Annual Water Quality Monitoring Report

2022-23

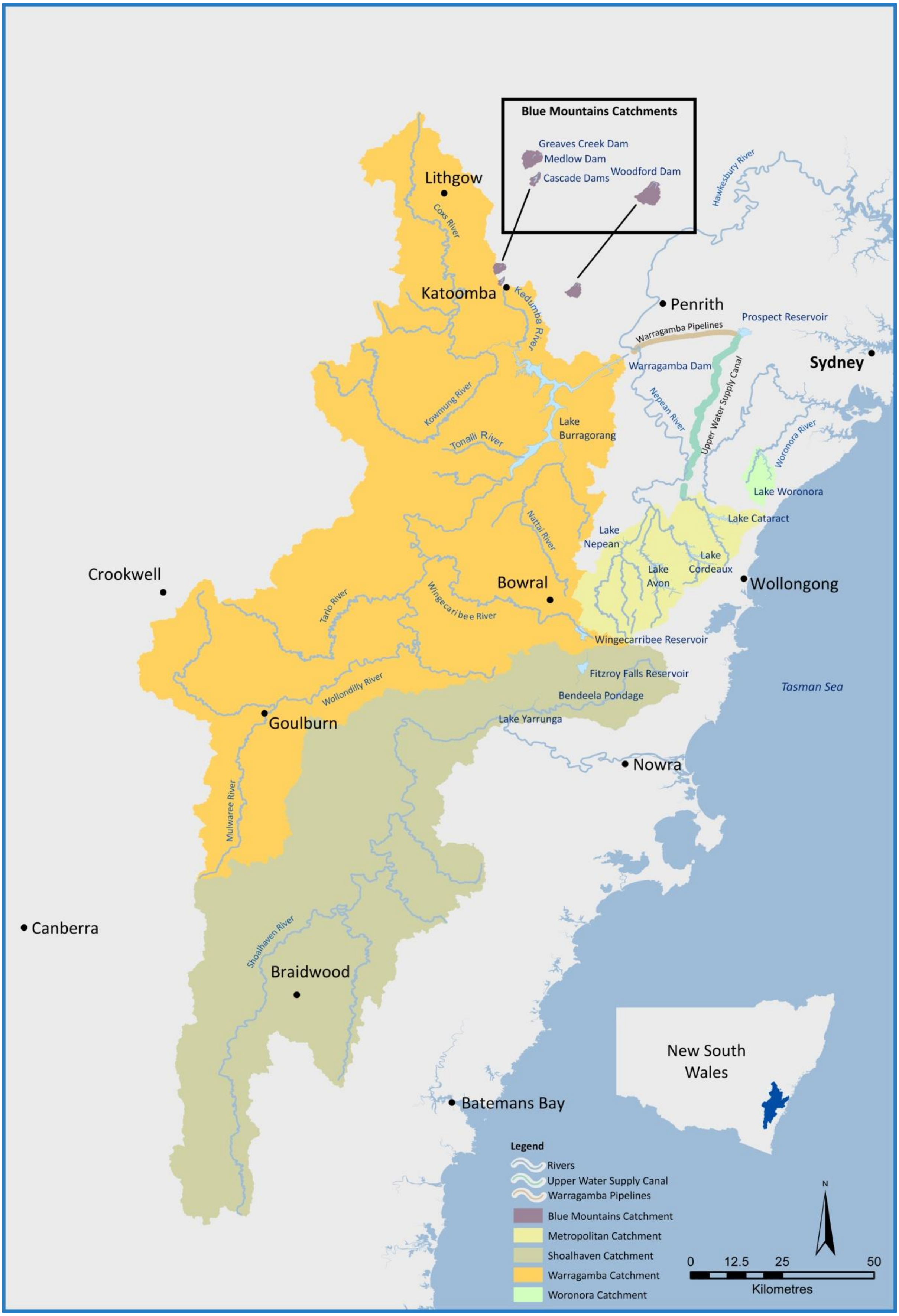

Figure 0.1: Sydney catchment area

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Front Cover: Waratah Rivulet in the Woronora catchment. 2023. Copyright WaterNSW.

Executive Summary

WaterNSW's Water Monitoring Program (WMP) for the Sydney catchment area details the comprehensive monitoring activities covering catchments, lakes, intakes to water filtration plants, picnic areas and downstream river sites. The WMP has been developed in collaboration with NSW Health, Sydney Water and councils. The program incorporates locations, frequency and benchmarks or guideline values for more than 200 water quality characteristics. The WMP includes routine and event monitoring employing field sampling, laboratory testing and telemetered 'real-time' data collection from in-situ instruments. Monitoring provides timely water quality data and information to inform water quality risks, operational decisions and verification of water quality to demonstrate compliance.

This report describes the results of the water quality monitoring undertaken by WaterNSW during 2022-23. The report is prepared to meet WaterNSW's statutory obligations and supports the implementation of WaterNSW Water Quality Management System, providing valuable information for the assessment of water quality changes and early identification of potential threats to water quality. This allows WaterNSW to proactively develop mitigation strategies, required for the protection of our water sources and water supplied for treatment. In addition, it provides stakeholders, students, researchers and the general public with water quality information for waters managed by WaterNSW in the greater Sydney catchment area.

Highlights

The 2022-23 reporting period commenced with a total storage volume of 96.4% on 1 July 2022. This high starting storage volume was due to large inflow events experienced in the previous reporting period in March and April 2022. It was only two days into the current reporting period that another major rainfall event began, with all Greater Sydney storages apart from Prospect Reservoir spilling on the 5^{th} of July 2022, with the total storage volume at 99.9%. Another major inflow event occurred in October 2022, again causing multiple major storages to have significant spills. Total storage volume at the end of the reporting period in June 2023 was still high at 93.2%.

Storage and catchment sample sites were less accessible due to catchment closures caused by multiple rainfall events. Some sites were not sampled due to safety reasons including catchment closures or access issues due to dam spills.

Guided by its Water Quality Management System, WaterNSW successfully delivered agreed quantities of high quality water to customers in full compliance with the Australian Drinking Water Guidelines (ADWG) for health-related characteristics.

A period of sustained high rainfall since February 2020, with repeated major storm events in both the preceding and current reporting periods, has resulted in challenging water quality conditions. An incident management team was established to manage water quality. Despite these significant challenges, through proactive modelling, monitoring and source selection, WaterNSW continued to deliver best available source water to our customers to ensure safety of the water supply was not compromised.

Water supplied to **water filtration plants** achieved 96.06% compliance with site specific standards in raw water supply agreements. Exceptions included algal ASU (a measure of filter clogging potential) plus those related to successive inflow events including turbidity, pH, hardness, alkalinity and metals (iron and aluminium). These issues were highlighted to customers and were managed in accordance with the Water Quality Incident Response Protocol.

WaterNSW continued to manage **picnic area supply** sites in accordance with the Quality Assurance Plans developed in line with NSW Private Water Supply Guidelines. Similar to the previous year, poor source water quality was an increasing challenge due to ongoing rain events particularly at Cataract and Cordeaux. This resulted in periods where potable water could not be supplied with picnic areas either closed to the public or signposted as not suitable for drinking. The efficacy of chlorine disinfection was demonstrated with high residuals achieved at the dosing plants, high chlorine contact times and the absence of *E. coli* and indicator bacteria in the supplies.

Water quality in the Greater Sydney **catchments** displayed similar patterns to previous years. Highly protected, natural bushland catchments continue to outperform catchments dominated by agricultural and urban land uses, predominantly for nutrients. Rainfall also had an impact on catchment water quality with heavy rainfall events in July and October 2022 causing an increase in ANZECC benchmark exceedances, particularly for aluminium.

Water quality in 2022-23 achieved
96.06% conformance with Raw Water Supply Agreements and
100% conformance with Australian Drinking Water Guidelines

Monitoring **downstream** of WaterNSW storages is part of the requirements of the Water Licences and Approvals package administered by Natural Resource Regulator. Similar patterns to 2021-2022 were observed across all downstream of storage sites. In the Nepean River system water quality remains poorer moving downstream due to uncontrolled catchment influences.

WaterNSW successfully managed three major water quality incidents as triggered by and in accordance with our Water Quality Incident Response Protocol, including filter clogging algae at Cascades WFP in January 2023, localised run off at Macarthur WFP containing E. coli and iron in September 2022, and a major flood event in July 2022.

Investigative monitoring was undertaken to assess the use of in situ algal fluorescence sensors in Lake Burragorang. The study involved the deployment of in situ sensors that generate high frequency data in near real time, that allows operators to track chlorophyll a as an indicator of algal growth in the storage.

The annual **Macroinvertebrate Monitoring Program** scored 80 routine sites against the AUSRIVAS band grades in 2022. Of the 76 sites monitored in both 2021 and 2022, 51 received a lower AUSRIVAS value in 2022, while 25 recorded higher values. This indicates a continuing decline in macroinvertebrate health across the declared catchment; however, changes were not always large enough to cause a AUSRIVAS band grade change at each site. The decline may have been influenced by suboptimal sampling conditions following high flow events and above baseline flow conditions.

A **trend analysis** was conducted for selected analytes and sites for the period from 2013 to 2023. Increasing trends were identified on analytes that are typically influenced by heavy rainfall, attributed to the prolonged period of recurring storm activity that commenced in February 2020, and is still impacting storage water quality to this day.

1 Introduction

WaterNSW is a state-owned corporation whose responsibilities include, inter-alia, supplying water in compliance with appropriate standards of quality (Section 6(1)(b), Water NSW Act 2014) in the Sydney catchment area. WaterNSW undertakes extensive monitoring within its catchments, lakes and raw water supply system and in rivers downstream of storages to meet this objective.

WaterNSW's Water Monitoring Program (WMP) sets out the location, frequency and analytes monitored for the Sydney catchment area and the regional area (WaterNSW, 2021). Specific and health-related characteristics are determined in consultation with our major customers and the program is developed to the satisfaction of NSW Health. Monitoring for operations and planning helps WaterNSW understand the threats to water quality throughout the supply system, including rivers, lakes and the delivery system. This information aids the selection of the best source water for our customers and the environment.

Data collected through the WMP is used to:

- provide early detection of possible contaminants to protect the health of consumers
- assist in proactive operational decisions
- ensure that the raw water delivered to our customers meets agreed standards and can be treated to meet the Australian Drinking Water Guidelines
- identify and target possible contamination sources in the catchments and storages
- prioritise monitoring to inform water quality risks and remedial actions
- identify emerging water quality issues and address them in forward configurational planning

WaterNSW's compliance monitoring activities are governed by the following key drivers:

- Operating Licence and Reporting Manual granted by the Governor of NSW and administered by Independent Pricing and Regulatory Tribunal (IPART)
- Water Licences and Approvals package granted by the Water Administration Ministerial Corporation and administered by Department of Planning and Environment (DPE – Water Division)
- Raw water supply agreements between WaterNSW and its customers
- Australian Drinking Water Guidelines
- NSW Private Water Supply Guidelines and Public Health Act 2010
- ANZECC benchmarks

This report describes the results of water quality monitoring undertaken by WaterNSW in the Sydney catchment area between 1 July 2022 and 30 June 2023 under the WMP. The report is a requirement of the Reporting Manual of the Operating Licence. The report also provides the community with information on water quality.

More specifically this report includes:

- a summary of the WMP, including objectives and applicable guidelines
- a summary of the results of the routine, event and investigative monitoring
- analysis of system performance relative to the criteria where relevant water quality or catchment health benchmarks are available
- information on the integrity of the data reported
- details of research activities
- summary of water quality incidents and actions taken to resolve, eliminate or mitigate the effect of those incidents, especially to protect public health during the incident
- an analysis of trends in water quality over the previous 10 years for selected sites and analytes.

Source water quality in 2022-23 was largely affected by several minor and major rainfall events.

2 Overview of the Sydney catchment area water supply network

WaterNSW collects water from river catchments to the south and west of Sydney and stores it in lakes and reservoirs to supply more than five million people in the Greater Sydney region.

It is transported via a network of rivers, lakes, pipes and canals to water filtration plants, where it is treated for consumers in Sydney, Illawarra, Shoalhaven, Goulburn, Blue Mountains and the Southern Highlands. Water is also released from storages as environmental flows to maintain the health of the downstream river systems.

The catchments cover an area of approximately 16,000 square kilometres, extending from the headwaters of the Coxs River north of Lithgow, south to the source of the Shoalhaven River near Cooma, and from Woronora in the east to the Wollondilly River near Crookwell in the west (Figure 0.1). Raw water is collected from the river systems of five major catchments:

- Warragamba (including Prospect)
- Upper Nepean
- Woronora
- Shoalhaven
- Blue Mountains, including supplementary flows from the Fish River system.

The transfer routes for water around the system and approximate number of people supplied by that part of the system are shown in the water supply system schematic (Figure 2.1).

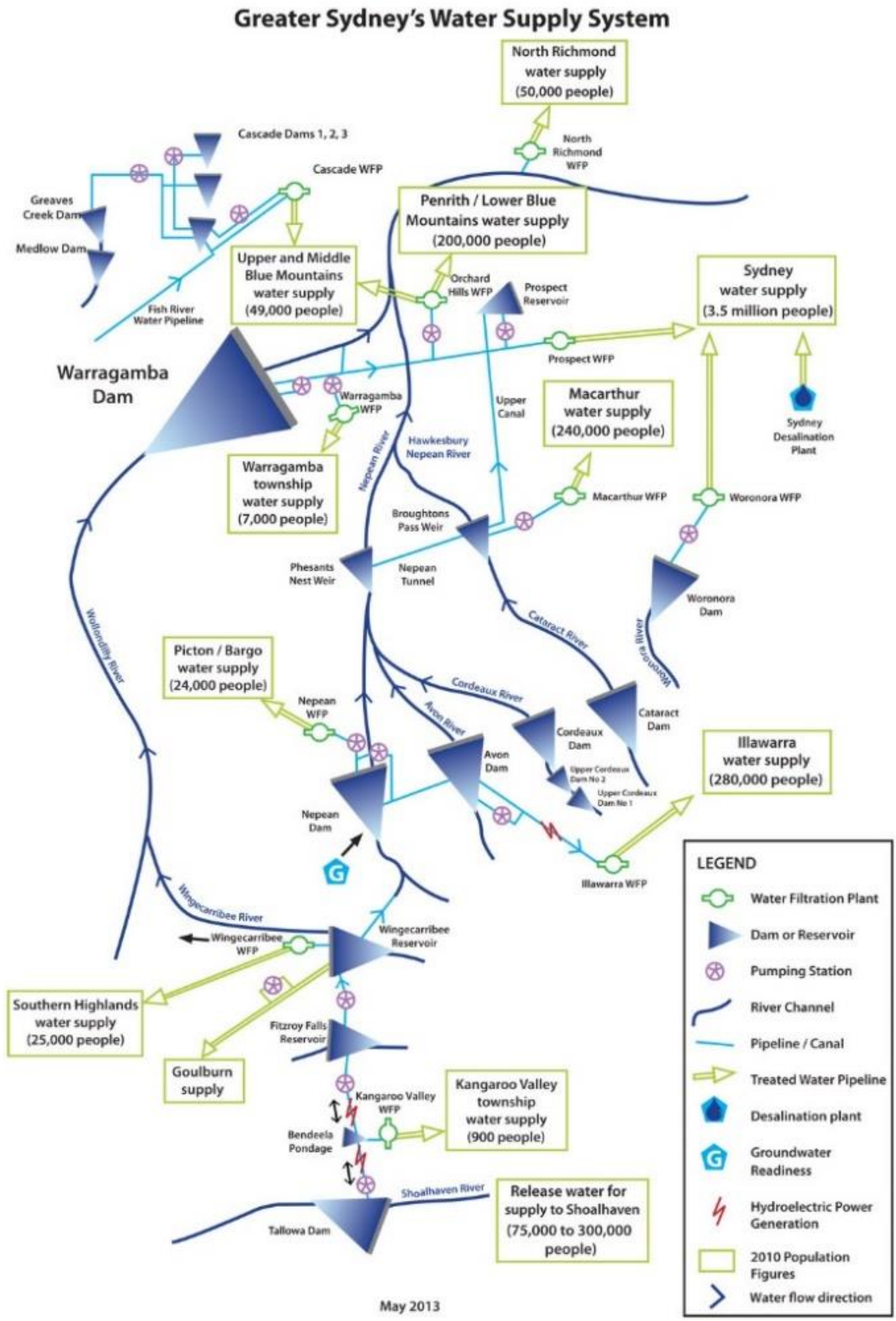

Figure 2.1: Schematic of the water supply system

3 Sydney catchment area water monitoring program

The Water Monitoring Program (WMP) consists of operational, verification and investigative monitoring. The WMP covers catchments, storages, inlets to water filtration plants, picnic taps, transfer canals and pipelines, as well as rivers downstream of water supply dams and weirs. Monitoring includes physical, chemical, biological, radiological, hydrological and meteorological parameters through on-line instruments, field sampling and laboratory analysis. A key feature of the WMP is an agreed list of water quality characteristics. The list contains:

- those characteristics that cannot be managed by conventional treatment and for which Australian Drinking Water Guidelines (ADWG) must be met; and,
- those characteristics for which ADWG exist but are not applicable to raw water, where WaterNSW must endeavour to supply raw water so that it can be treated to meet the ADWG.

WaterNSW is subject to a range of statutory requirements and standards set by regulatory agencies. WaterNSW is also benchmarked against other raw water suppliers to maintain best practice service standards.

The principal documents that outline requirements on WaterNSW with respect to water monitoring are listed below.

- 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 (2022) (Parts 5-8)
- Raw Water Supply Arrangements
- Water Quality Incident Response Protocol
- Private Water Supply Guidelines and Public Health Act 2010
- Water Act 2007 (Commonwealth)

The WMP specifies the requirements for water sample collection and analysis. It describes sampling locations and frequencies, and the parameters to be analysed. Additional samples are collected and analysed for quality assurance and quality control (QA/QC) purposes and during events. The QA/QC program provides confidence in the data collected.

