Victorian Water Quality Analysis 2022

Summary Report

Acknowledgements

The Victorian Water Quality Analysis 2022 was developed through a collaboration between the Department of Environment, Energy and Climate Action (DEECA), the University of Melbourne, Monash University and the Australian National University and its communication partner Scientell. Report development was overseen by the project team within the DEECA, and a steering committee with representatives from DEECA, the Environment Protection Authority, Goulburn-Murray Water, and Melbourne Water. Specialist input was provided by representatives from Goulburn Broken Catchment Management Authority, North Central Catchment Management Authority, North East Catchment Management Authority, and Grampians Wimmera Mallee Water.

Assessments of the impacts of the 2019-20 bushfires on water quality were based on the unpublished analysis 'Impacts of the 2019-2020 Bushfires on water quality North East Victorian and Gippsland' undertaken by Dr Darren Baldwin.

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Acknowledgement of Traditional Owners

The Victorian Government acknowledges all Traditional Owners of Victoria and pays respect to their Elders past and present. Traditional Owners hold the knowledge, stories, custodial obligations, and cultural expertise that has always ensured the health of waterways, water-dependent landscapes and Country.

The Victorian Government is committed to working with Traditional Owners to increase access to water entitlements under current frameworks and increase cultural benefits from the way we store, deliver, and use water. *Water is Life* (2022) outlines pathways to increase Traditional Owner self-determination, decision-making and access to water within the existing water entitlement framework.

The *Victorian Water Quality Analysis 2022* presents data on water quality across Victoria. This analysis provides a base of information that may be useful for Traditional Owners and other parties working with Traditional Owners in water management.

Future analyses will seek to increase the opportunities for Traditional Owners across Victoria to contribute to and benefit from the state's water quality monitoring and analyses.

For further information regarding future analyses, please contact rwmp.wim@delwp.vic.gov.au.

Contents

Barham River, 2012. Photographer: Alison Pouliot.

Goulburn River, 2022. © State of Victoria, DELWP. Photographer: Darryl Whitaker.

1. Introduction

Water quality is a measure of the physical and chemical characteristics of water. The quality of water affects its suitability for essential human activities like drinking, recreation, agriculture and cultural uses. Good water quality underpins ecosystem health and is essential for maintaining biodiversity.

Victorian Water Quality Analysis 2022 is Victoria's five-yearly water quality analysis required under s.22 of the *Water Act 1989*. It follows the previous two reports – Victorian Water Quality Trends 1991-2010 and Victorian Water Quality Trends 1991-2016.

The scope and approach of the current analysis are new and have been developed in collaboration with our delivery partners: the University of Melbourne, Monash University and the Australian National University. The project was overseen by the Department of Energy, Environment and Climate Action (DEECA) and guided by a Steering Committee with representatives from DEECA, Goulburn-Murray Water, Melbourne Water, and the Environment Protection Authority Victoria, and supported by additional agencies.

The study addresses seven questions about surface water quality in Victoria. The first four questions relate to the spatial and temporal variability and trend of water quality, and seek to reveal how climate variation has, and may in the future, affect water quality. These four questions are:

1. What is the overall status of water quality in Victoria?
2. How and why does water quality vary across Victoria?
3. How and why has water quality varied over recent decades?
4. How has, and how will, long-term climate variability and change impact water quality?

Questions five to seven address specific water quality issues of particular relevance to communities and practitioners. These questions are:

5. How do bushfires affect water quality?
6. How are blue-green algal blooms changing?
7. How can continuous water quality data be used to understand water quality events?

The analysis for questions 2-4 focussed on six key parameters regularly collected across the state, each of which has an objective under Victoria's Environment Reference Standard (ERS) (previously the objectives of the State Environment Protection Policy (Waters)). These six parameters are salinity/electrical conductivity (EC), turbidity, total phosphorus (TP), total nitrogen (TN), pH and dissolved oxygen (DO). Table 1 describes these parameters and their significance.

TABLE 1: Water quality parameters and their importance.

Parameter analysed	Description
Salinity/electrical conductivity (µS/cm)	Measure of salt concentration (salinity) in water. It affects water's suitability for human and animal consumption, irrigation and the habitat quality for aquatic fauna and flora.
Turbidity (NTU)	Caused by suspended sediments entering waterways. It affects light penetration and is an indicator of the presence of fine sediments that can smother fauna and flora. High turbidity can change water treatment requirements. Suspended sediments often have attached nutrients that also affect water quality.
Total phosphorus concentration (mg/L)	Phosphorus can influence the growth of plants and algae, altering the food web. High concentrations can increase the risk of algal blooms.
Total nitrogen (mg/L)	Nitrogen can influence the growth of plants and algae, altering the food web. High concentrations can increase the risk of algal blooms.
Dissolved oxygen concentration (mg/L)	Dissolved oxygen is required to sustain aquatic fauna such as fish and can have a strong influence on biochemical processes and odours.
pH	Acidity affects a range of biogeochemical and ecological processes. pH close to neutral is desirable for waterways.

Across the state, 137 sites were identified with sufficient data over 27 years (1995-2021 inclusive) for analysis of at least one of the six parameters. The selected sites were located across a variety of Victorian landscapes and ecosystems. The spread of sites informs water quality across varying climate, ecology, hydrology, topography, geology, land management and land use (Figure A1 of the Appendix). Details of the site selection process are included in the Technical Report. Analysis was conducted at site, region and state scales.

To support spatial and regional analysis, the geographic segments of the ERS (Figure 1) were used as reference. The segments are regions of generally similar aquatic environmental character and generally reflect higher to lower position in the catchments, as well as less to more human impact.

Question 5 examined a broader range of parameters relevant to bushfire impacts. Question 6 used data from Goulburn-Murray Water, Grampians Wimmera Mallee Water and Southern Rural Water collected through their roles in blue-green algae management. Periods of recreational risk notifications for multiple water bodies were used as a proxy for algal blooms, as well as blue-green algae sampling data. Question 7 piloted analysis of continuous dissolved oxygen and turbidity data.

The Victorian Water Quality Analysis 2022 is delivered through the following documents, the:

1. Technical Report
2. Time-series Report
3. Summary Report

In addition, summary data and findings will be made available on the Water Measurement Information System at data.water.vic.gov.au.

A complementary report, *Analysis of Attainment of ERS Water Quality Objectives 2021*, also provides valuable analysis of how water quality was performing against objectives of the ERS. Figure 1 shows Victoria's ERS segments.

For further information on the scope and background to the study, see Chapter 1, the Introduction of the Victorian Water Quality Analysis 2022 Technical Report.

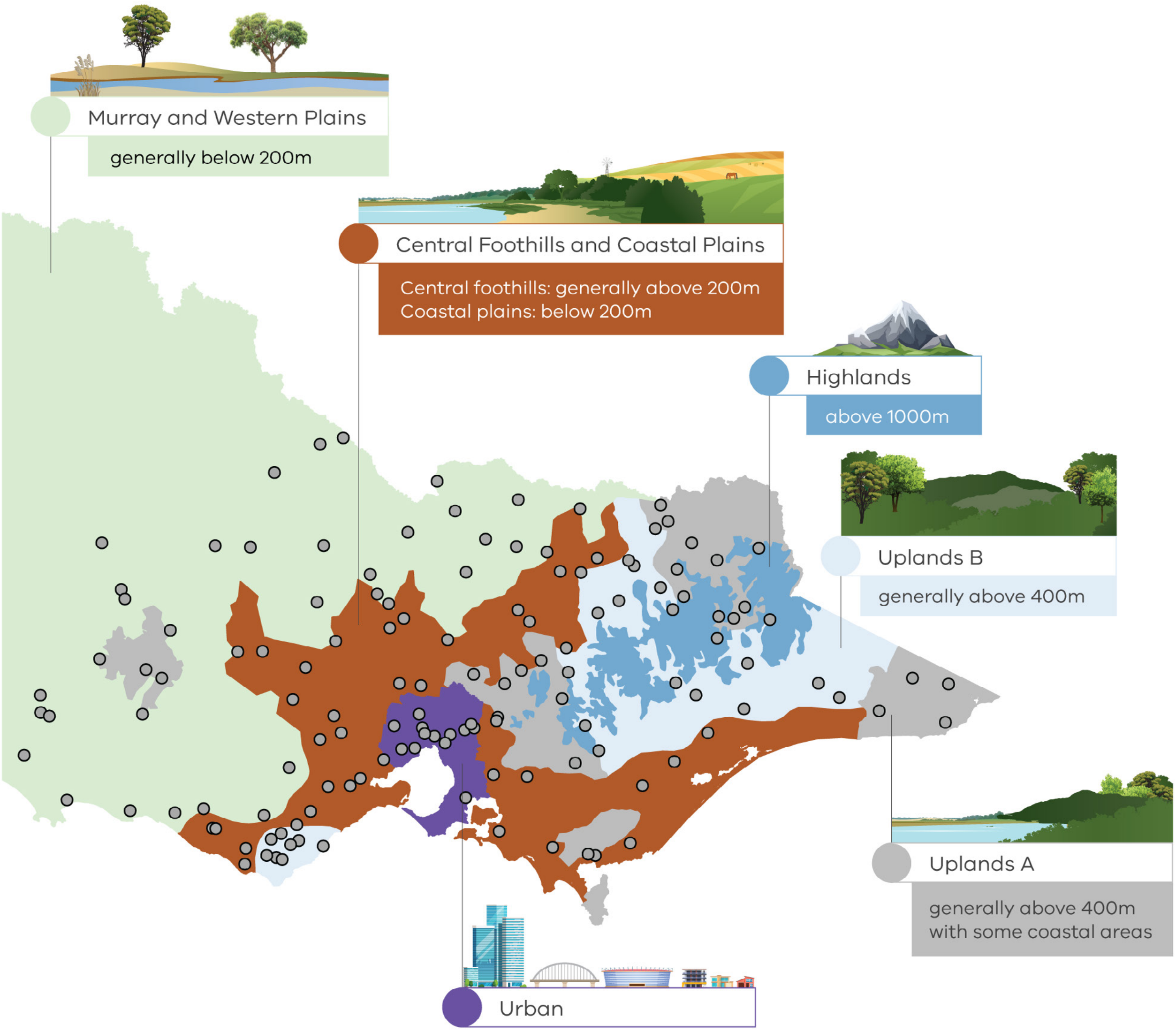


FIGURE 1: Understanding Victoria's different environments.

2. Status of water quality in Victoria

- Examination of long-term water quality, and its comparison with water quality objectives of Victoria's Environment Reference Standard, indicates that water quality continues to be under pressure across the state.
- Long-term *underlying trends* (modelled to remove water quality fluctuations caused by streamflow and seasonality) over 27 years showed an increase in turbidity at 80% of sites, and an increase in total phosphorus at 40% of sites analysed for this report.
- The *underlying trend* over 27 years showed decreasing levels of salinity at 46% of sites over a period when significant investment has been made to improve salinity levels in waterways and there have been marked changes in irrigation practices.
- In contrast to this *underlying trend*, salinity levels increased markedly during the extreme dry period of the Millennium Drought. It is therefore anticipated that in a drying climate salinity levels will likely face the same upward pressure under reduced streamflow conditions in many locations across Victoria.

The overall status of water quality could be considered by examining a combination of factors:

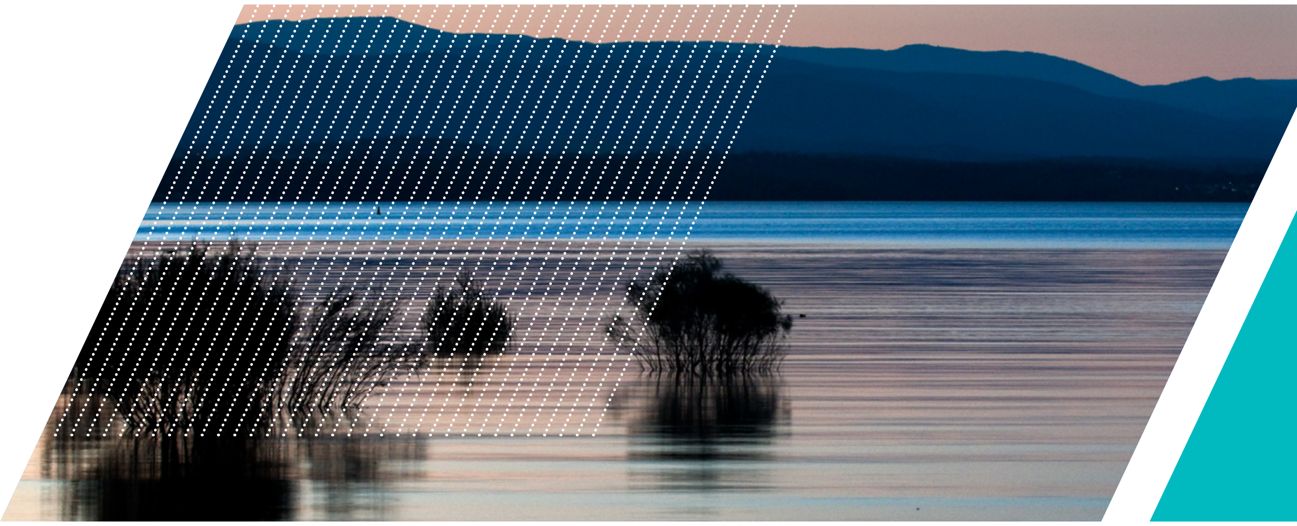
- the long-term median of water quality at sites (and consideration against objectives)
- how underlying water quality at a site is trending in the long-term
- how a site might respond to the expected changes to drivers and pressures in the future.

Chapter 3 presents the median values for six water quality parameters for sites with 27 years of record. It shows varying water quality across and within regions of the state. Some of this variation is in line with different natural conditions and drivers, and some variation is driven by changed land cover and land use from the establishment of agricultural, urban and industrial developments.

A recent report by DEECA, *Analysis of ERS Attainment in Water Quality 2021*, analysed how water quality compared with the objectives of the ERS at the site and regional scale. Figure 2 shows a combined score built from attainment of salinity, turbidity, pH, total phosphorus and total nitrogen scores across sites and regions, demonstrating overall attainment in the period 2018-21. This map shows very poor and poor water quality at sites concentrated around Melbourne and the Yarra, and at various locations across the state, with multiple sites demonstrating excellent water quality in the north-east.

It is clear then that water quality continues to be under pressure at many locations across the state, with the potential to affect suitability for a breadth of ecological, cultural, agricultural, urban and industrial uses.

Lake Glennmaggie, 2011. Photographer: Alison Pouliot.



