Charles Sturt University

Menindee Lakes and Darling River Preliminary Water and Sediment Quality Assessment 2023

Corrigendum Revision (December 2023)

Report produced for the Office of the Chief Scientist and Engineer

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Disclaimer

CORRIGENDUM

This version of the report corrects a rounding error. Table 10 did not contain SI units in the original version which led to a discrepancy when compared against SI units referenced in ANZECC guidelines. This has now been corrected and all references to this data have been updated accordingly. The report is unaltered in all other respects.

Executive Summary

Introduction

In March 2023, a mass fish death event occurred in the Darling River at Menindee, NSW. This event was similar to a 2019 incident where a million fish died due to low dissolved oxygen (DO) levels. While both events had low DO as a likely cause, the mechanisms differed; in 2019, severe drought and stagnant water led to algal blooms, whereas in 2023, extensive flooding initially benefited fish but left organic material and sediment, deteriorating water quality, and reducing DO levels. Fish mortality events are likely to occur again in future.

In response to community concerns for a baseline understanding of the health of the river, the Office of the Chief Scientist and Engineer (NSW) sought a report to summarise a rapid assessment of the Menindee Lakes / Darling River system to:

(1) establish a baseline understanding of water and sediment chemistry information and;

(2) aid in the development of any water / sediment quality management plans for future monitoring programs.

Methodology

This report details a sampling strategy for assessing water- and sediment quality in the Menindee Lakes / Darling River (Menindee). Sampling involved a combination of in-situ measurements (edge- and middle- sampling using a two water quality meters (Horiba, Sonde)) and water and sediment samples for laboratory analysis (including nutrients in water, BOD, COD, metals, herbicides and pesticides). These results were then compared to available ANZECC guideline trigger values for water and sediment quality in slightly – moderately disturbed systems. This sampling plan (methodology) and the results presented here are a snapshot from August 2023 and can be used as baseline data and applied for future applications.

Results and Conclusion

Nutrients in water: Nutrient levels (e.g. phosphorus, nitrogen) generally in exceeded ANZECC water quality guidelines for slightly-moderately disturbed ecosystems. In addition, chlorophyll and dissolved oxygen results indicated an algal bloom was already present in the Darling River / Menindee Lakes system and nutrient levels were elevated. At the present levels, it is predicted that any change in temperature and / or water flow (e.g. drought conditions), or the further addition of nutrients into the waterway may see increased algal blooms and low dissolved oxygen levels and should be monitored for potential fish death events in the near future.

Metals in water and sediment: Aluminium and copper were detected at all sites (S1-6) in the water column and exceeded ANZECC guideline trigger values. In the sediment samples, aluminium, barium, cobalt, chromium, copper, iron, lanthanum, manganese, nickel, lead, strontium, titanium, vanadium, zinc were detected.

Pesticides / Herbicides in water and sediment: Several herbicides including metolachlor, atrazine, simazine, terbuthylazine, tebuthiuron, clopyralid, fluroxpyr were detected from the laboratory-analysed water samples. Pesticides / herbicides were not detected in sediment samples.

The results presented here (in particular, the detection of moderate nutrient levels and herbicides) are consistent with agricultural land-use in the area. The detection of an algal bloom during the August sampling event requires further monitoring prior to temperatures increasing (e.g. summer) and flows declining (e.g. during drought conditions). Water and sediment quality should be monitored in future to detect longer-term trends. Water and sediment quality results can be used as a baseline to compare to other future sampling events and to aid in the development of any water / sediment quality management plans for future monitoring and fish death prevention programs.

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1. Introduction

During March 2023, a mass fish death event occurred in the Darling River at Menindee, far west New South Wales (NSW) (Figure 1). A similar event took place in 2019, during which the devastating drought in New South Wales led to the demise of up to one million fish in the same area (Figure 1). The fish deaths likely occurred because of low dissolved oxygen (DO) levels, but the underlying mechanisms leading to these low DO levels are believed to be different. The occurrence of low DO levels, leading to the fish mortality, arises from a combination of various factors. These can include prevailing weather conditions, blue-green algae outbreaks, the volume of water present in the river before and during the event and the overall quality of the water (Edwards and Joehnk, 2019; CSIRO, 2023).

In the case of 2019, the low DO was primarily attributed to severe drought and low river flows. These conditions gave rise to stagnant water and stratification (layering) within the river, fostering the development of an extensive blue-green algae bloom. Subsequently, the abrupt arrival of a cold front weather system caused a sudden mixing of deoxygenated bottom waters (anoxic) with the rest of the water column, resulting in a decline in DO levels (CSIRO, 2023).

For the 2023 event, extensive flooding in Menindee and the areas upstream between 2022–2023 had a significant positive impact on fish populations. This flooding created suitable conditions for fish spawning and the growth of young fish. However, as the floodwaters receded, a substantial accumulation of organic material and sediment persisted in the water. This deterioration in water quality resulted in lower levels of dissolved oxygen. Furthermore, as water levels dropped, fish became concentrated in the main river channel, intensifying their competition for the limited oxygen available. This, in turn, contributed to the fish deaths.