The collection and analysis of routine and QA/QC water samples is performed by WaterNSW monitoring staff and external service providers. Service contracts include requirements for quality assurance practices in the monitoring, sampling, testing and reporting processes. A chain of custody system allows individual samples to be tracked from field collection, through laboratory analysis, to the transfer of results to WaterNSW's database. Further details of the QA/QC monitoring for 2022-23 are included in Section 5.1.

4 Applicable guidelines and benchmarks

WaterNSW has adopted nationally recognised standards and guidelines for a range of water quality characteristics in each part of the water supply network. Different guidelines and standards apply to each part of the supply cycle as water passes from catchment waterways into lakes and then into the delivery network or downstream rivers.

4.1 Australian Drinking Water Guidelines (ADWG)

The Australian Drinking Water Guidelines (NHMRC, 2011 and later revisions) apply to any water intended for drinking, irrespective of the source or where it is consumed. The ADWG framework for managing drinking water quality advocates risk management and preventive measures at all barriers from catchment to consumer.

For water quality characteristics that have been specified as 'health related', including metals, pesticides and synthetic organic compounds (Table 4.1a-b), raw water must conform to the ADWG. As conventional water treatment methods are not designed to remove these compounds from raw water, it is preferable to avoid them in the raw water supply through catchment and storage management practices. Drinking water supply at picnic areas is managed in accordance with the ADWG.

Routine monitoring of radionuclides is performed at water filtration plants by screening for gross alpha and gross beta activity concentrations. Testing for individual radionuclides is performed in the case of a positive gross alpha or gross beta result. Gross alpha and gross beta screening is now carried out three-yearly in accordance with ADWG. Gross alpha and gross beta screening was not conducted in this reporting period.

4.2 Raw water supply agreements

WaterNSW has established terms and conditions of supply with wholesale customers to ensure treated water is not harmful to consumers' health. WaterNSW maintains raw water supply agreements with Sydney Water, Wingecarribee Shire Council, Goulburn Mulwaree Council and Shoalhaven City Council. Raw water supplied for treatment is required to conform to site-specific standards specified in raw water supply agreements (Table 4.3). These standards are based on the treatment capabilities of the plants and the natural characteristics of the catchment. This ensures that raw water can be treated to meet ADWG requirements.

Table 4.1a: Health-related water quality characteristics: Synthetic Organics, Radiological and Pesticide Characteristics

	SPECIFIC WATER CHARACTERISTIC	DRIVER	ADWG (2011) Health Guideline
SYNTHETIC ORGANICS - RADIOLOGICAL - PESTICIDES	**Synthetic Organic Compounds**	Operating Licence[1]	
	Benzene		0.001 mg/L
	Vinyl chloride		0.0003 mg/L
	Pesticides		
	2,4-D (2,4-Dichlorophenoxyacetic acid)		0.03 mg/L
	Atrazine		0.02 mg/L
	Chlorfenvinphos		0.002 mg/L
	Chlorpyrifos		0.01 mg/L
	Diuron		0.02 mg/L
	Flupropanate		0.009 mg/L
	Glyphosate		1.0 mg/L
	Hexazinone		0.4 mg/L
	MCPA (2-methyl-4-clorophenoxyacetic acid)		0.04 mg/L
	Picloram		0.3 mg/L
	Simazine		0.02 mg/L
	Triclopyr		0.02 mg/L
	Radiological	ADWG recommends screening level test for radiological parameters	
	Gross alpha		0.5 Bq/L
	Gross beta		0.5 Bq/L

1 Section shaded yellow contains health related water quality characteristics. These characteristics must not exceed Australian Drinking Water Guidelines (NHMRC, 2011) in raw water supplied as treatment may not remove them. Minimising these in raw water effectively minimises risk to consumers.

Table 4.2b: Health-related and aesthetic Water Quality Characteristics: (Physical, Chemical, Biological and Organic)

	SPECIFIC WATER CHARACTERISTIC	DRIVER	Guideline
PHYSICAL - CHEMICAL - BIOLOGICAL - ORGANIC	Arsenic	ADWG (2011)[1] Health Guideline	0.01mg/L
	Barium		2 mg/L
	Beryllium		0.06mg/L
	Boron		4 mg/L
	Iodide		0.5 mg/L
	Manganese		0.5 mg/L
	Mercury		0.001 mg/L
	Molybdenum		0.05 mg/L
	Selenium		0.01 mg/L
	Silver		0.1 mg/L
	Tin		N/A
	Antimony	ADWG (2011)[2] Health Guideline (NSW Private Water Supply Guidelines, 2016)	0.003 mg/L
	Cadmium		0.002 mg/L
	Chromium (Cr^{VI})		0.05 mg/L
	Copper		2 mg/L
	Fluoride		1.5 mg/L
	Lead		0.01 mg/L
	Nickel		0.02 mg/L
	Nitrate		50 mg/L
	Nitrite		3 mg/L
	E. coli Enterococci *C. perfringens* *Cryptosporidium* *Giardia* Toxin producing cyanobacteria Toxicity Total cyanobacteria biovolume	ADWG (2011) Operating Licence[3]	Seek advice from NSW Health
	Algae (ASU) Alkalinity Aluminium Hardness Iron Manganese Odour pH True colour Turbidity	Water Supply Agreements	Refer to Water Supply Agreements
	Total cyanobacteria biovolume Total toxin producing cyanobacteria Toxicity Enterococci	Water Licences and Approvals Package (WLAP)[4]	Refer to *Guidelines for Managing Risks in Recreational Water* (NHMRC 2008)

1 Section shaded **yellow** contains health related water quality characteristics – these characteristics must not exceed Australian Drinking Water Guidelines (NHMRC, 2011) in treated waters or in raw water supplied as treatment may not remove them. Minimising these in raw water effectively minimises risk to consumers.

2 Section shaded **orange** contains health related water quality characteristics for private water supplies – these characteristics must not exceed Australian Drinking Water Guidelines (NHMRC, 2011) in treated waters.

3 Section shaded **blue** contains characteristics for which drinking water guidelines exist but these are not applicable for raw water. However, WaterNSW must endeavour to supply the best quality raw water available so that it can be treated to meet Australian Drinking Water Guidelines.

4 Section shaded **green** contains characteristics which apply for recreational waters and releases.

Table 4.3: Raw water supply agreements – Site specific standards

<table>
<tr><th colspan="2" rowspan="2"></th><th>Turbidity</th><th>True Colour @400 nm</th><th>Iron</th><th>Manganese</th><th>Aluminium</th><th>Hardness</th><th>Alkalinity</th><th>pH</th><th>Odour</th><th>Algae</th></tr>
<tr><th>NTU</th><th>CU</th><th>mg/L</th><th>mg/L</th><th>mg/L</th><th>mg/L as CaCO3</th><th>mg/L as CaCO3</th><th>pH units</th><th>Rating</th><th>ASU</th></tr>
<tr><td colspan="2">**Prospect WFP**</td><td rowspan="3">40</td><td rowspan="3">60</td><td rowspan="3">3.50</td><td rowspan="3">1.40</td><td rowspan="3">2.6</td><td rowspan="3">25 – 70</td><td rowspan="3">15 - 60</td><td rowspan="11">NA</td><td rowspan="7">NA</td><td>1000[(i)]</td></tr>
<tr><td colspan="2">**Warragamba WFP**</td><td rowspan="2">2000</td></tr>
<tr><td colspan="2">**Orchard Hills WFP**</td></tr>
<tr><td rowspan="4">**Macarthur WFP** Based on Demand (ML/day)</td><td>185 - <265</td><td>10</td><td rowspan="4">40</td><td>0.60</td><td>0.20</td><td>0.40</td><td>6 – 30</td><td rowspan="4">15</td><td rowspan="2">100[(ii)]</td></tr>
<tr><td>125 - <185</td><td>25</td><td>0.80</td><td>0.25</td><td>0.50</td><td rowspan="3">6 – 32.20</td></tr>
<tr><td>80 - <125</td><td>50</td><td>1.10</td><td>0.30</td><td>0.75</td><td rowspan="2">500[(ii)]</td></tr>
<tr><td><80</td><td>60</td><td>1.30</td><td>0.35</td><td>0.95</td></tr>
<tr><td colspan="2">**Illawarra WFP**</td><td rowspan="2">10</td><td>50</td><td>1.1</td><td>0.4</td><td>1.4</td><td>30</td><td>10</td><td rowspan="2">Not objectionable</td><td rowspan="2">5000</td></tr>
<tr><td colspan="2">**Woronora WFP**</td><td>70</td><td>1</td><td>0.1</td><td>0.4</td><td>2 – 30</td><td>15</td></tr>
<tr><td colspan="2">**Nepean WFP**</td><td>150</td><td rowspan="2">60</td><td>5.0</td><td>1.5</td><td>1.0</td><td>2 – 35</td><td>0.5 – 25</td><td rowspan="5">NA</td><td rowspan="2">2000</td></tr>
<tr><td colspan="2">**Cascade WFP**</td><td>15</td><td>3.0</td><td>0.3</td><td>0.2</td><td>40</td><td>30</td></tr>
<tr><td colspan="2">**Kangaroo Valley WFP**</td><td>20</td><td rowspan="3">70</td><td rowspan="3">1.1</td><td>0.4</td><td rowspan="3">NA</td><td rowspan="3">36.5</td><td>29</td><td rowspan="3">6.5 – 8.5</td><td rowspan="3">5000</td></tr>
<tr><td colspan="2">**Wingecarribee WFP**</td><td rowspan="2">40</td><td rowspan="2">NA</td><td rowspan="2">35</td></tr>
<tr><td colspan="2">**Goulburn Mulwaree**</td></tr>
</table>

(i) Maximum for Prospect WFP is 1000 ASU, except if turbidity is greater than 10 NTU or true colour is greater than 30 CU, then the algae maximum will be 500 ASU.

(ii) Algal limits for Macarthur WFP (average of 3 samples): 500 ASU small individual cells (<10 µm) of filamentous or colonial species, typically *Chlorella*, *Dolichospermum*, *Monodus* and *Melosira*; or 100 ASU large (>10 µm) cells, branching species, and/or gelatinous species, typically *Asterionella*, *Taballaria*, *Fragillaria*, *Synedra*, *Cyclotella*, *Dinobryan*, *Elakatothrix*, and *Volvox*.

(iii) Upper limits are shown for analytes where ranges are not provided.

4.3 ANZECC 2018

The Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2018) (ANZECC, 2018) provide a guide for setting water quality objectives required to sustain current or likely future environmental values for natural and semi-natural water resources in Australia and New Zealand. Water quality in WaterNSW Sydney catchment area waterways is compared against relevant sections of the ANZECC Guidelines.

Benchmarks for storages

Benchmarks for storages are derived from the guidelines for freshwater lakes and reservoirs (ANZECC, 2018) for the 95-99 percent level of species protection (Table 4.4). Site specific benchmarks are to be developed for temperature and conductivity, and as such are not included in the table below.

Table 4.4: Water quality benchmarks for storages

Analyte	Units	Benchmark range
pH	pH units	6.5 - 8.0
Chlorophyll *a*	µg/L	< 5
Dissolved oxygen	% sat	90 – 110
Total nitrogen	mg/L	< 0.35
Oxidised nitrogen	mg/L	< 0.01
Ammoniacal nitrogen	mg/L	< 0.01
Total phosphorus	mg/L	< 0.01
Filterable reactive phosphorus	mg/L	< 0.005
Turbidity	NTU	< 20.0
Total manganese	mg/L	< 1.9
Total aluminium	mg/L	< 0.055

Benchmarks for catchments

WaterNSW benchmarks water quality in metropolitan catchment streams against the ANZECC (2018) guideline ranges for upland rivers (Table 4.5).

Table 4.5: Water quality benchmarks for catchment streams

Analyte	Units	Benchmark range
pH	pH units	6.5 – 8.0
Chlorophyll *a*	µg/L	< 5
Dissolved oxygen	% sat	90 – 110
Total nitrogen	mg/L	< 0.25
Ammoniacal nitrogen	mg/L	< 0.013
Oxidised nitrogen	mg/L	< 0.015
Total phosphorus	mg/L	< 0.02
Filterable reactive phosphorus	mg/L	< 0.015
Turbidity	NTU	< 25
Total aluminium	mg/L	< 0.055
Total manganese	mg/L	< 1.9
Conductivity	mS/cm	< 0.35

4.4 Benchmarks for recreational areas

To minimise risks to public health, WaterNSW manages recreational exposure risk by benchmarking water quality against the Guidelines for Managing Risks in Recreational Waters (NHMRC, 2008) (Table 4.5).

Table 4.6: Water quality benchmarks for recreation areas

Analyte	Units	Primary Contact		Secondary Contact
		Minor Alert Threshold	Major Alert Threshold	Alert Threshold
Enterococci	cfu/100mL	40	200	200
Microcystis aeruginosa	cells/mL	5,000	50,000	50,000
Toxic cyanobacteria biovolume	mm^3/L	0.4	4	4
Total cyanobacteria biovolume	mm^3/L	-	10	10
Algal toxins (microcystin variants)	µg/L	NA	10	10

4.5 Benchmarks for downstream rivers

Benchmarks for water quality downstream of WaterNSW's dams and weirs are derived from ANZECC (2018) lowland rivers ecosystem types (Table 4.6).

Table 4.7: Water quality benchmarks downstream of storages

Analyte	Units	Benchmark range
pH	pH units	6.5 - 8.5
Chlorophyll *a*	µg/L	< 5
Dissolved oxygen	% sat	85 – 110
Total nitrogen	mg/L	< 0.5
Total phosphorus	mg/L	< 0.05
Turbidity	NTU	< 50

4.6 Benchmarks for picnic area supplies

Benchmarks for the picnic area supplies are based on ADWG (2011) threshold ranges, where relevant (**Error! Reference source not found.**7). Some benchmarks are prompts for action, such as chlorophyll *a*, which triggers algal monitoring in the picnic area supply.

Table 4.8: Water quality guidelines for specific parameters at picnic areas

Analyte	Units	Threshold
Free chlorine residual	mg/L	> 0.5
pH	pH units	6.5 - 8.5
Turbidity	NTU	< 3
Total iron	mg/L	< 0.3
Total aluminium	mg/L	< 0.2
Total manganese	mg/L	< 0.1
Total coliforms	orgs/100 mL	NA
E. coli	orgs/100 mL	Should not be detected
Algal toxins (microcystin variants)	µg/L	< 1.3
Chlorophyll *a*	µg/L	< 5
Potentially toxin producing algal cells	cells/mL	< 6,500[i]

(i) See cyanobacteria benchmarks in Table 4.8

4.7 Benchmarks for cyanobacteria

WaterNSW routinely monitors levels of algae in major storages to provide early warning of possible bloom conditions and to ensure that raw water supplied to customers can be treated to meet drinking water guidelines. Algal monitoring is also conducted to avoid contaminating downstream waterways through environmental releases or transfers.

While the ADWG stipulate cyanobacteria guidelines and alert levels for drinking water, WaterNSW applies those guidelines to the raw water supplied for treatment in Greater Sydney. At Lake Yarrunga and Fitzroy Falls Reservoir, the only WaterNSW storages in the Sydney catchment area with recreational access, the National Health and Medical Research Council Recreational Waters Guidelines (NHMRC, 2008) for catchments and lakes are applied (**Error! Reference source not found.**8). The raw water and picnic areas benchmarks are from the ADWG.

Table 4.9: Cyanobacteria benchmarks throughout Sydney catchment area

Analyte		Units	Threshold
Catchment and lake sites(i)			
Cells	*Microcystis aeruginosa*	cells/mL	50,000
Toxicity	Microcystin variants	µg/L	10
Biovolume	Total cyanobacteria	mm^3/L	4
Raw water and picnic area water supplies(ii)			
Cells	*Microcystis aeruginosa*	cells/mL	6,500
	Raphidiopsis raciborskii	cells/mL	15,000
	Dolichospermum circinale	cells/mL	20,000
Toxicity	Microcystin variants	µg/L	1.3
	Cylindrospermopsin	µg/L	1.0
	Saxitoxin	µg/L	3.0
Biovolume	Potentially microcystin-producing species	mm^3/L	0.6
	Potentially cylindrospermopsin-producing species	mm^3/L	0.6
	Potentially saxitoxin-producing species	mm^3/L	5

(i) National Health and Medical Research Council Guidelines for Managing Risks in Recreational Water 2008.

(ii) These triggers are based on cell counts, toxin concentration and biovolume ADWG 2011 specify actions in response to various alert level ranges for *Microcystis aeruginosa, Dolichospermum circinale* and *Raphidiopsis raciborskii*, and the consolidated biovolumes of the species known to produce microcystin, saxitoxins and cylindrospermopsin toxins.

4.8 Benchmarks for *Cryptosporidium* and *Giardia*

The ADWG do not contain guideline values for *Cryptosporidium* and *Giardia* in raw or treated drinking water. However, ADWG (2011) recommends a multi-barrier approach to minimise the risks of these pathogens. Investigative testing is encouraged in response to events that could increase the risk of contamination. WaterNSW implements additional monitoring during high-risk events. *Cryptosporidium* and *Giardia* monitoring in the catchments is undertaken to provide early warning to enable optimal configuration of the raw water supply system in the event of high concentrations of protozoan pathogens within the storages. Catchment monitoring also contributes to the understanding of sources which can then improve the robustness of risk assessments and catchment actions.

5 Routine monitoring

Water quality monitoring was conducted as per the Water Monitoring Program. Samples were collected from catchment streams, lakes and delivery sites and analysed by National Association of Testing Authorities (NATA) accredited laboratories. Online instruments were used to supplement this monitoring. This report summarises the results of routine monitoring compared against appropriate guidelines or benchmarks.

Data from routine samples was extracted from the WaterNSW water quality database. Storage data was filtered so that surface samples were used. Routine data was compared to the relevant guideline, standards and benchmark value for each analyte. The number of guideline exceedances was calculated as a percentage of the total compliance samples taken in the reporting year. The appendices provide summary statistics for all samples collected on each routine sampling occasion.

Compliance was 100% with the ADWG and 96.06% with Raw Water Supply Agreements. Overall, the water quality monitoring of the reservoirs in the declared catchment areas indicated good water quality apart from impacts associated with the July and October 2022 inflow events. The impacts of the recent inflow events were managed by adjusting the supply system configuration (e.g., offtake depth changes and source selection) and working with customers to reduce challenges in treating the water.

