Annual Water Quality Monitoring Report

2018-19

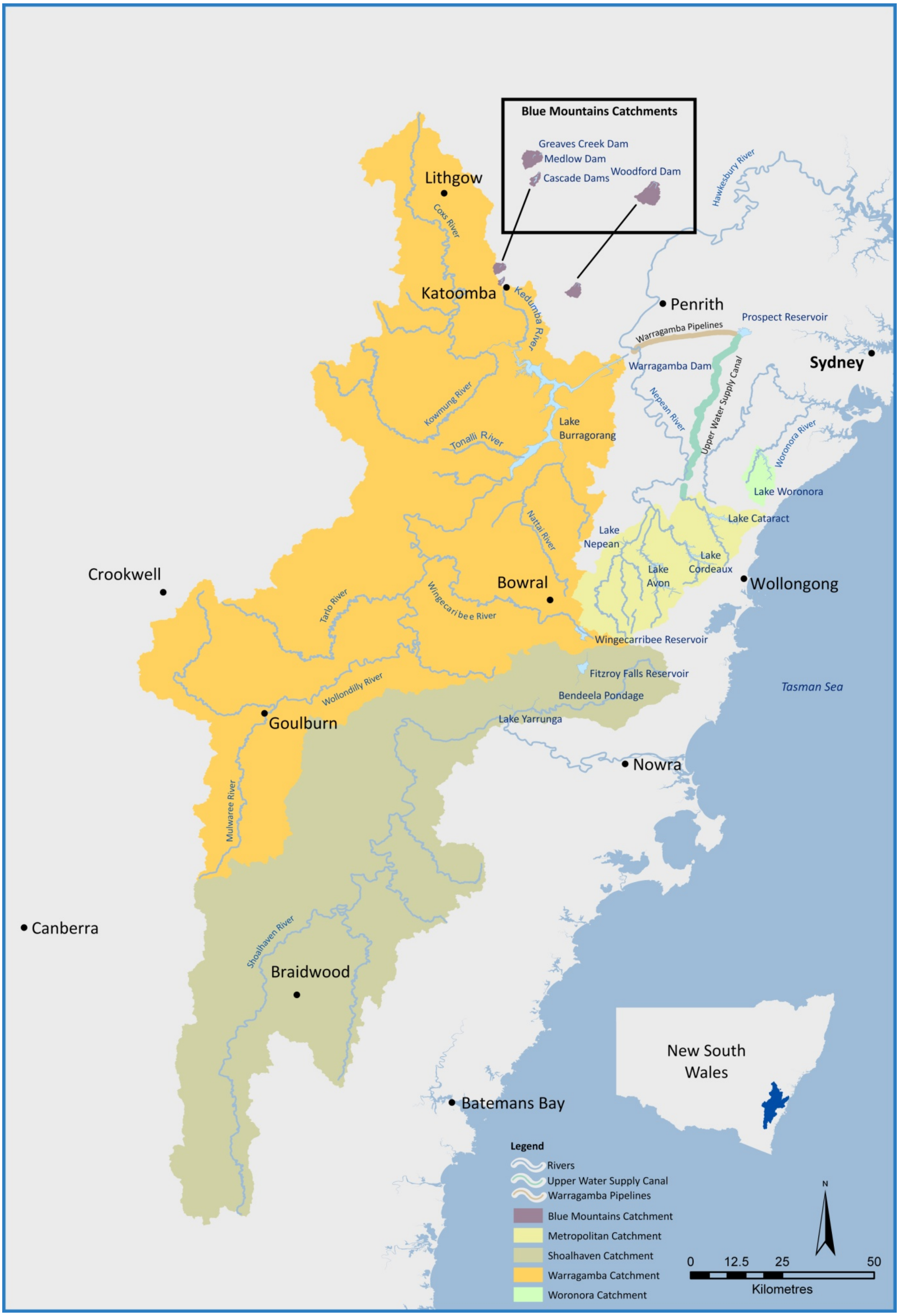

Figure 0.1: Sydney catchment area

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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 sites. The WMP has been developed in collaboration with NSW Health, Sydney Water and other wholesale customers. The program incorporates locations, frequency, 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. Monitoring provides timely water quality data and information to inform operational decisions and verification of water quality to demonstrate compliance.

This report describes the results of the water quality monitoring undertaken by WaterNSW during 2018-19. The report is prepared to meet WaterNSW's statutory obligations in addition to providing stakeholders, students, researchers and the general public with water quality information for waters managed by WaterNSW in the greater Sydney catchment area.

Highlights

The 2018-19 reporting period commenced with the total storage volume at 68.9% on 1 July 2018. Ongoing drought and very low inflows over the reporting period caused the total storage volume to decrease to 52.1% by 30 June 2019. Warm weather and ongoing drought conditions have been favourable for algal growth in some storages but generally the lack of large inflow events has resulted in good, stable water quality.

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. Through proactive, modelling, monitoring and source selection, WaterNSW avoided or effectively managed water quality incidents to minimise impacts to customers.

Water supplied to **water filtration plants** achieved near full compliance with site specific standards in raw water supply agreements. The exceptions were one occasion of elevated filter clogging algal potential and two occasions of elevated alkalinity in raw water supplied to Cascades Water Filtration Plant in April 2019 and one occasion of alkalinity in the raw water supplied to Illawarra Water Filtration Plant. True colour in raw water supplied from Lake Burragorang and Lake Nepean continued to decline through the year with proactive systems configuration. True colour in raw water supplied complied with raw water supply agreement standards.

WaterNSW continued to monitor and manage **picnic area supply** sites in accordance with the Quality Assurance Plans developed in line with NSW Private Water Supply Guidelines. Monitoring results were generally consistent with the previous year and manual dosing was implemented to improve residual chlorine levels.

Consistent with recent years, nutrients and chlorophyll-*a* often exceeded ANZECC benchmarks in **catchment sites** with significant agricultural or urban development (e.g. Wollondilly and Kangaroo Rivers), although there was a general decrease in phosphorus exceedances in the Warragamba catchment. Largely natural catchments (e.g. Burke and Avon Rivers) rarely exceeded ANZECC benchmarks and continue to demonstrate the effectiveness of Special Areas in protecting water quality.

Levels of phosphorus were similar in Lake Burragorang relative to last year, indicating a low risk of an algal bloom over the upcoming 2019-20 season in the absence of a large rainfall event.

Water quality in 2018-19 achieved
99.95% conformance with Raw Water Supply Agreements and
100% conformance with Australian Drinking Water Guidelines

Monitoring **downstream** of WaterNSW storages is undertaken as part of the requirements of the Water Licences and Approvals package administered by Department of Planning, Industry and Environment. The impact of pollutant sources from downstream catchments is evidenced by the deterioration of water quality downstream of WaterNSW release points, particularly in the Hawkesbury – Nepean system. Levels of nutrients and chlorophyll *a* were frequently higher than last year at most sites.

WaterNSW successfully managed one major and six significant **water quality incidents** as triggered by and in accordance with our Raw Water Quality Incident Response Plan:

- Alkalinity in raw water supplied to Illawarra WFP;
- Algal toxin in Wingecarribee Reservoir;
- Turbidity at Cataract and Fitzroy Falls Picnic Areas;
- Low chlorine at Cataract Picnic Area; and
- Potentially toxin producing algal biovolume in Lake Burragorang.

A trend analysis was conducted for selected analytes and sites for the period from 2009 to 2019. The analysis did not identify any significant negative trends impacting on water quality supplied for treatment.

1 Introduction

WaterNSW is a state-owned corporation responsible for 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) for the Sydney catchment area sets out the location, frequency and analytes monitored (WaterNSW, 2017). Specific and health-related characteristics are determined in consultation with our major customers and the program is endorsed by 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 wholesale 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 four key drivers:

- Operating Licence 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 Industry and Environment (DPIE – Water Division)
- Raw water supply agreements between WaterNSW and its wholesale customers
- Australian Drinking Water Guidelines

This report describes the results of water quality monitoring undertaken by WaterNSW in the Sydney catchment area between 1 July 2018 and 30 June 2019 under the WMP. The report is a requirement of the Reporting Manual of the Operating Licence (2017-2022). The report also provides the community with information on water quality.

More specifically this report includes:

- a summary of the Water Monitoring Program, 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 at selected sites.

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 supplements 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).

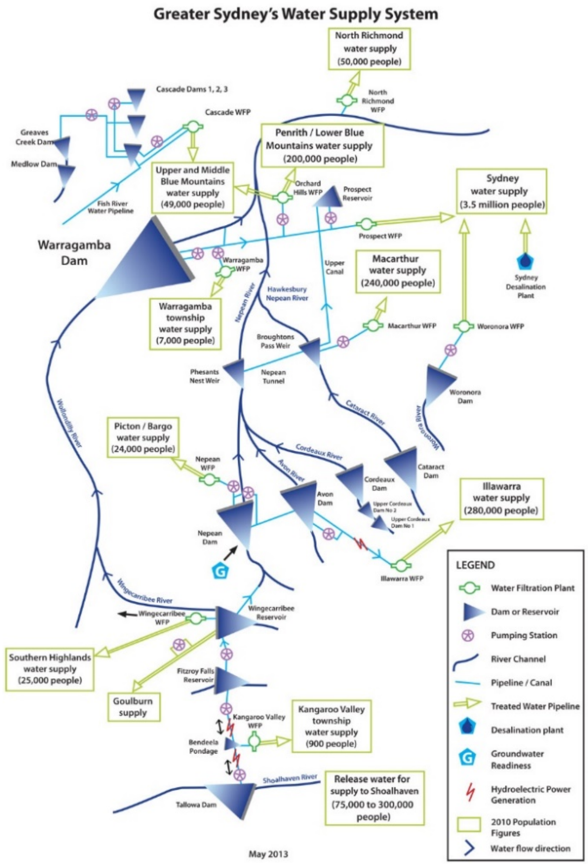

Figure 2.1: Schematic of the water supply system

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 modified or removed 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.

- Operating Licence (Part 2), *Water NSW Act 2014 (Division 4)*
- Water Licences and Approvals Package under *Water Management Act 2000*
- Memorandum of Understanding between NSW Health and WaterNSW (2016) (Parts 5-8) *Water NSW Act 2014* (Part 20-21)
- Raw Water Supply Arrangements
- Private Water Supply Guidelines and *Public Health Act 2010*
- *Water Act 2007* (Commonwealth)
- *Water NSW Act 2014*.

The Water Monitoring Program 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. 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 2018-19 are included in Section 5.

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) 2011

The Australian Drinking Water Guidelines (NHMRC, 2011) 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.

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, but all screening tests were clear in 2018-19. Radionuclide screening results are included in Appendix A.

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. Raw water supply agreements are in place between WaterNSW and 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 4.2). 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]	
	1,1-Dichloroethane		NA
	1,2-Dichloroethane		0.003 mg/L
	1,2-Dichloroethene		0.06 mg/L
	1,3-Dichloropropene (cis- and trans-)		0.1 mg/L
	Benzene		0.001 mg/L
	Hexachlorobutadiene		0.0007 mg/L
	Vinyl chloride		0.0003 mg/L
	Trichloroethylene		NA
	Pesticides		
	2,4-D		0.03 mg/L
	Acephate		0.008mg/L
	Aminopyralid		NA
	Amitrole		0.009 mg/L
	Atrazine		0.02 mg/L
	Azinphos-methyl		0.03 mg/L
	Chlorfenvinphos		0.002 mg/L
	Chlorothalonil		0.05 mg/L
	Chlorpyrifos		0.01 mg/L
	Clopyralid		2 mg/L
	Diazinon		0.004 mg/L
	Dichlobenil		0.01 mg/L
	Dimethoate		0.007 mg/L
	Diuron		0.02 mg/L
	Flupropionate		0.009 mg/L
	Fluroxypyr		NA
	Glyphosate		1.0 mg/L
	Hexazinone		0.4 mg/L
	MCPA (2-methyl-4-clorophenoxyacetic acid)		0.04 mg/L
	Metsulfuron-methyl		0.04 mg/L
	Picloram		0.3 mg/L
	Simazine		0.02 mg/L
	Triclopyr		0.02 mg/L
	Trifluralin		0.09 mg/L
	Radiological[2]		
	Gross alpha		0.5 Bq/L
	Gross beta		0.5 Bq/L

Notes:

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.

