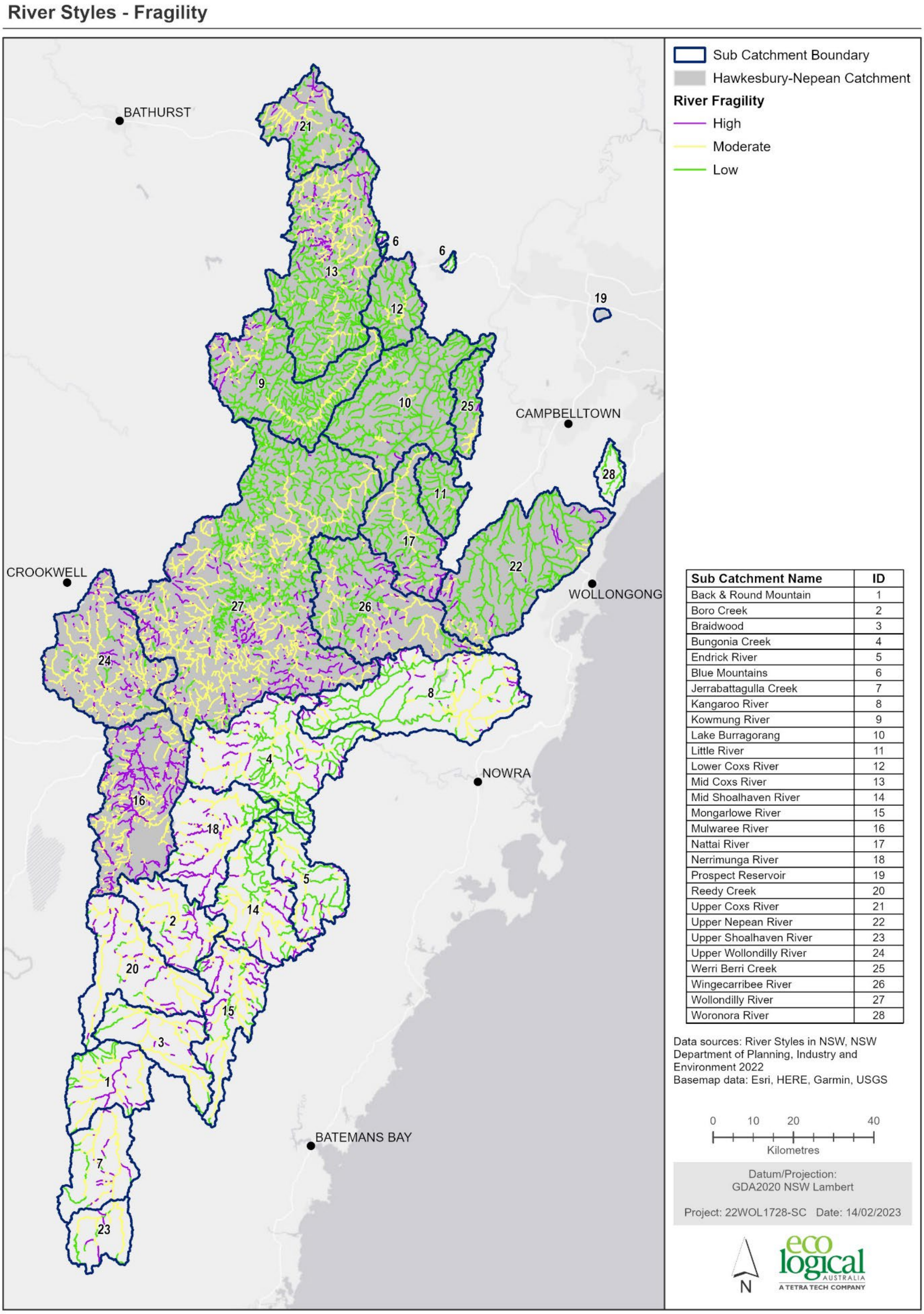


Figure 15-4: River Styles fragility

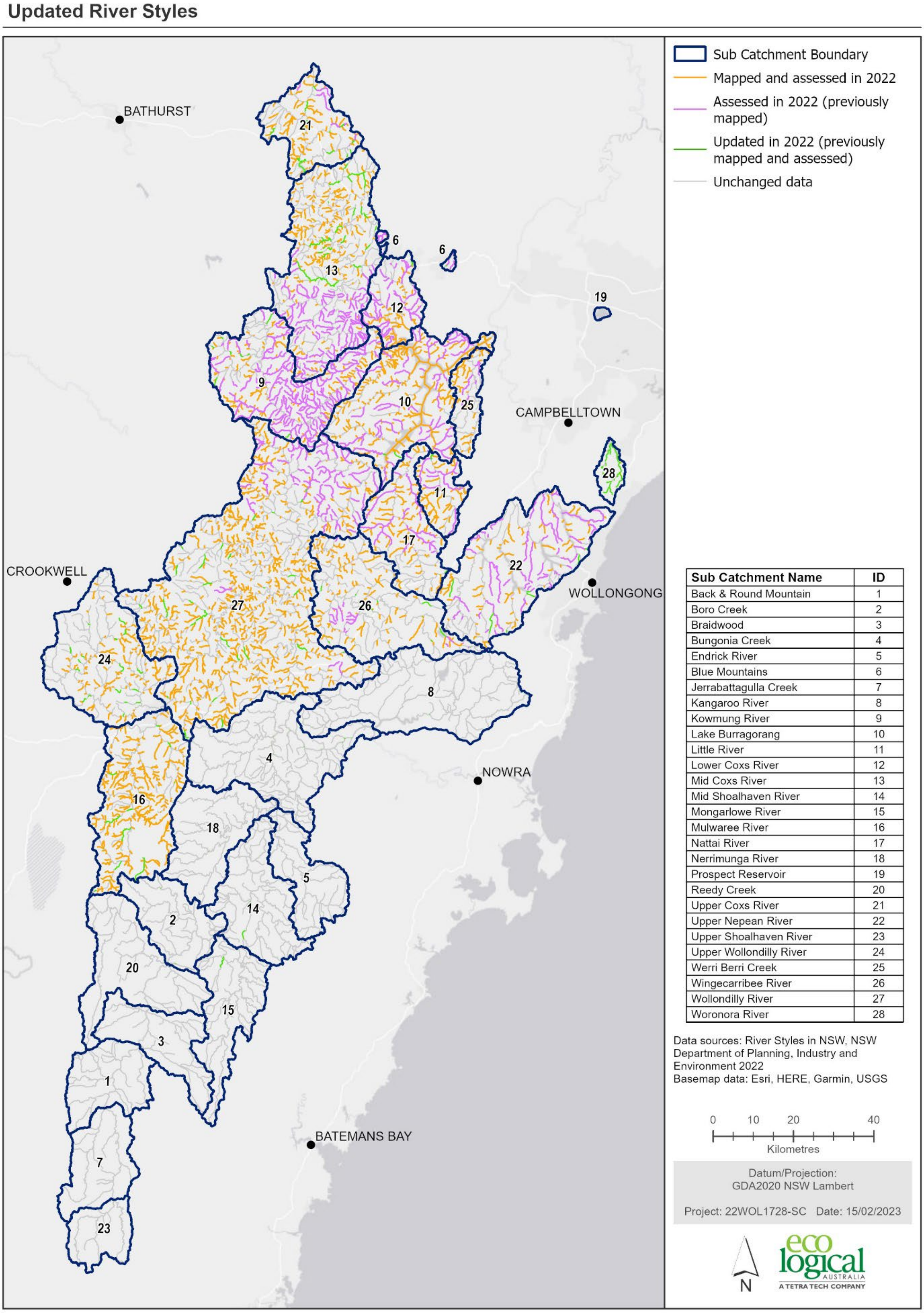
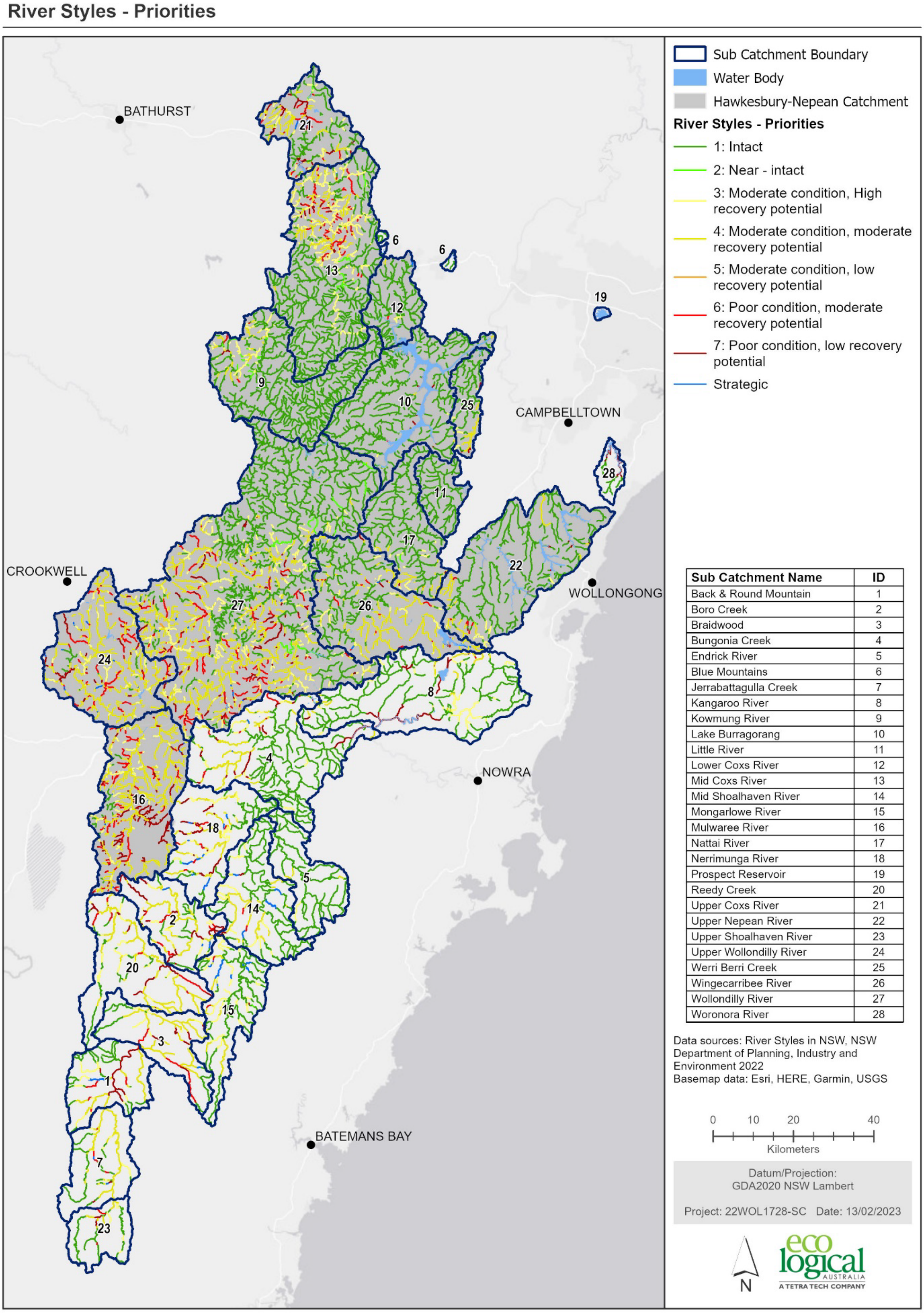


Figure 15-5: Updated River Styles analysis 2022



Sub Catchment Name	ID
Back & Round Mountain	1
Boro Creek	2
Braidwood	3
Bungonia Creek	4
Endrick River	5
Blue Mountains	6
Jerrabattagulla Creek	7
Kangaroo River	8
Kowmung River	9
Lake Burragorang	10
Little River	11
Lower Coxs River	12
Mid Coxs River	13
Mid Shoalhaven River	14
Mongarlowe River	15
Mulwaree River	16
Nattai River	17
Nerrimunga River	18
Prospect Reservoir	19
Reedy Creek	20
Upper Coxs River	21
Upper Nepean River	22
Upper Shoalhaven River	23
Upper Wollondilly River	24
Werri Berri Creek	25
Wingecarribee River	26
Wollondilly River	27
Woronora River	28

Figure 15-6: River Styles priorities

Table 15-1: Priorities of River Styles valley settings – sum of length (km)

Priority type	Warragamba*	Shoalhaven	Metropolitan	Total
Intact	4486.90	1669.20	20.83	6176.93
Near – intact	92.03	3.05		95.08
Moderate condition, high recovery potential	733.83	347.73		1081.55
Moderate condition, moderate recovery potential	1786.51	685.23		2471.74
Poor condition, moderate recovery potential	451.25	108.03		559.28
Poor condition, low recovery potential	332.65	237.26	18.36	588.27
Strategic	31.82	61.30		93.12
Water bodies	320.24			320.24
Total	**8235.23**	**3111.81**	**39.19**	**11,386.23**

*Including Blue Mountains sub-catchments. (There are no River Styles for Prospect Reservoir sub-catchment.)

15.4. Conclusion and recommendation

All third order streams and above in the Catchment have been assessed using the River Styles framework. This information can be used to inform land management priorities. To help achieve the Source Water Protection Strategy goal to increase regenerative agricultural practices across the Catchment by 50% by 2040, it is recommended that rural program protocols are adjusted by WaterNSW to provide funding for projects that feature active or passive rehabilitation of the physical form of watercourses for reaches mapped as having moderate condition and high recovery potential.

16. Soil erosion

Heavy rainfall following extended drought and severe bushfires during the audit period increased erosion in parts of the Catchment, and modelling predicts erosion will worsen in future due to climate change. However, water quality monitoring results during the audit period showed turbidity in streams and storages almost always complied with guidelines (see section 19). The state of erosion during the audit period was therefore assessed as moderate with a worsening trend.

16.1. Types of erosion

Soil erosion by wind and/or water is a natural landscape process. However, when anthropogenic processes modify soil, vegetation or climatic conditions this can lead to rates of erosion that exceed natural variability. The risk and rate of wind erosion within the Catchment is low (Butler et al. 2007, Zhang et al. 2022) and has not been considered further in this section.

Water erosion can generally be categorised as hillslope erosion (sheet and rill erosion), gully erosion or streambank erosion. Hillslope and gully erosion are the focus of this section. Erosion related to urban development is also considered as its potential impacts are not well represented in the available data for the Catchment.

Past audits and assessments have stated that gully erosion is the most prominent form of soil erosion within the Catchment (NOW 2009, GHD 2013), and it is readily observable and measurable. It may be for this reason that gully and stream bank erosion in agriculturally dominated sub-catchments have been the focus of attention from agencies such as WaterNSW and LLS in terms of evaluation and management intervention. However, hillslope erosion is known to be an important source of sediment in steeper forested areas, particularly after intense bushfires (WaterNSW 2016, DPIE 2010a).

16.2. Causes of erosion

Accelerated erosion and sedimentation are typically caused by land clearing for agriculture, poor ground cover maintenance on grazed pastures (overstocking), poorly managed disturbance associated with infrastructure development and construction, mining, pest species and some recreational activities (e.g., walking and 4WD tracks). Intense bushfires can also reduce the protective vegetation cover in naturally vegetated areas and, if this is followed by heavy rainfall, can result in the mobilisation of surface soil and ash into adjacent waterways. The management of areas with known erosion risk and the remediation of areas that are affected by soil erosion are important for protecting soil resources, agricultural productivity, water quality and ecosystem health.

Climate change will likely increase the risk of erosion across all land uses in the Catchment because the State of the Climate report (BoM 2022) predicts:

- A longer fire season and more dangerous fire weather. There has already been an increase in the annual frequency of dangerous fire weather days across eastern Australia and there is a significant trend in some regions of southern Australia towards more days with weather that is conducive to extreme bushfires.
- Heavy rainfall will become more intense. Observations have shown an increase in the intensity of heavy rainfall events in Australia that occur on timescales of less than a day. The intensity of

short-duration (hourly) extreme rainfall events has increased by around 10% or more in some regions and in recent decades. As the climate warms, the atmosphere can hold 7% more water vapour per degree of warming. This can cause an increased likelihood of heavy rainfall events, even in parts of Australia where average rainfall is expected to decrease. Increased atmospheric moisture can also provide more energy for some processes that generate extreme rainfall events, which can further increase the intensity of heavy rainfall.

Even without fire-induced erosion events, both rainfall erosivity and hillslope erosion risk are predicted to increase in the Greater Sydney LLS region by about 10.5% in 2020–2039, and about 21.6% in the far future (2060–2079) compared with the baseline period (1990–2009) (Yang et al 2015).

16.3. Impacts of erosion

Accelerated water erosion causes an increase in sediment loss from the land surface and an increase in suspended sediment loads in affected waterways. Suspended sediment not only impacts water quality and aquatic ecosystem health directly, but also helps transport nutrients, pathogens, pesticides and other contaminants into and through the Catchment. Suspended sediment leads to siltation of watercourses and water storages, affects the performance of water treatment plants, and reduces the effectiveness of ultraviolet treatment and natural sunlight for the removal of pathogens.

Figure 16-1: Erosion at Farmers Creek

16.4. Status

16.4.1. Gully erosion

Gully erosion in the Catchment has been a long-term land management issue, with the development of many current gullies forming pre mid 20th century (Benn 2015). The gully erosion evaluation trial was undertaken by WaterNSW from 2011 to 2015 in selected grazing areas to map the location, extent and severity of gully erosion within the Catchment. The resultant map is presented in Figure 16-2.

The 2016 Catchment audit (Alluvium Consulting Australia 2017) noted that the erosion data available for 2013-16 was not directly comparable with data used in previous audits due to a change in the units of measurement used. This meant that the 2016 audit could not assess the spatial trends in gully erosion.

No new data were made available for the 2019 audit (ELA 2020) to allow the status of the erosion mapping presented in the 2016 audit to be updated. The 2019 audit (ELA 2020) recommendation for updated gully erosion analysis and updated mapping was not accepted by WaterNSW. WaterNSW has stated that the 2015 dataset for 70% of known erosion in the Catchment (Figure 16-2) remains effective to inform current programs (WaterNSW 2021a).

The current approach does not provide any data that shows the contemporary status of gully erosion or how sediment yield from gully erosion has changed since the 2013 audit. The auditor was advised that gully erosion is likely to be progressing or increasing in severity in some areas. This may be halted or reversed by active intervention for ongoing Catchment health.

The availability of such data does not signal a lack of focus or action on managing erosion, rather it is reliant on a single data point supplemented by expert knowledge from WaterNSW and LLS. Therefore, the impact of erosion and sediment loss on water quality can be only indicated by turbidity measurements for the Catchment health audit.

More detailed analysis of data routinely collected by WaterNSW should be considered. This would involve assessing the high flow and flood sectors of the hydrograph to examine temporal changes in turbidity at Catchment monitoring sites. Factors including rainfall totals, intensity and precedent conditions could all be examined. Historic changes (if any) could then be used to determine whether further erosion assessment would be beneficial.

Benn (2005) used LiDAR to measure annual changes in the dimensions of two gullies in the Wollondilly River and Upper Wollondilly River sub-catchments as a method of measuring soil loss. Assuming that only silt and clay fractions were mobilised out of the gullies, Benn (2015) calculated that the gullies studied yielded between c. 0.5 t/ha/annum and 17.8 t/ha/annum. The losses were the same order of magnitude of the range of hillslope soil loss estimated in 2020 (Table 16-1; DPIE (2020a). LiDAR can therefore be a useful technique for assessing gully erosion and should be considered for further application.

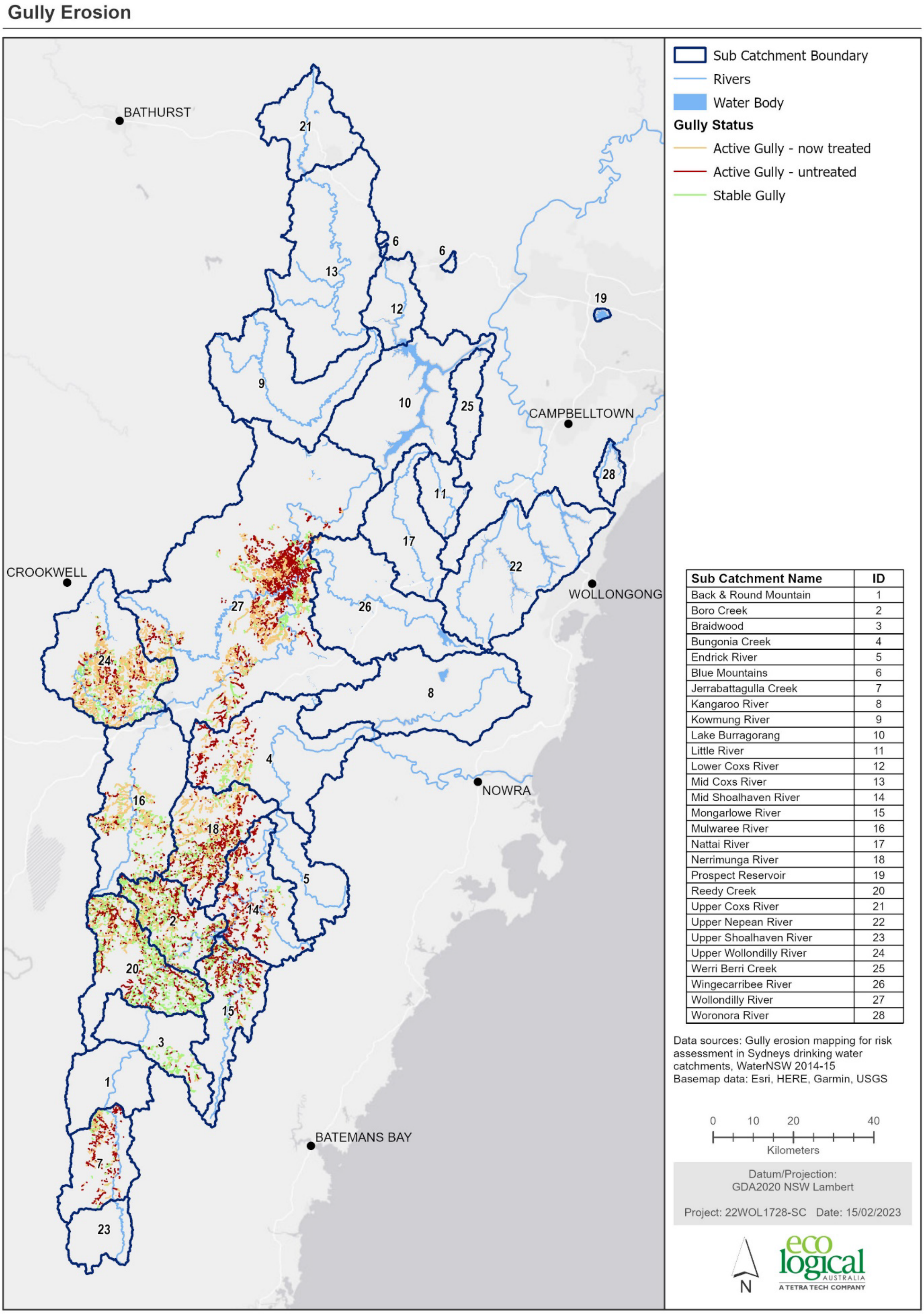


Figure 16-2: Gully erosion (WaterNSW 2015)

Table 16-1: Estimated hillslope erosion for each sub-catchment over the audit period (t/ha/annum) (DPE 2020)

Catchment	2019	2020	2021
Back & Round Mountain Creeks	0.50	2.44	2.07
Boro Creek	0.25	0.87	0.76
Braidwood	0.46	2.91	1.89
Bungonia Creek	0.84	5.65	2.98
Endrick River	0.81	7.40	4.20
Blue Mountains	1.17	10.08	5.32
Jerrabattagulla Creek	0.59	3.75	2.66
Kangaroo River	1.69	13.30	5.55
Kowmung River	1.32	11.01	5.90
Lake Burragorang	1.08	13.39	5.89
Little River	1.06	11.25	5.10
Lower Coxs River	1.52	16.57	7.75
Mid Coxs River	1.87	14.34	7.92
Mid Shoalhaven River	0.50	3.10	2.01
Mongarlowe River	0.57	3.72	2.33
Mulwaree River	0.34	0.89	0.75
Nattai River	0.94	9.42	4.34
Nerrimunga River	0.24	0.95	0.76
Reedy Creek	0.37	1.81	1.30
Upper Coxs River	0.99	4.02	2.55
Upper Nepean River	0.83	5.32	2.90
Upper Shoalhaven River	0.71	7.21	3.81
Upper Wollondilly River	0.36	0.95	0.74
Werri Berri Creek	0.49	5.14	2.71
Wingecarribee River	0.45	2.44	1.77
Wollondilly River	0.77	5.02	2.69
Woronora River	0.90	4.41	2.32
Prospect Reservoir	0.21	0.68	0.45

16.4.2. Hillslope erosion

There are no routine direct measurements of hillslope erosion in the Catchment. The revised universal soil loss equation (RUSLE) is used to estimate hillslope erosion rates in NSW. Predicted soil loss is a product of a range of factors including ground cover, soil erodibility (a function of soil texture, organic matter content, structure and permeability), slope (length and angle), rainfall erosivity (intensity and duration) and soil conservation practice as described in Yang (2020).

Yang et al. (2022) estimated that between 2001 and 2020, the annual rate of hillslope erosion across NSW ranged from 0.4 t/ha/annum in 2019 to 1.8 t/ha/annum in 2020 with an average of 0.9 t/ha/annum. The areas with the highest rates of erosion are largely confined to the eastern regions of NSW. For example, the average rate of soils loss in the Greater Sydney LLS region is 3.0 t/ha/annum. The estimated annual rates of hillslope erosion with the Catchment during the audit period are shown in Figure 16-3 and reflect changes in groundcover vegetation due to the 2019/20 bushfires.

A breakdown of soil loss across each sub-catchment is presented in Table 16-1. The estimates of soil loss available from DPE (2020) are far greater than those previously estimated for Wingecarribee sub-catchment by Olley et al. (2003) (<0.1 t/ha). The occurrence of erosion does not necessarily mean that all eroded sediment will reach waterways, with some being redistributed downslope.

The rate of hillslope erosion within the Catchment when rainfall was well below average at the end of the drought in 2019 was 0.84 t/ha/annum. However, this was still more than double the average for the whole of NSW over the same period (DPE 2020). The bushfires of 2020 reduced protective vegetation cover over large parts of the Catchment and was followed within two weeks by significant rainfall in affected areas. This caused an increase in the Catchment-wide erosion rate to 6.23 t/ha/annum and erosion rates were significantly increased in fire affected areas.

The effect of the fire and subsequent rainfall is shown in the monthly modelling data presented in Figure 16-4. This indicates that most of the annual erosion for 2020 occurred in February immediately after the fires were contained.

Area-specific modelling was undertaken for WaterNSW within the Burragorang sub-catchment (DPIE 2020b) following the 2019-20 fires. This showed that:

- With low fire severity, the mean annual hillslope erosion was predicted to be 1.2 t/ha/annum
- With high fire severity, the mean annual hillslope erosion was predicted to be 7.9 t/ha/annum
- With extreme fire severity, the mean annual hillslope erosion was predicted to be 54.1 t/ha/annum.

The potential impacts of severe bushfires on sediment and nutrient loads, and water quality have been well documented in Australia (Rustomji and Hairsine 2006, Wilkinson et al., 2007, Morris et al. 2008, Nyman and Sheridan, 2014, Canning et al. 2020) and overseas (Meyer and Pierce 2003, Wondzella and King 2003, Paul et al. 2022, Touma et al. 2022). Fires result in the loss of protective vegetative and litter groundcover, the loss of fine soil-binding surface roots and an increase in water repellency of the soil surface that combine to cause increased runoff, erosion and discharge of sediment, ash, nutrients and other pollutants into waterways during subsequent rainfall events (Meyer and Pierce 2003, Canning et al. 2020, DPIE 2020b, Touma et al. 2022, Paul et al. 2022). Based on data collected following the 2001 bushfires in the Lake Burragorang sub-catchment, Wilkinson et al. (2007 2011) warned that a worst-case combination of severe fire and above-average runoff in the post-fire period could result in sediment yields approximately six times pre-fire levels and that individual post-fire rainfall events can transport one to two orders of magnitude more sediment and nutrients than during pre-fire events. Similar effects have been seen in other fires in Australia (Nyman and Sheridan 2014) and the modelling of erosion after the 2020 bushfires (DPIE 2020b) yielded similar predictions.

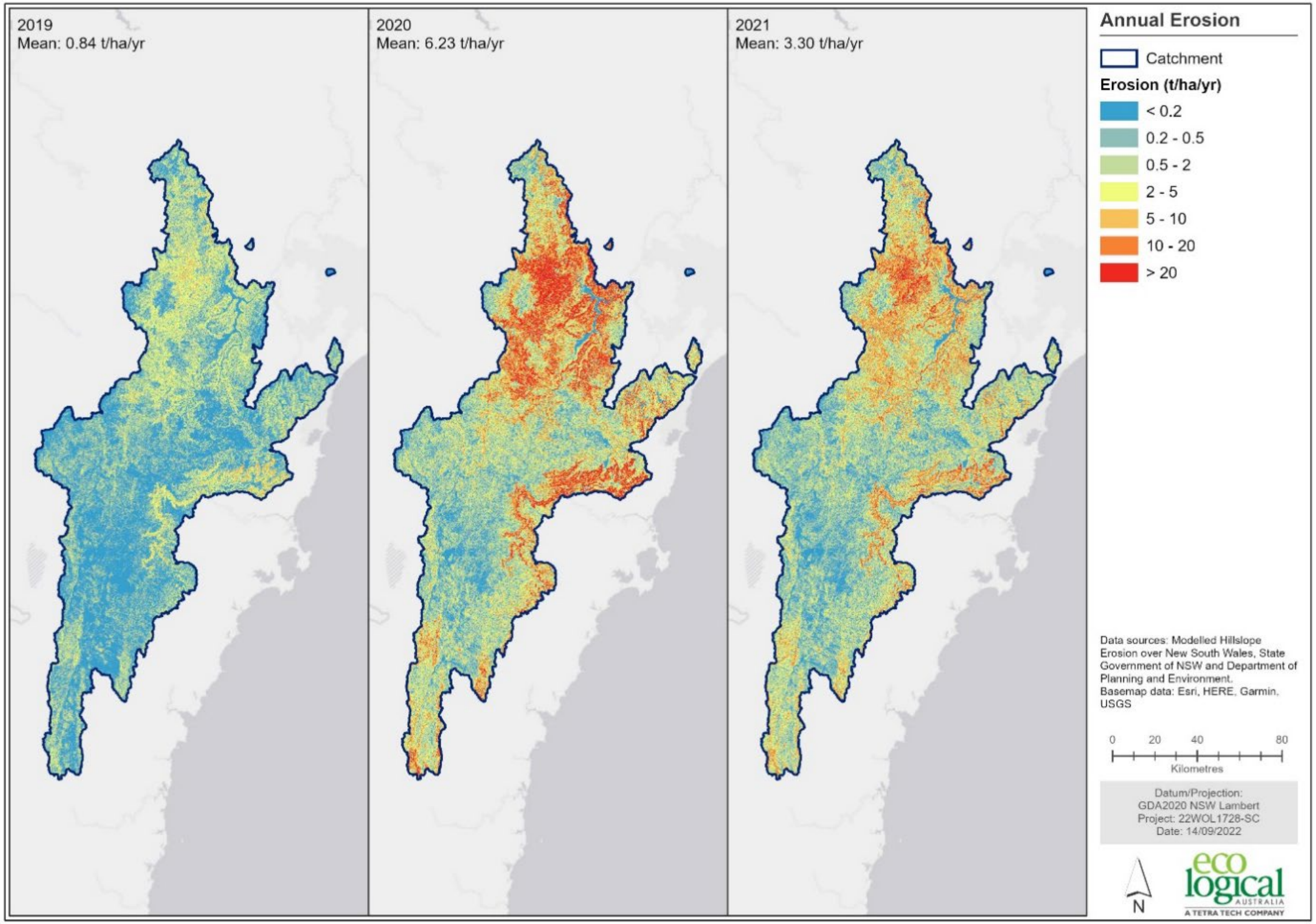


Figure 16-3: Estimates of annual rates on hillslope erosion across the Catchment during the audit period (DPE 2020)

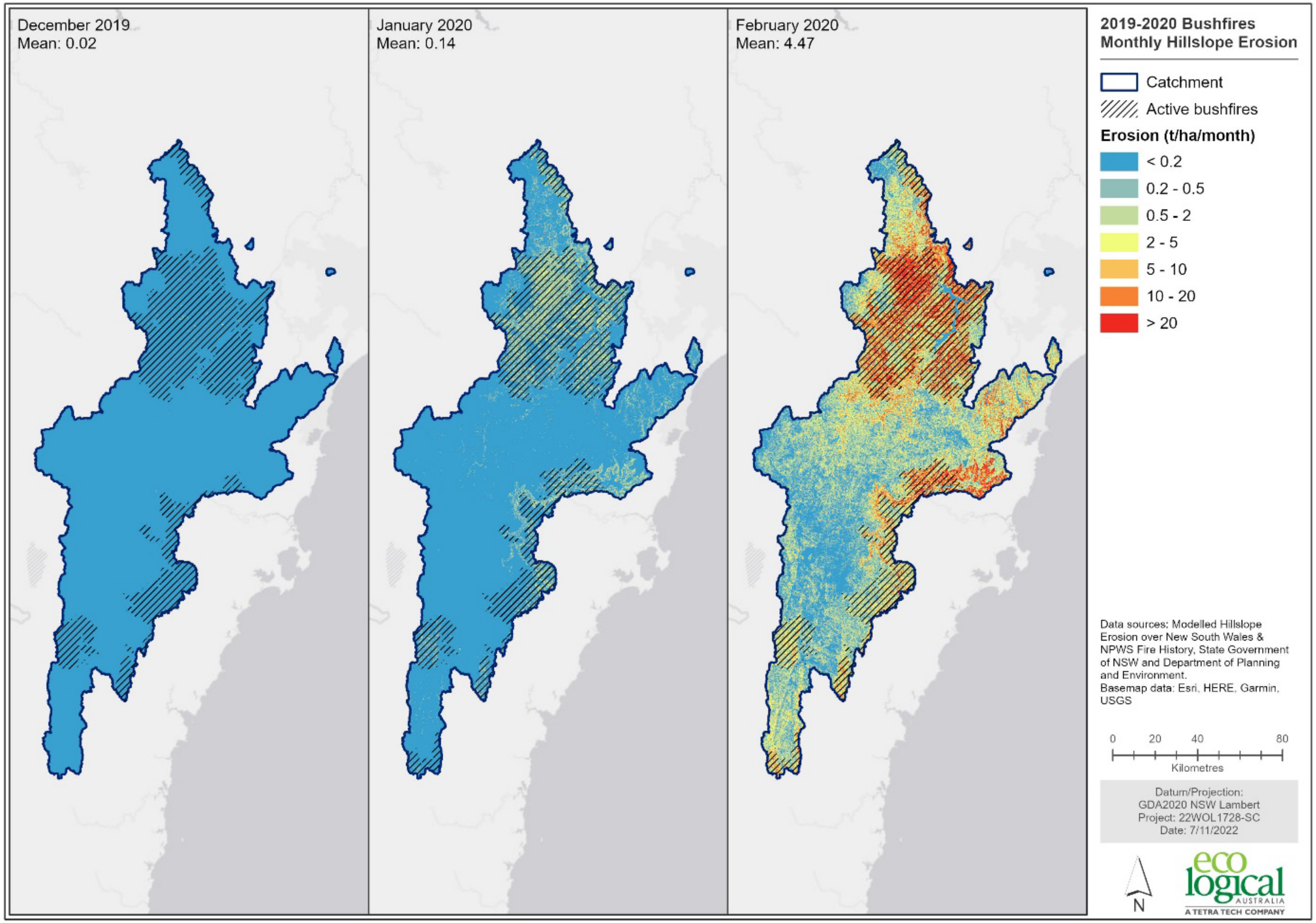


Figure 16-4: Estimates of monthly rates of hillslope erosion during and after the 2020 bushfires (DPE 2020)

The effects of the 2019-20 fires were still apparent in 2021. Literature sources indicate that it can take several years (generally 3-5 years but up to 15 years) for soils and vegetation to recover sufficiently to return sediment and pollutant yields to pre-fire levels after severe fire events (Meyer and Pierce 2003, Rustomji and Hairsine 2006, Wilkinson et al. 2007, Nyman and Sheridan 2014, Paul et al. 2022).

Although hillslope erosion is less visible than gully erosion, it is widespread and particularly high in areas with elevated topography such as in the Special Areas. The rates of hillslope erosion in circumstances where there is a combination of severe fire and above-average runoff in the post-fire period are comparable to rates of erosion measured from well-established gullies.

16.5. Erosion management in agricultural land

16.5.1. Identification of priorities

The Pollution Source Assessment Tool (WaterNSW 2016) suggested that grazing land was a high-risk priority because it has the potential to contribute the greatest pollutant loads in the Catchment. Through a combination of data, expert knowledge and literature sources, WaterNSW (2016) identified priority (highest risk) drainage units and properties for each major water quality hazard (nitrogen, phosphorus, pathogens and suspended sediment). This was based on the notion that the greatest improvement in water quality can be made through management intervention at the highest risk sites.

Livestock grazing covers 35.9% of the land area of the Catchment (as of 2017 land use data; Figure 7-4). WaterNSW has advised that around 19,000 properties in the Catchment have at least some portion of the property under grazing and around 2,000[21] properties have been identified as high risk in terms of their contribution to one or more water quality hazards. Much of the effort to date has been directed toward gully erosion using conservation earthworks techniques such as banks, shaping, rock ramps, log piles, log jams and flumes. Hillslope erosion impacts are partly mitigated by riparian management and stock exclusion, as well as the practices of paddock subdivision and cell grazing, which are both supported by the WaterNSW Rural Landscape Program.

16.5.2. Erosion management

The now superseded Catchment Protection Scheme had a focus on repairing and halting severe gully erosion on a site-by-site basis. However, WaterNSW concluded that the scheme did not treat some of the underlying causes of erosion such as landholders' practices, stock accessing waterways, diminished riparian vegetation, over stocking and loss of ground cover. In recent years WaterNSW has taken a holistic landscape management approach to erosion and its causes, where landholders are willing to participate in improved management practices.

Since 2013, the Rural Landscape Program (developed by WaterNSW in partnership with the South East LLS) has aimed to manage gully erosion by better management of grazing from a land and soil health perspective. The program contributes to the Source Water Protection Strategy priority 04 'increasing regenerative agriculture' (WaterNSW 2022d), which aims to manage:

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[21] The Annual Catchment Management Report 2020/21 (Water NSW 2021a) incorrectly stated that there were 1,600 rather than 2,000 priority target high risk properties (Stuart Naylor, pers. comm., email dated 27 October 2022).

- Uncontrolled stock access to waterways (Rural Landscape Program Riparian management practices funding stream)
- Diminished riparian vegetation (Riparian management practices funding stream)
- Continuous grazing / pressure (Grazing practices funding stream)
- Stream bank and gully stability (Erosion control practices funding stream).

The Rural Landscape Program is aimed at providing funding assistance to land managers to implement a range of land and water management practises that address known water quality hazards; thereby protecting and improving water quality in the Catchment. Funding is available for improving:

- Erosion control practices designed to control gully and or stream bank/stream bed erosion through:
  - Soil conservation earthworks
  - Channel protection works
  - Fencing of vulnerable areas
  - Alternative stock water supplies
  - Complementary native vegetation regeneration/planting.
- Riparian management practices designed to protect and enhance native riparian areas through:
  - Provision of fencing materials and native trees and shrubs
  - Alternative stock watering points
  - Stock crossing and minor erosion control works.
- Grazing practices designed to promote more sustainable utilisation of grazing land within its inherent capability constraints and maintain good ground cover through:
  - Stock fencing to improve the management of land and grazing practices
  - Alternative water supplies where access has been cut off.

Eligibility requirements ensure the Rural Landscape Program funding is directed to larger properties that actively graze stock with a commitment to implementing permanent changes in practice. The current program focuses on regenerative agriculture which is expected to reduce hillslope erosion from areas under grazing use. This is because the increased focus on improved grazing management practices, such as rotational grazing, helps to maintain ground cover to protect soil from sheet erosion.

16.5.3. Management progress

The Catchment Protection Work Program provides an annual program of works for the delivery of the Source Water Protection Strategy. The operational budget for delivering increasing regenerative agriculture in the 2021-22 Catchment Protection Work Program was $2,083,000 (WaterNSW 2021d).

The locations of projects supported by the Rural Landscape Program over the audit period are provided in Figure 16-5. The annual catchment management reports for 2019-20, 2020-21 and 2021-22 (WaterNSW 2020a, 2021, 2022) contain a range of metrics that cover the implementation of ‘Catchment program – rural’ (the metrics associated with the Rural Landscape Program) and ‘improved practices outcomes’ (outcomes related to the adoption of regenerative agricultural practices). These are summarised in Table 16-2. However, the metrics used in the annual catchment management reports have been slightly amended for each report (also a previous audit finding) and it is not explicitly clear which targets are annual targets and which are long-term strategic goals. It appears that the metrics may have become standardised following the release of the Source Water Protection Strategy (Water NSW 2022) which should make it easier to track in the future.

