Department of Climate Change, Energy, the Environment and Water

NSW Water Quality Monitoring Framework

Schedule D: Monitoring and Gap Analysis

June 2026

NSW GOVERNMENT

Acknowledgement of Country

Department of Climate Change, Energy, the Environment and Water acknowledges the traditional custodians of the land and pays respect to Elders past, present and future.

We recognise Australian Aboriginal and Torres Strait Islander peoples' unique cultural and spiritual relationships to place and their rich contribution to society.

Artist and designer Nikita Ridgeway from Aboriginal design agency – Boss Lady Creative Designs, created the People and Community symbol.

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Email **water.enquiries@dcceew.nsw.gov.au**

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Contents

Glossary

Term	Description
Alkalinity	Water's ability to neutralise acids, mainly due to bicarbonate and carbonate ions. Alkalinity helps stabilise pH in water
BoM	Bureau of Meteorology
CDOM	Coloured Dissolved Organic Matter
Chlorophyll-a	A photosynthetic pigment found in algae and aquatic plants
CPHR	Conservation, Programs, Heritage and Regulations (DCCEEW Branch)
Cyanobacteria	Photosynthetic bacteria commonly found in freshwater environments
Dissolved oxygen	The concentration of oxygen dissolved in water, essential for the respiration of aquatic organisms
SPSE	Strategic Policy, Science and Engagement group (DCCEEW Branch), formerly EES
EPA	NSW Environmental Protection Authority
Hydrometric	Relating to the measurement/monitoring of hydrological parameters
Hypoxia	When dissolved oxygen levels are too low to support most aquatic life
LGA	Local government area
MDBA	Murray-Darling Basin Authority
MHL	Manly Hydraulics Laboratory
NHMRC	National Health and Medical Research Council
NSW DCCEEW	NSW Department of Climate Change, Energy, the Environment and Water
NSW SEED/SEED	NSW Sharing and Enabling Environmental Data (Portal)
Phaeophytin	Degradation product of chlorophyll-a, helps distinguish living algae from degraded
Phycocyanin	A blue pigment found in cyanobacteria that plays a role in photosynthesis

Term	Description
Real-time	Measurements that are collected, processed and made available immediately
Suspended solids	Particles of inorganic or organic matter that are carried in the water column
SWAMP	State Water Quality Assessment and Monitoring Program
Turbidity	Measure of water clarity caused by suspended particles that scatter light
WRPA	Water resource plan area
WSP	Water sharing plan

1 Background

The NSW Water Quality Monitoring Framework project (the Framework) aims to improve the collection, sharing, and publication of water quality data across NSW.

It is being developed as part of the NSW Government's broader response to the Office of the Chief Scientist and Engineer's review of the Menindee fish death event. Delivery of full responses and commitments are progressing through the Restoring the Darling–Baaka River program.

The Framework also aligns with the NSW Water Strategy's priority to improve the health of river, floodplain, and aquifer ecosystems.

The Framework is a central component of the NSW Water Quality Governance Roadmap.

As part of the Framework's development, a high-level desktop analysis of water quality monitoring coverage and issues was conducted to identify areas for improvement. This document presents the findings of that analysis and provides recommendations for maintaining and improving the network.

2 Introduction

Monitoring of surface water quality is inherently difficult due to the complexity of water sources, which can vary in size, depth, flow and accessibility. Water quality can also change quickly in response to environmental factors such as rainfall, temperature shifts and biological activity, making it hard to capture these temporal fluctuations with periodic sampling. The wide range of parameters needed to effectively monitor water quality further adds to the difficulties involved. Monitoring is costly and integrating data across different programs can be challenging due to different objectives, methods, standards and formats. As a result of limited modelling and forecasting capability, many programs are reactive, designed to detect issues after they occur (e.g., fish deaths), rather than predict or prevent them.

In inland freshwater rivers of NSW, water quality monitoring is supported by a wide range of programs, with the 2 key pillars being the State Water Quality Assessment and Monitoring Program (SWAMP) and the NSW Hydrometric Network. Although these programs offer broad coverage, they serve different purposes. The NSW Hydrometric Network provides real-time measurements while SWAMP is more suited for assessing long-term trends due to its monthly manual sampling approach. Both programs have different and overlapping data gaps, which can limit their ability to monitor water quality in some areas of NSW.

In coastal NSW, water quality monitoring is supported by the Estuary Health Program, which focuses on long-term assessment. Coastal NSW hydrometric network sites also provide real-time data, although the majority of gauges are situated within the Greater Metropolitan and Hunter WSP areas. Complementary and localised monitoring programs that exist (for example, local councils or affiliated council groups like Georges RiverKeeper, other agencies and water utilities) are often constrained spatially or are short-term and have limited public visibility.

This analysis aims to highlight the existence of water quality monitoring programs in NSW (both primary and complementary) while identifying their strengths and weaknesses. It also provides recommendations to address data gaps, whether through improvements to existing programs and processes or by leveraging complementary datasets. Through better organisation, data availability can be improved and promoted.

3 Scope and approach

In line with the overall approach of the Framework, this analysis focuses on government or state-owned corporation monitoring programs in NSW that measure a select range of water quality variables. This analysis is limited to surface water quality monitoring related to the health of rivers and streams. It does not include monitoring for drinking water source supply or management (for example, algal monitoring in dams used for drinking water). Analysis was conducted using publicly available resources.

The programs within scope include:

- water quality monitoring programs measuring parameters that include: water temperature, dissolved oxygen, nutrients (nitrogen and phosphorus), algal counts/biovolume (including cyanobacteria and chlorophyll-a), pH, electrical conductivity and turbidity
- monitoring programs undertaken or funded by government organisations, agencies and state-owned corporations
- programs that currently or have recently monitored the environmental health of rivers and streams.

The programs outside of scope include:

- monitoring programs operated by or in other states (e.g., Victorian and Queensland governments in the MDB catchments)
- monitoring programs focused on groundwater quality, drinking or recreational water quality and supply (including drinking water dams), contaminants and pollutants and licensed discharge monitoring
- smaller-scale academic studies and related monitoring programs.

Bearing the above scope in mind, a desktop analysis was conducted to evaluate active and recently active water quality monitoring programs with publicly available data or metadata. Programs were categorised into two groups:

- primary statewide monitoring programs: broad-scale programs designed to assess water quality across the whole of NSW over long time periods
- complementary water quality monitoring programs: regionally or locally focused monitoring or event-specific programs.

All programs were reviewed for data accessibility gaps, such as the availability and usability of data for stakeholders. Statewide programs were assessed for temporal, spatial and parameter-based limitations. Complementary water quality monitoring programs were assessed for their data quality and potential to supplement gaps in statewide monitoring programs.

Additionally, given that some water quality parameters are more difficult to monitor than others and that their monitoring frequency and spatial coverage vary significantly between monitoring programs, section 4.4 of this document provides an analysis of each parameter's coverage within the NSW context.

4 Analysis

4.1 Primary statewide monitoring programs

There are 3 statewide water quality monitoring programs in NSW that are dedicated to, or have the potential to, inform the environmental health of rivers and streams. These are:

- State Water Quality Assessment and Monitoring Program (SWAMP)
- NSW Hydrometric Network
- Estuary Health program.

4.1.1 State Water Quality Assessment and Monitoring Program

The SWAMP program commenced in 2007. Initially the program included about 120 sampling sites located throughout the upland, slopes and lowland regions of NSW. Currently, the network operates 125 active sites (Appendix A, Figure 4). Water quality data is manually collected once a month, providing substantial spatial coverage for a range of water quality parameters (Table 4). Additional data is also sourced from 9 sites in the Border Rivers Water Quality Program and 6 sites from the Intersecting Streams Water Quality Program, bringing the total amount of statewide monitoring sites to 140 (also included in Figure 4). As this program collects water quality parameters monthly, and lab results can be delayed several months, it is mostly used for long-term reporting purposes rather than incident response.

Data from SWAMP provides measures of compliance with state and national guidelines and standards and informs various departmental reporting and decision support products including the NSW Annual Water Quality Index (WaQI) reporting, the NSW River Condition Index (RCI) tool, Matter 12 reporting set out in Chapter 9 of the Basin Plan, related technical reports and the NSW State of the Environment report. The strengths and weaknesses of this program are outlined in Table 1.