2 Australian Drinking Water Guidelines recommends that a screening level test is performed for radiological parameters.

Table 4.1b: Health-related Water Quality Characteristics: Physical, Chemical, Biological and Organic Characteristics

	SPECIFIC WATER CHARACTERISTIC	DRIVER	ADWG (2011) Health Guideline
PHYSICAL - CHEMICAL - BIOLOGICAL - ORGANIC	Arsenic Barium Beryllium Boron Iodide Mercury Molybdenum Selenium Silver Tin	ADWG (2011)[1] Health Guideline	0.01mg/L 2 mg/L 0.06mg/L 4 mg/L 0.5 mg/L 0.001 mg/L 0.05 mg/L 0.01 mg/L 0.1 mg/L N/A
	Antimony Cadmium Chromium (Cr^{VI}) Copper Lead Nickel	ADWG (2011)[2] Health Guideline via NSW Private Water Supply Guidelines (NSW Health, 2014)	0.003 mg/L 0.002 mg/L 0.05 mg/L 2 mg/L 0.01 mg/L 0.02 mg/L
	E. coli Enterococci *C. perfringens* *Cryptosporidium* *Giardia* Toxin producing cyanobacteria Toxicity Total cyanobacteria biovolume	Operating Licence[3]	Seek advice from NSW Health
	Geosmin MIB Total dissolved solids	Operational	N/A N/A N/A
	Algae (ASU) Alkalinity Aluminium Hardness Iron Manganese True colour Turbidity	Water Supply Agreements	Refer to Water Supply Agreements
	Total cyanobacteria biovolume *Microcystis aeruginosa* Toxicity Enterococci	Water Licences and Approvals Package (WLAP)[4]	Refer to *Guidelines for Managing Risks in Recreational Water* (NHMRC, 2008)
	Chlorophyll-a Lorenzen Phaeophytin Secchi depth	Operational	N/A N/A N/A N/A

Notes:

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.

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 4.2: Raw water supply agreements – Site specific specifications

<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 $CaCO_3$</th><th>mg/L as $CaCO_3$</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 rowspan="3">NA</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">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 2000

The Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000) (referred to as ANZECC, 2000) 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 are 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, 2000) for the 95-99 percent level of species protection (Table 4.3). Site specific benchmarks are to be developed for temperature and conductivity, and as such are not included in the table below.

Table 4.3: 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 (2000) guideline ranges for upland rivers (Table 4.4).

Table 4.4: 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 4.5: 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
Total cyanobacteria biovolume	mm^3/L	0.4	4	4
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 lowland rivers ecosystem types (Table 4.6).

Table 4.6: 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 (Table 4.7). Some benchmarks are prompts for action, such as chlorophyll-*a*, which triggers algal monitoring in the picnic area supply.

Table 4.7: 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	< 5
Total iron	mg/L	< 0.3
Total aluminium	mg/L	< 0.2
Total manganese	mg/L	< 0.1
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. Lake Yarrunga and Fitzroy Falls Reservoir being the only WaterNSW storages in the Sydney catchment area with recreational access, WaterNSW applies the National Health and Medical Research Council Recreational Waters Guidelines (NHMRC, 2008) for catchments and lakes (Table 4.8). The raw water and picnic areas benchmarks are from the ADWG.

Table 4.8: 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 levels of *Cryptosporidium* and/or *Giardia* detections 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 only samples from the upper 6 metres were included. On each sampling date, the mean of the data at each site was taken and compared to the relevant guideline 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 surface samples collected on each sampling occasion.

Compliance was 100% with the ADWG and 99.95% with Raw Water Supply Agreements. Overall, the water quality monitoring of the reservoirs in the declared catchment areas indicated good water quality which is typical for ongoing low inflow conditions.

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. 10.8% of the number of routine samples were taken for QA/QC purposes in 2018-19 to ensure the validity and accuracy of the WaterNSW's water quality data.

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 ISO 17025. 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 providers' QA/QC specialists analyse conformance with specified standards of accuracy and precision defined by WaterNSW to identify any contamination, outliers or errors.

Trip blanks

A total of 141 trip blanks were taken in 2018–19 across the Sydney catchment area. Sixteen trip blanks detected at least one analyte, representing a 11% anomaly rate. Anomalous detections included UV-absorbing constituents, ammoniacal nitrogen, chlorophyll-*a*, phaeophytin, alkalinity, manganese, aluminium, phosphorus and oxidised nitrogen. Biological indicators (lorenzen, chlorophyll-*a* and phaeophytin) were the most common detections (representing more than 50% of anomalous results). All detections were low and were not viewed as significant.

Field blanks

A total of 157 field blanks were taken in 2018–19. Twenty five field blanks returned positive results, equating to an anomaly rate of 16%. The analytes detected were oxidised nitrogen, dissolved organic carbon, lorenzen, phaeophytin, chlorophyll-*a*, manganese, aluminium, phosphorus, reactive silica and various metals. The detections were low level and represented minor contamination in the sampling process. Due to the ultra-trace levels of reporting for these analytes, intermittent anomalies are to be expected, the levels of detection did not impact operational decision making.

Duplicates

Duplicate samples can identify any contamination or procedural errors in all elements of sampling and analysis. The samples are used as a pass/fail performance metric. Duplicate results are assessed on the acceptable performance criteria determined by WaterNSW and the respective laboratory. If the variation of the sample is outside the performance criteria the duplicate is reanalysed. During 2018–19, 272 duplicate samples were collected for which 14 samples showed significant variation. Of these 14 samples, 25 analytes were outside of acceptable variation. Analytes that showed large duplicate variation included chlorophyll-*a*, organic carbon, phaeophytin, lorenzen, *C. perfringens*, nitrogen, sodium, aluminium, phosphorus, suspended solids, colour, chloride and UV absorbance. Investigations of anomalous duplicates suggested that the majority where due to sample heterogeneity. No duplicate pair showed variation of a magnitude to which WaterNSW would not accept the result.

5.2 Warragamba system

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

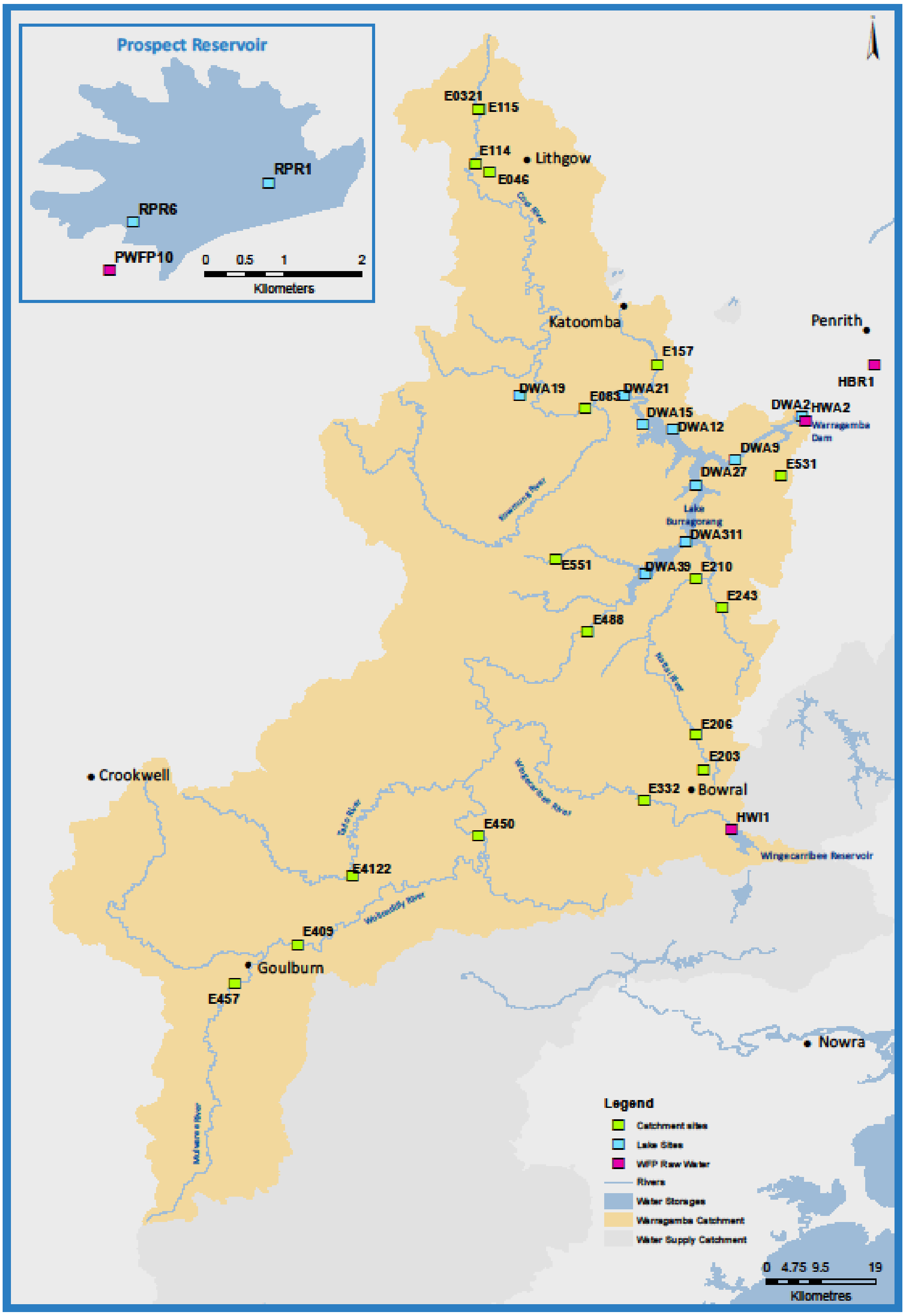

Figure 5.1: Sampling sites in the Warragamba system (including inset Prospect Reservoir)

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

Site	Station Code	Physico-Chemical							Nutrients						Metals			Cyanobacteria	
		Alkalinity (mgCaCO3/L)	Dissolved Oxygen (%Sat)	pH (Lab/Field)	Total Hardness (mgCaCO3/L)	True Colour at 400nm	Turbidity Lab/Field (NTU)	Conductivity (mS/cm)	Nitrogen Total (mg/L)	Phosphorus Total (mg/L)	Filtered Reactive Phosphorus (mg/L)	Oxidised Nitrogen (mg/L)	Ammoniacal Nitrogen(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).																			
Coxs River D/S Lake Lyell	E0114		42	92			8	92	100	100	100	83	8	25		0		25
Coxs River U/S Lake Lyell	E0115		25	100			0	100	100	75	33	17	0	50		0		75
Coxs River at Lithgow (next to the Power Station)	E0321		17	83			8	100	92	25	17	100	83	100		0		0
Farmers Creek Mt Walker	E046		0	17			25	42	100	75	67	100	33	58		0		58
Coxs River @ Kelpie Point	E083		17	58			0	67	50	33	17	33	8	83		0		25
Kowmung River @Cedar Ford	E130		33	8			0	0	25	17	8	25	17	33		0		8
Kedumba River@ Maxwells Crossing	E157		17	0			0	0	50	8	8	92	33	67		0		8
Gibbergunyah Ck 400m d/s of Mittagong STP Disch.	E203		17	0			0	92	100	92	25	100	83	100		0		42
Nattai River @ The Crags	E206		8	8			0	67	100	17	0	100	8	50		0		0
Nattai River @ Smallwoods Crossing	E210		50	0			0	50	33	8	0	50	25	17		0		25
Little River @ Fireroad W4I	E243		25	0			0	0	0	8	0	0	0	0		0		0
Wingecarribee River @ Berrima	E332		58	0			8	0	100	58	0	100	92	100		0		58
Wollondilly River @ Murrays Flat	E409		67	17			8	100	100	83	50	17	25	100		0		83
Wollondilly at Upper Tarlo	E4122		100	0			0	92	100	58	8	0	8	8		0		83
Wollondilly River @ Golden Valley	E450		33	17			0	83	92	8	0	25	33	92		0		67
Mulwaree River @ Towers Weir	E457		42	67			0	100	100	100	58	67	100	42		0		58
Wollondilly River @ Jooriland (Fowlers Flat)	E488		8	92			0	100	92	17	0	25	8	75		0		58
Werriberri Creek @ Werombi	E531		100	50			0	8	17	33	0	8	33	33		0		17