5.1 Quality Assurance and Quality Control

The WaterNSW quality assurance and quality control (QA/QC) program ensures the sampling and analysis process is accurate and representative. Specific QA/QC samples are collected and analysed to provide confidence that errors are controlled in the sampling and analysis process. Field collected QA/QC samples include field duplicates and field blanks. Trip blanks are also prepared at the laboratory and taken on designated sampling trips. In 2022-23, 2.6% of the number of routine samples were taken for QA/QC purposes to ensure the validity and accuracy of the WaterNSW's water quality data. This was above the effort on QA/QC recommended by ISO 5667 at 2% of routine samples.

In addition to WaterNSW QA/QC samples, WaterNSW's analytical service providers have management systems that require them to maintain their own internal QA/QC program. These systems are accredited with the NATA and aligns with ISO17025. The analytical service providers conduct internal quality control analysis per each batch of samples including matrix spikes, internal and inter-laboratory duplicates, blanks, replicate analysis and inter-laboratory proficiency trials. The service provider QA/QC specialists analyse conformance with specified standards of accuracy and precision defined by WaterNSW to identify any contamination, outliers or errors (either random or systemic).

Trip blanks

A total of 41 trip blanks were taken in 2022-23 across the greater Sydney catchment area. Of these 10 individual trip blanks saw positive detections for at least one analyte, representing a 24% anomaly rate per sample. Positive analyte detections totalled 20 across all samples. Dissolved organic carbon (7) and total organic carbon (6) were the most common detections, predominantly trace detections. Odour being an interpretive analysis can be expected to show some bias with 2 detections. Ammoniacal nitrogen, oxidised nitrogen and lab turbidity saw 1 trace detections each. One trip blank recorded detections for dissolved organic carbon, total organic carbon, total iron and total manganese while another recorded 5.8 mg/L for total organic carbon. Both samples have been referred to the analytical laboratory and sampling contractors.

Field blanks

A total of 70 field blanks were taken in 2022-23. Of these 23 field blanks returned positive results, equating to an anomaly rate of 33%. Similar to field blanks, dissolved and total organic carbon saw high detection rates at ~25%. These were all trace detections excluding one sample which recorded 1.1 mg/L and was referred to the laboratory and contractors for further investigation. Trace detections were recorded for nitrogen analytes (7), phosphorous analytes (2), odour (3), alkalinity (1), total iron (2) and phaeophytin (1). Two detections for field turbidity (1.76 and 4.59 NTU) were also recorded and referred to sampling contractors for further investigation.

Duplicates

For the reporting period WaterNSW has applied the Relative Percent Deviation (RPD) to routine and duplicate samples. Where the RPD is greater than 50% the two sample results are considered anomalous and discussed below. Sample results with detections of less than 10x the Limit of Reporting (LOR) are excluded due to the innate variability of results at low concentrations. Biological results such as bacteria or algae are included although it is noted that there is typically a high degree of variability between routine and duplicate samples.

During 2022-23, 103 duplicate samples were collected for which 27 samples showed significant RPD with the routine. Within the 27 samples, 62 analyses saw significant RPD although many of these were algal results (43 analyses). Other biological analytes accounted for 14 anomalies which included bacteria, lorenzen and phaeophytin. Total manganese and oxidised nitrogen recorded 1 significant RPD and were referred to the laboratory for investigation. Field turbidity recorded 1 significant RPD which was referred to monitoring team who confirmed a data entry error was the cause.

5.2 Warragamba system

Sampling sites in the Warragamba system (including Prospect Reservoir) are shown in Figure 5.1 below.

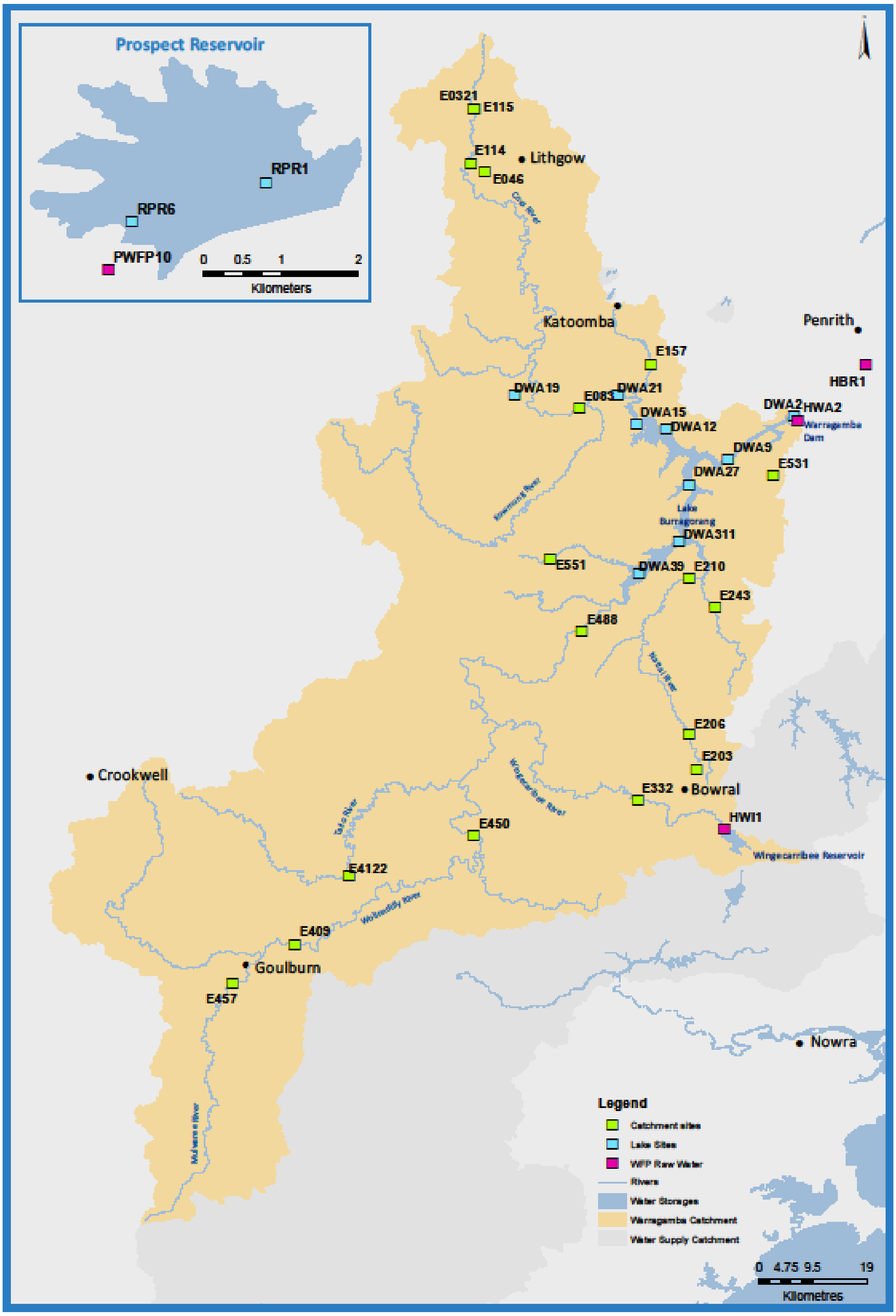

Figure 5.1: Sampling sites in the Warragamba system (Prospect Reservoir inset)

Table 5.1: Warragamba system catchments - percentage of routine samples outside benchmarks

Site	Station Code	Physico-Chemical							Nutrients					Metals			Cyanobacteria	
		Total Alkalinity as CaCO3 (mg/L)	Conductivity @25 C - Field (mS/cm)	Dissolved Oxygen - Field (%Sat)	pH - Field	Total Hardness as CaCO3 (mg/L)	True Colour at 400nm (PES filter)	Turbidity - Field (NTU)	Nitrogen Ammoniacal (mg/L)	Nitrogen Oxidised (mg/L)	Nitrogen Total (mg/L)	Phosphorus Soluble Reactive (mg/L)	Phosphorus Total (mg/L)	Aluminium Total (mg/L)	Iron Total (mg/L)	Manganese Total (mg/L)	Areal Standard Unit (algae)	Chlorophyll-a (ug/L)
Catchments (ANZECC guidelines refer Table 4.4, where there is no applicable benchmark the cells are greyed out).																		
D/S Lake Lyell	E0114		0%	42%	0%			0%	33%	100%	100%	0%	42%	67%		0%		8%
U/S Lake Lyell	E0115		33%	25%	17%			0%	33%	58%	58%	0%	33%	58%		0%		8%
Coxs R. at Lithgow (next to the Power Station)	E0321		75%	50%	0%			0%	67%	67%	42%	0%	25%	83%		0%		0%
Farmers Ck Mt Walker	E046		0%	17%	17%			0%	42%	100%	100%	0%	75%	83%		0%		17%
Coxs at Glenroy Br	E073		0%	8%	25%			0%	50%	92%	100%	0%	50%	67%		0%		8%
Coxs River @ Kelpie Point	E083		0%	17%	33%			0%	8%	50%	42%	0%	42%	42%		0%		8%
Kowmung River @ Cedar Ford	E130		0%	8%	0%			0%	8%	67%	17%	0%	0%	42%		0%		0%
Kedumba River@ Maxwells Crossing	E157		0%	0%	0%			8%	33%	92%	33%	0%	8%	58%		0%		8%
Gibbergunyah Ck 400m d/s of Mittagong STP Disch.	E203		33%	25%	0%			0%	100%	100%	100%	8%	83%	100%		0%		17%
Nattai River @ The Crags	E206		0%	8%	0%			0%	25%	100%	100%	0%	25%	50%		0%		17%
Nattai Ck @ Smallwoods Crossing	E210		25%	0%	0%			17%	67%	100%	58%	0%	25%	75%		0%		8%
Little River @ Fireroad W4I	E243		0%	0%	8%			0%	8%	83%	0%	0%	0%	25%		0%		0%
Mittagong Creek downstream WPCP Bowral	E306		42%	83%	0%			0%	83%	100%	92%	8%	58%	100%		0%		42%
Whites Ck 350m d/s of Moss Vale STP disch	E3151		67%	92%	0%			8%	100%	100%	100%	83%	100%	100%		0%		33%
Wingecarribee River @ Berrima	E332		0%	92%	0%			8%	92%	92%	100%	0%	100%	100%		0%		92%
Wollondilly River @ Murrays Flat	E409		92%	58%	50%			0%	67%	83%	100%	25%	92%	100%		0%		91%
Wollondilly at Upper Tarlo	E4122		58%	75%	0%			0%	67%	42%	100%	0%	58%	75%		0%		50%
Wollondilly River at ford 1km u/s Paddys River	E433		8%	100%	8%			0%	100%	83%	67%	0%	50%	100%		0%		33%
Wollondilly River @ Golden Valley	E450		83%	33%	8%			17%	50%	75%	100%	8%	58%	92%		0%		83%
Mulwaree River @ Towers Weir	E457		100%	83%	25%			17%	92%	83%	100%	83%	83%	75%		0%		73%
Wollondilly River @ Jooriland	E488		67%	0%	42%			17%	17%	42%	67%	0%	42%	75%		0%		25%
Wollondilly River @ u/s Goul Rossi Weir	E490		75%	83%	33%			0%	83%	50%	100%	8%	83%	67%		0%		73%
Werriberri Ck @ Werombi	E531		8%	50%	0%			0%	67%	83%	50%	0%	25%	92%		0%		17%
Tonalli R. @ Fire Road W2 (Site No.2)	E551		83%	33%	17%			0%	0%	100%	0%	0%	0%	17%		0%		0%

Site	Station Code	Physico-Chemical							Nutrients					Metals			Cyanobacteria	
		Total Alkalinity as CaCO3 (mg/L)	Conductivity @25 C - Field (mS/cm)	Dissolved Oxygen - Field (%Sat)	pH - Field	Total Hardness as CaCO3 (mg/L)	True Colour at 400nm (PES filter)	Turbidity - Field (NTU)	Nitrogen Ammoniacal (mg/L)	Nitrogen Oxidised (mg/L)	Nitrogen Total (mg/L)	Phosphorus Soluble Reactive (mg/L)	Phosphorus Total (mg/L)	Aluminium Total (mg/L)	Iron Total (mg/L)	Manganese Total (mg/L)	Areal Standard Unit (algae)	Chlorophyll-a (ug/L)
Storages (ANZECC guidelines refer Table 4.3, where there is no applicable benchmark the cells are greyed out).																		
Lake Burragorang Coxs R. arm 24km U/S of dam wall	DWA12			27%	0%			9%	45%	100%	100%	18%	95%	59%		0%		59%
Lake Burragorang Coxs R. arm 4km U/S Butchers Ck	DWA15			20%	20%			0%	20%	100%	80%	20%	80%	40%		0%		80%
Lake Burragorang Kedumba R. 36km U/S of dam wall	DWA19			40%	0%			0%	20%	60%	20%	0%	100%	40%		0%		100%
Lake Burragorang 500m U/S of dam wall	DWA2			33%	7%			11%	52%	100%	100%	30%	85%	70%		0%		41%
Lake Burragorang Coxs R. arm 37km U/S of dam wall	DWA21			40%	40%			0%	20%	60%	60%	0%	80%	40%		0%		100%
Lake Burragorang Wollondilly R. arm 23km U/S of dam wall	DWA27			41%	5%			9%	50%	100%	100%	9%	86%	68%		0%		50%
Lake Burragorang Wollondilly R. arm 300m U/S of Nattai R.	DWA311			20%	0%			0%	40%	100%	100%	20%	80%	80%		0%		40%
Lake Burragorang Wollondilly R. arm 40km U/S dam wall	DWA39			60%	0%			0%	80%	100%	100%	20%	100%	100%		0%		60%
Lake Burragorang 14km U/S of dam wall	DWA9			55%	0%			14%	50%	100%	100%	9%	86%	68%		0%		59%
Prospect Reservoir @ Midlake	RPR1			0%	0%			0%	67%	100%	42%	0%	33%	100%		0%		75%
Prospect Reservoir @ Inlet to RWPS	RPR6			0%	0%			0%	67%	100%	33%	0%	33%	100%		0%		67%
Raw Water (raw water supply agreement site specific standards refer Table 4.2, where there is no applicable benchmark the cells are greyed out).																		
Orchard Hills WFP raw water	HBR1	0%				0%	0%	0%						0%	0%	0%	0%	
Warragamba WFP raw water	HWA2	0%				0%	0%	0%						0%	0%	0%	0%	
Prospect WFP Inlet - Channel 2, 2nd dosing bridge	PWFP10	17%				17%	0%	0%						0%	0%	0%	0%	

5.2.1 Catchments

Water quality in Lake Burragorang's river catchments in 2022-23 showed similar characteristics to previous years, with catchments dominated by agricultural and urban land uses regularly exceeding ANZECC benchmarks. Water monitoring sites in the upstream parts of all the catchments continued to frequently exceed benchmarks, particularly for nutrients, aluminium and conductivity.

Nitrogen and aluminium continued to be elevated throughout the catchment streams in both of the major arms of the lake.

Highly protected natural catchments such as the Kowmung, Kedumba and Little River returned fewer exceedances for most parameters when compared to upstream sites, though continued to show exceedances for nitrogen and aluminium.

Additionally, upstream sites in the Wollondilly catchment once again showed significant numbers of exceedances for chlorophyll a and dissolved Oxygen.

The Coxs River continues to show significant effects of pollution sources in the upper catchment, showing notable improvements in the lower Coxs River catchment where the river enters protected areas. The Coxs River near the Lithgow Power Station continues to show high numbers of exceedances for conductivity.

5.2.2 Storages

The lake again showed a high number of exceedances for nitrogen and aluminium at all sites.

Chlorophyll *a* exceedances showed slightly poorer performance compared to last year throughout the lake, and likely reflect the longer term impacts of bushfire on the trophic status.

There were no associated algal issues or impacts downstream.

Water quality in Prospect Reservoir returned a significant number of exceedances for nitrogen and aluminium, but was of generally good quality and posed few challenges for treatment to the Prospect Water Filtration Plant.

5.2.3 Water Filtration Plants

Water supplied for filtration remained of high quality throughout the period with no exceedances recorded beyond a small number of samples at Prospect WFP which failed to meet the guidelines for alkalinity and hardness. These exceedances did not impact the ability of the plant to treat the water to ADWG standards.

5.3 Upper Nepean system

Sampling sites in the Upper Nepean system are shown in Figure 5.2 below.

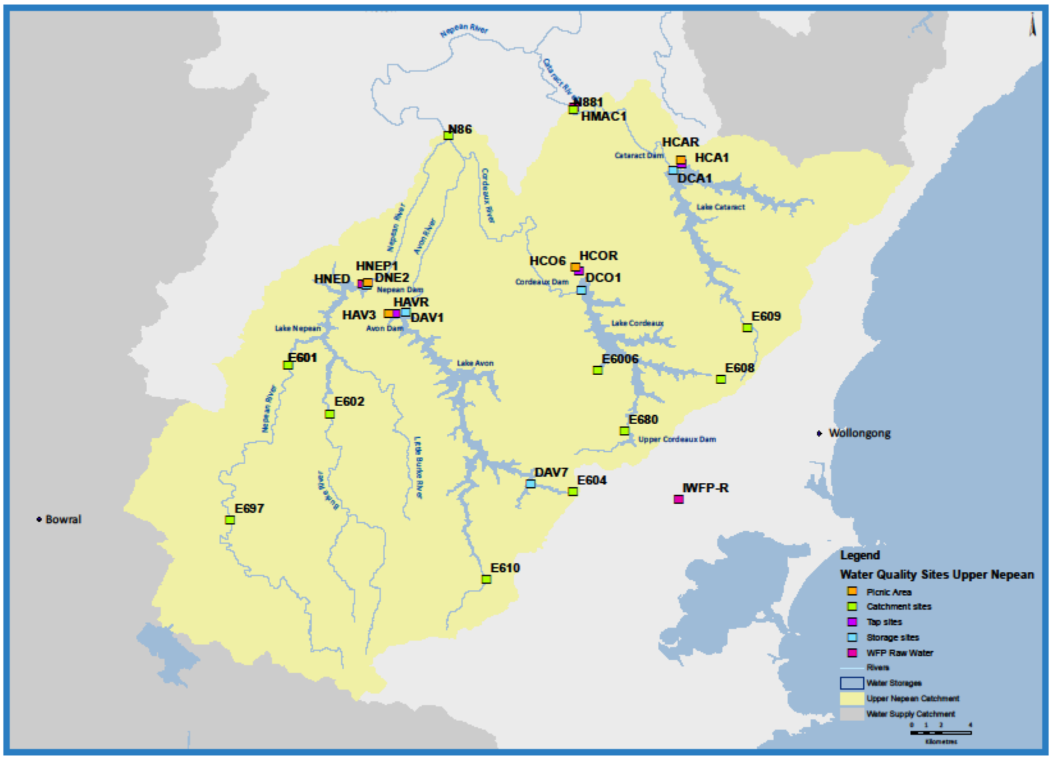

Figure 5.2: Sampling sites in the Upper Nepean system.