Fish deaths in Jan 2019
Photo credit: Amy Edwards and Klaus Joehnk

Fish deaths in Mar 2023
Photo credit: Graeme McCrabb

Figure 1. Dead fish in the Darling River at Menindee

Fish mortality events are likely to occur again in future. Therefore, it is important to establish a baseline understanding of water and sediment quality information and develop a sound sampling methodology for future applications.

In response to community concerns for a baseline understanding of the health of the river, this report summarises a rapid assessment of the Menindee Lakes / Darling River system based on a number of water and sediment quality parameters to 1) aid in the detection of deteriorating water conditions or pollution and 2) aid in the development of any water / sediment quality management plans for future monitoring programs.

2. Sampling Methodology

2.1 Sampling sites

Sampling was undertaken at six sites (S1–S6) between 8–9 August 2023 (Table 1, Figure 2). At each site, both the edge of the river/lake and middle of river/lake were sampled (Figure 3).

Table 1. Name and location of each sampling site

Site name	Site samples	GPS co-ordinates	
Weir 32	S1 (Middle)	142.375833°E	-32.400533°S
	S1 (Edge)	142.375767° E	-32.400600° S
Menindee Lake	S2 (Middle)	142.367100° E	-32.393450° S
	S2 (Edge)	142.370488° E	-32.398097° S
Old Town Weir	S3 (Middle)	142.431617° E	-32.389750° S
	S3 (Edge)	142.431400° E	-32.389833° S
Lake Pamamaroo	S4 (Middle)	142.497983° E	-32.301467° S
	S4 (Edge)	142.500083° E	-32.302350° S
Pamamaroo/Weatherall outlets	S5 (Middle)	142.499700° E	-32.305467° S
	S5 (Edge)	142.499787° E	-32.305561° S
Lake Weatherall	S6 (Middle)	142.513567° E	-32.308200° S
	S6 (Edge)	142.511712° E	-32.312434° S

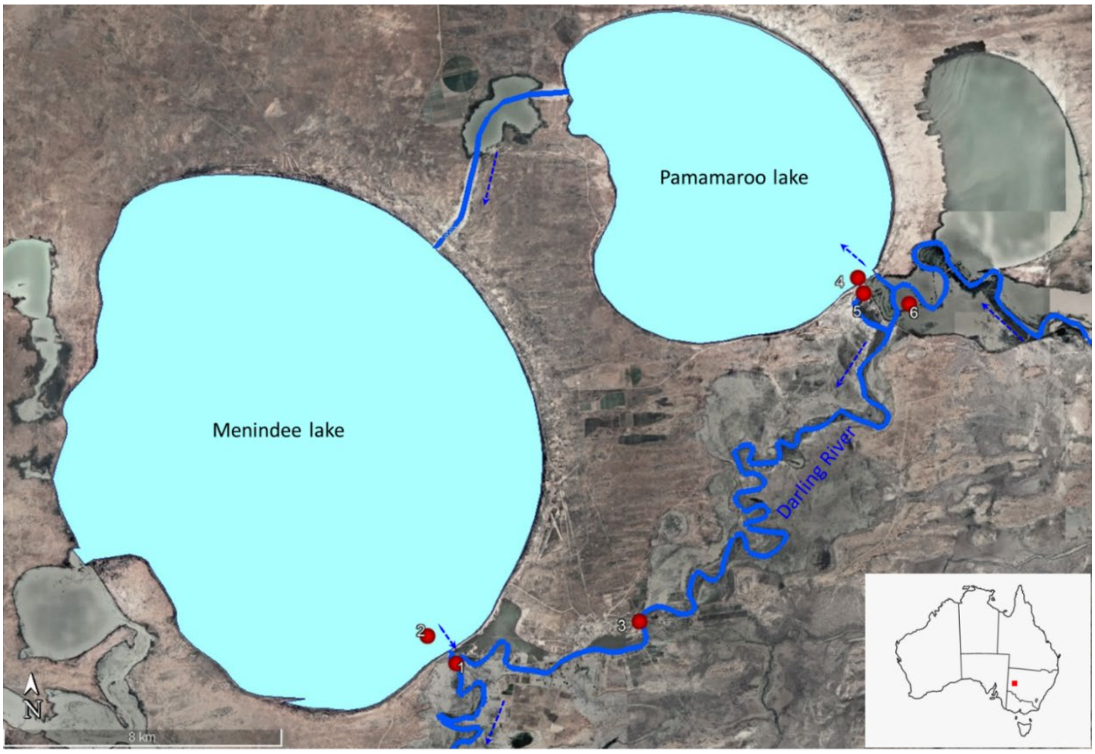


Figure 2. Samling sites (1–6) at Menindee, NSW. Arrows indicate water flow direction.

Sampling consisted of 1) in-situ water quality measurements using water quality meters (Sonde / Horiba) and 2) water- and sediment samples that were collected and sent for laboratory analysis (https://www.alsglobal.com/en/, Victoria)(Figure 3).