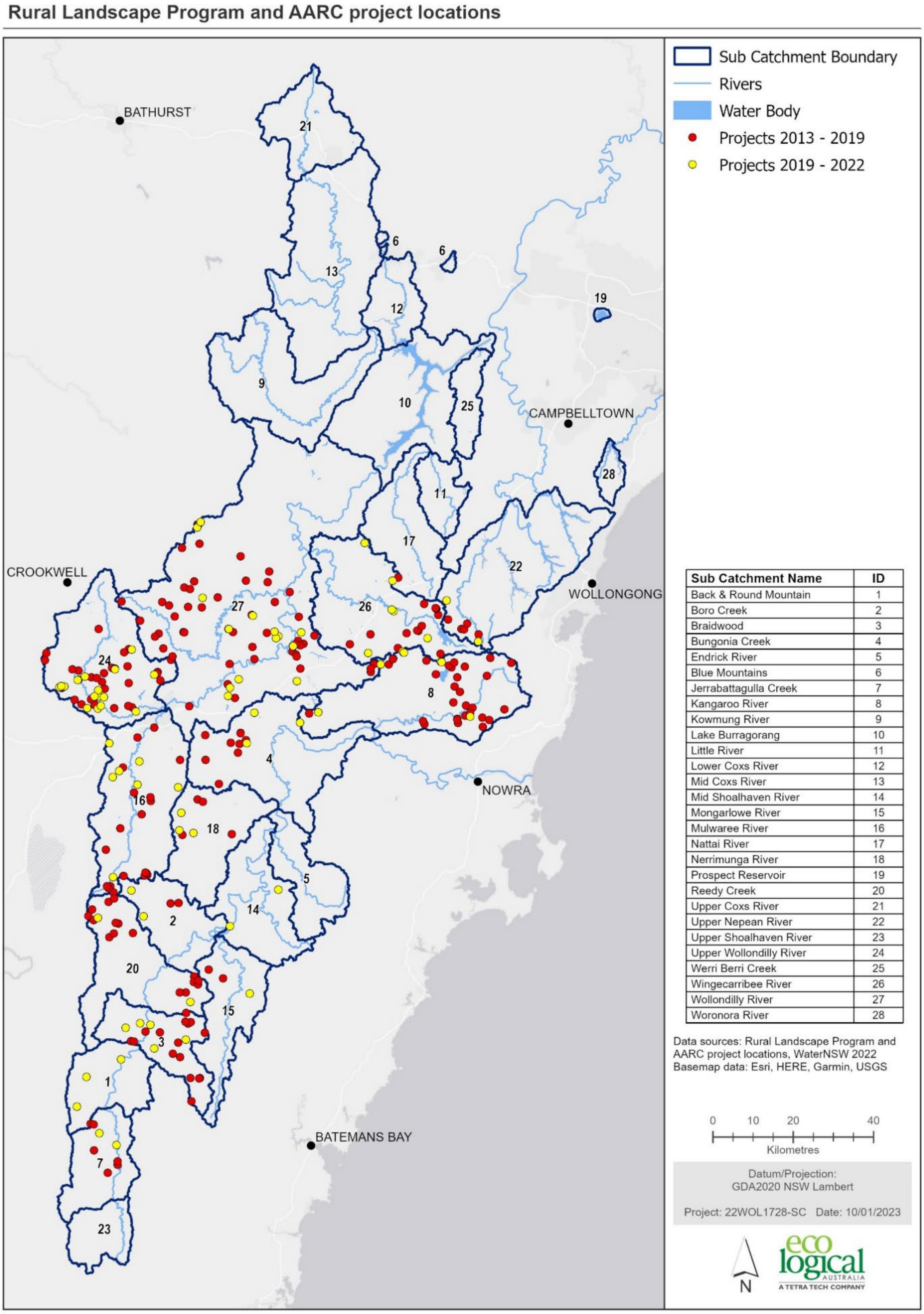
Table 16-2 shows that progress against the nominated targets has been variable. However, progress is being made against the key metrics that are reported.

WaterNSW commissioned an evaluation of the Rural Landscape Program in 2022 and a draft had been provided to WaterNSW at the time of preparing this audit report. While program improvements are continuously implemented, WaterNSW wanted to evaluate the on-ground outcomes of the program against its objectives. The review was undertaken by a consultant, with field work undertaken during 2022, when rainfall patterns allowed. Around 10% of the projects funded in the program have been assessed. At each site on each property, an overall assessment was made of progress against five key program objectives:

- Engineered assets in good condition
- Erosion halted
- Fences in place to exclude stock
- Revegetation 70% survival
- Groundcover >80%.

The preliminary results showed that 13 out of 15 properties assessed that conducted erosion repair works, seven properties had successfully halted erosion at all sites. At six of the properties, there was a risk that that objectives of halting erosion would not be met for at least one of the sites in each property.

Being able to measure success is critical part of implementation a long-term project of this nature. The feedback of what has and what has not worked, and the lessons learned by stakeholders through implementing erosion control work are expected to be used as part of an adaptive management to continually improve the program outcomes.



Sub Catchment Name	ID
Back & Round Mountain	1
Boro Creek	2
Braidwood	3
Bungonia Creek	4
Endrick River	5
Blue Mountains	6
Jerrabattagulla Creek	7
Kangaroo River	8
Kowmung River	9
Lake Burragorang	10
Little River	11
Lower Coxs River	12
Mid Coxs River	13
Mid Shoalhaven River	14
Mongarlowe River	15
Mulwaree River	16
Nattai River	17
Nerrimunga River	18
Prospect Reservoir	19
Reedy Creek	20
Upper Coxs River	21
Upper Nepean River	22
Upper Shoalhaven River	23
Upper Wollondilly River	24
Werri Berri Creek	25
Wingecarribee River	26
Wollondilly River	27
Woronora River	28

Figure 16-5: RLP and ARRC projects funded in the current (2019-2022) and previous two (2013-2019) periods (WaterNSW)

Table 16-2: Progress of management interventions related to erosion from agricultural sources

Planned activities (targets in brackets)	2019/2020 ACMR outcomes	2020/2021 ACMR outcomes	2021/2022 ACMR outcomes
20% (320/1600)[3] of high-risk grazing properties have effectively excluded stock from waterways to protect riparian areas by 2024 (targets revised to 330/2000)	Not included	261/2000 (13%) landholders have adopted one or more of four critical practices	288/2000 (14%) landholders have adopted one or more of four critical practices
Collaborate with South East LLS (SELLS) and Rivers of Carbon (ROC) (ARRC) to award 50 or more (SELLS 35 + ROC 15 and/or >18 km of riparian protection) grants to landholders to protect riparian areas, treat erosion, and improve grazing management.[1] Targets include: • Length of riparian protection (70 km) • Erosion treated (20 head cuts) [1] • Area of grazing land improved with best practices (,1000 ha)	• 31 project agreements were established with landholders (SELLS 16 and ROC 15) in priority areas and grants awarded • 53 km of riparian area protected • 21 eroding head cuts treated and repaired 9 km of gully erosion • Improved grazing practices introduced on 2,295 ha of land	• 46 km of riparian area protected • 9 eroding head cuts treated • Improved grazing practice introduced on 119 ha of land	• 43.6 km of riparian length fenced • 475 ha of riparian area protected • 33 head cuts treated • 1,024 ha of improved grazing practices introduced.
Engage landholders using social media, print, field days, workshops, and events around grazing management, waterway protection and sustainable grazing and Increasing interest and engagement from landholders in new management practices, and financial incentive programs [2]	SELLS: • Delivered three training course (Prograze, 'Thinking outside the square bale' and Farm Water workshop) attended by 95 people. ARRC: • Over 120 people participated in National Tree day to plant over 1200 trees, shrubs and grasses on a property involved in the ROC. • Over 50 landholders attended a community	SELLS: • delivered Prograze training and a Whole Farm Planning Workshop to over 30 graziers. • produced online resources for Farm water management • produced a four-part video series on managing small scale erosion • produced a five-part video series on grazing management. ARRC:	SELLS: • delivered Prograze training and Landslip and Whole Farm Planning workshops to over 100 landholders. ARRC: • delivered a field day along the Wollondilly River which attracted 30 people. It focussed on water quality, riparian health, animal health and engagement with local traditional owners regarding indigenous land management.

Planned activities (targets in brackets)	2019/2020 ACMR outcomes	2020/2021 ACMR outcomes	2021/2022 ACMR outcomes
	conversation event on restoring threatened native species in the Goulburn region.	• delivered webinar training on managing stock and waterways • produced three films about landholder stories to support the development of Story Maps • produced a range of web resources related to riparian management, native plants, water quality, and stock management • ran email and social media campaigns to promote Stock and Waterway resources	• Two workshops in Canyonleigh and Southern Highlands took participants through long-term projects to showcase project improvements over time and to • introduce them to the range of financial assistance available. • Two new story maps focused on landholder stories and landscape change were published on the internet. • An effective social media campaigns was developed to direct graziers to web-based resources including the story maps and the Stock and Waterways publication.

1. Target only provided for head cuts in 2020/2021 ACMR. Targets for the number of projects only provided in 2019/2020 ACMR. Length of riparian protection, erosion treated and land improved with best practices was under a separate activity.
2. Only included in the 2020/2021 ACMR.
3. Included since the 2020/2021 ACMR (Water NSW 2021a) presumably to align with the Source Water Protection Strategy targets. The 2020/2021 ACMR report incorrectly stated that there were 1,600 rather than 2,000 priority target high risk properties and the target for 2024 is not 20 % or 320 but rather 16 % or 330 properties (Stuart Naylor, pers. comm., emails dated 27 October 2022 and 1 December 2022).

16.6. Erosion management in urban land

Poorly planned, designed or managed construction of urban development has the potential to cause impacts on water quality from accelerated water erosion. This is particularly true for subdivisions and large-scale urban developments. This not only affects water quality, but managing deposited sediment adds to the maintenance costs for councils. Mobilised sediment can also compromise the efficiency, maintenance costs and aesthetics of urban water sensitive design assets associated with efforts to create water sensitive cities (Source Water Protection Strategy priority 01).

As part of the Urban Program, WaterNSW joined the 'Get the Site Right' campaign in 2022. This aims to educate developers, builders and home renovators about the environmental impacts of unmanaged runoff from development sites. Further information is in section 9.

Figure 16-6: Example of urban development in the Catchment

16.7. Erosion management in the Special Areas

16.7.1. Identification of priorities

The Special Areas Strategic Plan of Management 2015 (SASPoM – WaterNSW and OEH 2015) states that the Special Areas primarily comprise intact native forest and largely exclude land uses with the potential to generate excessive nutrients, sediments, pathogens and other substances that can pose a threat to water and as such, provide a critical barrier in a multi-barrier approach to protecting water quality. Nevertheless, as has been shown in sections 6.8 and 16.4.2, erosion can occur within the Special Areas. These risks are recognised in the SASPoM and the key findings for Pollution Source Assessment Tool 2012-2016 (WaterNSW 2016). The main erosion risks in the Special Areas are:

- Hillslope and gully erosion associated with disturbed areas.
- Hillslope, gully and in-channel erosion during and after bushfire and floods.
- Soil loss from unsealed tracks (a risk common to many forested catchments according to Rustomji and Hairsine 2006).

Gully erosion priorities are determined by considering sub-catchment size and location, previous investments in land management, main tracks breached, leased lands, proximity to watercourses, conservation significance, fire priorities and cultural heritage values. Actions for the trail network are assigned by trails' criticality, defect location, number and type defects, water crossings and traffic-ability. Individual priority erosion areas requiring specific management are identified through the Catchment Protection Work Program (e.g., WaterNSW 2021d).

The network of unsealed roads that exists throughout the Special Areas is important for fire management including suppression and for safe access to key infrastructure. According to the Catchment Protection Work Program (WaterNSW 2021d), upgrades, repairs, and maintenance of the network are aligned with construction guidelines and achieve standards required under the *Rural Fires Act 1997.* The intent being to prevent erosion and provide for the safe operational needs of all users.

16.7.2. Erosion management

Unauthorised access is managed through the installation and maintenance of barriers, fences, and gates (WaterNSW 2021a) and the installation of Special Area enforcement signs. This is supported by compliance activities. These measures minimize the risk of unauthorized trails being created, with associated erosion issues.

The management of vegetative and ground cover is the most important management measure for minimizing erosion (i.e., sediment generation) in Special Areas. This is largely achieved through a well-documented approach to managing bushfire threats with the aim to minimize the aerial extent, duration and intensity of fires (WaterNSW and OEH 2015, WaterNSW 2021a, WaterNSW undated).

In addressing the Source Water Protection Strategy priority 05 'fulfilling land management responsibilities' goal of 30% reduction in water quality risks from fire, pests and weeds in the Special Areas, progress will be measured by the following performance indicators (WaterNSW 2022d):

- Range and density of priority pests and weeds
- Asset condition profile for fire trails and fire blocks (slash breaks plus HR blocks) are consistent with desired condition
- Number of wildfires that exceed 10 ha annually.

Therefore, the focus of performance assessment in the Source Water Protection Strategy is on fire prevention and the prevalence and proliferation of priority pest and weed species.

Post-fire sediment control in the Special Areas is initially managed under a section 44 instruction to make areas safe. This includes rehabilitation of control lines and repair to the trail network so that access to critical water supply infrastructure such as storages and water monitoring stations can safely recommence. Erosion management in the initial post-fire stage has generally been a low priority in the Special Areas due to poor access in remote areas and reliance on natural regeneration processes. Longer-term post-fire erosion controls are managed as part of the annual catchment protection work program.

Following the 2019-20 bushfires, WaterNSW established a bushfire recovery project to identify and implement recovery and rehabilitation works including making the location and access to the site safe, restoring essential functionality, and reducing risk to water quality and land degradation. As outlined in section 6.8.1, for management of erosion this included:

- Installation of booms in the lake to protect water offtakes
- Prioritisation of immediate trail works required to develop RFS 'make safe plans'
- Joint NPWS and WaterNSW trail and fire break damage and repair assessment undertaken by the Soil Conservation Service
- Trail and fire break repair program implemented by WaterNSW and NPWS
- Sediment and erosion risk modelling and on ground assessment of feasibility assessment of on ground interventions.
- Installation and monitoring of coir logs and 'in channel' structures to arrest ongoing erosion at one severely burnt location and monitoring of recovery at two other sites (Soil Conservation Service 2023).

There appeared to have been limited preparedness for managing hillslope and instream erosion across the Special Areas after the large and severe fires in 2020. However, WaterNSW and NPWS were prepared to undertake trail assessments and repairs based on the knowledge that fire trails are a significant sources of post-bushfire sediment.

A review of literature and approaches taken by other water authorities indicated many had undertaken post fire intervention works but there was little performance monitoring. It was difficult to determine the cost benefit of intervention, especially in large scale and remote environments. WaterNSW engaged the Soil Conservation Service to implement a catchment intervention program to better understand effort and performance required to actively intervene post fire.

Comprehensive research initiated following the 2019-20 fires (see section 6.8.1) should inform development of a decision tool or procedure that identifies when practical and effective soil erosion interventions should be applied in future by the joint managers of the Special Areas. Considerations should include safe access, remote location, poor access, event scale as well as storage type, location, cost and available resources.

16.7.3. Management progress

Over the period of the audit, erosion repair works were significantly affected by a redirection of resources to bushfire recovery and poor weather conditions. However, it is hard to gauge what the scale of erosion is within the Special Areas and public recreation areas, and how much progress has been made. In addition, none of the performance assessment measures identified in the Source Water Protection Strategy (WaterNSW 2022d) for 'fulfilling land management responsibilities' relate directly to erosion prevention or management. They relate only to priority weed and pest management, asset maintenance and minimising wildfires.

It can be difficult to review year on year progress of erosion management in the Special Areas due to inconsistent presentation of outcomes in the annual reports. It is acknowledged that priorities may change from year to year given circumstances at the time, but the metrics should be universal enough to allow progress against strategic or policy priorities to be readily measured. For example:

- The 2018-19 Annual Catchment Management Report (WaterNSW 2019a) had

  - No listed 'Planned Activities' directly related to erosion repair or management.
  - A 'Planned Outcome' of 'Unsealed roads are maintained for their intended purpose, and erosion and sediment loss are minimised.'
  - An 'Actual Outcome' of 'Unsealed roads are open and trafficable for their intended use' but did not mention whether erosion had been minimised.

- The 2019-20 Annual Catchment Management Report (WaterNSW 2020a) had
  - 'Planned Activities' that included 'Treat 3 priority erosion sites within the Declared Catchment'.
  - Actual Activities that included
    - 'Priority erosion sites repair have been delayed as key resources were diverted to bushfire response and recovery operations.'
    - 'Environmental and financial approvals and contacts are in place to commence work on Lizard Creek in the Metropolitan Special Area and South Virginia in Braidwood once specialist crews are released from bushfire recovery work.'
  - A 'Planned Outcome' of 'Erosion and sediment loss minimised and risks to water quality and ecological integrity minimised.'
  - 'Actual Outcomes' that included
    - 'NPWS completed 1 km of walking track near Mt Solitary. This was the last stage of a multiyear approach to reducing the water quality impacts from erosion.'
    - 'Fire trails across the Special Areas were significantly impacted by bushfire and the subsequent February flood event,' though it is not clear how severe or what length of track was affected by erosion (to offset the positive actions taken above).
- The 2020-21 Annual Catchment Management Report (WaterNSW 2021a) had
  - 'Planned Activities' that included 'Treat 3 priority erosion sites within the Declared Catchment'.
  - 'Actual Activities' that included
    - 'Work commenced at Virginia South (Braidwood) but were delayed by wet weather.'
    - 'Four other sites were planned but were unable to proceed due unsuitable ground conditions following wet weather.'
  - No listed 'Planned Outcomes' 'directly related to erosion repair or management, but a variation comment for the 'Unsealed Roads Program' that 'a major rainfall event in March made conditions unsuitable for road and erosion control works during Autumn. When works recommenced priority was given to bushfire recovery works which resulted in expenditure being under budget by $367K'.

In addition to land management activities and outcomes, the Annual Catchment Management Report 2020-21 (WaterNSW 2021a) included a 'planned activity' under 'climate and extreme event research' to conduct a 'Literature review and field observational research into the current and lasting effects of wildfires on catchment water quality' and 'Actual Outcomes' of:

- Developed fire research strategy formalising WaterNSW research objectives and documenting high-level planning for 8 fire research projects and collaborations
- Business case approved for field research on ash contaminant and sediment erosion impacts of prescribed and uncontrolled fire.

These examples demonstrate that there is an opportunity to improve performance evaluation and reporting.

16.8. Conclusions and recommendations

It is acknowledged that WaterNSW has a sound understanding of which areas of the Catchment are at greatest risk of gully erosion and the 2015 mapping continues to provide valid information to inform management priorities. However, there appears to be no available data that shows the contemporary status of gully erosion and how the sediment yield from gully erosion has changed since the 2013 audit. It is therefore recommended that detailed analysis of erosion and sediment loss be undertaken using long-term turbidity and hydrograph datasets for Catchment monitoring sites. Methods such as LiDAR or drone photogrammetry should also be considered to determine if they can directly measure changes in gully dimensions net soil loss from managed gullies. If the technique is effective, it should be applied to priority areas identified in the detailed analysis. The resultant database should be shared with stakeholders via SEED.

To minimise the risk of mobilisation of sediment into waterways in the Special Areas it is recommended that an erosion management decision support tool or guide is developed. This must include consideration of potential post-fire rainfall events. Development of this tool should draw on outcomes of ongoing research and local experience, including:

- The 2023 report by Soil Conservation Service that reviews post-fire erosion mitigation works by WaterNSW.
- Research by Neris et al (2021) into tools to predict and mitigate impacts on water quality following wildfire in the Catchment.
- Performance of different sediment control measures/devices, such as:
    - Bushfire erosion mitigation plans (or erosion and sediment control in bushfire management plans) published by other agencies that provide guidance on a range of possible treatments and their suitability or limitations in particular circumstances (e.g., DSE 2011).
    - Existing national level guidance and the learnings from other significant recent fires (particularly in the ACT, SA and VIC) (Morris et al. 2008, Morris, 2010, DSE 2011, Canning et al. 2020) should be used to develop interim best practice guidance.
- A risk and vulnerability analysis to identify areas most likely to contribute sediment to waterways and storages following a bushfire. This should account for risk of increased fire frequency and rainfall intensity predicted to occur as a result of climate change (DPIE 2020d).
- Potential limitations in implementing treatment methods such as
    - Limited vehicular access to affected areas (damage or no road access) and practicality
    - Limited availability of certified weed free organic materials (mulches, logs, straw bales)
    - Disturbing problematic soils

  - Disturbance of recovering biodiversity values or heritage assets.

- Considering any pre-permitting requirements for the installation of sediment control structures downstream from high hazard areas.
- Collaboration with other State based agencies to share experiences.

The Source Water Protection Strategy (WaterNSW 2022d) has a stated goal of achieving a '50% increase in regenerative agricultural practices across the Catchment'. However, the desired outcome in the graphic is for 'Improved grazing landscape conditions and water quality'. The metrics selected to monitor performance and presented in the annual catchment management reports relate to the number of graziers implementing improvement land management practices, the length of riparian and waterway protected, and the number of head cuts and stream bank erosion treated. Although these metrics provide a good measure of the implementation of the Rural Landscape Program and actions that will reduce erosion on priority properties, they do not provide a direct measure of performance against the stated goal or an indication of net reduction in catchment sediment yield or improved water quality. It is therefore recommended that WaterNSW clarify goals and performance measures for the Source Water Protection Strategy, document methods for measures, establish a baseline and report against the established baseline in future annual catchment management reports.

Figure 16-7: Good vegetation cover on steep slopes reduces erosion risk (Shoalhaven River, photo provided by WaterNSW)

State of the Catchment – Water Availability and Quality

17. Water flow

Surface water flow and environmental flows were affected by the drought at the start of the audit period followed by heavy rainfall in 2020-22. Climate-driven disasters disrupted water monitoring at some locations, and reduced data available for decision-making. Overall, surface water flows across the Catchment were good during the audit period. However, there is a long-term worsening trend associated with increasing extreme weather patterns. Environmental flows had good compliance with water sharing plan rules during the audit period, with a stable trend compared to previous audit results.

17.1. Surface water flow

Surface water flow refers to the rate (ML/day) at which water moves in creeks or rivers within the Catchment. It is calculated using measured river levels at gauging stations. Rates of flow can affect aquatic ecosystems, erosion and water quality. The availability of surface water flow was assessed for this audit by considering:

- The variability of streamflow at stream gauge locations throughout the Catchment
- Surface water extraction.

17.1.1. Flow rate

Flow data for the Catchment were collected at WaterNSW's network of 49 river gauging stations (Figure 17-1). Table 17-1 indicates the date when records began at each station and the change in daily median streamflow during the audit period compared to the long-term values. Percentage changes in median streamflow for the audit period compared to long term records are graphed for each station in Figure 17-2. Key findings from the available data include:

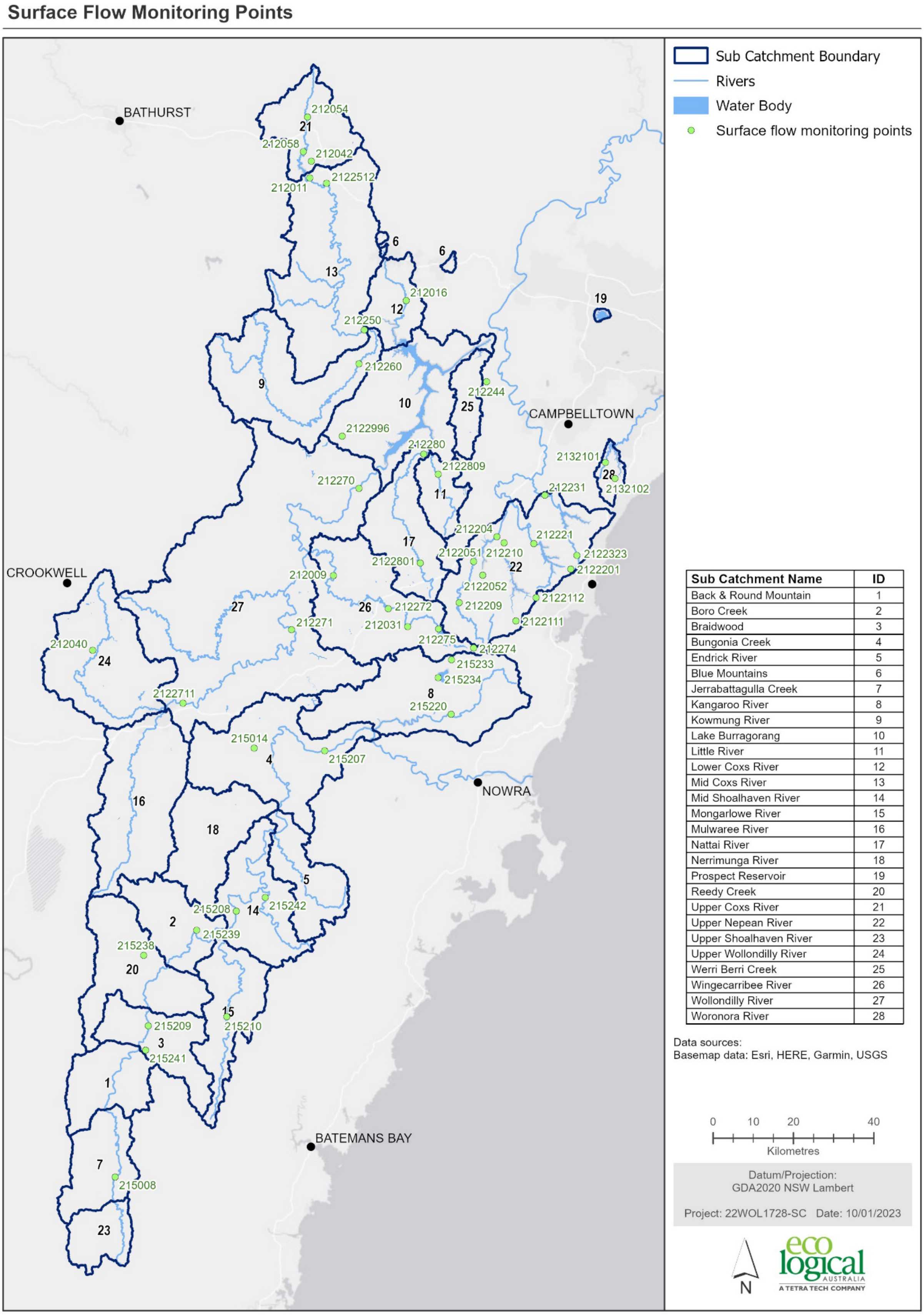
- 90% of sites experienced higher median surface water flow during the current audit period than long-term. This was due to periods of heavy rainfall in 2020-2022.
- Sites that had lower median stream flows during the audit period compared to long-term were:
    - 2122996 Tonalli No 2 – flow has been monitored at this site since 2003. Median flow during the audit period was 0.9 ML/day compared to 2.7 ML/day in previous years (Table 17-1). The graph in section 5.1 of Appendix E shows that there were negligible flows in 2019-21 but flows substantially increased in 2022.
    - 212275 Wingecarribee River at Sheepwash Bridge – flow has been monitored at this site since 1986. Median flow during the audit period was 5.5 ML/day compared to 8.3 ML/day in previous years (Table 17-1). The higher historic flow appears to have been influenced by a series of high flows between 2003 and 2009 (see graph in section 5.1 of Appendix E).
    - 212016 Kedumba River at Kedumba Crossing – flow has been monitored at this site since 1990. Median flow during the audit period was 19.2 ML/day compared to 19.6 ML/day in previous years (Table 17-1). The graph in section 5.1 of Appendix E indicates frequent fluctuations in flows at this site, although no flows were recorded in early 2020. Measurements at this time may have been disrupted by bushfires in the area.
    - 212231 Cataract River at Jordans Crossing – flow has been monitored at this site since 1967. The site experiences some of the highest median daily flows at monitoring sites in the Catchment. The drought at the end of 2019 may have influenced the lower median flow

during the audit period, which was 100.7 ML/day compared to 115.4 ML/day in previous years (Table 17-1; Appendix E).

    - 2122111 Avon River at Summit Tank – flow has been monitored at this site since 1990, although the graph in Appendix E shows no flow recorded from 1996 to 2007. The drought at the end of 2019 may have influenced the lower median flow during the audit period, which was 3.9 ML/day compared to 4.3 ML/day in previous years (Table 17-1).

- The graphs in section 5.1 of Appendix E indicate that even sites with lower median stream flows during the audit period compared to long-term experienced days of high stream flow during the audit period.
- Four sites experienced notably greater median streamflow during the audit period compared to long-term, as shown in bold text in Table 17-1 and results are graphed in section 5.2 of Appendix E. These four sites had notably higher flows since 2020 compared to previous years, mostly likely associated with rainfall patterns:
    - 2122512 Coxs River at Glenroy Bridge – median flow during the audit period was 83.2 ML/day compared to 16.6 ML/day in the preceding years, back to when monitoring began in 1999.
    - 2122711 Wollondilly River at Murrays Flat – median flow during the audit period was 57.3ML/day compared to 10.6 ML/day in the preceding years, back to when monitoring began in 1990.
    - 215241 Jembaicumbene Creek at Bendoura – median flow during the audit period was 63.9 ML/day compared to 11.6 ML/day in the preceding years, back to when monitoring began in 1994.
    - 215238 Reedy Creek at Manar – median flow during the audit period was 67.2 ML/day compared to 4.9 ML/day in the preceding years, back to when monitoring began in 1994.
- Another site of interest is 2122725 Mulwaree River at Towers Weir (upstream of Goulburn), which had a median flow prior to the audit period of 0 ML/day but 8.4 ML/day during the audit period. As graphed in Appendix E, the site frequently experienced no flows prior to 2020 back to when monitoring commenced in 1990.

Overall, the long-term data record for monitoring sites in the Catchment indicates increasing variability of flows under the influence of more extreme periods of droughts and heavy rainfall.



Sub Catchment Name	ID
Back & Round Mountain	1
Boro Creek	2
Braidwood	3
Bungonia Creek	4
Endrick River	5
Blue Mountains	6
Jerrabattagulla Creek	7
Kangaroo River	8
Kowmung River	9
Lake Burragorang	10
Little River	11
Lower Coxs River	12
Mid Coxs River	13
Mid Shoalhaven River	14
Mongarlowe River	15
Mulwaree River	16
Nattai River	17
Nerrimunga River	18
Prospect Reservoir	19
Reedy Creek	20
Upper Coxs River	21
Upper Nepean River	22
Upper Shoalhaven River	23
Upper Wollondilly River	24
Werri Berri Creek	25
Wingecarribee River	26
Wollondilly River	27
Woronora River	28

Figure 17-1: WaterNSW streamflow gauging station locations

Table 17-1: Streamflow during the audit period compared to long term records (WaterNSW)

No.	Site	Sub-catchment	First record	Median flow (ML/day)		% difference*
				Long-term (n years)	Audit period (n years)	
215239	Boro Creek at Marlowe	Boro Creek	24/02/1994	3.2 (24.1 yrs)	5.5 (3 yrs)	70.9%
215209	Shoalhaven River at Mount View	Braidwood	8/11/1973	145.1 (37.4 yrs)	363 (2.6 yrs)	150.2%
215241	Jembaicumbene Creek At Bendoura	Braidwood	29/08/1994	11.6 (22.6 yrs)	63.9 (2.4 yrs)	**453.4%**
215014	Bungonia Creek at Bungonia	Bungonia Creek	14/04/1981	0.9 (38.2 yrs)	1.7 (3 yrs)	92.8%
215207	Shoalhaven River at Fossickers Flat	Bungonia Creek	15/07/1977	349.1 (41.4 yrs)	634.1 (2.1 yrs)	81.6%
215008	Shoalhaven River at Kadona	Jerrabattagulla Creek	16/09/1950	45.6 (48.5 yrs)	110.6 (2.9 yrs)	142.8%
215220	Kangaroo River at Hampden Bridge	Kangaroo River	7/11/1973	160.8 (44.6 yrs)	202.4 (2.8 yrs)	25.9%
215233	Yarrunga Creek at Wildes Meadow	Kangaroo River	15/11/1973	6.4 (44.9 yrs)	7.9 (2.9 yrs)	23.2%
215234	Yarrunga Creek at Fitzroy Falls	Kangaroo River	1/03/1983	12 (35.8 yrs)	13.2 (3 yrs)	10.3%
212260	Kowmung River @ Cedar Ford	Kowmung River	18/05/1968	124.4 (50.1 yrs)	289.1 (1.6 yrs)	132.5%
2122996	Tonalli No 2	Lake Burragorang	19/07/2003	2.7 (7.6 yrs)	0.9 (1.3 yrs)	-66.4%
2122809	Little River @ fire road (W4I)	Little River	21/08/1990	3 (22.3 yrs)	4.2 (3 yrs)	37.6%
212016	Kedumba River @ Kedumba Crossing	Lower Coxs River	2/06/1990	19.6 (27.6 yrs)	9.2 (2.2 yrs)	-53.1%
212011	Coxs River at Lithgow	Mid Coxs River	27/05/1960	29.2 (57.8 yrs)	64.3 (3 yrs)	119.8%
212250	Coxs River @ Kelpie Point	Mid Coxs River	1/11/1966	156 (51.6 yrs)	320.5 (2.6 yrs)	105.4%
2122512	Coxs River @ Glenroy Bridge	Mid Coxs River	1/05/1999	16.6 (19.6 yrs)	83.2 (3 yrs)	**402.0%**
215208	Shoalhaven River at Hillview	Mid Shoalhaven River	7/11/1973	286.2 (45 yrs)	617.9 (3 yrs)	115.9%
215242	Corang River at Meangora	Mid Shoalhaven River	3/12/1994	19.3 (23.5 yrs)	42.6 (2.9 yrs)	120.9%
215210	Mongarlowe River at Mongarlowe	Mongarlowe River	8/11/1973	47.6 (36.5 yrs)	97.7 (2.7 yrs)	105.4%
212280	Nattai River @ Smallwoods	Nattai River	7/07/1965	17.6 (50.8 yrs)	40.4 (1.7 yrs)	130.3%
2122801	Nattai River @ The Crags	Nattai River	12/07/1990	5.5 (28 yrs)	17.5 (2.9 yrs)	220.0%
215238	Reedy Creek at Manar	Reedy Creek	18/02/1994	4.9 (24.8 yrs)	67.2 (1.9 yrs)	**1285.2%**

No.	Site	Sub-catchment	First record	Median flow (ML/day)		% difference*
212042	Farmers Creek at Mt Walker	Upper Coxs River	24/09/1980	14.8 (37.4 yrs)	23.4 (3 yrs)	58.2%
212054	Coxs River at Wallerawang	Upper Coxs River	18/01/1992	16.7 (27.3 yrs)	20.9 (3 yrs)	24.5%
212058	Coxs River at u/s Lake Lyell	Upper Coxs River	14/12/2000	25.3 (18.2 yrs)	52.3 (3 yrs)	107.0%
212204	Nepean River at Avon Dam Road	Upper Nepean River	23/07/1986	92.2 (30.4 yrs)	197.9 (2.8 yrs)	114.8%
212209	Nepean River at Maguires Crossing	Upper Nepean River	5/02/1970	35.8 (49 yrs)	76.9 (3 yrs)	114.9%
212210	Avon River at Avon Weir	Upper Nepean River	27/06/1969	2.4 (46.9 yrs)	7.9 (2.6 yrs)	236.3%
212221	Cordeaux River at Cordeaux Weir	Upper Nepean River	22/06/1990	33.8 (27.2 yrs)	59.3 (3 yrs)	75.2%
212231	Cataract River at Jordans Crossing	Upper Nepean River	9/11/1967	115.4 (42.3 yrs)	100.7 (3 yrs)	-12.7%
2122051	Nepean River at Nepean Dam Inflow	Upper Nepean River	17/02/1990	29.4 (28 yrs)	87.2 (3 yrs)	196.8%
2122052	Burke River at Nepean Dam Inflow	Upper Nepean River	19/02/1990	10.7 (28.5 yrs)	15.8 (2.9 yrs)	46.9%
2122111	Avon River at Summit Tank	Upper Nepean River	29/03/1990	4.3 (17.5 yrs)	3.9 (3 yrs)	-8.4%
2122112	Flying Fox No3 Creek at Upper Avon	Upper Nepean River	26/06/1990	0.5 (11.9 yrs)	0.6 (3 yrs)	11.8%
2122201	Goondarrin Creek at Kemira ‘D’ Cast	Upper Nepean River	3/08/1990	0.8 (14 yrs)	0.8 (3 yrs)	0.8%
2122323	Cataract River at Angels Creek	Upper Nepean River	3/06/1990	4.6 (14.3 yrs)	4.6 (2.9 yrs)	1.3%
212040	Kialla Creek at Pomeroy	Upper Wollondilly River	1/01/1990	3.1 (29.5 yrs)	8.1 (2.2 yrs)	164.3%
212244	Werriberri Ck @ Werombi	Werriberri Creek	30/06/1988	2.6 (29.1 yrs)	5.3 (1.8 yrs)	105.0%
212009	Wingecarribee River at Greenstead	Wingecarribee River	26/10/1989	43.6 (28.5 yrs)	58.5 (2.5 yrs)	34.0%
212031	Wingecarribee River @ Bong Bong Weir	Wingecarribee River	7/06/1989	18.9 (29.5 yrs)	21.1 (2.9 yrs)	12.0%
212272	Wingecarribee River @ Berrima	Wingecarribee River	22/08/1975	26.6 (43 yrs)	34.4 (3 yrs)	29.5%
212274	Caalang Creek at Maugers	Wingecarribee River	26/11/1986	6.9 (32 yrs)	8.9 (3 yrs)	29.7%
212275	Wingecarribee River At Sheepwash Bridge	Wingecarribee River	9/10/1986	8.3 (32.2 yrs)	5.5 (3 yrs)	-33.4%
212270	Wollondilly River @ Jooriland	Wollondilly River	15/12/1961	213.2 (55.9 yrs)	407.5 (2.6 yrs)	91.2%
212271	Wollondilly River @ Golden Valley	Wollondilly River	2/01/1974	35.4 (36.3 yrs)	50.5 (1.8 yrs)	42.7%
2122711	Wollondilly River @ Murrays Flat	Wollondilly River	17/08/1990	10.6 (27.4 yrs)	57.3 (2.9 yrs)	**442.5%**

No.	Site	Sub-catchment	First record	Median flow (ML/day)		% difference*
2122725	Mulwarree River @ Towers	Wollondilly River	7/06/1990	0 (28.4 yrs)	8.4 (2.8 yrs)	n/a
2132101	Woronora River at Fire Rd 9F	Woronora River	21/02/2007	0.9 (11.2 yrs)	1.6 (2.7 yrs)	72.1%
2132102	Waratah River at Fire Rd No 95	Woronora River	21/02/2007	4.4 (12.3 yrs)	6.1 (3 yrs)	38.6%

*(Long term median – Audit median) / Long term median (refer to Figure 17-2 for graphed results)

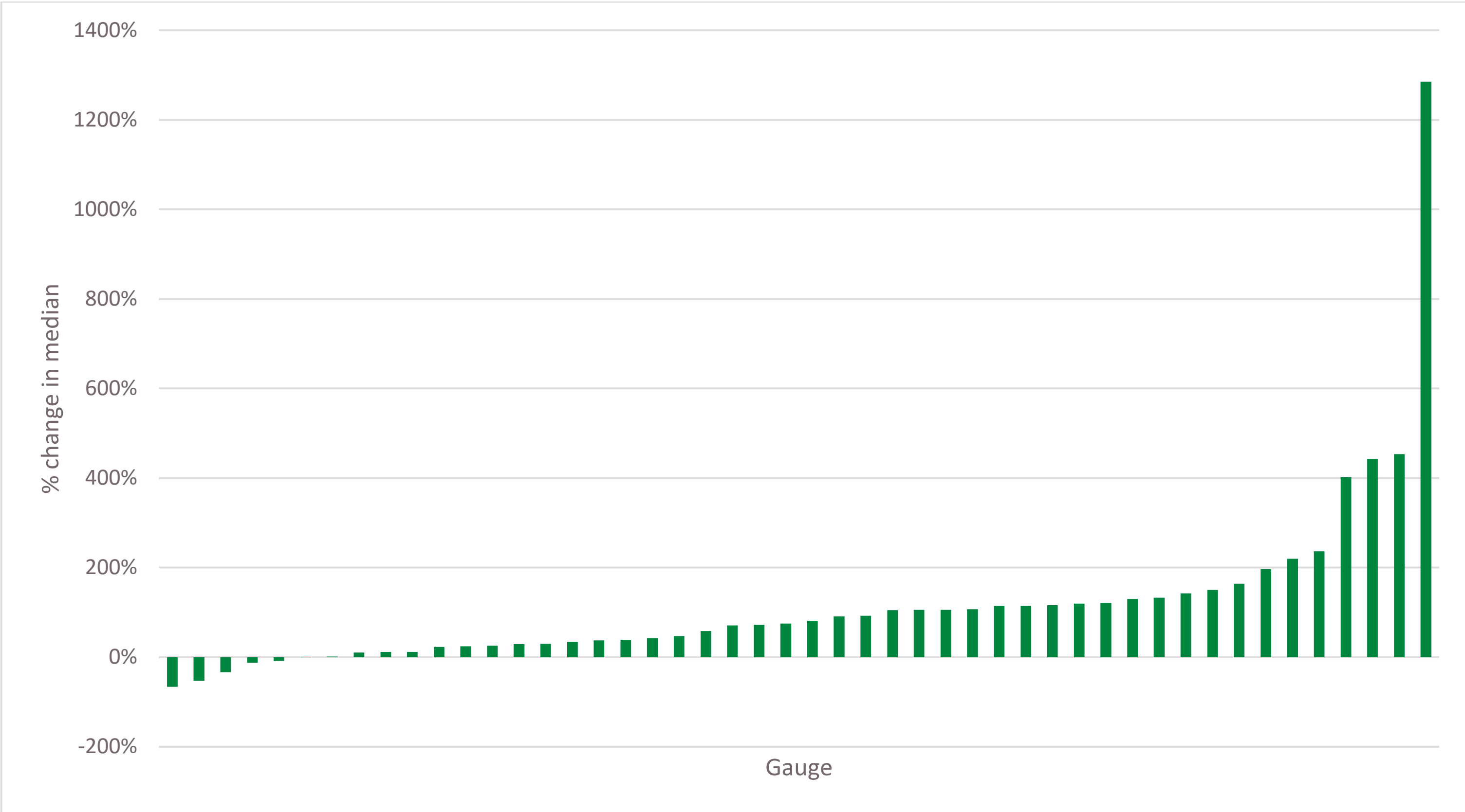


Figure 17-2: Percentage change in median streamflow for the audit period compared to long term records

17.1.2. Surface water extraction

Surface water extraction in the Catchment is regulated in accordance with the Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources 2011 (section 3.7). The vision stated in the Plan 'is to provide for healthy and enhanced water sources and water dependent ecosystems and for equitable water sharing among users in these water sources'. The Plan aims to:

- Provide water users with a clear picture of when and how water will be available for extraction
- Protect the fundamental environmental health of the water source
- Ensure the water source is sustainable in the long-term.