Table 5.2: Upper Nepean catchments - percentage of routine samples outside benchmarks

Site	Station Code	Physico-Chemical							Nutrients					Metals			Cyanobacteria	
		Total Alkalinity as CaCO3 (mg/L)	Conductivity @25 C - Field (mS/cm)	Dissolved Oxygen - Field (%Sat)	pH - Field	Total Hardness as CaCO3 (mg/L)	True Colour at 400nm (PES filter)	Turbidity - Field (NTU)	Nitrogen Ammoniacal (mg/L)	Nitrogen Oxidised (mg/L)	Nitrogen Total (mg/L)	Phosphorus Soluble Reactive (mg/L)	Phosphorus Total (mg/L)	Aluminium Total (mg/L)	Iron Total (mg/L)	Manganese Total (mg/L)	Areal Standard Unit (algae)	Chlorophyll-a (ug/L)
Catchments (ANZECC guidelines refer Table 4.4, where there is no applicable benchmark the cells are greyed out).																		
Sandy Ck inflow	E6006		0%	42%	100%			0%	42%	8%	0%	0%	42%	75%		0%		0%
Nepean River @ Inflow to Lake Nepean	E601		0%	8%	0%			0%	18%	100%	82%	0%	18%	91%		0%		0%
Burke River @ inflow to Lake Nepean	E602		0%	8%	42%			0%	17%	0%	0%	0%	0%	83%		0%		0%
Little Burke R. @ Nepean Dam Inflow	E603		0%	25%	100%			0%	33%	0%	0%	0%	0%	67%		0%		0%
Flying Fox Ck. No 3	E604		0%	33%	8%			0%	8%	100%	0%	0%	0%	17%		0%		0%
Goondarrin Creek @ Kemira 'D' cast	E608		0%	33%	8%			0%	8%	100%	0%	0%	8%	92%		0%		0%
Cataract River downstream Angels Creek	E609		0%	83%	92%			0%	92%	83%	0%	0%	0%	100%		0%		8%
Avon River - Summit Tank	E610		0%	42%	8%			0%	42%	0%	0%	0%	0%	25%		0%		0%
Loddon R. Inflow	E676		0%	58%	100%			0%	75%	0%	8%	0%	0%	100%		0%		0%
Cordeaux River at causeway between U.cord. 1 & 2	E680		0%	42%	25%			0%	67%	25%	0%	0%	0%	25%		0%		42%
Nepean River @ AT McGuire's Crossing	E697		0%	17%	0%			0%	33%	100%	83%	0%	17%	100%		0%		17%
Storages (ANZECC guidelines refer Table 4.3, where there is no applicable benchmark the cells are greyed out).																		
Lake Avon @ 45m U/S dam wall	DAV1			42%	100%			0%	67%	83%	0%	0%	0%	83%		0%		33%
Lake Avon @ 3 km D/S Gallahers Ck Jn	DAV16			36%	82%			0%	55%	55%	0%	0%	0%	82%		0%		9%
Lake Avon @ Upper Avon Valve Chamber	DAV7			50%	100%			0%	67%	58%	0%	0%	8%	83%		0%		50%
Lake Cataract @ Dam wall	DCA1			33%	100%			0%	50%	50%	0%	0%	8%	100%		0%		17%
Lake Cataract @ Cataract arm 5km U/S	DCA2			25%	100%			0%	58%	58%	0%	0%	0%	100%		0%		17%
Lake Cataract @ Loddon arm 4.5km U/S	DCA3			17%	100%			0%	17%	50%	0%	0%	0%	100%		0%		17%
Lake Cordeaux 60 m U/S of dam wall	DCO1			50%	17%			0%	58%	50%	0%	0%	42%	83%		0%		75%
Lake Cordeaux @ Jn. of Kentish & Cord. R.	DCO3			50%	30%			0%	60%	50%	0%	0%	20%	90%		0%		80%
Lake Nepean 50 m U/S of dam wall	DNE2			50%	58%			0%	75%	100%	83%	8%	100%	100%		0%		17%
Lake Nepean @ D/S Burke Junction	DNE6			50%	58%			0%	92%	100%	33%	8%	92%	100%		0%		42%
Raw Water (raw water supply agreement site specific standards refer Table 4.2, where there is no applicable benchmark the cells are greyed out).																		
Macarthur WFP raw water at Inlet to PS	HMAC1	0%				33%	0%	0%						0%	8%	0%	0%	

Site	Station Code	Physico-Chemical							Nutrients					Metals			Cyanobacteria	
		Total Alkalinity as CaCO3 (mg/L)	Conductivity @25 C - Field (mS/cm)	Dissolved Oxygen - Field (%Sat)	pH - Field	Total Hardness as CaCO3 (mg/L)	True Colour at 400nm (PES filter)	Turbidity - Field (NTU)	Nitrogen Ammoniacal (mg/L)	Nitrogen Oxidised (mg/L)	Nitrogen Total (mg/L)	Phosphorus Soluble Reactive (mg/L)	Phosphorus Total (mg/L)	Aluminium Total (mg/L)	Iron Total (mg/L)	Manganese Total (mg/L)	Areal Standard Unit (algae)	Chlorophyll-a (ug/L)
Nepean WFP raw water	HNED	0%				8%	0%	0%						8%	0%	0%	0%	
Illawarra WFP raw water	IWFP-R	0%				0%	0%	0%						0%	0%	0%	0%	

5.3.1 Catchments

Water quality across the Upper Nepean catchment sites displays variations stemming from rainfall, land use and natural catchment characteristics. In the 2022-23 period, water quality exhibited similar patterns to the previous year.

The Upper Nepean catchment experienced significant catchment wide rainfall events in July and October 2022, as well as more localised rainfall events at other times throughout the year. Turbidity in the catchment streams increased with the high flows induced by these rain events, then steadily declined as flows returned to their baseline levels. However, due to the timing of sample collection, routine monitoring did not capture any elevated turbidity above the ANZECC benchmark. The periods of high rainfall in 2022-2023 year, coupled with the natural geology of the Upper Nepean catchments, resulted in frequent guideline exceedances for total Aluminium. pH is also influenced by the natural geology of some Upper Nepean sub-catchments, with Sandy Creek, Little Burke River, Cataract River and Loddon River all continuing longer term trends of consistently registering pH results below the 6.5 pH unit lower guideline value.

Consistent with previous years, there were regular guideline exceedances for ammonia and oxidised nitrogen in the Upper Nepean catchment. There was however an overall improvement in total nitrogen concentrations with only three sites recording exceedances in this reporting year. The sites of most concern for total nitrogen are the two Nepean River sites, due to the rural residential land use in this sub-catchment. Phosphorus concentrations generally remained low throughout most of the Upper Nepean catchment, with Sandy Creek being the only site reporting regular total phosphorus exceedances. There were no guideline exceedances recorded for soluble reactive phosphorus. The lower levels of available phosphorus in most streams limited algal growth, resulting in only a small number of chlorophyll-a guideline exceedances. Dissolved oxygen saturation levels at all Upper Nepean catchment sites fell below the lower guideline of 90% at least once during the year. The majority of these instances occurred in January, February and March when warmer air temperatures combined with a period of lower flow conditions and increased biological activity.

5.3.2 Storages

Water quality in the Upper Nepean storages during the 2022-23 year was heavily influenced by rainfall events occurring in July and October 2022. These rain events generated significant wet weather intrusions, transporting increased sediment, organics, and catchment-derived metals into the storages and adversely impacting water quality.

Turbidity within the storages increased following rain events, however full compliance to the ANZECC benchmark was still achieved with all routine samples remaining below the 20 NTU guideline value. Elevated aluminium levels persisted in all storages following multiple years of above average rainfall and further significant wet weather events in 2022. Lake Avon and Lake Cordeaux did see a reduction in aluminium levels to acceptable values in May and June 2023, following a period of reduced rainfall. Lake Cataract and Lake Nepean recorded exceedances across the full year. Manganese concentrations remained consistently low and achieved full compliance against the ANZECC benchmark.

Compliance with nutrient levels varied across the storages, with Lake Nepean registering the highest number of exceedances for all forms of nitrogen and phosphorus. The primary source of these exceedances is runoff from the rural residential land use areas within the Nepean River sub-catchment. Bioavailable forms of nitrogen (ammoniacal and oxidised nitrogen) recorded exceedances in all storages. While total nitrogen and soluble reactive phosphorus achieved full compliance except in Lake Nepean. Chlorophyll-a exceedances were found in all storages, with Lake Cordeaux continuing the trend of recording the highest percentage of exceedances. Notably, there were no potentially toxic cyanobacteria identified in Lake Cordeaux during this reporting period.

5.3.3 Water Filtration Plants

Full compliance with the raw water standards was achieved for Illawarra WFP. Nepean WFP and Macarthur WFP had infrequent exceedances to the raw water standards following rain events. All three plants had 100% compliance with health related characteristics.

Nepean WFP had one off exceedances to the raw water standards for total hardness and total aluminium in July 2022, following a significant wet weather event at the beginning of the month.

Macarthur WFP had exceedances to the raw water standards for total hardness and total iron. Total iron was a single exceedance in September 2022, contributed to by flow from unregulated tributaries downstream of Cataract Dam. Total hardness had four exceedances following the July and October 2022 rain events due to the additional floodwater diluting calcium and magnesium concentrations in the supply to the filtration plant.

During these events the treated water produced by the WFPs continued to meet the Australian Drinking Water Guidelines.

5.4 Woronora system

Sampling sites in the Woronora system are shown in Figure 5.3 below.

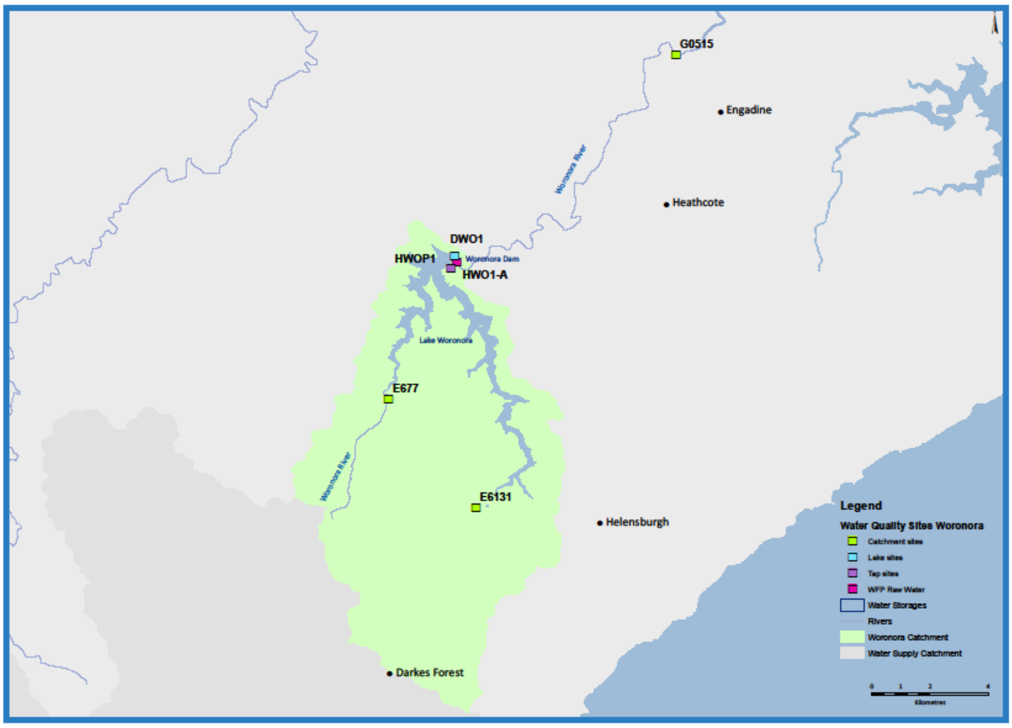

Figure 5.3: Sampling sites in the Woronora system.

Table 5.3: Woronora system catchments - percentage of routine samples outside benchmarks

Site	Station Code	Physico-Chemical							Nutrients					Metals			Cyanobacteria	
		Total Alkalinity as CaCO3 (mg/L)	Conductivity @25 C - Field (mS/cm)	Dissolved Oxygen - Field (%Sat)	pH - Field	Total Hardness as CaCO3 (mg/L)	True Colour at 400nm (PES filter)	Turbidity - Field (NTU)	Nitrogen Ammoniacal (mg/L)	Nitrogen Oxidised (mg/L)	Nitrogen Total (mg/L)	Phosphorus Soluble Reactive (mg/L)	Phosphorus Total (mg/L)	Aluminium Total (mg/L)	Iron Total (mg/L)	Manganese Total (mg/L)	Areal Standard Unit (algae)	Chlorophyll-a (ug/L)
Catchments (ANZECC guidelines refer Table 4.4, where there is no applicable benchmark the cells are greyed out).																		
Waratah Rivulet d/s Flatrock Crossing	E6131		0%	42%	8%			0%	25%	0%	0%	0%	0%	58%		0%		0%
Woronora R. Inflow	E677		0%	50%	92%			0%	42%	0%	0%	0%	0%	100%		0%		0%
Storages (ANZECC guidelines refer Table 4.3, where there is no applicable benchmark the cells are greyed out).																		
Lake Woronora @ Honeysuckle Ck Junction	DWO_THMD			50%	100%			0%	80%	100%	0%	0%	0%	100%		0%		10%
Lake Woronora 50 m U/S of dam wall	DWO1			50%	100%			0%	75%	92%	0%	0%	8%	100%		0%		8%
Raw Water (raw water supply agreement site specific standards refer Table 4.2, where there is no applicable benchmark the cells are greyed out).																		
Woronora WFP raw water	HWO1-A	0%				33%	0%	0%						33%	0%	0%	0%	

5.4.1 Catchments

Water quality in the Waratah Rivulet and Woronora River during the 2022-2023 period was influenced by significant rainfall events in July 2022, October 2022 and February 2023. These rain events, combined with the natural catchment characteristics, resulted in regular ANZECC benchmark exceedances in aluminium and pH. Aluminium levels in both tributaries peaked in samples collected following rain events due to the transportation of sandstone particles from the catchment in higher flows. Aluminium concentrations in Waratah Rivulet fell below the guideline level in between rain events, while Woronora River remained above the guideline level for 100% of samples. Similar to previous years, Woronora River also recorded a higher number of pH results falling below the lower guideline value of 6.5 pH units. Turbidity in the catchment streams increased with the high flows induced by these rainfall events, then steadily declined as flows returned to their baseline levels. However, routine monitoring did not capture any instances of elevated turbidity above the guideline value due to the timing of sample collection.

Nutrient compliance was generally good due to the largely natural bushland catchment. Both Waratah Rivulet and Woronora River demonstrated full compliance with all forms of nitrogen and phosphorus, except for ammoniacal nitrogen. Ammoniacal nitrogen exceedances decreased from the previous year in Waratah Rivulet, while Woronora River displayed an increasing trend. The overall low levels of nutrient exceedances aided in 100% compliance to the chlorophyll-a benchmark in both tributaries. Dissolved oxygen saturation levels fell below the lower guideline of 90% at both sites on multiple occasions. The majority of these instances occurred between November and March when warmer air temperatures coincided with a period of lower flow conditions and increased biological activity.

5.4.2 Storage

Water quality in Lake Woronora in 2022-2023 was again impacted by multiple rainfall events that generated significant inflows into the storage. These wet weather inflows contributed to elevated aluminium concentrations across the full year. Oxidised nitrogen and ammoniacal nitrogen were also above the ANZECC benchmark level for much of the period, which is consistent with data from previous years in Lake Woronora. Dissolved oxygen fell below the lower guideline, predominantly throughout the cooler months. pH saw an increase in benchmark exceedances when compared to recent years with 100% of routine samples falling below the lower guideline. Other parameters were largely compliant with the ANZECC benchmarks, including chlorophyll-a which saw increased compliance compared to the previous year.

5.4.3 Water Filtration Plant

Near full compliance with the raw water standards was achieved for supply to Woronora WFP, with total aluminium and total hardness following rainfall events the only exceptions. All samples complied with ADWG for health-related characteristics.

5.5 Blue Mountains system

Sampling sites in the Blue Mountains system are shown in Figure 5.4 below.