Site	Station Code	Physico-Chemical							Nutrients					Metals			Cyanobacteria	
		Alkalinity (mgCaCO3/L)	Dissolved Oxygen (%Sat)	pH (Lab/Field)	Total Hardness (mgCaCO3/L)	True Colour at 400nm	Turbidity Lab/Field (NTU)	Conductivity (mS/cm)	Nitrogen Total (mg/L)	Phosphorus Total (mg/L)	Filtered Reactive Phosphorus (mg/L)	Oxidised Nitrogen (mg/L)	Ammoniacal Nitrogen(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)																		
Lake Burragorang 9km d/s of DWA15	DWA12		31	46			0		8	19	0	54	8	4		0		0
Lake Burragorang @ 4KM U/S BUTCHERS CK.	DWA15		33	50			0		0	17	0	100	0	0		0		17
Lake Burragorang @ Kedumba River arm	DWA19		33	0			0		67	33	0	67	100	33		0		100
Lake Burragorang @ 500m u/s Dam Wall	DWA2		23	65			0		12	12	0	69	0	8		0		0
Lake Burragorang @ Coxs Arm 37km u/s Dam	DWA21		33	0			0		0	0	0	67	33	67		0		67
Lake Burragorang @ Woll. Arm 23 km u/s Dam	DWA27		27	54			0		8	8	0	46	0	12		0		0
Lake Burragorang @ Woll. Arm 300m u/s of Nattai R.	DWA311		17	50			0		0	17	0	33	0	17		0		17
Lake Burragorang @ Wollondilly Arm, 40km from dam	DWA39		0	33			0		0	0	0	67	0	67		0		33
Lake Burragorang @ 14km u/s of Dam Wall	DWA9		27	46			0		12	12	4	60	0	8		0		0
Lake Prospect @ Midlake	RPR1		0	0			0		0	33	0	25	8	8		0		45
Lake Prospect @ Inlet to RWPS	RPR6		0	0			0		0	17	0	17	0	0		0		33
Raw Water (raw water supply agreement site specific standards refer Table 4.2)																		
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	0			0	0	0							0	0	0	0	

5.2.1 Catchments

Water quality in Lake Burragorang's river catchments in 2018-19 showed similar characteristics to previous years, with catchments dominated by agricultural and urban land uses regularly exceeding ANZECC benchmarks. Water monitoring sites in the Mulwaree, Wingecarribee, Wollondilly and upper Coxs catchments most frequently exceeded benchmarks, particularly for nutrient loads and conductivity. An increase in total aluminium exceedances is noted throughout the catchment sites when compared to 2017-18.

Sites downstream of sewage treatment plants continued to regularly exceed benchmarks. These sites are located at Farmers and Gibbergunyah Creeks.

Highly protected natural catchments such as the Kowmung, Kedumba and Little River returned considerably fewer exceedances for most parameters when compared to upstream sites. The Coxs River continues to show significant effects of pollution sources in the upper catchment, showing improvements in the lower Coxs River catchment where the river enters protected areas.

5.2.2 Storages

Water was of excellent quality in Lake Burragorang during 2018-19. Turbidity remained particularly low due to the absence of significant inflow events.

Total nitrogen exceeded on fewer occasions than in 2017-18, though conversely, the total phosphorous exceeded the guidelines more frequently. Filterable reactive phosphorus, however remained stable with very few exceedances.

Chlorophyll-*a* showed a decreasing number of exceedances at all sites except for the Coxs River arm of the lake near the Kedumba River (site DWA19), which exceeded the guideline in all samples. This upper lake site was only sampled on three occasions, with low lake levels restricting access to this site for most of the year. There were no associated algal issues or impacts downstream.

Aluminium exceedances showed a significant increase when compared to the previous year, particularly in the upstream inflow sites of both major tributaries.

Water quality in Prospect Reservoir was of good quality and posed no challenges for treatment to the Prospect Water Filtration Plant. While total nitrogen was below benchmarks for each site, a small number of exceedances were noted for oxidised nitrogen (nitrate + nitrate). A significant increase in the number of exceedances for total phosphorus is noted.

5.2.3 Water Filtration Plants

Water supplied to the water filtration plants remained of excellent quality throughout the period, with no exceedances recorded.

5.3 Upper Nepean system

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

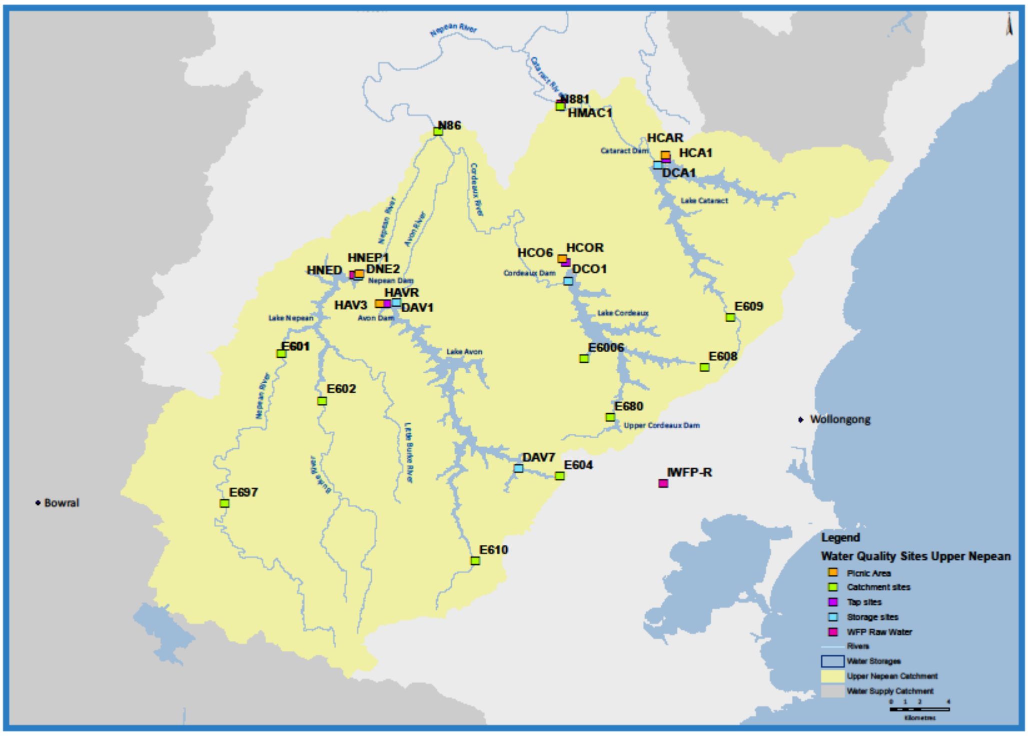

Figure 5.2: Sampling sites in the Upper Nepean system.

5.3.1 Catchments

Water quality across the Upper Nepean catchment sites varies according to land use and natural catchment characteristics. This year recorded increases in the percentage of nitrogen and phosphorus samples outside benchmarks at both of the Nepean River sites. These sites typically record the highest median nutrient levels of the Upper Nepean catchments, which is expected given the land use. However, increases this year were also associated with the increased nutrients received from Wingecarribee Reservoir as part of inter-basin water transfers. Transferred water contributed to most of the flow during these dry periods. The transferred water also contained a higher algal load which contributed to the rise in chlorophyll-*a* at these sites.

pH was frequently lower than the ANZECC benchmark range at some sites, particularly Sandy Creek, Burke River and Cataract River, but this is typical for these sub-catchments. Dissolved oxygen recorded improvements at most sites in the Upper Nepean catchment.

Natural geology, drought and groundwater contributions frequently drive the aluminium above benchmarks in the Cordeaux and Cataract catchment sites. The highest median this year was recorded in the Sandy Creek while the maximum concentration was recorded in the Cataract River.

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

Site	Station Code	Physico-Chemical							Nutrients						Metals			Cyanobacteria	
		Alkalinity (mgCaCO3/L)	Dissolved Oxygen (%Sat)	pH (Lab/Field)	Total Hardness (mgCaCO3/L)	True Colour at 400nm	Turbidity Lab/Field (NTU)	Conductivity (mS/cm)	Nitrogen Total (mg/L)	Phosphorus Total (mg/L)	Filtered Reactive Phosphorus (mg/L)	Oxidised Nitrogen (mg/L)	Ammoniacal Nitrogen(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 cells are greyed out.																		
Sandy Creek inflow	E6006		83	100			0	0	0	33	0	0	0	100		0		0
Nepean River @ Inflow to Lake Nepean	E601		8	0			0	0	50	17	0	92	8	33		0		25
Burke River @ inflow to Lake Nepean	E602		0	50			0	0	8	8	0	0	0	33		0		0
Flying Fox Creek No.3	E604		67	0			0	0	33	8	0	75	0	17		0		0
Goondarin Creek inflow	E608		50	17			0	0	25	0	0	100	0	92		0		0
Cataract River inflow	E609		58	33			0	0	8	0	0	100	75	67		0		0
Avon River - Summit Tank	E610		42	8			0	0	0	0	0	8	0	17		0		0
Cordeaux River at causeway between U.Cord. 1 & 2	E680		50	0			0	0	0	0	0	100	33	8		0		25
Nepean River @ McGuire's Crossing	E697		17	17			8	0	58	33	0	92	33	50		0		42
Storages (ANZECC guidelines refer Table 4.3)																		
Lake Avon @ Dam Wall	DAV1		8	17			0		0	8	0	67	33	0		0		0
Lake Avon @ Upper Avon Valve Chamber	DAV7		17	0			0		0	8	0	25	8	8		0		33
Lake Cataract @ Dam wall	DCA1		0	8			0		8	0	0	92	75	33		0		17
Lake Cordeaux @ Dam wall	DCO1		17	0			0		8	33	0	58	50	25		0		75
Lake Nepean @ 300m u/s dam wall	DNE2		58	0			0		50	58	8	100	67	25		0		25
Raw Water (raw water supply agreement site specifications refer Table 4.2)																		
Nepean WFP raw water	HNED	0			0	0	0							0	0	0	0	
Illawarra WFP raw water	IWFP-R	8			0	0	0							0	0	0	0	
Macarthur WFP raw water	HMAC1	0			0	0	0							0	0	0	42	

5.3.2 Storages

Water quality in the Upper Nepean lakes continued to record a high compliance against ANZECC benchmarks. Lake water quality is driven by local geology and catchment inflow quality. Turbidity, filterable reactive phosphorus and manganese achieved full compliance. The percentage of samples outside benchmarks for pH improved at most sites.

Lake Nepean recorded increases in the total phosphorus and total and oxidised nitrogen. Despite the increased nutrients there was no associated increase in chlorophyll-*a*, which recorded an improvement to 25% samples above the 5 µg/L benchmark. The other lakes in the Upper Nepean recorded low phosphorus and nitrogen concentrations. Full compliance was achieved in Lake Avon for both total phosphorus and total nitrogen, while Lake Cataract recorded only one sample above the total nitrogen benchmark.

Chlorophyll-*a* exceedance against the ANZECC benchmark remained highest in Lake Cordeaux with no change from last year, where 75% of samples were above the benchmark. There was an associated increase in algal concentrations particularly in spring 2018. Lake Cordeaux was not on supply to downstream customers for most of the year due to low storage levels and storage balancing in the Upper Nepean system.

5.3.3 Water Filtration Plants

Alkalinity exceeded the raw water standards on one occasion at Illawarra WFP with a result of 14 mg$CaCO_3$/L. The elevated result was confirmed with lab re-analysis. The result was higher than the 5 mg$CaCO_3$/L recorded in the upper lake supply point, indicating that any spike in the raw water was likely to have only been for a short period. The WFP reported no issues with their raw water or treatment process.

The filter clogging algae potential at Macarthur WFP was elevated for most of the year with five samples above the raw water supply agreement trigger. Filter run times were reduced at Macarthur WFP, but the finished water 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.