Table 1. SWAMP strengths and weaknesses comparison

Strengths	Weaknesses
• There is an extensive range of appropriate water quality parameters (outlined in Table 4). • Data collection and upload have been consistent, with minimal missing values. Inland datasets are 95.5% to 98.4% complete. Coastal dataset is 96.8%	• There is limited coastal coverage, with the majority of sites situated inland to assist in Murray-Darling Basin Plan reporting (Appendix A, Figure 4). • Infrequent sampling is unable to detect sudden changes or allow the prediction of short-term water quality incidents.

Strengths	Weaknesses
completed (RAW Water Quality Data | Dataset | SEED). • SWAMP is an important resource for long-term monitoring, particularly for under-represented water quality parameters like total nitrogen and phosphorus.	• There are restricted data accessibility and awareness, with datasets only available on SEED, where publicly available data is limited to 2016-2021, reducing its significance for contemporary analysis by third parties. • There is no coverage within the Hawkesbury-Nepean catchment (the WaterNSW declared catchment area). Complementary monitoring is conducted by WaterNSW in this area and is consistently available in annual reports but is not published with or in relation to the SWAMP data, making the dataset appear incomplete.

4.1.2 NSW Hydrometric Network

The NSW Hydrometric Network collects data from over 1,300 monitoring stations across NSW, measuring a variation of river flow and level, water quality parameters and meteorological conditions, depending on the equipment installed at each site (Table 4). It is one of the most extensive water monitoring systems in Australia. Data from the network is managed by agencies such as WaterNSW, NSW DCCEEW, Bureau of Meteorology and the Murray-Darling Basin Authority. Historical and real-time data are publicly accessible for over 800 water sources through the WaterInsights website and its predecessor, the WaterNSW 'Real-time data' website.

The hydrometric network is predominantly focused on monitoring water levels, discharge rates and storage volumes and is crucial for water accounting and flood warning systems. However, there are over 300 sites that provide continuous real-, or near real-time data for a variety of water quality parameters (NSW Department of Planning, Industry and Environment, 2021a). Of the sites that collect water quality data, the majority measure water temperature and electrical conductivity, while a smaller number of sites measure other water quality variables including dissolved oxygen or turbidity.

There has been recent focus on expanding the water quality coverage and capability of the network under the Hydrometric Improvement Plan (NSW Department of Planning, Industry and Environment, 2021b) and the NSW Restoring the Darling-Baaka Program, which has had a focus on improving monitoring of dissolved oxygen and added 40 new sites since 2024. The strengths and weaknesses of this program is outlined in Table 2.

Table 2. NSW hydrometric network strengths and weaknesses comparison

Strengths	Weaknesses
• Provides real-time data, which is essential for water quality incident response.	• There is limited coastal coverage, with most water quality monitoring sites situated

Strengths	Weaknesses
• Datasets are easily accessed and downloaded using the WaterInsights and Real-time data website. • Multiple agencies collaborate to monitor water quality. • There is an extensive network of sites that collect real-time stream level and discharge data. These parameters are often used as reference variables when analysing water quality trends.	within the Greater Metropolitan and Hunter regions. • Only a narrow set of water quality variables can be measured using real-time monitoring methods. • There are occasional incomplete datasets. Data audits showed that water temperature and electrical conductivity data on average was either lost or not available 15% and 20% of the time, respectively (NSW Department of Planning, Industry and Environment, 2021a). • It is expensive to install and maintain new monitoring sites and monitoring equipment.

4.1.3 Estuary Health program

The NSW Estuary Health program provides long-term statewide water quality monitoring of NSW estuaries. Currently monitoring is conducted under the NSW Marine Estate Management Strategy (NSW Marine Estate Management Authority, 2018). NSW DCCEEW, in collaboration with local councils, monitors water quality parameters (outlined in Table 4) across 184 estuaries along the NSW coastline (Appendix D, Figure 6), providing Estuary Health report cards for all estuaries in NSW.

For practical purposes, the program divides the NSW coast into three regions, North, Central and South, and annually samples a subset of estuaries from each region. Typically, all estuaries on the NSW coast will be sampled over a 3-year period, providing a long-term indication of their health. The strengths and weaknesses of this program are outlined in Table 3.

Table 3. Estuary Health program strengths and weaknesses comparison

Strengths	Weaknesses
• There is extensive coastal coverage (Appendix D). • Water quality report cards provide letter grades for algae abundance, water clarity and overall estuary health. • There are a broad range of water quality parameters. • It is good for assessing long-term trends in estuarine health.	• It specifically looks at estuarine zones. There is reduced sampling of tidal pools. • Infrequent sampling limits the ability to detect rapid changes or water quality incidents. • Dataset is available on SEED and limited to the 2007-2020 period. The amount and consistency of data vary between estuaries and water quality parameters.

Strengths	Weaknesses
	• There is an incomplete dataset (NSW Estuary Water Quality Data Compilation: 2007 - 2020 | Dataset | SEED).

4.2 Statewide coverage review

Despite serving different purposes, these statewide monitoring programs work together effectively, with each helping to fill the gaps left by the other (Table 4). For example, SWAMP's periodic data collection can be complemented by the hydrometric network's real-time data capabilities. In contrast, the hydrometric network's reduced range of water quality parameters can be enhanced by the broader water quality monitoring provided by SWAMP. As shown in Figure 1, both SWAMP and the NSW hydrometric network together provide efficient inland monitoring coverage, while the Estuary Health program tries to address the coastal gap left by the other primary programs. Collectively, these programs are vital to the water quality monitoring within NSW, providing essential insight into the health of freshwater ecosystems. The remaining data gaps include:

- the need for more frequent water quality sampling along the coast
- additional inland sites capable of monitoring certain parameters (e.g., dissolved oxygen, pH) in real-time or near real-time.

These limitations could potentially be addressed by expanding the existing programs or integrating additional water quality monitoring programs (Table 5).

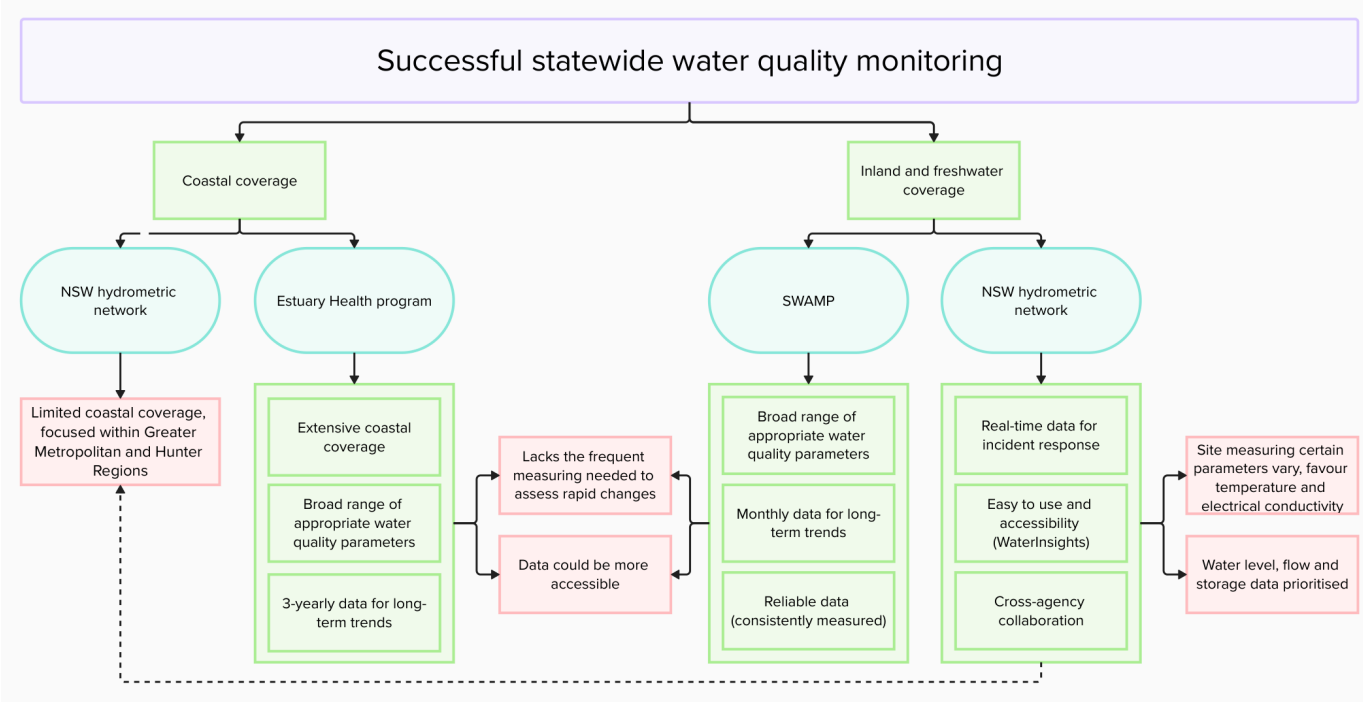

Figure 1. Successful statewide water quality monitoring system conceptual model, highlighting the primary monitoring programs ("pillars"). Green boxes represent the advantages of each program, whereas the red boxes indicate the limitations/gaps.