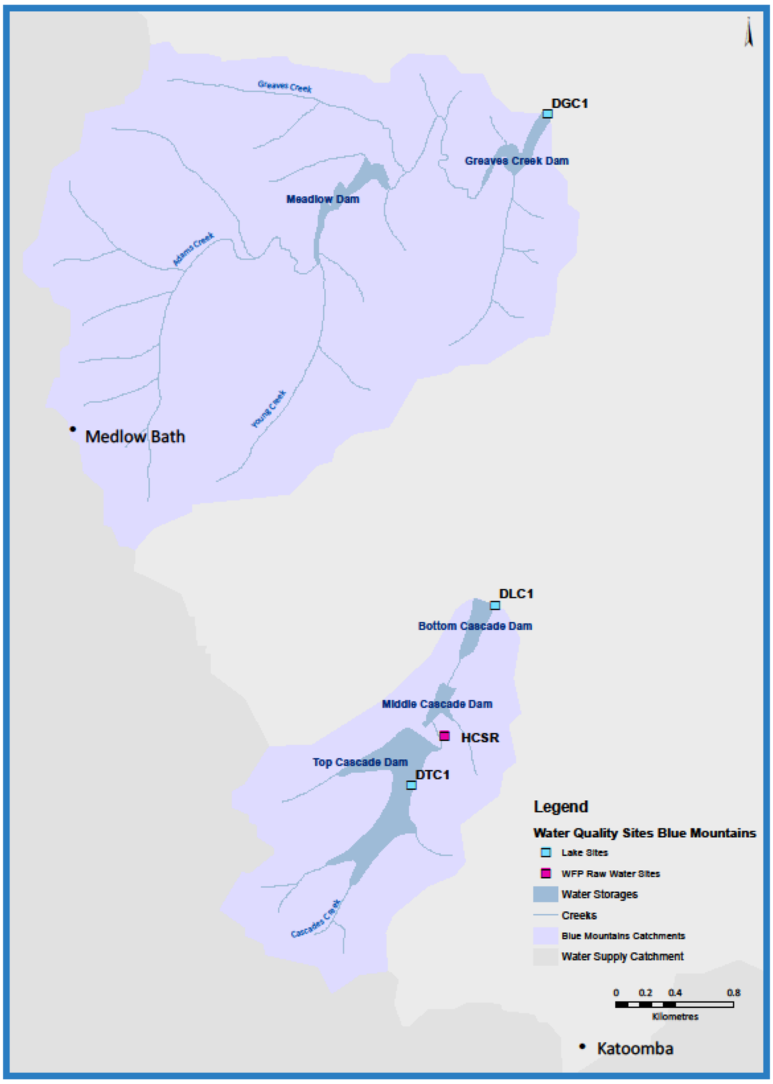

Figure 5.4: Sampling sites in the Blue Mountains system.

Table 5.4: Blue Mountains system storages - percentage of routine samples outside benchmarks

Site	Station Code	Physico-Chemical							Nutrients					Metals			Cyanobacteria	
		Total Alkalinity as CaCO3 (mg/L)	Conductivity @25 C - Field (mS/cm)	Dissolved Oxygen - Field (%Sat)	pH - Field	Total Hardness as CaCO3 (mg/L)	True Colour at 400nm (PES filter)	Turbidity - Field (NTU)	Nitrogen Ammoniacal (mg/L)	Nitrogen Oxidised (mg/L)	Nitrogen Total (mg/L)	Phosphorus Soluble Reactive (mg/L)	Phosphorus Total (mg/L)	Aluminium Total (mg/L)	Iron Total (mg/L)	Manganese Total (mg/L)	Areal Standard Unit (algae)	Chlorophyll-a (ug/L)
Storages (ANZECC guidelines refer Table 4.3, where there is no applicable benchmark the cells are greyed out).																		
Lake Greaves @ dam wall	DGC1			8%	100%			0%	33%	83%	0%	0%	8%	100%		0%		17%
Lower Cascade Lake 25 m U/S of dam wall	DLC1			0%	0%			0%	17%	83%	0%	0%	0%	50%		0%		17%
Upper Cascade Lake 20m U/S of dam wall	DTC1			8%	50%			0%	17%	75%	0%	0%	0%	67%		0%		8%
Raw Water (raw water supply agreement site specific standards refer Table 4.2, where there is no applicable benchmark the cells are greyed out).																		
Cascade WFP raw water	HCSR	0%				0%	0%	0%						8%	0%	0%	17%	

5.5.1 Catchments

The Blue Mountains catchments are very small (<20 km^2 in total) and inflow quality is represented by water quality in the lakes. There are no routine monitoring sites in the Blue Mountains catchments.

5.5.2 Storages

Water quality in the Blue Mountains lakes during the 2022-2023 year was again impacted by rainfall events, including a significant event in July 2022. All three lakes recorded increased levels of Aluminium following the July rainfall event, with elevated concentrations remaining in Upper and Lower Cascades for several months before returning to below guideline levels. Aluminium levels in Greaves Creek gradually reduced following a peak in July 2022, however remained above the ANZECC benchmark for the full year.

Elevated concentrations of nitrogen (specifically ammoniacal and oxidised nitrogen) were recorded in all three lakes. While phosphorus remained below guideline levels with the exception of one exceedance in Lake Greaves following the rainfall event in July. Chlorophyll compliance improved in all three storages when compared to the previous year, with only one or two guideline exceedances recorded in each of the lakes.

Dissolved oxygen levels were kept high through use of destratification fans in the lakes, with good compliance to the ANZECC benchmark recorded in all three lakes.

5.5.3 Water Filtration Plant

Water supplied to the Cascade WFP was of a high standard throughout the year, however there were three exceedances of the raw water standards recorded – one for total aluminium and two for algal ASU. Elevated aluminium was present in July 2022 following heavy rainfall. While algal ASU exceeded the standard in January and February 2023 due to the presence of filter clogging diatoms. Water supplied for treatment had 100% conformance with ADWG health characteristics.

5.6 Shoalhaven system

Sampling sites in the Shoalhaven system are shown in Figure 5.5 below.

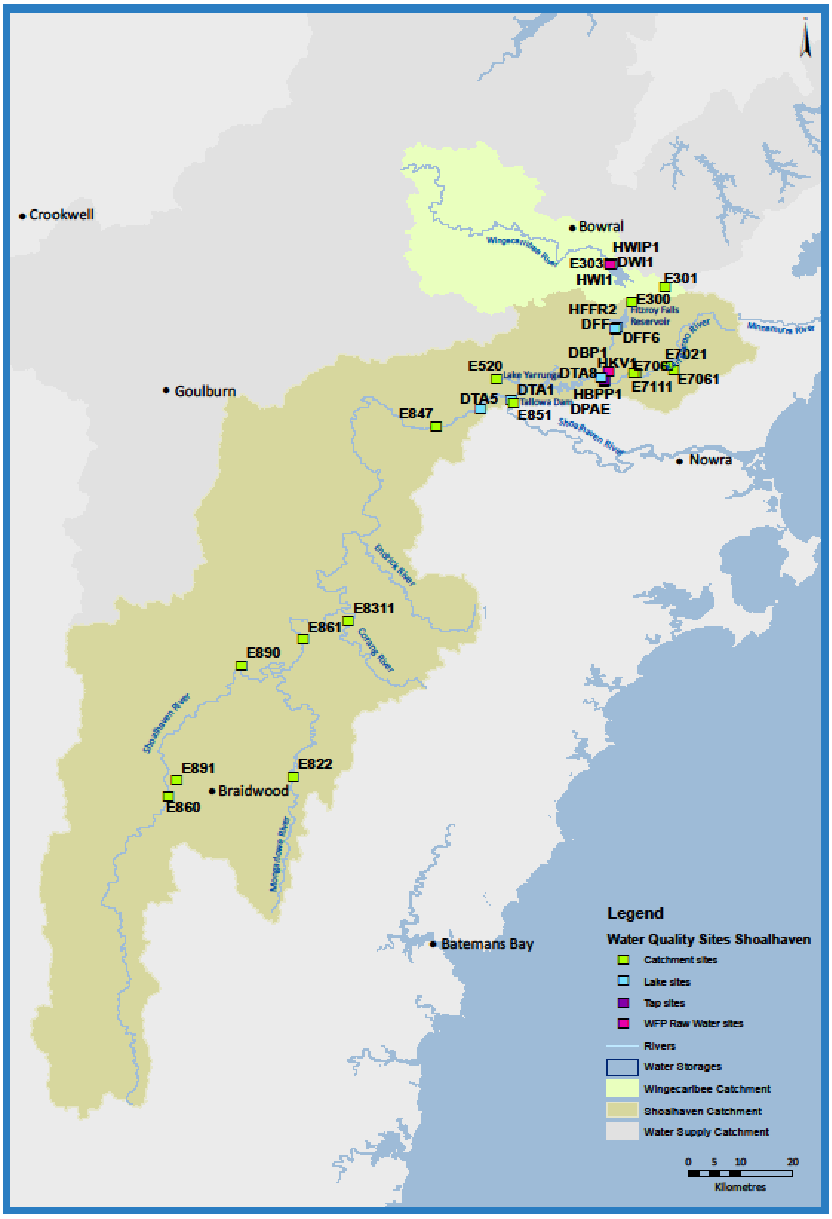

Figure 5.5: Sampling sites in the Shoalhaven system

Table 5.5: Shoalhaven system catchments - percentage of routine samples exceeding benchmarks

Site	Station Code	Physico-Chemical							Nutrients					Metals			Cyanobacteria	
		Total Alkalinity as CaCO3 (mg/L)	Conductivity @25 C - Field (mS/cm)	Dissolved Oxygen - Field (%Sat)	pH - Field	Total Hardness as CaCO3 (mg/L)	True Colour at 400nm (PES filter)	Turbidity - Field (NTU)	Nitrogen Ammoniacal (mg/L)	Nitrogen Oxidised (mg/L)	Nitrogen Total (mg/L)	Phosphorus Soluble Reactive (mg/L)	Phosphorus Total (mg/L)	Aluminium Total (mg/L)	Iron Total (mg/L)	Manganese Total (mg/L)	Areal Standard Unit (algae)	Chlorophyll-a (ug/L)
Catchments (ANZECC guidelines refer Table 4.4, where there is no applicable benchmark the cells are greyed out).																		
Yarrunga Creek @ Wildes Meadow	E300		0%	92%	25%			0%	100%	100%	100%	25%	75%	100%		0%		50%
Caalang CK Old Kangaloon Rd Ford	E301		0%	58%	17%			0%	83%	100%	100%	0%	33%	100%		0%		17%
Bundanoon Creek at the Rocks	E520		8%	17%	0%			0%	50%	75%	50%	0%	33%	83%		0%		42%
Brogers Creek@Clinton Park	E7021		0%	17%	33%			8%	75%	100%	17%	8%	67%	100%		0%		0%
Kangaroo River @ Hampden Bridge	E706		0%	8%	8%			17%	92%	100%	75%	25%	83%	100%		0%		17%
Kangaroo River at Oakdale	E7061		0%	8%	17%			8%	67%	100%	17%	0%	33%	100%		0%		0%
Mongarlowe R. at Mongarlowe	E822		0%	67%	25%			0%	42%	100%	0%	0%	17%	83%		0%		0%
Corang River	E8311		0%	50%	17%			8%	75%	0%	8%	0%	17%	100%		0%		0%
Shoalhaven R @ Fossickers Flat	E847		0%	0%	0%			8%	8%	33%	25%	0%	25%	75%		0%		17%
Shoalhaven R @ Mount View	E860		0%	25%	0%			8%	58%	33%	25%	0%	100%	100%		0%		8%
Shoalhaven R @ Hillview	E861		8%	8%	0%			8%	67%	33%	50%	0%	50%	92%		0%		25%
Boro Ck @ Marlowe	E890		0%	100%	25%			8%	92%	92%	83%	0%	92%	100%		0%		50%
Gillamatong Creek @ Braidwood	E891		83%	83%	0%			8%	92%	100%	100%	58%	100%	75%		0%		67%
Storages (ANZECC guidelines refer Table 4.3, where there is no applicable benchmark the cells are greyed out).																		
Bendeela Pondage	DBP1			0%	17%			0%	33%	33%	33%	33%	33%	33%		0%		0%
Lake Fitzroy Falls @ Midlake	DFF6			9%	0%			0%	83%	100%	92%	8%	92%	100%		0%		100%
Lake Yarrunga@ 100m from Dam Wall	DTA1			50%	0%			0%	67%	75%	50%	17%	100%	75%		0%		50%
Lake Yarrunga @ Shoalhaven River	DTA5			25%	0%			17%	83%	75%	42%	8%	92%	92%		0%		42%
Lake Yarrunga @ Kangaroo R at Bendeela PS	DTA8			25%	33%			8%	100%	92%	67%	50%	100%	100%		0%		67%
Wingecarribee Lake at outlet	DWI1			25%	0%			0%	75%	100%	75%	0%	100%	83%		0%		100%
Raw Water (raw water supply agreement site specific standards refer Table 4.2, where there is no applicable benchmark the cells are greyed out).																		
Kangaroo Valley WFP Inlet	HKV1	0%			18%	0%	0%	0%							0%	0%	0%	
Wingecarribee WFP raw water	HWI1	0%			0%	0%	0%	0%							0%		0%	

5.6.1 Catchments

Similar to previous years, nitrogen and aluminium returned a significant number of exceedances throughout the catchments.

Water quality in the upper catchment sites such as Boro Ck in the Shoalhaven and Wildes Meadow Creek and Caalang Creek in the Kangaroo River remain poor, with regular exceedances for dissolved oxygen, nutrients and aluminium.

5.6.2 Storages

Monitoring of the storages in the Shoalhaven system continued to return high exceedance rates for chlorophyll *a* and nutrients. This is typical of the Shoalhaven system and reflects the agricultural land use in the catchment.

Aluminium concentrations continued to be high across the Shoalhaven storages, with all lake sites regularly exceeding the guidelines. The high levels of aluminium are typical of the geology of the region.

Wingecarribee Reservoir and Fitzroy Falls Reservoir once again returned a significant number of exceedances for chlorophyll a, with potentially toxin producing species present on a numbers of occasions, particularly in the Wingecarribee Reservoir.

5.6.3 Water Filtration Plants

Raw water supplied to Kangaroo Valley Water Filtration Plant met the relevant standards in all samples with the exception of 18% of samples failing for pH.

Sampling at the inlet of Wingecarribee WFP had 100% compliance against the benchmarks. Cyanobacterial blooms were managed in accordance with Water Quality Incident Response Protocol throughout the monitoring period and details of incidents involving potentially toxin producing cyanobacteria in Wingecarribee Reservoir are reported in section 8.1.

5.6.4 Recreational Monitoring

Fitzroy Falls did not exceed either the minor or major alert benchmarks for enterococci. The minor alert benchmark for potentially toxic cyanobacteria was exceeded 18% of the time. Cyanobacteria in the lake was primarily dominated by benign species.

Lake Yarrunga exceeded the minor alert benchmark for enterococci in 50% of samples, an increase from 8% over the last reporting period. The major alert for enterococci was exceeded on one occasion following a rain event. Algal activity was low through the reporting period with no minor or major benchmarks for cyanobacteria exceeded.

Table 5.6: Recreational monitoring - percentage of samples exceeding benchmarks

Site	Station Code	Primary Contact Minor Alert Benchmark Percentage Exceeedance					Secondary Contact & Primary Contact Major Alert Percentage Exceedance				
		Enterococci (cfu/100ml)	Microcystin LR+RR+YR (ug/L)	Toxic Cyanobacterial biovolume (mm3/L)	Toxic Cyanobacterial Count (cells/mL)	Cyanobacterial biovolume (mm3/L)	Enterococci (cfu/100ml)	Microcystin LR+RR+YR (ug/L)	Toxic Cyanobacterial biovolume (mm3/L)	Toxic Cyanobacterial Count (cells/mL)	Cyanobacterial biovolume (mm3/L)
Recreational monitoring (NHMRC guidelines - refer Table 4.5).											
Lake Fitzroy Falls @ Midlake	DFF6	0%	-	18%	0%	-	0%	0%	0%	0%	0%
Lake Yarrunga @ Kangaroo R at Bendeela PS	DTA8	50%	-	0%	0%	-	3%	0%	0%	0%	0%

5.7 Algal monitoring

All routine catchment and lake samples are analysed for algae if chlorophyll *a* exceeds 5 µg/L. Selected lake sites, which are the closest point to supplying water filtration plants have unconditional algae counts and speciation undertaken regardless of chlorophyll *a*. At locations with a history of algal activity, seasonal monitoring is conducted more frequently in the warmer months between October and May to facilitate early detection of emerging algal events. Routine algal monitoring is also undertaken in raw water supplied to water filtration plants. Statistical summaries are provided in Appendix A. Refer to section 4.7 for relevant benchmarks.

5.7.1 Warragamba system

Similar to last year, a slight improvement is again noted in the Coxs River catchment with regard to chlorophyll *a* exceptions, particularly in the Coxs River sites above and below Lake Lyell and in the Farmers Creek.

Exceedances for chlorophyll *a* increased slightly in the Wollondilly catchment samples this year with the Wingecarribee River at Berrima continuing to exceed benchmarks in 92% of samples.

Potentially toxic cyanobacterial species were detected at Gibbergunyah Ck (two samples), Wingecarribee River at Berrima (five samples), Wollondilly River at u/s Goul Rossi Weir (one sample), Whites Ck 350m d/s of Moss Vale STP discharge (one sample), Mulwaree River at Towers (two samples) and Wollondilly River at Upper Tarlo (one sample), suggesting that inflows into Warragamba have improved in terms of toxic cyanobacterial presence copared to previous years.

In the major arms of Lake Burragorang, sporadic low numbers of potentially toxin producing cyanobacteria were reported in the counts throughout the lake through spring, summer and autumn, peaking with only 2,150 cells/mL of potentially toxin producing species being detected in the Wollondilly River Arm (DWA27) in January.

Downstream in the gorge, small positive detections of potentially toxin producing cyanobacteria occurred throughout the year, with the majority of detections occurring from January to April of 2023. Populations of these organisms are managed via drawing from deep in the water column during their presence.

Chlorophyll *a* concentrations in Prospect Reservoir exceeded the benchmarks at a similar frequency to last year, with 75% and 67% of the samples, respectively at both the mid lake site and at the inlet to the Raw Water Pumping Station recording results above the threshold. Low to moderate concentrations of potentially toxin producing algal species were periodically recorded but remained well below levels of concern. No algal toxins (combined microcystin) were detected during the reporting period.

Algal ASU did not exceed Raw Water Supply Agreement standards at Prospect, Orchard Hills or Warragamba WFPs.