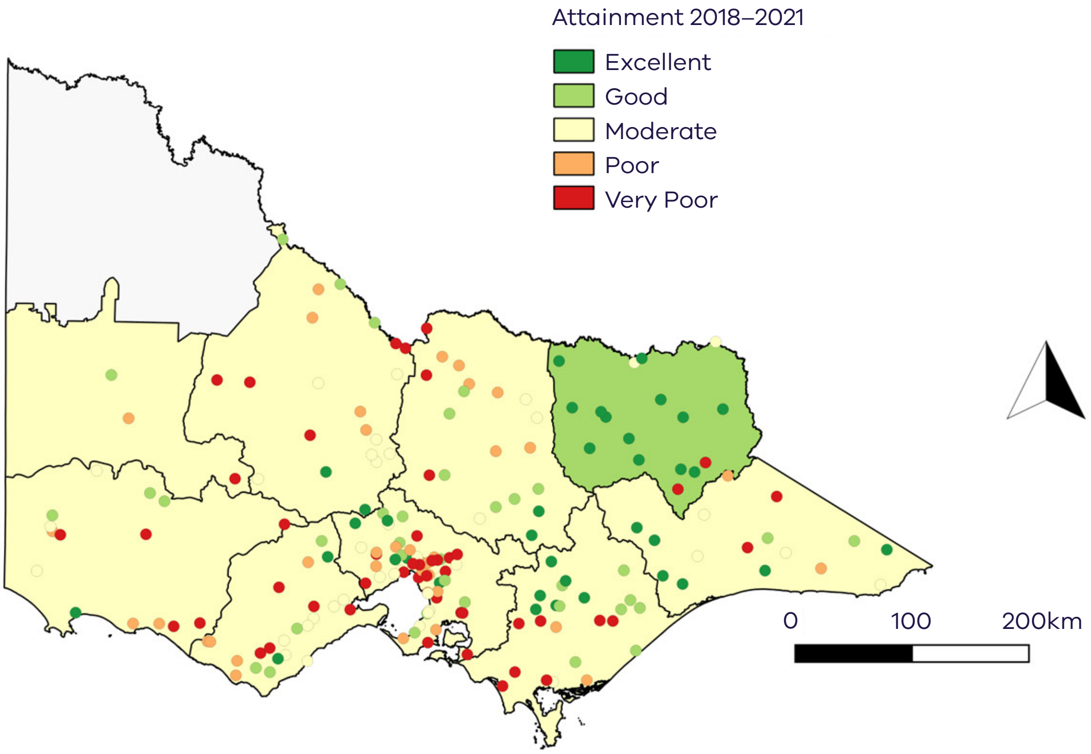


FIGURE 2: ERS combined water quality score for Victorian CMA regions (2018-2021) showing scores for individual sites[1]. No fill colour indicates no data.

To understand how water quality is tracking over time, modelling was undertaken to remove the short- to medium-term influence of streamflow and seasonality (and water temperature for dissolved oxygen) to determine long-term *underlying trends* (Chapter 4). The *underlying trends* indicate how water quality has changed over the long term due to causes such as land and water management or longer-term climate impacts (Table 2).

Significantly, the *underlying trend* of turbidity has increased over the 27 years of the study, with nearly 80% of sites showing a significant[2] increase, compared with just 7% of sites significantly decreasing. Additionally, 40% of sites showed significant increases in total phosphorus compared with 24% significantly decreasing. 35% of sites experienced a decrease in *underlying trend* in dissolved oxygen, primarily in the west of the state, compared with just 17% of sites with an increasing trend. However, no significant change in frequency or periods of low or critical dissolved oxygen events over time were identified from the continuous data (Chapter 8).

Salinity has a significantly decreasing *underlying trend* at 46% of sites, compared with just 16% of sites significantly increasing. This has occurred over a period when there have been significant changes to irrigation practices, and investment in salinity management. Whilst streamflow impacts are removed from the underlying trend, declining salinity may have been influenced by changes in groundwater levels as a result of the Millennium Drought.

These findings indicate the value of further examination of turbidity in particular as well as total phosphorus and dissolved oxygen. For each parameter, *underlying trends* can be examined in more detail at local and regional levels.

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[1] The waters of the Murray River is a shared resource that is located within New South Wales. This earlier analysis applied Victorian ERS objectives to data of the adjacent Murray River to provide a broader understanding of regional water quality.

[2] Any 'significant trend' in this report refers to a trend that has passed a statistical significance test. Refer to Chapter 4 of the Technical Report for the detailed trend analysis approach.

TABLE 2: Percentage of sites across the study where the *underlying trend* in a parameter has increased, decreased or not changed with statistical significance.

	Percentage of sites (green shading indicates the category with the largest number of sites) where *underlying trend* over 27 years was significantly:		
	Decreasing	**Not changing**	**Increasing**
Salinity	46%	39%	16%
Turbidity	7%	13%	80%
Total phosphorus	24%	36%	40%
Total nitrogen	28%	47%	26%
pH	13%	29%	58%
Dissolved oxygen	35%	48%	17%

The study has identified various water quality patterns. In wetter periods turbidity, total nitrogen, total phosphorus and dissolved oxygen were higher at most sites. In drier times these parameters were each lower. Therefore it is anticipated under climate change, turbidity, total nitrogen and total phosphorus levels are expected to decline during periods of low flow that reduce erosion and inputs of nutrients from catchments to streams.

As identified, in contrast to the decreasing *underlying trends*, salinity levels increased at most sites during the dry period and low streamflow of the Millennium Drought. Therefore, despite the long-term decreasing trend at many sites, it is anticipated that in a drying climate, salinity levels will likely face the same upward pressure under reduced streamflow conditions in many locations across Victoria.

Investigation of the potential impact of climate change on water quality, separate from the impact of decreased streamflow and increased temperature, was also undertaken (Chapter 5). While the analysis showed that climate-related processes other than flow and temperature appeared to be driving change in water quality, the mechanism is still unclear and further analyses is warranted (see details in the Technical Report).

Bushfires have a major and extended impact on water quality (Chapter 6). Bushfires are expected to increase under a drying climate, exacerbating this impact. Further analysis is warranted, including on recovery of water quality in catchments from bushfire, as well as investigating how repeated major fires in a catchment may affect the water quality response.

Frequency and occurrence of two types of challenging water quality events were analysed: blue-green algal blooms in water bodies, and low/critical dissolved oxygen events. While there were some site-specific changes in the duration and timing of blue-green algal bloom events, there was no broad-scale trend, either state-wide or in any particular region (Chapter 7). However, the period of record was relatively short, limiting the ability to detect changes. Warmer conditions and decreased streamflow can increase the frequency, extent and duration of algal blooms under a warmer and drier climate – a topic worthy of further investigation. There is a need for improved, longer-term monitoring of blue-green algae to provide the necessary information to address this risk. Continuous water quality monitoring can help identify diurnal and seasonal patterns in low dissolved oxygen events. The frequency and duration of low/critical dissolved oxygen events are strongly associated with climate variation (Chapter 8).

There has been significant investment over several decades in rural and urban settings to protect water quality, and there have been significant changes to water management and use. While the long-term routinely collected data have not necessarily been collected to assess the impacts of individual interventions, some improving *underlying trends* were identified. Although not all sites have had improvements in water quality, the improvements at some sites give confidence in the potential for change.

Results varied by location, and while improvements were identified in some locations, there were declines elsewhere. Further examination of the project data at local and regional scales will identify trends and patterns for specific waterways and systems.

This study set out to answer questions about water quality to inform practitioners, communities and policymakers. The study found each question can be answered to varying degrees. Each may be answered in more detail as data gaps are filled, and analytical and multi-disciplinary experts collaborate to better understand the complexities and interactions involved.

Human systems are designed around the long-term suitability of water quality for specific uses. Water supplies are treated to make them suitable for drinking. Agricultural endeavours take into consideration the quality (and availability) of water. However ecological systems may decline as water quality changes its suitability for different species and ecological communities. Cultural values, uses and practices may also be impacted and change in response to reduced water quality.

For further information on Victoria's overall water quality, see Chapter 2 of the Victorian Water Quality Analysis 2022 Technical Report.

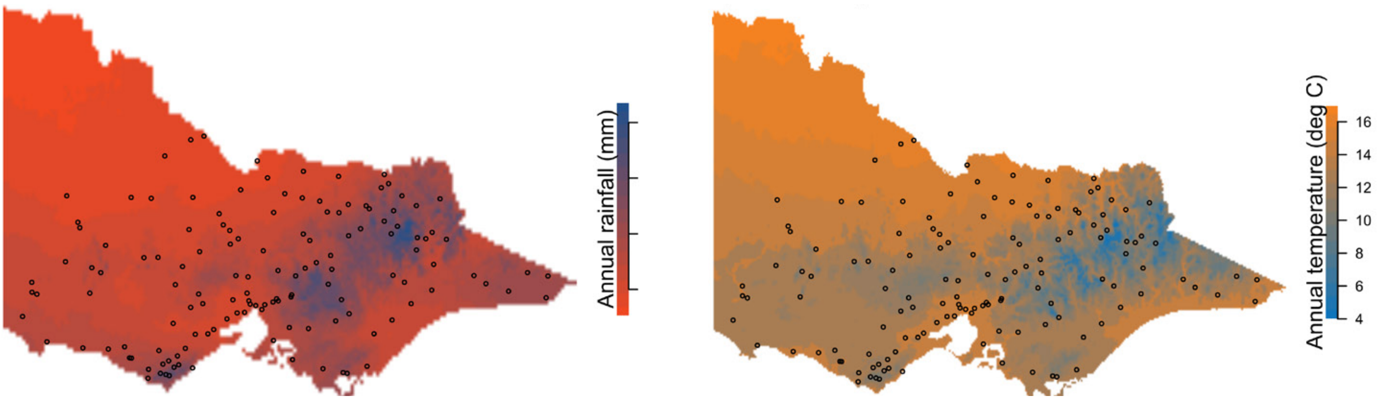
3. Variation of water quality across Victoria

The 25th, 50th and 75th percentile values of salinity, turbidity, total phosphorus, total nitrogen, pH and dissolved oxygen at 137 sites over 27 years showed:

- Cooler mountainous forested regions in Victoria's east demonstrated lower salinity, turbidity, total phosphorus and nitrogen, pH and higher dissolved oxygen levels.
- Warmer lowland agricultural and cropping regions, and urban areas demonstrated higher levels of salinity, turbidity, total phosphorus and nitrogen, pH and lower dissolved oxygen levels.
- An examination of drivers of spatial water quality variation found that water quality varies along a continuum between the two extreme types of catchment described above.

Water quality varies across Victoria and is influenced by a variety of landscape features. Some of these features are natural and some are related to human activities. A wide range of landscape features were examined to determine their influence, including climate, hydrology, topography, soils and geology, land use and land management (Figure 3). Natural and human factors influence water quality parameters differently. It can be difficult to differentiate the impact of these natural and human factors based purely on the data analysis. However, the combination of the different analysis results and our knowledge of the underlying processes influencing water quality parameters enables us to comment on the likely relative impacts of human and natural factors across the state.

Werribee River at the Melton Reservoir in southern Victoria, 2022. © State of Victoria, DELWP. Photographer: Darryl Whitaker.


a) Annual rainfall

b) Annual temperature

c) Elevation

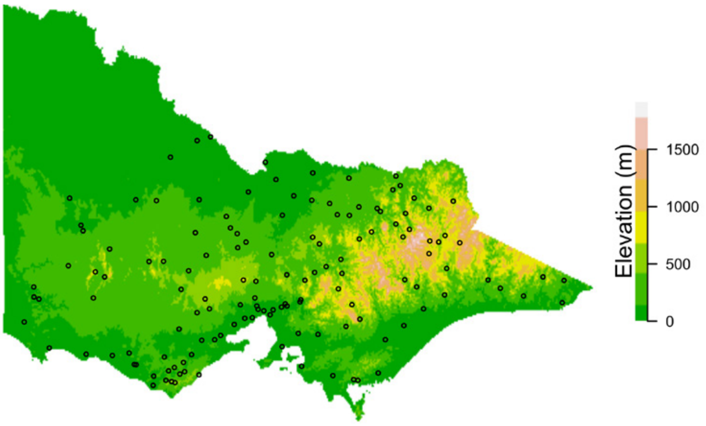


FIGURE 3: Mapping of Victoria's long-term climate conditions and topography, as: a): annual rainfall; b): annual temperature; c): elevation). The maps show strong geographical correlation between areas of higher rainfall, higher elevation and lower annual temperature which play a part in consequent land use, as well as water quality.

Historically, uplands have remained more forested due to their lower suitability for cropping and pastures, and foothills and plains have been long used for agriculture with its accompanying land clearing, soil disturbance and application of fertilisers.

This study examined 27 years of data at up to 137 sites to determine spatial variation in long-term water quality for key water quality parameters of: electric conductivity/salinity (EC), turbidity, two nutrient indicators total phosphorus (TP) and total nitrogen (TN), pH, and dissolved oxygen. While turbidity, salinity and dissolved oxygen are monitored continuously at some sites, only sample data collected during regular sampling visits were used for this analysis. Data were generally available at monthly intervals, though sampling at higher frequency (weekly or daily) occurred at some sites.

Salinity, turbidity, total phosphorus and total nitrogen were markedly lower and dissolved oxygen was higher in cooler, mountainous, typically more forested regions of Victoria's eastern ranges than in the warmer lowland agricultural and cropping regions of the central north and west and the urban areas.

This pattern translated to regional trends when looking at the segments (regions) of Victoria's ERS.

- Murray and Western Plains, Central Foothills and Coastal Plains and Urban segments had the highest salinity, turbidity, total phosphorus, total nitrogen, pH and lowest overall dissolved oxygen levels – as well as high variation of site-level water quality.
- Uplands A and B segments had lower levels of salinity, turbidity, total phosphorus, total nitrogen and pH and higher levels of dissolved oxygen – with low variation of each parameter between sites.

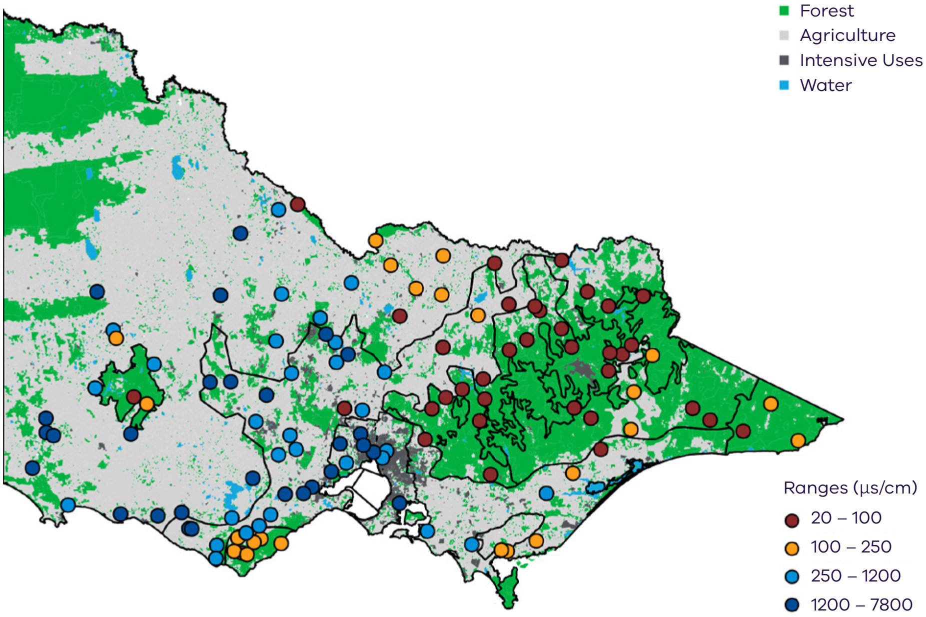


FIGURE 4: Median salinity for each monitoring site. Black lines show the boundaries of ERS segments.

Salinity

Salinity was lower in the less developed, cooler, forested and mountainous regions. It was higher in the warmer, lower-elevation agricultural regions (Figure 4). There was high variation between sites within the Central Foothills and Coastal Plains and the Murray and Western Plains ERS segments. Surface water salinity changes naturally depending on the geology of the land and the rainfall. Salinity can also be affected by human activities such as vegetation clearing and agriculture.