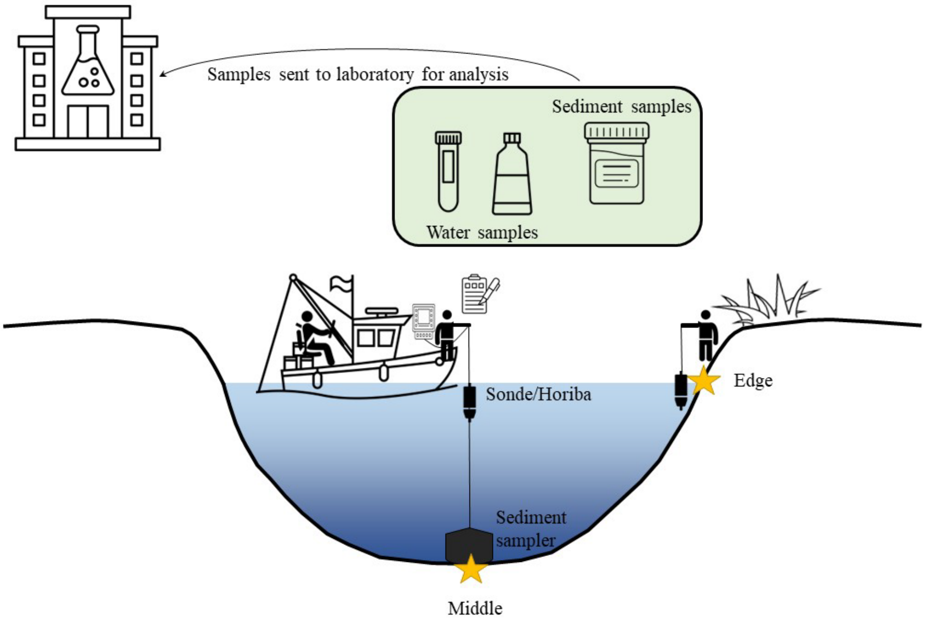


Figure 3. Schematic of middle and edge-sampling methodology including in-situ measurements (Sonde / Horiba) and water and sediment samples collected for laboratory analysis.

At Site's 1, 3 and 5, additional in-situ measurements were taken at intervals downstream of the sampling site as well as throughout the water column to understand water quality parameters across a vertical and horizontal profile in the Darling River (Figure 4).

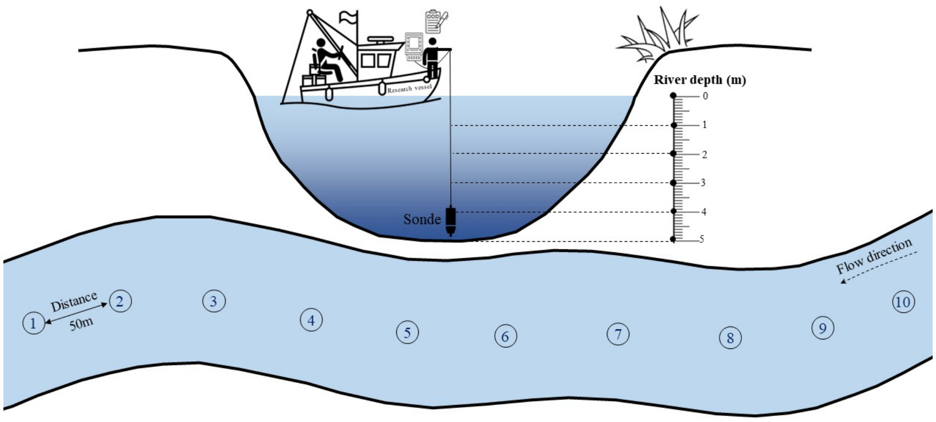


Figure 4. Schematic of additional in-situ sampling methodology (using the Sonde meter) at Site's 1, 3 and 5 (Darling River sites).

2.2 Water and sediment quality parameters

The following water and sediment parameters were collected:

In-situ measurements

1. Portable Horiba water quality meter (Model U-5000, Made in Japan, 2021). Parameters include;
    - Turbidity (NTU)

2. Portable Sonde meter (EX-02 Multiparameter). Parameters include;
    - Temperature (°C)
    - pH
    - Specific conductivity (µS/cm)
    - Salinity (g/L)
    - Dissolved oxygen (mg/L)
    - Dissolved oxygen saturation (%)
    - Chlorophyll (µg/L)
    - Chlorophyll (RFU)
    - Phycocyanin or PC (RFU)
    - Phycocyanin or PC (µg/L)

Water samples (laboratory analysis)

- Biological Oxygen Demand (BOD)
- Chemical Oxygen Demand (COD)
- Nutrients (TN, P, Ammonia, Nitrate, Nitrate, NOx)
- Metals
- Herbicides
- Pesticides

Sediment samples (laboratory analysis)

- Metals
- Herbicides
- Pesticides

2.3 Comparison of water and sediment quality results to the ANZECC guidelines

Once the water and sediment results were received from the field sampling (in-situ measurements) or following laboratory analysis, water and sediment results were then compared to the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000). These guidelines can be sourced at:

https://www.waterquality.gov.au/sites/default/files/documents/anzecc-armcanz-2000-guidelines-vol1.pdf

Interpreting the guidelines: The ANZECC guidelines include numerical concentration limits recommended to support and maintain a designated water use. The ANZECC guidelines (*'guideline trigger values'*) are used as a general tool for assessing water / sediment quality and are the key to determining water quality objectives that protect and support the designated environmental values of our water resources, and against which performance can be measured (ANZECC 2000).