Table 4. Primary NSW statewide monitoring program information

Program	Responsible organisation	Coverage	Parameters measured	Sampling frequency	Number of sites	Data sources
State Water Quality Assessment and Monitoring Program (SWAMP)	NSW DCCEEW - Water	Statewide (Appendix A, Figure 4).	Total phosphorus and nitrogen, conductivity, water temperature, turbidity, suspended solids, pH, dissolved oxygen and major ions.	Monthly	140 sites	RAW Water Quality Data | Dataset | SEED 2016–2021
NSW Hydrometric Network	NSW DCCEEW Water, WaterNSW, BoM, MDBA, MHL	Statewide	Varies from site to site. Discharge, rainfall, stream level, temperature, conductivity, dissolved oxygen, turbidity and pH.	Real-time, 15-minute intervals	>300 with varying water quality parameters	WaterInsights - WaterNSW
Estuary Health program	NSW DCCEEW-SPSE group	Statewide coastal coverage (Appendix D, Figure 6).	Total phosphorus and nitrogen (and associated measurements), water temperature, salinity, dissolved oxygen, turbidity, coloured dissolved organic matter (CDOM), chlorophyll and suspended solids.	3 yearly cycles with 10 estuaries sampled yearly. Sampled 6 times over summer	184 estuaries	NSW Estuary Water Quality Data Compilation: 2007 - 2020 | Dataset | SEED

4.3 Complementary water quality monitoring programs

For this analysis, complementary water quality monitoring programs refer to the regionally or locally focused water quality monitoring programs that are designed for specific purposes. These may be routine monitoring for a specific purpose, an incident-based water quality event or short-term program. These programs may be carried out by state or local government entities and can provide valuable localised data and context to water quality or rivers and streams. Additionally, they have the potential to fill data gaps in the primary statewide water quality monitoring programs, particularly in under-monitored regions or areas that have infrequent sampling.

Table 5 presents a non-exhaustive list of complementary water quality monitoring programs in NSW identified as part of this review. As part of the Framework pilot implementation, NSW DCCEEW Water Group has made the data and metadata for these programs available in NSW SEED under the NSW Surface Water Quality Monitoring group.

Table 5. List of complementary water quality monitoring programs

Program	Responsible organisation	Coverage	Parameters measured	Sampling frequency	Number of sites	Data sources
Darling-Baaka River Smart Buoy Network	NSW DCCEEW – SPSE	Darling-Baaka River	At 4 depths: water temperature, dissolved oxygen, turbidity, chlorophyll, phycocyanin, pH, conductivity and coloured dissolved organic matter	Real-time	6 sites	Darling-Baaka River Health Project smart buoy dashboard | Dataset | SEED
Water monitoring program (WMP)	WaterNSW	Greater Sydney catchment	Conductivity, dissolved oxygen, pH, turbidity, nutrients, metals and chlorophyll-a	Routine sampling, lab testing and 'real-time' data	50 catchment sites, 32 storage sites	No data access available

Program	Responsible organisation	Coverage	Parameters measured	Sampling frequency	Number of sites	Data sources
Sydney Water Aquatic Monitoring (SWAM) Program	Sydney Water	Hawkesbury-Nepean River, Georges River	Temperature, dissolved oxygen, pH, conductivity, turbidity, nutrients, metals and chlorophyll-a	3 weekly sampling	Hawkesbury-Nepean: 53 sites Georges: 3 Reference sites: 7	No open data access available
Blue Mountains Waterway Health monitoring program	Blue Mountains City Council	Blue Mountains LGA	Conductivity, pH, dissolved oxygen, turbidity, alkalinity, nitrate-nitrogen/phosphate and faecal coliforms	Varies, mostly annually	68 sites	No data access available
Hawkesbury Watch	Hornsby Shire Council, MHL	Hawkesbury estuary	Temperature, turbidity, salinity and chlorophyll-a	Real-time, 15-30min	7 sites	Hornsby Shire Council
EPA Flood Recovery Program for water quality monitoring (No longer active)	EPA	28 LGAs within the North coast, Mid coast and Hawkesbury-Nepean	Real-time parameters: Temperature, conductivity, salinity, pH, dissolved oxygen, turbidity and chlorophyll-a 2022-2024 parameters: Water clarity, algae, total nitrogen, total phosphorus, bacteria and dissolved oxygen	Real-time and sampling between 2022-2024 Jan	186 sites	Flood recovery program for water quality monitoring - east coast dashboard | Dataset | SEED
River Murray Water Quality Monitoring Program	MDBA	Murray River- NSW, VIC, SA	Conductivity, pH, temperature, turbidity, total phosphorus/nitrogen, soluble	Weekly and monthly,	28 sites in total, 6 in NSW	River Murray Water Quality Monitoring

Program	Responsible organisation	Coverage	Parameters measured	Sampling frequency	Number of sites	Data sources
			organic carbon, silica, sulphate/bicarbonate, chlorophyll and phaeophytin.	depending on parameter		Program - Dataset - Data.gov.au
Catchment Pressures program	SPSE	Coast-wide	Total phosphorus and Nitrogen, Stream level, temperature, salinity, dissolved oxygen, turbidity, CDOM, chlorophyll and suspended solids.	Most sites are sampled twice per year	61 sites	No open data available
Hunter Water Coastal Basins water quality monitoring	Hunter Water Corporation	Hunter River-coastal	Manual discrete water quality sampling	Unknown	6 sites	No open data available
StreamWatch	Greater Sydney Landcare-citizen science volunteer program	Greater Sydney, Blue Mountains and Illawarra	Water temperature, phosphate, nitrate, turbidity, dissolved oxygen, electrical conductivity and pH.	Variable	Variable. Catchments with sites include: Hawkesbury-Nepean, Parramatta River, Georges River, Cooks River, Illawarra, Coastal and Lane Cove.	Streamwatch | Dataset | SEED

4.4 Water quality parameters and processes

Water quality is an important driver of ecological processes and is a key factor in determining the overall condition of a waterway. Physical and chemical parameters such as temperature, pH, electrical conductivity (EC), nutrients, turbidity and dissolved oxygen (DO) can affect the biology and ecology of aquatic organisms, especially when outside tolerable levels (Watson et al., 2009).

As outlined in the approach (Section 3), this section examines the water quality parameters measured by both the primary statewide and complementary monitoring programs across NSW. The extent to which each parameter is monitored varies, with some, like water temperature, being measured more consistently than others due to a range of practical and ecological reasons. Understanding the statewide coverage of different water quality indicators is therefore essential for identifying monitoring gaps. Additionally, this section explores water quality processes such as stratification, which require more targeted monitoring approaches.

4.4.1 Water temperature

Temperature affects the rates of all chemical and biological reactions in aquatic environments. Furthermore, since temperature affects water density, it is a major factor in how water mixes in the water column. Water temperature is often monitored to assess the occurrence of thermal stratification in rivers and streams, which increases the risk of algal blooms and hypoxia, and the impact of cold-water pollution from storage releases.

Water temperature is the most commonly measured water quality parameter across current NSW monitoring programs. Real-time temperature data is available through the NSW Hydrometric Network, EPA Flood Recovery program, Darling-Baaka River Smart Buoy Network and Hawkesbury Watch. SWAMP and the Estuary Health program also maintain an extensive record for long-term water temperature monitoring across NSW.

Inland temperature monitoring coverage is widespread, with 188 NSW Hydrometric Network sites providing real-time measurements across all Water Resource Plan Areas (WRPAs). However, some WRPAs have substantially more sites than others, such as the Murrumbidgee (46 gauges) and the Murray and Lower Darling regions (61 gauges) (Appendix B, Table 6). In contrast, SWAMP sites are more evenly distributed throughout inland NSW (Appendix A, Figure 4). Together, these primary statewide monitoring programs provide extensive spatial coverage of both real-time and long-term water temperature data.

In coastal systems, water temperature monitoring coverage is generally limited, with some Water Sharing Plan (WSP) areas supported by only one, or in some cases no, SWAMP monitoring sites. This pattern is also reflected in the NSW hydrometric network, where of the 129 sites measuring water temperature, 106 are located within the Greater Metropolitan and Hunter WSP areas (Appendix B, Table 7). Consequently, just under half of all WSP areas have no water temperature monitoring, with several others having only minimal coverage.