5.7.2 Upper Nepean system

Catchment sites in the Upper Nepean system continue to record very low chlorophyll a concentrations, with only 6% of samples across all locations exceeding the 5 µg/L trigger for algal speciation. The site with the highest number of samples with elevated chlorophyll a concentrations was Cordeaux River, followed by Nepean River at McGuire's Crossing, and then Cataract River. This is in line with historical results with Nepean and Cordeaux catchments typically recording the highest levels of chlorophyll a. Only one catchment sample recorded the presence of potentially toxic cyanobacteria during the reporting period, and that was at Nepean River at McGuire's Crossing, where a small number of *Dolichospermum circinale* cells were identified in November 2022.

All Upper Nepean storages recorded chlorophyll a results above the 5 µg/L trigger for algal speciation at times throughout the year, with the two Lake Cordeaux sites having the highest percentage of samples exceeding this benchmark. Elevated chlorophyll a levels were frequently measured alongside increased algal ASU concentrations, with Lake Cordeaux also recording the highest ASU levels of the Upper Nepean storages within this reporting period. There were two instances of potentially toxin producing cyanobacteria within the Upper Nepean storages in 2022-2023, with both occurring in Lake Nepean (*Microcystis sp.* in July 2022 and *Dolichospermum sp.* in November 2022). Both detections had low cell numbers, below the level of concern for toxin production.

The elevated ASU experienced in the storages did not impact the raw water supplied to Macarthur, Nepean and Illawarra WFP's, with no samples from 2022-2023 exceeding the site specific raw water supply agreement for ASU at each filtration plant. This was an improvement on 2021-2022 where Macarthur WFP had over 50% of samples above the site specific standard for ASU. There was a single occurrence of the potentially toxin producing cyanobacteria *Microcystis sp.* in the raw water to Nepean WFP in July 2022, however cell numbers were low and not of concern for toxin production.

5.7.3 Woronora system

The two catchment sites in the Woronora System (Waratah Rivulet and Woronora River) continued to record very low chlorophyll a concentrations, with both sites remaining below the threshold for algal speciation throughout the year. Lake Woronora also recorded low chlorophyll a concentrations, with March 2023 the only samples rising above the 5µg/L guideline level. Similar to the chlorophyll a concentrations in the lake, algal concentrations also remained low throughout the year. Raw water supplied to Woronora WFP for treatment therefore remained of a high standard with low ASU recorded throughout 2022-2023. There was a single occurrence of the potentially toxin producing cyanobacteria *Microcystis sp.* in July 2022, however cell numbers were low and not of concern for toxin production.

5.7.4 Blue Mountains system

Chlorophyll a concentrations in Top Cascades, Lower Cascades and Greaves Creek all improved in 2022-2023, with fewer samples exceeding the 5 µg/L guideline than in the previous year. The lower chlorophyll a concentrations were indicative of reduced algal activity in all three lakes. However Top Cascade Lake did experience elevated algal ASU in January and February 2023. This was primarily due to the presence of large numbers of the diatom *Aulacoseira sp*. This diatom bloom was also detected in the supply to Cascade WFP, with both the January and February inlet to plant samples recording concentrations above the raw water site specific standard of 2000 ASU/mL. There was a single occurrence of the potentially toxin producing cyanobacteria *Planktothrix sp.* in Top Cascade Lake in April 2023, however cell numbers were low and not of concern for toxin production. There were no potentially toxic cyanobacteria detected at the inlet to Cascade WFP in 2022-2023.

5.7.5 Shoalhaven system

A similar performance in chlorophyll *a* exceedances is noted throughout the Shoalhaven catchment when compared to last year's results, with some notable increases in the number of samples above the benchmark at Yarrunga Ck, Caaland Ck and Bundanoon Ck.

The Upper Shoalhaven River sites showed similar numbers of exceedances compared to last year, with samples from Boro Ck and Gillamatong Ck regularly exceeding the benchmark.

All storages in the Shoalhaven system once again exceeded the chlorophyll *a* benchmark regularly throughout the year. Low numbers of potentially toxin producing cyanobacteria were present in most samples in Bendeela pondage, peaking in March 2023 with a result of 10,710 cells/mL. Likewise, Fitzroy Falls returned low to moderate detections of potentially toxin producing cyanobacteria throughout the year, peaking at DFF6 recording 26,820 cells/mL in June 2023.

Once again, potentially toxin producing cyanobacteria blooms persisted in Wingecarribee Reservoir throughout the year, with significant concentrations of combined microcystin present in samples taken between February and May 2023.

Raw water supplied to Kangaroo Valley Water Filtration Plant did not exceed the site-specific standard for algal filter clogging potential (ASU) in 2022 - 2023. Supply to Wingecarribee WFP complied with the guidelines throughout the reporting period with no ASU exceedances.

5.8 *Cryptosporidium* and *Giardia* monitoring

Routine monitoring is undertaken in catchments, storages and delivery networks at varying frequencies as agreed between WaterNSW, Sydney Water and NSW Health. Statistical summaries are provided in Appendix A.

5.8.1 Catchments

Routine monitoring for *Cryptosporidium* and *Giardia* is undertaken at seven selected streams in the Warragamba catchment as part of the pathogen monitoring program. The sampling schedule is monthly, except for Werriberri Creek (E531) which is weekly. This section discusses routine monitoring for *Cryptosporidium* and *Giardia*, refer to Section 7.1 for wet weather monitoring.

During the reporting period *Cryptosporidium* oocysts were detected in 18% over all sites (ranging from 0 – 42%), mostly at alert levels (<10/10 L], with only two samples at minor incident level (10-100/10 L). *Giardia* cysts were detected in 45% over all sites (ranging from 8 – 75%), also mostly at alert levels (<10/10 L], with only nine samples at minor incident level. The occurrence of pathogens decreased generally compared to the previous year, which was expected given the reduced number of heavy rain events compared to the previous reporting period.

5.8.2 Storages

Routine monitoring was conducted weekly at Wingecarribee (DWI1) reservoir, and monthly sampling of water from Prospect Reservoir (RPR1) and Lake Oberon (DOBR01). Sampling was also conducted in storages at a higher frequency during events.

Of the 236 routine samples collected during the reporting period, *Cryptosporidium* and *Giardia* were detected in 18 (3%) and 40 (8%) samples respectively, with none above the alert range for both *Cryptosporidium* and *Giardia*.

5.8.3 Water Filtration Plants

A joint monitoring program for raw water at the inlet to the water filtration plants is undertaken by Sydney Water and results are provided to WaterNSW and NSW Health. Larger sample volumes (up to ~100 L) are used to improve the detection limit and assist in quantifying catchment risk.

There were no incident level detections (i.e. ≥10 oocysts/10 L) of *Cryptosporidium* from routine monitoring of water at inlet of filtration plants during the reporting period. Three *Giardia* minor incidents occurred; two from Woronora (HWO1-A); 19 and 16 cysts/10 L in July and one from Nepean raw water (HNED), where up to 15 cysts/10 L. All three samples that exceeded the minor incident threshold were detected during the heavy rain event in July 2022.

5.9 Picnic area monitoring

WaterNSW undertakes routine monitoring at picnic taps where the water is supplied directly from the storages or where potable water is carted in, both water sources undergo chlorination prior to distribution. Annual monitoring is also done at the picnic areas which receive reticulated town water.

Table 5.7: Picnic areas - percentage of samples exceeding benchmarks

Site	Station Code	pH - Field	Turbidity - Field (NTU)	Aluminium Total (mg/L)	Iron Total (mg/L)	Manganese Total (mg/L)	Free Chlorine residual - Field (mg/L)	Chlorophyll-a (ug/L)	Toxic Cyanobacterial Count (cells/mL)	Coliforms Total (cfu/100mL)	E. coli (orgs/100mL)
Picnic taps (PWS guidelines refer Table 4.6)											
Avon Picnic Area Tap	HAV3	0%	2%	0%	52%	0%	100%	0%	0%	2%	0%
Cataract picnic area tap / fountain	HCA1 / HCA2	29%	8%	8%	31%	0%	96%	0%	0%	2%	0%
Cordeaux Picnic Area Tap	HCO6	0%	67%	25%	100%	27%	98%	0%	0%	2%	0%
Fitzroy Falls Picnic Tap	HFFR2	2%	10%	8%	0%	0%	40%	0%	0%	2%	0%

Closures of the picnic areas increased in the first half of the reporting period due to rainfall events. Wet weather impacts at Lake Cataract and Cordeaux resulted in high turbidity, above critical limits for extended periods of time. As the critical limit was exceeded picnic areas were signposted as not suitable for drinking. Fitzroy Falls recorded five turbidity exceedances due to low water level and the subsequent replenishment by the water carter.

Similar to previous years, low chlorine residuals were observed in the picnic area end taps due to low water usage resulting in high residence time and chlorine decay in the reticulation system. The efficacy of chlorination is measured based on chlorine concentrations and contact times at the dosing plant. The absence of indicator bacteria is also used to ensure adequate disinfection. No *E. coli* were detected at the picnic areas in this reporting period.

At Cordeaux aesthetic guidelines for metals exceeded through the year. Cordeaux recorded the greatest exceedance for iron, followed by Avon and Cataract. This is largely due to low water usage, corrosive water in the reticulation resulting in metal leaching as well as poor water quality in the lakes. Cataract has seen improvements in the metal concentrations in the supply due to drinking water fountain with point source filtration.

Cataract picnic area has seen a slight increase in results below pH targets with 29% of samples below 6.5 units. This is due to source waters and the absence of any pH adjustment in the treatment chain. Filtration at drinking water points helps limit the impacts of low pH and leaching from the reticulation.

6 Monitoring for the Water Licences

6.1 Water quality

Sampling of downstream storages is undertaken in accordance with the requirements of the Water Licences. Table 6.1 reports the results of downstream sampling against the ANZECC benchmarks.

Table 6.1: Downstream of storages - percentage of samples exceeding benchmarks

Site	Station Code	Number of samples	pH - Field	Turbidity - Field (NTU)	Dissolved Oxygen - Field (%Sat)	Nitrogen Total (mg/L)	Phosphorus Total (mg/L)	Chlorophyll-a (ug/L)
Wingecarribee River								
Wingecarribee River @ Sheepwash Bridge	E303	12	0%	0%	33%	50%	0%	92%
Shoalhaven River								
Shoalhaven R @ d/s Tallowa Dam	E851	12	0%	0%	17%	17%	8%	25%
Woronora River								
Woronora River @ the Needles	G0515	12	50%	0%	0%	0%	0%	17%
Nepean River								
Nepean River @ Yarramundi	N44	12	0%	0%	8%	100%	0%	67%
Nepean River @ Penrith	N57	12	0%	0%	33%	100%	8%	50%
Nepean River 500m D/S of confluence of Warra R.	N64	12	0%	0%	25%	100%	0%	50%
Warragamba River U/S of confluence of Nepean R.	N641	12	0%	0%	42%	100%	0%	33%
Nepean River @ Wallacia Bridge	N67	12	0%	0%	17%	100%	33%	83%
Nepean River @ Sharpes Weir	N75	12	0%	0%	17%	92%	0%	58%
Nepean River @ Menangle Br	N85	12	8%	0%	17%	0%	0%	50%
Pheasant's Nest Weir Pool	N86	8	0%	0%	0%	0%	0%	0%
Cataract River @ Broughtons Pass	N881	12	33%	0%	0%	0%	0%	0%
Nepean River @ Maldon Weir	N92	12	0%	0%	0%	8%	0%	50%

Wingecarribee River nitrogen concentrations have increased since last year, with 50% of samples exceeding guidelines compared with 25% of samples from last year. pH at the Sheepwash Bridge site was within targets in all samples collected, though 11 out of 12 samples exceeded the benchmark for chlorophyll a at this site.

The downstream Shoalhaven River site was accessible for sampling for the whole year. Water quality has improved from last year with nitrogen exceeding guidelines in 2 out of 12 samples, and phosphorus only once. Chlorophyll *a* concentrations exceeded the benchmark in only 25% of samples this year.

Woronora River downstream of the storage recorded largely similar levels of benchmark exceedances to the previous year. Turbidity, total nitrogen and total phosphorus matched last year's performance and again achieved full compliance to the benchmarks. Dissolved oxygen showed improvement from the previous year and also achieved full compliance. Chlorophyll a saw a minor increase in benchmark exceedances, but remained largely compliant. pH saw an increase in benchmark exceedances, contributed to by the lower pH in Lake Woronora as well as downstream tributaries following rain events.

The Nepean River downstream sites exhibited similar water quality patterns to previous years, with water quality indicators typically declining with increased distance from the storages, largely due to contributions from downstream tributaries. Nutrient and dissolved oxygen compliance to benchmarks at Menangle bridge and further upstream was high, with compliance generally declining at the sites further downstream. Turbidity achieved full compliance at all Upper Nepean downstream sites, which was a slight improvement on the previous year. Chlorophyll compliance followed a similar pattern to the previous year, but with a small increase in benchmark exceedances recorded at most sites.

7 Targeted and investigative monitoring

WaterNSW undertakes targeted and investigative monitoring to understand and assess impacts that are not addressed by the routine monitoring program. The results of the monitoring are discussed in greater detail in the sections below.

A summary of water quality incidents during the reporting period is included in Section 8.

7.1 Wet weather inflow monitoring

WaterNSW conducts wet weather sampling to assist in evaluating impacts on water quality from runoff during significant rainfall events. A key component of the wet weather monitoring program is the use of autosampler stations at strategic catchment sites which are programmed to automatically take samples once a river height trigger has been reached.

Wet weather monitoring is used to quantify the water quality risks from inflows to storages. During high rainfall events, catchments are often closed to operational traffic and storages closed to boat traffic to protect the health and safety of staff and members of the public. Using autosamplers helps to acquire valuable water quality information on the water quality effects of rainfall events.

Autosamplers are programmed to collect samples for:

- total organic carbon, suspended solids, total phosphorus, total nitrogen, total aluminium, total iron and total manganese (Type 1).
- *Cryptosporidium* and *Giardia* (Type 2), plus total nitrogen, total phosphorus (site E203 only).
- Or both Type 1 and Type 2.

Where specific water quality issues have been identified, additional characteristics are analysed on request. At high priority reservoir inflow locations, both autosampler types have been installed. Given the differing sampling mechanisms, trigger values may differ between the two autosampler types. Type 2 samples are reserved for locations identified as potentially significant pathogen sources, requiring a much larger sample volume (hence the lower number of samples). Appendix B tabulates the number of samples collected from Type 1 and Type 2 autosamplers for each site during the year.

7.2 Catchment Risk Characterisation

The average pathogen risk for catchments supplying each storage lake was determined from an assessment of catchment hazards and historical water quality monitoring data based on the Health Based Targets (HBT) section of the Australian Drinking Water Guidelines (ADWG).

It is recognised that the greatest challenges to water treatment occur during heavy rain events when contaminants from the catchment and higher river flows result in poor water quality. At such times water quality monitoring is increased at raw water intakes and selected catchment and storage sites. The Pathogen Campaign Monitoring Program was instituted to enhance pathogen monitoring during high inflow events at selected catchment sites to allow the pathogen risk to be refined during events.

Cryptosporidium hazard assessment is conducted weekly and more frequently during events, to inform any decisions on potential advisory for boil water if filtration plants fail their turbidity targets. The assessments are based on a range of pathogen risk factors such as the condition of the storages and catchments, rainfall, inflow volumes, reports of overflows from sewage treatment plants, dairy effluent ponds and stormwater overflows, and turbidity and pathogen data.

During the reporting period there were two events that triggered autosamplers at Werriberri Creek (E531) in November 2022 and April 2023, resulting in four samples tested for pathogens. *Cryptosporidium* oocysts and *Giardia* cysts were each detected in three samples, with one result exceeding the minor incident threshold (10.2 *Giardia* cysts/10 L). Many of the auto-samplers were triggered during the major event in July 2022 but the catchments were inaccessible so the samples could not be collected in time to be tested.

7.3 Macroinvertebrate monitoring

Macroinvertebrates are monitored annually under the Macroinvertebrate Monitoring Program (MMP) as a catchment health indicator across the Sydney Drinking Water Declared Catchment. In 2022, 80 of 86 scheduled sites were sampled, with high flow conditions preventing sampling at the remaining six sites. Many streams across the catchment experienced sustained high flows in the 2022 Spring AUSRIVAS sampling period, associated with ongoing La Nina conditions. Several sites had to be sampled at higher than baseflow conditions, or within two weeks of the most recent high flow event peak (noted in Table 7.1). These sampling conditions may have contributed to lower AUSRIVAS OE50 scores at some sites in 2022.

Figure 7.1 shows the distribution of 2021 and 2022 AUSRIVAS band grade ratings for each individual catchment. Of the 76 sites monitored in both 2021 and 2022, 51 received a lower AUSRIVAS score in 2022, and 25 received a higher AUSRIVAS score. This indicates a continuing decline in macroinvertebrate health across the declared catchment from 2021, although the change in OE50 score value at each site was not always large enough to result in a change of AUSRIVAS band grade.

Across the Warragamba, Tallowa, Metropolitan and Woronora catchments, most sites in 2022 were rated as below reference, and fell within the AUSRIVAS band B. Macroinvertebrate health declined in the Warragamba catchment in 2022, with eight sites decreasing and one site increasing by one band grade. In the Tallowa catchment, two sites declined by one band grade and site E861 decreased by two band grades, while three sites increased by one band grade. Across the Metropolitan catchment, one site increased, and one site decreased by one band grade. One Woronora catchment site increased by one band grade, and there was no change in the other. The Blue Mountains catchment site declined by one band grade from 2021. Further site information and site-averaged AUSRIVAS scores are presented in Table 7.1.