'Guideline trigger values' are concentrations that, if exceeded, would indicate a *potential* environmental problem, and so 'trigger' a management response, e.g. further investigation and/or subsequent refinement of the guidelines according to local conditions (ANZECC 2000). For the present report, the level of protection applied was 95% (slightly to moderately disturbed ecosystems, Appendix 1)(ANZECC 2000), though 80%, 90% and 99% protection values are presented for reference. (For further information on protection levels, see page 3.4-3 of ANZECC 2000).

Water quality parameters can be divided into those that have direct toxic effects on organisms and animals (e.g. insecticides, herbicides, heavy metals and temperature) and those that indirectly affect ecosystems causing a problem for a specified environmental value (e.g. nutrients, turbidity and enrichment with organic matter). Where guideline values were not available, the data presented here is considered as a rapid baseline assessment tool for understanding and monitoring trends in water / sediment quality for future applications (ANZECC 2000).

3. Results

3.1. Site images (Figure 5)

Site 1: Weir 32

Water from the Menindee lake flowing into the Darling River

Mixing water in the Darling River

Site 2: Menindee lake

605 metres from the lake bank

Menindee lake bank

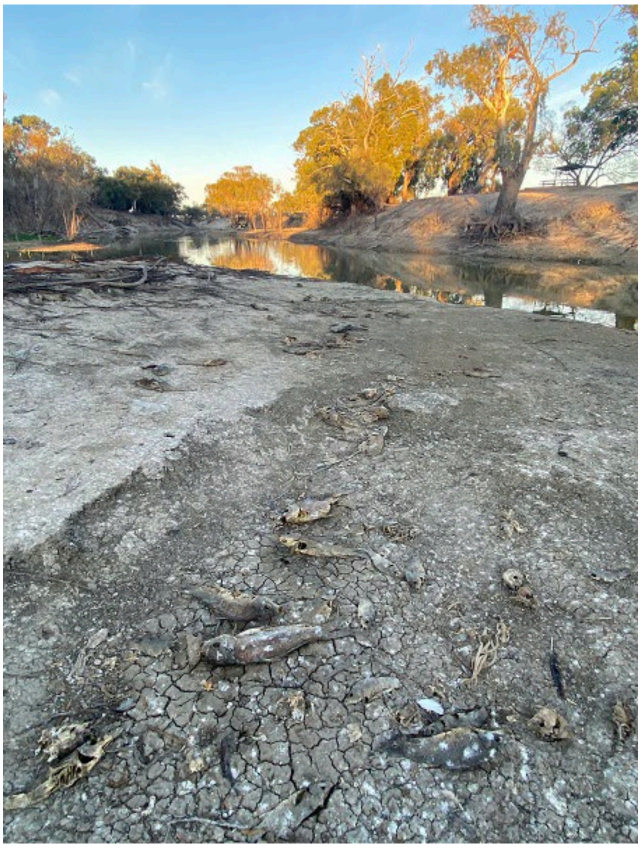
Site 3: Old Town Weir, Darling River

Site 4: Pamamaroo lake

175 metres away from the lake bank

Pamamaroo lake bank

Site 5: Pamamaroo / Weatherall Outlets



Site 6: the Darling River (flooded wetland)

720 metres away from the bank

River bank

3.2. Results: Physio-chemical water quality (in-situ measurements, raw data)

Table 2. In-situ water quality results measured at Sites 1–6 at Menindee, NSW (measured by Sonde water quality meter. NTU was measured by Horiba water quality meter).

Site	Temperature (ºC)	Dissolved oxygen (mg/L)	Dissolved gas saturation (%)	Conductivity (µS/cm)	Specific Conductivity (µS/cm)	pH	Chlorophyll (µg/L)	Chlorophyll (RFU)	Phycocyanin or PC (RFU)	Phycocyanin or PC (µg/L)	Turbidity (NTU)
S1 (Middle)	12.298	7.5	70.2	639	844	8.17	36.85	6.65	0.38	0.98	95.2
S1 (Edge)	12.386	8.28	77.7	605	797	8.22	33.89	5.91	0.42	1.01	81.3
S2 (Middle)	11.794	10.70	99.0	368	492.7	8.61	7.42	-0.71*	-0.41*	0.19	90.5
S2 (Edge)	12.848	11.15	105.6	376	490.2	8.73	7.19	-0.77*	0.37	0.97	97.3
S3 (Middle)	12.667	8.13	76.7	618	808	8.22	35.35	6.27	0.62	1.22	60.2
S3 (Edge)	14.405	10.4	102	643	807	8.43	26.47	4.05	0.48	1.08	87.2
S4 (Middle)	13.474	10.57	101.6	613	786	8.56	41.07	7.70	0.65	1.25	72.2
S4 (Edge)	16.391	11.66	119.4	644	770	8.63	16.77	1.63	0	0.60	84.5
S5 (Middle)	12.943	9.54	90.7	606	787	8.34	26.96	4.17	0.46	1.05	83.1
S5 (Edge)	13.301	9.87	94.6	604	777	8.40	21.28	2.75	0.27	0.87	93.5
S6 (Middle)	12.596	12.01	113.2	655	859	8.72	31.84	5.39	0.52	1.12	46.7
S6 (Edge)	13.808	11.08	107.3	684	870	8.60	31.28	5.25	0.73	1.33	86.5

*Negative values unreliable indicators as they are likely a result of high NTU (turbidity) levels and potential clogging of wipers.