An audit of the 2011 Plan by the Natural Resources Commission (NRC) in 2021 found that:

- Current long term average annual extraction limits (LTAAELs) were not based on sound evidence of sustainability
- LTAAELs were not easily calculated as they were based on poor historical records
- Multiple LTAAELs could not be compared within and across catchments to manage impacts overall extraction
- Without numerical LTAAELs analysis of compliance with the LTAAELs could not be undertaken
- Available water determinations were ineffective
- Some extractions were not accounted within the LTAAELs.

The NRC concluded that the plan should be revised by DPE Water to:

- Set sustainable extraction limits, including:
  - Develop numeric, sustainable LTAAELs based on improved knowledge
  - Consider all extraction in LTAAEL calculation, including currently unlicenced mining activities
  - Finalise policies around exempt extraction
  - Use available water determinations to more effectively manage droughts
- Define environmental water requirements
- Consider surface and groundwater holistically to secure Sydney's water supply
- Make the plans fit for purpose
- Enhance equity.

An updated water sharing plan is scheduled for release in mid-2023 and is being developed by DPE Water using:

- Recommendations from the NRC (2021) review
- Updated data, information and science
- Deliberations across government agencies e.g., DPE, DPI, NRAR, EPA
- Consultation with stakeholders including Sydney Water and WaterNSW
- Development of the draft Greater Sydney Water Strategy.

In June 2022, DPE published the Background and Proposed Changes for the Draft Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources 2023. This summarises changes proposed in the draft 2023 plan, although it did not consider implications of the floods that occurred in

2022. A key aim of the revised plan is to provide clearer rules for water users to follow and implement. Other changes have been proposed to:

- The general structure of the plan
- Water source names
- The vision, objectives, strategies, and performance indicators
- The identification of individual planned environmental water provisions
- Review of environmental flow releases from storages in the Greater Metropolitan region
- New definition for LTAAELs
- Change the map to reflect plan updates
- Changes to system operation rules for the release of environmental flows from major storages
- Updating flow reference points and access rules
- Update the basic land holder right estimate and access licence share components
- Remove total and individual daily extraction limits
- Changes to trade provisions
- Updating metering provisions to account for the non-urban metering framework
- Prohibit water supply works approvals near State Environmental Planning Policies wetlands and near potential acid sulphate soils
- Prohibit in-river dams in high-value water sources
- Adaptive management and amendment provisions.
- Remove exemptions to access rules in the Hawkesbury and Lower Nepean extraction management unit.

The next Catchment audit will consider the adopted revised water sharing plan.

17.1.3. Case study – Upper Coxs River sub-catchment

Surface water flows in the Upper Coxs River are affected by land uses that include mining, agriculture, urban and industrial. Substantial changes are underway in this area as part of the long-term transition from coal mining and coal-fired power stations to more sustainable land uses. As outlined in section 8.8, this auditor met with representatives of EnergyAustralia to discuss water management in the Upper Coxs River sub-catchment. Water Access Licence 27428, issued under the *Water Management Act 2000* and in accordance with the water sharing plan rules, for the (now closed) Wallerawang power station and (currently operational) Mt Piper power station states:

> 'The Licence Holder must not take water under this access licence other than in compliance with the conditions of the water supply work and water use approval nominated by this licence. The nominated water supply work and water use approval for this licence is 10CA117220.'

This requirement prevents water being reallocated to benefit Catchment health in the Upper Coxs River sub-catchment even when there is a change of land use. As indicated in section 8.8.2, it is likely that EnergyAustralia will seek to modify the terms of the current 30-year licence to reflect changing conditions and improve environmental outcomes.

17.2. Environmental flows

17.2.1. Definition and context

Dams and weirs within the Catchment affect the natural flow of water through waterways and can impact the shape and structure of the river channels, their water quality and the ecological communities that depend on them. The Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources 2011 requires environmental flows to be released by WaterNSW from dams to reinstate a more natural flow regime downstream. The volumes released from dams for environmental flows aim to balance moderate to high water level water storage needs with downstream base flow river health.

Water sharing plan requirements for environmental flows are defined as either a specified quantity of water over a set period for some storages (e.g., Warragamba Dam), or as a proportion of inflows for others (e.g., storages within the Nepean catchment). Environmental releases are not usually required when the storage is spilling at a rate equal to or greater than the defined environmental release (NSW Office of Water 2011).

17.2.2. Data and method

Consistent with previous audits, environmental flows were assessed by measuring the degree of compliance of the environmental water deliveries during the audit period with the environmental flow rules defined in the water sharing plans. The result was expressed as a percentage of days where the actual release met the water sharing plan requirement and results were categorised as follows:

- Good – Environmental flow rules were achieved more than 95% of the time.
- Moderate – Environmental flow rules were achieved between 85-95% of the time.
- Poor – Environmental flow rules were achieved less than 85% of the time.

To assess the trend in environmental flow delivery at each declared storage, the degree of achievement of the environmental flow rules was compared between the current audit period (2019-22) and previous audit periods (2013-16 and 2016-19). These periods were considered as they cover the duration of the current (2011) Water Sharing Plan environmental rules. Consistent with the previous audit, the categories used to determine the trend were:

- Improving – Proportion of time environmental flow rules were achieved increased by 5% or more.
- Stable – Proportion of time environmental flow rules were achieved in 2016-2019 was within 5% of the previous results.
- Worsening – Proportion of time environmental flow rules were achieved reduced by 5% or more.

17.2.3. Findings

Compliance data in Table 17-2 were provided by WaterNSW for the current audit period and demonstrate overall good compliance with the environmental flow rules in the 2011 Water Sharing Plan. Further details were available from the annual compliance reports by WaterNSW for the Greater Metropolitan Region Unregulated River Water Sources Water Sharing Plan. As stated in the annual compliance reports:

> 'In accordance with the operating protocol, notifications were provided to NRAR for any planned or unplanned events which had the potential to result in noncompliance with approval

conditions. On each occasion, WaterNSW and NRAR agreed on a strategy to compensate for any shortfall of daily requirements.'

Table 17-2: Compliance with environmental flow rules 2019-22

Dam/Weir	Sub-catchment	River system	% Compliance	Status
Warragamba Dam	Lake Burragorang	Warragamba System	100.00%	**Good**
Wingecarribee Dam	Wingecarribee River	Shoalhaven System	93.70%	**Moderate**
Tallowa Dam	Kangaroo River	Shoalhaven System	91.70%	**Moderate**
Fitzroy Falls	Kangaroo River	Shoalhaven System	86.10%	**Moderate**
Cataract Dam	Upper Nepean	Upper Nepean System	99.70%	**Good**
Cordeaux Dam	Upper Nepean	Upper Nepean System	95.50%	**Good**
Avon Dam	Upper Nepean	Upper Nepean System	93.70%	**Moderate**
Nepean Dam	Upper Nepean	Upper Nepean System	94.80%	**Moderate**
Broughton Pass Weir	Upper Nepean	Upper Nepean System	100.00%	**Good**
Pheasants Nest Weir	Upper Nepean	Upper Nepean System	99.50%	**Good**
Woronora Dam	Woronora River	Woronora System	99.50%	**Good**
Average			95.80%	**Good**

Comparison of the current compliance results with previous audit results indicates an overall stable trend, although three storages (Wingecarribee, Fitzroy Falls and Avon Dams) experienced a worsening trend.

Table 17-3: Trends in environmental flow compliance

Dam/Weir	2013-16	2016-19	2019-22	Status
Warragamba Dam	99%	100%	100.00%	**Stable**
Wingecarribee Dam	100%	100%	93.70%	**Worsening**
Tallowa Dam	93%	93%	91.70%	**Stable**
Fitzroy Falls	92%	100%	86.10%	**Worsening**
Cataract Dam	99%	100%	99.70%	**Stable**
Cordeaux Dam	100%	99%	95.50%	**Stable**
Avon Dam	98%	99%	93.70%	**Worsening**
Nepean Dam	99%	94%	94.80%	**Stable**
Broughton Pass Weir	100%	100%	100.00%	**Stable**
Pheasants Nest Weir	100%	99%	99.50%	**Stable**
Woronora Dam	100%	100%	99.50%	**Stable**
Average	98%	98%	95.80%	**Stable**

17.3. Conclusions and recommendations

Surface water flows during the audit period were strongly influenced by the drought and subsequent periods of heavy rainfall. Gaps in the data record indicate some gauges were damaged or inaccessible due to floods, landslips, etc. It is recommended that a Catchment disaster mitigation plan be developed that considers the resilience of critical water monitoring infrastructure in the Catchment during extreme climate-driven events. The plan should determine what is monitored or used, where, how, by whom, and for what purpose. This information should be assessed against an integrated hierarchy of requirements, with a program of changes developed with relevant agencies, if needed.

18. Groundwater availability

Groundwater availability in the Catchment was assessed as good with a stable trend. The confidence in this assessment would be improved with additional monitoring data.

18.1. Groundwater management

Groundwater is an important environmental and economic resource that needs to be managed sustainably. Extraction of groundwater for human consumption, such as for drinking water, agriculture or industrial use can reduce the water that is available to the environment. Environmental water requirements include maintaining surface water base flow, wetlands and other groundwater dependent ecosystems.

The *Water Management Act 2000* defines a 'water source' as the primary unit for managing groundwater. Groundwater sources consist of one or more groundwater systems that comprise aquifers that have been categorised into broad hydrogeological types. Groundwater sources are constrained by hydrogeological boundaries (watersheds, aquitards or other physical boundaries to groundwater flow, such as the coast or igneous intrusions) and can overlie one another, thus causing all or part of another groundwater source to be buried. The Catchment features seven groundwater sources (Figure 18-1).

18.1.1. 2011 Water Sharing Plan

The Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011 provided a legislative basis for sharing water between the environment and other users during the audit period. It sets long-term average annual extraction limits (LTAAELs) for each water source, and addresses access, trade and works (bore) approvals and rules for the use and trade of groundwater. The take of groundwater for consumptive uses and any aquifer interference activities are required to be accounted for through a water access licence (WAL), unless an exemption applies (e.g., stock and domestic rights), except where an access dealing rule is in force.

Licences to take groundwater are linked to a particular groundwater source and entitle their holder to one or more shares in the available water within that groundwater source. The volumetric equivalent of these shares is determined by rules and management arrangements that align with the *Water Management Act 2000* for water sources which are specified in statutory water sharing plans. A share is nominally set at 1 ML/a unless groundwater extraction exceeds sustainable limits (see section 18.2.1).

18.1.2. Draft revised Water Sharing Plan

As outlined in section 3.7, DPE released a draft *Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2023* and it is expected that the replacement plan will come into effect by 1 July 2023. In general, and where possible, the changes aim to modernise and simplify the water sharing plan to make it easier to read while ensuring provisions are implementable and legally accurate. Changes have been proposed that reflect recommendations from the NRC (2021), contemporary water resource policy, updated data, information and science, the need for clear rules which are easier for water users to follow, and the draft Greater Sydney Water Strategy (DPE 2022b).

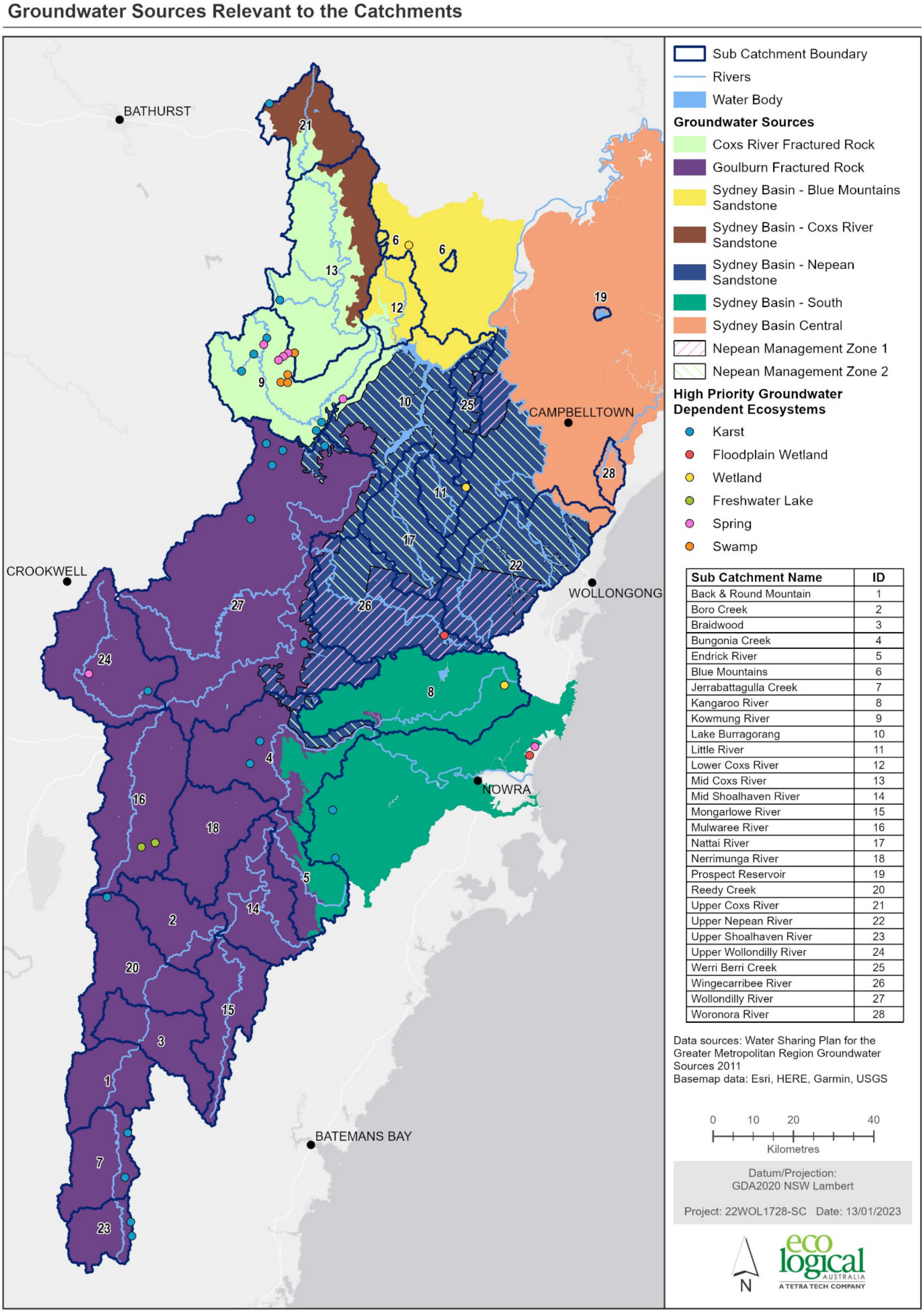


Figure 18-1: Groundwater sources in the Catchment

Major changes in the draft 2023 water sharing plan include:

- The amalgamation of some groundwater sources to recognise shared aquifers, hydrogeological characteristics and comparable rainfall patterns between the combined groundwater sources.
- Changes to groundwater source boundaries to recognise the 'stacked' nature of the region's groundwater sources.
- Changes to groundwater source definitions to complement the boundary changes.
- Removal of recharge figures from the plan – recharge volume estimates were made and used to derive the LTAAEL and establish and maintain planned environmental water.
- Revised LTAAELs based on updated rainfall data, an improved method for estimating groundwater recharge, the identification of additional groundwater dependent ecosystems, updated information on groundwater demand and a revised risk assessment method.
- Changes to access rules, particularly for cease to pump and commence to pump rules, very low flow class conditions, and rules for water supply works on waterfront land.
- Revised schedule of groundwater dependent ecosystems.
- Greater protection for coastal wetlands.
- Changes to the distance rules from contaminated sites.

Although the draft 2023 plan was not in force during the audit period, the draft plan and its supporting documents provide updated information and data about the groundwater sources within the Catchment, and thus have been incorporated into the audit where relevant. Adoption of the draft Plan changes will substantially address management concerns raised in the 2019 Catchment audit.

18.2. Water access rights and extraction limits

18.2.1. Sustainable extraction limits

Sustainable groundwater extraction limits in the 2011 water sharing plan were developed using an approach that clarifies a range of values and risks. It included calculation of the recharge volume to each groundwater source. The recharge calculations for all the Greater Metropolitan Region groundwater sources in the 2011 water sharing plan were a percentage of average annual rainfall between 1921 and 1995 over the groundwater source area. This was updated in the 2015 review of the plan to include rainfall up to 2012.

As part of the five-year plan review, DPI Water commissioned a review of rainfall recharge rates for coastal porous rock groundwater sources. This review identified that recharge rates used for coastal porous rock aquifers might be overestimating true recharge to the system (EMM 2015). Rather than a 6% infiltration rate as used in the water sharing plan, EMM (2015) recommended use of a 1% infiltration rate for Permian and 5% infiltration rate for Triassic sandstones in the Sydney Basin. The recharge infiltration rates and recharge volumes from the 2011 water sharing plan (NOW 2011) and the revised recharge rates and volumes (EMM 2015) are presented in Table 18-1.

The draft 2023 plan used updated information and data to determine the recharge volumes for each of the groundwater sources, taking into account the infiltration rate for all the rock types at the surface of the groundwater source, an expanded rainfall dataset to 2019, and the effects of climate change on average annual rainfall. Infiltration rates for the revised 2023 water sharing plan have not been published. The revised rainfall recharge is shown for each water source in Table 18-1, noting some water sources have been amalgamated in the draft 2023 plan. In all cases, the estimated rainfall recharge has been reduced.

Table 18-1: Estimated groundwater recharge in groundwater sources within the Catchment

<table>
<tr><th rowspan="2">Source</th><th colspan="2">Recharge infiltration rate (% average rainfall)</th><th colspan="3">Recharge (ML/year)</th></tr>
<tr><th>2016 audit[a]</th><th>2019, 2022 audits[b]</th><th>2016 audit[a]</th><th>2019, 2022 audits[b]</th><th>Draft 2023 WSP</th></tr>
<tr><td>Sydney Basin North</td><td>6</td><td>5</td><td>269,187</td><td>224,322</td><td>219,851</td></tr>
<tr><td>Sydney Basin South</td><td>6</td><td>5</td><td>225,326</td><td>187,772</td><td>92,897</td></tr>
<tr><td>Sydney Basin Nepean</td><td>6</td><td>5</td><td>224,483</td><td>187,069</td><td>161,763</td></tr>
<tr><td>Sydney Basin Central</td><td>6</td><td>5</td><td>229,223</td><td>191,019</td><td>173,372</td></tr>
<tr><td>Sydney Basin Richmond</td><td>6</td><td>5</td><td>127,878</td><td>106,565</td><td rowspan="3">169,889[c]</td></tr>
<tr><td>Sydney Basin Blue Mountains</td><td>6</td><td>5</td><td>78,474</td><td>65,395</td></tr>
<tr><td>Sydney Basin Coxs River</td><td>6</td><td>5</td><td>31,312</td><td>26,094</td></tr>
<tr><td>Coxs River Fractured Rock</td><td>4</td><td>1</td><td>67,087</td><td>16,574</td><td rowspan="2">355,944[d]</td></tr>
<tr><td>Goulburn Fractured Rock</td><td>4</td><td>1</td><td>259,784</td><td>64,946</td></tr>
</table>

NOTES: [a] NOW (2011), with update as recorded in the 2015 update to the WSP, [b] EMM (2015), [c] the Sydney Basin Richmond, Blue Mountains and Cox's River Groundwater Sources have been amalgamated in the proposed 2023 Draft WSP into the Sydney Basin West Groundwater Source, [d] the Cox's River and Goulburn Fractured Rock Groundwater Sources have been amalgamated in the proposed 2023 Draft WSP into the Lachlan Fold Belt Greater Metropolitan Groundwater Source.

A risk assessment was then used to reserve the volume of recharge for planned environmental water and the volume that is potentially available for extraction in each groundwater source. Sustainable groundwater volumes beneath high value conservation areas (such as national parks, nature reserves and historic and Aboriginal sites) are treated separately to the rest of the water source in that 95 or 100% of the estimated recharge is reserved as planned environmental water and is therefore not available for extraction. Across the remainder of the water source the percentage of recharge that is reserved as environmental water is determined by the sustainability factor, which determines the proportion of recharge from non-conservation areas available for extraction. The sustainability factor weighs the environmental values in each groundwater source against the socio-economic dependence on groundwater. Sustainability factors are determined based on a risk matrix and vary from 25% to 60% for groundwater sources within the Catchment (Table 18-2).

The risk assessments for each groundwater source were reviewed as part of the development of the 2023 draft plan. As a result, sustainability factors for five of the seven groundwater sources in the Catchment have been revised (Table 18-3). Significantly, the environmental and socio-economic risks are considered to have generally decreased, except for the north-western groundwater sources which have a higher socio-economic risk. The Fractured Rock Groundwater Sources have changed from high to low environmental risk in the 2023 water sharing plan.

Table 18-2: Sustainability factors for groundwater sources within the Catchment (2011 WSP)

Environmental risk	Low socio-economic risk	Moderate socio-economic risk	High socio-economic risk
High	5%	25% Goulburn Fractured Rock Coxs River Fractured Rock	50%
Moderate	25% Sydney Basin Blue Mountains Sydney Basin Central	50% Sydney Basin South	60% Sydney Basin Nepean
Low	50%	60% Sydney Basin Cox's River	70%

Table 18-3: Sustainability factors for groundwater sources within the Catchment in the proposed 2023 Draft WSP

Environmental risk	Low socio-economic risk	Moderate socio-economic risk	High socio-economic risk
High	5%	25%	50%
Moderate	25%	50%	60% Sydney Basin Nepean
Low	50% Sydney Basin South [a,b] Lachlan Fold Belt [d]	60%	70% Sydney Basin West[c]

NOTES: [a] groundwater sources that have lower environmental risk in the 2023 WSP as compared to the 2011 WSP. [b] groundwater sources that have higher environmental risk in the 2023 WSP as compared to the 2011 WSP, [c] groundwater sources that have lower socio-economic risk in the 2023 WSP as compared to the 2011 WSP, [d] Lachlan Fold Belt Greater Metropolitan Groundwater Source will replace the Goulburn and Coxs River Fractured Rock Groundwater Sources and Sydney Basin West Groundwater Source will replace Sydney Basin Coxs River and Sydney Basin Blue Mountains Groundwater Sources.

The percentage of water potentially available for extraction is termed the long-term average annual extraction limit (LTAAEL) and is expressed in megalitres per year (ML/year); this is the estimated sustainable limit for each of the groundwater sources. The changing LTAAEL for the groundwater sources in the Greater Metropolitan Region over successive audit periods are listed in Table 18-4. The LTAAEL was calculated by applying the sustainability factor derived from the risk assessment process, which determined the percentage of the average annual rainfall recharge over the non-high environmental areas that can be potentially made available for extraction. Also added to this figure is 5% of the recharge from the high environmental value areas where applicable.

Table 18-4 also includes the proposed LTAAEL for each groundwater source from the draft 2023 plan. The LTAAEL of three water sources has increased; all others have decreased when compared to the 2011 plan. This reflects changes to the recharge estimates and/or the risk assessment and resulting sustainability factor applied.

Table 18-4: LTAAEL for each groundwater source within the Catchment

Source	LTAAEL (ML/year)		
	2016 audit[a]	**2019, 2022 audits[b]**	**Draft 2023 WSP**
Sydney Basin North	19,682	16,402	25,297
Sydney Basin South	69,892	58,243	30,584
Sydney Basin Nepean	99,568	82,973	64,785
Sydney Basin Central	45,915	38,263	31,859
Sydney Basin Richmond	21,103	17,586	36,045[c]
Sydney Basin Blue Mountains	7,039	3,245	
Sydney Basin Coxs River	17,108	14,257	
Coxs River Fractured Rock	7,005	1,702	133,949[d]
Goulburn Fractured Rock	53,074	13,269	

NOTES: [a] NOW (2011), with update as recorded in the 2015 update to the WSP, [b] EMM (2015), [c] the Sydney Basin Richmond, Blue Mountains and Cox's River Groundwater Sources have been amalgamated in the proposed 2023 Draft WSP into the Sydney Basin West Groundwater Source, [d] the Cox's River and Goulburn Fractured Rock Groundwater Sources have been amalgamated in the proposed 2023 Draft WSP into the Lachlan Fold Belt Greater Metropolitan Groundwater Source.

Total extraction in the groundwater source is managed to the LTAAEL. A growth in use response will be triggered if average annual usage over a three-year period in a groundwater source exceeds the LTAAEL by more than 5%. Growth in use is managed through a reduction (from 100%) in the available water determination for aquifer access licences in the groundwater source. That is, each share will be reduced from 1 ML/a by the stipulated reduction factor. The available water determination will be reduced by an amount necessary to return total water extractions to the LTAAEL.

18.2.2. Unassigned water

Unassigned water is the water potentially available for extraction under the LTAAEL that is not yet allocated to an access licence, and not estimated to be required to meet current and potential future priority requirements for extraction. This includes basic landholder rights extraction, extractions by specific purpose access licences (for example major and local utilities, i.e., town and urban water supplies) and Aboriginal cultural rights or from other exemptions under the *Water Management Act 2000*.

A staged process for any release of new entitlements has been developed for those water sources that have a defined volume of unassigned water. There will be no unassigned water made available where entitlements plus basic landholders' rights equal 90% or more of the LTAAEL. In groundwater sources where total entitlement plus basic landholder rights is less than 90% there may be trading in existing water entitlement. However, in these groundwater sources there is also the potential for the Minister to issue new entitlement through a controlled allocations order under the *Water Management Act 2000*.

18.2.3. Basic landholder rights

Part of the LTAAEL is reserved for basic landholder rights, which includes water for domestic and stock purposes that is extracted from an aquifer underlying the landholder's property. Under section 52 of the *Water Management Act 2000*, groundwater may be extracted to meet defined domestic and stock purposes without a licence, although the work (usually a bore) must still be approved by WaterNSW. The *Water Management Act 2000* requires that water sharing must protect basic landholder rights, which is achieved by reserving a water volume for the water requirements for domestic and stock users.

The volume reserved for basic landholder rights has increased since the 2019 audit for the Sydney Basin North, and South groundwater sources, and for the Sydney Basin Richmond/Blue Mountains/Cox's River groundwater sources (amalgamated and reported as the Sydney Basin West Groundwater Source). The volume reserved for the remaining groundwater sources (i.e., the Sydney Basin Nepean and Central Groundwater sources, and the Goulburn River and Cox's River Fractured Rock groundwater sources – amalgamated and reported as the Lachlan Fold Belt Greater Metropolitan Groundwater Source) have decreased (Table 18-5).

Table 18-5: Estimated requirement for basic Landholder Rights in each water source within the Catchment

<table>
<tr><th>Groundwater source</th><th colspan="3">Volume reserved for basic landholder rights (ML/yr)</th></tr>
<tr><th></th><th>2013 Audit[a]</th><th>2016 & 2019 Audits[b]</th><th>2022 Audit[c]</th></tr>
<tr><td>Sydney Basin North</td><td>722</td><td>722</td><td>860</td></tr>
<tr><td>Sydney Basin South</td><td>2098</td><td>2098</td><td>2263</td></tr>
<tr><td>Sydney Basin Nepean</td><td>5971</td><td>5971</td><td>5776</td></tr>
<tr><td>Sydney Basin Central</td><td>2601</td><td>2601</td><td>1972</td></tr>
<tr><td>Sydney Basin Richmond [d]</td><td>1623</td><td>1623</td><td rowspan="3">2578</td></tr>
<tr><td>Sydney Basin Blue Mountains [d]</td><td>421</td><td>421</td></tr>
<tr><td>Sydney Basin Coxs River [d]</td><td>454</td><td>454</td></tr>
<tr><td>Goulburn Fractured Rock [e]</td><td>3114</td><td>3114</td><td rowspan="2">4083</td></tr>
<tr><td>Coxs River Fractured Rock [e]</td><td>179</td><td>190</td></tr>
</table>

NOTES: [a] GHD (2013), [b] WSP (version 1/1/2015, accessed 5/2/2020), [c] estimates are based on the report cards for each groundwater source for the proposed Draft 2023 WSP, [d] the Sydney Basin Richmond, Blue Mountains and Cox's River Groundwater Sources have been amalgamated in the proposed 2023 Draft WSP into the Sydney Basin West Groundwater Source, [e] the Cox's River and Goulburn Fractured Rock Groundwater Sources have been amalgamated in the proposed 2023 Draft WSP into the Lachlan Fold Belt Greater Metropolitan Groundwater Source.

18.2.4. Licenced groundwater entitlement

The total licensed groundwater entitlement includes the volumes assigned (or estimated) to all current groundwater access licenses under the *Water Management Act 2000* (also referred to as unit shares). These are licenses for local water utilities, for aquifer interference and for general purpose water access for consumptive purposes, which includes industrial, irrigation and recreation use. The total entitlement does not include unresolved water licence applications nor current aquifer interference activities that have not yet been assigned a volume (i.e., for which a groundwater access licence has yet to be issued).

Licenced entitlement has grown over the audit period in the Sydney Basin South (789 ML; an additional 3 WALs), Sydney Basin Central (548 ML; an additional 21 WALs), Sydney Basin Nepean (100ML; an additional 7 WALs) and Goulburn Fractured Rock (810 ML; an additional 5 WALs) groundwater sources. Table 18-6 shows the current volumes of licensed entitlement and the number of licences for each groundwater source.

Table 18-6: Licenced groundwater entitlement (or unit shares) for each water source

Groundwater source	Total licenced groundwater entitlement [a] (ML/yr) Values in brackets are town water supply							
	2018/2019		2019/2020		2020/2021		2021/2022	
	Licenced Entitlement	Number of WALs	Licenced Entitlement	Number of WALs	Licenced Entitlement	Number of WALs	Licenced Entitlement	Number of WALs
Sydney Basin North	1,027	29	1,027	29	1,027	29	1,027	29
Sydney Basin South	3,480	99	3,655	101	4,444	105	4,444	104
Sydney Basin Nepean	31,281.4 (13)	382 (2)	31,346.4 (13)	384 (2)	31,446.4 (13)	387 (2)	31,446.4 (13)	391 (2)
Sydney Basin Central	3,554.5	165	3,779.5	175	3,929.5	183	4,327.5	196
Sydney Basin Richmond [b]	16,605.5 (29)	84 (2)	16,605.5 (29)	84 (2)	16,605.5 (29)	84 (2)	16,605.5 (29)	85 (2)
Sydney Basin Blue Mountains [b]	113.7	9	113.7	9	113.7	9	113.7	9
Sydney Basin Coxs River [b]	9,987.5	19	9,987.5	19	9,987.5	19	9,987.5	20
Goulburn Fractured Rock [c]	6,436 (100)	145 (2)	6,726 (100)	150 (2)	7,276 (100)	153 (2)	7,536 (100)	155 (2)
Coxs River Fractured Rock [c]	255.5	13	255.5	14	255.5	14	255.5	14

NOTES: [a] data is sourced from the NSW Water register: https://waterregister.waternsw.com.au/water-register-frame , [b] the Sydney Basin Richmond, Blue Mountains and Cox's River Groundwater Sources have been amalgamated in the proposed 2023 Draft WSP into the Sydney Basin West Groundwater Source however at the time of the audit are still reported as separate water sources in the Register, [c] the Cox's River and Goulburn Fractured Rock Groundwater Sources have been amalgamated in the proposed 2023 Draft WSP into the Lachlan Fold Belt Greater Metropolitan Groundwater Source however at the time of the audit are still reported as separate water sources in the Register.

18.2.5. Groundwater dealings

Permanent and temporary trading is allowed within a groundwater source within the Catchment, but no trading is allowed into or out of a groundwater source. This is to ensure that any groundwater source cannot be further degraded by trading into or out of that source.

The proposed amalgamation of the Sydney Basin Richmond, Blue Mountains and Cox's River Groundwater Sources into the Sydney Basin West Groundwater Source and the Cox's River and Goulburn Fractured Rock Groundwater Sources into the Lachlan Fold Belt Greater Metropolitan Groundwater Source under the proposed draft 2023 water sharing plan, however, means that trade will be allowed between areas which are currently restricted. In addition, the draft plan defines the limit to the sum of share entitlements in Nepean Management Zone 1 as a number of shares, representing the number of shares in the zone at the commencement of the 2011 plan. This was the intent of the 2011 plan and improves the transparency and administration of trade rules.

Permanent dealings

Dealings for groundwater licences can be made under sections 71M (licence transfer), 71N (term licence transfer), 71P (subdivision/consolidation), 71Q (assignment of shares) and 71W (nomination of works) of the *Water Management Act 2000.* Dealings to convert the licence purpose to another category (section 71O) and assign a share component to another water source (section 71R) are not permitted. There are specific dealing restrictions between management zones in the Sydney Basin Nepean groundwater source. That is, section 71Q dealings are not permitted from Management Zone 2 to Management Zone 1 if the dealing exceeds the total access share component at the commencement of the water sharing plan in 2011.

Dealings that can result in a change to the potential volume that can be extracted from a location and therefore have the potential to cause third party impacts are subject to a hydrogeological assessment and may be approved subject to conditions being placed on the nominated work or combined approvals such as bore extraction limits to minimise potential impact on neighbouring bores.

Table 18-7 shows the statistics for dealings that resulted in a change in the potential volume that can be extracted from a location since commencement of the 2011 water sharing plan. Section 71M (licence transfer) dealings are not considered, as these are change of ownership only and therefore have no potential for additional third-party impacts.

Table 18-7: Number of permanent dealings and associated unit shares (volumes) within the Catchment

<table>
<tr><th>Groundwater sources</th><th colspan="3">Permanent dealings [a] (ML/yr)</th></tr>
<tr><td></td><td>2019/2020</td><td>2020/2021</td><td>2021/2022</td></tr>
<tr><td>Sydney Basin North</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Sydney Basin South</td><td>1 (15 unit shares)</td><td>1 (12 unit shares)</td><td>0</td></tr>
<tr><td>Sydney Basin Nepean</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Sydney Basin Central</td><td>0</td><td>0</td><td>1 (3 unit shares)</td></tr>
<tr><td>Sydney Basin Richmond [b]</td><td rowspan="3">0</td><td rowspan="3">0</td><td rowspan="3">0</td></tr>
<tr><td>Sydney Basin Blue Mountains [b]</td></tr>
<tr><td>Sydney Basin Coxs River [b]</td></tr>
<tr><td>Goulburn Fractured Rock [c]</td><td rowspan="2">0</td><td rowspan="2">2 (72 unit shares)</td><td rowspan="2">0</td></tr>
<tr><td>Coxs River Fractured Rock [c]</td></tr>
</table>

NOTES: [a] Draft Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2023: https://www.industry.nsw.gov.au/__data/assets/pdf_file/0017/517031/background-document.pdf https://waterregister.waternsw.com.au/water-register-frame, [b] the Sydney Basin Richmond, Blue Mountains and Cox's River Groundwater Sources have been amalgamated in the proposed 2023 Draft WSP into the Sydney Basin West Groundwater Source however at the time of the audit this data is reported under the proposed WSP water sources, [c] the Cox's River and Goulburn Fractured Rock Groundwater Sources have been amalgamated in the proposed 2023 Draft WSP into the Lachlan Fold Belt Greater Metropolitan Groundwater Source however at the time of the audit this data is reported under the proposed WSP water sources.

Temporary dealings

Generally, the most common type of dealings between groundwater licences are allocation assignments (temporary trades) made under section 71T of the *Water Management Act 2000*. These are permitted between water access licences linked to metered bores only.

There are dealing restrictions between management zones in the Sydney Basin Nepean groundwater source: section 71T dealings are not permitted from Management Zone 2 to Management Zone 1 if the sum of water allocations credited to the water allocation accounts of all access licences of that water year exceeds the total access share component at the commencement of the water sharing plan in 2011. There are no section 71T dealing restrictions in other water sources. Table 18-8 shows section 71T dealings during the last three years.

Table 18-8: Number of temporary dealings and associated volumes within the Catchment

<table>
<tr><th>Groundwater source</th><th colspan="3">Permanent dealings [a] (ML/yr)</th></tr>
<tr><th></th><th>2019/2020</th><th>2020/2021</th><th>2021/2022</th></tr>
<tr><td>Sydney Basin North</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Sydney Basin South</td><td></td><td>1 (12 ML)</td><td>0</td></tr>
<tr><td>Sydney Basin Nepean</td><td>1 (8 ML)</td><td>0</td><td>2 (50 ML)</td></tr>
<tr><td>Sydney Basin Central</td><td>0</td><td>1(10 ML)</td><td>2 (5 ML)</td></tr>
<tr><td>Sydney Basin Richmond [b]</td><td rowspan="3">0</td><td rowspan="3">1 (1,000 ML)</td><td rowspan="3">1 (1,500 ML)</td></tr>
<tr><td>Sydney Basin Blue Mountains [b]</td></tr>
<tr><td>Sydney Basin Coxs River [b]</td></tr>
<tr><td>Goulburn Fractured Rock [c]</td><td rowspan="2">8 (420 ML)</td><td rowspan="2">7 (390 ML)</td><td rowspan="2">0</td></tr>
<tr><td>Coxs River Fractured Rock [c]</td></tr>
</table>

NOTES: [a] data is sourced from the NSW Water register: https://waterregister.waternsw.com.au/water-register-frame , [b] the Sydney Basin Richmond, Blue Mountains and Cox's River Groundwater Sources have been amalgamated in the proposed 2023 Draft WSP into the Sydney Basin West Groundwater Source however at the time of the audit this data is reported under the proposed WSP water sources, [c] the Cox's River and Goulburn Fractured Rock Groundwater Sources have been amalgamated in the proposed 2023 Draft WSP into the Lachlan Fold Belt Greater Metropolitan Groundwater Source however at the time of the audit this data is reported under the proposed WSP water sources.

18.3. Water allocations

A water allocation is the percentage of a licensed water user's entitlement that is credited to their water account for use. Water is allocated using water sharing plans and allocations vary based on the water available in the water source, and the prevailing catchment and weather conditions. For the Catchment groundwater sources, allocations were 1 ML per unit share for each year of the audit period (that is, for every share of water access licence, 1 ML of groundwater could be taken).

18.4. Groundwater use

Groundwater use across the Catchment has showed a decreasing trend over the previous four years in all groundwater sources, except the Sydney Basin Richmond Groundwater Source, which showed a steady increase over the period. However, groundwater meters aren't mandatory so these figures may be misleading.

Table 18-9: Groundwater use for each water source in the Catchment. Values in brackets are Town Water Supply.

Groundwater source	Groundwater use [a] (ML/yr)			
	2018/2019	**2019/2020**	**2020/2021**	**2021/2022**
Sydney Basin North	18.7	17.6	1.8	0
Sydney Basin South	90.8	0	2.1	0
Sydney Basin Nepean	2858.8 (0)	345.7 (0)	151.6 (0)	70.1 (0)
Sydney Basin Central	9.9	0	19	0
Sydney Basin Richmond [b]	13,458.3 (0)	13,802 (0)	14,082.4 (0)	16,934.9 (0)
Sydney Basin Blue Mountains [b]	0	0	0	0
Sydney Basin Coxs River [b]	3,764.2	2,642	2,639	1,517.9
Goulburn Fractured Rock [c]	172.3 (0)	46.5 (0)	30.2 (0)	6.8 (0)
Coxs River Fractured Rock [c]	0	0	0	0

NOTES: [a] data is sourced from the NSW Water register: https://waterregister.waternsw.com.au/water-register-frame , [b] the Sydney Basin Richmond, Blue Mountains and Cox's River Groundwater Sources have been amalgamated in the proposed 2023 Draft WSP into the Sydney Basin West Groundwater Source however at the time of the audit are still reported as separate water sources in the Register, [c] the Cox's River and Goulburn Fractured Rock Groundwater Sources have been amalgamated in the proposed 2023 Draft WSP into the Lachlan Fold Belt Greater Metropolitan Groundwater Source however at the time of the audit are still reported as separate water sources in the Register.

In summary, over the audit period:

- Groundwater use was below LTAAEL in all groundwater sources in each year during the audit period.
- Groundwater entitlement is higher than the LTAAEL in the Goulburn Fractured Rock Groundwater Source, however groundwater use was much lower than both the entitlement and LTAAEL.
- Groundwater use in the Sydney Basin Richmond Water Source was higher than the licenced entitlement (but lower than the LTAAEL) in 2021/2022.

This is shown graphically for each audit year in Figure 18-2, Figure 18-3 and Figure 18-4 for the water years 2021/2022, 2020/2021 and 2019/2020, respectively.