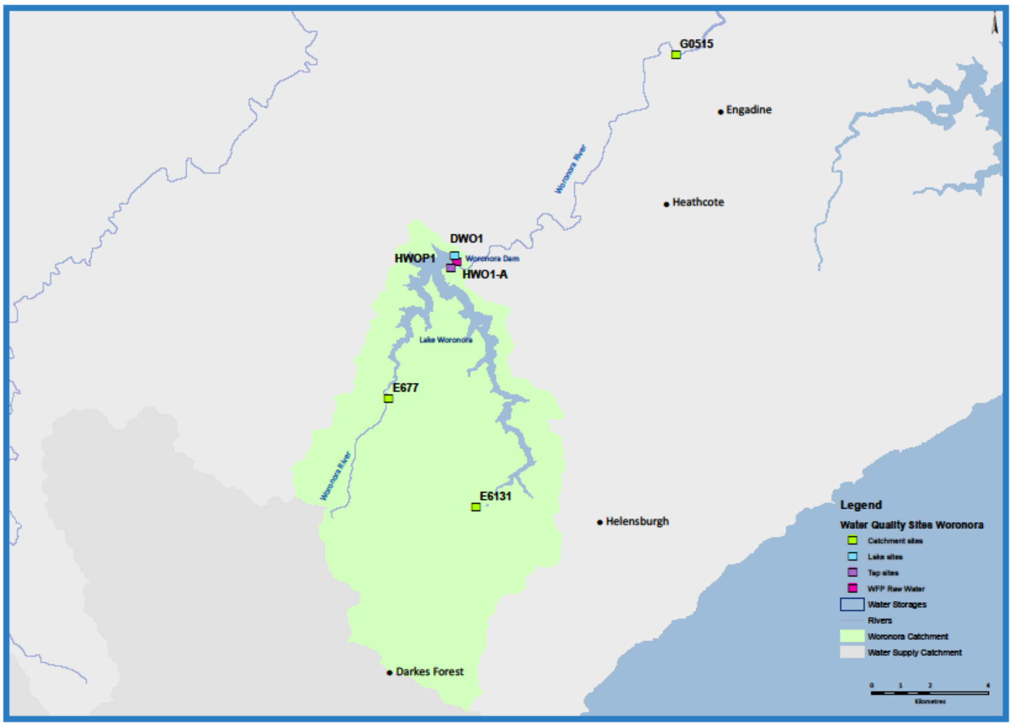

Figure 5.3: Sampling sites in the Woronora system.

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

Site	Station Code	Physico-Chemical							Nutrients					Metals			Cyanobacteria	
		Alkalinity (mgCaCO3/L)	Dissolved Oxygen (%Sat)	pH (Lab/Field)	Total Hardness (mgCaCO3/L)	True Colour at 400nm	Turbidity Lab/Field (NTU)	Conductivity (mS/cm)	Nitrogen Total (mg/L)	Phosphorus Total (mg/L)	Filtered Reactive Phosphorus (mg/L)	Oxidised Nitrogen (mg/L)	Ammoniacal Nitrogen(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 cells are greyed out.																		
Waratah Rivulet d/s Flatrock Crossing	E6131		33	0			0	0	0	0	0	17	0	17		0		0
Woronora River	E677		83	83			0	0	0	0	0	8	0	33		0		8
Storages (ANZECC guidelines refer Table 4.3)																		
Lake Woronora @ Dam Wall	DWO1		25	0			0		0	8	0	100	17	17		0		8
Raw Water (raw water supply agreement site specific specifications refer Table 4.2)																		
Woronora WFP	HWO1-A	0			0	0	0							0	0	0	0	

5.4.1 Catchments

Water quality in the Waratah Rivulet and Woronora River was consistently good. Turbidity, conductivity, total nitrogen, total phosphorus and total manganese were below the ANZECC benchmarks on all sampling occasions during the period.

The percentage of pH samples outside the ANZECC benchmarks remained the same as last year, with Waratah Rivulet recording full compliance but most samples from the Woronora River outside the benchmarks. The Woronora River recorded typically low pH ranging from 5.5 to 6.8 pH units throughout the year. This is common for the Woronora River catchment due to groundwater infiltration from surrounding Hawkesbury sandstone.

One sample exceeded the chlorophyll-*a* benchmark in September with a result of 6 µg/L. Despite the increase in chlorophyll-*a* there were no issues with problematic algae at this site.

The dissolved oxygen recorded in the catchment rivers did not meet the ANZECC benchmarks on several occasions. Dissolved oxygen saturation is closely linked with low flow conditions.

5.4.2 Storage

Water quality in Lake Woronora remained at a superior standard with high compliance against ANZECC benchmarks. Full compliance was also achieved for turbidity, total nitrogen, filterable reactive phosphorus and total manganese.

High levels of dissolved oxygen saturation were maintained throughout the year in Lake Woronora. These oxygen levels are maintained naturally during the cooler months and by using the aeration system throughout spring and summer. Operation of the aeration system at times can contribute to dissolved oxygen saturation above the benchmark. Keeping the lake de-stratified avoids water quality issues which occur under very low oxygen conditions.

Oxidised nitrogen remains above the ANZECC benchmark on all occasions. This is typical for Lake Woronora and despite these levels algal bloom development was not noticed. Only one chlorophyll-*a* sample was above the benchmark.

Aluminium concentrations continued to steadily decrease this year, following peaks recorded from June 2016 wet weather inflow (83% exceedance). Last year recorded 33% of samples exceedance while this year recorded only 25% exceedance. Concentrations are expected to remain low during periods of drought.

5.4.3 Water Filtration Plant

All water sample results were within the raw water supply agreement specifications for raw water supplied to Woronora Water Filtration Plant. Aesthetic qualities, such as true colour, have improved to low levels which are only recorded in periods of drought. 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.

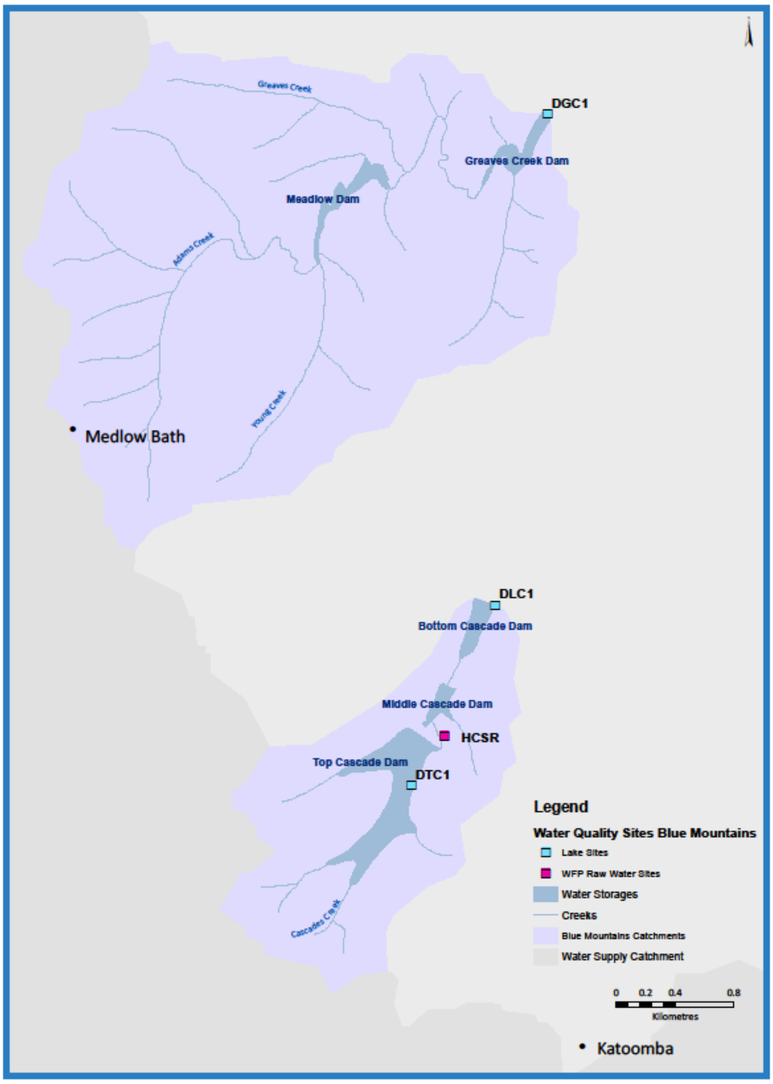

Figure 5.4: Sampling sites in the Blue Mountains system.

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

Site	Station Code	Physico-Chemical							Nutrients						Metals			Cyanobacteria	
		Alkalinity (mgCaCO3/L)	Dissolved Oxygen (%Sat)	pH (Lab/Field)	Total Hardness (mgCaCO3/L)	True Colour at 400nm	Turbidity Lab/Field (NTU)	Conductivity (mS/cm)	Nitrogen Total (mg/L)	Phosphorus Total (mg/L)	Filtered Reactive Phosphorus (mg/L)	Oxidised Nitrogen (mg/L)	Ammoniacal Nitrogen(mg/L)	Aluminium Total (mg/L)	Iron Total (mg/L)	Manganese Total (mg/L)	Areal Standard Unit (algae)	Chlorophyll-a (ug/L)
Storages (compliance with ANZECC guidelines – refer Table 4.3). Where there is no applicable benchmark cells are greyed out.																			
Lake Greaves @ dam wall	DGC1		67	100			0		8	42	17	58	67	100		0		50
Lake Lower Cascade@ 50m U/S	DLC1		17	0			0		0	17	0	100	33	0		0		17
Lake Top Cascade @ 100m u/s Dam Wall	DTC1		33	0			0		33	25	0	75	42	0		0		42
Raw Water (compliance with raw water supply agreement site specific standards - refer Table 4.2)																			
Cascade WFP raw water	HCSR	17			0	0	0							0	0	0	8	

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 reflected drier weather and the increased proportion of flow sourced from Lake Oberon. Dissolved oxygen levels are kept high through use of destratification fans in the lakes. Dissolved oxygen at times fell below the 90% saturation benchmark, however minimum levels ranged from 85 to 88% saturation which did not impact on lake or water supply quality.

One-third of the samples collected in Top Cascade Lake exceeded the benchmarks for total nitrogen and total phosphorus. This is associated with Lake Oberon transfers, which have high nutrients from a largely agricultural catchment.

Lake Greaves and Top Cascade Lake experienced an increase in the number of samples which exceeded the chlorophyll-*a* benchmark. There were periods when the algal concentrations were also elevated. Lake Greaves recorded elevated filter clogging algae concentrations in late summer but were lower in comparison to summer and autumn 2017-2018. Top Cascade Lake recorded high concentrations of algae in autumn 2019, which may have been associated with the increased nutrients in the lake.

5.5.3 Water Filtration Plant

Transfers from Lake Oberon are reflected in the water quality supplied to Cascades Water Filtration Plant. There was one sample which was above the raw water supply agreement for algae ASU. The sample recorded 2,072 ASU/mL in April 2019. Odour and issues with treating the high filter load were reported by the WFP. Cooling water temperatures saw a large reduction in algae, with the May sample recording a decline to 611 ASU/mL.

Alkalinity exceeded the raw water standard of >30 $mgCaCO_3/L$ on two occasions at Cascades WFP, with results of 32 $mgCaCO_3/L$ in July 2018 and 33 $mgCaCO_3/L$ in June 2019. The elevated results may be associated with long term increases in alkalinity associated with transfers from Oberon Dam (naturally higher in alkalinity). The WFP reported no issues with their raw water or treatment process.