Various water quality parameters were also measured at different depths in the water column along selected transects at Site 1, Site 3 and Site 5, Darling River.

Site 1 (Weir 32, Darling River)

Table 3. In-situ water quality parameters measured (Sonde meter) along a section of 52 m in the Darling River, including water temperature (°C), dissolved oxygen (mg/L), pH *Error! Reference source not found.* ***and chlorophyll (µg/L).***

	Water temperature (°C)		*Dissolved Oxygen (mg/L)*		*pH*		*Chlorophyll (µg/L)*	
	Distance (m)		*Distance (m)*		*Distance (m)*		*Distance (m)*	
Depth (m)	0	52	0	52	0	52	0	52
1	12.298	12.744	7.50	11.03	8.16	8.44	36.85	53.61
2	12.159	12.100	7.70	8.48	8.15	8.20	37.68	62.29
3	12.073	12.029	7.62	7.66	8.13	8.11	53.70	52.90

Site 3 (Old Town Weir, Darling River)

Table 4. In-situ water quality parameters measured by Sonde meter at different depths along a section of 461 m in the Darling River (Site 3): water temperature (^oC), dissolved oxygen (mg/L), pH and chlorophyll (µg/L). Dashed lines represent no record due to shallow water.

Depth (m)	***Water temperature (°C)***									
	Distance travelled									
	0	**51**	**105**	**159**	**210**	**260**	**312**	**362**	**413**	**461**
1	12.976	12.627	13.107	12.667	12.614	12.971	12.521	12.542	12.474	12.453
2	12.642	12.566	12.554	12.514	12.498	12.572	12.733	12.467	12.434	12.403
3	12.560	12.528	12.519	12.488	12.476	12.487	-	12.437	12.401	12.395
4	12.545	12.519	12.515	12.487	12.473	12.499	-	12.414	12.404	12.382
5	12.556	12.529	12.511	12.487	-	-	-	12.420	12.418	12.397
Depth (m)	***Dissolved Oxygen (mg/L)***									
	0	**51**	**105**	**159**	**210**	**260**	**312**	**362**	**413**	**461**
1	8.70	7.86	9.22	8.13	8.03	9.42	8.35	8.39	8.07	8.25
2	8.45	7.83	8.05	7.76	7.84	8.38	8.53	7.93	7.90	7.87
3	7.83	7.59	7.42	7.71	7.73	7.85	-	7.79	7.65	7.78
4	5.57	7.36	7.23	7.63	7.56	7.56	-	7.64	7.50	7.68
5	7.12	7.19	6.99	7.58	-	-	-	7.39	7.29	7.50
Depth (m)	***pH***									
	0	**51**	**105**	**159**	**210**	**260**	**312**	**362**	**413**	**461**
1	8.30	8.18	8.31	8.22	8.18	8.32	8.19	8.21	8.19	8.19
2	8.19	8.17	8.15	8.18	8.16	8.20	8.25	8.17	8.17	8.17
3	8.15	8.14	8.13	8.17	8.16	8.16	-	8.16	8.15	8.17
4	8.14	8.12	8.11	8.16	8.14	8.12	-	8.15	8.14	8.16
5	8.09	8.10	8.09	8.16	-	-	-	8.13	8.12	8.14
Depth (m)	***Chlorophyll (µg/L)***									
	0	**51**	**105**	**159**	**210**	**260**	**312**	**362**	**413**	**461**
1	45.37	36.15	29.21	35.35	28.09	35.06	35.11	33.20	28.11	29.51
2	36.26	35.58	32.25	36.16	27.92	35.75	46.15	33.88	29.09	28.76
3	37.35	28.52	30.05	38.13	26.09	29.88	-	27.39	28.79	28.85
4	35.65	36.52	37.81	36.04	27.59	44.29	-	29.76	28.91	32.76
5	33.32	42.86	29.08	33.29	-	-	-	31.52	31.96	41.30

Site 5 (Pamamaroo / Weatherall outlets)

Table 5. Water quality parameters measured by Sonde meter at different depths along a section of 470 m in the Darling River (Site 3): water temperature (°C), dissolved oxygen (mg/L), pH and chlorophyll (µg/L). Dashed lines represent no record due to shallow water.