The Estuary Health program provides extensive coastal coverage for water temperature; however its temperature data is primarily designed to assess long-term trends. Since water temperature is widely monitored across programs, the existing gaps in coastal systems could potentially be addressed by leveraging data from complementary programs such as the Catchment Pressures program, SWAM, Hawkesbury Watch and the EPA flood recovery program.

The only active complementary water quality monitoring program that provides real-time data is HawkesburyWatch, this program has an insufficient number of sites (Table 5) to effectively represent the NSW coastline. As a result, coastal water quality monitoring is significantly limited in temporal resolution, reducing the ability to detect issues along the coastline.

4.4.2 Electrical Conductivity

Salinity is commonly measured as electrical conductivity. Salinity is the presence of dissolved salts in water and is a common problem throughout Australia as the arid climate provides insufficient rainfall to dilute naturally high salt levels within some catchments. Many freshwater species cannot tolerate elevated salt levels, leading to population declines and shifts in community structure. High salinity can also impact water quality and can degrade riparian vegetation, causing soil erosion and habitat loss.

Like temperature, electrical conductivity monitoring is well-represented by the NSW Hydrometric Network with 290 sites statewide that are able to record this parameter in real-time (Appendix A, Figure 3).

Inland context

Salinity measurements are of particular importance in the Murray Darling Basin. Conditions such as low rainfall, flat terrain and high evaporation rates that are common within the basin favour the accumulation of salt. Salt mobilisation into surface water increased with the development of agriculture and clearing of native vegetation across the basin as more water drained into the groundwater systems. Driven largely by damage to irrigated crops and salt levels exceeding the recommended levels for human consumption, salinity was recognised as one of the most significant economic and environmental issues in the Murray Darling Basin by the mid-1980s. This led to the development of the Salinity and Drainage strategy, which has since evolved into the Basin Salinity Management Strategy (Murray–Darling Basin Authority, 2015).

In current inland salinity management, electrical conductivity data is used for informing and reporting on catchment salinity trends and risks (based on end-of-system targets), accounting and adapting salt interception schemes and informing models that provide data for salinity registers.

Under the current Basin Salinity Management Strategy (BSM2030), the Murray Darling Basin Authority and Basin states maintain a core salinity network within the Murray Darling Basin (Murray–Darling Basin Authority, 2015). Sites are reviewed at least every 5 years with the next review scheduled for 2026. Consequently, a project to analyse gaps, develop catchment profiles and update risk assessments across the NSW Murray Darling Basin is about to commence, led by the Basin Salinity Program. This will include a review of the core salinity monitoring network and end of valley target sites. The review is likely to lead to recommendations regarding the effectiveness of the current monitoring network in detecting salinity risk to the shared water resource.

The distribution of inland gauges measuring electrical conductivity is similar to that of temperature, with 161 sites spread across inland NSW and the greatest coverage in the Murrumbidgee, Murray, and Lower Darling WRPAs (Appendix B, Table 6). The SWAMP program also provides additional monitoring support (Appendix A, Figure 4).

Coastal context

In coastal rivers, electrical conductivity data may be used to monitor the extent of oceanic and estuarine salinity ingress due to reduced river flow or freshwater extraction, and to inform modelling work, assess risks and evaluate Water Sharing Plans.

Both the NSW Hydrometric Network and EPA Flood Recovery Program provide coastal real-time electrical conductivity measurements; however, these datasets are limited spatially and do not provide statewide insight. Although the Hydrometric Network includes 124 gauges monitoring this parameter, WSP areas outside the Greater Metropolitan and Hunter regions have restricted coverage (Appendix B, Table 7). SWAMP monitoring sites also record electrical conductivity at monthly intervals and can be used to assess long-term trends.

The Estuary Health program offers an extensive coverage of salinity, a parameter closely related to electrical conductivity. However, like SWAMP, it is not publicly available in real-time and is suited for evaluating long-term changes rather than short-term variability. Additional monitoring of electrical conductivity in coastal tidal pools would provide an improved understanding of salinity dynamics which would inform rules to manage water use in these areas. A pilot project in the Hunter estuary has commenced.

4.4.3 Dissolved oxygen

Fish and other aquatic animals require dissolved oxygen to respire and survive in water. However, when excessive amounts of organic material are added to water, bacteria break it down, using oxygen in the process. Dissolved oxygen monitoring is driven by the need to maintain appropriate conditions for aquatic ecosystems, particularly native fish. Low dissolved oxygen levels can result in fish kills, the release of metals and chemicals from sediments, as well as disruptions to aquatic plant growth and other ecological processes. The availability of continuous dissolved oxygen data has been critical when managing flows to prevent hypoxic events that could potentially result in fish deaths. The data is also used for Basin Plan and Water Sharing Plan evaluation and reporting and risk assessments.

The current dissolved oxygen monitoring network (Appendix A, Figure 2), operated by the NSW Hydrometric Network, delivers real-time data with sites mostly situated along the Lachlan, Murrumbidgee, Barwon-Darling, Murray and Lower Darling rivers (Appendix B, Table 6). This network has incomplete coverage across inland NSW, however, it is improving. In 2021, only 16 sites in the NSW Hydrometric Network were able to collect dissolved oxygen data (NSW Department of Planning, Industry and Environment, 2021a), which has increased to 67 (Appendix B, Table 6). In coastal areas, dissolved oxygen monitoring is heavily concentrated within the Greater Metropolitan WSP area, with 52 of the 53 coastal gauges recording this parameter located there (Appendix B, Table 7). As a result, the remainder of the coastline has either very limited (1 site in Hunter WSP area) or no real-time dissolved oxygen monitoring coverage.

Installation of real-time dissolved oxygen monitors is typically in response to hypoxic events or other water quality issues, which is the case for the Darling-Baaka River Smart Buoy Network and the EPA Flood Recovery Program. These programs operate in specific locations and do not provide coverage across all of NSW. Other instances include the deployment of real-time dissolved oxygen monitors in the Edward, Wakool and Neimur systems as well as at Maude, Redbank and Balranald Weirs between 2011 and 2015, following hypoxic events during 2010-11. Further sensors were installed in the Barwon-Darling and Lachlan Rivers in 2019-20. The Federal Funding Agreement

program has expanded the monitoring network into the Border Rivers, Gwydir, Namoi and Macquarie rivers as well as Yanco and Billabong creeks. Further sites have also been installed in the Murray, Murrumbidgee and lower Darling rivers (Appendix B, Figure 2). Three multi depth monitoring pontoons have been installed at Menindee as part of the NSW government's response to the Office of the Chief Scientist and Engineer report on the Menindee fish deaths.

The SWAMP, WMP, SWAM and the Blue Mountains City Council's Waterway Health monitoring program all record dissolved oxygen. However, these measurements are taken at intervals ranging from monthly to annually, making them more suitable for assessing long-term trends rather than informing short-term management decisions. Similarly, the Estuary Health program provides long-term representation across the NSW coastline. Except in specific locations like Menindee, the lack of more frequent sampling needed to assess rapid changes in dissolved oxygen is currently a major gap in the monitoring network of this parameter.

4.4.4 Nutrients, Major Ions, Turbidity, Suspended solids, pH

Water quality parameters such as nutrients, major ions, turbidity, suspended solids and pH can influence the chemical and physical condition of freshwater ecosystems, particularly when in excessive levels. Monitoring these parameters is essential for accurately assessing riverine health.

There is currently no real-time (or near real-time) monitoring network for nutrients or suspended solids, primarily because these parameters require laboratory-based analysis. The SWAMP program collects data on nutrients, major ions, total suspended solids, turbidity, and pH, offering extensive and historical data; however, limited temporal coverage and analysis lead times make it difficult to inform incident awareness and response.

The NSW hydrometric network can provide real-time monitoring of pH and turbidity, with 12 and 15 inland sites dedicated to these parameters, respectively (Appendix B, Table 6). Interestingly, the coast has more gauges recording both pH and turbidity, however the coverage is almost entirely within the Greater Metropolitan WSP area (52 sites) (Appendix B, Table 7). Similarly, the Estuary Health program includes measurements of turbidity and suspended solids but does not operate in real-time. Overall, the primary statewide monitoring programs offer long-term inland coverage for these water quality parameters and long-term coastal coverage for turbidity and suspended solids only. Real-time data availability remains very limited across both inland and coastal NSW.