Turbidity

Turbidity generally increased moving from highlands to lowlands (Figure 5). This gradient is indicative of increasing human activities and landscape disturbance. There tends to be high turbidity on the riverine plains in northern Victoria, where fine sediments dominate the alluvial valleys. There is high variation between sites within the Urban, Central Foothills and Coastal Plains and the Murray and Western Plains ERS segments.

Turbidity also varies naturally due to differences in geology (type and amount of sediment erosion) and to climate variability, largely rainfall.

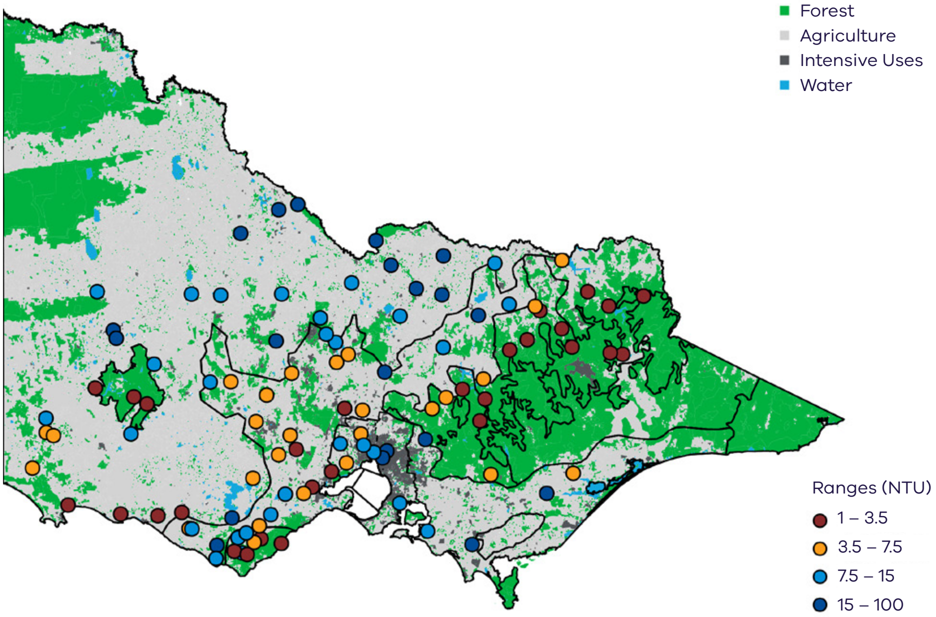


FIGURE 5: Median turbidity for each monitoring site. Black lines show the boundaries of ERS segments.

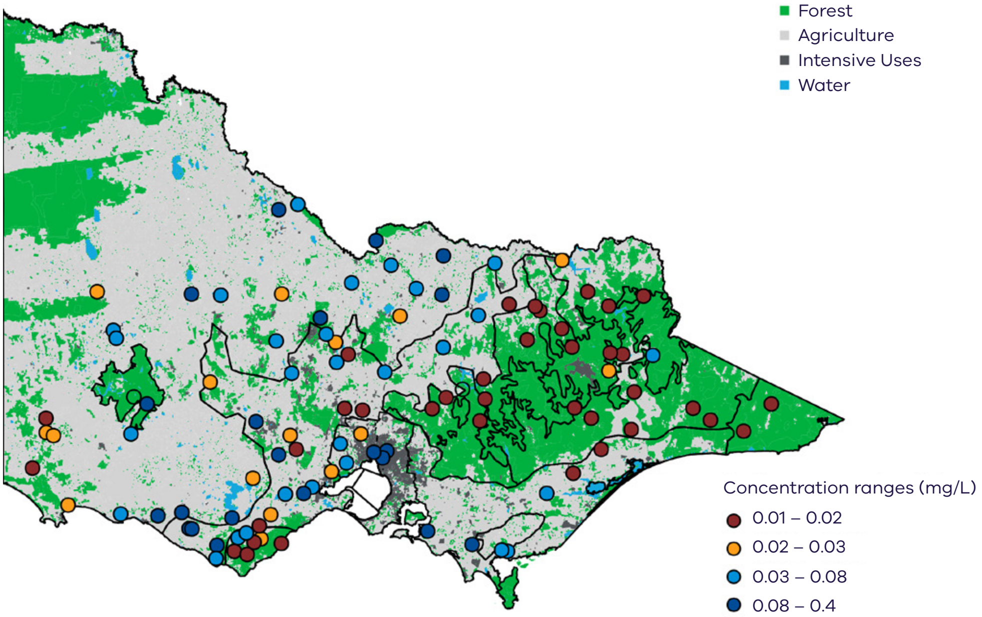


FIGURE 6: Median total phosphorus levels for each monitoring site. Black lines show the boundaries of ERS segments.

Nitrogen and phosphorus

These elements were measured as 'total' amounts. 'Total' means the nitrogen and phosphorus in their various forms in the water were each tallied. Total phosphorus and total nitrogen share similar spatial patterns, with marked differences between colder mountainous, forested regions (lower total phosphorus and total nitrogen) and warmer lowland agricultural/ cropping regions (higher total phosphorus and total nitrogen) (Figures 6 and 7). There appears to be more variability between neighbouring sites in the Murray and Western Plains, Foothills and Coastal Plains, and Urban segments than there is for salinity and turbidity.

Nitrogen and phosphorus can vary naturally. However, fertilisers, organic wastes and animal feed in agricultural areas are important human-induced influences that likely have a larger influence than natural effects.

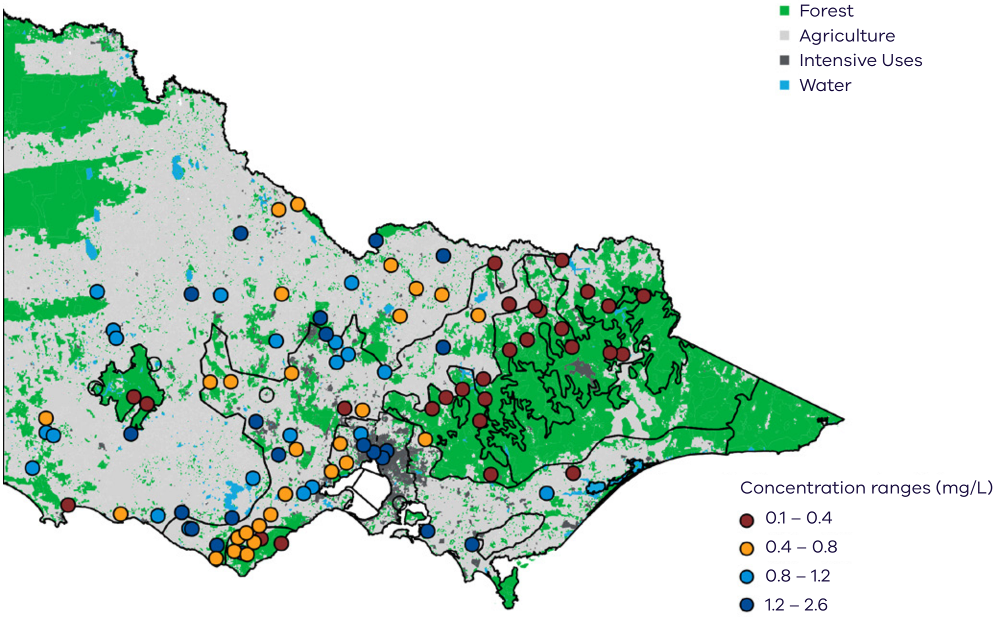


FIGURE 7: Median total nitrogen levels for each monitoring site. Black lines show the boundaries of ERS segments.

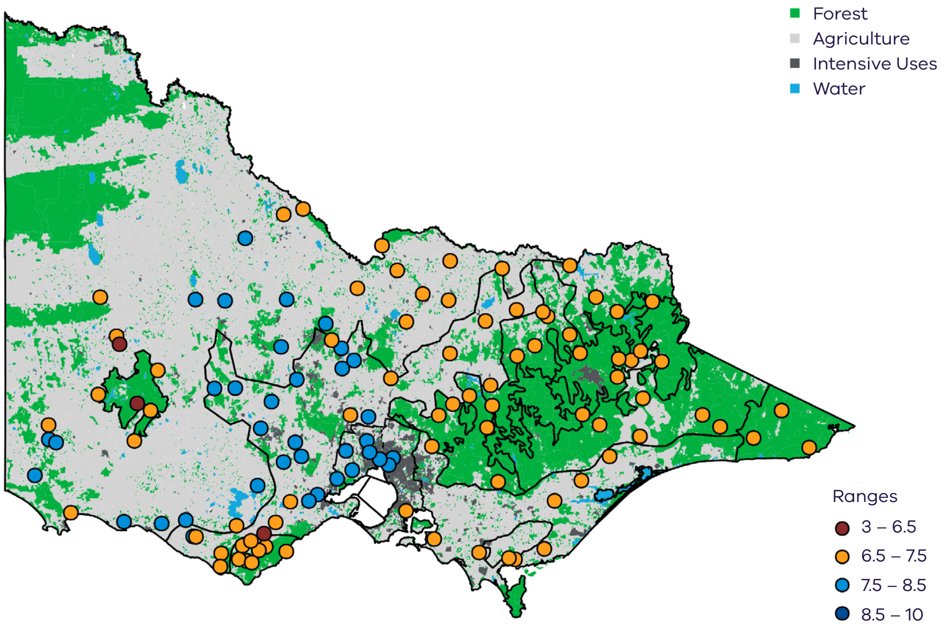


FIGURE 8: Median pH for each monitoring site. Black lines show the boundaries of ERS segments.

pH

Victorian waterways were mostly within a neutral pH range. pH naturally varies across the state due to differences in rainfall, soil and geology (Figure 8). Soils and streams in regions with higher rainfall tend to have a lower pH due to leaching. Human activities influence pH, mostly through agricultural production, soil conditioning chemicals (e.g. lime) and fertilisers.

Dissolved oxygen

Spatial patterns of dissolved oxygen are influenced by water temperature, flow velocity and turbulence, as well as the amount of organic matter and photosynthesis within the water body. Dissolved oxygen concentrations were lower at lower elevations, and western areas of Victoria, where streamflow is less consistent and temperatures are warmer, compared with the eastern forested, mountainous regions (Figure 9). Low streamflow can result in lower dissolved oxygen as it reduces gas exchange. Higher temperatures also lower dissolved oxygen as warmer water holds less oxygen.

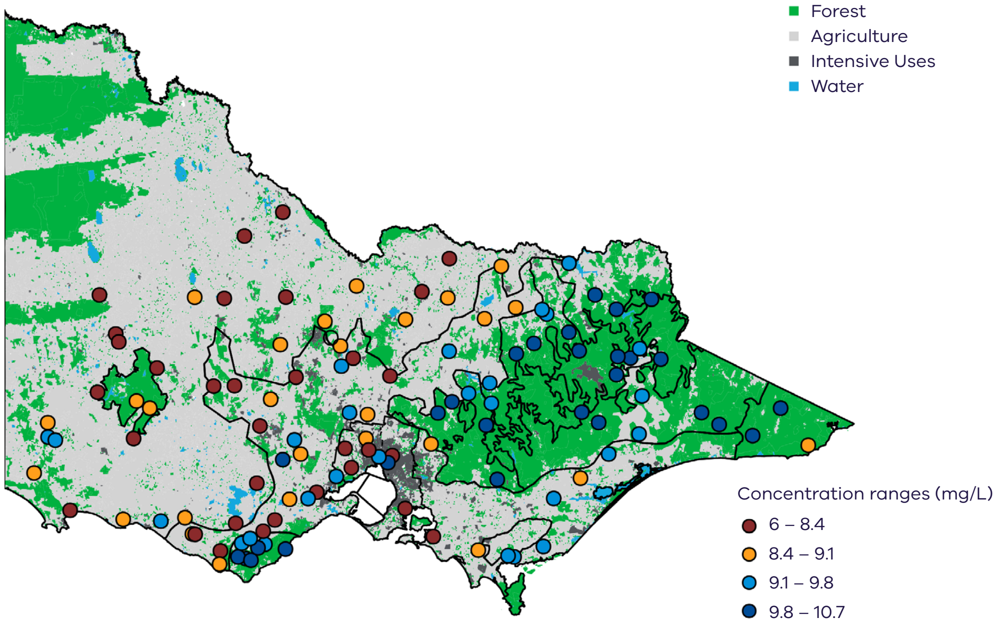


FIGURE 9: Median dissolved oxygen for each monitoring site. Black lines show the boundaries of ERS segments.

Drivers of water quality

Analysis was undertaken to determine the key drivers of water quality that could explain the spatial variation identified. 48 catchment characteristics of climate, land use and land cover, topography and soil were examined using multivariate analyses to assess how these characteristics influence spatial variation of water quality.

A 'principal component analysis' was undertaken to identify underlying relationships between water quality and these catchment characteristics. Only the two most important spatial patterns (which are each a combination of multiple catchment characteristics) could explain the great majority (>85%) of spatial variations of all 48 catchment characteristics. That is, the catchment characteristics often vary in similar ways, making it difficult to attribute the spatial patterns in water quality to individual catchment characteristics.

Individual drivers for this spatial variation (in the form of catchment characteristics) could not be identified due to high direct correlation between them, such as altitude and annual temperature. Instead, the spatial variation in water quality is associated with groups of catchment characteristics. They reinforce the pattern that warmer, drier lowland catchments with more agriculture and intense usages have higher levels of stream salinity, turbidity, total nitrogen, total phosphorus, pH and lower dissolved oxygen. Colder highland catchments with higher rainfall and more natural and forested lands have lower levels of stream salinity, turbidity, total nitrogen, total phosphorus, pH and higher dissolved oxygen.

Erskine River, 2010. © Alison Pouliot.

While much of the systematic variation in water quality between catchments follows the dominant spatial patterns in catchment characteristics highlighted above, there is also significant local variation, which is likely related to the local characteristics and processes of individual catchments.

Overall, water quality varies along a continuum across Victoria. Figure 10 summarises the group of catchment characteristics that best describe differences in Victoria's catchments. As a group, these characteristics closely correlate to water quality variations across the state.