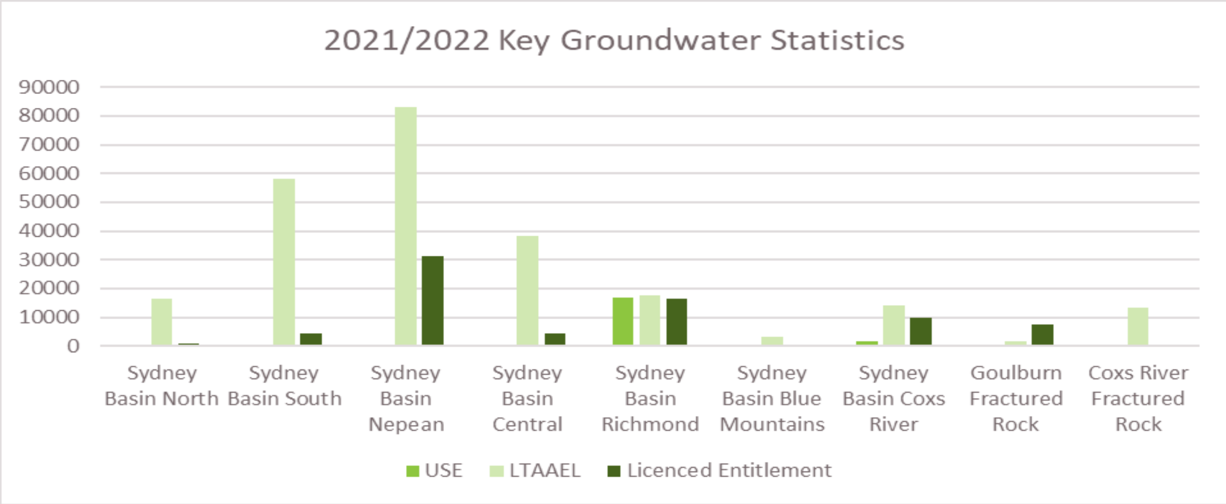


Figure 18-2: Groundwater use, LTAAEL and licenced entitlement in 2021/2022 for each groundwater source in the Catchment

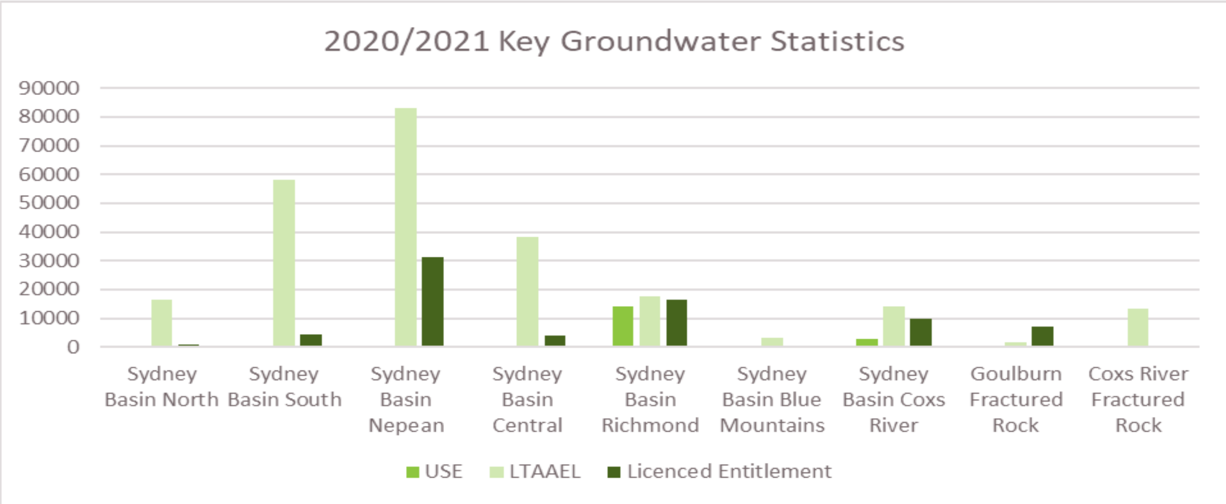


Figure 18-3: Groundwater use, LTAAEL and licenced entitlement in 2020/2021 for each groundwater source in the Catchment

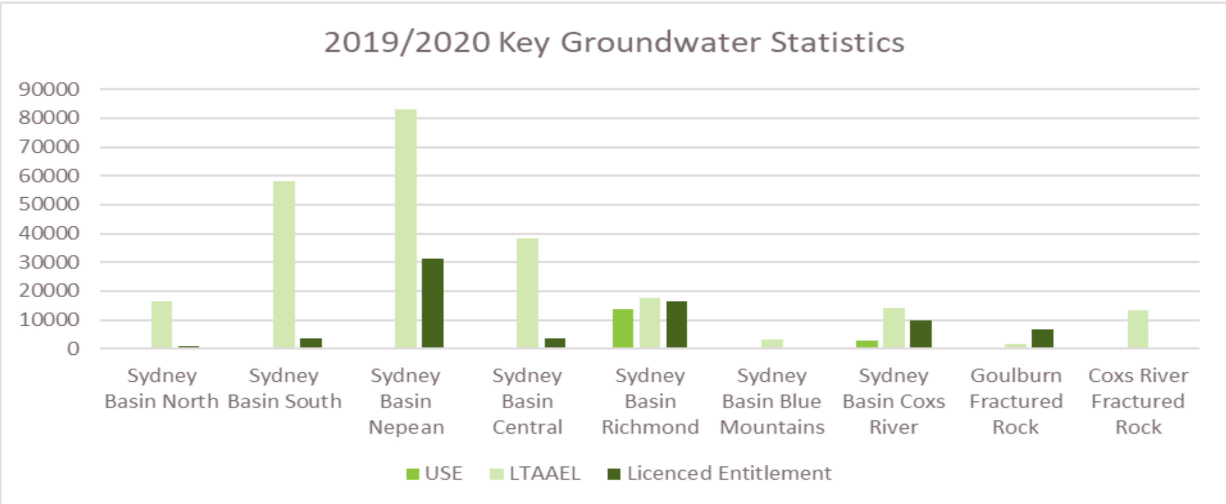


Figure 18-4: Groundwater use, LTAAEL and licenced entitlement in 2020/2021 for each groundwater source in the Catchment

18.5. Water supply works

Water supply work approvals authorise a holder to construct and use a specific water supply work at a specific location. Water supply works are either linked to a water access licence, which specifies the volumetric extraction limits they entitle the holder to extract, or link to water access as part of basic landholder rights. Water supply works include installation works such as wells, excavations, bores or spear points.

18.6. Groundwater level monitoring

Data for 123 monitoring bores at 117 sites were provided by WaterNSW. This represents data from more than double the number of bores provided for the previous audit period (n=45), though areal coverage is still largely restricted to the mining and Special Areas (Figure 18-5). Four additional bores reported in the last audit did not have data for this period and records for an additional seven bores ceased during the audit period. Of the 123 bores, 30 bores are equipped with real-time data loggers. This represents nearly doubling the number that were reported to have been equipped with real-time data loggers for the previous audit (n=17).

Seventy-eight of the 123 recorded sites are clustered within the Upper Nepean sub-catchment and relate to coal mining activities. A small cluster of three bores is in the Lower Coxs River sub-catchment with the remainder scattered across the Wingecarribee River and Little River sub-catchments. Single sites occur in the Kangaroo River and Woronora River sub-catchments. Twenty-one sub-catchments have no groundwater monitoring. Notably, none of the sub-catchments that host high-priority potential groundwater dependent ecosystems (Figure 18-5) have any reported groundwater data, though bores in the Lower Coxs River sub-catchment can inform on groundwater supporting the groundwater dependant ecosystems in the Sydney Basin Blue Mountains Sandstone Groundwater Source in the north of the Catchment.

Guided by a recommendation in the 2019 audit and in line with the NSW Water Monitoring Framework (DPIE 2020c), the NSW Groundwater Strategy and the Water Monitoring Guidelines for Underground Mining Activities in the Special Areas, 10 new monitoring bores were drilled at five locations within the Metropolitan Special Area (Sydney Basin Nepean Groundwater Source – eight bores) and one site (two nested bores) within the Woronora Special Area (Sydney Basin Central Groundwater Source). These bores have been equipped with real-time data loggers and a water sampling pump to monitor water quality periodically.

Of the bores with data that only commenced during the audit period, typically only 3–4 water level measurements have been recorded. Whilst 3–4 measurements are insufficient to define a statistical trend, some bores did show significant changes. This data, however, should be carefully interpreted until a longer time series is acquired.

This audit supports provisions contained in the Water Monitoring Guidelines for Underground Mining Activities in the Special Areas (WaterNSW 2021e). Namely, monitoring should be located based on location of potential environmental damage from mining operations and should focus on data collection that provides for numerical analysis of change in baseflow discharge to streams or permanent water volume changes.

Further, groundwater level fluctuations and recession rates in swamps should be assessed to allow quantitative evaluation of mining impacts on groundwater dependent ecosystems. This should also include assessment of surface to mine connectivity and potential for water fluxes between water sources.

The monitoring network should therefore be re-assessed and augmented, where possible, to support groundwater dependent ecosystem management, particularly in the western sub-catchments. The network should be rationalised in the Upper Nepean sub-catchment where there is an over-abundance, for audit purposes, of monitoring bores from the legacy investigations for Millennium Drought supplementary groundwater supplies. Resources used for this cluster of monitoring bores (e.g., telemetry infrastructure) might be re-assigned to bores in sub-catchments that are currently not monitored. Monitoring in the Kowmung River, for example, should be undertaken to support management of the numerous springs and swamps as well as the karst groundwater dependent ecosystems.

In undertaking any review of the monitoring network, consideration should be made of locations that can aid informing the revised (2023) water sharing plan and future groundwater demand. This should include consideration of the impacts of a transition from coal mining to renewable resource development in the region.

Fifty-nine monitoring bores were selected for trend analysis over the audit period and assessed against possible climate drivers (refer to graphs in Appendix F). A summary of water level observations is provided in Table 18-10. Where sufficient data (i.e., >100 temporal records across the full audit period) can provide a statistical trend, most records suggest a climate response, with the majority of water levels rising over the audit period, reflecting increased rainfall. Local falling trends are observed at deep bores within the mining area of the Upper Nepean sub-catchment and reflect local mining activities on deep aquifers. As noted above and as shown in Figure 18-5, however, monitoring bores only cover a very small proportion of the Catchment, with only two sub-catchments (Upper Nepean and Wingecarribee Rivers) exhibiting a reasonable spatial distribution and therefore this assessment can only provide a very localised picture of groundwater level trends across the Catchment.

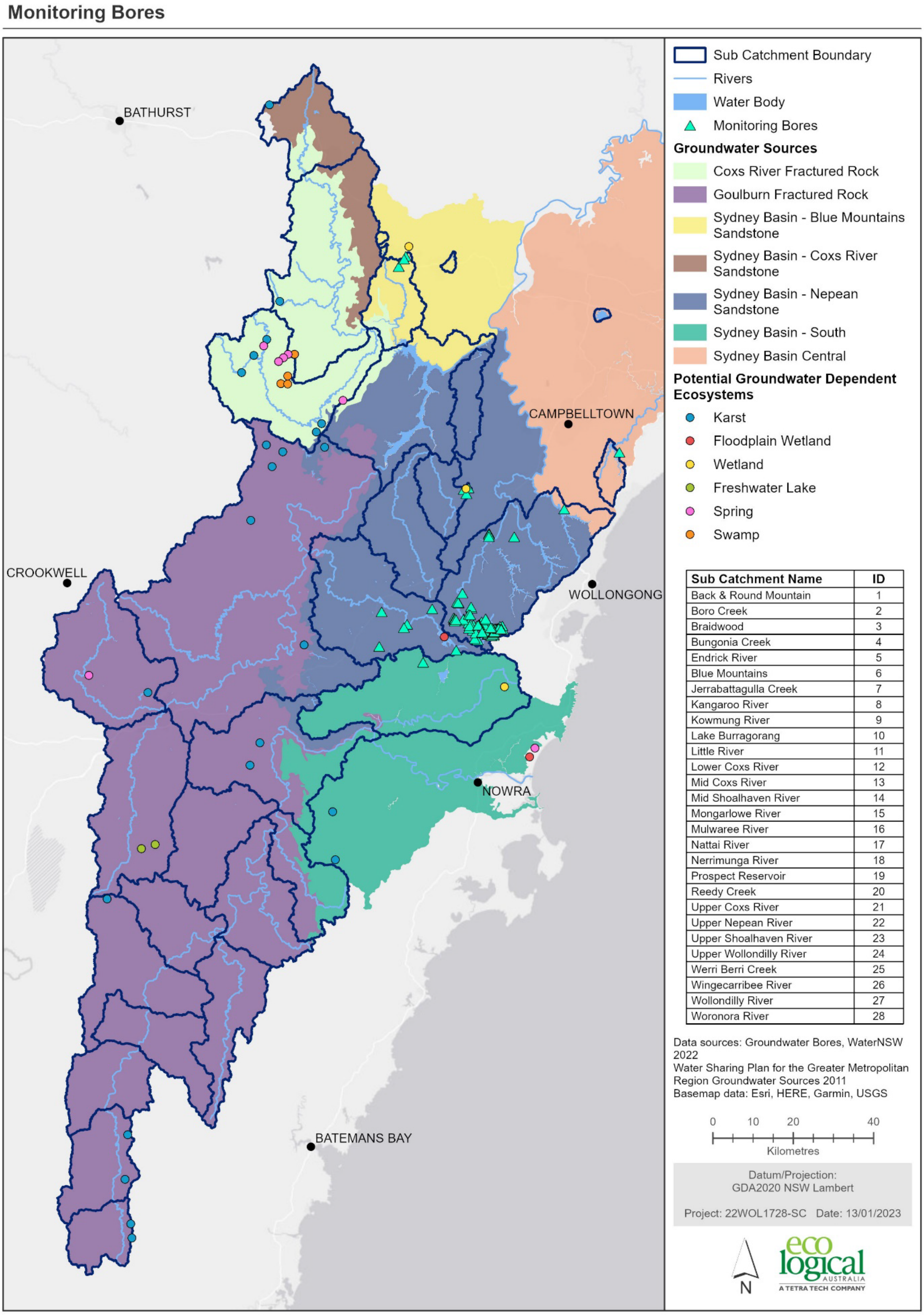


Figure 18-5: Groundwater monitoring bores

Table 18-10: Summary of groundwater level trends

Legend	
Increase in groundwater level observed	
Stable groundwater level observed	
Decline in groundwater level observed	
Short term climate response observed	
No observed climate response recorded	
No or insufficient data available for assessment	

NOTES:
Stable levels are within historical variation.
Decline and increase is observed to be outside of historical variation.

Sub-catchment	Bores	Trend	Climate impact	Rainfall station
	GW075005.1.1			63227
	GW075005.2.2			63227
Lower Coxs River	GW075006.1.1			63227
	GW075006.2.2			63227
	GW075007.1.1			63039
	GW075007.2.2			63039
Kangaroo River	GW075412			68009
	GW40955			68202
	GW409701			68202
	GW409702			68202
	GW40971			68202
	GW40972			68202
	GW40982			68202
	GW40983			68202
	GW40986			68202
	GW40994			68202
Upper Nepean River	GW40996			68202
	GW40997			68202
	GW41040			68202
	GW41044			68202
	GW41045			68202
	GW41051			68202
	GW41052			68202
	GW41057			68202
	GW75100			68202
	GW75101			68202
	GW75102			68202

Sub-catchment	Bores	Trend	Climate impact	Rainfall station
	GW75110			68202
	GW75171			68202
	GW75175			68202
	GW75176			68202
	GW75181			68202
	GW752011			68202
	GW752012			68202
	GW75216			68202
	GW273003			68224
	GW273005			68224
	GW273006			68224
	GW40992			68224
	GW41063			68224
	GW75112			68224
	GW75113			68224
	GW75114			68224
	GW75115			68224
	GW75182			68224
	GW75210			68224
	GW75214			68224
	GW75215			68224
Wingecarribee	GW075032.1.1			68186
	GW075032.2.2			68186
	GW075033.1.1			68045
	GW075033.2.2			68045
	GW075034			68045
	GW075036			68045
	GW075413			68033
Little River	GW075409.1.1			68166
	GW075409.2.2			68166
	GW075410			68166
	GW075411			68166

*GW075413 located outside the Sydney Catchment boundary, closest sub-catchment area is Endrick River (located west of the bore).

18.7. Conclusions and recommendations

The revised water sharing plan is expected to be enacted in June 2023. Recognition of shared aquifers and the 'stacked' nature of groundwater sources has resulted in revised groundwater source boundaries and amalgamation of some of the current groundwater sources. Thus, the seven groundwater sources defined beneath the Catchment will be rationalised to four for subsequent audits.

Continued re-assessment of groundwater recharge and sustainable extraction limits will further reduce the LTAAELs, particularly in light of a revised risk assessment for each groundwater source. This suggests the environmental and socio-economic risks across the region have reduced, except for the north-eastern groundwater sources where the socio-economic risk has increased.

Within the sustainable extraction limits' context, the volume reserved for basic landholder rights has increased since 2019 for the Sydney Basin North, and South groundwater sources, and for the Sydney Basin Richmond/Blue Mountains/Cox's River groundwater sources (to be amalgamated and reported as the Sydney Basin West Groundwater Source under the proposed 2023 water sharing plan). The volume reserved for the remaining groundwater sources (i.e., the Sydney Basin Nepean and Central Groundwater sources, and the Goulburn River and Cox's River Fractured Rock groundwater sources – to be amalgamated and reported as the Lachlan Fold Belt Greater Metropolitan Groundwater Source) have decreased. Licenced entitlement has grown for the audit period in the Sydney Basin South (789 ML; an additional 3 WALs), Sydney Basin Central (548 ML; an additional 21 WALs), Sydney Basin Nepean (100ML; an additional 7 WALs) and Goulburn Fractured Rock (810 ML; an additional 5 WALs) groundwater sources.

Very few licence dealings occurred over the audit period. Four permanent trades and 25 temporary trades were enacted. The proposed amalgamation of some groundwater sources over the next audit period will allow trading between areas that are currently restricted and may result in increased future trading.

Groundwater use over the audit period has shown a decreasing trend in all groundwater sources and significantly below the LTAAEL or the licenced entitlements.

Despite a significant increase in the number of groundwater monitoring bores reported for this audit, the spatial distribution remains restricted, with seventy-eight of the 123 recorded sites clustered within the Upper Nepean sub-catchment and relating to coal mining activities. A small cluster of three bores is in the Lower Coxs River sub-catchment with the remainder scattered across the Wingecarribee River and Little River sub-catchments. Single sites occur in the Kangaroo River and Woronora River sub-catchments. Twenty-one sub-catchments have no groundwater monitoring. Notably, none of the sub-catchments that host high-priority potential groundwater dependent ecosystems have any reported groundwater monitoring data.

Of the monitored sites, the majority show rising groundwater level trends and can be correlated with rainfall trends.

The NSW Government has recognised the need to expand its groundwater monitoring network across NSW, consistent with the NSW Water Monitoring Framework (DPIE 2020c), the NSW Groundwater Strategy (DPE 2022e) and the Water Monitoring Guidelines for Underground Mining Activities in the Special Areas. It is recommended that the location and function of non-government groundwater bores in the mining areas of the Catchment be audited to determine which ones can practicably and feasibly be appropriated and maintained by the NSW Government for their groundwater monitoring network, with a focus on long-term nested monitoring bores used by the mining sector and in areas where increasing public use is occurring for stock and domestic supply or irrigation.

Mine water discharge is currently dealt with by DPE – Mining Approvals and the Resources Regulator on a case-by-case basis. To assist with an understanding of cumulative impacts of water discharge associated with active and closed mines and quarries in the Catchment, it is recommended that these sources are identified and mapped. The resultant map should be made available via SEED.

19. Water quality

There are three indicators of Catchment health relevant to water quality. Ecosystem and raw water quality in Catchment streams and storages were in moderate condition during the audit period, with a worsening long-term trend. High nutrient concentrations in many waterways indicate nutrient loads were poor and worsening, although this may also be influenced by cycling of nutrients within waterways. Cyanobacterial blooms had a moderate state and stable trend.

19.1. Water quality agreements and guidelines

19.1.1. Existing arrangements

Water quality guidelines[22] and supply agreements are tailored to different parts of the water supply network (Figure 2-2) as follows:

1. Raw water from streams flows into storages (lakes and reservoirs). WaterNSW is required by IPART[23] to assess raw water quality using the nationally recognised Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC & ARMCANZ 2000)[24] for streams and storages. The water quality analytes that were reviewed for this audit are listed with their ANZECC & ARMCANZ (2000) guideline values in Table 19-1.

2. Stored raw water is then either:

    a. Directed to a water filtration plant in accordance with a raw water supply agreement with a 'wholesale customer' (i.e., Sydney Water, Wingecarribee Shire Council, Goulburn Mulwaree Council or Shoalhaven City Council). Each agreement has site-specific requirements for raw water quality because of the different technological capabilities of the water filtration plant and the natural characteristics of their sub-catchments. Water filtration plants are required to treat the raw water to a standard that satisfies the 2011 Australian Drinking Water Guidelines[25] before water is supplied to customers.

    OR

[22] The National Water Quality Management Strategy (Australian Government 2018) defines a 'guideline value' as:

> 'A measurable quantity (for example, concentration) or condition of an indicator for a specific community value below and/or above which (such as in the case of stressors such as pH, dissolved oxygen and many biodiversity responses) there is considered to be a low risk of unacceptable effects occurring to that environmental value.'

[23] Refer to Table D1 in the WaterNSW Reporting Manual 2022-2024 (IPART 2022b)

[24] Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ). These guidelines were updated in 2018, but IPART and WaterNSW continue to refer to the 2000 guidelines.

[25] Australian Drinking Water Guidelines are dated 2011 but the current version 3.8 was updated in September 2022 (at the time of this audit) and is used by WaterNSW.

b. Released (untreated) to downstream rivers. ANZECC & ARMCANZ (2000) has benchmark guidelines for downstream rivers which are derived from the guidelines for lowland stream ecosystems. There are also requirements for environmental flows which are defined in the Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources 2011 (see section 17.2).

Conventional water treatment methods remove pollutants from raw water according to the pollutant type and treatment plant capability. Treatment processes are less costly and have lower health risks if they are avoided in the raw water supply through catchment and storage management practices. The Australian Drinking Water Quality Guidelines state that 'prevention of contamination provides greater surety than removal of contaminants by treatment, so the most effective barrier is protection of source water to the maximum degree practical'. This is also reflected in the Source Water Protection Strategy (WaterNSW 2022d).

The water quality guideline values in Table 19-1 are from Tables 3.3.2 and 3.3.3 of ANZECC & ARMCANZ (2000) and are the default trigger values for physical and chemical stressors for south-east Australia for slightly disturbed ecosystems. The topographic map of the Catchment (Figure 2-1 in this audit report) indicates that streams in the Catchment would be defined by ANZECC & ARMCANZ (2000) as a mix of upland streams (>150 m altitude) and lowland streams. Table 19-1 shows that the more conservative ANZECC & ARMCANZ (2000) guidelines for upland streams are applied to assess compliance for most analytes monitored in the Catchment. All WaterNSW routine water quality monitoring sites in the Woronora and Metropolitan Special Areas and the Blue Mountains and Southern Highlands are in upland streams.

Annual water monitoring reports by WaterNSW indicate the percentage compliance with guidelines for metals such as aluminium. This auditor notes that WaterNSW applies the ANZECC & ARMCANZ (2000) guideline value of '<0.055 mg/L (if pH>6.5)' for 'total aluminium', as required under the operating licence (IPART 2022a). Table 3.4.1 of ANZECC & ARMCANZ (2000) includes this freshwater trigger guideline value at 95% species protection for aluminium. However, the ANZECC & ARMCANZ (2000) guidelines state that 'Comparison of total concentrations will, at best, overestimate the fraction that is bioavailable'. Total aluminium tends to be a poor indicator of 'bioavailable' soluble aluminium as aluminium forms a high proportion of minerals found in suspended sediment. Even moderate suspended solids concentrations (unrelated to the presence of aluminium toxicity) may result in an exceedance of the guideline value based on total aluminium concentrations, resulting in a false flag. Therefore, compliance results for metals have not been replicated from the WaterNSW annual water monitoring reports in this audit. Recommendations are made in this audit to review the water quality guidelines being applied to assess Catchment health (see sections 19.8 and 21.3.1), including methods for measuring aluminium.

Table 19-1: ANZECC & ARMCANZ (2000) water quality guideline values for storages and streams

Water quality analyte	Storages		Streams	
	Guideline	Context	Guideline	Context
Chlorophyll-*a* (*Chl-a*)	<5.0 µg/L	In guidelines for freshwater lakes and reservoirs	<5.0 µg/L	In guidelines for lowland streams (there is no guideline value for upland streams)
pH	6.5 – 8.0 pH units	In guidelines for freshwater lakes and reservoirs	6.5 – 8.0 pH units	In guidelines for upland streams (guideline for lowland streams is 6.5 – 8.5 pH units)
Dissolved Oxygen (DO)	90 - 110% saturation	In guidelines for freshwater lakes and reservoirs	90 - 110% Saturation	In guidelines for upland streams. (guideline for lowland streams is 85-110%.)
Turbidity	<20.0 NTU	Upper end of range (1-20 NTU) in the guidelines for freshwater lakes and reservoirs	<25.0 NTU	Upper end of upland stream range 2-25 NTU. (guideline for lowland streams is 6-50 NTU.)
Ammonium (NH_4)	<0.01 mg/L	In guidelines for freshwater lakes and reservoirs	<0.013 mg/L	In guidelines for upland streams (guideline for lowland streams is <0.02 mg/L)
Oxides of Nitrogen (NO_x)	<0.01 mg/L	In guidelines for freshwater lakes and reservoirs	<0.015 mg/L	In guidelines for upland streams (guideline for lowland streams is <0.04 mg/L)
Total Nitrogen (TN)	<0.35 mg/L	In guidelines for freshwater lakes and reservoirs	<0.250 mg/L	In guidelines for upland streams (guideline for lowland streams is <0.50 mg/L)
Soluble Reactive Phosphorus (SRP)	<0.005 mg/L	In guidelines for freshwater lakes and reservoirs	<0.015 mg/L	In guidelines for upland streams (guideline for lowland streams is <0.02 mg/L)
Total Phosphorus (TP)	<0.01 mg/L	In guidelines for freshwater lakes and reservoirs	<0.02 mg/L	In guidelines for upland streams (guideline for lowland streams is <0.05 mg/L)
Salinity (Electrical Conductivity)	<0.35 mS/cm	Given as the maximum default value for upland rivers. (guideline for lakes and reservoirs is 0.2-0.3 mS/cm)	<0.35 mS/cm	Given as the maximum default value for upland streams. (guideline for lowland streams is 0.125-2.20 mS/cm)

19.1.2. Updated water quality guidelines and objectives

The Australian and New Zealand Guidelines for Fresh and Marine Water Quality were updated in 2018 (ANZG 2018). The 2018 guidelines include a water quality management framework which involves defining community values and management goals, and defining, refining, and assessing guideline values for water and sediment. ANZG (2018) recommends site-specific guideline values be adopted for physical and chemical stressors from:

- Strategic monitoring programs
- Submissions for proposed or existing scheduled activities
- Environmental quality management plans developed by proponents.

The NSW water quality objectives for coastal catchments (including the Sydney Drinking Water Catchment) are currently under review by DPE in consultation with stakeholders. The objectives are the agreed environmental values and long-term goals for NSW's surface waters and will be available, following public exhibition in mid-2023, as a map on the DPE website.

They will set out:

- The community's values and uses for rivers, creeks, estuaries and lakes (i.e., healthy aquatic life, water suitable for recreational activities like swimming and boating, and drinking water)
- A range of water quality indicators to help assess whether the current condition of a waterway supports those values and uses.

The water quality indicators for aquatic ecosystems will continue to be consistent with ANZECC and ARMCANZ guidelines.

19.2. Water quality monitoring programs

The water monitoring program for the Catchment was developed by WaterNSW with NSW Health, Sydney Water and other raw water customers to inform operational decisions and demonstrate compliance and identify risks. The monitoring program includes routine (monthly) and event monitoring, employing field sampling, laboratory testing and telemetered 'real-time' data collection. Locations of sites routinely monitored by WaterNSW in streams and storages are mapped in this chapter. Annual water quality results and analysis are reported to the community via the WaterNSW website, including the percentage compliance with guidelines.

WaterNSW uses the results of routine and other water quality monitoring to guide operational and strategic management of the water supply system. Examples of how the results are used include:

- By the operations team to understand the current raw water quality to deliver to WaterNSW wholesale customers (see section 19.1.1) and guide those decisions
- As input to short and long-term modelling (e.g., for incidents and strategic planning)
- To inform Catchment management programs and advise other agencies where they have a role (e.g., NSW Health and the EPA).

Water quality monitoring is also undertaken in the Catchment by a range of government and non-government stakeholders for other purposes, such as for short-term or annual programs, or compliance with environment protection licences. Results of these water quality monitoring activities are not available in a consistent or consolidated format which constrains understanding of water quality data and conditions across the Catchment for decision-makers and researchers. This issue was explored in the 2020 Review of water-related data collections, data infrastructure and capabilities report by the NSW Chief Scientist and Engineer.

Stakeholders interviewed for this audit supported improved coordination and access to water quality data and analysis reports. The recommendations in the report from the NSW Chief Scientist and Engineer are being progressively implemented. This includes publication of additional datasets, and the appointment of a Chief Knowledge Officer in DPE Water who takes on the role of the Water Data Custodian, reporting to the CEO Water.

19.3. Water quality analysis methods

Key water quality findings in this audit have been informed by three analysis methods using data from WaterNSW. The combined analysis aimed to determine where water quality is of greatest concern in the Catchment. Key findings are summarised in section 19.4 for each sub-catchment that has routine monitoring data collected. Maps of routine monitoring site locations are included in section 19.4.

19.3.1. Compliance during the audit period

Routine water quality monitoring data sampled during the audit period were reviewed to determine compliance with ANZECC & ARMCANZ (2000) guidelines for storages and streams. Compliance data were obtained from the WaterNSW annual monitoring reports for 2019-20, 2020-21 and 2021-22. The annual compliance values represent the percentage of routine samples outside benchmark water quality guidelines at each site, for each analyte. Results are tabulated in Appendix G for each sub-catchment.

Water quality monitoring sites and analytes of greatest concern during the audit period were those that were 100% non-compliant (i.e., all samples during the audit period were outside guidelines). These results are included in the summary tables in section 19.4.

19.3.2. Ten-year statistical trend analysis

WaterNSW statistically analyses long-term water quality trends biennially, with the most recent analysis performed for the 2011-2021 period. The sites and analytes included in the trend analysis were agreed by NSW Health and DPIE. Details of statistical methods and results were presented in the 2020-21 Annual Water Monitoring Report (WaterNSW 2021c). Statistically significant trends (99%) were identified by WaterNSW using a Seasonal Kendall Trend test with rates of change quantified using the Sen slope method. Statistically significant trends were reported in WaterNSW (2021c) in units per annum.

Key findings for statistically significant trends are included in the tables in section 19.4 for cases where water quality results were found to be deteriorating over the ten-year period because they are more frequently outside ANZECC & ARMCANZ (2000) guidelines.

19.3.3. Comparison of audit period to pre-audit period

The third water quality analysis method applied in this audit was a comparison of routine monitoring data from the audit period to data from prior to the audit period. Median values were calculated for water quality experienced during the audit period and water quality prior to the audit period. This method aimed to determine:

- If median values for the audit period and/or the previous years exceeded ANZECC & ARMCANZ (2000) water quality guidelines.
- Where median results were outside the guidelines, if median water quality values during the audit period were better (improved), worse or the same as median values for the previous years.

Steps in the analysis method are described in Appendix H. Appendix H also includes summary tables of results for storages and streams, and detailed results for each monitoring site.

Sites that had analytes with median values outside guidelines during the audit period and in the preceding years, and that were the same or worse during the audit period, are included in the tables in section 19.4 below.

19.4. Key findings

19.4.1. Blue Mountains sub-catchment

Blue Mountains storages are in bushland reserves on the northern side of the Great Western Highway (Figure 19-1). There are no townships in the sub-catchment of the Cascades storages. The township of Medlow Bath is in the sub-catchment of Lake Greaves. Blue Mountains storages receive water transfers from the Fish River during dry periods. There have been no mining activities in this sub-catchment.

This sub-catchment has three water quality monitoring sites: DLC1, DGC1 and DTC1. Monitoring site DLC1 has contributions from another creek (Whipcord Creek) and is a balancing reservoir subject to inter-basin transfers so it would have limited comparability to DGC1 and DTC1.

Table 19-2: Blue Mountains water quality key findings

Method	Key findings
Compliance during audit period	All samples were outside guidelines for the following sites: • DGC1 - pH in 2020-21 • DLC1 – oxidised nitrogen in 2019-20 and 2021-22
Ten-year statistical trend	Chlorophyll-a concentrations at sites DGC1 and DTC1 were more frequently outside ANZECC benchmarks in recent years (i.e., worsening).
Comparison of audit period to pre-audit period	Sites that had analytes with median values outside guidelines during the audit period and in the preceding years, and were the same or worse during the audit period were as follows: • DGC1 - pH • DLC1 – oxidised nitrogen • DTC1 – oxidised nitrogen

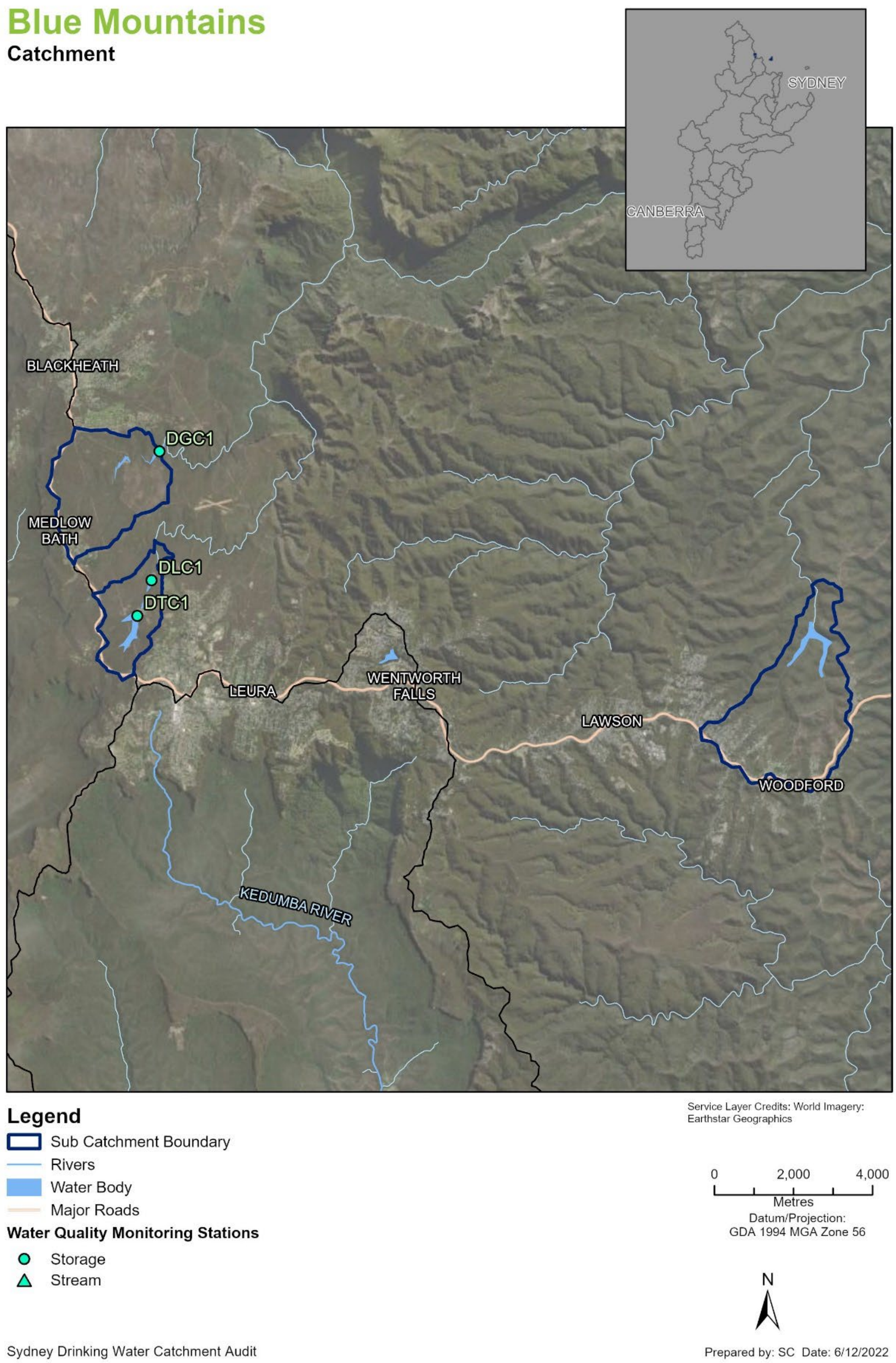


Figure 19-1: Blue Mountains water quality monitoring sites

19.4.2. Shoalhaven overview

Water quality in the Shoalhaven is influenced by the dominant land uses of cleared grazing (36% of the total Shoalhaven catchment area), as well as national parks (31%) and forests (27%). The Shoalhaven also supports horse studs, piggeries, dairies and poultry production, vineyards, olive groves, and canola and cereal crops. Urban populations in the Shoalhaven are concentrated at Braidwood and towns across the Southern Highlands.

As indicated in Figure 2-2, the Shoalhaven system supplies water to parts of the Shoalhaven and Southern Highlands, and tops up Sydney, Goulburn and Illawarra water supplies. Water released from Tallowa Dam into the Shoalhaven River is used by Shoalhaven City Council to supply Nowra and surrounding areas. Wingecarribee Reservoir supplies Bowral, Mittagong, Moss Vale and various villages via Wingecarribee Shire Council's water filtration plant. Bendeela Pondage supplies Kangaroo Valley township. Water from Wingecarribee Reservoir can be released into the Wingecarribee River, which flows into the Wollondilly River and Lake Burragorang to top up Sydney's main water supply at Warragamba Dam. Water can also be released from Wingecarribee Reservoir via canals and pipelines, collectively known as Glenquarry Cut, into the Nepean River which flows into Nepean Dam. From there it can be transferred to Sydney via the Upper Canal or to the Illawarra region via the Nepean-Avon tunnel and Avon Dam. Wingecarribee Reservoir can top up Goulburn's water supply during drought, via an 84 km pipeline. Water is also released into the Shoalhaven and Wingecarribee Rivers as environmental flows.

Water quality monitoring sites across the Shoalhaven are mapped in Figure 19-2.

19.4.3. Shoalhaven - Boro Creek sub-catchment

The Boro Creek sub-catchment is characterised by mixed agriculture and bushland areas (Figure 19-3). Aerial imagery indicates that there is a narrow vegetated riparian corridor along much of Boro Creek (also known as Borough Creek) with cleared pasture on the adjacent alluvial flats. The routine water sampling site at Boro Creek is located less than 1 km upstream of its junction with the Shoalhaven River. WaterNSW water monitoring staff have advised that organic matter was removed from the station during the current audit period to improve its functionality, however, organic matter regularly accumulates due to the characteristics of the site. The creek at this location is intermittent but with a pool of water behind the weir.

This sub-catchment has one water quality monitoring station: E890.