Complementary water quality monitoring programs may boost the nutrients, major ions, turbidity, suspended solids and pH coverage in NSW. For example, programs that frequently measure one or more of these parameters are WMP, SWAM, the River Murray Water Quality Monitoring Program and the SPSE Catchment Pressures program. Streamwatch also monitors the relevant parameters within its Greater Sydney reach, however, as a citizen science program, the consistency and reliability of its data can vary. Notably, the Darling-Baaka River Smart Buoy Network, EPA Flood Recovery Program and Hawkesbury Watch provide real-time data on either pH or turbidity or both.

4.4.5 Algal concentrations and blue-green algae

In freshwater ecosystems, algae are a diverse group of photosynthetic organisms (e.g., microscopic phytoplankton) that live in and on the water's surface. They are natural components of riverine systems, playing an essential role in oxygen production, nutrient cycling, and supporting food webs. However, excessive growth, often driven by high nutrient levels and warm conditions, can lead to algal blooms, which negatively impact the environment (Mitrovic & Bowling, 2013). These impacts

include reduced water quality, shading aquatic plants, oxygen depletion during decomposition and, in the case of certain species such as cyanobacteria, the production of harmful toxins.

Since algal identification requires laboratory analysis, which can be time-consuming and costly, chlorophyll-a is often monitored to determine the number of microalgae or phytoplankton present within freshwater environments. These measurements can provide an early indication of algal blooms (NSW Department of Climate Change, Energy, the Environment and Water, 2023). When chlorophyll-a concentrations exceed a defined threshold, further investigation is typically initiated. For example, buoys used in the Hawkesbury Watch program continuously monitor chlorophyll-a levels and trigger an alert when concentrations exceed 20 µg/L. At this point, water samples are collected for laboratory analysis to determine the species present, the extent of the bloom, and whether it is producing toxins (Manly Hydraulics Laboratory, n.d.). Primary statewide monitoring programs in NSW currently do not measure chlorophyll-a in inland waters and is only monitored in coastal systems through the Estuary Health Monitoring Program. Although, chlorophyll-a is commonly included in supplementary monitoring programs, such as:

- Darling-Baaka River Smart Buoy Network
- WMP
- SWAM
- Hawkesbury watch
- EPA flood recovery program
- River Murray water quality monitoring program
- EES catchment pressures program

Cyanobacteria (Blue-green algae) is monitored to assess the risk to recreation, town water supplies, stock and domestic use. It is also used to inform water management actions in cases where a water quality allowance for algal management is available. Cell counts and identification are typically carried out in a laboratory following manual sample collection, but the risk level may be informed by remote sensing approaches such as the review of satellite imagery (WaterNSW, 2026). Certain water quality buoys can monitor phycocyanin, which is a pigment primarily found in cyanobacteria, and which provides an indication of blue-green algae presence (NSW Department of Climate Change, Energy, the Environment and Water, 2023). This method is used by Darling-Baaka River Smart Buoy Network, and the WaterNSW multi depth monitoring pontoons installed at Menindee, a region that is particularly prone to blue-green algal blooms.

Sampling for blue-green algae is carried out routinely in high-risk locations such as major storages, rivers and other locations frequently used for recreation (Appendix F, Figure 7). This is the responsibility of the relevant water body manager which includes WaterNSW and local councils and water utilities. Additional samples may also be collected in response to reports of algal blooms and scums. Water utilities are required to manage the risk of algal blooms in drinking water supplies.

Blue-green algae recreational water targets have been developed with the primary aim of protecting the health of humans from threats posed by the recreational use of water. This includes a low level of risk to human health from exposure to blue-green algae (cyanobacteria) through ingestion, inhalation or contact during recreational use of water resources. The targets are based on Chapter 6 of the National Health and Medical Research Council Guidelines for Managing Risk in

Recreational Water (NHMRC, 2008). In addition, it is also a general target that cyanobacterial scums should not be consistently present. The recreational water targets are listed in Appendix F, Table 9.

Stratification and depth profiles

As both routine manual and telemetered water quality samples are typically collected from near the surface, trends occurring within the water column may be underrepresented. For example, stratification can occur when layers of water form due to differences in salinity, temperature and oxygen (and in many cases the interaction of all three). Inland, stratification is a major issue when the flow rates of rivers are reduced and temperatures are high. In a coastal context, stratification can be an issue in estuaries and shallow coastal lakes, where salinity can strongly stratify the water column and help induce stratification of oxygen and temperature.

Stratification can potentially lead to hypoxic environments and impact water quality parameters such as temperature, dissolved oxygen and nutrient concentrations. Although stratification has caused major water quality issues in the past, such as the Menindee mass fish death event (Vertessy et al., 2019), monitoring and predicting this process is uncommon, mainly limited by cost, as well as technical and resource constraints. As a result, programs that assess stratification using depth profiles are often localised, designed to monitor and detect stratification incidents after a major event has occurred.

An example of this is the Darling-Baaka River Smart Buoy Network (Table 5). The Darling Baaka River Health Project was established following the 2023 fish kill (Vertessy et al., 2019) which included 6 telemetered loggers that continuously monitor water quality parameters (Outlined in Table 5) at 4 different depths within the river. Darling-Baaka River condition updates were reported weekly during critical periods and monthly otherwise by NSW DCCEEW from 2023 to 2025. These loggers provided valuable insights into water quality dynamics throughout the water column and observed the effects of stratification on different parameters. This information has allowed hydrodynamic modelling for the area to be developed which may help alleviate stratification issues through identifying high-risk periods in advance and managing river flow accordingly.

Another instance of depth profile monitoring is the Bushfire-affected waterways study conducted by NSW DCCEEW following the 2019-20 bushfire season (NSW Department of Climate Change, Energy, the Environment and Water, 2020). This study used 5 solar-powered buoys to monitor vulnerable estuaries in NSW, measuring water quality parameters in real-time. This data was collected from the surface and the bottom of the water column to account for stratification.

While depth profile monitoring is effective at capturing detailed localised water quality data, it is expensive, and historically this type of monitoring has only been used after significant water quality issues arise. Expanding the use of telemetered temperature monitoring with depth profiles, particularly at sites vulnerable to stratification, algal blooms, or cold-water pollution, would enhance data availability and could help support more informed management decisions through the design of predictive models and tools.

5 Summary and Recommendations

We found that primary statewide programs provide reasonable water quality monitoring coverage, particularly for inland NSW. However, limited real-time capabilities for coastal and certain

parameters in inland sites remain a major gap. These limitations may be partially addressed by additional water quality monitoring programs. Water temperature and electrical conductivity are the most frequently monitored parameters, while nutrients such as total nitrogen and phosphorus are underrepresented due to the need for laboratory analysis. Recommendations based on our findings include:

- Maintain and expand funding for primary statewide monitoring programs, ensuring the water quality data they generate remains publicly accessible, downloadable and easy to use. Improving NSW Hydrometric Network's capabilities along the coast, expanding sites beyond the Greater Metropolitan and Hunter regions.
- Strengthen the Estuary Health Program by increasing the frequency of measurements, allowing for more proactive and timely responses to emerging coastal water quality issues.
- Expand targeted monitoring initiatives, such as the Darling-Baaka River Smart Buoy Network, in locations that are particularly vulnerable to poor water quality, stratification or other high-risk processes.