Variations in water quality across Victoria's catchments

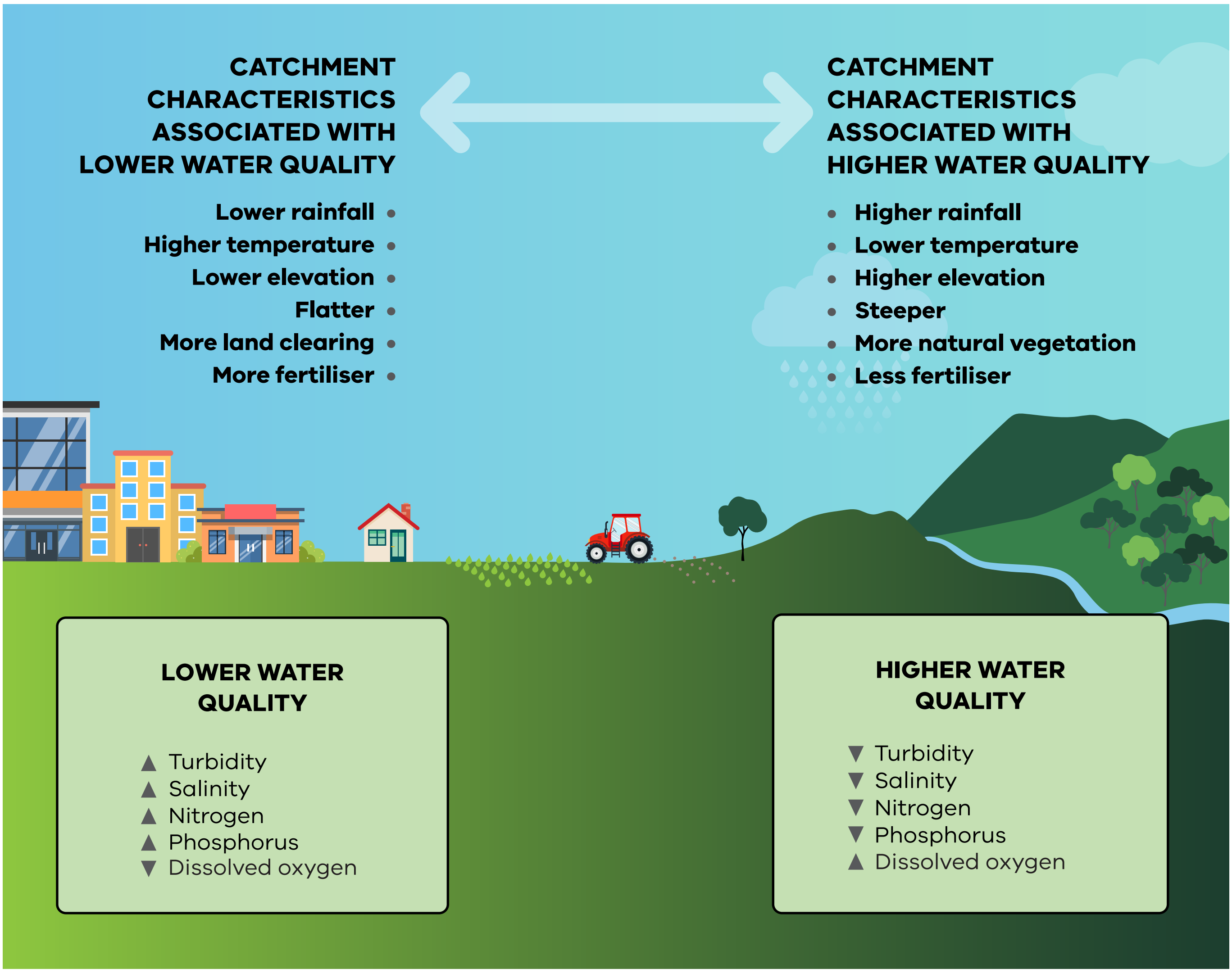


FIGURE 10: **Catchment characteristics strongly influence water quality. The left and right ends of the figure highlights two extreme types of catchments in Victoria, and catchments tend to have varying conditions along a continuum between them.**

For further information on how and why water quality changes across Victoria's landscapes, see Chapter 3 of the Victorian Water Quality Analysis 2022 Technical Report.

4. Variation in water quality over recent decades

- Over the last 27 years, streamflow was the key factor affecting salinity, turbidity, total nitrogen, total phosphorus and pH over time, and water temperature was the key factor affecting dissolved oxygen.
- In wetter periods, turbidity, total nitrogen, total phosphorus and dissolved oxygen were higher; and in dry periods, salinity and pH were higher.
- *Underlying trends* were identified through modelling. The models removed the influence of streamflow and seasonality on the data record, to enable us to identify the long-term direction of water quality change.
- The *underlying trend* of turbidity increased at 80% of sites across Victoria. The majority of sites also had increasing *underlying trends* in pH and total phosphorus.
- The *underlying trends* are contributing to changes in attainment of ERS objectives. As *underlying trends* in turbidity, total nitrogen, total phosphorus increase, attainment of ERS objectives declined.
- Over the 27 years, total phosphorus deteriorated at more sites in the two most modified regions (Central Foothills and Coastal Plains and Murray and Western Plains) than in the less modified regions (Uplands A and B).

Water quality varies over time. It can be helpful to consider two types of temporal change for water quality management. The first is water quality variation that is driven by fluctuating conditions – like short- to medium-term wet or dry periods. This variation is represented by graphs of water quality data showing changes in quality over time (*Time-series Report*). Understanding how fluctuating conditions drive water quality variations allows us to consider how water quality will respond when these conditions repeat or change in frequency or length.

The second is the long-term trend in water quality at a site, independent of short- to medium-term weather patterns. These trends may be able to identify shifts in quality attributable to human intervention, such as land or water management practices, or potentially climate change. Understanding this long-term trend has been difficult, as it has been hidden by the short- to medium-term fluctuations in water quality.

This report sought to address this challenge by determining an *underlying trend* that is independent of streamflow and seasonality by removing their influence from trend results. Figure 11 shows that water quality concentration is the sum of the influence of seasonality, flow and the *underlying trend*. The long-term *underlying trend* can be determined by understanding the influence of flow and seasonality. Changes to the *underlying trend* may then inform whether changes to management interventions or adaptation could be considered.

Bemm River, 2009. © Alison Pouliot.

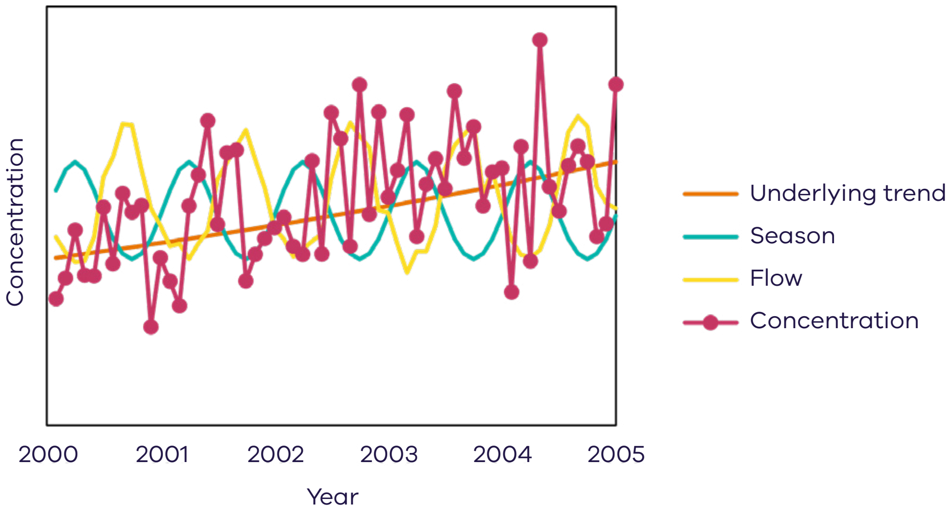


FIGURE 11: **Representation of water quality temporal variability as made up of streamflow, seasonality and an *underlying trend*.**

This study examined 27 years of data at up to 137 sites for salinity, turbidity, total phosphorus and total nitrogen, pH and dissolved oxygen. While turbidity, salinity and dissolved oxygen are monitored continuously at some sites, generally monthly sample data were used for this analysis.

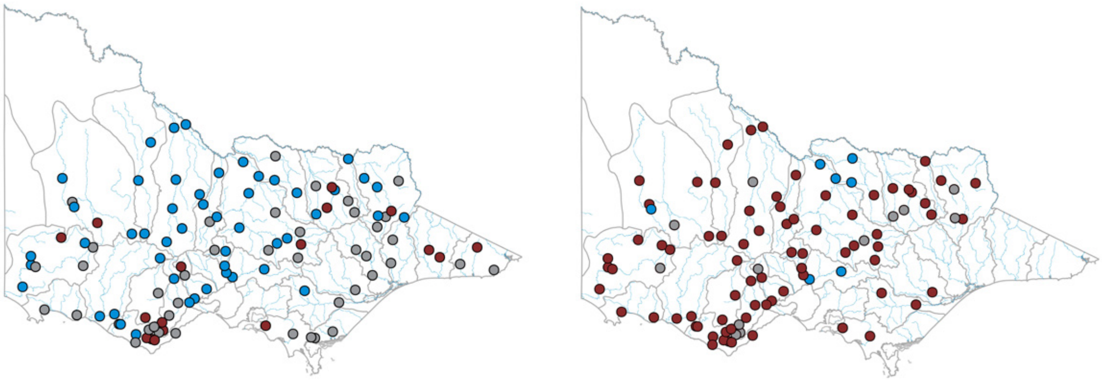
A multiple linear regression model was used to examine the *underlying trend*, streamflow and seasonality, as well as water temperature for dissolved oxygen only. The relative importance of each was assessed.

For each site, the direction and strength of the *underlying trend* were determined. Site results were mapped and presented state-wide, and by ERS segment. Hot spot sites with the strongest increasing and decreasing *underlying trend* for each parameter were identified to support further analysis.

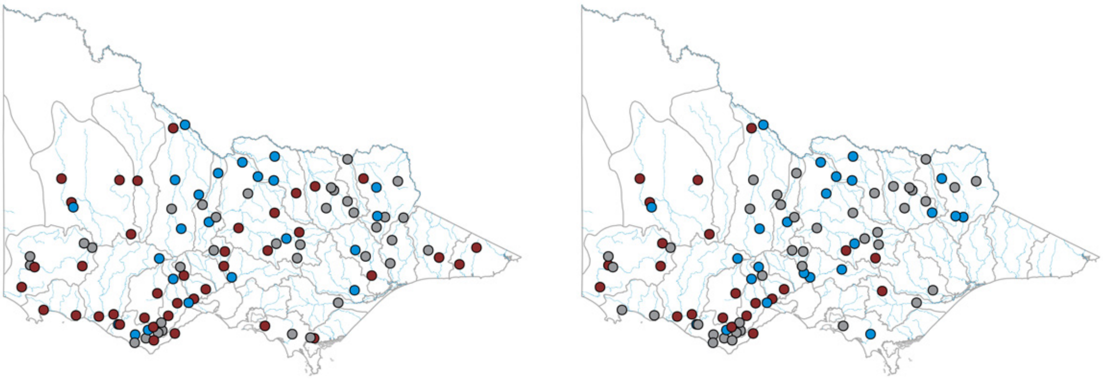
Lastly, differences in ERS attainment for 1995-2007 and 2009-21 for all Victorian sites were calculated and the relationship between *underlying trends* and changes in attainment examined.

Streamflow was the key factor affecting variability in salinity, turbidity, total nitrogen, total phosphorus and pH over time. In wetter periods, turbidity, total nitrogen, total phosphorus and dissolved oxygen were higher at most sites. In drier periods, salinity and pH were higher at most sites. Water temperature was the key factor affecting dissolved oxygen over time. This examination is extended in the climate change chapter of this report (Chapter 5) and Chapter 5 of the Technical Report, examining the impacts of the Millennium Drought and climate change.

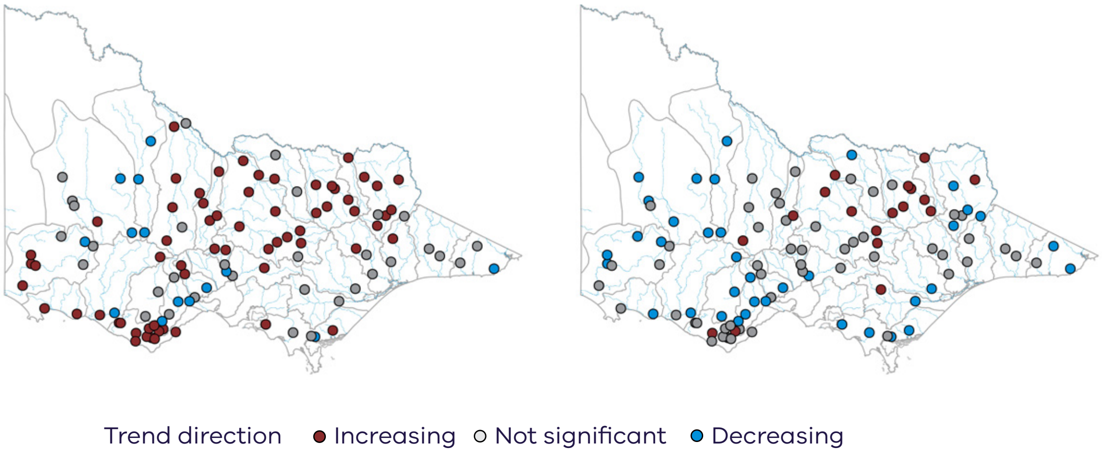
Figure 12 shows the long-term direction of water quality for each parameter at each site assessed.


a) Salinity

b) Turbidity


c) Total phosphorus

d) Total nitrogen


e) pH

f) Dissolved oxygen

FIGURE 12: ***Underlying trends*** **at sites across Victoria from 1995 to 2021.**

Salinity: decreasing *underlying trend* at 46% of sites and increasing *underlying trend* at 16% of sites state-wide. There were increasing trends in the Otways Coast region and in the Snowy Basin in the east. The trends are largely not significant in the south and in the east of the state.

Turbidity: increasing *underlying trend* at 80% of sites state-wide. Some regions in the central north and in the Yarra catchment had a decreasing trend.

Total phosphorus: increasing *underlying trend* at 40% of sites.

Total nitrogen: the largest proportion of sites (47%) had no significant trend, though there were trends in some regions.

pH: increasing *underlying trend* at 58% of sites, noting that 96% of sites stay within the neutral range of pH 6.5-8.5.

Dissolved oxygen: 48% of sites experienced no significant trend. Increasing trends experienced in the north-east, and decreasing trends in the west.

Over the 27 years, total phosphorus deteriorated at a greater proportion of sites in the two most modified regions (Central Foothills and Coastal Plains and Murray and Western Plains) than in the less modified regions (Uplands A and B) (Figure 13).

Beyond identifying an increasing, decreasing or insignificant trend, the strength of trends was identified for each site. The study identified the eight sites with the highest increasing or decreasing trends in all parameters. The Technical Report presents the details.

Figure 13 shows water quality trends at each ERS segment for each of the six parameters. Figure 14 shows the number of sites across the state with increasing, decreasing and no significant *underlying trend* in water quality.