Table 19-3: Boro Creek water quality key findings

Method	Key findings
Compliance during audit period	All samples were outside guidelines at E890 for: • Dissolved oxygen 2019-22 • Total nitrogen 2020-22
Ten-year statistical trend	Nil
Comparison of audit period to pre-audit period	Analytes with median values outside guidelines during the audit period and in the preceding years at E890, that were the same or worse during the audit period were: • Dissolved oxygen • Total nitrogen

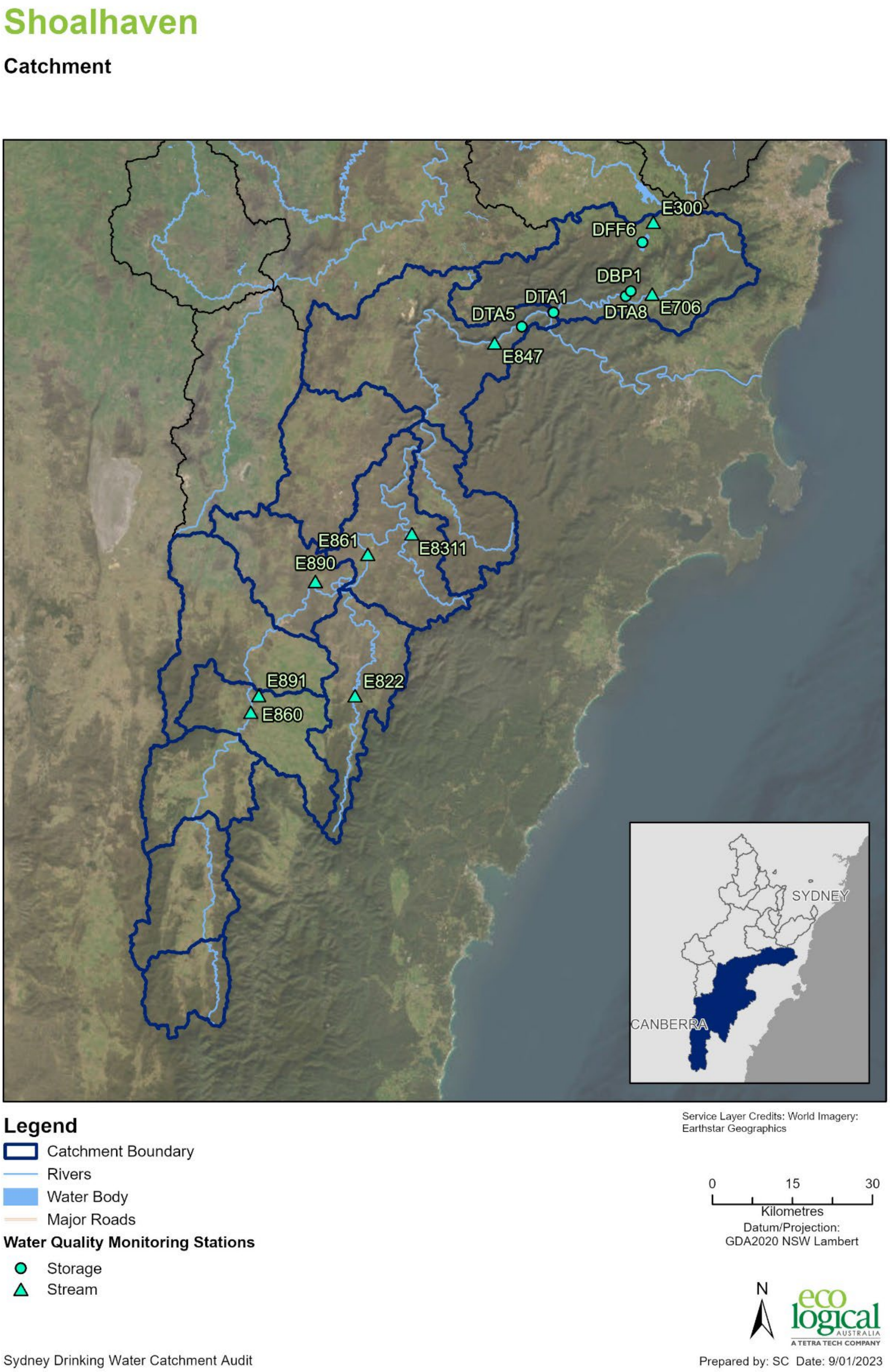


Figure 19-2: Shoalhaven water quality monitoring sites

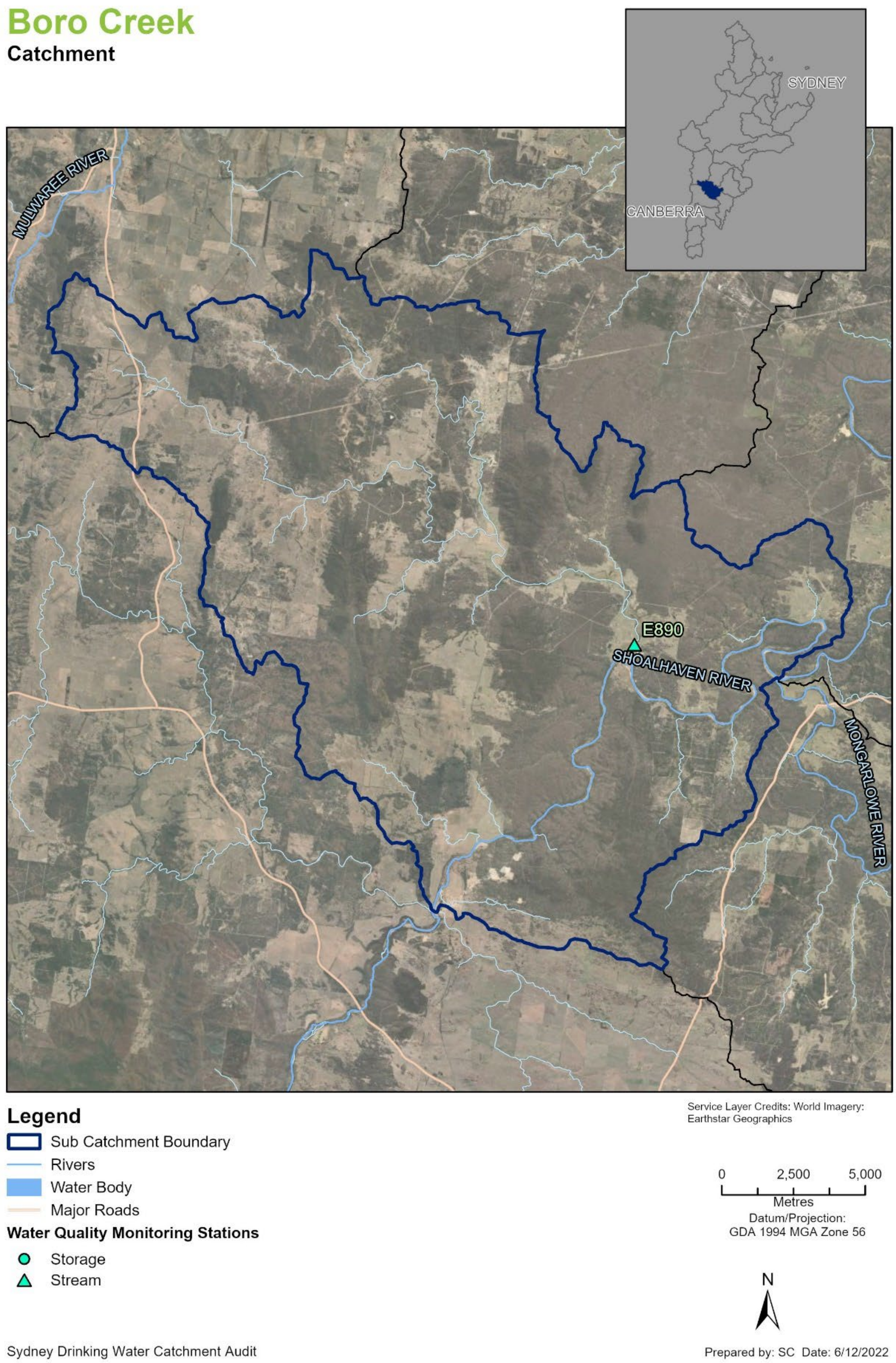


Figure 19-3: Boro Creek water quality monitoring sites

19.4.4. Shoalhaven - Braidwood sub-catchment

The Braidwood sub-catchment is characterised by agricultural and bushland uses (Figure 19-4). Gillamatong Creek flows from the township of Braidwood into the Shoalhaven River.

This sub-catchment has two water quality monitoring stations: E891 and E860. The Gillamatong Creek monitoring site (E891) is approximately 2 km upstream of the junction of the creek with the Shoalhaven River. The Shoalhaven River monitoring site E860 is upstream of the junction of Gillamatong Creek with the Shoalhaven River. Intensive urban land uses at Braidwood, including a sewage treatment plant, are likely the main reason for poor water quality in Gillamatong Creek (E891).

Site E891 is a priority for further investigation and ameliorative action.

Table 19-4: Braidwood water quality key findings

Method	Key findings
Compliance during audit period	All samples were outside guidelines for E891 as follows: • Dissolved oxygen 2019-20 • Conductivity 2019-20 • Total nitrogen 2020-22
Ten-year statistical trend	Nil
Comparison of audit period to pre-audit period	Analytes with median values outside guidelines during the audit period and in the preceding years at E891, that were the same or worse during the audit period were: • Chlorophyll-a • Dissolved oxygen • Conductivity • Total nitrogen • Total phosphorus

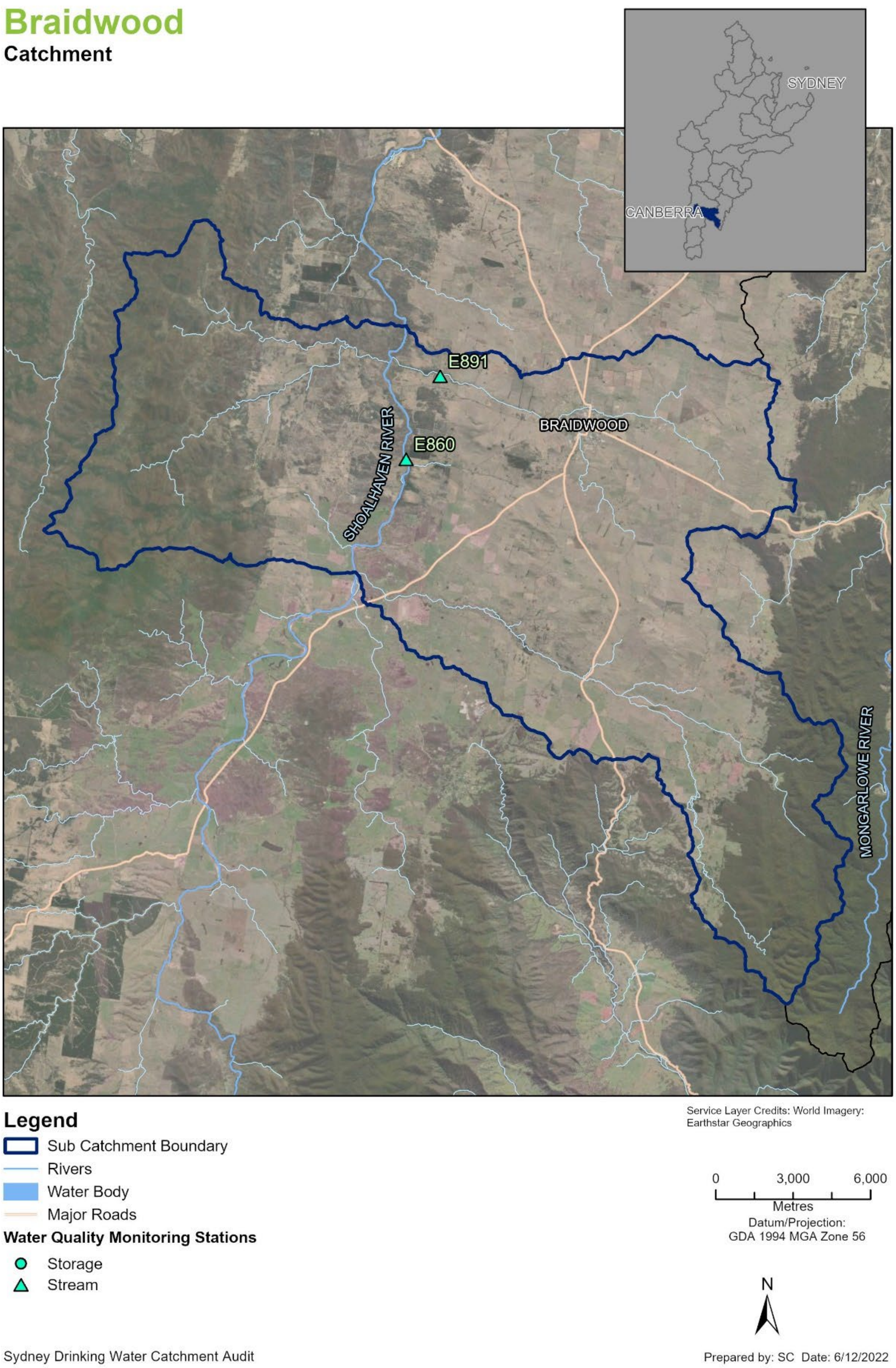


Figure 19-4: Braidwood water quality monitoring sites

19.4.5. Shoalhaven - Bungonia Creek sub-catchment

Water quality in the Bungonia Creek sub-catchment (Figure 19-5) is affected by the entire Shoalhaven River catchment upstream of Tallowa Dam. The lower reaches of the Bungonia Creek sub-catchment feature dense bushland and steep rocky gorges within Bungonia National Park and State Conservation Area.

This sub-catchment has two water quality monitoring stations: E847 (stream) and DTA5 (storage). Monitoring station E847 is at a camping site on the Shoalhaven River. The Lake Yarrunga monitoring site DTA5 is in the Shoalhaven Special Area above the Tallowa Dam wall where the Shoalhaven River meets Kangaroo River. These monitoring sites can be heavily influenced by the Kangaroo River under significant rainfall.

Nutrients monitored in the adjacent upstream Mid Shoalhaven River sub-catchment (section 19.4.7) during the audit period were more often compliant with guidelines than sites monitored in the Bungonia Creek sub-catchment. Poorer water quality downstream of the Mid-Shoalhaven monitoring sites suggest that activities within the Bungonia Creek sub-catchment are contributing, despite the bushland context for the monitoring stations. Further investigation would be required to identify potential causes.

Site DTA5 is a priority for further investigation and ameliorative action.

Table 19-5: Bungonia water quality key findings

Method	Key findings
Compliance during audit period	At least some samples were within guidelines during the audit period for each analyte at monitoring sites in this sub-catchment
Ten-year statistical trend	Nil
Comparison of audit period to pre-audit period	Analytes with median values outside guidelines during the audit period and in the preceding years at DTA5, that were the same or worse during the audit period were: • Ammoniacal nitrogen • Oxidised nitrogen • Total nitrogen • Total phosphorus

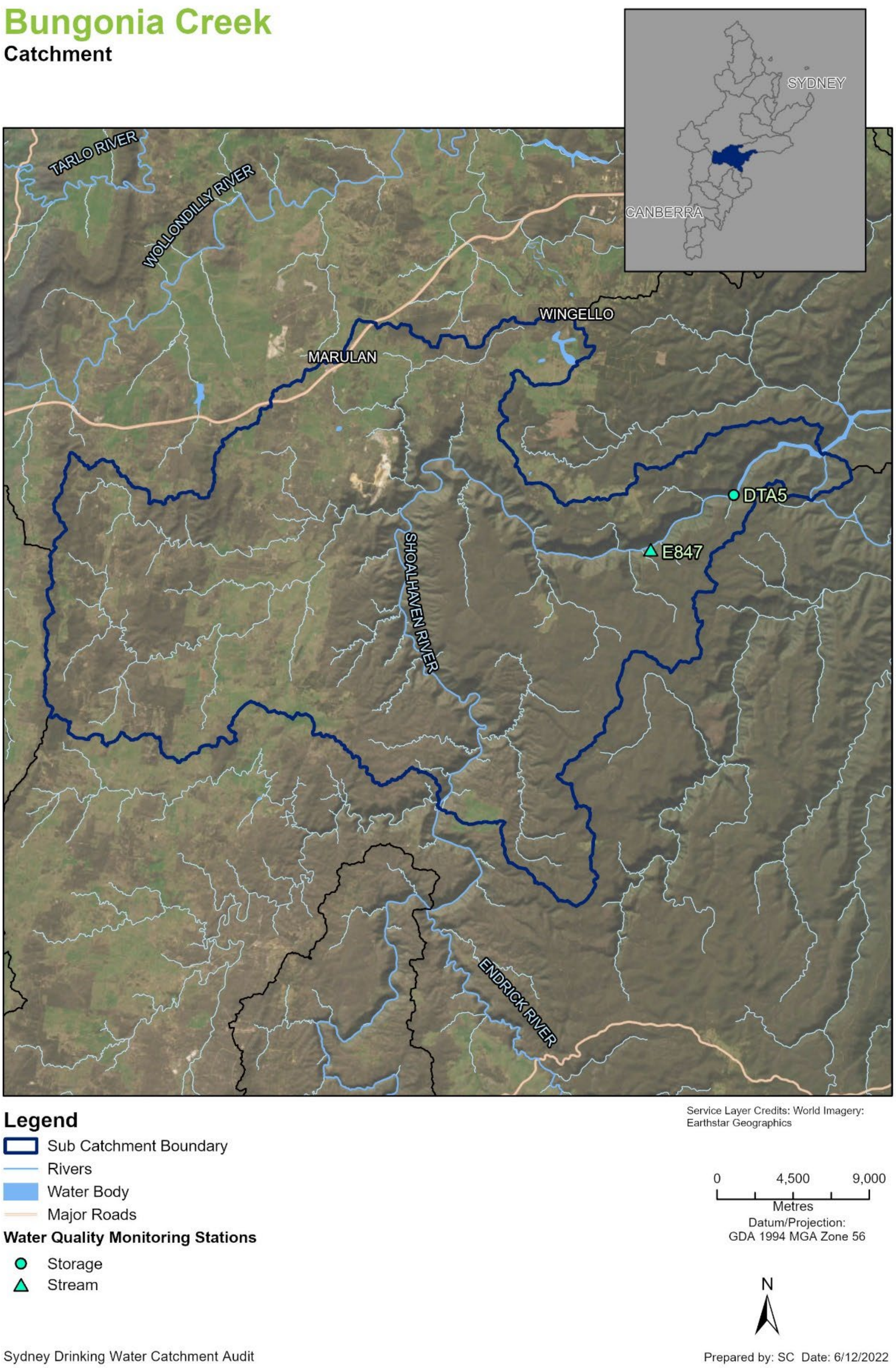


Figure 19-5: Bungonia Creek water quality monitoring sites

19.4.6. Shoalhaven - Kangaroo River sub-catchment

Figure 19-6 shows there are six water quality monitoring stations in this sub-catchment: in streams E300 and E706, and storages DTA1, DTA8, DFF6 and DBP1.

Fitzroy Falls Reservoir (DFF6) in the upper reaches of the Kangaroo River sub-catchment is fringed by a Special Area (Figure 3-1). Most of the land-based part of the Special Area is owned by WaterNSW and access is not permitted, except fishing from the land and picnicking at one area adjacent to Myra-Vale Road. Sailing is permitted, launching from one point adjacent the picnic area off Nowra Road. The width of the Special Area at these two sites varies between 50 m and 400 m.

Land uses surrounding Lake Fitzroy Falls are predominantly private agriculture. Water from Fitzroy Falls Reservoir is piped to the Bendeela pondage (DBP1), then to Kangaroo River (DTA8) via the Bendeela hydroelectric pumping station.

Hampden Bridge (monitoring station E706) is downstream of the Kangaroo Valley township and agricultural land uses, and upstream of DTA8.

Yarrunga Creek at Wildes Meadow (E300) is intermittent with a narrow, vegetated corridor surrounded by agricultural land uses until it enters the bushland reserve of the Twin Falls. This monitoring site informs water quality modelling when undertaking transfers to and from Tallow Dam.

Water quality guideline exceedances at these sites (including cyanobacterial alerts for Fitzroy Falls Lake and Wingecarribee Lake) may have been caused by poor agricultural practices and urban land uses. The vegetated riparian corridors and bushland are not sufficient to maintain water quality within guideline levels.

Investigation of water quality management across this entire sub-catchment is warranted, with a focus on E706 and DBP1.

Table 19-6: Kangaroo River water quality key findings

Method	Key findings

Compliance during audit period	All samples were outside guidelines for the following sites:
	• E300
	  ○ Dissolved oxygen 2019-20
	  ○ Oxidised nitrogen 2019-22
	  ○ Total nitrogen 2019-22
	• E706
	  ○ Ammoniacal nitrogen 2019-20
	  ○ Oxidised nitrogen 2019-22
	  ○ Total nitrogen 2021-22
	  ○ Total phosphorus 2021-22
	• DFF6
	  ○ Oxidised nitrogen 2021-22
	  ○ Total nitrogen 2019-20 and 2021-22
	  ○ Total phosphorus 2021-22
	  ○ Chlorophyll-a 2019-20
	• DTA1 - Total phosphorus 2021-22

<table>
<tr><th>Method</th><th>Key findings</th></tr>
<tr><td></td><td>DTA8
Oxidised nitrogen 2021-22
Total phosphorus 2019-22
DBP1
Oxidised nitrogen 2019-20 and 2021-22
Total phosphorus 2019-21
Chlorophyll-a 2019-20</td></tr>
<tr><td>Ten-year statistical trend</td><td>Long term statistical trend analysis by WaterNSW for the period 2011-2021 found the following were more frequently outside ANZECC benchmarks in recent years (i.e., worsening trend):
Dissolved oxygen levels at sites DTA1 and DTA8
Chlorophyll-a at DTA8
WaterNSW stated ‘A significant increasing trend in the numbers of dissolved oxygen failures is notable in the sites of Lake Yarrunga in the Shoalhaven catchment, and an increasing trend in chlorophyll-a failures is also evident.’</td></tr>
<tr><td>Comparison of audit period to pre-audit period</td><td>Analytes with median values outside guidelines during the audit period and in the preceding years, and were the same or worse during the audit period were as follows:
E300
Oxidised nitrogen
Total nitrogen
E706
Ammoniacal nitrogen
Oxidised nitrogen
Total nitrogen
Total phosphorus
DFF6
Oxidised nitrogen
Total nitrogen
DTA1
Ammoniacal nitrogen
Oxidised nitrogen
DTA8
Ammoniacal nitrogen
Oxidised nitrogen
Total phosphorus
DBP1
Ammoniacal nitrogen
Oxidised nitrogen
Total nitrogen
Total phosphorus</td></tr>
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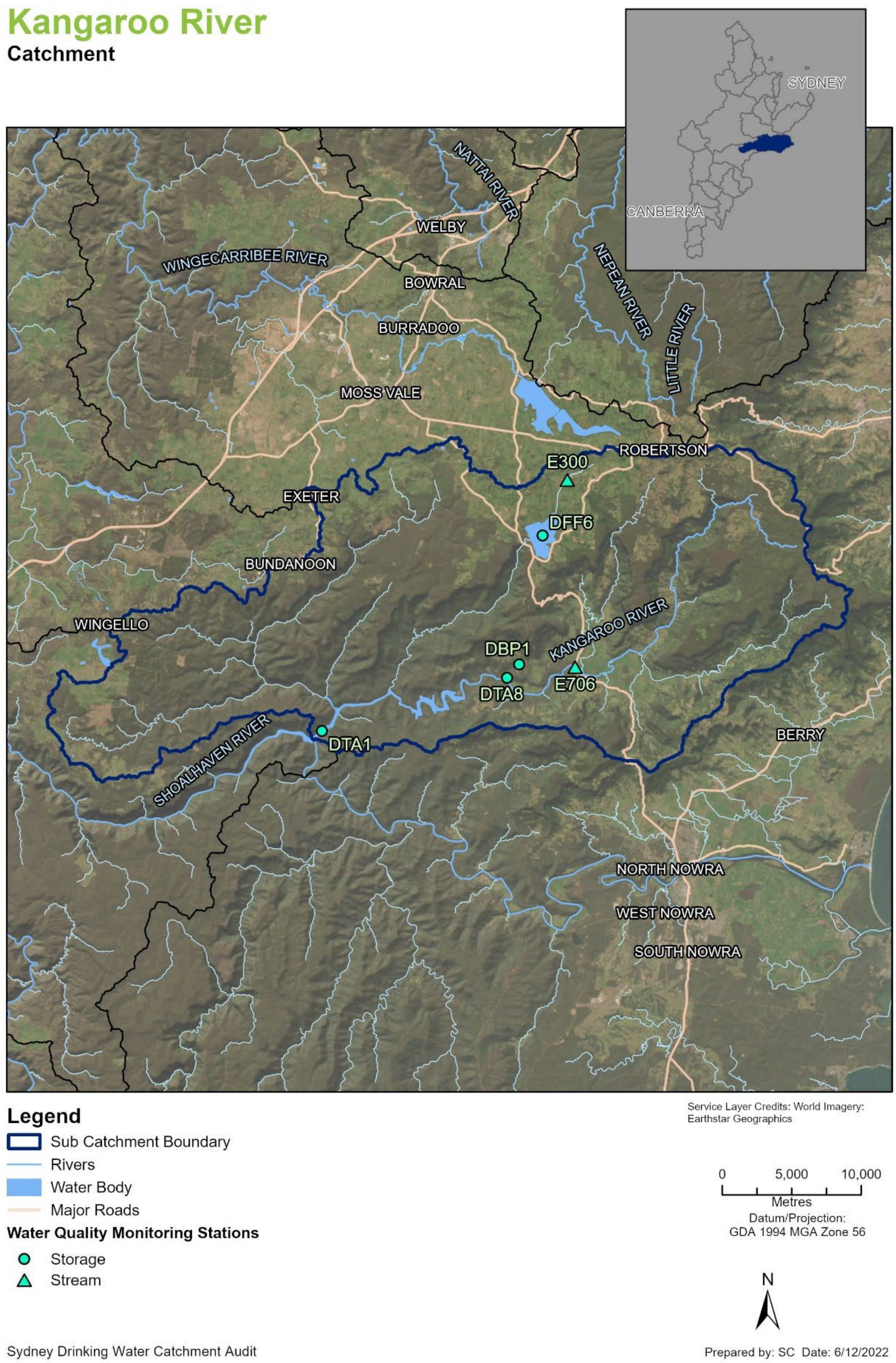

Figure 19-6: Kangaroo River water quality monitoring sites

19.4.7. Shoalhaven - Mid Shoalhaven River sub-catchment

There are two water quality monitoring stations in this sub-catchment: E8311 and E861.

Water quality in the Mid Shoalhaven River sub-catchment was better than in many other parts of the Catchment, presumably due to the prevalence of natural landscapes and well-vegetated riparian corridors rather than intensive or agricultural land uses (Figure 19-7).

Site E8311 could be considered as a potential benchmark site for updated water quality guidelines due to its good water quality.

Table 19-7: Mid Shoalhaven River water quality key findings

Method	Key findings
Compliance during audit period	At least some samples were within guidelines during the audit period for each analyte at monitoring sites in this sub-catchment
Ten-year statistical trend	Nil
Comparison of audit period to pre-audit period	There were no analytes with median values outside guidelines during the audit period and in the preceding years, the same or worse during the audit period.

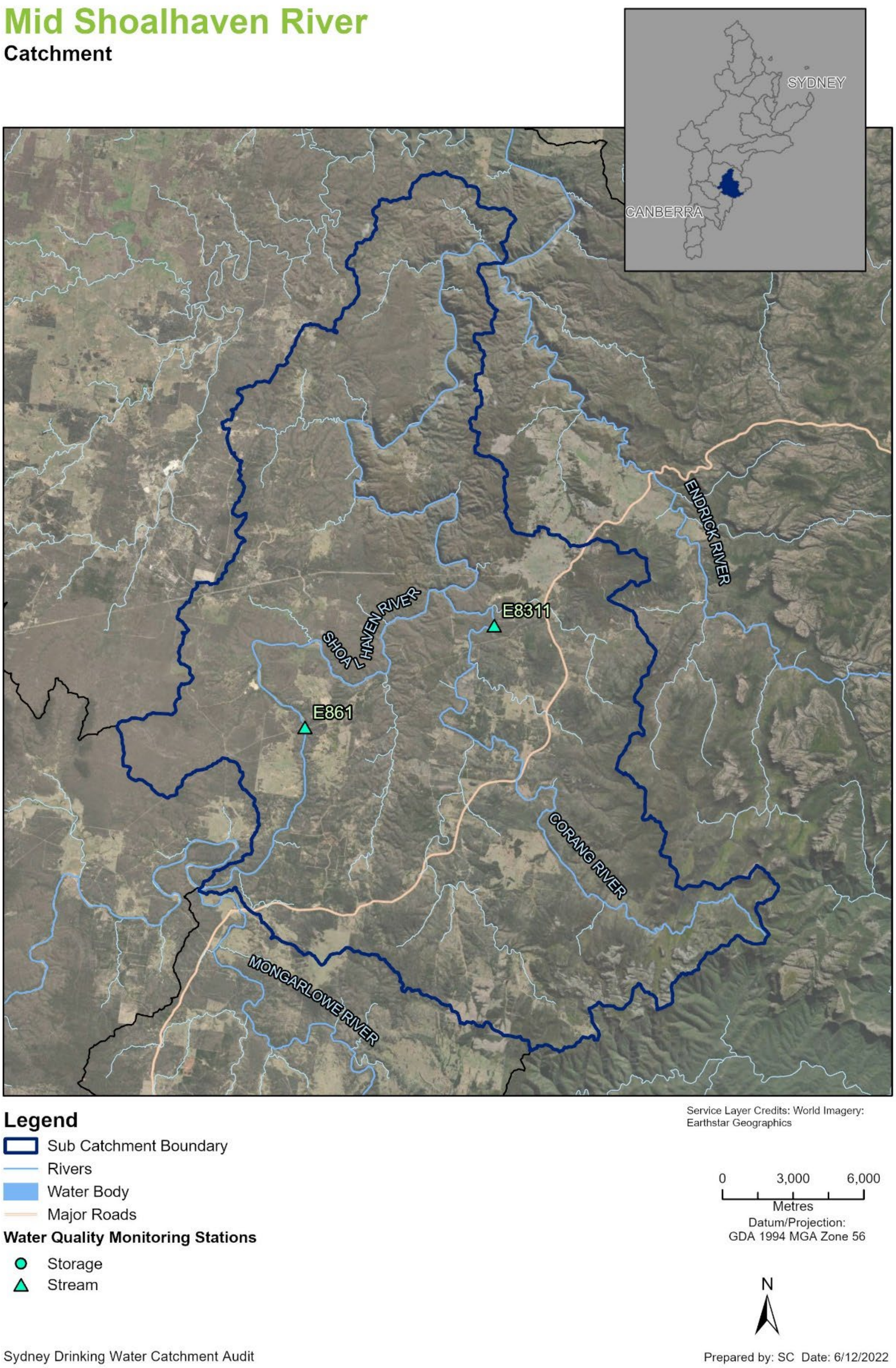

Figure 19-7: Mid Shoalhaven water quality monitoring sites

19.4.8. Shoalhaven - Mongarlowe sub-catchment

The Mongarlowe River routine monitoring site (E822) is located on the downstream side of the village of Mongarlowe in the Southern Tablelands. The site is characterised by rural-residential landholdings (hobby farms). The broader sub-catchment comprises a mix of bushland and agriculture, and the river generally has a well-vegetated buffer. Water quality at this site has generally been good.

Table 19-8: Mongarlowe water quality key findings

Method	Key findings
Compliance during audit period	All samples of oxidised nitrogen were outside guidelines at E822 in 2020-22.
Ten-year statistical trend	Nil
Comparison of audit period to pre-audit period	There were no analytes with median values outside guidelines during both the pre-audit and audit periods.

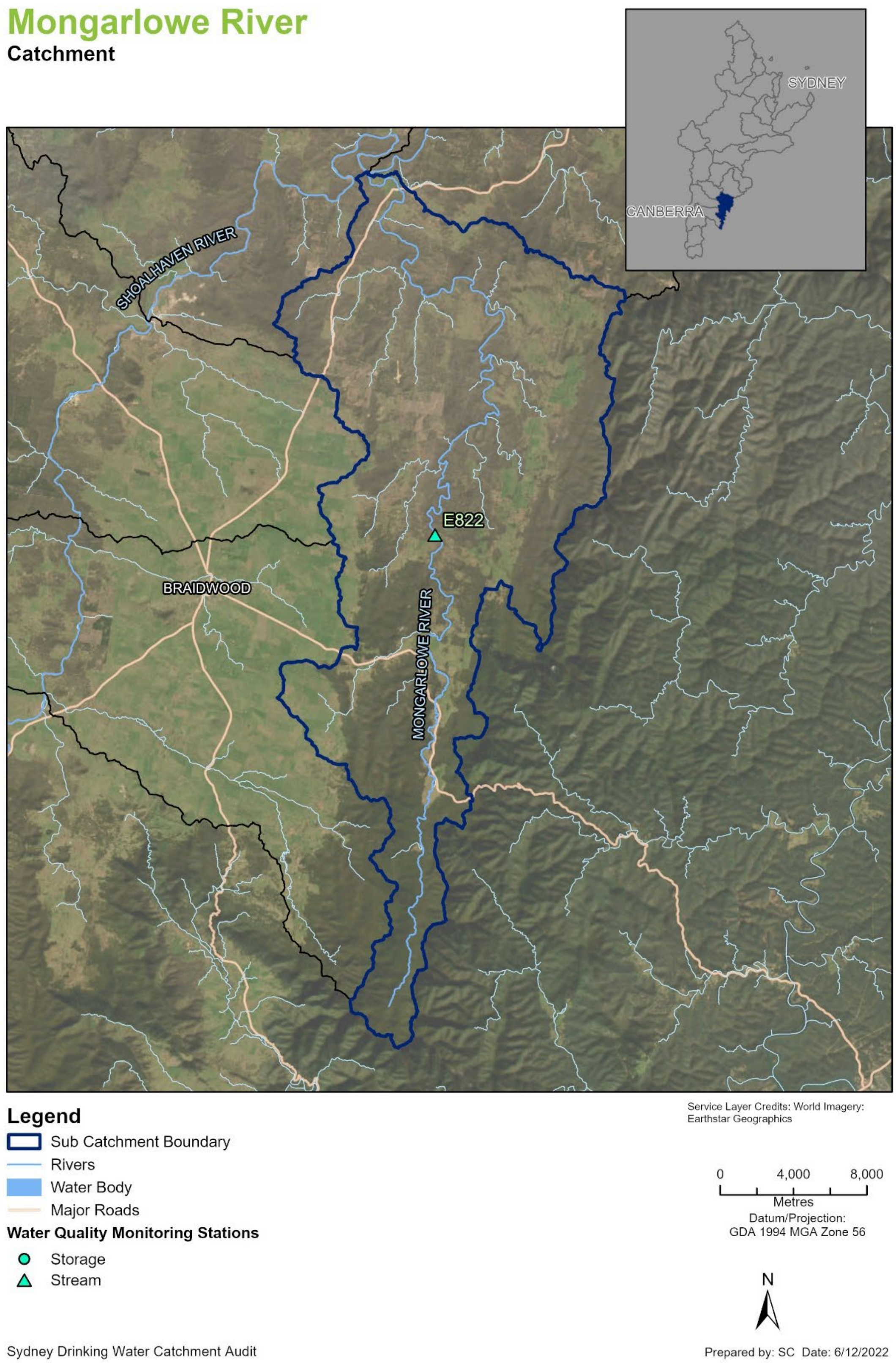

Figure 19-8: Mongarlowe River water quality monitoring sites

19.4.9. Upper Nepean sub-catchments

As indicated in Figure 2-2, the Upper Nepean system supplies water to Sydney, the Macarthur and Illawarra regions. It is characterised by bushland and bordered by the Illawarra escarpment in the east, Wilton in the north-west and the villages of Bargo and Yerrinbool in the south-west. Most of the Upper Nepean is within the Metropolitan Special Area although there are pockets of agricultural use, including one dairy farm. Underground coal mining leases exist across much of this area (refer to section 8 for information about mining in the Catchment).

Routine water monitoring sites within the Upper Nepean streams and storages (Figure 19-9) are as follows:

- Lake Cataract – E609, E676, DCA1, DCA2 and DCA3
- Lake Cordeaux – E608, E680, E6006, DCO1 and DCO3
- Lake Avon – E604, E610, DAV1, DAV7 and DAV16
- Lake Nepean –E601, E602, E603, E697, DNE2 and DNE6

Water quality in streams typically resembled that in downstream storages, likely due to the homogenous nature of each reach.

Water quality at Goodarin Creek (E608) may be affected by pest animals in pastures in the upper reaches. Sandy Creek (E6006) water quality may be affected by discharge from hanging swamps.

Table 19-9: Lake Nepean water quality key findings

Method	Key findings

Compliance during audit period	All samples were outside guidelines as follows:
	• E697
	  ○ Oxidised nitrogen 2019-22
	  ○ Total nitrogen 2020-21
	• E601
	  ○ Oxidised nitrogen 2019-22
	  ○ Total nitrogen 2021-22
	• DNE2
	  ○ Oxidised nitrogen 2020-22
	  ○ Total nitrogen 2019-21
	• DNE6
	  ○ Oxidised nitrogen 2019-22
	  ○ Total nitrogen 2019-20

Ten-year statistical trend	Nil

Comparison of audit period to pre-audit period	Analytes with median values outside guidelines during the audit period and in the preceding years, that were the same or worse during the audit period were as follows:
	• E697 and E601
	  ○ Oxidised nitrogen
	  ○ Total nitrogen
	• DNE2 – oxidised nitrogen

Table 19-10: Lake Cataract water quality key findings

Method	Key findings
Compliance during audit period	All samples were outside guidelines as follows: • E676 – pH 2021-22 • E609 – oxidised nitrogen 2021-22 • DCA1 – oxidised nitrogen 2019-20 • DCA2 – pH 2021-22
Ten-year statistical trend	Nil
Comparison of audit period to pre-audit period	Only two sites in the Lake Cataract sub-catchment had routine data available for all three years of the audit period: DCA1 near the dam wall of the lake and E609 downstream of the lake. DCA1 did not have any analytes with median values outside guidelines during both the audit and pre-audit periods. At E609: • Ammoniacal nitrogen median values were outside guidelines during the audit period and in the preceding years and were worse during the audit period. • pH median values were outside guidelines during the audit period and the same in the preceding years.

Table 19-11: Lake Cordeaux water quality key findings

Method	Key findings
Compliance during audit period	All samples were outside guidelines as follows: • E608 – oxidised nitrogen 2019-22 • E6006 – pH 2019-22
Ten-year statistical trend	Nil
Comparison of audit period to pre-audit period	pH with median values outside guidelines during the audit period and in the preceding years, were worse during the audit period at E6006.

Table 19-12: Lake Avon water quality key findings

Method	Key findings
Compliance during audit period	All samples were outside guidelines as follows: • E604 – oxidised nitrogen 2019-22 • DAV1 – oxidised nitrogen 2019-21
Ten-year statistical trend	Nil
Comparison of audit period to pre-audit period	Oxidised nitrogen with median values outside guidelines during the audit period and in the preceding years, were worse during the audit period at DAV1.

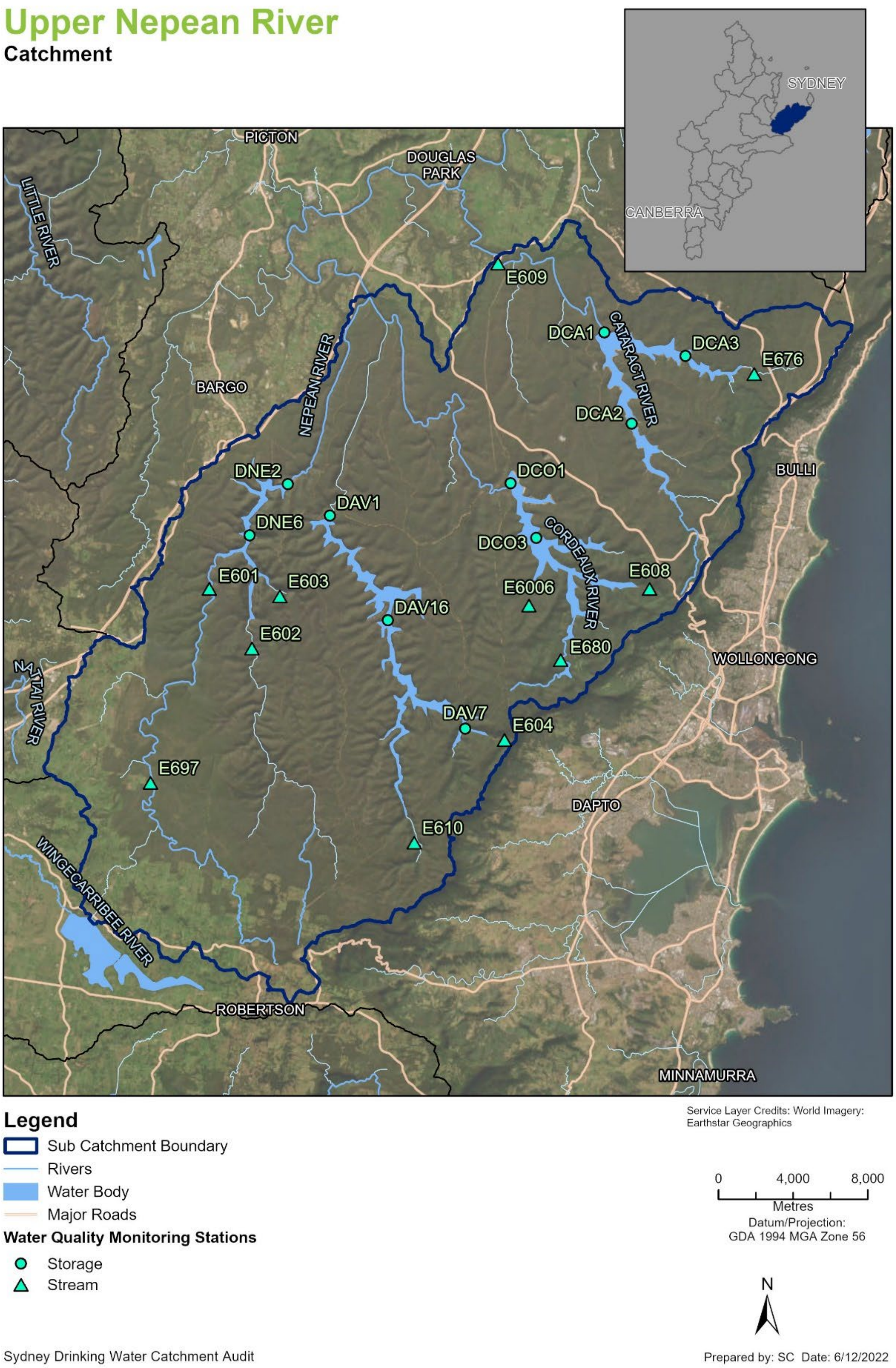

Figure 19-9: Upper Nepean water quality monitoring sites

19.4.10. Warragamba overview

Warragamba stretches from north of Lithgow at the head of the Coxs River, to the source of the Wollondilly River west of Crookwell, and south of Goulburn along the Mulwaree River. It has diverse land uses including agriculture, mining, urban, industrial and conservation, with more than one-quarter of its area comprising the Warragamba Special Area. Water from the Coxs and Wollondilly Rivers flows to Warragamba Dam. The Warragamba system can be supplemented by water from the Shoalhaven system (see Figure 2-2).

19.4.11. Warragamba - Kowmung River sub-catchment

Overall water quality in the Kowmung River sub-catchment (Figure 19-10) was good during the audit period as indicated by the relatively low number of guideline exceedances. This reflects the predominantly bushland character of the sub-catchment and absence of towns or other intensive land uses. Increased oxidised nitrogen exceedances are likely to have resulted from increased organic loads associated heavy rainfall following the Black Summer bushfires.

Table 19-13: Kowmung River water quality key findings

Method	Key findings
Compliance during audit period	All samples of oxidised nitrogen were outside guidelines at E130 in 2021-22.
Ten-year statistical trend	Nil
Comparison of audit period to pre-audit period	E130 had oxidised nitrogen with median values outside guidelines during the audit period and in the preceding years, that were worse during the audit period.