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7 Appendices

7.1 Appendix A Monitoring sites

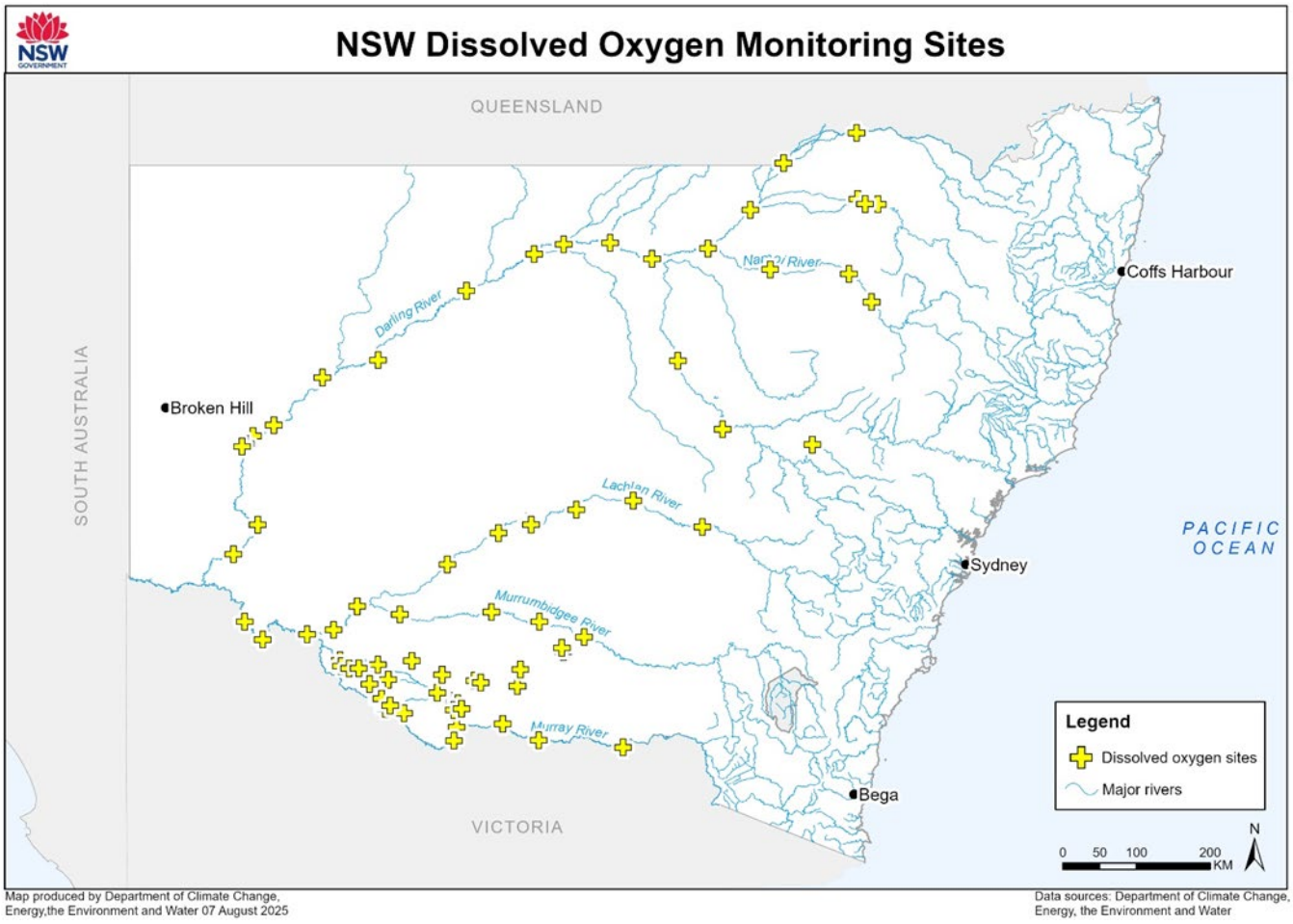

Figure 2. Map of existing dissolved oxygen monitoring sites in NSW

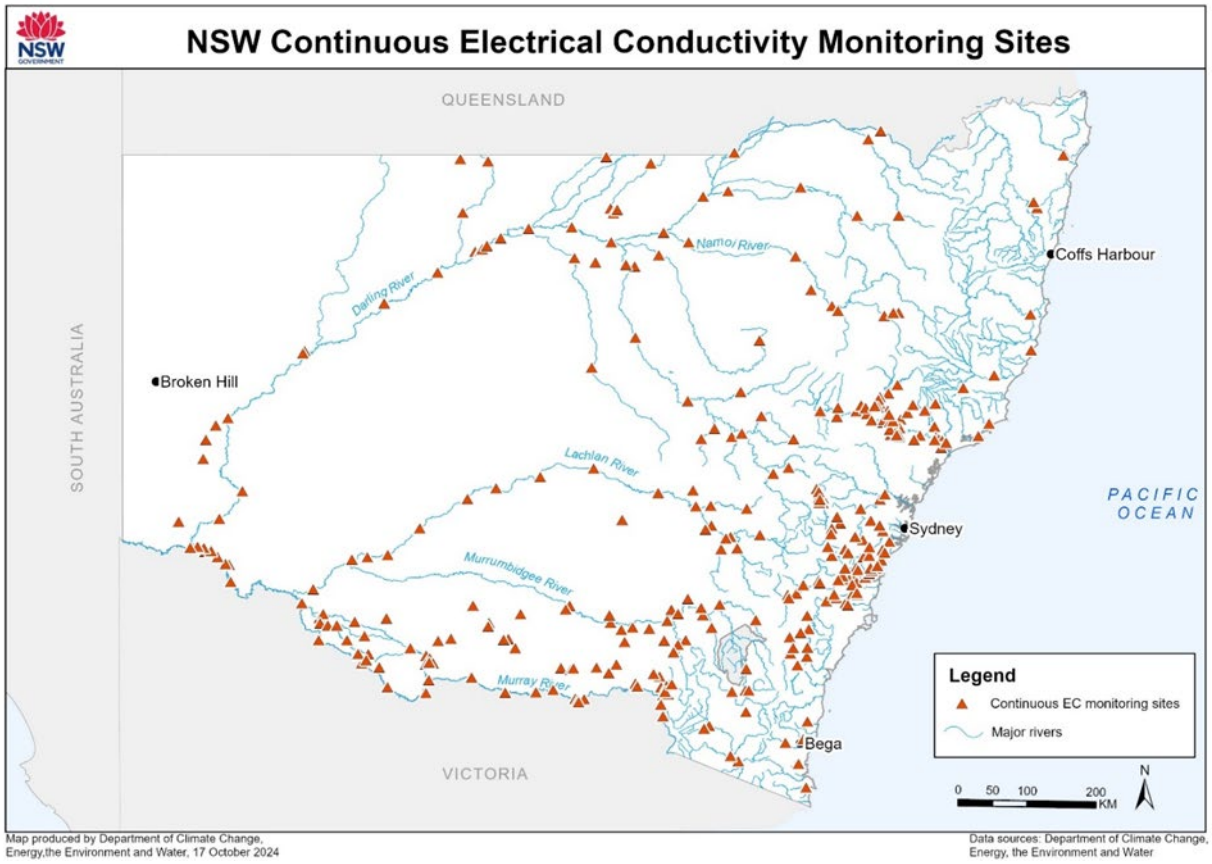

Figure 3. Map of continuous electrical conductivity (EC) monitoring sites in NSW

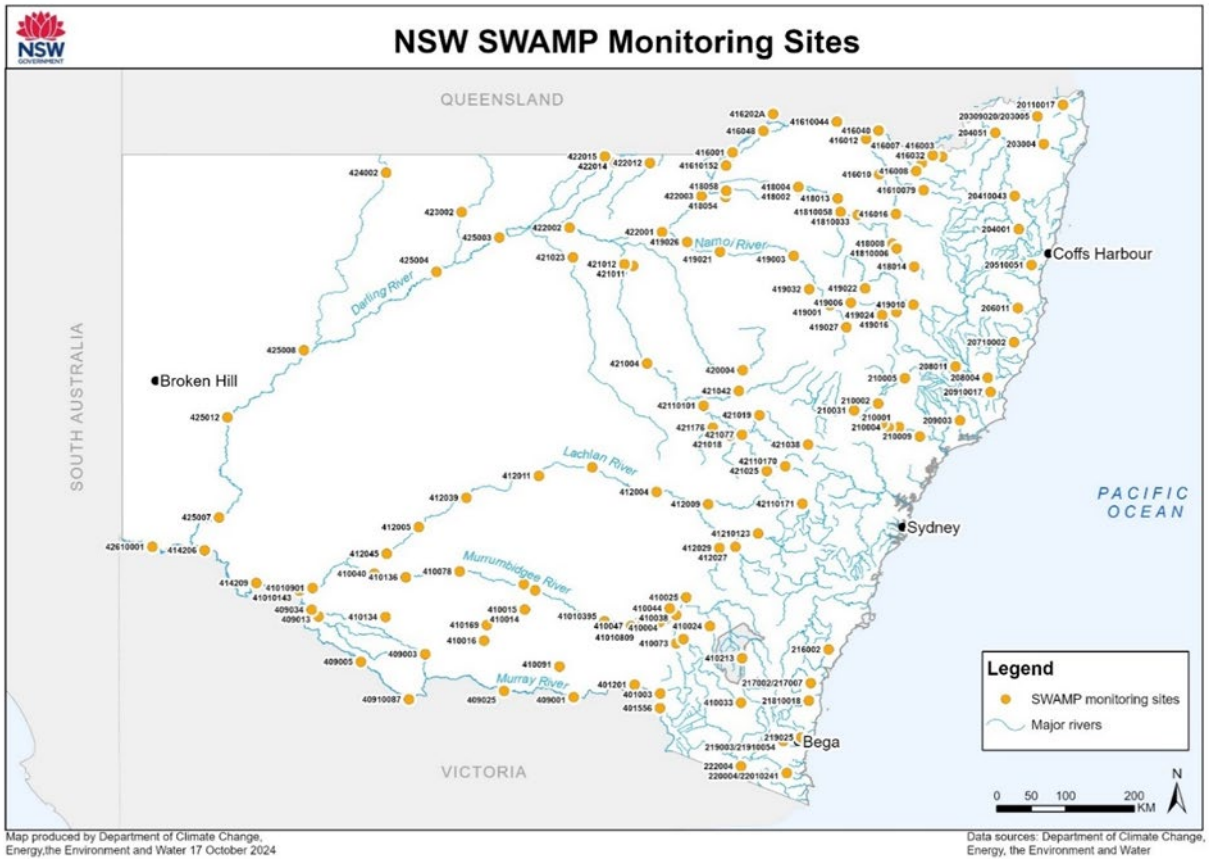

Figure 4. Map of monitoring sites for the NSW State Water Quality Monitoring and Assessment Program (SWAMP)