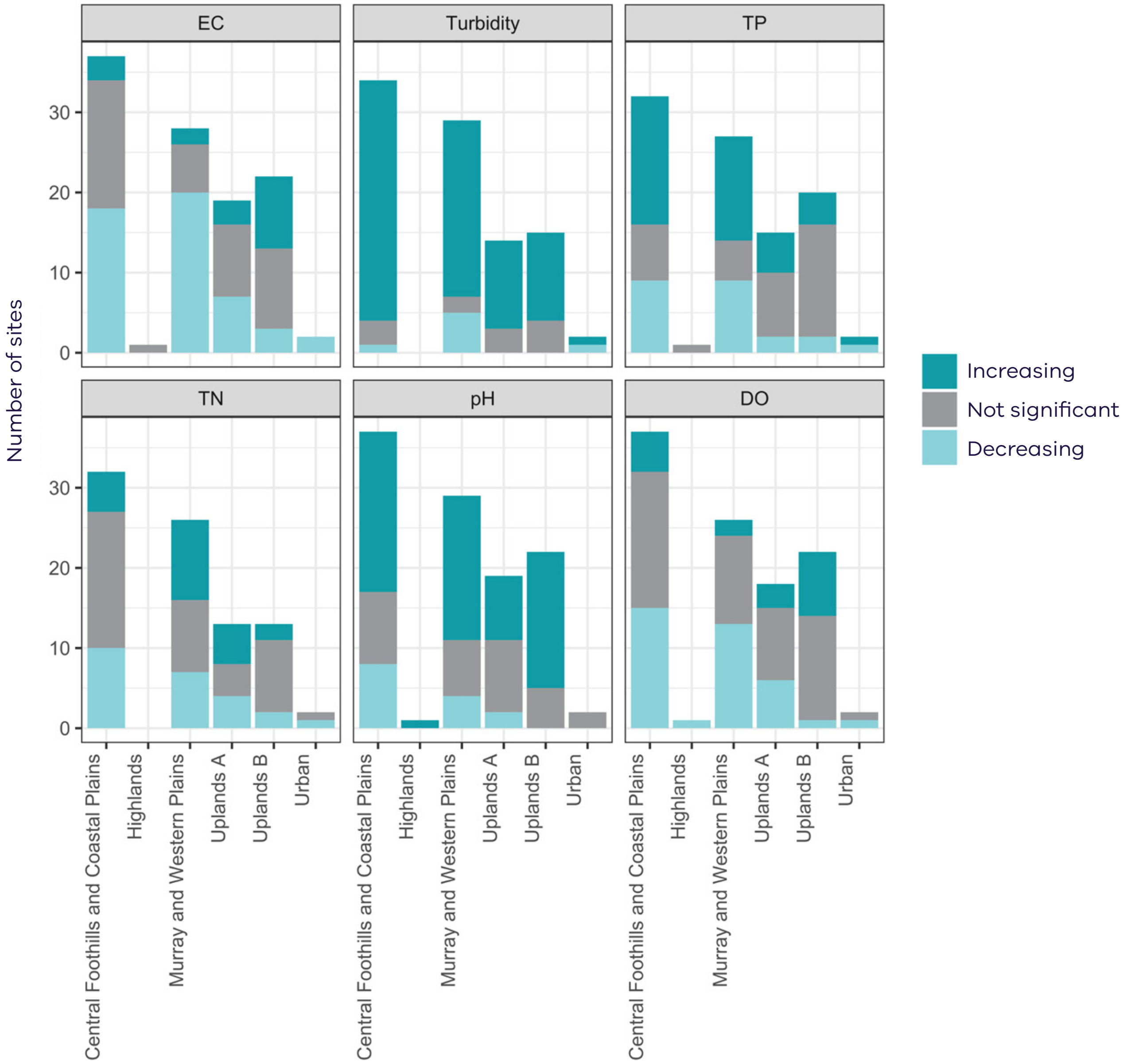


FIGURE 13: **Number of sites with significant increasing, significant decreasing and not significant *underlying trends* in water quality across each ERS segment.**

There were three sites with three or more water quality parameters with strong improving *underlying trends*:

- Moonee Ponds Creek at Racecourse Road, Flemington (229643): turbidity, total phosphorus and total nitrogen
- Goulburn River at Shepparton (405204): dissolved oxygen, salinity, turbidity, total phosphorus and total nitrogen
- Goulburn River at McCoys Bridge (405232): salinity, turbidity, total phosphorus and total nitrogen

Figure 15 shows the significantly decreasing *underlying trends* in salinity at two sites along the Goulburn River.

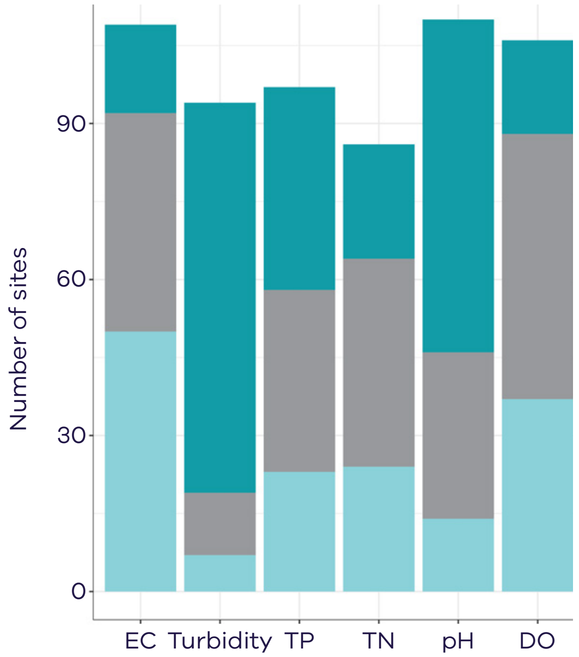


FIGURE 14: Number of sites with significant increasing, significant decreasing and not significant *underlying trends* in water quality.

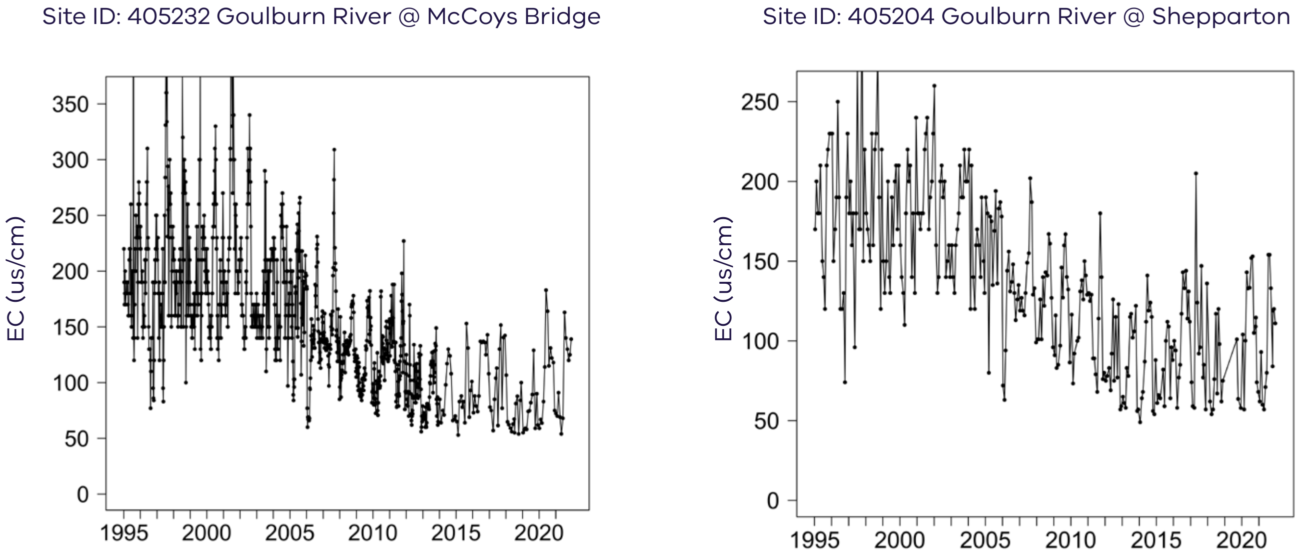


FIGURE 15: Salinity values of two Goulburn River sites, which demonstrated strong declining *underlying trends* over 27 years.

There were eight sites with three or more parameters with strong declining *underlying trends*:

- Little River at Little River (232200): pH (increasing acidity), total phosphorus and total nitrogen
- Avoca River at Coonooer (408200): dissolved oxygen, pH (increasing acidity), turbidity and total phosphorus
- Avoca River at Amphitheatre (408202): dissolved oxygen, pH (increasing acidity), and turbidity
- Avoca River at Quambatook (408203): dissolved oxygen and pH (increasing acidity)
- Wimmera River at Eversley (415207): dissolved oxygen, turbidity, total phosphorus and total nitrogen
- Wimmera River at Lochiel Railway Bridge (415246): turbidity, total phosphorus and total nitrogen
- Richardson River at Donald (415257): dissolved oxygen, pH (increasing acidity), turbidity, total phosphorus and total nitrogen

As there are both *underlying trends* in water quality and changes in flow between wet years and dry years, this study investigated the attainment of target water quality as specified by the ERS by comparing different periods.

ERS attainment declined between the 1995-2007 period and the 2009-21 period for dissolved oxygen, turbidity and total phosphorus. Attainment improved for pH and remained stable for salinity and total nitrogen (Table 3). As the initial period of comparison incorporates the Millennium Drought, and the second period includes the strongly wet period following, it is likely this shift in attainment is strongly influenced by climate factors.

Victoria's Environment Reference Standard sets out water quality objectives for all regions of Victoria. The objective is a reference point for consideration in making decisions relating to water quality. Objectives are usually defined as '75th percentile' and 'attainment' of the objective is generally that 75% of values are at or below the objective in a year (with a minimum of 11 data points).

TABLE 3: **Percentage of sites with changes in ERS attainment from 1995-2007 to 2009-2021.**

Parameter	**Percentage of sites shifting to attainment in second period**	**Percentage of sites shifting to non-attainment in second period**	**Percentages of sites with unchanging in attainment**	**Average change in attainment – all sites**
EC	21%	15%	64%	+1%
Turbidity	16%	61%	23%	-14%
TP	16%	51%	33%	-8%
TN	28%	39%	33%	-3%
pH	51%	30%	19%	+6%
DO	11%	35%	54%	-5%

Changes in attainment at each site for the water quality parameters are detailed in Appendix G of the Technical Report.

Broken Creek near confluence with the Murray River, 2012. © Alison Pouliot.

5. Long-term climate variability impact on water quality

- Changes in weather and streamflow patterns expected under climate change have the potential to substantially alter water quality.
- Reductions in streamflow would be expected to decrease turbidity, total nitrogen, total phosphorus, while salinity would increase with decreased flows. Dissolved oxygen is expected to decrease due to lower flows and higher water temperatures.
- The Millennium Drought was used as a case study of potential future impacts of climate change on water quality. This analysis showed flow reductions led to decreases in total nitrogen, total phosphorus and turbidity, and increases in salinity. These changes were most pronounced in the Murray and Western Plains ERS segment due to larger reductions in streamflow in this area.
- Further work is needed to determine likely climate change impacts on Victoria's water quality.

In Victoria, climate change is likely to result in increased drying and increased frequency of extreme weather events. An overall reduction in rainfall across Victoria is likely to translate into substantially reduced streamflow, although the impact is site specific and somewhat uncertain. Higher temperatures, and higher frequency and intensity of extreme events under climate change, such as drought, will likely also affect frequency and severity of bushfires. Each of these processes can potentially affect water quality and can be considered separately.

With reduced streamflow under climate change, there are likely to be decreases in turbidity, total nitrogen and total phosphorus. Salinity is likely to increase with reduced flow. Dissolved oxygen is expected to decrease due to lower flows and higher water temperatures. Climate change is likely to affect other catchment processes, including land use, which may also have consequences for water quality.

The study investigated the impact of the Millennium Drought on water quality. Flow reductions led to reductions in total nitrogen, total phosphorus and turbidity, and increases in salinity, all of which were most pronounced in the Murray and Western Plains ERS segment due to larger reductions in streamflow (Figure 16, Figure 17).

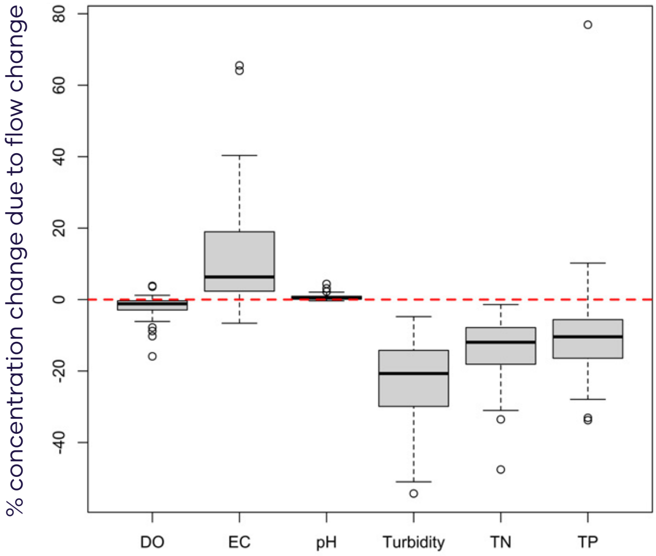


FIGURE 16: Per cent changes in water quality due to changes in streamflow during the Millennium Drought (1997-2009 inclusive) compared with non-drought periods. Positive values indicate an increase in concentration; negative values indicate a decrease.

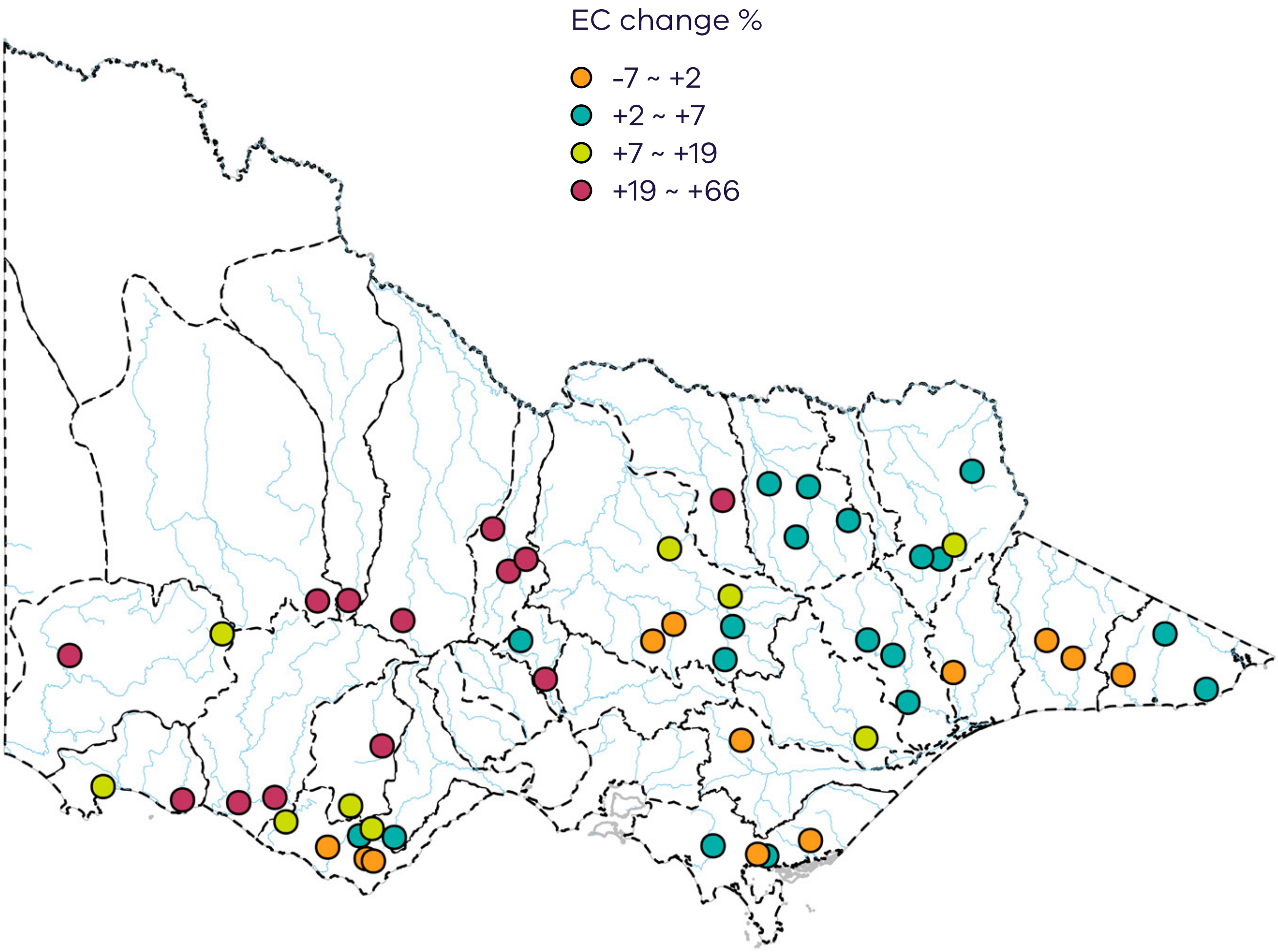


FIGURE 17: Per cent changes in electrical conductivity (a proxy for salinity) due to flow changes during the Millennium Drought.