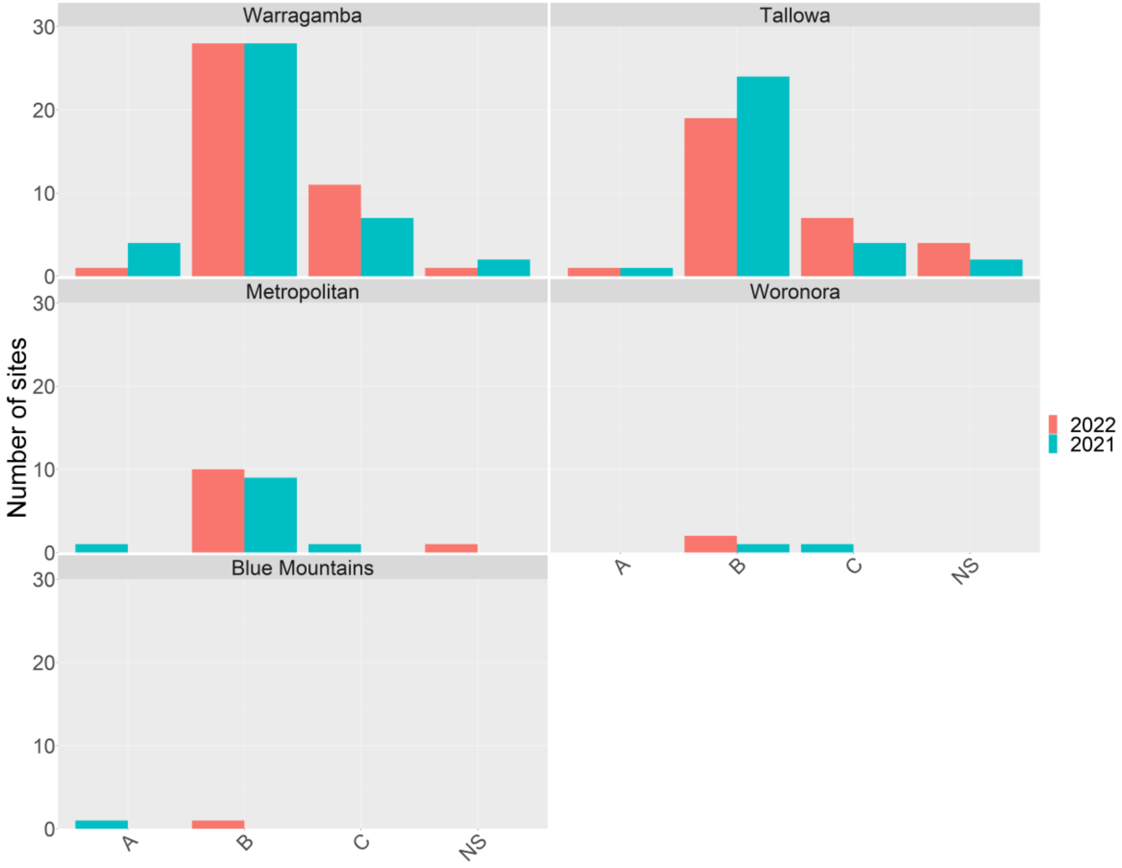

Figure 7.1: Distribution of AUSRIVAS band grades for sites monitored in 2021 and 2022.

Band grades are Reference (A), Below Reference (B), Well Below Reference (C) or Not Sampled (NS).

Table 7.1: Mean 2022 AUSRIVAS scores, compared to 2021 results.

Band grades are Reference (A), Below Reference (B), Well Below Reference (C), Outside experience of the AUSRIVAS model (OEM) or Not Sampled (NS).

AUSRIVAS band thresholds are adjusted to the mean edge and riffle band value for sites where both edge and riffle habitats were sampled.

***shows sites sampled within 2 weeks of high rainfall or flow events.**

Sub-catchment	Site	Site Name	OE50		Band Grade	
			2021	2022	2021	2022
Warragamba Dam catchment						
Kowmung	E130	Kowmung River at Cedar Ford	0.77	0.67	B	B
Lake Burragorang	MMP59	Butchers Creek u/s of Lake Burragorang	0.91	0.56	A	B
Little River	E243	Little River at Fire Trail W4I	0.45*	0.55*	B*	B*
Lower Cox's	E153	Leura Falls Creek at FT W7F	0.57	0.51	B	B
Lower Cox's	E157	Kedumba River at Kedumba Crossing	0.99	0.75	A	B
Mid Cox's	E0114	Cox’s River d/s Lake Lyell	0.79	0.66	B	B
Mid Cox's	E083	Cox’s River at Kelpie Point	0.91	0.93	A	A
Mid Cox's	MMP276	Lowther Creek @ Ecclesbourne	0.6	0.54	B	B
Mid Cox's	MMP55	Little River at Six Foot Track	0.81	0.73	B	B
Mulwaree	A5	Mulwaree River at Lake Bathurst	0.64	0.27*	B	C*
Mulwaree	E457	Mulwaree River at Towers Weir	0.76	0.54	B	B
Mulwaree	MMP188	Mulwaree River @ Currawang Rd	0.56	0.34*	B	C*
Nattai	E203	Gibbergunyah Creek at Welby	0.29	0.36	C	C
Nattai	E206	Nattai River at The Crags	0.53	0.47	B	B
Nattai	E210	Nattai River at the causeway	0.57	0.81	B	B
Nattai	MMP277	Drapers Creek at Colo Vale Firetrail	0.26*	0.36*	C*	C*
Nattai	MMP278	Nattai Creek @ Wombeyan Caves Rd	0.6	0.33*	B	C*
Nattai	MMP279	Nattai River d/s Mittagong pool	0.62	0.49	B	B
Upper Cox's	A16	Cox’s River at Lidsdale	0.53	0.4*	B	C*
Upper Cox's	E0115	Cox River u/s Lake Lyell	0.93	0.69	A	B
Upper Cox's	E0321	Coxs River at Lithgow	0.59	0.55*	B	B*
Upper Cox's	E046	Farmers Creek d/s of Lithgow STP	0.5	0.58*	B	B*
Upper Cox's	MMP280	Farmers Creek u/s STP at Geordie St	0.35	0.46*	C	C*
Upper Wollondilly	MMP27	Wollondilly River at Goonagulla	0.56	0.47	B	B
Upper Wollondilly	MMP281	Mount Wayo Creek @ Fenwicks Ck Rd	0.77	0.64	B	B
Upper Wollondilly	MMP282	Sooley Creek @ Crookwell Rd	0.6	0.64	B	B
Upper Wollondilly	Uwol1	Wollondilly River at Baw Baw Bridge	0.64	0.27	B	C
Werri Berri	E531	Werri Berri Creek at Serenity Park	0.8	0.67	B	B
Wingecarribee	E301	Caalang Creek @ Maugers	0.52*	0.51	B*	B
Wingecarribee	MMP283	Medway Rivulet at Cosh Park	0.65	0.46*	B	B*
Wingecarribee	MMP284	Whites Creek @ Cosgrove Park	0.07	0.07	C	C
Wingecarribee	MMP285	Mittagong Creek @ Mount Rd	0.22*	0.25	C*	C
Wingecarribee	U10	Wingecarribee River at Berrima	0.46	0.32*	C	C*
Wingecarribee	Winge2	Wingecarribee River at Greenstead	0.38	0.66*	C	B*
Wollondilly	E409	Wollondilly River d/s Goulburn STP	0.51	0.5	B	B
Wollondilly	E4122	Wollondilly River at Upper Tarlo	0.49	NS	B	NS
Wollondilly	E450	Wollondilly River at Golden Valley	NS	0.48*	NS	B*
Wollondilly	E488	Wollondilly River at Jooriland	0.51	0.57	B	B
Wollondilly	E5001	Wollondilly River u/s Goulburn STP	0.74	0.62	B	B

Sub-catchment	Site	Site Name	OE50		Band Grade	
			2021	2022	2021	2022
Wollondilly	MMP130	Tarlo River at Swallowtail Pass	NS	0.5*	NS	B*
Wollondilly	MMP226	Long Swamp Creek u/s Paddy's River	0.65	0.65	B	B
Tallowa Dam catchment						
Back and Round	MMP17	Shoalhaven River at Farringdon Crossing	0.45*	NS	B*	NS
Boro	E890	Boro Creek at Marlowe	0.36	0.42	C	C
Boro	MMP33	Kings Creek upstream of Boro Creek	0.44	0.65	B	B
Braidwood	E860	Shoalhaven River at Mount View	0.56	0.46	B	B
Braidwood	E891	Gillamatong Creek at Braidwood	0.57	0.43*	B	B*
Braidwood	MMP62	Jembaicumbene Creek at Bendoura	0.47*	0.42	C*	C
Bungonia	A8	Bungonia Creek at Bungonia	0.65	0.5*	B	B*
Bungonia	E847	Shoalhaven River at Fossickers Flat	NS	0.32	NS	C
Endrick	MMP12	Endrick River at Nerriga	0.71	0.47	B	B
Jerrabattagulla	MMP09	Jerrabattgulla Creek at Warragandra	0.61	0.61	B	B
Jerrabattagulla	MMP168	Jerrabattagulla Ck @ Hereford Hall Rd	0.54*	0.66	B*	B
Jerrabattagulla	MMP273	Shoalhaven River at Wyanbene Rd	0.8	0.65*	B	B*
Jerrabattagulla	MMP67	Stoney Creek @ Cooma Rd	0.45*	0.47*	B*	B*
Kangaroo	E300	Yarrunga Creek @ Wildes Meadow	0.44*	0.27	B*	C
Kangaroo	E520	Bundanoon Creek at the Rocks	0.7	NS	B	NS
Kangaroo	E7021	Brogers Creek at Clinton Park	0.63	0.62	B	B
Kangaroo	E706	Kangaroo River at Hampden Bridge	0.75	0.61*	B	B*
Kangaroo	E7061	Kangaroo River at Oakdale	0.52	0.6	B	B
Mid Shoalhaven	E8311	Corang River at Meangora	0.57	0.5	B	B
Mid Shoalhaven	E861	Shoalhaven River at Hillview	0.81	0.29	A	C
Mongarlowe	E822	Mongarlowe River at Mongarlowe	0.56	0.65	B	B
Mongarlowe	MONG1	Mongarlowe River at Charleyong	0.74	0.81	B	A
Mongarlowe	R13	Mongarlowe River at Monga	0.62*	NS	B*	NS
Nerrimunga	E8361	Nerrimunga Creek at Minshull Trig	NS	0.47	NS	B
Nerrimunga	MMP51	Jacqua Creek at Lumley Road	0.53	0.39	B	C
Nerrimunga	MMP52	Nadgigomar Creek at Oallen Ford	0.57	0.33	B	C
Reedy	MMP194	Manar Creek at The Dip	0.36	0.54	C	B
Reedy	MMP258	Durran Durra Creek at Nerriga Road	0.51	0.49*	B	B*
Reedy	R7	Mulloon Creek at Tawarri	0.43*	0.53*	C*	B*
Reedy	REED1	Reedy Creek at Mayfield Road	0.56	0.51	B	B
Upper Shoalhaven	MMP06	Shoalhaven River at Yarra Glen	0.63*	NS	B*	NS
Metropolitan Dams catchment						
Upper Nepean	E6006	Sandy Creek at Fire Road 15	0.44	NS	B	NS
Upper Nepean	E601	Nepean River at Nepean Dam inflow	0.82*	0.66*	A*	B*
Upper Nepean	E602	Burke R @ Nepean Dam Inflow	0.4	0.47	C	B
Upper Nepean	E604	Flying Fox Creek No.3 U/S of Gauge	0.58	0.67	B	B
Upper Nepean	E608	Goondarrin Creek @ Kemira 'D' cast	0.53	0.53*	B	B*
Upper Nepean	E609	Cataract River D/S Angles Creek	0.55	0.48*	B	B*
Upper Nepean	E610	Avon River at Summit Tank	0.52	0.43*	B	B*
Upper Nepean	E680	Cordeaux River b/w upper Cordeaux 1&2	0.58	0.53	B	B
Upper Nepean	E697	Nepean River at Maguires Crossing	0.46	0.66*	B	B*
Upper Nepean	MMP100	Wongawilli Creek DS of Fire Road 6	0.53	0.72	B	B
Upper Nepean	MMP136	Lizard Creek DS Fire Road 8H	0.52	0.51	B	B

Sub-catchment	Site	Site Name	OE50		Band Grade	
			2021	2022	2021	2022
Blue Mountains and Woronora Dam catchments						
Grose	MMP246	Woodford Creek u/s Woodford Dam	0.81	0.7	A	B
Woronora	E677	Woronora River at Fire Road 9F	0.41	0.52*	C	B*
Woronora	E678	Waratah River at Flatrock Crossing	0.77	0.68*	B	B*

7.4 Investigative monitoring

WaterNSW's investigative monitoring program is designed to target known risks, emerging issues and inform management options. Investigative monitoring can be used for identifying pollution sources, understanding pollutant fate and transport in a variety of flow conditions and investigating the risk of pollutants reaching inflows and raw water offtake points. Investigative monitoring is also one means of evaluating the effectiveness of actions to address pollutants in the catchments and lakes.

7.4.1 Operational use of chlorophyll a sensors in Lake Burragorang

Algal growth in the Greater Sydney storages is closely monitored due to potential risks including production of taste and odour compounds, toxins, or impeding filtration efficacy at water filtration plants. Traditional monitoring techniques have focussed on the collection of grab samples for laboratory analysis, including analysis for chlorophyll a as an indicator for the presence of phytoplankton, as well as algal count and speciation analysis methods.

An investigative study was completed in the period from 2020 to 2022 focussing on in situ high frequency monitoring using total algal sensors to improve the understanding of spatial and temporal algal dynamics in water storages. The study aimed to determine whether in situ algal fluorescence sensors deployed on existing monitoring infrastructure, reporting high frequency data in near real time, could be used to track chlorophyll a as an indicator of algal growth in typical operating conditions in Lake Burragorang. Consideration was given to sensor reliability, accuracy, robustness and cost effectiveness.

The results of the investigation indicated the in situ sensors performed well in the photic zone when compared with laboratory results from grab samples. The study recommended that the in situ sensors continue to be deployed for operational and research purposes within Lake Burragorang to monitor algal populations in surface waters. Existing visualisation tools are able to be used by operators for the detection of algal taxa within the water column profile.

8 Incidents and events

Water quality incidents are managed in accordance with the WaterNSW Water Quality Incident Response Protocol. The protocol sets out agreed water quality trigger levels for various actions and notifications. Any issue that poses a potential risk to public health is reported to NSW Health immediately and incident responses are developed in consultation with NSW Health and relevant customers.

The Water Monitoring Program also specifies monitoring required in anticipation of events which pose potential threats to raw water quality, such as large inflow events and seasonal turnover in lakes. The pre-planned monitoring during periods leading to and during such events allows operational changes to be made proactively and prevents such events manifesting into incidents.

During 2022–23, 3 major and 32 minor water quality incidents were recorded in the Greater Sydney catchment area (see Appendix C for details of these incidents).

8.1 Major and significant water quality incidents

There were three major incidents relating to water quality during 2022-23. Details of all incidents and their management are provided in Appendix C. Prompt notifications and effective incident response ensured no interruptions in the supply of high quality treated drinking water to customers. Incident management responses for major and significant incidents are discussed in detail below.

8.1.1 Exceedance of Raw Water Supply Agreement site specific standards

There were twenty-four results outside Raw Water Supply Agreement standards during the year. Two of these were due to elevated algal ASU (an indicator of filter clogging potential) in raw water supplied to Cascades Water Filtration Plant for treatment, in January and February 2023. The remainder were associated with intense rainfall events that fell across the Greater Sydney catchments. Successive inflow events across the network resulted in elevated metals, and reduced alkalinity and hardness in raw water that could not be avoided through source selection. Total aluminium exceeded site specific standards at Nepean in July 2022, at Woronora in July, August, September and November 2022 and at Cascades in July 2022. Total iron exceeded site specific standards at Macarthur in September 2022. Total hardness and total alkalinity fell below the lower limit of the site specific standards at Prospect in July and August 2022. While just hardness was below the lower limit of the site specific standards at Macarthur in July, August, October and November 2022, at Nepean in July 2022 and at Woronora in July, August, November and December 2022. pH was below the lower limit of the site specific standards at Kangaroo Valley in July 2022 and April 2023. Each instance was reported to the water filtration plant operators and supply configuration options discussed. When requested, WaterNSW provided additional raw water samples to allow the plant to perform testing to optimise treatment processes.

8.1.2 July 2022 intense rainfall event

The Greater Sydney catchments received significant rainfall from an east coast low that began on the 1st of July 2022 and lasted several days. This rain event was a continuation of a very wet start to the year, with major rainfall events having already occurred in March and April 2022. The July 2022 event therefore began with wet catchments, dams at or near capacity, and with water quality in many locations already outside the preferred operating range of the water filtration plants. An incident management team (IMT) was established to oversee operations in liaison with the Bureau of Meteorology, State Emergency Services, Sydney Water and NSW Health.

Spills were experienced in almost all Greater Sydney storages including Warragamba, Woronora, Nepean, Avon, Cataract, Cordeaux, Wingecarribee, Fitzroy Falls, Tallowa, Upper Cascades, Lower Cascades, Greaves Creek and Medlow. The storage level at Warragamba peaked at 1.67m above full supply level, discharging at 515 GL/day, which made this the fourth highest spill on record behind events in 1961, 1964 and 1990. This contributed to major flooding in the Hawkesbury Nepean system.

Water quality was impacted in the storages with increased turbidity, colour, organics and metals. Supply configuration was optimised where possible in consultation with Sydney Water and samples were provided to Sydney Water for jar testing to optimise treatment processes.

8.1.3 October 2022 Intense rainfall event

The July 2022 rain event was followed by another significant rainfall event three months later, beginning on the 5th of October 2022 and again lasting several days. Rainfall totals were not as high as those experienced in July, however the event again started with wet catchments, dams at or near capacity and already compromised water quality. Spills occurred at Warragamba, Woronora, Nepean, Avon, Cordeaux, Tallowa, Lower Cascades and Greaves Creek. Water quality further deteriorated within the storages due to the new inflows. Turbidity became elevated at Warragamba due to the uplift of sediment from the lake bed, caused by suction from the spill going over the dam wall. Supply to Prospect WFP from Warragamba was paused, with the existing higher quality water in the Warragamba pipeline isolated to supply Orchard Hills and Warragamba WFPs until the turbidity in the lake reduced. Other supply configurations were also optimised where possible in consultation with Sydney Water, and samples were again supplied for jar testing to optimise treatment processes. The water quality impacts of the successive intense rain events in 2022 continued into 2023, and are still ongoing in some of the Greater Sydney storages.