7.2 Appendix B NSW hydrometric network water quality parameter distribution

Table 6. Number of inland water quality monitoring gauges within the NSW hydrometric network, categorised by Water Resource Plan Area (WRPA) and monitored water quality parameters. Source: (NSW Department of Climate Change, Energy, the Environment and Water, 2024b, 2024a)

WRPA	pH	Temperature	Electrical Conductivity	Dissolved Oxygen (DO)	Turbidity	Total Dissolved Solids	DO profile
Border Rivers	0	5	3	2	0	0	0
Gwydir	0	4	3	3	0	0	0
Namoi	0	12	8	3	1	0	0
Barwon-Darling	0	7	7	8	0	0	0
Intersecting Streams	0	10	6	0	0	0	0
Macquarie-Castlereagh	1	20	17	3	1	0	0
Lachlan	0	20	15	7	0	0	0
Murrumbidgee	1	49	42	14	6	1	0
Murray and Lower Darling	10	61	60	27	7	8	3
Total	**12**	**188**	**161**	**67**	**15**	**9**	**3**

Table 7. Number of coastal water quality monitoring gauges within the NSW hydrometric network, categorised by Water Sharing Plan (WSP) areas and monitored water quality parameters.

WSP areas	pH	Temperature	Electrical Conductivity	Dissolved Oxygen (DO)	Turbidity
Tweed	0	0	0	0	0
Brunswick	0	0	0	0	0
Richmond	0	3	3	0	0

WSP areas	pH	Temperature	Electrical Conductivity	Dissolved Oxygen (DO)	Turbidity
Clarence	0	2	2	0	0
Coffs Harbour	0	0	0	0	0
Bellinger	0	0	0	0	0
Nambucca	0	0	0	0	0
Macleay	0	4	3	0	0
Hastings	0	1	1	0	0
Lower North Coast	0	5	5	0	5
Hunter	0	36	33	1	0
Central Coast	0	0	0	0	0
Greater Metropolitan	52	70	70	52	52
Clyde	0	0	0	0	0
Deua	0	0	0	0	0
Tuross	0	0	0	0	0
Bega	0	1	1	0	0
Towamba	0	1	1	0	0
Snowy Genoa	0	6	5	0	0
Total	52	129	124	53	57

7.3 Appendix C Coastal monitoring sites

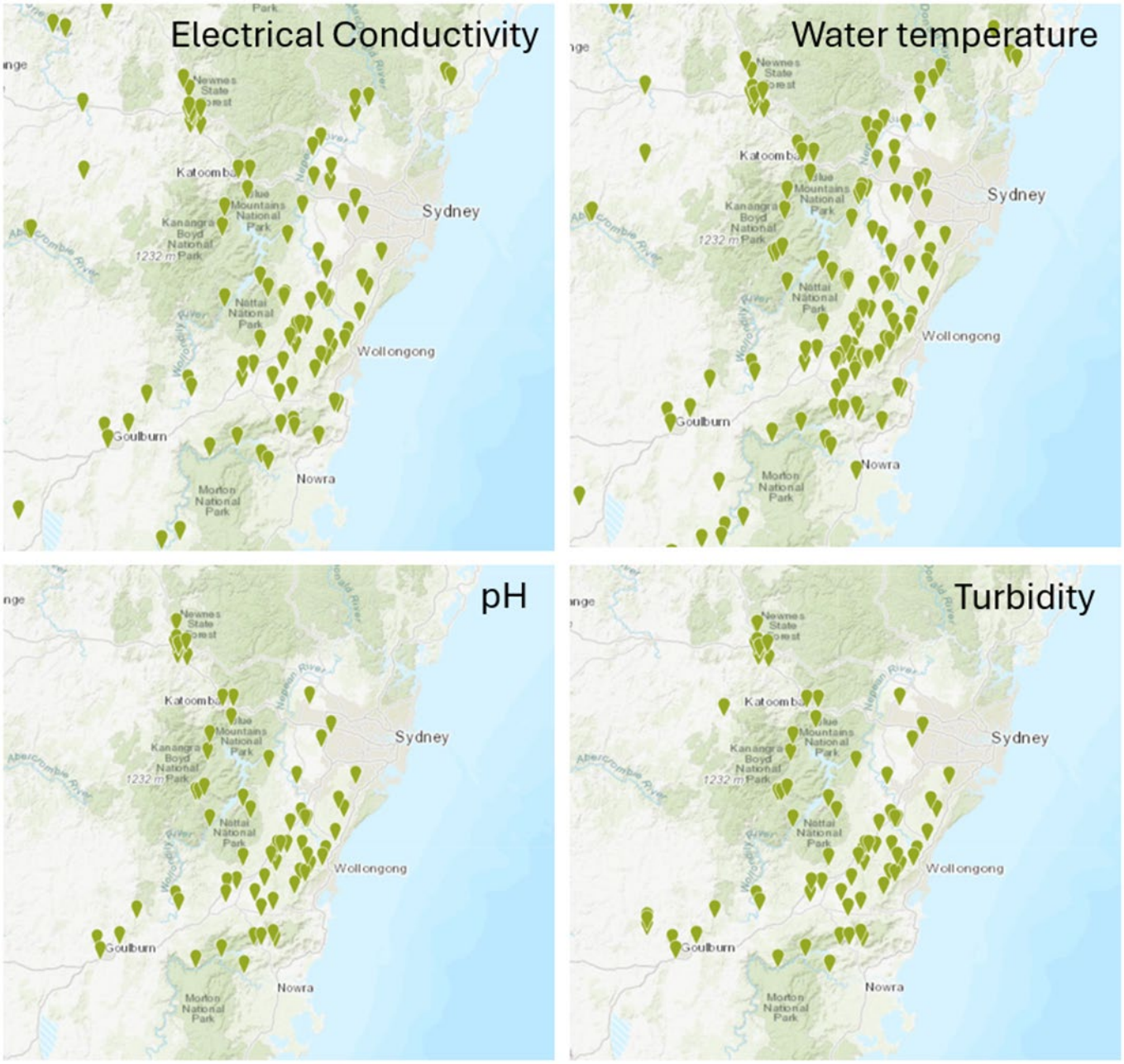

Figure 5. Water quality monitoring sites in the greater Sydney and surrounding areas. Source: Water Data Online: Water Information: Bureau of Meteorology