The study also investigated the potential impact of climate change on water quality that is separate from the impact of decreased streamflow and increased temperature. While the analysis showed that such climate change appeared to be driving change in water quality, the mechanism is still unclear (see details in the Technical Report). The preliminary results highlight some avenues for further analyses:

- Changes in the relationship between rainfall and streamflow observed in some regions may also be affecting water quality. There are well-documented links between streamflow and water quality associated with long-term hydrological changes.
- Changes to agricultural and urban water management due to climate change.
- Changes in other biogeochemical processes as a result of changes to rainfall and temperature.
- Bushfires are also expected to contribute to water quality risks under climate change. Chapter 6 presents findings on the significant impacts of the 2019-2020 bushfires on water quality, still experienced at some sites over two years later.

More research is needed to fully understand the impact of climate change on water quality and the processes underlying these impacts. Future studies could use sophisticated spatially distributed models to assess climate change impacts. In addition, multi-disciplinary investigations that include biogeochemical processes, hydrological processes, behavioural and governance changes, and fire regime changes are required to determine the likely impacts of climate change on water quality.

For further information on the impacts of climate change and climate variability on water quality, see Chapter 5 of the Victorian Water Quality Analysis 2022 Technical Report.

6. Impact of bushfires on water quality

- **All basins affected by the 2019-20 bushfires experienced changes to water quality. The impacts were high, with all water quality parameters studied having the highest or second highest concentration on record at many sites.**
- **Impacts on water quality were still occurring two years after the fires, in March 2022.**
- **Reservoirs played a role as 'settling ponds' for large volumes of sediment and accompanying nutrients, which lead to reduced fire impact on downstream water quality.**

Bushfires, particularly large and intense ones, have a significant impact on water quality through a range of processes, including:

- Loss of vegetation allowing soils to wash into waterways after rainfall.
- Introduction of ash into waterways.
- Baking of soil surfaces that can increase the rate of runoff in the catchment and increase erosion.

Consideration of the impact of bushfires on water quality is important for preparing for and responding to events as needed. The risk of bushfires in Victoria is expected to increase under the drier and warmer conditions associated with climate change.

The Black Summer bushfires of 2019-20 burnt over 1.5 million hectares in north-east Victoria and East Gippsland. DEECA engaged Dr Darren Baldwin to analyse water quality impacts from these fires. The results of that work have been summarised and built on in this study.

The study examined data from 59 sites across the affected basins as well as the Kiewa River Basin (which was unburnt). Different analyses were possible at different sites depending on the type of data available – continuous data from probes, field-analysed spot data and laboratory-analysed data.[3] Where possible, the study identified changes in water quality directly following the fires (where there was sufficient data before and after the event).

The study also examined enhanced satellite imagery of some reservoirs and was able to show the patterns of sediment movement associated with flows into the reservoirs.

All basins affected by the 2019-20 bushfires experienced changes to water quality. Impacts were high, with water quality parameters recording their highest or second-highest value on record at many sites. Across all fire-affected basins, 27 sites experienced impacts on three or more water quality parameters. The complete data record was examined through to March 2022, over two years after the fires occurred. Eight sites across the Tambo, Mitchell, Ovens and Upper Murray basins still showed evidence of ongoing water quality impacts arising from rainfall events flushing material through the system and waterways.

Figure 18 shows the extent and severity of the Black Summer bushfire and its impact on stream turbidity at sites across the fire-affected basins; 12 sites had the highest concentration on record post fire. The fire impact on other water quality parameters is presented in Figure 53 of the technical report.

Buffalo Creek showing fire impacts, 2009. © Alison Pouliot.

[3] Continuous turbidity, electrical conductivity (EC) and dissolved oxygen (DO) were analysed where available, in addition, spot turbidity, electrical conductivity, colour, total suspended solids (TSS), nitrogen oxides (NOx), Total Kjeldahl Nitrogen (TKN), total phosphorus (TP) and filterable reactive phosphorus (FRP) data were also available at some sites.

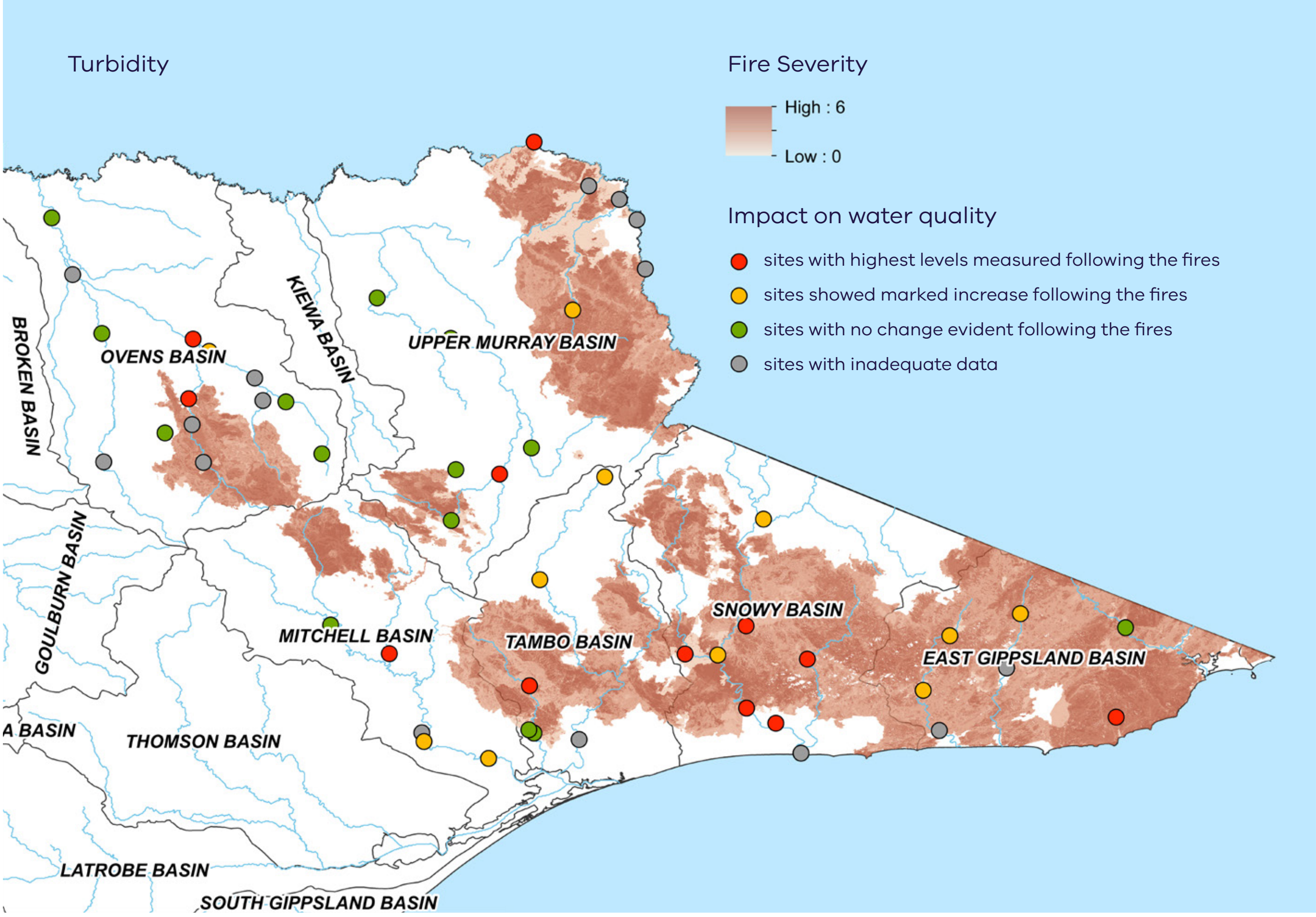


FIGURE 18: **The impact of the Black Summer bushfires on stream turbidity in eastern Victoria. The red/brown on the background map highlights the extent of fires with their severity, with a darker colour representing more severe burning.**

Major storages such as Lake Dartmouth on the Mitta Mitta River in the Upper Murray Basin, Lake Buffalo on Buffalo River in the Ovens Basin and Lake William Hovel on King River played a clear role in the dilution and settling of sediments, leaving downstream water quality far less impacted.

Figure 19 shows the distribution of suspended sediments over time in Lake Buffalo in the Ovens Basin post-fire. The first panel shows sediments moving after a 30 mm rainfall in 2018, the second shows the very high concentration of sediment on 3 January 2020 following the first rains after the fires. The third panel shows the settling of sediments by February. The final image shows a new flush of sediments entering the dam after a rain event in late February 2020.

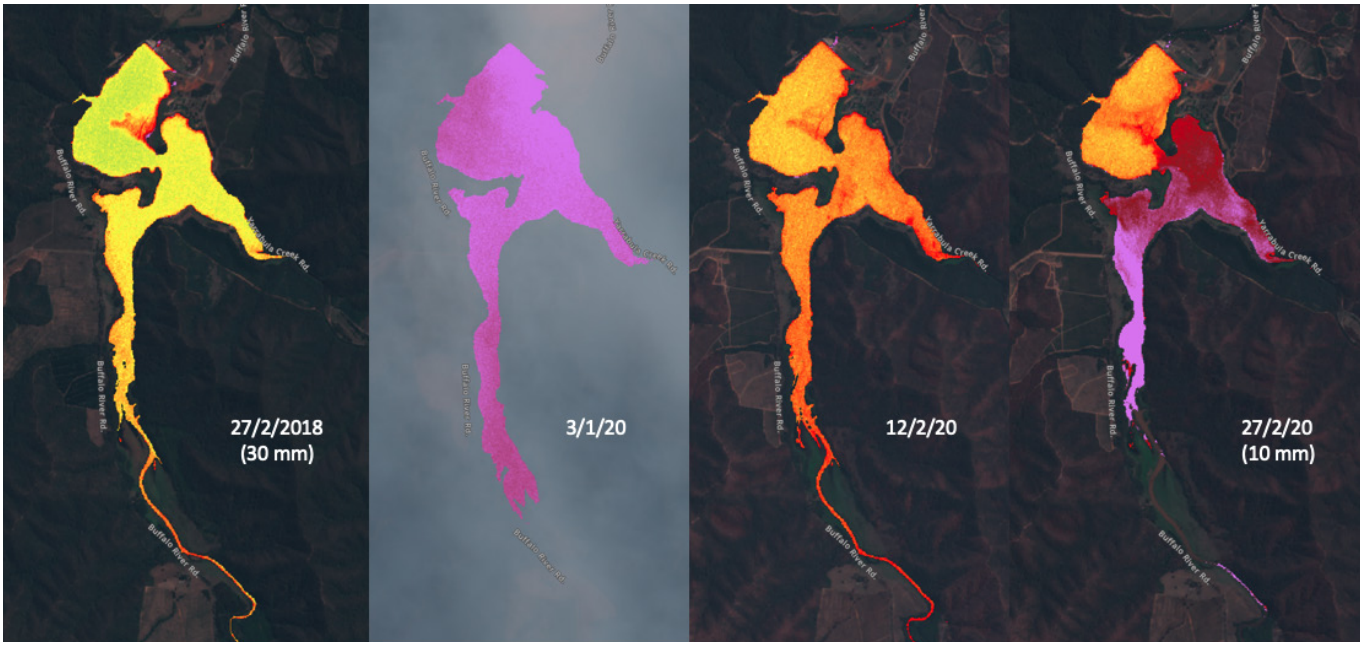


FIGURE 19: **Enhanced satellite images of Lake Buffalo from early 2020 processed to show the distribution of suspended sediments in the lake. Purple represents very high concentrations of suspended sediments, followed, in decreasing order, by the red, yellow, green and blue. The Buffalo River enters Lake Buffalo from the south.**

Climate change is expected to increase the frequency and intensity of bushfires. This will lead to impacts on water quality. More work needs to be undertaken to understand the time taken for waterways to respond and recover after bushfires. Also of interest is how water quality impacts vary following serial burning of a catchment, compared with impacts in catchments that have not been significantly burnt for several decades.

More intense rain events are likely to add sediment to fire-affected rivers. Nutrient-rich runoff flowing into waterways after fires may lead to blue-green algal blooms in lakes, reservoirs and estuaries. Higher temperatures may also exacerbate algal blooms.

For further information on how bushfires affect water quality, see Chapter 6 of the Victorian Water Quality Analysis 2022 Technical Report.

Campaspe River lower reaches near confluence with Murray River, 2012. © Alison Pouliot.

7. Patterns in blue-green algal blooms

- High temperatures and nutrient levels can contribute to an increased likelihood of blue-green algal blooms. However, algal blooms are a complex ecological process and not easy to predict.
- A proxy indicator for blue-green algal blooms used here was the period during which recreational warnings were issued at 16 waterbodies.
- The number of warnings and the duration of the occurrences have not changed significantly at most sites. The only exception is Lake Eppalock, where each occurrence has been around 16 days longer than the previous one.
- The pattern of no or little statistically detectable trend may be due to few events and short records. The adequacy of monitoring to detect changes in blue-green algae patterns should be considered.

Blue-green algae, also known as cyanobacteria, are photosynthetic bacteria. They are a natural part of most aquatic environments. There are a number of different species of blue-green algae, which can change in dominance over time.

Under favourable conditions – warm, well-lit, high nutrient and low turbidity water – blue-green algae thrive. When blue-green algae increase rapidly, this can result in an algal bloom. Algal blooms cause water discolouration, sometimes a thick surface scum, and reduced dissolved oxygen levels. Blue-green algae can make water unsuitable for drinking, stock water, irrigation and recreation. Some species produce toxins that could harm humans, native animals and livestock.

Understanding how blue-green algae respond to different drivers, including climate change, and trends is important for water resource management.

When blue-green algae exceed an accepted trigger level at a water body (e.g., reservoirs, lakes), water managers issue warning for recreational uses for this water body. Therefore, this analysis focuses on the periods of these recreational warnings as an indicator of blue-green algal bloom events.

The study identified 16 water bodies monitored regularly by Goulburn-Murray Water, Grampians Wimmera Mallee Water and Southern Rural Water and examined the data for changes in frequency, duration, and time of year of blue-green algal bloom events leading to recreational notifications. The study further investigated possible drivers of any patterns.

FIGURE 20: **Blue-green algae at Newlyn Reservoir in central-western Victoria.**
Photo courtesy: Goulburn-Murray Wate.