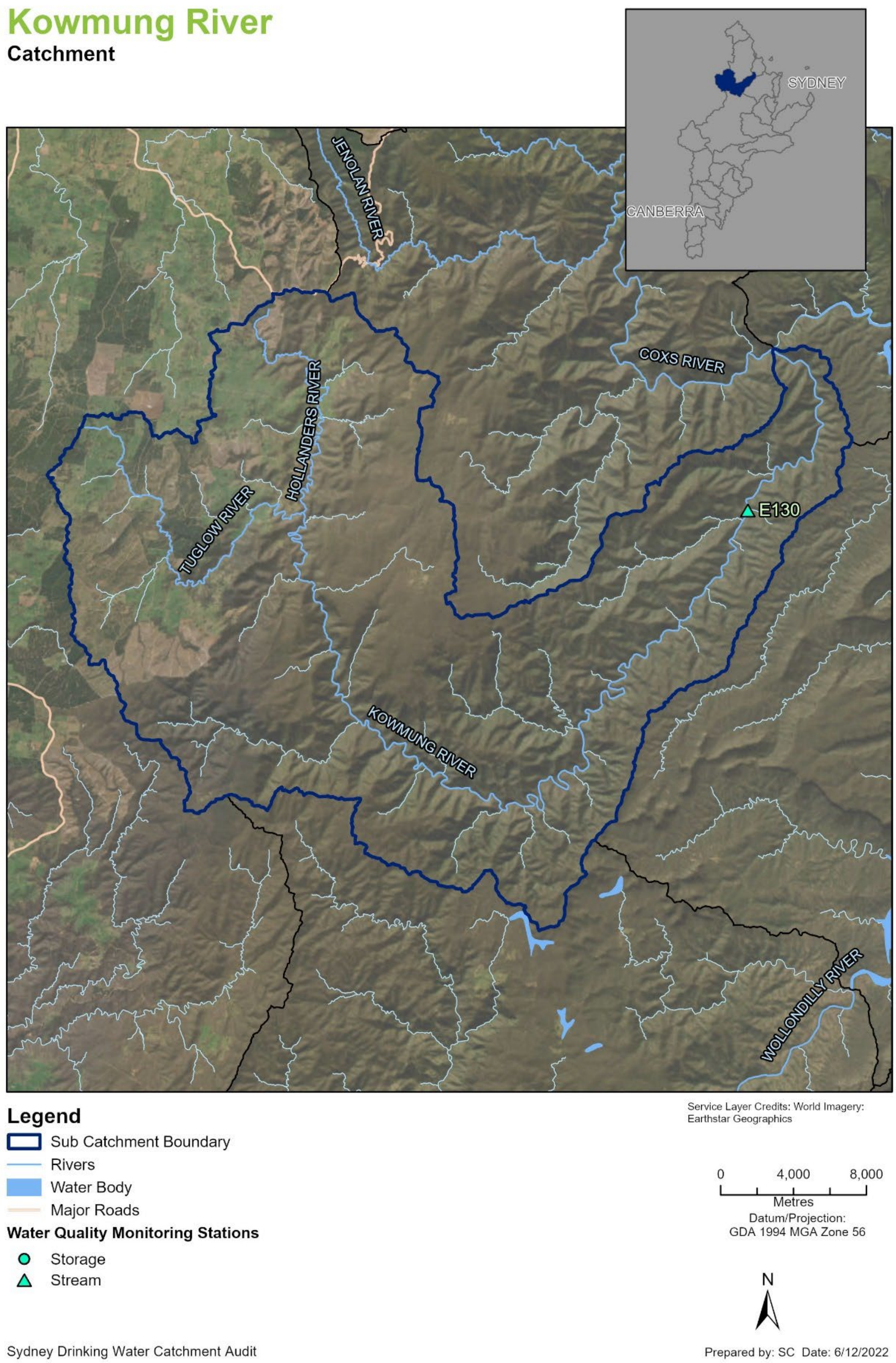

Figure 19-10: Kowmung River water quality monitoring site

19.4.12. Warragamba - Lake Burragorang sub-catchment

The Lake Burragorang sub-catchment is within the Warragamba Special Area and characterised by bushland surrounding the large lake. Approximately 88% of bushland in the Lake Burragorang sub-catchment was burnt in the 2019-20 fires (Table 6-1).

This sub-catchment has five water quality monitoring sites (all storages): DWA12, DWA2, DWA27, DWA311 and DWA9.

The 100% turbidity exceedances in 2019-20 at DWA39 are the only time this occurred in the Catchment during the audit period.

Table 19-14: Lake Burragorang water quality key findings

Method	Key findings

Compliance during audit period	All samples were outside guidelines for the following sites:
	• DWA12, DWA2, DWA27, DWA311 and DWA9
	    ○ Oxidised nitrogen 2020-22
	    ○ Total nitrogen 2020-22
	• DWA39
	    ○ Dissolved oxygen 2019-20
	    ○ Turbidity 2019-20
	    ○ Oxidised nitrogen 2019-22
	    ○ Total nitrogen 2019-22
	    ○ Total phosphorus 2019-20 and 2021-22

Ten-year statistical trend	Nil
Comparison of audit period to pre-audit period	Oxidised nitrogen with median values outside guidelines during the audit period and in the preceding years, were worse during the audit period for the following sites: • DWA12 • DWA2 • DWA27 • DWA311 • DWA9

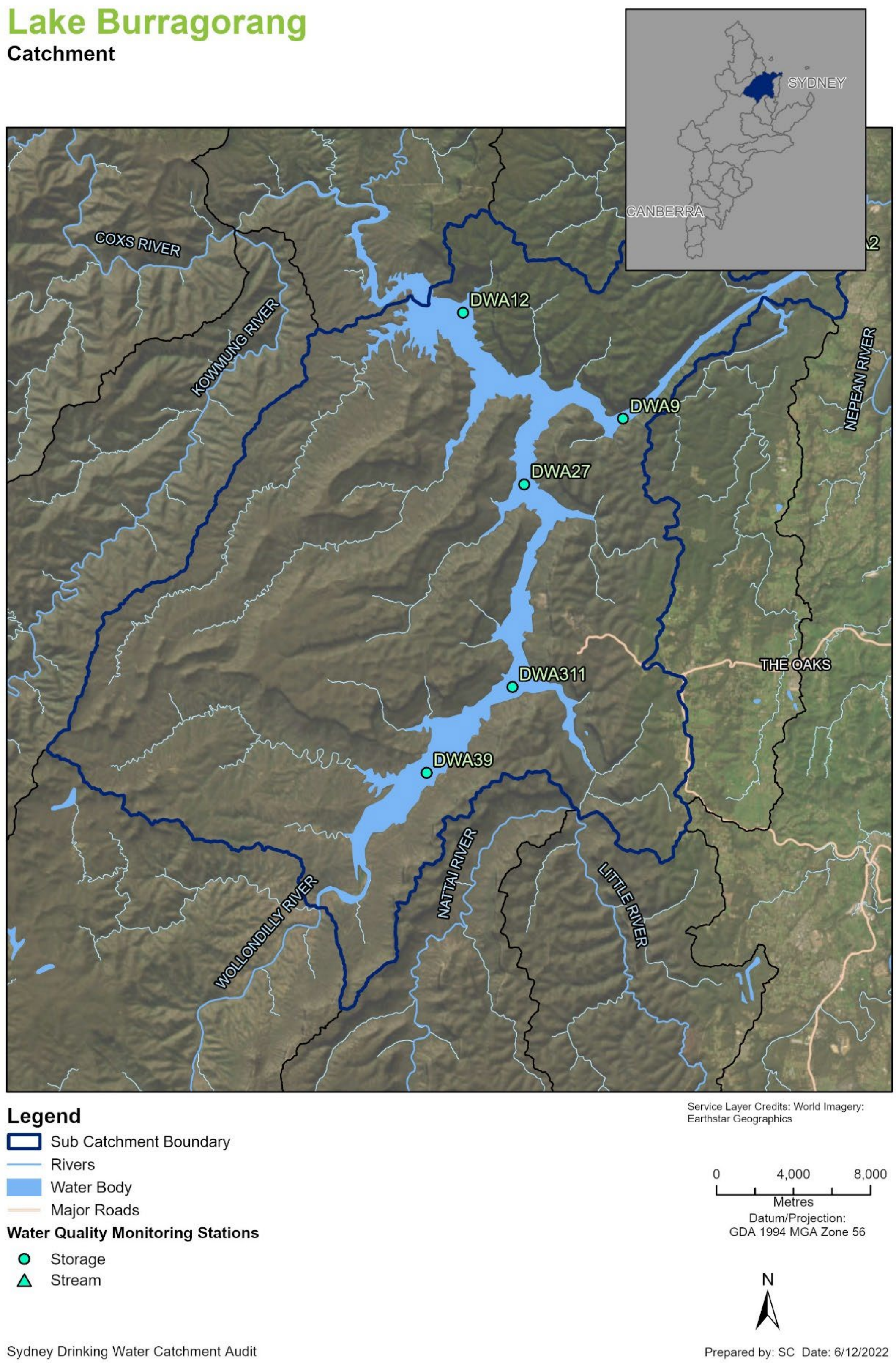

Figure 19-11: Lake Burragorang water quality monitoring sites

19.4.13. Warragamba - Little River sub-catchment

The Little River sub-catchment is within the Warragamba Special Area and characterised by bushland and steep terrain (Figure 19-12). There are pockets of cleared private land on the eastern edge of the sub-catchment, associated with rural-residential development at Buxton in south-western Sydney. The sub-catchment does not receive flows from other sub-catchments.

Routine monitoring in the Little River at E243 suggests that the sub-catchment has good water quality compared to most other sites in the Catchment. Similar to what was experienced for site E130 in the Kowmung sub-catchment, oxidised nitrogen values following the 2019-20 bushfires appear to have been affected by increased organic loads and rapid changes in hydrology under La Nina conditions.

The Little River (E243) monitoring site should be considered as potential benchmark for updated water quality guidelines for the Catchment.

Table 19-15: Little River water quality key findings

Method	Key findings
Compliance during audit period	All samples of oxidised nitrogen were outside guidelines at E243 in 2020-21.
Ten-year statistical trend	Nil
Comparison of audit period to pre-audit period	There were no analytes with median values outside guidelines both during the audit period and in the preceding years.

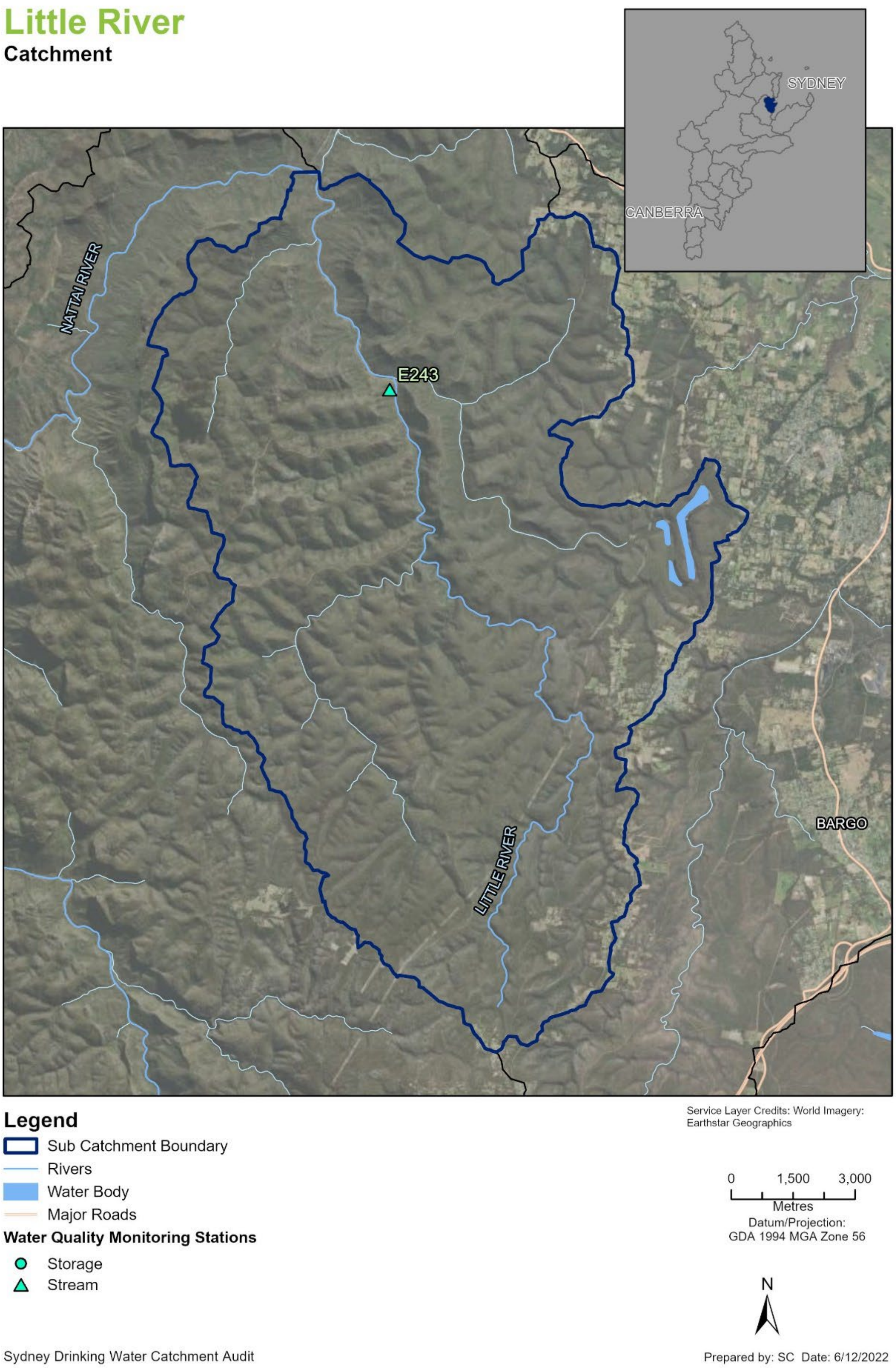

Figure 19-12: Little River water quality monitoring sites

19.4.14. Warragamba - Lower Coxs River sub-catchment

The Lower Coxs River sub-catchment (Figure 19-13) has the Kedumba River as a major tributary and receives water from the Mid and Upper Coxs River sub-catchments. This sub-catchment has four water quality monitoring stations: E157, DWA15, DWA19 and DWA21. The storage monitoring sites are located downstream of the junction of the Kedumba River with the Coxs River.

The upper reaches of the Kedumba River drain urban areas of the Blue Mountains (e.g., Katoomba, Leura) on the southern side of the Great Western Highway. Urban land uses may therefore have contributed to elevated nitrogen concentrations at monitoring station E157, despite it being in bushland well downstream of the urban environment.

It appears likely that land uses in the Mid and Upper Coxs River have contributed to the poorer water quality in the storages compared to at E157.

Table 19-16: Lower Coxs River water quality key findings

Method	Key findings

Compliance during audit period	All samples were outside guidelines for the following sites:
	• E157 - oxidised nitrogen 2020-22
	• DWA15 - oxidised nitrogen and total nitrogen 2020-22
	• DWA19 and DWA21
	  ○ Dissolved oxygen 2019-20
	  ○ Oxidised nitrogen 2019-22
	  ○ Total nitrogen 2019-22
	  ○ Total phosphorus 2019-20 and 2021-22
	  ○ Chlorophyll-a 2019-20

Ten-year statistical trend	Nil
Comparison of audit period to pre-audit period	Analytes with median values outside guidelines during the audit period and in the preceding years, that were the same or worse during the audit period were as follows: • E157 and DWA15 - oxidised nitrogen • DWA19 – chlorophyll-a

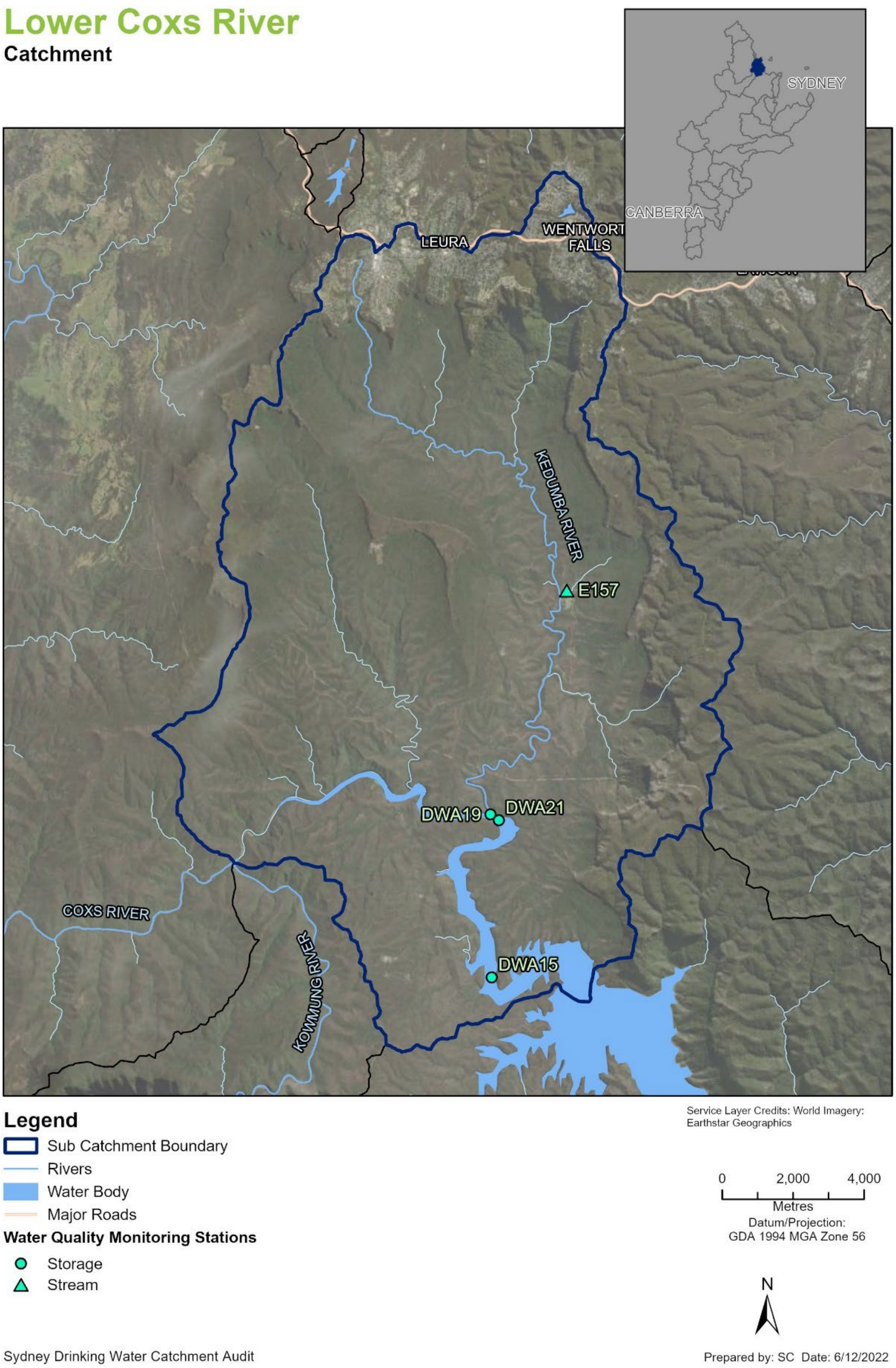

Figure 19-13: Lower Coxs River water quality monitoring sites

19.4.15. Warragamba - Mid Coxs River sub-catchment

The northern half of the Mid Coxs River sub-catchment (Figure 19-14) features agricultural land uses and the remainder comprises bushland within the Warragamba Special Area. There are three routine monitoring sites in this sub-catchment: E073, E083 and E0114. E083 is positioned to receive water from all tributaries in this sub-catchment.

Compliance data was not available for monitoring site E073 in the WaterNSW annual reports for 2019-20 and 2020-21. However, long-term monitoring data was provided by WaterNSW for this site.

Table 19-17: Mid Coxs River water quality key findings

Method	Key findings

Compliance during audit period	All samples were outside guidelines for the following sites:
	• E073 - oxidised nitrogen and total nitrogen 2021-22
	• E0114
	  ○ Oxidised nitrogen 2020-22
	  ○ Total nitrogen 2019-22
	  ○ Total phosphorus 2019-20
	  ○ Phosphorus soluble reactive 2019-20

Ten-year statistical trend	Nil

Comparison of audit period to pre-audit period	Analytes with median values outside guidelines during the audit period and in the preceding years, that were the same or worse during the audit period were as follows:
	• E073 and E0114
	  ○ Oxidised nitrogen
	  ○ Total nitrogen
	  ○ Total phosphorus

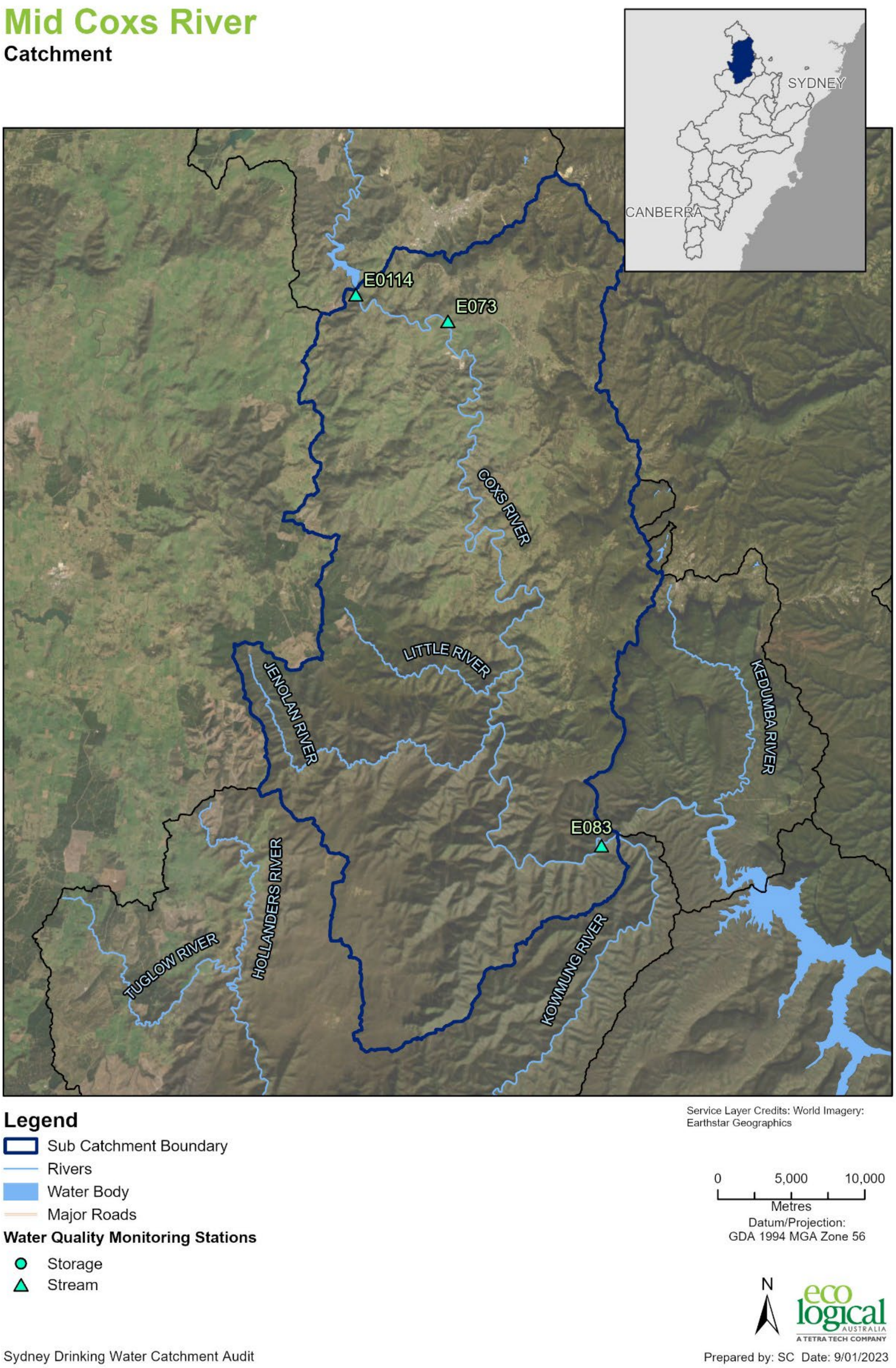

Figure 19-14: Mid Coxs River water quality monitoring sites

19.4.16. Warragamba - Mulwaree River sub-catchment

The Mulwaree River sub-catchment is mostly cleared for grazing (Figure 19-15). There is scope to improve water quality in this sub-catchment by increasing regenerative agricultural practices and native vegetation cover, particularly along riparian corridors (see River Styles priorities in section 15.3).

The routine monitoring site at Towers Weir upstream of Goulburn (E457) has poor water quality and is a priority for investigation and ameliorative measures.

Table 19-18: Mulwaree River water quality key findings

Method	Key findings
Compliance during audit period	All samples were outside guidelines for E457: • Dissolved oxygen 2019-20 • Ammoniacal nitrogen 2019-20 • Total nitrogen 2019-22 • Total phosphorus 2019-21 • Chlorophyll-a 2020-21
Ten-year statistical trend	Nil
Comparison of audit period to pre-audit period	Analytes with median values outside guidelines during the audit period and in the preceding years, that were the same or worse during the audit period were as follows for site E457: • Chlorophyll-a • Oxidised nitrogen • Total nitrogen • Total phosphorus • Phosphorus soluble reactive

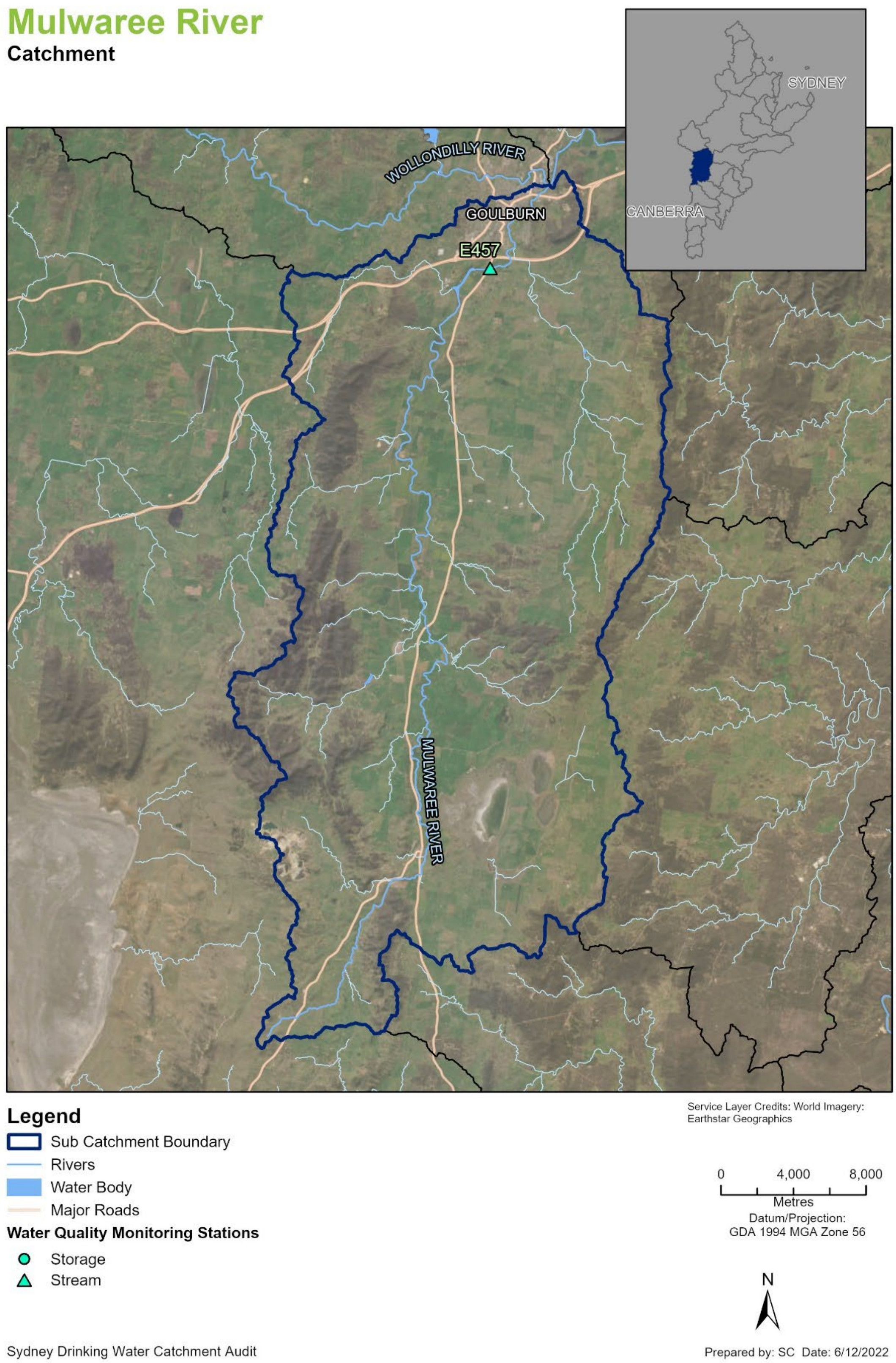

Figure 19-15: Mulwaree River water quality monitoring sites

19.4.17. Warragamba - Nattai River sub-catchment

Most of the Nattai River sub-catchment comprises bushland within Nattai National Park, part of which is within the Warragamba Special Areas (Figure 19-16). The upper southern reaches of the sub-catchment feature the township of Mittagong.

There are three water quality monitoring stations in this sub-catchment: E203, E206 and E210. Routine monitoring site E203 is 400 m downstream of Mittagong sewage treatment plant. The plant and other urban activities contribute high nutrient loads to waterways. The Mittagong sewage treatment plant is scheduled for upgrade in 2028.

Table 19-19: Nattai River water quality key findings

Method	Key findings

Compliance during audit period	All samples were outside guidelines for:
	• E203
	  ○ Ammoniacal nitrogen 2020-22
	  ○ Oxidised nitrogen and total nitrogen 2019-22
	• E206
	  ○ Oxidised nitrogen and total nitrogen 2019-22
	• E210
	  ○ Oxidised nitrogen 2020-22
	  ○ Total nitrogen 2020-21

Ten-year statistical trend	No worsening trend

Comparison of audit period to pre-audit period	Analytes with median values outside guidelines during the audit period and in the preceding years, that were the same or worse during the audit period were as follows:
	• E203
	  ○ Ammoniacal nitrogen
	  ○ Total phosphorus
	• E210
	  ○ Oxidised nitrogen
	  ○ Total nitrogen

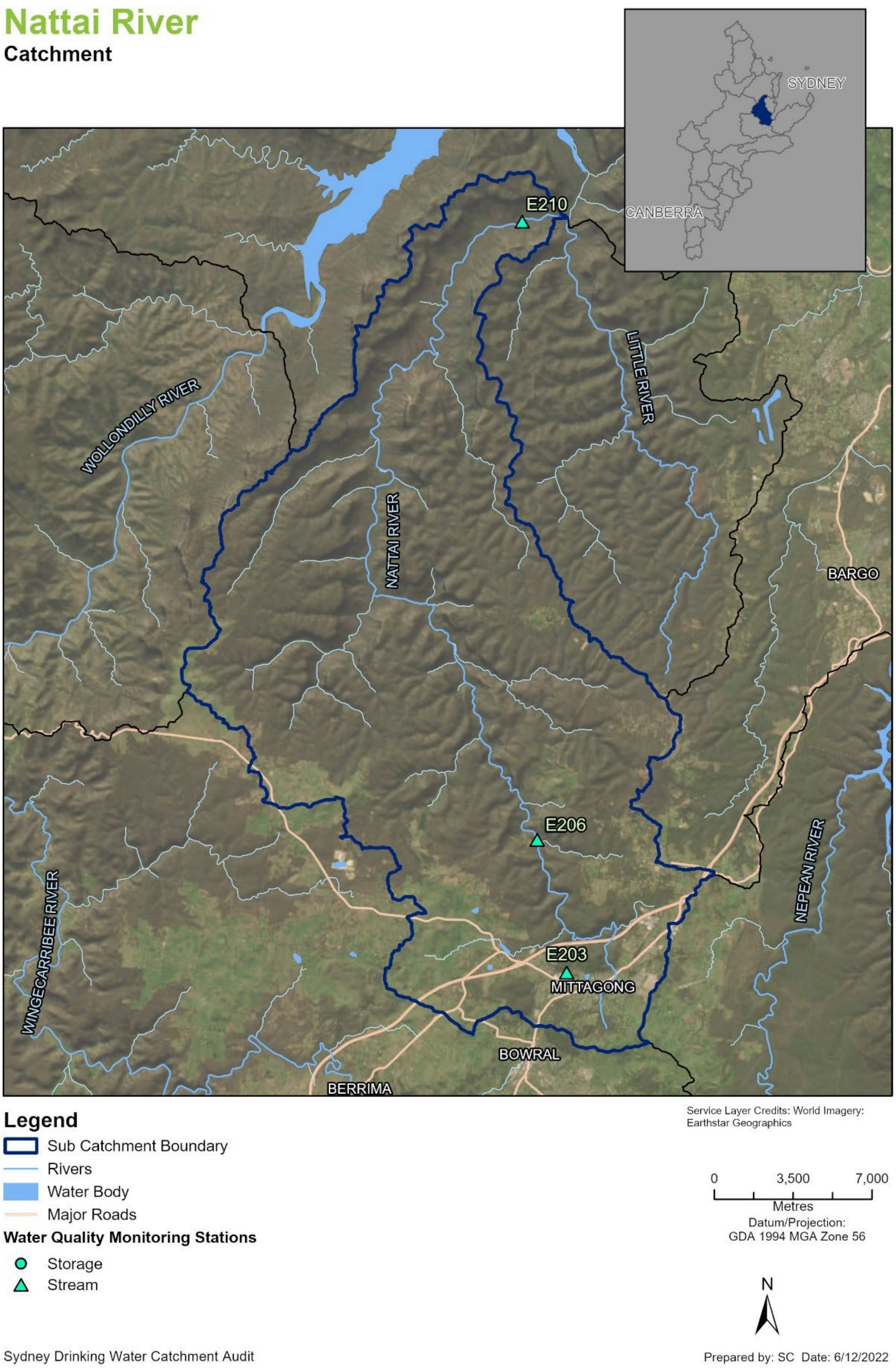

Figure 19-16: Nattai River water quality monitoring sites

19.4.18. Warragamba - Upper Coxs River sub-catchment

The Upper Coxs River sub-catchment (Figure 19-17) is characterised by current and past land uses that include mining, heavy industry (e.g., Mt Piper power station), urban areas (e.g., Lithgow), forestry and agriculture. Parts of this sub-catchment have bushland conservation reserves (e.g., Marrangaroo National Park and the recently declared Gardens of Stone State Conservation Area (see section 7.3)). Lake Wallace and Lake Lyell are used by the local community for boating, fishing and other recreational activities but are prone to cyanobacterial blooms which limits the public amenity.

WaterNSW routinely monitors three sites within this sub-catchment: E0115, E0321 and E046. Site E046 at Farmers Creek is downstream of Lithgow. Farmers Creek flows into Lake Lyell which is a storage on the Coxs River that is managed by EnergyAustralia as part of operations at Mt Piper. Water is allocated to EnergyAustralia in accordance with the Greater Metropolitan Water Sharing Plan for operation of the Mt Piper Power Station.

EnergyAustralia routinely monitors water quality at ten sites across the Upper Coxs River sub-catchment as part of its Water Access Licence 27428 and Water Supply Work and Water Use Approval 10CA117220, and detailed results and analysis are presented in annual compliance reports. EnergyAustralia's water quality monitoring for the audit period reported similar results to those tabulated below.

Table 19-20: Upper Coxs River water quality key findings

Method	Key findings

Compliance during audit period	All samples were outside guidelines for:
	• E046 - oxidised nitrogen and total nitrogen 2019-22
	• E0115
	  ○ Conductivity 2019-20
	  ○ pH 2019-20
	  ○ Total nitrogen 2019-20 and 2021-22
	• E0321
	  ○ Conductivity 2019-21
	  ○ Oxidised nitrogen 2019-20

Ten-year statistical trend	Nil
Comparison of audit period to pre-audit period	Analytes with median values outside guidelines during the audit period and in the preceding years, that were the same or worse during the audit period were as follows at E0115: • Total nitrogen • Total phosphorus

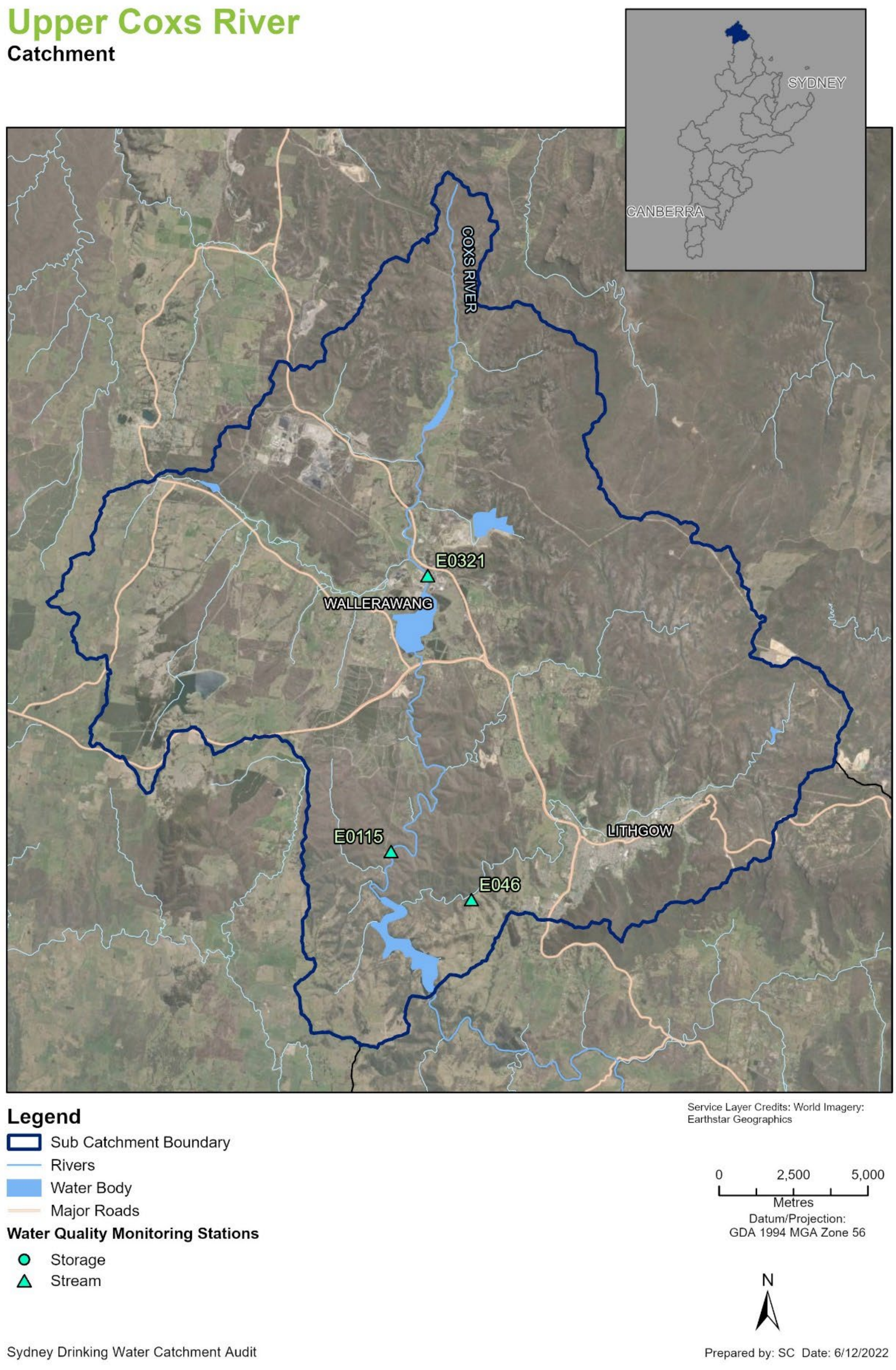

Figure 19-17: Upper Coxs River water quality monitoring sites

19.4.19. Warragamba - Upper Wollondilly sub-catchment

The Upper Wollondilly sub-catchment is dominated by dryland agriculture in private ownership (Figure 19-18). The monitoring site E490 is located upstream of the Goulburn township, just below the confluence with Sooley Creek, so water quality at this site is affected by agricultural land uses. However, there was only one year of data collected at this monitoring site (in 2021-22).

Similar to the Mulwaree River sub-catchment to the south of Goulburn (section 19.4.16), many watercourses in this sub-catchment would benefit from increased regenerative agricultural practices and native vegetation cover and have been identified as priorities for action under the River Styles assessment (see section 15.3).

Table 19-21: Upper Wollondilly water quality key findings

Method	Key findings
Compliance during audit period	All samples at E490 were outside guidelines for total nitrogen in 2021-22.
Ten year statistical trend	Insufficient data available to determine trends.
Comparison of audit period to pre-audit period	Insufficient data available to undertake comparison.