7.4 Appendix D Estuary Health program site coverage

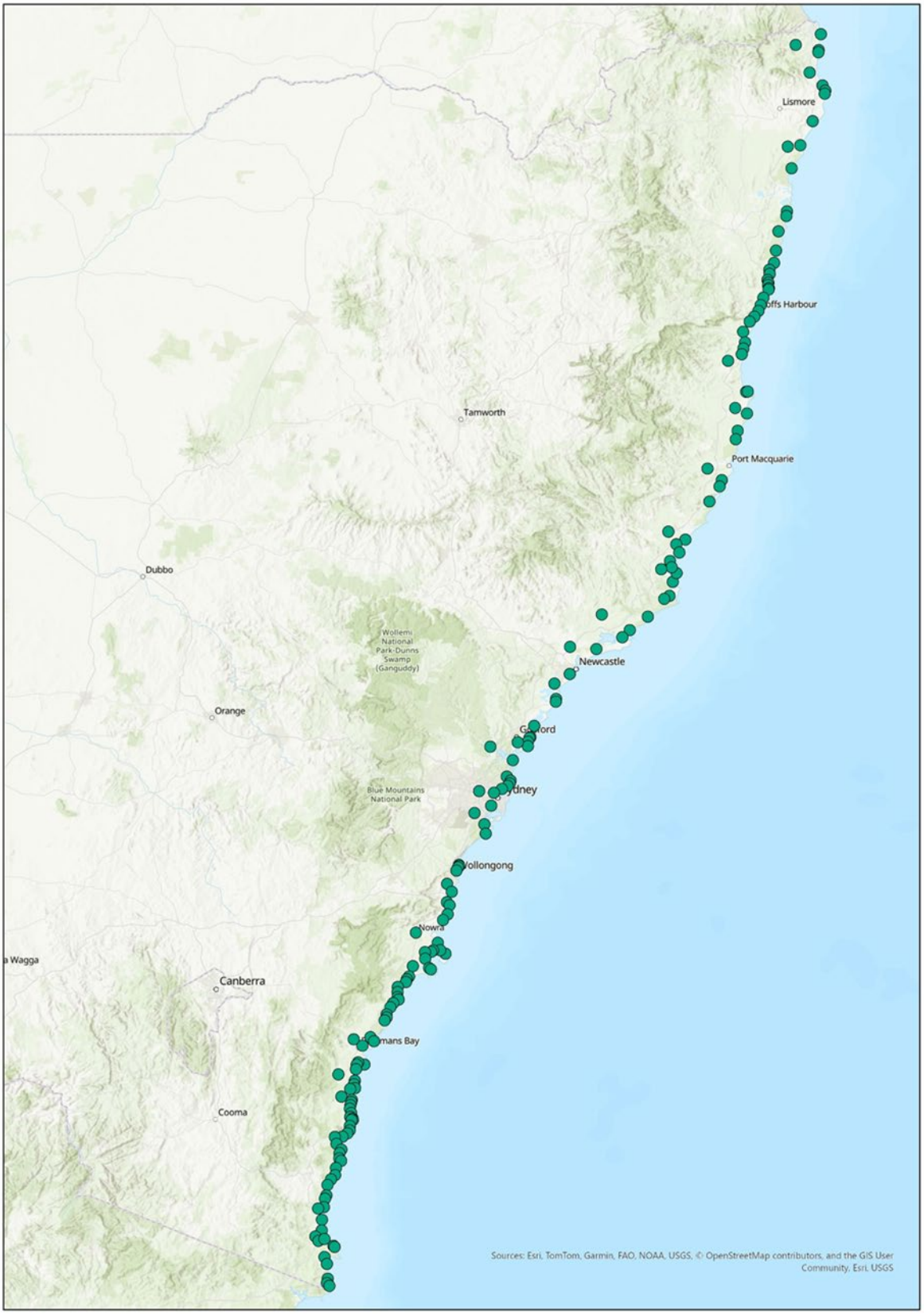

Figure 6. Estuary Health program sites along the NSW coast

7.5 Appendix E Beachwatch

The Beachwatch program was established in 1989 to monitor and report pollution at Sydney Ocean beaches. Since then, the program has expanded along the NSW coastline, partnering with local councils, government agencies and wastewater managers (Department of Planning and Environment, 2022) to improve water quality monitoring and public reporting.

While its primary focus remains on coastal beaches, Beachwatch also provides additional water quality data for 197 estuaries, lakes and rivers across the state. Weekly sampling is conducted at selected sites, measuring water quality parameters such as water temperature, electrical conductivity and enterococci. Water quality data of a site is then predictively modelled using measured data and available tide, surf swell, river discharge and weather data. Results of the measured samples and predictive models are displayed on the Beachwatch website, with bacterial data also available on SEED.

The Beachwatch monitoring program also supports various reporting products such as the NSW State of the Beaches, Heath of our Estuaries, NSW State of the Environment and Marine Estate Management Authority threat and risk assessments (Department of Planning and Environment, 2022). The strengths and weaknesses of this program is outlined in Table 8.

Table 8. Beachwatch strengths and weaknesses comparison

Strengths	Weaknesses
• Sampling is conducted weekly, which is more frequent than most other coastal monitoring programs. • Datasets are easily accessed and downloaded using Beachwatch - Download data. • Relevance to 'swimability' promotes engagement of local councils. • Water quality forecasting based on predicted rainfall, microbial concentrations, and recent pollution incident reports.	• Monitoring efforts are concentrated around the Greater Sydney, Newcastle, and Mid-North Coast regions, leaving significant gaps in coverage across other coastal areas. • Limited water quality parameters, the program currently monitors only basic indicators such as water temperature and electrical conductivity. • Focuses more on swim safety rather than environmental health.

7.6 Appendix F WaterNSW algae alerts

The WaterNSW algae alert system monitors and reports cyanobacteria levels in NSW waterways using a traffic-light system. This system triggers alerts when algal cell numbers or biovolume exceed thresholds for recreational use set by the National Health and Medical Research Council guidelines (2008). These guidelines recommend specific monitoring and management actions for each alert level, as outlined in Table 9.

Table 9. Guidelines associated with cyanobacterial alert levels for recreational use

Alert levels	Threshold	Management requirements
Green level (Surveillance mode)	≥500 to <5000 cells/mL or >0.04 to <0.4 mm^3/L of cyanobacteria.	Routine sampling to measure cyanobacterial levels
Amber level (Alert mode)	≥5000 to <50 000 cells/mL or >0.4 to <0.4 mm^3/L of cyanobacteria.	Investigate the cause of elevated levels and increased sampling to assess risks more accurately.
Red level (Action mode)	≥50 000 cells/mL or ≥ 4 mm^3/L of cyanobacteria.	Authorities warn the public that the water body is considered unsuitable.

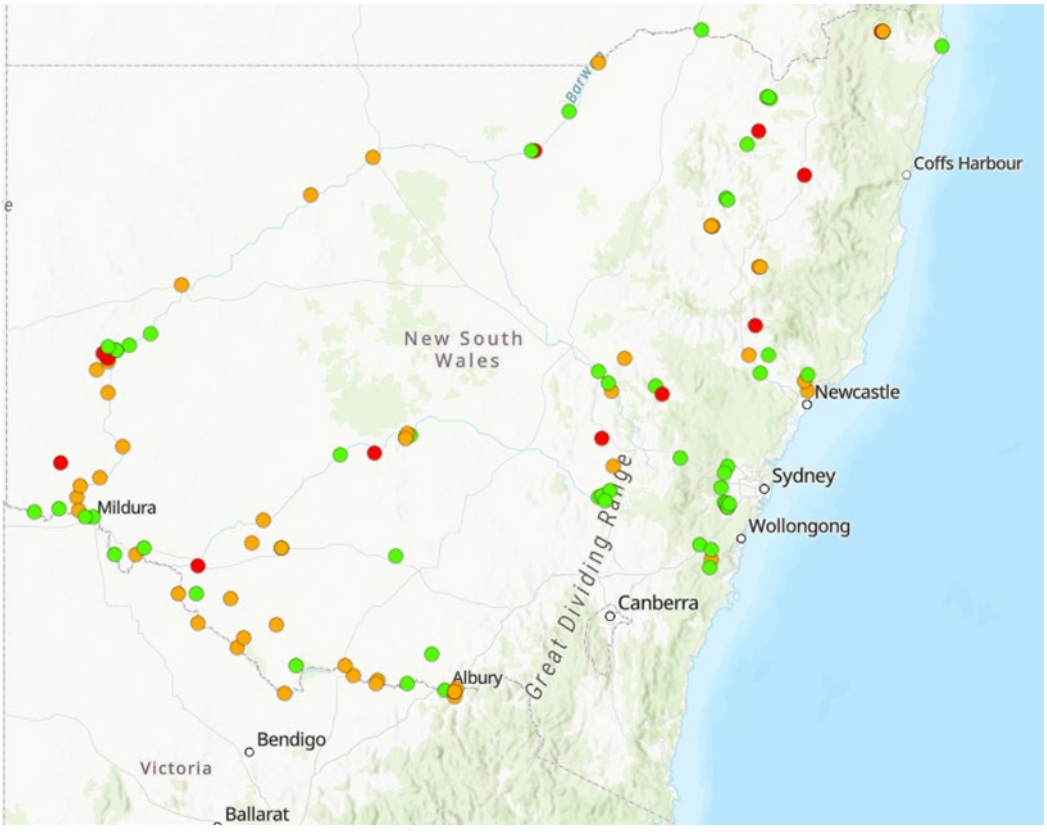

Figure 7. WaterNSW algae alerts. Source: Algae Alerts NSW map - WaterNSW