The periods during which recreational warnings were issued at each waterbody served as a proxy indicator for blue-green algal blooms. Data were available from 2003 for Goulburn-Murray Water, from 2013 for Grampians Wimmera Mallee Water, and from 2017 for Southern Rural Water. Figure 21 shows the periods during which recreational warnings were issued at 16 water bodies of the study.

Blue-green algae monitoring

Water most monitored for blue-green algae are storages (lakes and reservoirs) that are managed for rural and urban water supply, and often used for recreation. Monitoring is conducted in line with required risk management plans. Sampling identifies species of blue-green algae, and the cell-count in the water. Cell-counts can then be converted to biovolume based on the size of each blue-green algae species.

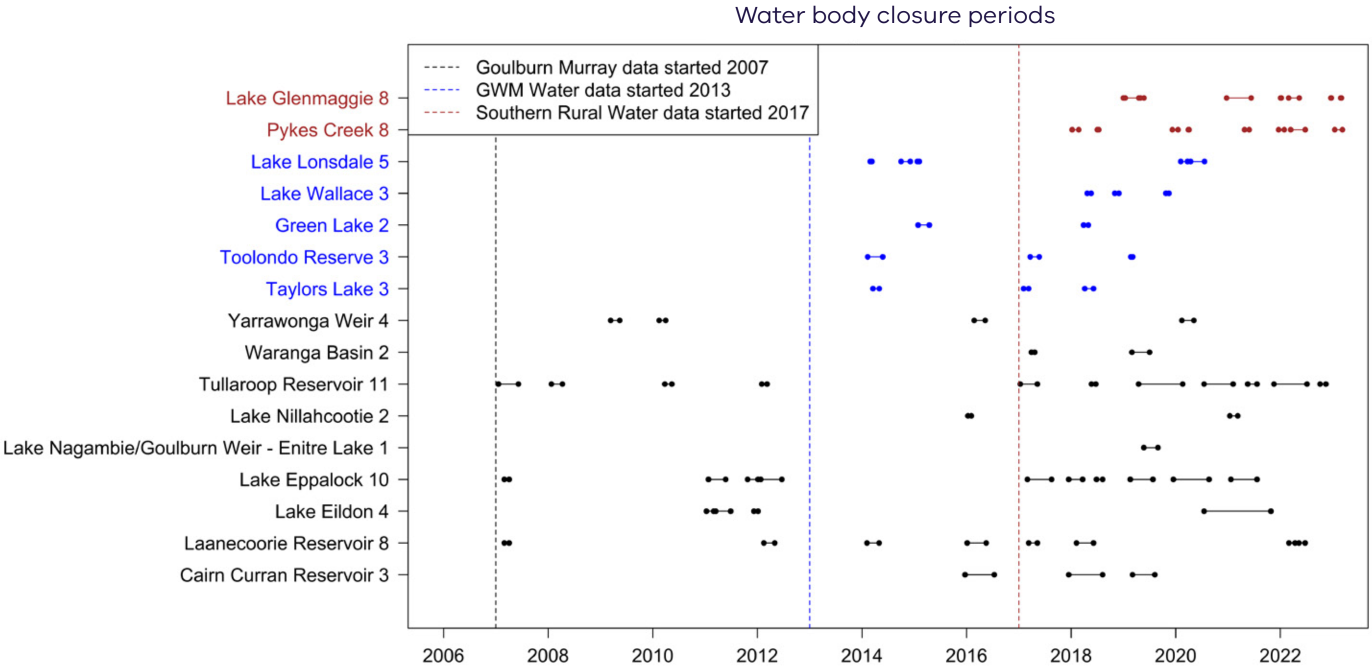


FIGURE 21: Summary of the periods of all blue-green algal bloom warnings issued across storages managed by Goulburn-Murray Water, Grampians Wimmera Mallee Water and Southern Rural Water. After the names of the water bodies is the total number of blue-green algal bloom warnings. The colours indicate the local water managers that issue warnings for each water body: Goulburn-Murray Water, Grampians Wimmera Mallee Water, and Southern Rural Water.

To determine if there had been changes in blooms over time, the data were analysed for changes in frequency and duration of warnings, and the day of the year on which blooms started.

The number of warnings and the duration of the occurrences at these sites have not changed significantly. The only exception is Lake Eppalock, where each occurrence was around 16 days longer than the previous one (over 10 events).

The date of the first occurrence each year has not changed significantly except for Laanecoorie and Tullaroop Reservoirs, where blooms started 1.2 days and 6.6 days later in each successive year, respectively.

The few statistically detectable changes in algal blooms may be due to the small number of events and short records. No water body has had more than three annual warnings; the longest record starts in 2007.

Site-specific investigations will be required to determine the impact of drivers of algal blooms, such as water level, inflow, phosphorus and turbidity.

For further information on how blue-green algal blooms affect water quality, see Chapter 7 of the Victorian Water Quality Analysis 2022 Technical Report.

8. Using continuous data to understand water quality events – dissolved oxygen

- Continuous water quality monitoring has increased greatly since the 1990s and provides opportunities for better event identification and potential for operational response.
- 2010 saw a large peak in identified low and critical dissolved oxygen events, coinciding with major floods. Future analysis may reveal a similar peak in the events following the extensive 2022 floods.
- Spatial mapping of low and critical dissolved oxygen events provides further insight into regional hotspots.

Technical definitions of dissolved oxygen events used in this study were built around the following concepts, that:

A **critical dissolved oxygen event** occurred when DO concentration dropped below 2mg / L for more than 24 hours.

A **low dissolved oxygen event** occurred when DO concentration dropped below 4 mg/L for more than 24 hours, but was not a critical event.

Detailed definitions of the two types of events can be found in Chapter 8 of the Technical Report.

Monitoring water quality has traditionally been undertaken through monthly sampling. Since the 1990s, the use of in-situ probes that record data more frequently (up to every 15 minutes) has grown significantly. Victoria's network now includes continuous turbidity, dissolved oxygen, temperature and chlorophyll *a* monitoring.

Continuous water quality monitoring, through in situ probes, provides far more data than traditional manual spot sampling. There are up to 35,000 measurements per year compared with 12 where traditional monthly on-site monitoring is undertaken. This provides the ability to identify short-term water quality events which are unlikely to be identified with less frequent monthly monitoring.

The study examined the frequency, duration, timing and spatial distribution of critical and low dissolved oxygen events across 131 sites. Low and critical events were defined based on known ecological thresholds and the persistence of DO level below such thresholds (see box on the left for details).

Figure 22 shows an increase in events during the second half of the Millennium Drought, with a major peak in 2010 coinciding with the floods. A further uptick occurred in 2021. The grey line plots the number of active sites, demonstrating the large increase in sites with installed in-situ continuous dissolved oxygen probes between 1995 and 2021.

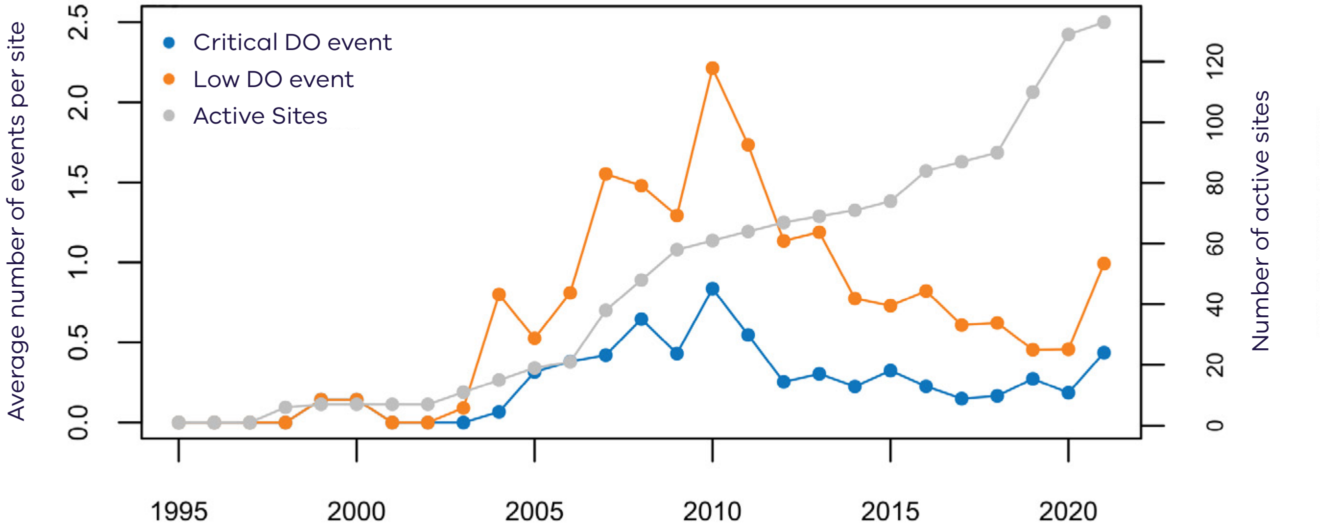


FIGURE 22: Critical and low dissolved oxygen events per site per year. The growth in continuous dissolved oxygen monitoring sites is shown with the grey line.

The typical duration of critical and low dissolved oxygen events was days to weeks, with approximately 67% of critical and 59% of low DO events lasting less than a week; and 94% of critical and 92% of low DO events lasting for less than a month (Figure 23).

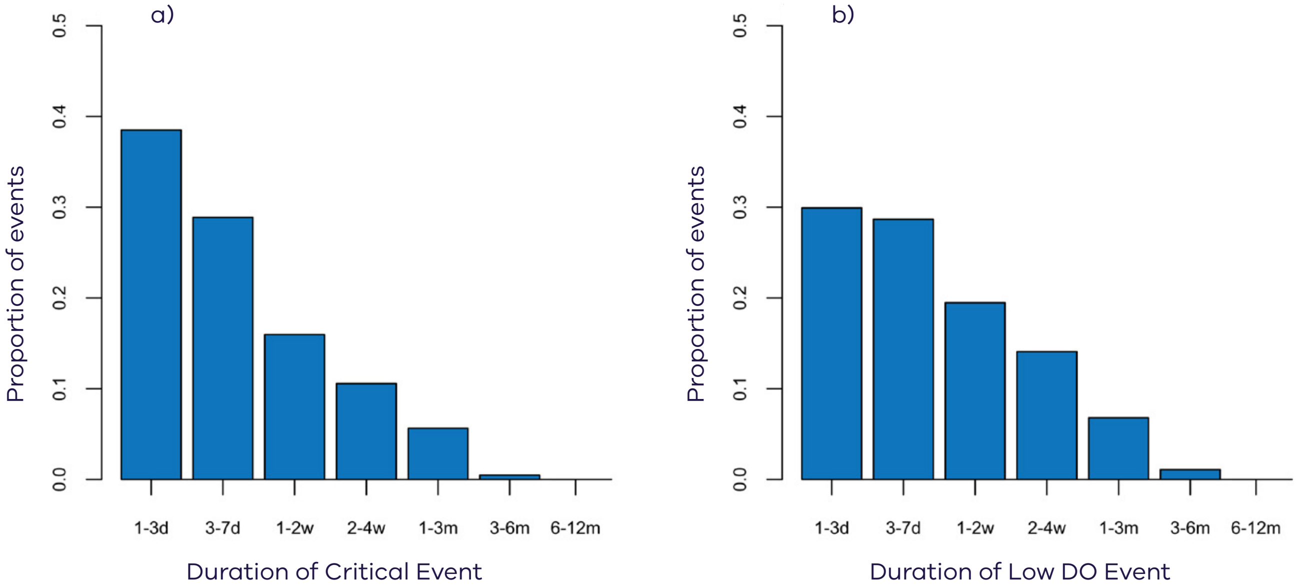


FIGURE 23: Duration of a) critical DO events and b) low DO events.

Figure 24 shows the total hours of critical and low dissolved oxygen events per year at study sites across the state. Specifically, the average hours of low/critical dissolved oxygen per year of record is identified by the size of the orange site marker. White spots represent monitoring sites where no events were identified during the period of record.

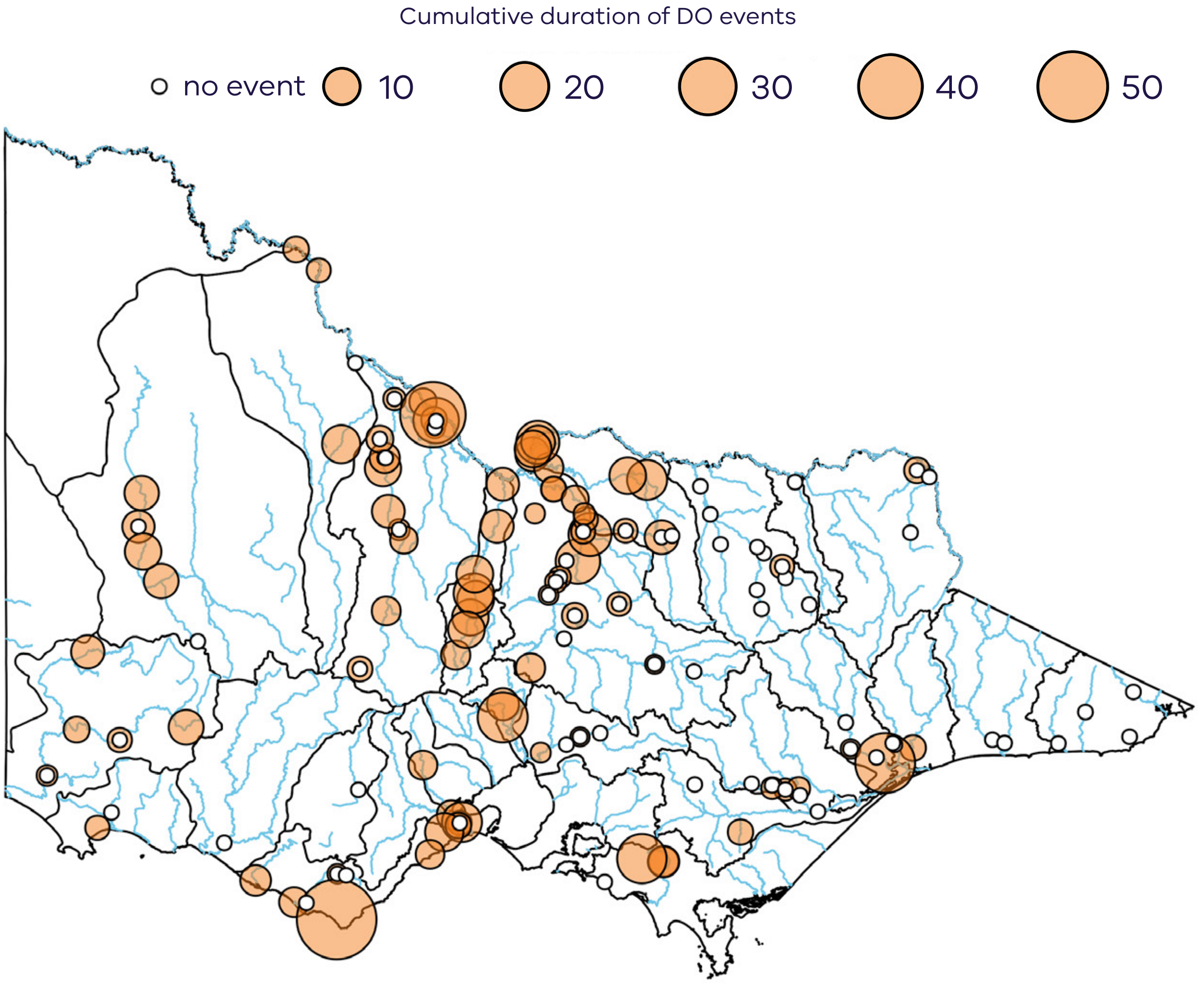


FIGURE 24: **Cumulative duration of DO events as hours of critical and low DO events each year. White dots indicate sites with no event.**

Analysis of continuous turbidity data at six study catchments revealed discharge and rainfall as the major contributors to high turbidity events.