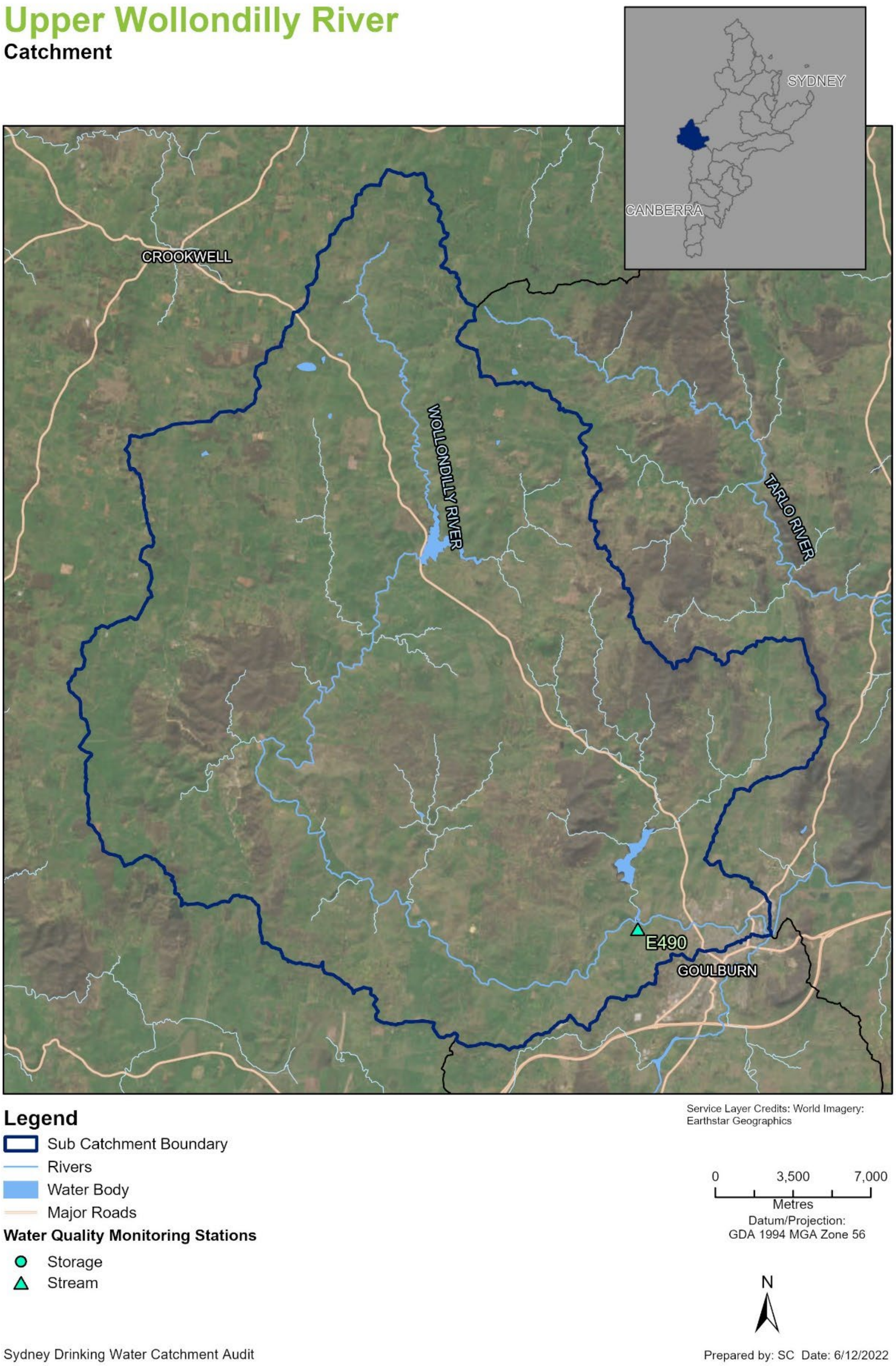

Figure 19-18: Upper Wollondilly River water quality monitoring sites

19.4.20. Warragamba - Werri Berri Creek sub-catchment

Werri Berri Creek flows into Lake Burragorang just upstream of the Warragamba Dam wall (Figure 19-19). Approximately half of the Werri Berri Creek sub-catchment comprises residential, semi-rural and rural residential land uses. The downstream part of the sub-catchment is bushland.

Residential areas (e.g., The Oaks) are likely to have influenced water quality experienced at routine monitoring site E531. Much of the development in these areas has been subject to NorBE requirements. Refer to section 9.4.4 for case study on urban development in Werri Berri sub-catchment.

WaterNSW advised that a large quantity of sediment was deposited at the gauging site post fire and flood, physically changing the site. This may have affected the water quality results during the audit period and may be a short-term change.

Table 19-22: Werri Berri Creek water quality key findings

Method	Key findings
Compliance during audit period	All samples were outside guidelines for E531: • Dissolved oxygen 2019-20 • Ammoniacal nitrogen 2020-21 • Oxidised nitrogen 2020-21
Ten-year statistical trend	Long term statistical trend analysis by WaterNSW for the period 2011-2021 found that dissolved oxygen levels at site E531 were more frequently outside ANZECC benchmarks in recent years.
Comparison of audit period to pre-audit period	Oxidised nitrogen with median values outside guidelines during the audit period and in the preceding years, were worse during the audit period at E531.

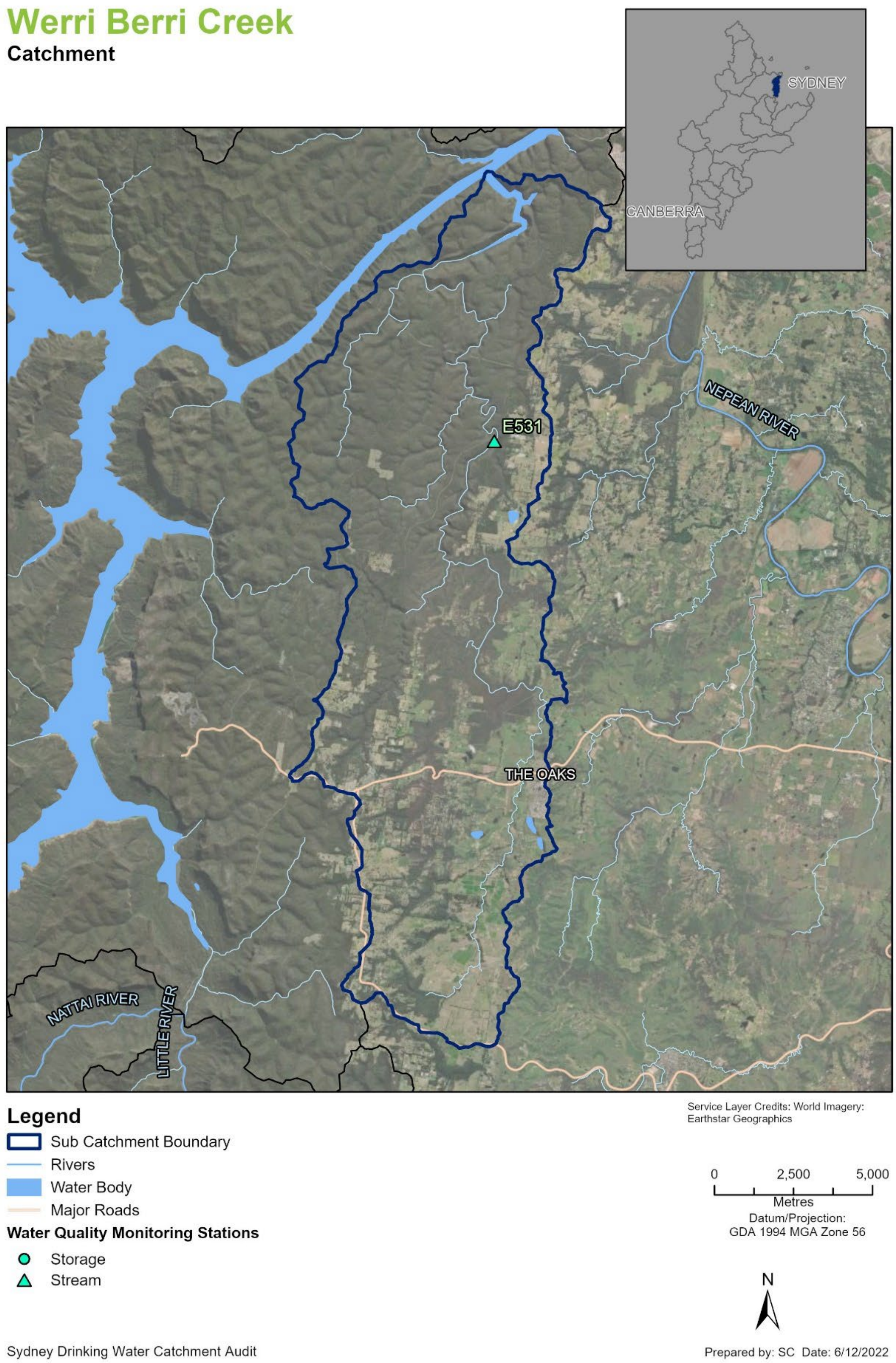

Figure 19-19: Werri Berri Creek water quality monitoring sites

19.4.21. Warragamba - Wingecarribee River sub-catchment

There are five routine water quality monitoring stations in this sub-catchment (Figure 19-20): E301, E306, E332, E3151 and DWI1.

The Wingecarribee River sub-catchment in the Southern Highlands flows to the Wollondilly River, however, it is managed by WaterNSW for raw water supply delivery as part of the Shoalhaven system. Caalang Creek flows into Wingecarribee swamp and lake. The Caalang Creek monitoring site (E301) is downstream of Robertson, although the Robertson sewage treatment plant discharges effluent downstream of E301. Wingecarribee Reservoir is surrounded by agricultural land uses and has very little riparian vegetation other than the upstream swamp. The Bowral and Moss Vale sewage treatment plants are also in this sub-catchment, although downstream of the two monitoring stations reported below, and these are scheduled to be upgraded in 2024 and 2026, respectively.

Water quality recorded at the lake outlet (DWI1) during the audit period had high nutrients and chlorophyll-a, which triggered cyanobacteria alerts, as discussed in section 19.6. Water quality upstream at Caalang Creek did not have elevated total phosphorus or chlorophyll-a concentrations during the audit period, which suggests that the additional nutrient may be from agricultural activities around the lake as well as Wingecarribee Swamp. The wet/dry cycles of the peat swamp can lead to internal nutrient cycling in the lake.

Detailed analysis of water quality in Wingecarribee Reservoir 1999-2020 (WaterNSW 2020e) aimed to understand the relative influence of:

- Water transfers from Fitzroy Falls Reservoir
- Storage level fluctuations
- Inflows on water quality and cyanobacterial growth in Wingecarribee Reservoir since the 1998 swamp collapse.

Graphical and statistical analyses were used to identify temporal patterns in the long-term dataset and identify the most likely factors contributing to cyanobacterial growth using multiple lines of evidence. The study found cyanobacterial growth in Wingecarribee Reservoir appears to be strongly driven by nitrogen released from lake storage level fluctuations, which trigger the exposure, degradation, and re-wetting of degraded peat. This process interacts with seasonal temperature fluctuations that produce cyanobacterial growth peaks in late summer and autumn. Catchment inflow volumes were not directly related to cyanobacterial dynamics, but their high nitrogen content likely contributes to long-term eutrophication and cyanobacterial proliferation in the lake. Water transfers from Fitzroy Falls Reservoir had a net neutral or even beneficial effect on cyanobacterial growth, potentially through reducing lake water residence time. The following management recommendations were made by WaterNSW to minimise the risk of further deterioration in the long-term:

- Maintain Wingecarribee Reservoir storage level within the current target operating window of 1-2 m below full storage level. Where lower storage levels cannot be avoided, prepare for increased cyanobacterial risk in the immediate or following bloom season.
- Investigate the feasibility of additional catchment management program options to reduce nitrogen export from the catchment upstream of and surrounding Wingecarribee Reservoir.

- Update operating protocols for work approvals at Wingecarribee Reservoir to consider making transfers from Fitzroy Falls Reservoir following works that require Wingecarribee storage level to be reduced below -2 m full storage level. These transfers may reduce cyanobacterial risk at Wingecarribee Reservoir by flushing nitrogen released from exposed peat and reducing water residence time in the reservoir. Any decision to undertake transfers must consider pumping costs, Fitzroy Falls water quality, potential impacts on receiving waters, and existing operating requirements, which may limit their implementation as a water quality management strategy.
- In-lake cyanobacteria treatment was not recommended as the modes of action of previously investigated cyanobacteria treatment options (see section 19.6.6) are unlikely to be successful in the long term unless nitrogen loading to the lake is also reduced.

The Wingecarribee River sub-catchment continues to be a priority for investigation and action.

Table 19-23: Wingecarribee River water quality key findings

Method	Key findings

Compliance during audit period	All samples were outside guidelines for:
	• E301
	  ○ Oxidised nitrogen and total nitrogen 2020-22
	• E332
	  ○ Oxidised nitrogen 2019-21
	  ○ Total nitrogen 2019-22
	  ○ Total phosphorus 2020-22
	  ○ Chlorophyll-a 2020-22
	• DWI1
	  ○ Oxidised nitrogen 2019-20
	  ○ Total nitrogen 2019-20 and 2021-22
	  ○ Total phosphorus 2019-20

Statistical trend	Long term statistical trend analysis by WaterNSW for the period 2011-2021 found the following were more frequently outside ANZECC benchmarks in recent years (i.e., worsening trend) at DWI1: • Dissolved oxygen levels • Chlorophyll-a • Total nitrogen

Comparison of audit period to pre-audit period	Analytes with median values outside guidelines during the audit period and in the preceding years, and were the same or worse during the audit period were as follows:
	• E301
	  ○ Oxidised nitrogen
	  ○ Total nitrogen
	• E332
	  ○ Dissolved oxygen
	  ○ Oxidised nitrogen
	  ○ Total nitrogen
	  ○ Total phosphorus
	• DWI1
	  ○ Oxidised nitrogen
	  ○ Total nitrogen

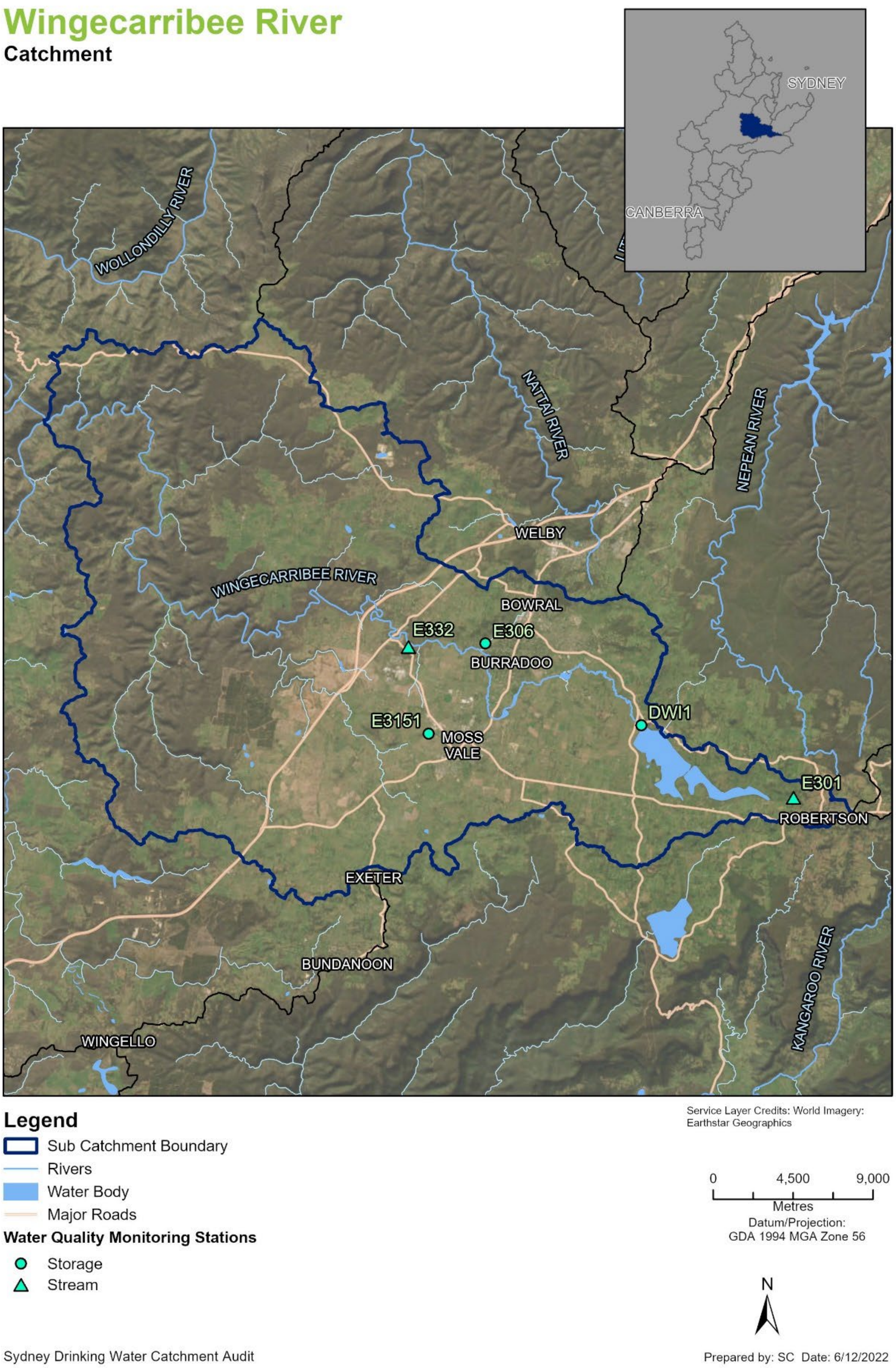

Figure 19-20: Wingecarribee River water quality monitoring sites

19.4.22. Warragamba - Wollondilly River sub-catchment

There are five routine water quality monitoring stations in this sub-catchment: E409, E433, E450, E488 and E4112.

Water quality in the Wollondilly River sub-catchment is strongly influenced by the townships of Goulburn, Taralga, Marulan, Wingello and Bundanoon (Figure 19-21). Monitoring site E409 is located immediately downstream of the township of Goulburn. The mid and lower reaches of the sub-catchment are characterised by bushland and agricultural land uses. Salt springs around Goulburn contribute salt loads to the Wollondilly River.

Table 19-24: Wollondilly River water quality key findings

Method	Key findings

Compliance during audit period	All samples were outside guidelines for:
	• E409
	  o Conductivity 2019-20
	  o Oxidised nitrogen 2021-22
	  o Total nitrogen 2019-22
	  o Total phosphorus 2021-22
	• E450
	  o Oxidised nitrogen 2021-22
	  o Total nitrogen 2020-22
	  o Total phosphorus 2021-22
	• E488
	  o Conductivity 2019-20
	  o Total nitrogen 2020-22

Ten-year statistical trend	Long term statistical trend analysis by WaterNSW for the period 2011-2021 found that chlorophyll-a levels at site E450 were more frequently outside ANZECC benchmarks in recent years (i.e., worsening).

Comparison of audit period to pre-audit period	Analytes with median values outside guidelines during the audit period and in the preceding years, that were the same or worse during the audit period were as follows:
	• E409
	  o Dissolved oxygen
	  o Ammoniacal nitrogen
	  o Total nitrogen
	• E450 and E488 – total nitrogen

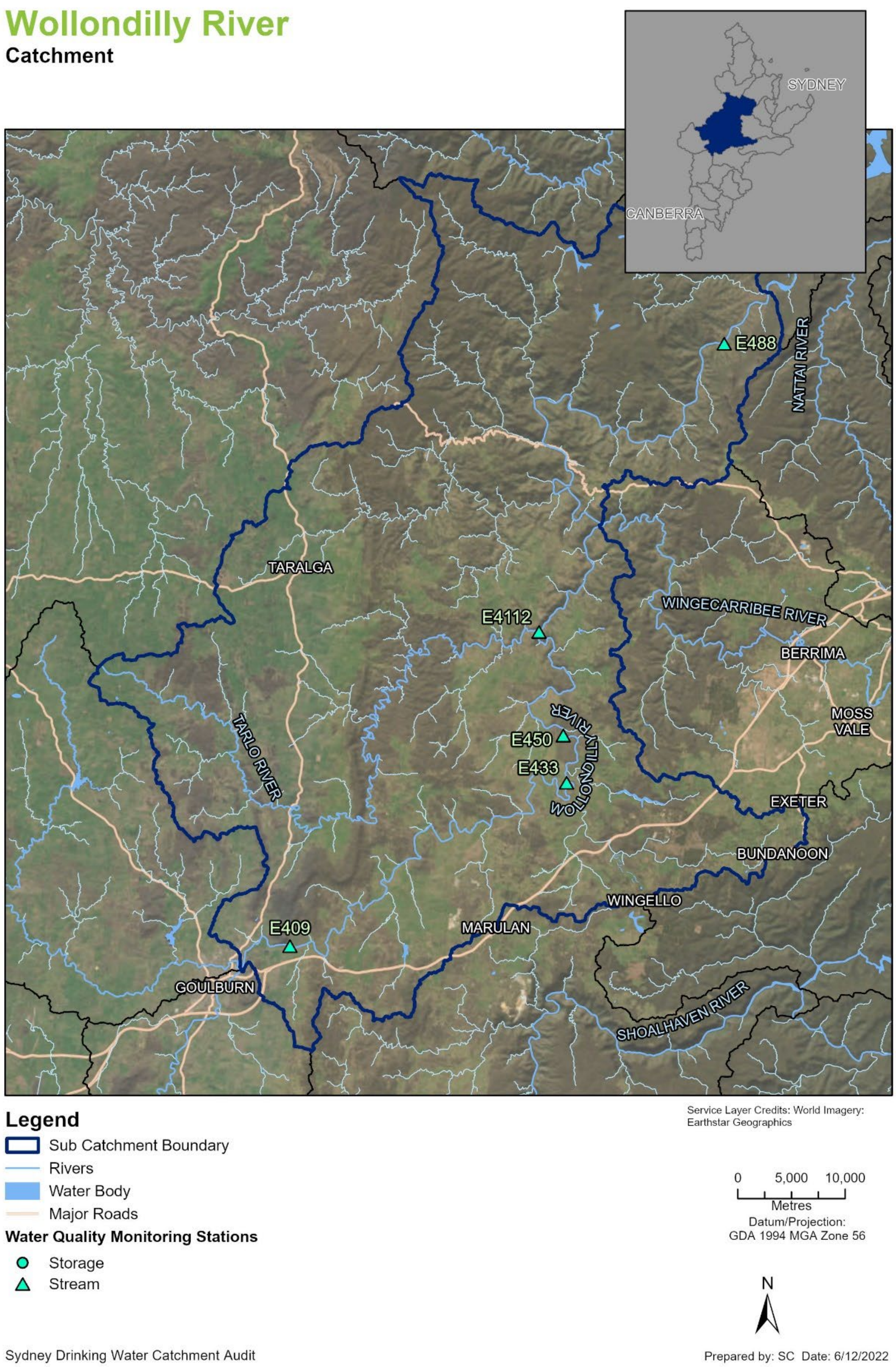

Figure 19-21: Wollondilly River water quality monitoring sites

19.4.23. Warragamba – Prospect Reservoir sub-catchment

Prospect Reservoir in western Sydney is part of the declared Catchment and referred to in WaterNSW annual monitoring reports as within the Warragamba system. Prospect Reservoir receives water from Warragamba via the Warragamba pipelines and from the Upper Nepean dams via the Upper Canal.

This sub-catchment has two water quality monitoring stations: RPR1 and RPR6.

Table 19-25: Prospect Reservoir water quality key findings

Method	Key findings

Compliance during audit period	All samples were outside guidelines for:
	• RPR1 – chlorophyll-a 2020-21
	• RPR6
	  ○ Oxidised nitrogen 2021-11
	  ○ Chlorophyll-a 2020-21

Ten-year statistical trend	No worsening trend
Comparison of audit period to pre-audit period	There were no analytes with median values outside guidelines both during the audit period and in the preceding years.

Figure 19-22: Prospect Reservoir water quality monitoring sites

19.5. Woronora sub-catchment

The Woronora sub-catchment (Figure 19-23) is dominated by bushland owned by WaterNSW and protected as a Special Area. There are no towns in the sub-catchment. Woronora Dam lies in a narrow gorge on the Woronora River upstream of its junction with the Georges River.

There are four routine monitoring stations operated by WaterNSW in this sub-catchment: E677, E6131, DWO_THMD and DWO1.

Table 19-26: Woronora River water quality key findings

Method	Key findings
Compliance during audit period	All samples were outside guidelines for: • E677 – pH 2020-21 • DWO_THMD – oxidised nitrogen 2021-22 • DWO1 – oxidised nitrogen 2019-22
Ten-year statistical trend	Nil
Comparison of audit period to pre-audit period	Analytes with median values outside guidelines during the audit period and in the preceding years, that were the same or worse during the audit period were as follows: • E677 - pH • DWO1 – oxidised nitrogen

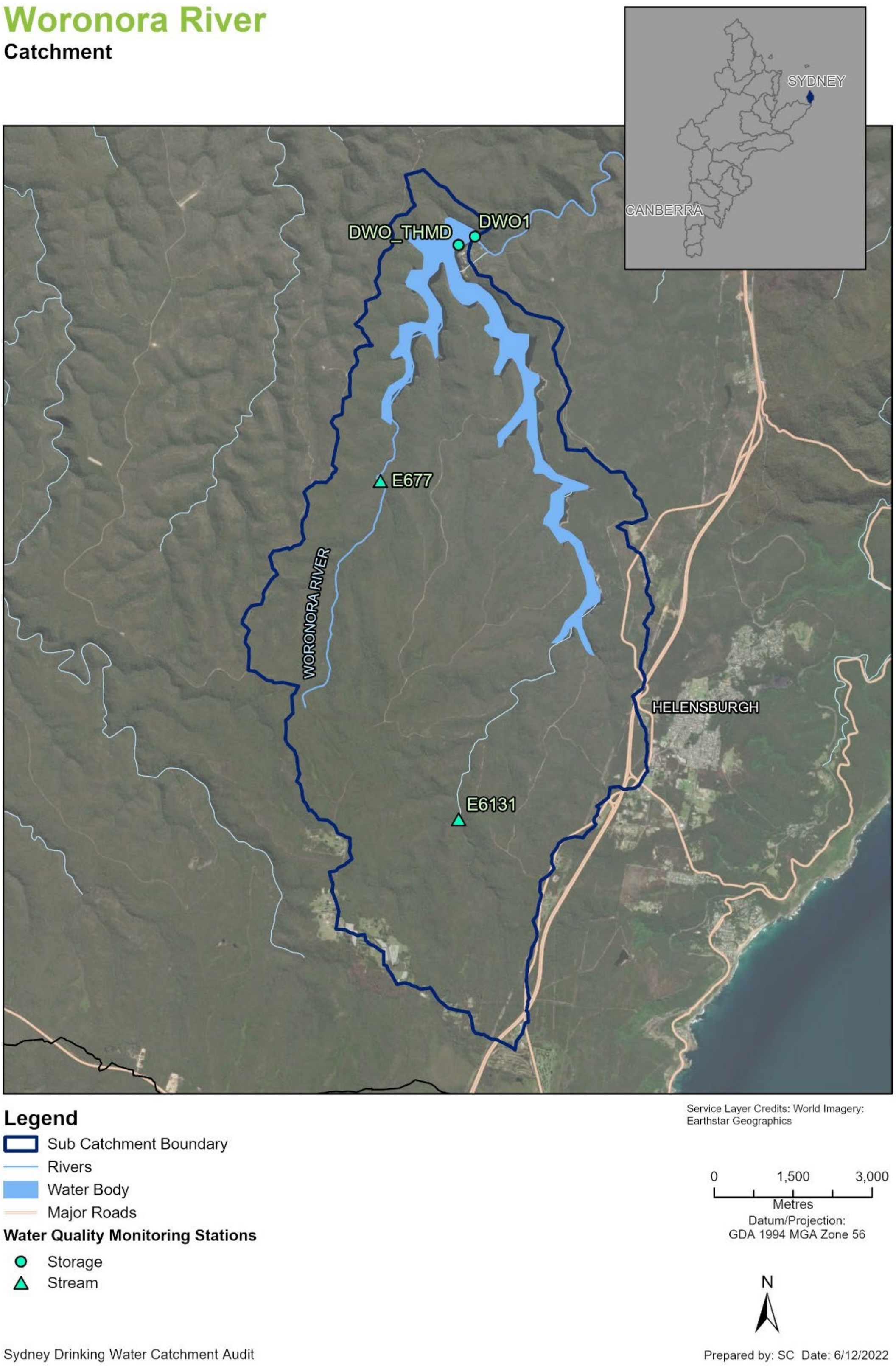

Figure 19-23: Woronora water quality monitoring sites

19.6. Cyanobacterial blooms

19.6.1. Definition and context

Cyanobacteria are a microscopic form of life found in water, commonly known as blue-green algae. A combination of natural and human factors can influence the abundance and types of cyanobacteria, with temperature, slow water flow, and availability of nitrogen and phosphorus the main triggers for visible blooms. When some species of cyanobacteria produce toxins, this can mean water affected by an algal bloom:

- Is not safe for humans to drink (due to the risk of algal toxins, NSW Health advises that any domestic use of surface water without appropriate treatment should be avoided)
- Can poison wildlife, livestock and domestic animals
- Is not safe for recreational activities such as swimming and boating
- Is difficult and expensive to treat to make it safe for drinking.

Algal blooms can also contribute to fish deaths. Like plants, blue-green algae do not photosynthesise at night. Instead, they use oxygen in a process called respiration. When large numbers of blue-green algae take oxygen out of the water (indicated by low dissolved oxygen levels), there may not be enough left for fish and other aquatic life to breathe.

The most effective method of preventing cyanobacterial blooms is to minimise the nutrient load entering waterways (especially phosphorus because it is the nutrient controlling growth and bloom formation; Newcombe et al 2010) by:

- Appropriate treatment and disposal of stormwater, agricultural, industrial and sewage effluent
- Planting or maintaining riparian vegetation
- Soil conservation and flow manipulation to prevent the build-up of blue-green algae.

Mechanical methods (e.g., aerators in Lake Lyell) are sometimes used in water reservoirs to mix water and prevent stratification which could bring about cyanobacterial blooms. However, once a bloom is detected there are few ways to disperse it without adverse side effects. Flushing the water body by adjusting river flows may disperse the blooms and break up stratification. The amount of flow needed to disperse algal blooms is not always available and toxins can remain in the water column, even when algae are not visible.

19.6.2. Monitoring

As part of the routine water monitoring program, WaterNSW analyses stream and storage samples for algal speciation when chlorophyll-a exceeds the ANZECC guideline of 5 µg/L. Selected sites in storages close to water filtration plants have unconditional algae counts and speciation undertaken regardless of chlorophyll-a results. Seasonal monitoring is conducted by WaterNSW more frequently in the warmer months between October and May at locations with a history of algal activity to facilitate early detection of emerging algal events.

19.6.3. Public alerts

Public alerts are declared by the Regional Algal Coordinators where algal cell numbers exceed the triggers identified in the Guidelines for Managing Risk in Recreational Water (NHMRC 2008). The algal alert website Algae - WaterNSW is updated daily to display current alerts for recreational waters and includes definitions of alert levels, which are summarised as follows:

- Red alert – The water is experiencing 'bloom' conditions. It may appear green and have strong, musty or organically polluted odours. Blue-green algae may be visible as clumps or as scums. The 'blooms' should be considered toxic to humans and animals, and the water should not be used for drinking (without prior treatment), stock watering, or for recreation. Waterbody managers are required to notify the public through signage and media.
- Amber alert – Increased sampling of algae is required at amber alert levels because blue-green algae may be multiplying in numbers. The water may have a green tinge and musty or organic odour. The water should be considered as unsuitable for potable use and alternative supplies or prior treatment of raw water for domestic purposes should be considered. The water may also be unsuitable for stock watering. The water remains suitable for recreational use, however algal concentrations can change rapidly. Water users should use caution and avoid water where signs of blue-green algae present.
- Green alert – Routine sampling will continue where blue-green algae are present in the water at low densities, possibly signalling the early stages of the development of a bloom, or a period where a bloom is declining. At these densities, the blue-green algae do not pose a threat to recreational, stock or domestic use.

19.6.4. Trends

A total of 737 cyanobacterial alerts for recreational waters were issued for monitoring sites in the Catchment during the audit period. This was a reduction from the number of alerts reported during the peak of the drought in 2017-19 (Table 19-27) when there were lower flows and higher water temperatures. There were 30 red alerts in 2019-20 and 7 red alerts in 2020-21, with most (n=33) occurring at Lake Lyell and Fitzroy Falls Lake. Previous audits also found these two lakes to be problematic. Red alerts during the audit period occurred throughout the year, suggesting seasonality is not the main driver.

Table 19-27: Cyanobacterial alert trends (WaterNSW)

Year	Green	Amber	Red	Total alerts
2013-14	139	32	4	175
2014-15	125	50	8	183
2015-16	143	44	11	198
2016-17	82	20	0	102#
2017-18	171	263	184	618
2018-19	300	207	39	546
2019-20	**112**	**112**	**30**	**264**
2020-21	**143**	**114**	**7**	**264**
2020-22	**123**	**86**	**0**	**209**

#incomplete dataset available

Table 19-28: Cyanobacterial alerts for recreational waters during the audit period (WaterNSW)

Monitoring site		2019-20				2020-21				2021-22			
		No alert	Green	Amber	Red	No alert	Green	Amber	Red	No alert	Green	Amber	Red
N86	Nepean River at Pheasants Nest Weir Pool	52	0	0	0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
N1158*	Lake Lyell Various Sites	2	13	21	16	34	4	11	3	12	25	15	0
EO114*	Coxs River below Lake Lyell	31	4	17	0	22	6	24	0	42	10	0	0
N1159*	Lake Wallace (Cox3)	22	5	23	2	27	19	6	0	48	4	0	0
N1160*	Coxs River below Lake Wallace	19	14	17	2	17	35	0	0	37	10	5	0
DFF6	Fitzroy Falls Lake at Midlake	6	22	10	10	0	0	48	4	0	4	48	0
E303	Wingecarribee River at Sheepwash Bridge	4	28	20	0	14	38	0	0	4	30	18	0
E332	Wingecarribee River at Berrima	48	4	0	0	44	5	3	0	44	8	0	0
DTA8	Lake Yarrunga at Kangaroo River	25	13	14	0	20	10	22	0	35	17	0	0
E851	Shoalhaven River d/s of Tallowa Dam	43	9	0	0	26	26	0	0	47	5	0	0
E457	Mulwaree River, Towers Weir	n/a	n/a	n/a	n/a	29	10	13	0	42	10	0	0
N1161	Pejar Dam	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	52	0	0	0
		252	**112**	**122**	**30**	**204**	**143**	**114**	**7**	**363**	**123**	**86**	**0**

*Monitored by EnergyAustralia

19.6.5. Case study – Lake Lyell

Lake Lyell in the Upper Coxs River sub-catchment is managed and monitored by EnergyAustralia as part of the Mt Piper power station operation. The lake is accessible to the community for recreational purposes and has been subject to cyanobacterial red alerts during most months of the year (Table 19-28). An aerator is positioned within the lake upstream of the dam wall to prevent and disperse cyanobacterial blooms. Routine monitoring by WaterNSW downstream of Lake Lyell at sites E0114 and E073 (Figure 19-14) shows that chlorophyll-a exceeded guidelines 25-40% of the time during the audit period (Table 7-16 in Appendix G).

Figure 19-24: Lake Lyell boat ramp – one of the recreational sites known to experience cyanobacterial blooms

19.6.6. Treatment trials

Aeration is conventionally used to prevent cyanobacteria blooms in source water storages but is often prohibitively expensive. There are several treatment products on the market that may offer an alternative approach to cyanobacteria bloom prevention by manipulating the microbial ecology of a lake. However, a laboratory and field trial of four products by WaterNSW found that destratification by aeration still had the strongest influence on cyanobacterial growth relative to other tested treatments (Rohlfs et al 2021).

19.7. Integrated water quality model

WaterNSW commenced development of an integrated water quality modelling system in 2019. The Catchment and River Management (CARM) System - Greater Sydney project is developing an integrated water quality modelling system for the Catchment using data from WaterNSW, councils, industry and others. The system provides decision-support tools for operators and strategic planners. The models within the system estimate flows and water quality in the streams through to the storages, supply system offtakes and water filtration plants. The project will bring in the capabilities to manage and improve flow and water quality conditions within the Catchment, including:

- Conducting quantity forecasts for events and day to day operations
- Managing forecasted water quality into reservoir and supply systems
- Managing asset outages and risks for planning and operations
- Assessing programs as part of Catchment planning
- Examining long-term water quality impacts, trends and changes as part of innovation and long-term planning.

As part of the Water Quality Science Program, WaterNSW has a complementary project to validate the model using satellite remote sensing data. Further opportunities to refine and utilise the model are expected in future as additional data become available.

The integrated water quality catchment modelling project currently excludes fire-affected sub-catchments to enable later calibration incorporating altered post-fire catchment processes. This approach allows more accurate calibration of water quality under both stable and fire-affected landscape conditions to support incident response and the review of management scenarios. Further development and application of the integrated water quality catchment model will target scenarios reflecting major bushfire events and management immediately following a fire event.

It is currently difficult for land managers such as WaterNSW to access and interrogate pollution datasets for application in the integrated water quality model. The EPA recognises this and is developing a spatial database of environment protection licences and associated information that can be queried and uploaded for analysis and investigation by other stakeholders whilst respecting privacy issues.

19.8. Conclusions and recommendations

Water quality during the audit period was strongly influenced by the shift from drought and bushfires to periods of intense rainfall. As stated in the WaterNSW Annual Water Quality Report 2020-21:

> ‘A combination of extended drought, widespread bushfire in the Warragamba catchment followed by major rain events in 2020 and 2021 resulted in some of the most challenging water quality conditions since 1998.’

The water quality monitoring program must be fit-for-purpose in the context of increasing extreme climate-driven events. This includes having robust monitoring equipment, access to monitoring sites and monitoring stations in all sub-catchments. It is recommended that these matters be considered when developing the Catchment disaster mitigation plan for critical water monitoring infrastructure.

Overall, median water quality values indicated conditions in storages were worse during the audit period than preceding years. The 2019-20 bushfires and subsequent heavy rainfall were contributing factors to this result. Priority locations that require further investigation and ameliorative action because they are in poor condition with a worsening water quality trend are as follows:

- Kangaroo River sub-catchment, with a focus on DBP1 (Bendeela Pondage), DTA8 (Lake Yarrunga at Bendeela pumping station) and E706 (Kangaroo River at Hampden Bridge)
- Mid Coxs River sub-catchment, with a focus on E0114 (Coxs River downstream of Lake Lyell) and E073 (Coxs River at Glenroy Bridge)
- Wingecarribee River sub-catchment, with a focus on E332 at Berrima
- Wollondilly River sub-catchment, with a focus on E409 (Murrays Flat) (this sub-catchment also had very poor fish community status – see section 11)
- DTA5 – Lake Yarrunga at the Shoalhaven River, Bungonia Creek sub-catchment
- E891 – Gillamatong Creek, Braidwood sub-catchment.
- E457 – Towers Weir, Mulwaree River sub-catchment (as noted in section 17.1.1, Towers Weir had lower median flow during the audit period compared to previous years; this sub-catchment also had very poor fish community status – see section 11).

Median turbidity values for all streams and storages complied with guidelines during and prior to the audit period, although all turbidity samples at DWA39 exceeded guidelines in 2019-20. This suggests that erosion management is not as high priority as managing other potential pollutants, such as nutrients.

ANZG (2018) water quality guidelines are currently under review by BCSD in consultation with other stakeholders, including WaterNSW. Draft regionally specific numeric water quality guidelines have been determined from a suite of WaterNSW monitoring sites that were assessed by BCSD and the EPA to be 'referential'. These included two of the three sites identified in this audit report as having median values for all analytes within guidelines during and prior to the audit period:

- E602 (Burke River inflow to Lake Nepean in the Lake Nepean sub-catchment)
- E610 (Avon River at Summit Tank in the Lake Avon sub-catchment)

BCSD and the EPA did not consider the third site (E8311 - Corang River at Meengora in the Mid-Shoalhaven sub-catchment) to be a suitable reference site for the updated guidelines due to the presence of agricultural discharges. Site E243 (Little River at Fireroad W4I in the Little River sub-catchment) was also nominated as referential by BCSD and the EPA and identified in this audit report as having good water quality other than during the 2019-20 bushfire.

It is recommended that WaterNSW consider the implications of DPE's 2023 review of water quality objectives for assessment and reporting of water quality in the Catchment. It is also recommended that methods for measuring aluminium to determine toxicity risk to aquatic ecosystems, including sampling and analysis, are reviewed.

Any change to the water quality guidelines would need to be agreed with IPART for inclusion in the WaterNSW operating licence.

Responses and Recommendations

20. Summary of actions 2019-22

This audit found that actions to strengthen Catchment health and resilience continue to be informed by evidence across multiple indicators and a culture of continuous improvement within agencies, industry and the community. Table 20-1 provides examples of actions taken to protect Catchment health in 2019-22, not limited to responses to recommendations from the 2019 audit.

Table 20-1: Summary of actions taken to maintain or improve Catchment health in 2019-22

Theme	Summary
Informed decisions	The strategic and policy framework for the Catchment, the availability of data and information, and collaboration and knowledge sharing between stakeholders, have improved compared to previous audit periods. Examples include the increased number and quality of spatial datasets available to the public via SEED, WaterInsights and other government websites. These improvements mean authorities, businesses and the community have greater guidance, context and support when investigating issues, forming decisions and implementing actions that affect Catchment health.
Pollution controls	Systems and technology for controlling pollution continue to be improved. This includes updated NorBE guidelines and tools for proposed development (including water sensitive urban design) and more robust impact assessment requirements for underground mining and other major projects. Pollution licence conditions issued by the EPA are also increasingly stringent, reflecting technological advances and community expectations (e.g., for the scheduled Wingecarribee sewage treatment plant upgrades).
Restoration and rehabilitation	The NSW Government has strengthened support for restoration and rehabilitation in the Catchment through policies and grant programs (e.g., for riparian corridors and regenerative agriculture), tighter rehabilitation requirements for mines under the Mining Amendment (Standard Conditions of Mining Leases – Rehabilitation) Regulation 2021, and increased extent of land for conservation purposes (e.g., Gardens of Stone State Conservation Area).