9 Trend analysis

Trend analysis identifies persistent changes in water quality parameters resulting from natural (e.g. rainfall, climate) and anthropogenic (e.g. land-use change, catchment interventions) perturbations. WaterNSW undertakes trend analysis biennially, with trend analysis last performed as part of the 2020-21 Annual Water Quality Monitoring Report.

Trend analysis for selected catchment, storage, water filtration plant raw water supply, and downstream river sites for the 2013 - 2023 period are reported in the sections that follow. The sites and analytes included in the trend analysis were agreed by NSW Health and DPIE. Statistically significant trends (95%) were identified using a Seasonal Kendall Trend test with rates of changes quantified using the Sen slope method. Statistically significant trends are reported in units per annum.

Where data gaps comprise > 20% of the total sampling events for the period, trend data has not been reported for the site or analyte. This may occur due to conditional analysis (algal speciation in catchments) or where an analyte is no longer routinely monitored. The Seasonal Kendall Trend test has not adjusted for discharge at time of sampling or long-term effects resulting from increased rainfall, stream discharge and groundwater baseflow discharges.
Statistically significant trends may not be of concern if:

a) The magnitude of the change is very small; and/or
b) The trend is not likely to result in the relevant guidelines/benchmarks being approached or exceeded. For relevant guidelines/ benchmarks refer to Section 4 (Applicable guidelines and benchmarks)

WaterNSW's Source Water Protection programs will target initiatives to address those trends where the magnitude of trend is large or results in more frequent exceedances of the relevant guidelines or benchmarks.

The following tables summarise identified trends. Sites are colour coded based on the following criteria:

NA	No significant trend
X	A statistically significant water quality trend (improving or declining), of lower importance as the site and analyte did not frequently (≤50%) exceed benchmark levels in 2022-2023.
X	A statistically significant, improving water quality trend, of higher importance as the site and analyte frequently (>50%) exceeded benchmark levels in 2022-2023.
X	A statistically significant, declining water quality trend, of higher importance as the site and analyte frequently (>50%) exceeded benchmark levels in 2022-2023.
	Insufficient dataset for trend analysis

The filtering method for testing true colour has changed over the timeline of this historical dataset. An assumption of this analysis is that these recent changes may have incrementally improved accuracy, leading to decreases in the reported true colour measurements in some sample matrices.

9.1 Warragamba system

Table 9.1: Trend results for the Warragamba system. Results displayed as per key in Section 9.

Site	Alkalinity (mg $CaCO_3$/L)	Aluminium Total (mg/L)	Areal Standard Unit (algae)	Chlorophyll a (µg/L)	Conductivity (mS/cm)	Dissolved Oxygen (%Sat)	E. coli (orgs/100mL)	Iron Filtered (mg/L)	Iron Total (mg/L)	Manganese Filtered (mg/L)	Manganese Total (mg/L)	Nitrogen Total (mg/L)	Phosphorus Total (mg/L)	Total Hardness (mg CaCO3/L)	Toxic Total Algal Count	True Colour (@400nm)	Turbidity (NTU)
Catchments																	
E083	NA	0.005		NA	NA	0.654	NA	0.007	0.016	NA	NA	0.014	NA	NA		0.738	0.169
E130	NA	NA		0.056	NA	0.498	NA	0.006	0.009	0.000	0.001	NA	NA	NA		NA	0.131
E157	0.505	NA		NA	0.002	0.999	-2.760	0.010	NA	0.001	NA	-0.011	0.000	0.998		NA	NA
E203	NA	NA		NA	NA	NA	NA	NA	0.036	0.002	0.002	NA	NA	NA		NA	NA
E206	NA	NA		NA	-0.006	NA	-1.130	0.009	NA	NA	NA	-0.031	-0.001	NA		NA	NA
E210	NA	0.005		NA	NA	1.096	NA	-0.021	NA	NA	NA	NA	NA	1.662		-0.945	0.369
E243	0.105	-0.001		NA	NA	0.479	-0.384	-0.010	-0.022	-0.001	-0.002	NA	0.000	NA		-0.516	-0.028
E409	-4.373	0.019	NA	NA	-0.040	NA	NA	0.023	0.044	NA	NA	0.043	NA	-9.114	0.000	2.062	0.635
E450	1.743	0.010		0.513	NA	NA	NA	0.031	0.036	NA	0.001	0.030	NA	NA		2.146	0.488
E488	NA	0.007		NA	NA	NA	NA	0.010	0.026	NA	NA	0.020	0.001	NA		1.340	0.337
E531	NA	NA		0.082	-0.009	1.199	NA	0.025	-0.031	NA	NA	NA	-0.001	-1.256		-1.032	0.128
Storages																	
DWA12	1.369	0.005		NA	0.002	NA	NA	NA	0.003	0.000	0.000	0.012	0.000	0.143		NA	0.134
DWA2	0.557	0.010	-10.394	NA	NA	-0.650	0.000	0.000	0.009	0.000	0.000	NA	0.000	NA	NA	NA	0.382
DWA27	1.218	0.005		0.073	0.003	NA	NA	NA	0.003	0.000	0.000	0.018	0.000	0.483		NA	0.141
DWA9	0.829	0.007	-14.096	0.059	NA	-0.394	NA	0.000	0.008	0.000	0.000	0.010	0.000	NA	-10.296	0.414	0.384
RPR1	-0.342	0.001	89.323	0.227	-0.009	-0.182	0.000	NA	0.004	0.000	0.001	NA	NA	-1.049	0.000	0.340	0.147
Water Filtration Plants																	
HBR1	NA	0.024	-3.682		NA	-1.691	0.000	0.019	0.040	0.000	0.002			NA	NA	1.165	0.707
HWA2	0.969	0.024	-6.594		NA	-1.561	NA	0.018	0.039	0.000	0.001			NA	0.000	1.125	0.616
PWFP10	-0.253	-0.006	15.586		-0.002	-0.295	NA	-0.010	-0.017	0.001	0.002			NA	0.000	1.008	0.766

Analysis of the catchment streams of Lake Burragorang showed few significant trends during the period. Where a trend is identified, the variance is generally small and not indicative of a significant change in conditions in the catchment. Most notable are the increase in Aluminium and Total Nitrogen.

True colour also continues to show the effects of catchment fires in 2021 and is expected to improve in coming years as the catchment recovery continues.

These analytes were also found to have a small but significant degradation trend in the lake sites.

9.2 Upper Nepean system

Table 9.2: Trend results for the Upper Nepean system. Results displayed as per key in Section 9.

Site	Alkalinity (mg $CaCO_3$/L)	Aluminium Total (mg/L)	Areal Standard Unit (algae)	Chlorophyll a (ug/L)	Conductivity (mS/cm)	Dissolved Oxygen (%Sat)	*E. coli* (orgs/100mL)	Iron Filtered (mg/L)	Iron Total (mg/L)	Manganese Filtered (mg/L)	Manganese Total (mg/L)	Nitrogen Total (mg/L)	Phosphorus Total (mg/L)	Total Hardness (mg CaCO3/L)	Toxic Total Algal Count	True Colour (@400nm)	Turbidity (NTU)
Catchments																	
E602	0.170	-0.007		NA	NA	-0.996	NA	-0.013	NA	NA	NA	-0.005	0.000	NA		-0.633	NA
E609	NA	NA		-0.012	NA	-0.427	NA	NA	-0.021	NA	NA	NA	-0.001	NA		0.374	NA
E610	NA	-0.005		NA	NA	-0.890	-1.851	NA	-0.011	0.000	-0.001	-0.005	0.000	NA		NA	NA
E680	NA	-0.004		NA	0.001	-0.985	NA	NA	-0.021	NA	NA	NA	NA	0.000		NA	NA
Storages																	
DAV1	NA	0.000		NA	-0.001	-1.165	0.000	0.002	0.005	NA	NA	0.003	0.000	-0.142		0.384	-0.074
DAV7	NA	0.002	34.931	0.149	-0.001	-0.984	NA	0.002	0.007	0.000	NA	0.002	NA	-0.333	NA	0.417	-0.036
DCA1	0.000	0.010		NA	NA	-1.133	NA	0.016	0.027	0.003	0.002	0.006	NA	NA		1.498	NA
DCO1	0.129	0.005		0.435	-0.001	-0.679	NA	0.023	0.038	0.000	0.001	0.009	0.000	NA		1.651	0.027
DNE2	0.162	NA	NA	NA	0.000	-1.073	NA	NA	NA	-0.001	-0.002	0.005	NA	NA	NA	NA	NA
Water Filtration Plants																	
HMAC1	-0.281	0.018	NA		-0.002	-0.821	NA	0.018	0.028	0.001	0.001			-0.341	NA	1.879	0.097
HNED	-0.176	0.038	9.072		-0.003	-0.897	NA	0.013	0.029	-0.002	-0.003			0.000	NA	1.266	0.311
IWFP-R	-0.054	NA	33.718		-0.002	-0.769	NA	NA	NA	NA	-0.002			-0.572	NA	NA	NA

The Upper Nepean catchment streams showed improving trends across many parameters including alkalinity, metals, *E. coli*, nutrients, and chlorophyll. Catchment streams typically recover from heavy rainfall events faster than the storages, so there has been less impact on long term trends from the high frequency of storm events that the Greater Sydney catchments have experienced since February 2020. The improving trend for total aluminium in the Burke River inflow to Lake Nepean (site E602) has been flagged as high importance, with continued reductions likely to reduce the 83% benchmark exceedances that were recorded in the 2022-2023 year. A declining trend was recorded at all Upper Nepean catchment sites for dissolved oxygen, with lowering percent saturation levels likely to increase benchmark failures below the lower guideline level. This was flagged as high importance in the Cataract River (site E609) with this site recording 83% benchmark exceedances below the lower guideline level in 2022-2023.

In the Upper Nepean storages, Lake Nepean (site DNE2) recorded no significant trend, or low magnitude trends across most parameters. Although the magnitude was low, the increasing trend for total nitrogen at DNE2 was flagged as high importance due to the 83% benchmark failures recorded at this site in 2022-2023.

Lake Avon also recorded mostly low magnitude trends, with minor improvements in turbidity, and a minor declining trend in dissolved oxygen, iron, total nitrogen and colour. The Upper Avon site (DAV7) recorded a low magnitude increasing trend in total aluminium that was flagged as high importance due to the 83% benchmark exceedances in 2022-2023.

Of the Upper Nepean storages, Lakes Cataract and Cordeaux recorded the highest magnitude declining water quality trends for parameters including total aluminium, chlorophyll, iron, manganese, total nitrogen, colour and turbidity. This indicates these lakes were likely the most impacted by the period of sustained high rainfall since February 2020. The increasing trend for total aluminium in both Lake Cataract and Cordeaux, and chlorophyll a in Lake Cordeaux, were all flagged as high importance due to having >50% benchmark exceedances in 2022-2023.

The Upper Nepean water filtration plants recorded increasing trends in aluminium, iron, true colour and turbidity. These parameters have all likely been influenced by the high rainfall period of the past three and a half years. Illawarra and Nepean WFPs also recorded increasing trends for algal ASU, however this is not expected to have a short term impact on treatability with both these sites recording zero benchmark exceedances in the 2022-2023 year.

9.3 Woronora system

Table 9.3: Trend results for the Woronora system. Results displayed as per key in Section 9.

Site	Alkalinity (mg $CaCO_3$/L)	Aluminium Total (mg/L)	Areal Standard Unit (algae)	Chlorophyll a (ug/L)	Conductivity (mS/cm)	Dissolved Oxygen (%Sat)	*E. coli* (orgs/100mL)	Iron Filtered (mg/L)	Iron Total (mg/L)	Manganese Filtered (mg/L)	Manganese Total (mg/L)	Nitrogen Total (mg/L)	Phosphorus Total (mg/L)	Total Hardness (mg CaCO3/L)	Toxic Total Algal Count	True Colour (@400nm)	Turbidity (NTU)
Catchments																	
E677	0.000	NA		NA	NA	NA	NA	NA	NA	0.001	NA	-0.004	0.000	NA		NA	-0.068
Storages																	
DWO1	NA	0.026	8.213	0.051	-0.001	-1.483	NA	0.015	0.025	0.001	0.001	0.005	NA	0.000	NA	2.422	0.051
Water Filtration Plants																	
HWO1-A	NA	0.031	3.814		-0.002	-1.880	NA	0.017	0.028	0.001	0.001			0.000	NA	2.535	0.165

An increasing trend was recorded in Lake Woronora as well as in the raw water supplied to Woronora WFP across multiple parameters. Increases in metals, true colour and turbidity are likely to have been influenced by a three year period of sustained high rainfall beginning in February 2020. Intense rainfall events generated inflows into the storage with increased concentrations of these parameters. Total aluminium in Lake Woronora is flagged as being of higher importance, with this parameter recording 100% benchmark exceedances in 2022-2023. Dissolved oxygen also recorded declining performance, with decreasing percent saturation levels in a lake where 50% of samples were below the lower benchmark in 2022-2023.

A rising trend in total algae ASU was identified in the lake and the raw water supply to Woronora WFP. However, baseline algal ASU concentrations are low in this system and minor rises are not expected to have an impact on treatability.

9.4 Blue Mountains system

Table 9.4: Trend results for the Blue Mountains system. Results displayed as per key in Section 9.

Site	Alkalinity (mg $CaCO_3$/L)	Aluminium Total (mg/L)	Areal Standard Unit (algae)	Chlorophyll a (ug/L)	Conductivity (mS/cm)	Dissolved Oxygen (%Sat)	*E. coli* (orgs/100mL)	Iron Filtered (mg/L)	Iron Total (mg/L)	Manganese Filtered (mg/L)	Manganese Total (mg/L)	Nitrogen Total (mg/L)	Phosphorus Total (mg/L)	Total Hardness (mg CaCO3/L)	Toxic Total Algal Count	True Colour (@400nm)	Turbidity (NTU)
Catchments																	
Storages																	
DGC1	NA	0.007	25.122	0.170	0.000	1.284	0.000	-0.007	-0.026	-0.001	-0.001	-0.003	0.000	NA	0.000	0.828	NA
DTC1	-1.276	0.006	26.479	NA	-0.002	1.429	NA	0.010	0.015	0.000	0.001	-0.013	NA	-1.242	0.000	0.849	0.046
Water Filtration Plants																	
HCSR	-1.975	0.011	29.156		-0.005	1.497	NA	0.017	0.031	0.001	0.002			-2.226	NA	1.160	0.162

The Blue Mountains storages and Cascades WFP all saw increasing trends in total aluminium, true colour and turbidity. These parameters have likely been influenced by the period of repeated heavy rainfall events received since February 2020. The increases in total aluminium in Greaves Creek (DGC1) and Top Cascades (DTC1) have been flagged with high importance due to their >50% benchmark exceedance in 2022-2023.

Algal ASU also saw an increasing trend in both storages and at the inlet to the WFP. If this trend continues it may result in an increase in to the 17% benchmark exceedances that were recorded at Cascades WFP in 2022-2023.

9.5 Shoalhaven system

Table 9.5: Trend results for the Shoalhaven system. Results displayed as per key in Section 9.

Site	Alkalinity (mg $CaCO_3$/L)	Aluminium Total (mg/L)	Areal Standard Unit (algae)	Chlorophyll a (ug/L)	Conductivity (mS/cm)	Dissolved Oxygen (%Sat)	E. coli (orgs/100mL)	Iron Filtered (mg/L)	Iron Total (mg/L)	Manganese Filtered (mg/L)	Manganese Total (mg/L)	Nitrogen Total (mg/L)	Phosphorus Total (mg/L)	Total Hardness (mg CaCO3/L)	Toxic Total Algal Count	True Colour (@400nm)	Turbidity (NTU)
Catchments																	
E706	NA	-0.013		NA	NA	-0.946	NA	0.009	NA	NA	NA	NA	NA	NA		NA	NA
E847	0.780	NA		0.163	NA	-0.500	NA	NA	NA	NA	NA	NA	NA	0.841		NA	0.301
Storages																	
DTA1	0.684	NA		NA	0.002	NA	NA	0.010	NA	NA	NA	0.010	NA	1.110		NA	NA
DTA8	NA	0.007	NA	NA	NA	-0.817	NA	NA	NA	NA	NA	NA	NA	0.000	0.000	NA	0.207
DWI1	0.204	-0.011	68.510	-0.546	NA	-0.982	NA	0.010	NA	0.000	NA	0.020	NA	0.000	603.749	0.668	-0.497
Water Filtration Plants																	
HKV1	0.258	NA	NA		NA	-0.890	NA	NA	NA	NA	NA			0.333	0.000	NA	NA
HWI1	0.000	-0.023	210.466		0.002	NA	NA	-0.014	-0.028	NA	NA			0.000	727.949	NA	NA

A moderately increasing trend is reported in hardness and alkalinity throughout the Shoalhaven system. A significant increasing trend for algal ASU and Toxic Total Algal Count is evident in Lake Wingecarribee and at the inlet to the WFP.

9.6 Downstream sites

Table 9.6: Trend results for selected downstream sites. Results displayed as per key in Section 9.

Site	Alkalinity (mg $CaCO_3$/L)	Aluminium Total (mg/L)	Areal Standard Unit (algae)	Chlorophyll a (ug/L)	Conductivity (mS/cm)	Dissolved Oxygen (%Sat)	*E. coli* (orgs/100mL)	Iron Filtered (mg/L)	Iron Total (mg/L)	Manganese Filtered (mg/L)	Manganese Total (mg/L)	Nitrogen Total (mg/L)	Phosphorus Total (mg/L)	Total Hardness (mg CaCO3/L)	Toxic Total Algal Count	True Colour (@400nm)	Turbidity (NTU)
N57	0.827	NA		-0.341	NA	NA		0.007	NA	0.001	NA	0.033	NA			0.676	NA
G0515	0.343	NA		0.147	NA	2.611		NA	NA	NA	0.000	NA	0.000			0.661	NA
E851	0.628	NA		NA	0.003	-0.828		0.008	NA	NA	0.001	NA	NA			NA	0.254

The three downstream sites recorded a high number of low magnitude trends, or no significant trends across the range of parameters. The single trend that was flagged as high importance was total nitrogen at the Nepean River at Penrith (site N57). This site showed an increasing trend at a site that had recorded benchmark exceedances in 100% of samples collected in 2022-2023.

10 References

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