5.6 Shoalhaven system

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

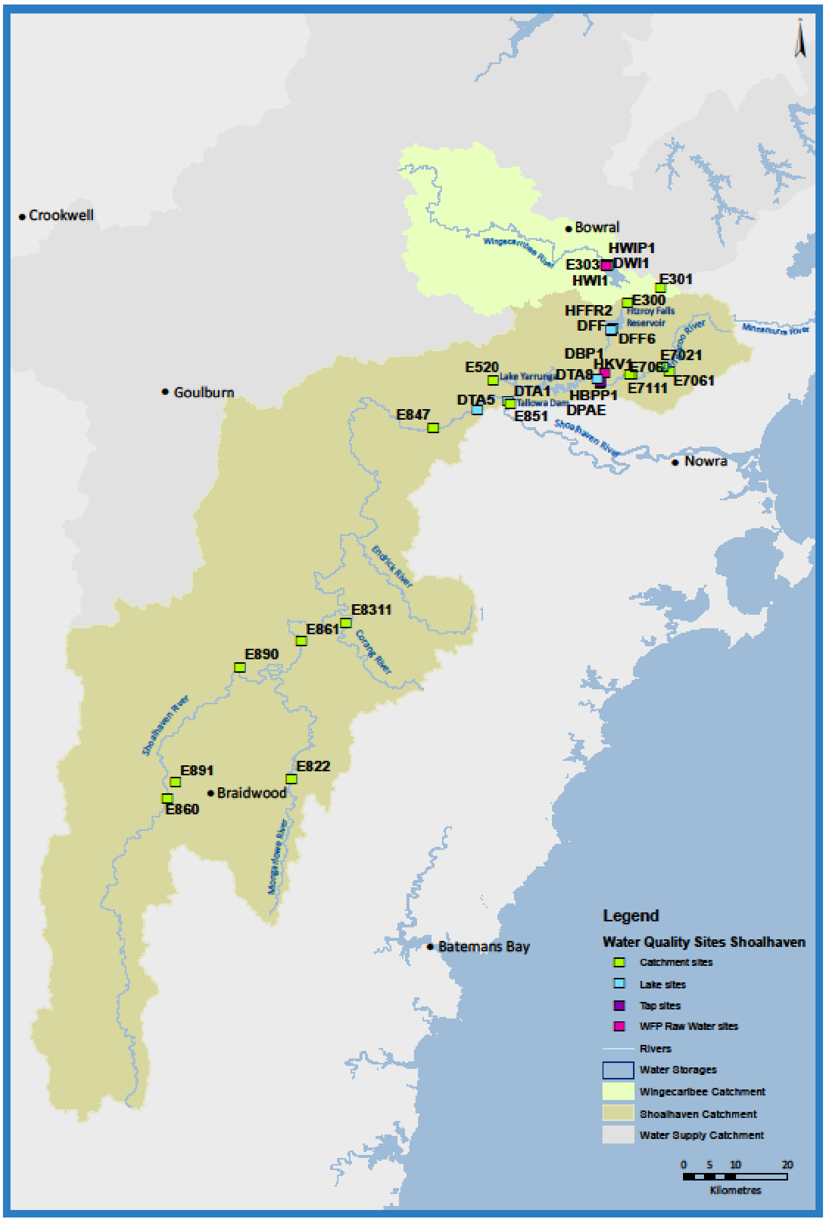

Figure 5.5: Sampling sites in the Shoalhaven system

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

Site	Station Code	Physico-Chemical							Nutrients						Metals			Cyanobacteria	
		Alkalinity (mgCaCO3/L)	Dissolved Oxygen (%Sat)	pH (Lab/Field)	Total Hardness (mgCaCO3/L)	True Colour at 400nm	Turbidity Lab/Field (NTU)	Conductivity (mS/cm)	Nitrogen Total (mg/L)	Phosphorus Total (mg/L)	Filtered Reactive Phosphorus (mg/L)	Oxidised Nitrogen (mg/L)	Ammoniacal Nitrogen(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 cells are greyed out.																			
Wildes Meadow Creek at gauge	E300		92	42			0	0	100	33	0	92	75	100		0		17
Caalang CK Old Kangaloon Rd Ford	E301		33	0			0	0	100	17	0	100	25	67		0		25
Bundanoon Creek at the Rocks	E520		0	0			0	0	17	17	0	58	0	25		0		0
Brogers Creek@Clinton Park	E7021		25	42			0	0	33	67	42	83	25	100		0		0
Kangaroo River @ Hampden Bridge	E706		25	0			0	0	67	83	67	100	92	92		0		42
Kangaroo River at Oakdale	E7061		42	8			8	0	25	25	0	83	8	58		0		8
Mongarlowe R. at Mongarlowe	E822		50	17			0	8	8	0	0	8	17	83		0		17
Corang River	E8311		25	50			0	0	25	8	0	0	8	92		0		8
Shoalhaven R @ Fossickers Flat	E847		0	8			8	0	42	17	0	33	8	100		0		17
Shoalhaven R @ Mount View	E860		42	8			0	0	33	33	8	0	8	33		0		17
Shoalhaven R @ Hillview	E861		0	8			8	0	25	25	0	17	8	58		0		17
Boro Ck @ Marlowe	E890		92	25			8	0	25	50	0	0	17	100		0		33
Gillamatong Creek @ Braidwood	E891		92	8			0	100	75	75	42	25	33	33		0		50

Site	Station Code	Physico-Chemical							Nutrients					Metals			Cyanobacteria	
		Alkalinity (mgCaCO3/L)	Dissolved Oxygen (%Sat)	pH (Lab/Field)	Total Hardness (mgCaCO3/L)	True Colour at 400nm	Turbidity Lab/Field (NTU)	Conductivity (mScm-1)	Nitrogen Total (mg/L)	Phosphorus Total (mg/L)	Filtered Reactive Phosphorus (mg/L)	Oxidised Nitrogen (mg/L)	Ammoniacal Nitrogen(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)																		
Bendeela Pondage	DBP1		50	0			0		83	100	17	83	100	100		0		100
Lake Fitzroy Falls @ Midlake	DFF6		8	8			0		100	75	0	92	92	92		0		92
Lake Yarrunga@ 100m from Dam Wall	DTA1		67	0			0		58	58	8	75	50	42		0		42
Lake Yarrunga @ Shoalhaven River	DTA5		67	0			0		67	67	8	67	58	50		0		50
Lake Yarrunga @ Kangaroo River at Bendeela PS	DTA8		42	8			0		58	100	42	92	92	92		0		100
Wingecarribee Lake at outlet	DWI1		25	0			0		100	75	8	100	100	100		0		100
Raw Water (raw water supply agreement site specifications refer Table 4.2)																		
Kangaroo Valley WFP Inlet	HKV1	0		0	0	0	0								0		0	
Wingecarribee WFP raw water	HWI1	0		0	0	0	0								0		0	

5.6.1 Catchments

Water quality was consistent with previous years, with sampling sites in agricultural and urbanised regions continuing to regularly exceed ANZECC benchmarks.

Aluminium continues to regularly exceed the guidelines at all sites, and nutrients continue to be a challenge across the system.

Wildes Meadow Creek and Caalang Creek continue to show regular exceedances, with the sites once again showing poor results with regards to dissolved oxygen, nutrients and aluminium.

5.6.2 Recreational Monitoring

Beendeela Campground exceeded major alert benchmarks for primary contact in 49% of samples due to enterococci results. Lake Yarrunga saw a slight increase in bacteria numbers with 10% of samples exceeding major alerts for primary contact. The associated health risk was managed through public notification.

Increased cyanobacteria activity in Fitzroy Falls resulted in minor alert exceedances in around 25% of samples. The lake was below secondary contact triggers throughout the year which did not impact on recreational activities in the lake.

Table 5.6: Recreational monitoring - percentage of samples exceeding benchmarks

Site	Station Code	Primary Contact Minor Alert Benchmark Percentage Exceedance				Secondary Contact & Primary Contact Major Alert Benchmark Percentage Exceedance			
		Enterococci (cfu/100 mL)	Microcystin LR+ YR + RR (µg/L)	Total Cyanobacterial biovolume (mm3/L)	Toxic Cyanobacterial cell count (cells/mL)	Enterococci (cfu/100 mL)	Microcystin LR+ YR + RR (µg/L)	Total Cyanobacterial biovolume (mm3/L)	Toxic Cyanobacterial cell count (cells/mL)
Recreational monitoring (MRRW and ADWG guidelines – refer Table 4.5).									
Fitzroy Falls	DFF	9	NA	9	24	0	0	0	0
Bendeela Camping Ground	DPAE	49	NA	0	5	13	0	0	0
Lake Yarrunga	DTA8	10	NA	0	0	7	0	0	0

5.6.3 Storages

Analysis of the storages in the Shoalhaven system continue 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 once again exceeded the benchmark in all samples collected from near Bendeela pumping station and Wingecarribee Reservoir. Concentrations continued to be high across the Shoalhaven storages, similar to the previous year. The high levels of aluminium are the result of the geology of the region and is consistent with knowledge of the area and previous analyses.

Wingecarribee Reservoir was once again troubled with high numbers of potentially toxin producing cyanobacteria for most of the year and was closely monitored throughout 2018-19. Wingecarribee Water Filtration Plant effectively managed the risk of algal cells and toxins through the use of powdered activated carbon in the treatment process. Multiple incidents were recorded throughout the monitoring period and details of incidents involving potential toxin producing cyanobacteria in Wingecarribee Reservoir are reported in section 8.1.

5.6.4 Water Filtration Plants

All routine sampling undertaken throughout the year met the site-specific guidelines of Kangaroo Valley and Wingecarribee water filtration plants.

5.7 Algal monitoring

All routine catchment and lake samples are analysed for algae if chlorophyll-*a* exceeds 5 µg/L. There are selected lake sites, which are the closest point to supplying water filtration plants, which 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

Similarly to prior years, the chlorophyll-*a* concentrations in the Wollondilly catchments regularly exceeded benchmarks triggering speciation but potentially toxin producing cyanobacteria were rarely detected. Brief blooms of potentially toxin producers were noted in the Wingecarribee River at Berrima and the Mulwaree River at Towers Weir.

Chlorophyll-*a* was low in the Coxs River sites excluding the sites upstream of Lake Lyell and Farmers Creek at Mt Walker, which both regularly exceeded the chlorophyll-*a* benchmarks. Whilst the site upstream of Lake Lyell showed regular populations of potentially toxin producing cyanobacteria, Farmers Creek recorded no detections of these organisms.

In Lake Burragorang algal speciation was rarely triggered in the upper Wollondilly arm.

The Coxs River arm again returned a significant number of chlorophyll-*a* exceedances, with the Kedumba River returning the highest median (100% of the samples above the benchmark, however only three samples collected during the year). High chlorophyll-*a* concentrations were noted in the Coxs River inflow site in September 2018, which was attributed to a short lived bloom of the chrysophyte *Dinobryon*.

Chlorophyll-*a* concentrations in Prospect Reservoir exceeded the benchmarks more often this year, with 45% of the samples at the mid lake site and 33% of those at the inlet to the RWPS above the threshold. Concentrations of potentially toxin producing algal species were periodically recorded but remained well below levels of concern. No algal toxins were detected during the reporting period.

Raw water supplied to Orchard Hills, Warragamba and Prospect WFPs continued to meet the Raw Water Supply Agreement and ADWG criteria with respect to algae.

5.7.2 Upper Nepean system

Catchment sites in the Upper Nepean system showed very low chlorophyll-*a* concentrations throughout most of 2018-19. Three of the nine catchment sites in the system recorded at least one exceedance above the 5 µg/L benchmark during the period. These sites were in the Nepean and Cordeaux catchments. Highest concentrations were recorded in the upper Nepean River from November through to February. The algal assemblage was reflective of water transferred from Wingecarribee Reservoir, including potentially toxin producing algae, with concentrations decreasing longitudinally in the Nepean River.

The potentially toxin producing cyanobacteria *Microcystis* was recorded at Lake Nepean above the minor incident level in December 2018 (one sample). To reduce the risk of potentially toxin producing cyanobacteria entering the raw water the supply was swapped to the lower outlet on 15 January 2019. Follow up sampling recorded significantly lower concentrations of *Microcystis* but remained above the alert level (>1,000 cells/mL) until 12 February.

Algal monitoring in the Cataract and Cordeaux lakes recorded nil potentially toxin producing cyanobacteria during the 2018-19 period. Lake Avon recorded low concentrations of *Radiocystis* in the upper lake in November 2018 and May 2019. This taxa is recognised as a toxin producer overseas however there are no published studies confirming toxin production in Australia.

Filter clogging algae were elevated in Upper Lake Avon with peaks in November 2018 (1,087 ASU/mL) and April 2019 (1,120 ASU/mL). During the year the algal ASU in the raw water to Illawarra WFP only rose to the alert level (>500 – 2,750 ASU/mL) with no impacts reported at the WFP.

Lake Cordeaux recorded unseasonally high filter clogging algae concentrations throughout 2018-19. During this period options for supply to Macarthur WFP were reviewed and releases adjusted to minimise impacts of filter clogging algae in the Broughtons Pass Weir. Initially the high concentrations were due to presence of a diatom, *Synedra*. This bloom commenced in April 2018 and persisted until October 2018, with peak concentrations of this taxa recorded in August and contributing 2,931 ASU of the total algae result of 4,030 ASU/mL. Monitoring in late October recorded a shift to green algae, dominated by *Spondylosium* and contributing 5,061 ASU to the total algae result of 5,857 ASU/mL before a sharp decline in December. Raw water supplied to Macarthur WFP recorded filter clogging algae above the supply agreement on five occasions, with algae concentrations typical for this site.

5.7.3 Woronora system

Chlorophyll-*a* remained below the threshold for algal analysis in the Waratah Rivulet and Woronora River throughout the year. Algal concentrations were low in Lake Woronora. There were no potentially toxin producing cyanobacteria species detected in the lake or in raw water supplied for treatment.

5.7.4 Blue Mountains system

Chlorophyll-*a* concentrations increased this year in both Lake Greaves and Top Cascade Lake. A rise in filter clogging algae was recorded in Top Cascade Lake from February to May 2019. The peak was recorded on 4 April 2019 at 3,296 ASU/mL. The dominant contributors were the diatom *Synedra* (4,804 cells/mL; 1,706 ASU/mL) and green alga *Dictyosphaerium* (34,994 cells/mL; 1,050 ASU/mL). The raw water sample on 11 April recorded 2,072 ASU/mL which was above the minor incident level and raw water supply agreement (see section 8.1.1. for further details). Significant algal decreases were recorded in May.