Table 20-2 to Table 20-7 summarise the responses to the 2019 audit recommendations. Comments are drawn from the WaterNSW Annual Catchment Management Report 2020-21, feedback from agencies and councils, and observations by the auditor. Most recommendations from the 2019 audit were accepted by the responsible agency/agencies during the 2019-22 audit period and were completed or are in progress. Some of the 2019 audit recommendations have been identified for further consideration in the current audit.

The 2019 audit categorised recommendations under the following objectives:

- Pollution – reduce pollutant loads discharged to Catchment waterways
- Water availability – sustainably manage surface and groundwater resources
- Natural areas, wetlands and riparian corridors – continue to maintain or improve the integrity of protective landscape barriers
- Fire – reduce risk of inappropriate fire regimes
- Community engagement – improve land management in collaboration with landholders and the community
- Data adequacy and availability – improve monitoring and datasets as a basis for good decision making and management.

Table 20-2: Response to 2019 audit recommendations – to reduce pollutant loads discharged to Catchment waterways

Recommendation from 2019 audit	Action taken 2019-22	Status
Recommendation A1: *Finalise investigations to support upgrades to sewerage infrastructure in the Wingecarribee LGA (Wingecarribee River and Nattai River sub-catchments). Undertake upgrades to sewerage infrastructure based on the outcomes of investigations.*	Bowral, Moss Vale and Mittagong sewage treatment plants are in detailed design and construction is scheduled as follows: Bowral 2024, Moss Vale 2026 and Mittagong 2028. WaterNSW and Wingecarribee Council are restricting occupation of new developments until sewage treatment capacity has increased. The EPA has attached more stringent limits on discharges from upgraded sewage treatment plants as part of the licence variations under the *Protection of the Environment Operations Act 1997*. For example, for Bowral the current limits are median total nitrogen 7.5 mg/L and total phosphorus 0.3 mg/L. The new limits to come into effect on 1 July 2024 for the upgraded treatment plant are 6 mg/L total nitrogen and 0.1 mg/L total phosphorus. The nutrient load limits should improve or maintain water quality as Bowral's population grows by a predicted 40% over the 20-year design life of the sewage treatment plant.	Accepted – in progress
Recommendation A2: *Undertake strategic investigations of cumulative environmental impacts in the Upper Coxs River and Wingecarribee River sub-catchments, including:* • Identify major past, present and reasonably foreseeable sources of water pollutants in the sub-catchments, including diffuse sources • Review the adequacy of measures to protect water quality and aquatic ecosystems and human health in the sub-catchments, now and in the future	WaterNSW is developing and calibrating an integrated water model (refer to section 19.7) to support future strategic investigations. The EPA upgraded its internal capabilities during the audit period to enable strategic investigations using a geographic information system. In 2019 the EPA undertook a strategic environmental compliance and performance review of small sewage treatment plants across NSW, including Mittagong sewage treatment plant in the Wingecarribee sub-catchment and Lithgow sewage treatment plant in the Upper Coxs sub-catchment. Recommendations from the EPA review included, 'ensure treatment processes are adequate to achieve compliance with licence requirements and with the end use of the water or with the receiving environment where it is discharged to not cause an environmental impact'. As outlined in section 9.2.1, the EPA and DPE are investigating the carrying capacity of aquatic ecosystems in parts of the Catchment to cope with nutrient loads. This may result in revised environment protection licence conditions for sources of pollutants.	Accepted – in progress
• Develop options to reduce high numbers of cyanobacterial alerts at Lake Wallace and Lake Lyell (in the Upper Coxs sub-catchment) and Wingecarribee Lake (in the Wingecarribee sub-catchment)	WaterNSW engaged a biostatistician to analyse water quality and cyanobacterial data at Wingecarribee Reservoir to identify any relationships between cyanobacterial dynamics and environmental / water quality drivers from the existing historical dataset. WaterNSW has also undertaken scientific research to explore ways to prevent algal response (refer to microbial treatment trials outlined in section 19.6.6).	Accepted – in progress

Recommendation from 2019 audit	Action taken 2019-22	Status
	EnergyAustralia manage Lake Lyell and Lake Wallace as part of the Coxs River water supply scheme to supply water for the operation of Mt Piper power station. Refer to sections 8.8 and 19.4.18 for further detail.	
• Review the obligations and capacity of EPA licenced activities in the Upper Coxs and Wingecarribee sub-catchments to address water quality and aquatic ecosystem concerns if current requirements as assessed as inadequate	WaterNSW has compiled all available information for the 40 environment protection licences within the Catchment which have water quality limits. WaterNSW is collaborating with the EPA to identify priorities and key actions regarding water quality for the next three years.	Accepted – in progress
• Review the obligations and capacity of polluting industries in the Upper Coxs and Wingecarribee sub-catchments to undertake rehabilitation and restoration works and identify options if current requirements are assessed as inadequate	Statutory requirements for rehabilitation of degraded sites have become more rigorous during the audit period. For example, see section 8.7.	Accepted – in progress
• Consider the role of water transfers and dam depth on water quality and supply	The 'Wingecarribee Reservoir Water Quality Review 1999-2020' was prepared as part of the WaterNSW Science Strategy. Refer to section 19.6.6 of this audit for further detail.	Accepted – complete
• Consider the context of a changing climate	Refer to NSW Government responses to climate change outlined in section 3.1. The transition from coal to more sustainable industries in the Upper Coxs River is ongoing.	Accepted - ongoing
• Develop and implement programs to address the outcomes of the investigations above.	Refer to comments above including the integrated water model cyanobacterial management trials.	Accepted - ongoing
Recommendation A3: *Investigate the reason for very poor dissolved oxygen, turbidity and total aluminium results in streams in the Boro Creek sub-catchment (station E890).*	Turbidity at Boro Creek improved during the current audit period. However, dissolved oxygen continued to be very poor (100% non-compliant with guidelines). Site investigation by WaterNSW found that organic matter accumulated at the monitoring station had affected results. Refer to section 19.4.3 for further context.	Accepted - complete
Recommendation A4: *Undertake an audit of neutral or beneficial effect (NorBE) related consent / approval conditions for a range of development types.*	WaterNSW conducted the following audits during 2019-20: • NorBE assessment audit – WaterNSW conducted an audit of councils' assessments of the NorBE test on water quality. The outcomes from the audit were presented to this auditor. WaterNSW advised each council of the audit outcomes, improved the NorBE Tool and provided training for councils on the upgraded NorBE Tool. • Concurrence conditions audit – WaterNSW conducted an audit of councils' development consents to determine whether WaterNSW's concurrence conditions were included in consents. The audit methodology and key findings	Accepted – It is further recommended that a compliance audit of Module 1 and 2 development assessments is undertaken to determine if the recent updates to the

Recommendation from 2019 audit	Action taken 2019-22	Status
	were presented to this auditor. A number of the report's recommendations have been actioned. WaterNSW's Catchment Protection Work Program 2022-2023 includes the following action – 'Audit council use of the NorBE tool and institute action to improve compliance with requirements'. Further comment is provided in section 3.11.	NorBE tool and processes, and associated training, have satisfied the desired outcomes.

Table 20-3: Response to 2019 audit recommendations – sustainably manage surface and groundwater resources

Recommendation from 2019 audit	Action taken 2019-22	Status
Recommendation B1: *Implement the recommendations from the Audit of the Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources 2011 (Alluvium and Vista Advisory 2019), as relevant to the Catchment. Review the long-term average annual extraction limit and adjust in the context of climate change.*	DPE Water is establishing a new work area focusing on climate change which will look to provide information short, medium and long term to inform a range of processes including water planning. DPE Water is also developing a sustainable long term average annual extraction limit (LTAAEL) method for future water sharing plans.	Accepted – in progress
Recommendation B2: *Review and update the Water Sharing Plans for the Greater Metropolitan Region Unregulated River Water Sources 2011 and the Greater Metropolitan Region Groundwater Sources 2011. This should include review and revision of surface water / groundwater interactions, with an assessment of the consequences of the (likely) higher proportion of total licensed groundwater entitlement and basic landholder rights of the long-term average annual extraction limits.*	The two metropolitan Water Sharing Plans are being updated following a review by the Natural Resources Commission in 2021. The revised plans being prepared by DPE Water in consultation with the community and are scheduled for commencement in July 2023.	Accepted – in progress
Recommendation B3: *Consider, as part of the scheduled review of the Metropolitan Water Plan, the option of managed aquifer recharge within the Catchment.*	A framework for enabling managed aquifer recharge across NSW is a commitment in the NSW Water Strategy. That framework will consider a range of legislative and policy issues, as well as some of the technical feasibility matters needing to be considered to ensure such systems are viable and cost effective. Following the development of that framework, each water sharing plan can be examined to determine whether changes are required to give effect to this new water storage and supply option.	Accepted – in progress
Recommendation B4: *Review the obligations and capacity of mines in the Catchment to undertake rehabilitation and restoration works.*	As outlined in section 8.7, mine rehabilitation is overseen by the Resources Regulator in accordance with the Mining Amendment (Standard Conditions of Mining Leases –	Accepted – in progress

Recommendation from 2019 audit	Action taken 2019-22	Status
	Rehabilitation) Regulation 2021. It includes a clause 'ensuring rehabilitation occurs promptly and achieves the final land use'. WaterNSW will advocate for the restoration of degraded wetlands with a focus on the Special Areas. As an example, as part of Longwalls 9 to 13 SMP approval, DPE required South32 (Dendrobium mine) to fund $3.5 million for swamp rehabilitation research program. DPE and South32 are managing the $3.5m fund and the project. WaterNSW supports the program and a small portion of this fund was allocated to WaterNSW for swamp research.	
Recommendation B5: *Consistent with the recommendations from the IEPMC:* • Establish an inter-agency working group to identify acceptable levels of surface water loss due to mining in the Catchment after considering the significance of different thresholds of surface water loss due to mining in the Catchment	The NSW Government established an inter-agency taskforce with representatives from key agencies including DPE, the Department of Regional NSW and WaterNSW. The taskforce meets to oversee and implement the action plan for mining in the catchment. The NSW Government endorsed the development of a new licensing regime that would allow mines operating in the Special Areas to obtain entitlements for incidental surface water take. The NSW Government has also approved an offsetting regime for any new mining development in the Special Areas. This requires mining companies to offset all surface water losses by paying the retail price of water. The Minister for Lands and Water will have the authority to spend these funds on projects that will increase Sydney's drinking water supply.	Accepted - complete
• Establish performance measures related to changes in groundwater pressure and/or pressure gradients where these have the potential to impact on surface water diversions or losses for all future mine approvals in the Special Areas	No new longwall mining projects have been approved since this recommendation was made. DPE will incorporate conditions into any future approval in consultation with WaterNSW and DPE Water. New standard conditions of consent for underground mines were developed as part of the recommended conditions for the Dendrobium Extension Project. DPE incorporated these conditions as standard conditions for any new state significant development underground mining proposals. These new standard conditions incorporate the report's recommendations to require applicants to develop quantitative performance measures and implement trigger action response plans to respond to any exceedances of performance measures. The Independent Advisory Panel for Underground Mining, which formed in 2020, will be involved in providing specialist expert advice on proposed underground mining within the Special Areas and continue to be consulted during any post-approval subsidence or extraction plan processes within these areas.	Accepted - complete

Recommendation from 2019 audit	Action taken 2019-22	Status
• Investigate and quantify the potential impacts of historic and current mining for long-term cumulative impacts on water quantity and quality in the Special Areas, for the purpose of properly informing mine design, offsets, mine rehabilitation and closure planning, planning assessments and rehabilitation bonds (see related recommendation B4).	Refer to the reports by the Independent Expert Panel for Mining in the Catchment and ongoing oversight by the Independent Advisory Panel for Underground Mining.	Accepted – complete
Recommendation B6: *Ensure sufficient water entitlements are retained by all mines operating in the Special Areas to cover potential surface water losses resulting from mining induced effects, including predicted climate change impacts.*	Refer to response to Recommendation B5.	Accepted – in progress

Table 20-4: Response to 2019 audit recommendations – continue to maintain or improve the integrity of protective landscape barriers

Recommendation from 2019 audit	Action taken 2019-22	Status
Recommendation C1: *Continue joint management of the Special Areas in accordance with the scheduled update of the Special Areas Strategic Plan of Management and long-term land management programs.*	WaterNSW has signed a service level agreement with NPWS to continue joint management of the Special Areas. In March 2021, the WaterNSW Board approved the business cases to extend the Rural and Urban Programs until 2024.	Accepted - ongoing
Recommendation C2: *Protect the ecological values of Wingecarribee Swamp through:* • continued weed control and implementation of the Wingecarribee Swamp Operations Plan (noting that weed control effort and funding should reduce to a maintenance level over time) • repair or replace fences adjacent to stocked land, especially on the higher risk areas on the northern side of the swamp.	Specific actions were incorporated into the WaterNSW Catchment Protection Work Program.	Accepted - ongoing
Recommendation C3: *Undertake strategic risk assessment for all swamp types in the Catchment to prioritise protection or restoration and identify swamps that may be vulnerable to existing or future development.*	The South East Ecosystems and Threatened Species Team within BCSD commenced the strategic swamp risk assessment to identify priorities for protection in the Catchment. This included collating existing mapping, undertaking a pilot project on Woronora Plateau for the risk assessment informed by on-ground impact surveys, and a framework for rolling this out across the whole Catchment in following years. Woronora Plateau was selected as	Accepted - the next areas of focus will be the Blue Mountains and Newnes Plateau

Recommendation from 2019 audit	Action taken 2019-22	Status
	the most urgent area for the risk assessment and prioritisation due to the extent of mining across the area (and mining impacts to hydrology)	

Table 20-5: Response to 2019 audit recommendations – reduce risk of inappropriate fire regimes

Recommendation from 2019 audit	Action taken 2019-22	Status
Recommendation D1: *Review and update all Bushfire Risk Management Plans relevant to the Catchment to better recognise and reduce the risks to natural assets and water quality. Apply Strategic Fire Advantage Zones principles to protect water storages.*	The RFS has set a 2024 deadline for revision of all Bushfire Risk Management Plans. WaterNSW has completed its bushfire plans for the nine districts.	Accepted – in progress

Table 20-6: Response to 2019 audit recommendations – improve land management in collaboration with landholders and the community

Recommendation from 2019 audit	Action taken 2019-22	Status
Recommendation E1: *Continue to evaluate the effectiveness of weed control, erosion control, revegetation and riparian zone protection programs to inform future strategies.*	WaterNSW evaluated the Rural Landscape Program (erosion control, revegetation and riparian zone protection) in conjunction with LLS in 2022. In March 2021, the WaterNSW Board approved the business cases to extend the Rural Landscape Program until 2024. LLS conducts regular monitoring of on-ground projects to assess the effectiveness of implementation. The *Biosecurity Act 2015* requires councils to inspect all properties over a five-year period. LLS maintain a Biosecurity information System to record inspections undertaken for 5+ year and it is currently establishing a baseline of weed extent and density at a species level. WaterNSW is exploring opportunities to share that data and document the initial baseline. All organisations involved in controlling pests and weeds in the Catchment are required to send data to LLS for recording in a Biosecurity Information System.	Accepted - ongoing
Recommendation E2: *Continue to work with councils to improve stormwater management.*	In March 2021, the WaterNSW Board approved the Urban Program business case which incorporates improvements to stormwater management.	Accepted - ongoing

Table 20-7: Response to 2019 audit recommendations – improve monitoring and datasets as a basis for good decision making and management

Recommendation from 2019 audit	Action taken 2019-22	Status
Recommendation F1: *Adopt CLUM as the WaterNSW land use dataset, consistent with other agencies.*	WaterNSW has adopted the CLUM dataset as its prime source of land use data. Where it is necessary, WaterNSW will enhance the default dataset to meet additional needs e.g., farm dams.	Accepted - complete
Recommendation F2: *Update the catchment-wide analysis and mapping of gully erosion, including some on-ground validation of data.*	WaterNSW did not accept this recommendation because comprehensive mapping of erosion was undertaken in 2014-15 for 70% of known erosion in the Catchment. WaterNSW advised that the mapping remains current and, in terms of informing current programs, effective.	Not accepted – refer to comments in section 16
Recommendation F3: *Expand the groundwater monitoring program and review data collection methods consistent with the NSW Water Monitoring Framework (WMF).*	Nine new monitoring bores were drilled at four locations within the Metropolitan and Woronora Special Areas. Water levels are monitored by WaterNSW in real-time with data transmitted to their website daily. Each bore is equipped with a water sampling pump to monitor water quality periodically.	Accepted – consider further action (see section 18.7)
Recommendation F4: *Consolidate fire data from multiple agencies and make this more widely available via SEED.*	RFS has adopted the SEED portal for sharing key data sets including fire history, fire thresholds, fire trails and fire zonings. These have been uploaded to the portal, with other datasets to follow as they are created.	Accepted - ongoing
Recommendation F5: *Post annual updates on implementation progress for audit recommendations that include all public authorities, not just the recommendations to be implemented by WaterNSW.*	WaterNSW has agreed to incorporate annual updates on Catchment audit actions in the Annual Catchment Protection Work Program reports, supplemented where necessary with further information on its website.	Accepted - ongoing

21. Recommended responses to this audit

This audit aimed to answer, 'what responses are needed to address the main pressures and risks to the Catchment'. In deciding this, the auditor also considered 'what outcomes are we trying to achieve?' Risks, desired outcomes, objectives and recommended actions are summarised in Table 21-1 to Table 21-3 under the themes of climate change, land management and pollution control. Further context and detail for the recommendations are given in the linked sections.

The overall aim of these recommendations is to reduce threats to Catchment health and increase ecological, social and economic resilience. Recommendations and timeframes for completion of each action were developed in consultation with stakeholders responsible for implementation. Recommendations are categorised into primary (most important) and secondary.

Table 21-1: Summary of risks, desired outcomes and recommendations – climate change

Risks:		*Catchment health and the security of Sydney's drinking water are increasingly threatened by climate-driven events, including severe drought, floods, heatwaves, storms and bushfires.*				
Desired outcomes:		*Greenhouse gas emissions in the Catchment are reduced to help meet the NSW Government net zero emissions targets (mitigation).* *Disruptions to Catchment management and monitoring caused by extreme climate-driven events are minimised (adaptation).*				
No.	**Section**	**Objective**	**Recommendation**	**Responsibility**	**Priority**	**Timing**
1	21.1.1	Inform future Catchment audits	Future Catchment audits to review climate data, climate impacts and NSW Government climate change policies, strategies and activities relevant to Catchment health.	Catchment auditor (WaterNSW lead)	Secondary	Dec-25
2	21.1.2	Reduce greenhouse gas emissions in the Catchment	Identify major sources of greenhouse gas emissions from the Catchment.	DPE (lead) OECC, EPA	Primary	Dec-23
3	21.1.2		Demonstrate how major sources of greenhouse gas emissions in the Catchment are being reduced or eliminated.	OECC (lead) EPA, DPE	Primary	Ongoing
4	21.1.2		Demonstrate how potential major sources of greenhouse gas emissions in the Catchment are being avoided or minimised.	DPE (lead) EPA	Primary	Ongoing
5	21.1.3	Minimise impacts from climate-driven events	Develop a Catchment disaster mitigation plan to support monitoring and management of Catchment health.	WaterNSW (lead) NSW Reconstruction Authority, NPWS, RFS and DPE	Primary	Jun-25
6	21.1.3		Inform sustainable use of groundwater by utilising non-government bores.	DPE	Secondary	Dec-24

Table 21-2: Summary of risks, desired outcomes and recommendations – land management

Risks:		*Ineffective and/or unsustainable land management practices are applied in the Catchment.*				
Desired outcomes:		*Sustainable land use practices, including water sensitive design and regenerative agriculture, are adopted more widely across the Catchment to improve ecosystem services and support communities.*				
No.	**Section**	**Objective**	**Recommendation**	**Responsibility**	**Priority**	**Timing**
7	21.2.1	Progress toward Source Water Protection Strategy goals	Clarify goals and performance measures for the Source Water Protection Strategy, document methods for measures, establish a baseline and report annually against the established baseline.	WaterNSW	Primary	Dec-23
8	21.2.1		Increase regenerative agriculture in priority reaches of the Catchment through refinements to WaterNSW rural programs.	WaterNSW (lead) LLS	Primary	Jun-25
9	21.2.1		Make locations and types of government-funded land management programs in the Catchment available via spatial datasets on SEED.	DPE (lead) WaterNSW, NPWS, LLS, Environmental Trust, councils	Secondary	Jun-25
10	21.2.2	Identify and protect sensitive ecosystems	Improve annual NSW vegetation mapping using satellite imagery to show native and non-native vegetation formation classifications, and areas of no vegetation.	DPE (lead) WaterNSW, LLS, NPWS	Secondary	Dec-24
11	21.2.2		Review the suitability of applying a 60 m buffer to assess potential mining impacts to swamps and streams.	DPE (lead)	Secondary	Dec-24
12	21.2.2		Improve access to data for organisations involved in assessing wetland significance, risk and impacts, as well as stream health and impacts.	DPE (lead) EPA, Resources Regulator	Secondary	Jun-24

Table 21-3: Summary of risks, desired outcomes and recommendations – pollution control

Risks:		*Pollution degrades Catchment health.*				
Desired outcomes:		*Less pollution in the Catchment.*				
No.	**Section**	**Objective**	**Recommendation**	**Responsibility**	**Priority**	**Timing**
13	21.3.1	Update guidelines and methods to assess water quality	Consider the implications of DPE's 2023 review of water quality objectives and the associated technical report for assessment and reporting of water quality in the Catchment by WaterNSW.	WaterNSW (lead) DPE, IPART	Primary	Jun-24
14	21.3.1		Review methods for measuring aluminium, including sampling and analysis, to determine toxicity risk to aquatic ecosystems.	WaterNSW (lead) DPE, IPART	Secondary	Jun-24
15	21.3.2	Reduce erosion and sedimentation risk	Develop and implement an erosion management decision support tool for the Special Areas.	WaterNSW (lead) NPWS (partner)	Primary	Dec-24
16	21.3.2		Undertake detailed analysis and mapping of erosion and sediment loss.	WaterNSW (lead) LLS, DPE	Secondary	Jun-24
17	21.3.3	Reduce sewage pollution	Upgrade sewage treatment plants in Wingecarribee LGA and comply with environment protection licences.	Wingecarribee Council (lead) EPA	Primary	Jul-24 (Bowral)
18	21.3.3		Review integration of the 2023 on-site sewage management system guidelines into councils' compliance and enforcement policies and programs to inform the need for future guidance and regulatory reform.	OLG (lead) Councils, EPA	Primary	Jun-25
19	21.3.4	Developments achieve NorBE	Audit stormwater management assets dedicated to council to determine if they are maintained to achieve NorBE objectives.	WaterNSW (lead) Councils	Primary	Jun-25
20	21.3.4		Audit Module 1 and 2 development applications, assessments and determinations against NorBE requirements.	WaterNSW	Primary	Dec-24
21	21.3.5	Reduce unauthorised polluting activities	Expand collaborative pollution control programs and campaigns in high-risk areas of the Catchment.	EPA (lead) Councils, WaterNSW	Primary	Dec-24
22	21.3.6	Improve management of poor water quality	Investigate causes of poor water quality at priority sites so that management can be targeted to the root cause.	WaterNSW (lead) EPA, Councils & EPL holders	Primary	Jun-25
23	21.3.6		Develop educational/promotional material on innovative stormwater management practices in the Catchment.	WaterNSW (lead) BMCC	Secondary	Jun-24
24	21.3.6		Identify and map sources of mine and quarry water discharges in the Catchment, including licenced and legacy premises.	EPA (lead) Resources Regulator	Secondary	Jun-25

21.1. Climate change

Climate-driven events during the 2019-22 audit period adversely affected many indicators of Catchment health. Climate change predictions indicate these risks will continue to increase. Worsening impacts to Catchment health from climate-driven events require avoidance and mitigation of greenhouse gas emissions and adaptation to a changing climate. The IPCC 2023 report emphasises the 'urgency of near-term integrated climate action':

> 'Climate change is a threat to human well-being and planetary health. There is a rapidly closing window of opportunity to secure a liveable and sustainable future for all. Climate resilient development integrates adaptation and mitigation to advance sustainable development for all… The choices and actions implemented in this decade will have impacts now and for thousands of years.'

The audit recommendations are centred on what can be achieved within the Catchment, although it is acknowledged responses to climate change require a global effort.

21.1.1. Inform future Catchment audits

Recommendation 1: **Future Catchment audits to review climate data, climate impacts and NSW Government climate change mitigation policies, strategies and activities relevant to Catchment health** – The climate is a primary driver of Catchment health conditions. However, climate and climate change are not gazetted indicators of Catchment health. Climate metrics, the influence of climate on indicators of Catchment health, and government responses to the changing climate in the Catchment must be considered in future Catchment audits. As a minimum, it is recommended that the 2022-25 audit provides an update on climate data and implementation of NSW Government strategies and policies identified in section 3.1 of this audit report as relevant to the Catchment. This will inform future audit findings and recommendations regarding Catchment health.

21.1.2. Reduce greenhouse gas emissions in the Catchment

Recommendation 2: **Identify major sources of greenhouse gas emissions from the Catchment** – Likely major sources of greenhouse gas emissions in the Catchment have been suggested in section 5.3 consistent with the National Greenhouse Gas Inventory sectorial analysis. It is recommended that further investigation be undertaken to confirm and rank the current major sources of greenhouse gas emissions in the Catchment to inform mitigation priorities. This links to Recommendation 3.

Recommendation 3: **Demonstrate how major sources of greenhouse gas emissions in the Catchment are being reduced or eliminated** – Future audits will seek evidence that major sources of greenhouse gas emissions in the Catchment (identified under Recommendation 2) are taking action to help achieve the NSW Government's net zero target. (This evidence is expected to be included in a net zero reporting framework for NSW.) Consistent with this and in accordance with Action 5 of the Climate Change Action Plan 2023-26, the EPA requires regulated sources of greenhouse gas emissions to develop and implement greenhouse gas mitigation plans. It is recommended that initial plans for major regulated sources in the Catchment be complete and made publicly available by June 2025.

Recommendation 4: **Demonstrate how potential major sources of greenhouse gas emissions in the Catchment are being avoided or minimised** – Future Catchment auditors will seek evidence that potential new major sources of greenhouse gas emissions have been avoided. It is recommended that the EPA partners with DPE to ensure development applications and post-approvals plans for proposed major projects include evidence on how greenhouse gas emissions will be avoided or minimised. Proposed projects that would become a major contributor to greenhouse gas emissions in the Catchment should not be supported as this would counter the collective efforts to reduce emissions.

21.1.3. Minimise impacts from climate-driven events

Recommendation 5: **Develop a disaster mitigation plan to support monitoring and management of Catchment health** – A detailed Catchment disaster mitigation plan needs to be prepared and implemented under guidance of the recently formed NSW Reconstruction Authority, consistent with the overarching NSW disaster mitigation plan, to better mitigate impacts of future climate-related disasters on communities and the environment in the Catchment. The Catchment disaster mitigation plan must identify, map and consider the resilience of critical water monitoring and management infrastructure (i.e., water gauging stations, water monitoring stations/sites and associated access trails). The plan should determine what is monitored or used, where, how, by whom, and for what purpose. This information should be assessed against an integrated hierarchy of requirements, with a program of changes developed with relevant agencies, if needed.

Recommendation 6: **Inform sustainable use of groundwater by utilising non-government bores** - The NSW Government has recognised the need to expand its groundwater monitoring network across NSW, consistent with the NSW Water Monitoring Framework (DPIE 2020c), the NSW Groundwater Strategy (DPE 2022e) and the Water Monitoring Guidelines for Underground Mining Activities in the Special Areas. It is recommended that the location and function of non-government groundwater bores in the mining areas of the Catchment be audited to determine which ones can practicably and feasibly be appropriated and maintained by the NSW Government for their groundwater monitoring network, with a focus on long-term nested monitoring bores used by the mining sector and in areas where increasing public use is occurring for stock and domestic supply or irrigation.

21.2. Land management

Land management practices in some parts of the Catchment are shifting from traditional farming, forestry and development. Practice changes include nature-based solutions, regenerative agriculture and increased uptake of water sensitive urban design. This shift has been complemented by increasing restoration and rehabilitation of degraded lands. However, further information is needed to gauge the collective extent and effectiveness of these changes.

Funding and delivery of land management programs have been increasingly fragmented across government agencies (all levels of government), landholders, commercial and not-for-profit organisations, and community groups. While this implies widespread and growing interest in these types of programs, it also makes it more difficult to prioritise and coordinate activities, efficiently access suitable programs, and evaluate their collective outcomes. On the other hand, increasing access to shared data (e.g., via the SEED portal) has informed understanding of key issues and priorities for all stakeholders.

21.2.1. Progress toward Source Water Protection Strategy goals

Recommendation 7: **Clarify goals and performance measures for the Source Water Protection Strategy, document methods for measures, establish a baseline and report annually against the established baseline** – The Source Water Protection Strategy (WaterNSW 2022d) states that the 'Annual Catchment Management Report will specifically track the annual progress of each of the six priorities and goals of this Strategy' (which are listed in Table 3-3). WaterNSW has assigned activities to the six priorities in the 2023 Catchment Protection Work Program, but during this audit it was not possible to determine progress against all goals based on performance measures and reported information. It is recommended that future annual catchment management reports should clearly articulate how progress has been measured toward the six goals, including how the baseline was established for each goal.

Recommendation 8: **Increase regenerative agriculture in the Catchment through refinements to WaterNSW rural programs –** The Source Water Protection Strategy has a goal to increase regenerative agricultural practices across the Catchment by 50% by 2040. To help achieve this goal it is recommended that rural program protocols are adjusted to provide funding for projects that feature regenerative agriculture and/or landscape rehydration where this also is consistent with the recommendations of the 2023 strategic review of the Rural Landscape Program (see section 16.5). Consideration should also be given to active or passive rehabilitation of the physical form of watercourses in areas that have reaches with moderate condition and high recovery potential (defined by River Styles analysis, see Figure 15-6).

Recommendation 9: **Make locations and types of government-funded land management programs in the Catchment available via spatial datasets on SEED** – To improve planning and evaluation of land management activities, it is recommended that agencies responsible for funding environmental management projects across the Catchment provide attributed spatial datasets (GIS maps) to BCSD. The land management datasets can then be collated and made available to other agencies and the community via SEED (hosted by BCSD). Attributes should include the general types of activities that have been performed (e.g., revegetation, weed control, erosion control). Matters relevant to landholder privacy must be protected. Historic records should be provided, where possible, to give a more complete picture of land management activities across the Catchment.

21.2.2. Identify and protect sensitive ecosystems

Recommendation 10: **Improve annual NSW vegetation mapping using satellite imagery to show native and non-native vegetation formation classifications, and areas of no vegetation** – As discussed in sections 12 to 14 of this audit, improved understanding of riparian vegetation, native vegetation and wetland indicators would require additional mapping. It is recommended that maps and datasets are prepared using satellite imagery and made available annually to show the extent and formation classification of native and non-native vegetation across NSW. Areas with no vegetation cover (e.g., built areas, water bodies) should also be identified in the dataset. Spatial datasets should be available to interested landholders, communities and agencies via SEED to inform land management priorities and activities in a timely manner.

Recommendation 11: **Review the suitability of applying a 60 m buffer to assess potential mining impacts to swamps and streams** – Mine impact assessments and subsidence management plans are currently required to consider potential impacts within a 60 m buffer of swamps and streams because it has been assumed that this is where impacts are likely to occur. It is recommended that this assumption is reviewed by investigation of reports and data pertaining to impacts on swamps and 1st, 2nd and 3rd order streams in historic and active mining leases in the Newnes Plateau and Woronora Plateau, including fracturing of rock bars, subsidence, upsidence, pollution, iron flocculant, draining of swamps and streams, and indirect impacts to threatened species. The assessment should include statistical analysis to determine probabilities of impacts in different size buffer zones. This should be an independent report by one or more expert scientists in the field of groundwater hydrology, water quality and statistics, with a peer review by two external scientists with sufficient expertise in the field and no conflict of interest.

Recommendation 12: **Improve access to data for organisations involved in assessing wetland significance, risk and impacts, as well as stream health and impacts** - Some agencies have noted challenges accessing Catchment monitoring data from mining companies to make timely decisions and recommendations regarding proposed developments that may have cumulative impacts. As an initial step, it is recommended that formal data sharing agreements be established between mining companies operating in the Special Areas and DPE (the department that hosts SEED), with a focus on datasets relevant to swamps and stream health.

21.3. Pollution control

To date, government agencies have focussed on establishing a regulatory framework to minimise the risks to public health from point source pollution in the Catchment, such as sewage treatment plants, dairy farms, mines and other major development. Point sources need to continue to be rigorously managed and regulated, and further effort is required to avoid harm to Catchment health from diffuse sources of pollution as the population gradually increases. This will involve application of emerging tools and technologies for pollution surveillance and control.

21.3.1. Update guidelines and methods to assess water quality

Recommendation 13: **Consider the implications of DPE's 2023 review of water quality objectives and the associated technical report for assessment and reporting of water quality in the Catchment by WaterNSW)** – DPE is the custodian of the water quality guidelines in coastal NSW (including the Sydney Drinking Water Catchment) and has a public commitment to update the guidelines under the Marine Estate Management Strategy, Greater Sydney Water Strategy and NSW Water Strategy by the end of 2023. DPE completed a review of water quality objectives in mid-2023 and is preparing a technical report that will include Catchment specific guidelines for protection of aquatic ecosystems. The draft water quality guidelines were determined from a suite of WaterNSW monitoring sites that were assessed to be 'referential' by DPE and the EPA. It is recommended that the finalised guidelines are considered by WaterNSW prior to issue to IPART for consideration and inclusion in the WaterNSW operating licence.

Recommendation 14: **Review methods for measuring aluminium, including sampling and analysis, to determine toxicity risk to aquatic ecosystems** – It is recommended that the methods for assessment of metal toxicity risk to aquatic ecosystems are reviewed. Section 19.1.1 outlines issues to be considered. Any change would need to be agreed with IPART for inclusion in the WaterNSW operating licence.

21.3.2. Reduce erosion and sedimentation risk

Recommendation 15: **Develop and implement an erosion management decision support tool for the Special Areas** - It is recommended that an erosion management decision support tool or guide is developed to minimise the risk of mobilisation of sediment into wetlands and waterways in the Special

Areas. This must include consideration of potential post-fire rainfall events. Development of this tool should draw on outcomes of ongoing research and local experience (refer to section 16.8 for details).

Recommendation 16: **Undertake detailed analysis and mapping of erosion and sediment loss** – Erosion is predicted to be an increasing hazard to Catchment health as the climate changes. To ensure Catchment management actions and erosion controls are effectively targeted, it is recommended that detailed analysis of long-term turbidity and hydrograph datasets be undertaken for selected Catchment monitoring sites. Methods such as LiDAR or drone photogrammetry should also be considered to determine if they can directly measure changes in gully dimensions net soil loss from managed gullies. If the technique is effective, it should be applied to priority areas identified in the detailed analysis. The resultant database should be shared with stakeholders via SEED and used to inform land management programs.

21.3.3. Reduce sewage pollution

Recommendation 17: **Upgrade sewage treatment plants in Wingecarribee LGA and comply with environment protection licences** - Sewerage services must be upgraded to avoid significant environmental harm as the population grows. Delays to sewage treatment plant upgrades risks increasing poor water quality outcomes and breaches of environment protection licences. Upgrades in the Wingecarribee LGA are scheduled no later than: Bowral 2024, Moss Vale 2026 and Mittagong 2028, and these sewage treatment plants will have more stringent environment protection licence conditions than currently apply. Councils should not consent to developments that would result in sewage treatment plants being non-compliant with environment protection licences.

Recommendation 18: **Review integration of the 2023 on-site sewage management system guidelines into councils' compliance and enforcement policies and programs to inform the need for future guidance and regulatory reform** – As discussed in section 9.4.3, poorly installed or managed on-site sewage management systems are a risk to Catchment and public health. Updated NSW guidelines for on-site sewage management are scheduled for release in mid-2023. As part of the roll-out of the new guidelines, it is recommended that the Office of Local Government requests councils in the Catchment to review integration with the new guidelines and provide feedback that can be used to inform community and industry education programs and updates to the Local Government (General) Regulation 2015.

21.3.4. Developments achieve NorBE

Recommendation 19: **Audit stormwater management assets dedicated to council to determine if they are maintained to achieve NorBE objectives** - The Biodiversity and Conservation SEPP requires all new developments in the Catchment to have a neutral or beneficial effect on water quality. However, as discussed in sections 3.11 and 9.4.4, there are concerns about the long-term maintenance of some stormwater[26] control devices and associated landscape features. It is therefore recommended that an audit be conducted of stormwater management assets dedicated to councils in the Catchment to

[26] It is acknowledged that NorBE assessments apply to all activities associated with new development that have the potential to pollute (not just stormwater). However, these are generally managed during construction or long-term through an environment protection licence. Concern was raised only in relation to long-term maintenance of unlicenced stormwater controls.

determine if they are maintained to achieve NorBE objectives. Key findings and recommendations of the review to be led by WaterNSW should be shared with councils to inform future development consent conditions, funding arrangements and maintenance regimes.

Recommendation 20: **Audit Module 1 and 2 development applications, assessments and determinations against NorBE requirements** - Part 6.5 of SEPP (Biodiversity and Conservation) 2021 sets NorBE requirements for developments in the Catchment. It is recommended that a compliance audit of Module 1 and 2 development assessments is undertaken to determine if the recent updates to the NorBE tool and processes, and associated training, have satisfied the desired outcomes. Refer to the response to the 2019 audit recommendation A4 in section 20 for further context.

21.3.5. Reduce unauthorised polluting activities

Recommendation 21: **Expand collaborative pollution control programs and campaigns in high-risk areas of the Catchment** - Many councils interviewed for this audit expressed interest in enhanced regulation of unauthorised polluting activities, especially due to concerns that this was an increasing problem. It is therefore recommended that collaborative pollution control programs such as, but not limited to, the Get the Site Right and RID squads are expanded or realigned to meet high-risk areas in the Catchment, as defined by councils in consultation with the EPA.

21.3.6. Improve management of poor water quality

Recommendation 22: **Investigate causes of poor water quality at priority sites so that management can be targeted to the root cause –** The Source Water Protection Strategy (WaterNSW 2022d) has a goal to undertake scientific research into water quality risks and emerging issues in the Catchment. Priority sites that require further investigation were identified from the water quality analysis described in section 19.4, and are as follows:

- Kangaroo River sub-catchment, with a focus on DBP1 (Bendeela Pondage), DTA8 (Lake Yarrunga at Bendeela pumping station) and E706 (Kangaroo River at Hampden Bridge)
- Mid Coxs River sub-catchment, with a focus on E0114 (Coxs River downstream of Lake Lyell) and E073 (Coxs River at Glenroy Bridge)
- Wingecarribee River sub-catchment, with a focus on E332 at Berrima
- Wollondilly River sub-catchment, with a focus on E409 (Murrays Flat)
- DTA5 – Lake Yarrunga at the Shoalhaven River, Bungonia Creek sub-catchment
- E891 – Gillamatong Creek, Braidwood sub-catchment.
- E457 – Towers Weir, Mulwaree River sub-catchment

Recommendation 23: **Develop educational/promotional material on innovative stormwater management practices in the Catchment** – Consistent with the goal to transition to Water Sensitive Cities, it is recommended that educational material be developed by WaterNSW in consultation with councils based on experience in innovative stormwater management practices in the Catchment. The material should showcase successful initiatives in the Catchment (including on-ground outcomes) and provide information on what should be avoided. The material should be targeted to practitioners from councils and other organisations (e.g., WaterNSW, Transport for NSW, LLS) that includes design engineers, construction and maintenance personnel, environmental scientists, bush regenerators and community volunteers.

Recommendation 24: **Identify and map sources of mine and quarry water discharges in the Catchment, including licenced and legacy premises** – Mine water discharge is currently dealt with by DPE – Mining Approvals and the Resources Regulator on a case-by-case basis. To assist with an understanding of cumulative impacts of water discharge associated with active and closed mines and quarries in the Catchment, it is recommended that these sources are identified and mapped. The resultant map should be made available via SEED and agencies involved in assessing and regulating mining impacts notified.

21.4. Monitoring and measuring audit responses

Subsequent audits conducted in accordance with section 42 of the *Water NSW Act 2014* will determine if the implemented recommendations and other actions taken have been effective in maintaining or improving Catchment health. Those audits will continue to review information relevant to the 18 indicators of Catchment health. WaterNSW will continue to report progress on implementation of audit recommendations in the annual catchment management reports.

To assist WaterNSW with this statutory duty and minimise the risk of recommendations 'slipping through the cracks', the heads of agencies that have had a recommendation assigned will be notified by WaterNSW at the time the audit is tabled in Parliament and each subsequent year. Each agency assigned responsibility for action in this audit has an obligation to report progress to WaterNSW so that a collective response can be provided each year to the community and Minister.

Figure 21-1: Example of landscape regeneration in the Shoalhaven (photo provided by WaterNSW)

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Appendix A: Audit team

Refer to Volume 2 of the audit report.

Appendix B: Catchment indicators, measurements and data sources

Refer to Volume 2 of the audit report.

Appendix C: Consultation for the audit

Refer to Volume 2 of the audit report.

Appendix D: Current recommended practices and standards

Refer to Volume 2 of the audit report.

Appendix E: Long-term median stream flow

Refer to Volume 2 of the audit report.

Appendix F: Groundwater analysis

Refer to Volume 2 of the audit report.

Appendix G: Water quality analysis – compliance during audit period

Refer to Volume 2 of the audit report.

Appendix H: Water quality analysis – audit to pre-audit comparison

Refer to Volume 2 of the audit report.

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