Depth (m)	***Temperature (°C)***									
	Distance travelled (m)									
	0	53	111	164	217	267	317	366	419	470
1	12.931	12.938	12.939	12.919	12.905	12.895	12.847	12.811	12.831	12.767
1.5 to 2	12.958	12.926	12.925	-	12.906	12.863	-	-	12.840	-
	Dissolved oxygen (mg/L)									
	0	53	111	164	217	267	317	366	419	470
1	9.50	9.44	9.48	9.49	9.49	9.56	9.46	9.46	9.52	9.47
1.5 to 2	9.50	9.38	9.42	-	9.42	9.47	-	-	9.40	-
	pH									
	0	53	111	164	217	267	317	366	419	470
1	8.34	8.33	8.31	8.32	8.32	8.32	8.31	8.32	8.32	8.31
1.5 to 2	8.34	8.31	8.30	-	8.31	8.31	-	-	8.31	-
	Chlorophyll (µg/L)									
	0	53	111	164	217	267	317	366	419	470
1	29.96	31.16	27.53	30.70	33.02	26.82	30.92	29.56	29.93	36.62
1.5 to 2	28.23	36.00	29.38	-	33.36	37.01	-	-	35.84	-

3.3. Results: Physio-chemical water quality (raw data, laboratory analysis)

Table 6. BOD, COD and nutrients in water chemistry results (mg/L). NS: no sample taken as this could not be analysed within the 24 hr time period.

	BOD / BOD5	COD / COD	TKN	TOTAL P	TN	Ammonia ($NH3^{+}$)	Nitrite (NO2)	Nitrate (NO3)	NOX
S1 (Middle)	4	31	1.2	0.22	1.2	< 0.1	< 0.01	0.01	0.01
S1 (Edge)	3	27	1.2	0.35	1.2	0.2	< 0.01	0.02	0.02
S2 (Middle)	*NS*	27	1	0.31	1	< 0.1	< 0.01	0.01	0.01
S2 (Edge)	*NS*	24	1.1	0.34	1.1	< 0.1	< 0.01	< 0.01	< 0.01
S3 (Middle)	6	37	1.4	0.14	1.4	< 0.1	< 0.01	< 0.01	< 0.01
S3 (Edge)	5	33	1.3	0.13	1.3	< 0.1	< 0.01	< 0.01	< 0.01
S4 (Middle)	*NS*	35	1.3	0.12	1.3	< 0.1	< 0.01	0.02	0.02
S4 (Edge)	*NS*	33	1.1	0.16	1.1	< 0.1	< 0.01	0.01	0.01
S5 (Middle)	4	34	1.1	0.18	1.1	< 0.1	< 0.01	< 0.01	< 0.01
S5 (Edge)	4	32	1.4	0.13	1.4	< 0.1	< 0.01	< 0.01	< 0.01
S6 (Middle)	*NS*	33	1.3	0.1	1.3	< 0.1	< 0.01	0.01	0.01
S6 (Edge)	*NS*	35	1.2	0.1	1.2	< 0.1	< 0.01	< 0.01	< 0.01

3.4. Results: Physio-chemical water quality results and comparisons with ANZECC guidelines

Table 7. Physio-chemical water quality results including chlorophyll, P, N, NOx, DO, pH, ammonia and nitrate and comparisons of results with ANZECC guidelines.

Site	Chlorophyll (µg/L)	Total P	TN	NOX	DO (%)	pH	Ammonia ($NH3^{+}$)	Nitrate (NO3)
S1 (Middle)	36.85	0.22	1.2	0.01	70.2	8.17	< 0.1	0.01
S1 (Edge)	33.89	0.35	1.2	0.02	77.7	8.22	0.2	0.02
S2 (Middle)	7.42	0.31	1	0.01	99.0	8.61	< 0.1	0.01
S2 (Edge)	7.19	0.34	1.1	< 0.01	105.6	8.73	< 0.1	< 0.01
S3 (Middle)	35.35	0.14	1.4	< 0.01	76.7	8.22	< 0.1	< 0.01
S3 (Edge)	26.47	0.13	1.3	< 0.01	102	8.43	< 0.1	< 0.01
S4 (Middle)	41.07	0.12	1.3	0.02	101.6	8.56	< 0.1	0.02
S4 (Edge)	16.77	0.16	1.1	0.01	119.4	8.63	< 0.1	0.01
S5 (Middle)	26.96	0.18	1.1	< 0.01	90.7	8.34	< 0.1	< 0.01
S5 (Edge)	21.28	0.13	1.4	< 0.01	94.6	8.40	< 0.1	< 0.01
S6 (Middle)	31.84	0.1	1.3	0.01	113.2	8.72	< 0.1	0.01
S6 (Edge)	31.28	0.1	1.2	< 0.01	107.3	8.60	< 0.1	< 0.01
Default ANZECC trigger values for physical and chemical stressors for south-east Australia for slightly disturbed ecosystems								
Lowland river	*5*	*0.050*	*0.5*	*0.04*	*85-110*	*6.5-8.0*	*0.9 (95%)*	*0.7 (95%)*
Freshwater lakes / reservoirs	*5*	*0.010*	*0.35*	*0.01*	*90-110*	*6.5-8.0*	-	-

*Grey shading are those values that exceed the default trigger values for slightly disturbed ecosystems. See Appendix 2 for values. Dashed lines represent parameters that do not have trigger values.