Similar to the 2017-18 season a bloom of green algae in Lake Greaves resulted in very high filter clogging potential for several months. The peak was recorded in February 2019 with a total of 4,112 ASU/mL, which was significantly less than last year's peak of 10,540 ASU/mL in March 2018. As in 2018, the green alga *Kirchneriella* provided the largest biomass and filter clogging potential during the bloom. Management of transfers from Lake Greaves to the Cascade lakes mitigated the impacts of algae in the receiving lakes and raw water supply.

Low concentrations of potentially toxin-producing cyanobacteria were recorded in Top Cascade Lake from December through to May. There was a single sample with a low concentration of potentially toxin-producing cyanobacteria in Lake Greaves.

The raw water recorded low counts of potentially toxin-producing cyanobacteria on several occasions throughout the year, with the maximum of 1,404 cells/mL recorded in January. These counts were sporadic and generally not present in follow up sampling. The raw water supplied to the Cascades WFP complied with cyanobacteria guidelines in all samples during 2018-19.

5.7.5 Shoalhaven system

Algae are historically common in the Shoalhaven system and chlorophyll-*a* exceeded the 5 µg/L threshold at most catchment sites at least once during the year. Gillamatong Creek showed a slight improvement from the previous year, with 50% of the samples analysed exceeding the guideline (a decrease from 67% in 2017-18). Total nitrogen and phosphorus routinely exceeded the guidelines at this site, contributing to the poor chlorophyll-*a* performance.

Similarly to 2017-18, the Hampden Bridge site on the Kangaroo River once again exceeded the chlorophyll-*a* criterion in 42% of samples.

All storages in the Shoalhaven system once again exceeded the chlorophyll-*a* benchmark regularly throughout the year. Lake Yarrunga at the Kangaroo River, Bendeela Pondage and Wingecarribee reservoir all exceeded the guideline on 100% of the sampling occasions, with Fitzroy Falls recording exceedance on 92% of occasions.

Potentially toxin producing cyanobacterial blooms persisted in Wingecarribee Reservoir again throughout the year. Combined microcystin concentration in Wingecarribee Reservoir peaked in February 2018 with a concentration of 1.35 µg/L. See section 8.1.2 for more details on this incident. Details of all algal incidents and the responses can be found in Appendix C.

Raw water supplied to Kangaroo Valley and Wingecarribee WFPs complied with the ADWG cyanobacterial toxin guidelines throughout the reporting period.

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

Monitoring for *Cryptosporidium* and *Giardia* is undertaken at seven selected streams in the Warragamba catchment as part of the routine 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.

Cryptosporidium oocysts were detected at three of the catchment sites during the reporting period:
1/50 (2%) of samples from Werriberri Creek (E531) at a concentration of 1.5 oocysts/10 L
1/12 (8%) of samples from Kowmung River (E130) at a concentration of 1.2 oocysts/10 L
1/12 (8%) of samples from Kedumba River (E157) at a concentration of 1.2 oocysts/10 L.

Giardia cysts were detected at two of the catchment sites during the reporting period:
2/12 (17%) of samples from Coxs River (E083) at a concentration of 5.3 cysts/10 L
1/50 (2%) of samples from Werriberri Creek (E531) at a concentration of 1.3 cysts/10 L.

5.8.2 Storages

Routine monitoring was conducted six days per week at one lake site in Lake Burragorang (DWA2), weekly at Prospect (RPR1) and Wingecarribee (DWI1) reservoirs and monthly at Prospect Reservoir (RPR6). *Cryptosporidium* was detected at DWA2 (2/313), RPR1 (1/52) and DWI1 (3/52) and *Giardia* at DWA2 (1/313), RPR1 (2/52) and DWI1 (1/52); none reached the minor incident threshold of 10/10 L.

5.8.3 Water Filtration Plants

A joint monitoring program in raw water at the inlet of Sydney Water's 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 (oo)cysts/10 L) of *Cryptosporidium* or *Giardia* from routine monitoring of water filtration plants during the reporting period.

(Oo)cysts were detected at alert levels (≥1 (oo)cysts/10 L) at two raw water supplies during the reporting period. *Cryptosporidium* oocysts exceeded the alert threshold on two occasions (max. 1.4/10 L) and *Giardia* cysts on one occasion (1.25/10 L) at Macarthur WFP, and once at Cascades (1.25 oocysts/10 L and 1.9 cysts/10 L).

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. Monitoring is also undertaken at the picnic areas which receive reticulated town water.

Table 5.7: Picnic areas - percentage of samples exceeding benchmarks.

Site	Station Code	pH (Lab/Field)	Turbidity Lab/Field (NTU)	Aluminium Total (mg/L)	Iron Total (mg/L)	Manganese Total (mg/L)	Free Chlorine residuals (mg/L)	Chlorophyll a (ug/L)	Toxic Cyanobacteria (calls/mL)	Microcystin variants (µg/L)	*E. coli* (orgs/100 mL)
Picnic taps (ANZECC guidelines refer Table 4.6).											
Avon Picnic Area Tap	HAV3	0	4	0	14	0	94	0	-	-	2
Cataract Picnic Area Tap	HCA1	6	4	13	78	12	76	0	-	-	2
Cordeaux Picnic Area Tap	HCO6	0	10	0	35	10	94	8	0	-	2
Fitzroy Falls Picnic Area Tap	HFFR2	0	4	0	6	0	6	0	-	-	2

Low residual chlorine was again observed and is due to long residence times and chlorine decay in the reticulation system. The efficacy of chlorination is based on chlorine concentrations and contact times at the treatment plants, as well as the absence of indicator bacterial.

Each of the treated sites returned a single *E. coli* detection. Avon and Cordeaux was attributed to contamination of the samples in November. A detection in the Cataract sample in December was due to a localised rainfall event resulting in poor water quality in the system. This event was identified prior to the bacteria results through turbidity monitoring. Management actions were implemented as agreed with the Public Health Unit as per the Quality Assurance Plan (QAP). Response as per the QAP was also implemented at Fitzroy Falls in October following the detection of 2 org/100mL.

Exceedances in turbidity have increased this year. Localised rainfall in Cataract and Cordeaux catchments in December contributed to these results. On multiple occasions exceedance values were higher at the end tap than the dosing reservoir. This is due to increased residence time in the reticulation system during times when the picnic areas have been closed through the week for maintenance work.

Aesthetic guidelines for iron and manganese were exceeded in samples primarily from Cataract and Cordeaux which typically have higher metal concentrations in source waters. While these results are in line with previous years, avoidance of elevated metals is currently more difficult due to lowering storage levels.

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 (Lab/Field)	Turbidity Lab/Field (NTU)	Dissolved Oxygen (%Sat)	Nitrogen Total (mg/L)	Phosphorus Total (mg/L)	Chlorophyll a (ug/L)
Wingecarribee River								
Wingecarribee River @ Sheepwash Bridge	E303	12	0	0	8	100	0	100
Shoalhaven River								
Shoalhaven R @ d/s Tallowa Dam	E851	12	0	0	0	8	0	42
Woronora River								
Woronora River @ the Needles	G0515	12	42	0	83	0	0	42
Nepean River								
Nepean River @ Yarramundi	N44	12	8	0	25	100	0	36
Nepean River at Penrith Weir	N57	12	8	0	25	64	0	64
Nepean River 500m D/S of confluence of Warragamba River	N64	12	0	0	25	100	0	82
Warragamba River U/S of confluence of Nepean River	N641	12	0	0	42	0	0	0
Nepean River @ Wallacia Bridge	N67	12	0	0	33	92	0	92
Nepean River @ Sharpes Weir	N75	12	0	0	8	92	8	67
Nepean River @ Menangle Br	N85	12	0	0	25	9	0	67
Pheasant's Nest Weir Pool	N86	12	0	0	0	0	0	25
Cataract River @ Broughtons Pass	N881	12	0	0	0	0	0	17
Nepean River @ Maldon Weir	N92	12	0	0	50	17	8	50

Water quality in the Hawkesbury-Nepean system typically declines in a downstream direction which can be seen again this year. Increases in chlorophyll-*a* concentrations were also observed at sites upstream of the Warragamba River confluence. Nepean River sites have also shown an increase in total nitrogen for the year.

Wingecarribee River samples again exceeded chlorophyll-*a* benchmarks for all samples which is to be expected due to sustained algal numbers in the upstream Wingecarribee Reservoir. All samples also exceeded total nitrogen which is up from 58% of samples for 2018-19.

In the Shoalhaven River results were similar to previous years. A single total nitrogen result slightly exceeded the benchmark (>0.5 mg/L) with a result of 0.53 mg/L. Chlorophyll-*a* was above the benchmark for 42% of samples, down from 67%. Algal concentrations in the upstream storage were also lower than previous years.

The Woronora River results showed improvement when compared with last year particularly for pH, which has increased overall to be within targets more frequently. Dissolved oxygen remained low in the majority of samples.

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 for 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) procedure developed by Water Services Association of Australia (WSAA).

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.

During an event the 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 are used to reassess pathogen risk.

A few heavy rain events that were sufficient to trigger autosamplers and provide data for the Campaign Monitoring program occurred during the reporting period.

- The widespread rain event that occurred in November 2018 triggered 12 autosamplers, with pathogens being detected in 11 of these.
- Localised rain in the southern parts of the Sydney basin triggered four autosamplers in the Shoalhaven, Warragamba, Wingecarribee and Nepean catchments, with pathogens detected in all of these.

7.3 Macroinvertebrate monitoring

The Macroinvertebrate Monitoring Program (MMP) is an annual assessment of ecological health at stream sites in the Sydney Drinking Water catchment area. Drought conditions prevailed throughout 2018, with average rainfall decreasing across the Sydney Drinking Water catchment for a second consecutive year. In 2018, a total of 117 individual macroinvertebrate samples were collected as duplicates from 58 sites across 27 sub-catchments. Sampling was affected by low to no flow at many of the sites; at one site (MMP60), only one replicate could be taken, and a further five sites could not be sampled as they had dried out. Site information and AUSRIVAS scores are presented in Table 7.1.

In 2018, 23 of 58 sites (40%) had AUSRIVAS ratings that were at Reference condition (A rating), while 29 sites (50%) were rated below reference (B rating) and two sites (3%) were rated well below reference (C rating). Four sites could not be scored as they were outside the experience of the AUSRIVAS model. These results represent an overall decline in ecological health across the Sydney Drinking Water catchment area, with 38% of sites decreasing by at least one band grade since 2017. Only 3% of sites increased by one band grade rating and 50% remained stable.

In 2018, macroinvertebrate sampling was conducted at 22 sites across 11 sub-catchments in the Warragamba Dam catchment. Both sites in the Lake Burragorang sub-catchment (MMP59 and MMP251) were dry and could not be sampled in 2018. Of the sampled Warragamba catchment sites, 9 (40%) were rated at Reference condition, 10 (45%) were at ‘Below Reference’ condition and one site was in ‘well below Reference’ condition. Compared to 2018, one site improved in condition rating, while 9 sites (40%) declined and 10 (45%) remained stable. A further two sites could not be rated as they were outside the experience of the AUSRIVAS model.

Macroinvertebrates were monitored at 27 sites from 12 Tallowa Dam sub-catchments in 2018. Of the sites that were sampled, 11 (41%) were in Reference condition and 14 (52%) were classified as ‘below Reference’. Across the Tallowa catchment, the AUSRIVAS band rating increased at one site, decreased at 8 sites (30%) and remained the same at 15 sites (55%) compared to the previous year. Three sites could not be compared as they were not sampled in both years or were outside the experience of the AUSRIVAS model.

A total of four sites in the Metropolitan Dams catchments were monitored for macroinvertebrates in 2018. Three sites declined from reference condition in 2017 to below reference condition in 2018. One site remained at reference condition in 2018. In the Blue Mountains sub-catchments, three sites were sampled for the 2018 MMP, of which one was rated in Reference condition, one was in 'below reference' condition and one was rated 'well below reference'. These ratings represent a decline in condition relative to 2017 for two of the three sampled Blue Mountains sites. In the Woronora sub-catchment, one site was rated in reference condition, and one was rated below reference. There was no change in Woronora sub-catchment ratings relative to 2017.

It is highly likely the widespread decline in AUSRIVAS ratings in 2018 is related to the ongoing drought, which has seen a 33% decline in average rainfall across the Sydney Drinking Water catchment area since 2016.