These examples demonstrate the value of continuous water quality sampling to understanding the processes responsible for water quality changes. Such insights would not be possible using monthly sampling data.

Continuous water quality monitoring is a valuable tool for supporting the management of waterways and catchments. Continuous monitoring can detect water quality fluctuations in near real-time. This can enable early detection of poor water quality events as they emerge, enabling operational responses if necessary.

Continuous monitoring allows short ecologically-significant events to be detected and recorded. Governments, environmental agencies, and researchers can use the information to identify patterns, understand seasonal variations, and track the effectiveness of pollution control measures.

For further information on how continuous water quality data can be used to better understand water quality, see Chapter 8 of the Victorian Water Quality Analysis 2022 Technical Report.

Sandy Creek (Wilby Rd), 2022. Credit: Goulburn Broken Catchment Management Authority.

9. Looking forward

This study provides impactful information to a variety of audiences with different needs.

Where to for monitoring?

This study has confirmed the importance of the 137 sites used in this analysis in delivering a valuable long-term water quality record. Ongoing monitoring at these sites is critical to providing the length of record necessary to address current and emerging challenges in water resource management. The number of long-term sites will increase, giving further coverage across the state.

Continuous water quality monitoring has proved invaluable for detecting poor water quality events, and enabling operational responses. Expansion of the continuous water quality monitoring network is highly recommended. Similarly, new technologies – such as satellite imagery – should be examined to ensure the most effective and efficient choices are made for monitoring water quality.

The Victorian Waterway Management Strategy is currently being updated. The development of this strategy will be an opportunity to frame the future of water quality monitoring.

Where to for water quality analysis?

There were questions that this study was not able to answer fully. The study identified patterns in water quality that are anticipated under the drying conditions associated with climate change. Further examination of how water quality may be affected by the compounding impacts of climate change is warranted, such as: changing relationships between streamflow and water quality over long-term hydrological changes; changes to agricultural and urban water management in response to climate change and other pressures; and changes in other biogeochemical processes as a result of changes to rainfall and temperature. This will help provide more specific answers to why Victoria is experiencing changes in long-term conditions at individual sites and why this varies across the state.

The analysis of continuous data was undertaken for the first time in the five-year water quality reviews. There are opportunities to delve further, including examining local and regional hypoxia events and their ecological consequence via continuous dissolved oxygen recordings, and how river turbidity responds to events such as fire, drought and flood.

Where to for water resource managers?

The long-term *underlying trends* at 137 sites will support the development of state and regional strategies including the Victorian Waterway Management Strategy and regional waterway strategies. There is the potential to link the data with other information sources to deepen an understanding of processes and challenges in different systems and to inform management priorities and approaches.

Increasing our understanding of the risks to water quality under climate change, including through reduced streamflow and the potential for increased bushfire activity, will support risk analyses across the water sector to support adaptation and preparedness for future conditions.

The next water quality analysis for Victoria is anticipated in five years. This review will have the opportunity to build on the approaches trialled in this study and to go even further to build our knowledge of the status and trends in Victorian surface water quality.

Boggy Creek, 2013. © Alison Pouliot.

A Goulburn Murray Water field officer attends to an irrigation channel regulator outside Kyabram in northern Victoria, 2022. Photographer: Darryl Whitaker © State of Victoria, DELWP.

Appendix

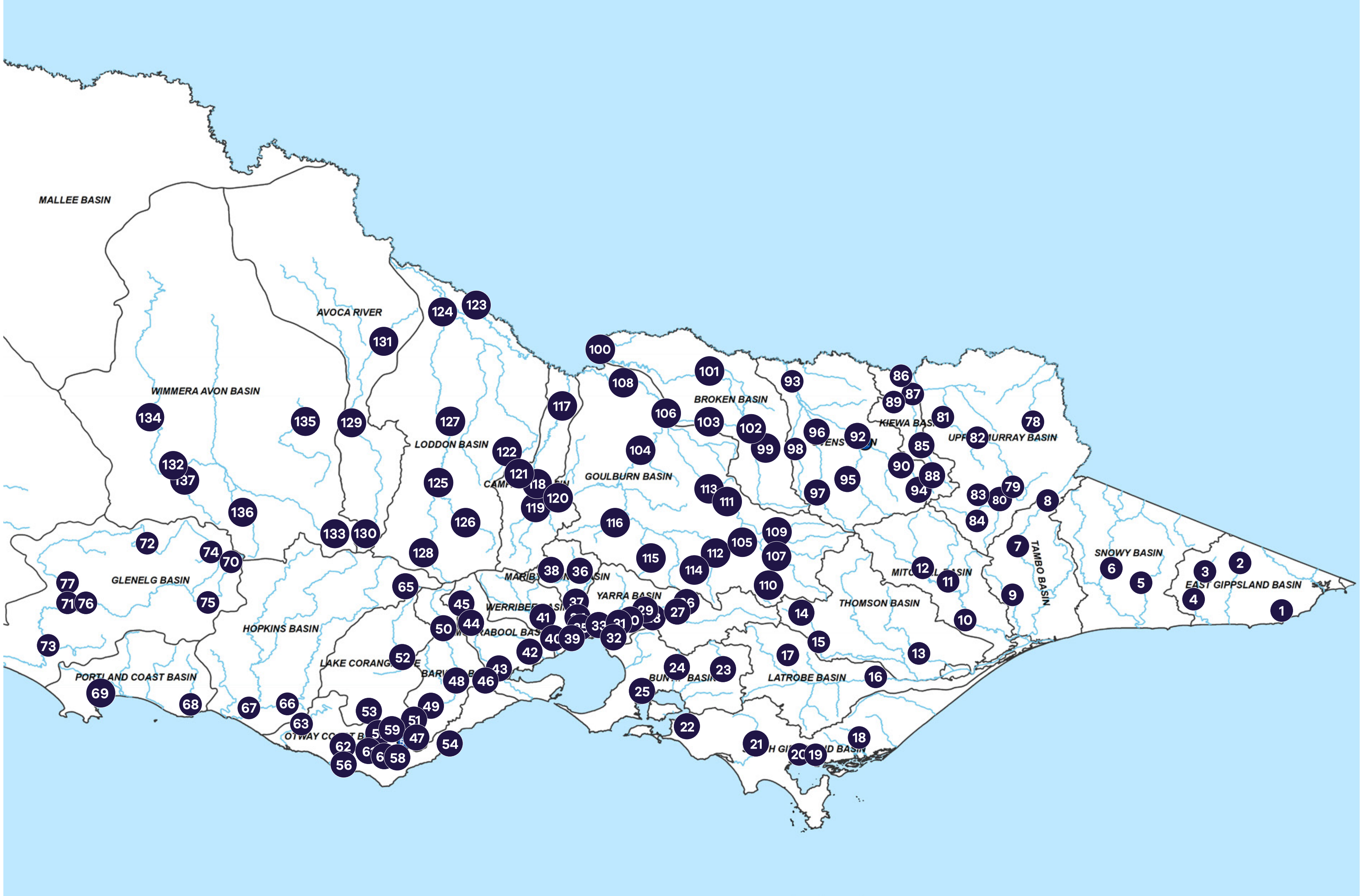


FIGURE A1: Map of the 137 sites selected for analysis for Chapters 3-5 in the study.

TABLE A1: List of the 137 sites used in core analysis in this report, listed by basin, with rivers listed east to west, and upstream to downstream.

Index	Site ID	Site name
1	221208	Wingan River @ Wingan Inlet National Park
2	221201	Cann River (West Branch) @ Weeragua
3	221211	Combienbar River @ Combienbar
4	221212	Bemm River @ Princes Highway
5	222202	Brodribb River @ Sardine Creek
6	222217	Rodger River @ Jacksons Crossing
7	223202	Tambo River @ Swifts Creek
8	223214	Tambo River @ U/S Of Smith Creek
9	223204	Nicholson River @ Deptford
10	224203	Mitchell River @ Glenaladale
11	224213	Dargo River @ Lower Dargo Road
12	224206	Wonnangatta River @ Crooked River
13	225201	Avon River @ Stratford
14	225114	Thomson River @ D/S Whitelaws Creek
15	225210	Thomson River @ The Narrows
16	226228	Latrobe River @ Rosedale (Main Stream)
17	226226	Tanjil River @ Tanjil Junction
18	227200	Tarra River @ Yarram
19	227211	Agnes River @ Toora
20	227237	Franklin River @ Toora
21	227202	Tarwin River @ Meeniyan
22	227231	Bass River @ Mcgrath Road
23	228248	Tarago River @ Labertouche (Morrisons Road)
24	228217	Toomuc Creek @ Pakenham
25	228250	Watsons Creek @ Somerville
26	229144	Watts River @ Healesville Racecourse
27	229232	Yarra River @ Healesville (Maxwell Bridge)
28	229252	Brushy Creek @ Lower Homestead Road Wonga Park
29	229608	Watsons Creek @ Henley Road
30	229250	Andersons Creek @ Warrandyte (Everard Drive)
31	229229	Koonung Creek @ Bulleen
32	229231	Gardiners Creek @ Glenferrie Road Hawthorn
33	229643	Moonee Ponds Creek @ Racecourse Road, Flemington
34	230105	Maribyrnong River @ Keilor (Brimbank Park Ford)
35	230235	Maribyrnong River @ Avondale Heights (Canning St. Ford)
36	230232	Deep Creek @ Bolinda
37	230205	Deep Creek @ Bulla (D/S of Emu Creek Junction)
38	230209	Barringo Creek @ Barringo (U/S Of Diversion)
39	231108	Skeleton Creek At Point Cook Road Laverton
40	231204	Werribee River @ Werribee (U/S Riversdale Rd. Weir)
41	231231	Toolern Creek @ Melton South
42	232200	Little River @ Little River (You Yangs Road)
43	232202	Moorabool River @ Batesford
44	232204	Moorabool River @ Morrisons
45	232210	Moorabool River West Branch @ Lal Lal
46	233200	Barwon River @ Pollocksford
47	233214	Barwon River East Branch @ Forrest
48	233218	Barwon River @ Inverleigh
49	233224	Barwon River @ Ricketts Marsh
50	233215	Leigh River @ Mount Mercer
51	233228	Boundary Creek @ Yeodene
52	234201	Woady Yaloak River @ Cressy (Yarima)
53	234203	Pirron Yallock Creek @ Pirron Yallock (Above H'wy Br.)
54	235216	Cumberland River @ Lorne
55	235202	Gellibrand River @ Upper Gellibrand
56	235224	Gellibrand River @ Burrupa
57	235227	Gellibrand River @ Bunkers Hill
58	235209	Aire River @ Beech Forest
59	235234	Love Creek @ Gellibrand
60	235204	Little Aire Creek @ Beech Forest
61	235205	Arkins Creek West Branch @ Wyelangta
62	235211	Kennedys Creek @ Kennedys Creek
63	235237	Scotts Creek @ Curdie (Digneys Bridge)
64	235203	Curdies River @ Curdie

Index	Site ID	Site name
65	236215	Burrumbeet Creek @ Lake Burrumbeet
66	236216	Mount Emu Creek @ Taroon (Ayrford Road Bridge)
67	236209	Hopkins River @ Hopkins Falls
68	237200	Moyne River @ Toolong
69	237207	Surry River @ Heathmere
70	238208	Jimmy Creek @ Jimmy Creek
71	238202	Glenelg River @ Sandford
72	238205	Glenelg River @ Rocklands Reservoir
73	238206	Glenelg River @ Dartmoor
74	238231	Glenelg River @ Big Cord
75	238204	Wannon River @ Dunkeld
76	238228	Wannon River @ Henty
77	238223	Wando River @ Wando Vale
78	401212	Nariel Creek @ Upper Nariel
79	401215	Morass Creek @ Uplands
80	401203	Mitta Mitta River @ Hinnomunjie
81	401204	Mitta Mitta River @ Tallandoon
82	401211	Mitta Mitta River @ Colemans
83	401216	Big River @ Jokers Creek
84	401226	Victoria River @ Victoria Falls
85	402203	Kiewa River @ Mongans Bridge
86	402205	Kiewa River @ Bandiana
87	402222	Kiewa River @ Kiewa (Main Stream)
88	402223	Kiewa River West Branch @ U/S Of Offtake
89	402204	Yackandandah Creek @ Osbornes Flat
90	403205	Ovens Rivers @ Bright
91	403210	Ovens River @ Myrtleford
92	403230	Ovens River @ Rocky Point
93	403241	Ovens River @ Peechelba
94	403244	Ovens River @ Harrietville
95	403217	Rose River @ Matong North
96	403223	King River @ Docker Road Bridge
97	403228	King River @ Lake William Hovell T.G.
98	403213	Fifteen Mile Creek @ Greta South
99	404207	Holland Creek @ Kelfeera
100	404210	Broken Creek @ Rices Weir
101	404214	Broken Creek @ Katamatite
102	404216	Broken River @ Goorambat (Casey Weir H. Gauge)
103	404224	Broken River @ Gowangardie

Index	Site ID	Site name
104	405200	GOULBURN RIVER @ MURCHISON (Mcphee's Rest)
105	405203	Goulburn River @ Eildon
106	405204	Goulburn River @ Shepparton
107	405219	Goulburn River @ Dohertys
108	405232	GOULBURN RIVER @ Mccoys BRIDGE
109	405214	Delatite River @ Tonga Bridge
110	405264	Big River @ D/S Of Frenchman Creek Junction
111	405251	Brankeet Creek @ Ancona
112	405209	Acheron River @ Taggerty
113	405234	Seven Creeks @ D/S Of Polly Mcquinn Weir
114	405205	Murrindindi River @ Murrindindi Above Colwells
115	405231	King Parrot Creek @ Flowerdale
116	405212	Sunday Creek @ Tallarook
117	406202	Campaspe River @ Rochester D/S Waranga Western Ch Syphn
118	406207	Campaspe River @ Eppalock
119	406213	Campaspe River @ Redesdale
120	406235	Wild Duck Creek @ U/S Of Heathcote-Mia Mia Road
121	406214	Axe Creek @ Longlea
122	407255	Bendigo Creek @ Huntly
123	407209	Gunbower Creek @ Koondrook
124	407202	Loddon River @ Kerang
125	407203	Loddon River @ Laanecoorie
126	407215	Loddon River @ Newstead
127	407229	Loddon River @ Serpentine Weir
128	407214	Creswick Creek @ Clunes
129	408200	Avoca River @ Coonooer
130	408202	Avoca River @ Amphitheatre
131	408203	Avoca River @ Quambatook
132	415200	Wimmera River @ Horsham
133	415207	Wimmera River @ Eversley
134	415246	Wimmera River @ Lochiel Railway Bridge
135	415257	Richardson River @ Donald
136	415203	Mount William Creek @ Lake Lonsdale (Tail Gauge)
137	415251	Mackenzie River @ Mckenzie Creek

Werribee River at the Melton Reservoir in southern Victoria, 2022.
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