Interpretation of physio-chemical water quality results

Various naturally occurring physical and chemical stressors can lead to significant deterioration of aquatic ecosystems when ambient values are too high and/or too low. Some of these physical and chemical stressors include nutrients (e.g. phosphorus, total nitrogen, NOx, nitrate, ammonia), dissolved oxygen, turbidity, temperature, salinity and pH (ANZECC 2000, Tables 2–6).

The raw data presented in Tables 2 – 6 provide a single snapshot of baseline information for physio-chemical parameters between August 8–9 2023.

- The Menindee Lakes sites and Darling River sites were all characterised by high turbidity values (Table 2).
- Nutrient levels (e.g. total phosphorus (TP), total nitrogen (TN)) were, in general, in excess of ANZECC water quality trigger values for slightly-moderately disturbed ecosystems (Table 6

and 7). Oxides of nitrogen (NOx) slightly exceeded trigger values for lowland rivers (Site 1, Weir 32) and freshwater lakes at Site 4 Pamamaroo Lake (Table 6 and 7).

- Chlorophyll exceeded ANZECC water quality trigger values for slightly-moderately disturbed ecosystems (Table 7) at all sites. However, in-situ analysis with the Sonde may not be as precise as certified extractive laboratory analysis, so its limitations should be considered, and combining it with traditional methods is advisable to improve accuracy, as it is meant to complement rather than replace them for chlorophyll determination. (Source: The Basics of Chlorophyll Measurement (ysi.com)). Nonetheless, observations of an algal bloom were apparent at Sites 1 and 3, coupled with the chlorophyll and phycocyanin results (Tables 2–6) indicate the presence of an algal bloom in the Darling River / Menindee Lakes system.
- pH range consistently exceeded ANZECC water quality trigger values for slightly-moderately disturbed ecosystems (Table 7).

Overall, the results summarised in Tables 2–6 indicate moderate nutrient loads in the system and are representative of agricultural land use in the area. At the present levels, it is predicted that any change in temperature (as summer approaches) and / or water flow (e.g. drought conditions), or the further addition of nutrients into the waterway may see increased algal blooms and low dissolved oxygen levels, and should be monitored for potential fish death events in the near future.

3.5. Results: Metals in water and sediment

Background: Some metals, such as manganese, iron, copper, and zinc are essential micronutrients. They are essential to life in the right concentrations, but in excess, these chemicals can be toxic. At the same time, chronic low exposures to heavy metals can have serious health effects in the long run (ANZECC 2000).

The recommended guideline values for a range of metals in freshwaters are listed in Table 3.4.1 of the Guidelines (Appendix 3) and for sediment metal contaminants are listed in Table 3.5.1 of the ANZECC guidelines (Appendix 4). In some cases, no DGVs will be specified for a toxicant of interest. This generally reflects absence of an adequate dataset for that toxicant. This is particularly notable with sediment guideline values, where only nine metal values contain a reference value (Appendix 4).

Raw data for metals in water and the associated ANZECC guidelines trigger values for freshwater is presented in Table 8. Raw data for metals in sediments and the associated ANZECC guidelines trigger values for sediment is presented in Table 9.

In water, both aluminium (Al) and copper (Cu) were detected at most sites above the ANZECC Guideline Trigger Values (Table 8). Barium, cobalt, chromium, iron, molybdenum, strontium, titanium and vanadium were also detected but no guideline values were specified (Table 6).

In sediment, no metals exceeded the available trigger values for sediments (Table 9). However, aluminium, barium, cobalt, iron, manganese, titanium, vanadium were all detected but, again, no guideline reference values are available (Table 9).

Water samples (laboratory analysis) results

Table 8. Metals in water (raw data) and associated ANZECC guidelines trigger values