Table 7.1: Mean AUSRIVAS ratings for sites monitored in 2018, with comparison to 2017 ratings. Site conditions are above reference (X), reference (A), Below Reference (B), Well Below Reference (C). AUSRIVAS band thresholds are adjusted to the mean edge and riffle band value for sites where both edge and riffle habitats were sampled.

Site	Name	Combined AUSRIVAS Rating	
		2017	**2018**
Warragamba Dam catchment			
A16	Coxs River at Lidsdale	OEM	OEM
A5	Mulwaree River at Lake Bathurst	A	A
A6	Tarlo River at Tarlo	B	A
E083	Cox's River at Kelpie Point	A	A
E130	Kowmung River at Cedar Ford	A	B
E157	Kedumba River at Maxwells Crossing	A	A
E206	Nattai River at The Crags	A	B
E210	Nattai River at Smallwoods Crossing	A	C
E243	Little River at Fireroad W4I	A	B
E457	Mulwaree River at Towers Weir	B	B
E488	Wollondilly River at Jooriland (Fowlers Flat)	B	B
E531	Werriberri Creek at Serenity Park	B	B
MMP04	Blue Gum Creek along fire trail W4I	B	Not sampled
MMP130	Long Swamp Creek u/s Paddy's River	A	B
MMP14	Kowmung River at Kowmung Fire Trail	A	B
MMP226	Tarlo River at Swallowtail Pass	A	B
MMP251	Tonalli River u/s Lake Burragorang FSL	A	Not sampled
MMP27	Wollondilly River at Goonagulla	X	A
MMP37	Coxs River at McKanes Bridge	A	A
MMP55	Little River at Six Foot Track	A	A
MMP57	Werriberri Creek at the Oaks	B	Not sampled
MMP59	Butchers Creek u/s of Lake Burragorang	B	Not sampled
MMP76	Leura Falls Creek at FT W74	A	A
U10	Wingecarribee River at Berrima	B	OEM
UWOL1	Upper Wollondilly River at Baw Baw Bridge	A	B
WINGE2	Wingecarribee River at Greenstead	A	A

Site	Name	Combined AUSRIVAS Rating 2017	2018
Tallowa Dam catchment			
A8	Bungonia Creek at Bungonia	A	A
E706	Kangaroo River at Hampden Bridge	A	B
E8311	Corang River at Meangora	A	B
E8361	Nerrimunga River at Minshull Trig	B	B
E847	Shoalhaven River at Fossickers Flat	A	B
E860	Shoalhaven River at Mount View	A	A
E861	Shoalhaven River at Hillview	Not sampled	B
E890	Boro Creek at Marlowe	A	A
MMP06	Shoalhaven River at Yarra Glen	A	B
MMP09	Jerrabattgulla Creek at Warragandra	A	A
MMP11	Titringo Creek at High Forest	OEM	OEM
MMP12	Endrick River at Nerriga	A	A
MMP16	Witts Creek at Krawaree Rd Crossing	A	A
MMP17	Shoalhaven River at Farringdon Crossing	A	B
MMP192	Budjong Creek at Sandy Point	C	B
MMP258	Durran Durra Creek at Nerriga Road	B	B
MMP269	Jinden Creek at Tallanganda State Forest	A	A
MMP273	Shoalhaven River at Wyanbene Rd	A	A
MMP33	Kings Creek u/s of Boro Creek	B	B
MMP43	Kangaroo River at upper Kangaroo Valley	A	A
MMP51	Jacqua Creek at Lumley Rd	B	OEM
MMP52	Nadgigomar Creek at Oallen Ford	B	B
MMP62	Jembaicumbene Creek at Bendoura	A	B
MONG1	Mongarlowe River at Charleyong	A	A
R13	Mongarlowe River at Monga	A	B
R7	Mulloon Creek at Tawarri	A	Not sampled
R8	Currembene Creek at Krawaree Rd Crossing	A	A
REED1	Reedy Creek at Mayfield Rd	A	B
Blue Mountains Dams catchment			
MMP246	Woodford Creek u/s Woodford Dam	X	A
MMP39	Woodford Creek at Woodford Dam	B	B
MMP60	Cascade Creek d/s of lower Cascade dam	B	C
Metropolitan Dams catchment			
E604	Flying Fox Creek No.3 u/s of Gauge	A	A
MMP100	Wongawilli Creek d/s of Fire Road 6	A	B
MMP136	Lizard Creek d/s Fire Road 8H	A	B
MMP20	Nepean River at Maguires crossing	A	B
Woronora Dam catchment			
E677	Woronora River at Fire Road 9F	B	B
E678	Waratah Rivulet at Flat Rock Crossing	A	A

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 method used in evaluating the effectiveness of actions in the catchments and lakes to address pollutants.

7.4.1 Taste and Odour Investigation in Metropolitan System

WaterNSW evaluates risk for potential taste and odour events by routinely assessing, both in isolation and collectively, chemical data, algal speciation data and odour analysis. WaterNSW uses results from these analyses to consider the presence of taste and odour (chemical, odour presence) and potential causes of taste and odour (chemical, algal).

In early June 2018, a very strong 'fishy swampy' odour was noted in raw water from Lake Cordeaux. Assessment of this event showed that no chemical or algal species known to be related to taste and odour could be identified, however, despite this event persisting to September, this was viewed as a localised event that was not impacting water treatability. In July, water was transferred from Lake Cordeaux, via the Upper Canal and exposed to chlorination, prior to entry to Prospect Reservoir. Shortly after the commencement of transfers, a strong 'fishy swampy' odour was also noted in Prospect Reservoir. Similar to Lake Cordeaux, no chemical or algal species in Prospect Reservoir relating to taste and odour issues were initially identified.

Water chemistry covariate analysis did not show any major functional changes in water chemistry in either reservoir before and after transfers. A broader suite of analyses based on analytes defined by the Water Research Foundation taste and odour wheel was also undertaken and showed no detections. Samples were sent to the University of NSW for high resolution odourant analysis using a non-standard analytical technique. The analysis involved GC/MS identification and separation of compounds where each peak was identified with the extracted compound sent to an odourant port for confirmation of aroma. This analysis showed a number of peaks fit the odour profile however the compound(s) extracted were too low in concentration to be positively identified.

The only covariate that was identified to have changed during this event was the absence pre-transfer then presence post-transfer of the diatom *Synedra* sp. in Prospect Reservoir. The hypothesis is that auxospores or intact cells of this araphid diatom were transferred from one reservoir to the other, generating growth and a subsequent taste and odour response. *Synedra* sp. as a source of taste and odour has been reported infrequently in literature, the class of odourant chemical produced (aldehyde) and the production mechanism also aligned with what was observed during this event. Further discussions are underway with the University of NSW to develop a more targeted analytical methodology to isolate taste and odour compounds and gain better understandings of triggers for production.

7.4.2 Geosmin and 16S rRNA bacteria community profiling in the Blue Mountains

The Blue Mountains lakes are periodically impacted by increases in geosmin concentrations. Geosmin can impart a strong earthy taste and odour at low concentrations, reducing the aesthetic quality of supplied water. The two primary sources of geosmin production are algae present in the water and microorganisms, specifically Actinobacteria phylum, which include both aquatic species and terrestrial species which can be washed into the water. Historical geosmin detections in the Blue Mountains had not shown co-occurrences with taste and odour producing algae. The elevations in geosmin were believed to be associated with Actinobacteria, however there had been no monitoring or evidence to confirm this hypothesis.

The higher risk period for geosmin production in the Blue Mountains is summer and autumn. Geosmin monitoring commenced in September 2018 in the Blue Mountains storages to identify any rising trends for the 2018/19 season. Initial monitoring in Top Cascade Lake (see Figure 7.1) reported geosmin at concentrations ranging from 8.1 to 9.6 ng/L. These concentrations were higher than typical for the lake and were above the odour thresholds. Elevated concentrations persisted into October and peaked at 15.7 ng/L. To identify the microorganisms contributing to the geosmin a next generation sequencing approach targeting the 16S rRNA SSU (a universal gene conserved across all prokaryotes) was employed.

The 16S rRNA method provides a community profile of bacteria, indicating the presence and relative abundance of bacterial populations in the lake water. Water samples were collected on 25 October, 1 November and 8 November 2018 for DNA extraction and 16S rRNA sequencing. During this period the geosmin concentrations remained elevated in Top Cascade Lake and relatively lower in Lake Greaves and Lower Cascade Lake. The bacterial community profiles revealed that bacterial species belonging to the Actinobacteria phylum constituted between 15-25% of bacterial communities in Top Cascades Lake, compared to 0.2-5% at Lake Greaves and Lower Cascades Lake. The high relative abundance of Actinobacteria in Top Cascade Lake indicated that the geosmin production was linked to the Actinobacteria. This information can be used to increase understanding of the ecological processes driving geosmin production which will assist in forecasting water quality changes and risks to aesthetic quality of the raw water supply in the Blue Mountains lakes.

Figure 7.1: Water monitoring in Top Cascade Lake on 25 October 2018.

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 2018–19 there was one major, six significant and 24 minor water quality incidents recorded in the Sydney catchment area (see Appendix C for details of these incidents). A further six 'events' were recorded indicating hazards with a potential water quality impact, such as animals falling into the Upper Canal. Some animals, such as cattle, can carry large numbers of pathogenic organisms like *Giardia*, which may be infectious to humans. If a high risk animal is found in the Upper Canal, the water can be diverted away from direct supply to the water filtration plant and into Prospect Reservoir. Other animals, such as wallabies pose less of a risk and can simply be removed.

8.1 Major and significant water quality incidents

There was one major and six significant incidents relating to water quality during 2018-19. Details of these incidents and their management are provided in Appendix C. Prompt notifications and effective incident response ensured no reported issues or customer complaints relating to the water supply. Examples of incident management response for major and significant incidents are discussed in detail below.

8.1.1 Exceedance of Raw Water Supply Agreement site specific standards

Three samples breached Raw Water Supply Agreement standards during the year, being a result for algal ASU in raw water supplied to Cascades Water Filtration Plant in April 2019 and alkalinity results on two occasions. Alkalinity in raw water supplied to Illawarra Water Filtration Plant in March 2019 was 13 mg/L $CaCO_3$, (standard is 10 mg/L). This was recorded as a major incident but the water filtration plant reported no issues and that the elevated alkalinity levels were beneficial to treatment.

Subsequent supply agreement exceedances were not logged as major incidents based on consultation with customers, as per the Water Quality Incident Response Protocol.

Alkalinity in raw water supplied to Cascades Water Filtration Plant in June 2019 was 33 mg/L $CaCO_3$ (standard is 30 mg/L). Suspected cause was elevated alkalinity in water transferred from the Fish River supply system. At the time this result was reported to Sydney Water, the plant operator responded that raw water levels within the plant were consistently around 19-20 mg/L and no issue for treatment.

Rises in filter clogging potential were recorded in Top Cascade Lake from late March to early April. Peak ASU concentrations were recorded in the lake on 4 April at 3,253 ASU/mL. This was associated with high concentrations of the diatom *Synedra* (4,804 cells/mL; 1,706 ASU/mL) and green alga *Dictyosphaerium* (34,994 cells/mL; 1,050 ASU/mL). Odour and issues with treating the high filter load were reported by the WFP. The monthly raw water verification sample on 11 April recorded 2,072 ASU/mL which exceeded the raw water supply agreement standard (2,000 ASU/mL). By the time this result was received, the plant was experiencing normal filter run times. Special monitoring was implemented to track algal populations. A sample on 24 April returned a total algae ASU of 748 ASU/mL and subsequent concentrations declined further. Fast growing algae are likely to have taken advantage of the nutrient-enriched water in Top Cascade Lake. Total phosphorus in the system were elevated through March and April (0.009 to 0.015 mg/L), significantly higher than typical (<0.005 mg/L).

8.1.2 Wingecarribee algae

Elevated biovolume (0.475 mm^3/L) was reported in Wingecarribee Reservoir in October 2018 and the plant was notified. Microcystin toxins were subsequently detected in the reservoir (0.41 µg/L in November, 0.81 µg/L in December).

Algal blooms are naturally common in Wingecarribee Reservoir and the Wingecarribee WFP has been designed to manage algal cells and toxins using Dissolved Air Floatation and Powdered Activated Carbon (PAC). PAC dosing continued throughout this event and the water was successfully treated to meet ADWG with no increase in customer complaints. Following advice from NSW Health, Wingecarribee Shire Council tested treated water but no toxins were detected, confirming effectiveness of these treatment processes.

8.1.3 Metropolitan Picnic Area treatment issues

Significant incidents were raised in respect of elevated turbidity at Cataract picnic area in December and ongoing low chlorine residual readings in February. Elevated turbidity was also reported in all picnic areas in April 2019, but this was subsequently identified as a fault in the turbidity sensor instrument. In response to ongoing issues with turbidity and low chlorine residual, maintenance staff were requested to implement a manual dosing regime to ensure adequate disinfection and record details of any actions taken. Possible additional treatment strategies are being investigated.

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 2015-17 Annual Water Quality Monitoring Report.

Trend analysis for selected catchment, storage, water filtration plant and downstream river sites for the 2009 - 2019 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 (99%) 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. Catchment and storage sites are colour coded based on the following criteria:

NA	No significant trend
X	A statistically significant trend of no concern because the magnitude of change is either very small or not expected to impact relevant guidelines / benchmarks
X	A statistically significant trend - frequently outside ANZECC benchmarks in recent years
X	A statistically significant trend - more frequently within ANZECC benchmarks in recent years
	Insufficient dataset for trend analysis

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 (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																	
E083	10	NA		0.194	0.027	-0.392	NA	-0.004	NA	0.001	NA	0.010	NA	2.750		NA	NA
E130	2.079	NA		0.052	0.004	NA	NA	NA	NA	0.000	0.000	NA	NA	1.785		NA	NA
E157	-0.316	NA		0.034	-0.001	NA	NA	NA	NA	NA	NA	NA	NA	-0.324		NA	NA
E203	NA	NA		NA	NA	1.476	NA	NA	-0.025	-0.002	-0.003	NA	-0.004	NA		NA	-0.380
E206	0.857	NA		NA	NA	NA	NA	NA	NA	NA	NA	NA	-0.001	NA		NA	NA
E210	2.057	NA		NA	NA	NA	NA	-0.029	-0.047	-0.002	NA	NA	NA	1.500		-1.266	NA
E243	NA	-0.002		NA	NA	NA	NA	NA	-0.019	-0.002	-0.002	NA	NA	NA		NA	-0.103
E409	3.615	0.010		0.569	NA	1.990	NA	NA	NA	NA	0.004	NA	NA	NA		NA	0.348
E450	2.624	0.007		0.189	NA	NA	NA	NA	NA	-0.001	NA	NA	NA	NA		NA	0.227
E488	3.727	-0.014		NA	0.020	0.843	NA	NA	-0.020	NA	-0.001	NA	-0.001	5.157		NA	-0.749
E531	NA	NA		NA	-0.005	-1.062	NA	0.031	NA	0.004	NA	-0.011	NA	NA		NA	-0.100
Storages																	
DWA12	2.035	-0.002		-0.094	0.007	NA	NA	-0.005	-0.004	NA	NA	NA	NA	1.436		-0.755	-0.183
DWA2	1.760	-0.001	NA	NA	0.007	NA	NA	-0.005	-0.005	NA	NA	NA	NA	1.250	NA	-0.750	-0.176
DWA27	1.780	-0.002		-0.085	0.007	NA	NA	-0.006	-0.005	NA	0.000	NA	NA	1.290		-0.902	-0.213
DWA9	1.789	-0.002			0.007	NA	NA	-0.005	-0.005	NA	0.000	NA	NA	1.397		-0.690	-0.170
RPR1	-1.599	0.002	19.659	0.138	-0.008	-0.867	NA	-0.005	NA	NA	NA	-0.003	NA	-2.434	5.250	NA	NA
Water Filtration Plants																	
HBR1	1.462	-0.007	NA		0.005	2.452	NA	-0.004	-0.009	NA	-0.001			0.941	NA	NA	-0.368
HWA2	1.259	-0.007	4.456		0.005	3.303	NA	-0.005	-0.009	NA	-0.001			1.000	NA	NA	-0.412
PWFP10	2.000	-0.004	NA		0.007	-0.800	NA	-0.005	-0.008	NA	-0.001			1.439	NA	NA	NA

Analysis of the catchment streams of Lake Burragorang showed few significant trends. Conductivity was generally stable, with the notable exception of Coxs River (E083) which again showed a slight increase. Chlorophyll-*a* in the catchment streams showed a slight increase at most sites, most notably in the Wollondilly River.

Hardness and alkalinity increased significantly in the upstream sites in both major tributaries and in Lake Burragorang.

Consistent with low inflow volumes, a significant improvement in the true colour and turbidity is noteworthy in the Lake Burragorang sites.

Similar to previous years, a slight downward trend in chlorophyll-*a* was notable at the Lake Burragorang sites, with a slight increasing trend in Prospect Reservoir.

The water filtration plant inlet samples continued to show significant increases in hardness and alkalinity, whilst recording a slight improvement in dissolved metals.

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	NA	NA		NA	NA	NA	NA	-0.017	NA	NA	NA	NA	NA	NA		NA	0.130
E609	0.656	-0.005		NA	0.002	-0.676	NA	-0.010	NA	NA	NA	NA	NA	0.286		NA	0.365
E610	NA	NA		NA	NA	-0.734	NA	-0.009	-0.010	-0.001	-0.001	NA	NA	NA		NA	0.189
E680	NA	-0.002		NA	NA	-0.544	NA	-0.018	NA	0.001	0.002	NA	NA	NA		NA	0.034
Storages																	
DAV1	-0.399	NA		-0.109	-0.002	NA	NA	-0.003	NA	NA	NA	NA	NA	-0.667		NA	NA
DAV7	-0.261	NA	26.308	NA	-0.002	NA	NA	-0.003	NA	NA	-0.001	NA	NA	-0.677	NA	NA	NA
DCA1	NA	NA		-0.180	NA	NA	NA	0.013	0.017	NA	NA	NA	NA	-0.117		NA	0.005
DCO1	-0.201	0.001		NA	-0.001	NA	NA	-0.003	NA	NA	NA	NA	NA	NA		NA	0.100
DNE2	-0.162	NA	NA	NA	-0.001	-1.578	NA	0.018	0.030	NA	NA	NA	NA	-0.451	NA	1.063	0.147
Water Filtration Plants																	
HMAC1	NA	NA	NA		NA	-0.277	0.769	0.009	0.018	-0.001	-0.001			NA	NA	0.338	NA
HNED	-0.245	NA	-9.662		-0.002	-1.169	NA	0.026	0.040	NA	NA			-0.341	NA	1.244	0.067
IWFP-R	-0.393	NA			-0.002	NA	NA	-0.005	NA	NA	NA			-0.667	NA	NA	0.033

Water quality was stable at most of the catchment sites and there were no trends likely to change the ANZECC compliance status. The notable trends were minor increases in alkalinity and hardness in the Cataract River. These increases, however, were not reflected in the Lake Cataract water quality trends. Conversely, alkalinity and hardness recorded a decreasing trend in Avon, Cordeaux and Nepean lakes.

In contrast to the Warragamba system, turbidity recorded an increasing trend at most Upper Nepean sites. The magnitude of change each year is very small and not expected to be a concern.

The previous 2007 to 2017 trend analysis showed total aluminium as an increasing trend in all of the Upper Nepean lakes. The was not replicated during this trend period, with only Lake Cordeaux recording a significant trend. This is expected to be associated with drier conditions.

Chlorophyll-*a* in lakes Avon and Cataract has improved in recent years. There was no trend identified in chlorophyll-*a* in Lake Nepean or Lake Cordeaux, despite elevated chlorophyll-*a* concentrations experienced during short-lived blooms in recent years.

Lake Nepean was the only storage which recorded a significant rise in true colour. This may be associated with local wet weather events during the period. The Burke River catchment inflow site did not record a significant trend in true colour. Rising true colour over the trend period also continued at raw water to the Macarthur and Nepean water filtration plants.

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	NA	NA		0.067	0.003	-1.825	NA	NA	0.012	-0.001	NA	0.005	NA	NA		NA	0.184
Storages																	
DWO1	0.081	-0.008	4.938	0.067	NA	NA	NA	-0.015	-0.022	-0.002	-0.001	NA	NA	NA	NA	-0.677	NA
Water Filtration Plants																	
HWO1-A	NA	-0.010	5.367		-0.002	NA	NA	-0.018	-0.023	-0.002	-0.002			NA	NA	-0.833	NA

Dissolved oxygen saturation in the Woronora River was identified as decreasing with the potential to impact on ANZECC compliance. Dissolved oxygen is regularly below ANZECC benchmarks at this site and is associated with low flows.

Minor decreases in metals and true colour were identified over the trend period. This is likely to be associated with dry conditions and increased retention time of stored lake water.

A rising trend in total algae ASU was identified in the lake and raw water to Woronora WFP. Baseline algal ASU concentrations are low in this system and minor rises are not expected to 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	-0.008	78.957	0.182	0.001	NA	NA	NA	NA	NA	NA	0.005	NA	NA	NA	NA	-0.168
DTC1	1.620	-0.004	28.113	0.129	0.004	NA	NA	-0.007	-0.012	NA	NA	0.026	NA	1.534	NA	-0.250	-0.110
Water Filtration Plants																	
HCSR	1.608	-0.003	NA		0.002	-1.575	NA	-0.007	-0.010	NA	NA			1.395	NA	NA	-0.060

Total algae ASU and chlorophyll-*a* were identified as increasing trends in both Greaves and Top Cascade Lakes. Green algae blooms, particularly at Lake Greaves, are becoming frequently common events each year. Minor increases recorded for total nitrogen may be one contributing factor to these algal increases.

Water quality in terms of aluminium, iron and true colour, has improved during the 10-year period.

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	NA		0.288	0.002	-1.553	88.190	NA	NA	0.001	0.001	NA	0.002	NA		NA	0.297
E847	NA	NA		NA	NA	NA	NA	-0.017	NA	0.000	NA	NA	NA	NA		NA	NA
Storages																	
DTA1	0.680	-0.013		NA	0.003	NA	-0.014	NA	NA	NA	NA	NA	-0.001	0.613		-2.162	NA
DTA8	0.687	-0.008	52.971	0.909	0.002	NA	NA	-0.017	-0.019	NA	0.001	0.009	NA	0.365	NA	-1.760	0.257
DWI1	NA	NA	134.060	NA	NA	NA	NA			NA	NA	0.032	NA	-0.302	513.608	0.500	0.347
Water Filtration Plants																	
HKV1	NA	0.007	NA		0.003	-0.974	NA	NA	NA	NA	0.001			0.424	-7.936	NA	0.460
HWI1	NA	NA	98.653		NA	NA	NA	NA	NA	NA	NA			-0.463	226.019	NA	0.400

A significant upward trend in the number of *E.coli* at Hampden Bridge (E706) was noted during the period. Significant numbers of indicator bacteria are common at this site after rain events, and blooms of environmental autochthonous *E.coli* are known to occur during the warmer months.

Chlorophyll-*a* and algal ASU increased significantly in the Kangaroo River arm of Lake Yarrunga.

Wingecarribee Reservoir also showed a significant increasing trend in algal ASU and total potentially toxic algal counts. This storage has been impacted by potentially toxin producing cyanobacterial blooms.

Turbidity showed an increasing trend across most Shoalhaven system sites. A significant increase in alkalinity and total hardness is evident in Lake Yarrunga

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	NA	NA		0.332	NA	NA	NA	NA	NA	NA	0.001	0.024	NA	NA		NA	NA
G0515	0.329	-0.006		0.125	NA	-4.824	NA	-0.009	NA	NA	NA	NA	NA	NA		NA	NA
E851	0.720			NA	0.003	NA	NA	NA	NA	0.002	0.002	NA	NA	NA		-1.714	0.159

Chlorophyll-*a* in the Nepean River at Penrith Weir (N57) was identified as increasing over the trend period and being frequently outside of ANZECC benchmarks in recent years. Total nitrogen at the site is also increasing with results more frequently exceeding ANZECC benchmarks. Further changes to the catchment due to urbanisation are likely to be the driver of these trends. No other notable trends were identified for the site.

Dissolved oxygen in the Woronora River (GO515) was again identified as a significant downward trend and in recent years frequently falls below ANZECC guidelines. Decreases in dissolved oxygen are influenced by flow conditions at this site, which is located upstream of a causeway. Water released from Woronora Dam typically has high dissolved oxygen concentrations throughout the year, as the lake is artificially destratified. An increasing trend in alkalinity and slight decreasing trends in aluminium and iron were also identified at the site.

In the Shoalhaven River (E851) true colour was shown to be a decreasing trend with similar values to the upstream storage. Also observed upstream was the minor increasing trend in turbidity at the downstream site. While other minor trends were identified (alkalinity, conductivity and manganese), these parameters remained relatively stable.

10 References

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