Site	AG	AL	AS	B	BA	BE	CD	CO	CR	CU	FE	HG	MN	MO	NI	PB	SB	SE	SN	SR	TI	TL	V	ZN
S1E	< 0.001	1.6	0.003	0.07	0.13	< 0.001	< 0.0002	0.001	0.002	0.003	1.6	< 0.0001	0.084	0.001	0.004	< 0.001	< 0.001	< 0.001	< 0.001	0.41	0.016	< 0.001	0.01	0.005
S1M	< 0.001	2.4	0.006	0.08	0.1	< 0.001	< 0.0002	< 0.001	0.003	0.004	2.3	< 0.0001	0.052	0.001	0.004	< 0.001	< 0.001	< 0.001	< 0.001	0.31	0.02	< 0.001	0.015	0.006
S2E	< 0.001	2.2	0.006	0.08	0.099	< 0.001	< 0.0002	< 0.001	0.003	0.004	2.2	< 0.0001	0.037	0.001	0.004	< 0.001	< 0.001	< 0.001	< 0.001	0.31	0.019	< 0.001	0.015	0.005
S2M	< 0.001	2.7	0.006	0.08	0.11	< 0.001	< 0.0002	< 0.001	0.004	0.005	2.6	< 0.0001	0.04	0.001	0.004	< 0.001	< 0.001	< 0.001	< 0.001	0.32	0.023	< 0.001	0.017	0.007
S3E	< 0.001	0.98	0.003	0.08	0.14	< 0.001	< 0.0002	0.001	0.002	0.003	1	< 0.0001	0.097	0.002	0.004	< 0.001	< 0.001	< 0.001	< 0.001	0.47	0.009	< 0.001	0.007	0.003
S3M	< 0.001	0.87	0.002	0.08	0.14	< 0.001	< 0.0002	0.001	0.002	0.003	0.89	< 0.0001	0.091	0.002	0.004	< 0.001	< 0.001	< 0.001	< 0.001	0.46	0.008	< 0.001	0.007	0.003
S4E	< 0.001	1.2	0.003	0.08	0.14	< 0.001	< 0.0002	0.001	0.002	0.003	1.2	< 0.0001	0.092	0.002	0.004	< 0.001	< 0.001	< 0.001	< 0.001	0.48	0.012	< 0.001	0.007	0.003
S4M	< 0.001	1.2	0.003	0.08	0.13	< 0.001	< 0.0002	< 0.001	0.002	0.003	1.2	< 0.0001	0.065	0.002	0.004	< 0.001	< 0.001	< 0.001	< 0.001	0.44	0.011	< 0.001	0.008	0.004
S5E	< 0.001	1.5	0.003	0.08	0.13	< 0.001	< 0.0002	0.001	0.002	0.003	1.5	< 0.0001	0.097	0.002	0.004	< 0.001	< 0.001	< 0.001	< 0.001	0.46	0.014	< 0.001	0.007	0.004
S5M	< 0.001	1.5	0.003	0.08	0.13	< 0.001	< 0.0002	0.001	0.002	0.003	1.5	< 0.0001	0.1	0.002	0.004	< 0.001	< 0.001	< 0.001	< 0.001	0.46	0.014	< 0.001	0.007	0.004
S6E	< 0.001	0.97	0.002	0.07	0.14	< 0.001	< 0.0002	0.001	0.002	0.003	0.99	< 0.0001	0.11	0.001	0.004	< 0.001	< 0.001	< 0.001	< 0.001	0.51	0.009	< 0.001	0.006	0.004
S6M	< 0.001	0.53	0.002	0.07	0.14	< 0.001	< 0.0002	< 0.001	0.001	0.002	0.43	< 0.0001	0.081	0.001	0.003	< 0.001	< 0.001	< 0.001	< 0.001	0.52	0.018	< 0.001	0.005	0.003
ANZECC Trigger Values (converted to mg/L)																								
99%	-	0.027	0.001	0.090	-	-	0.00006	-	-	0.001	-	0.00006	1.2	-	0.0088	0.001	-	0.055	-	-	-	-	-	0.0024
95%	-	0.055	0.024	0.370	-	-	0.0002	-	-	0.0014	-	0.0006	1.9	-	0.011	0.0034	-	0.011	-	-	-	-	-	0.008
90%	-	0.080	0.094	0.680	-	-	0.0004	-	-	0.0018	-	0.0019	2.5	-	0.013	0.0056	-	0.018	-	-	-	-	-	0.015
80%	-	0.15	0.36	1.3	-	-	0.0008	-	-	0.0025	-	0.0054	3.6	-	0.034	0.0094	-	0.034	-	-	-	-	-	0.031

*Green indicates no laboratory detection. Grey indicates sites / results that exceed 95% trigger values. (ANZECC Guidelines Trigger Values https://www.waterquality.gov.au/sites/default/files/documents/anzecc-armcanz-2000-guidelines-vol1.pdf) Appendix 3. Dashed lines represent parameters that do not have trigger values.

Sediment samples (laboratory analysis) results

Table 9. Metals in sediment (raw data) and associated ANZECC guidelines trigger values

Site	AG	AL	AS	B	BA	BE	CD	CO	CR	CU	FE	HG
S1E	< 5	17000	< 5	< 10	130	< 5	< 0.2	11	21	10	17000	< 0.05
S1M	< 5	12000	< 5	< 10	120	< 5	< 0.2	9	14	8	12000	< 0.05
S2E	< 5	6700	< 5	< 10	37	< 5	< 0.2	< 5	8	< 5	6200	< 0.05
S2M	< 5	20000	< 5	< 10	100	< 5	< 0.2	7	20	10	16000	< 0.05
S3E	< 5	12000	< 5	< 10	68	< 5	< 0.2	8	14	9	10000	< 0.05
S3M	< 5	22000	< 5	< 10	130	< 5	< 0.2	9	23	14	19000	< 0.05
S4E	< 5	1600	< 5	< 10	15	< 5	< 0.2	< 5	< 5	< 5	1800	< 0.05
S4M	< 5	18000	< 5	< 10	100	< 5	< 0.2	7	19	9	15000	< 0.05
S5E	< 5	6100	< 5	< 10	42	< 5	< 0.2	< 5	7	< 5	6100	< 0.05
S5M	< 5	19000	< 5	< 10	110	< 5	< 0.2	7	18	10	15000	< 0.05
S6E	< 5	20000	6	< 10	140	< 5	< 0.2	9	23	10	17000	< 0.05
S6M	< 5	24000	< 5	< 10	120	< 5	< 0.2	8	24	12	19000	< 0.05
ANZECC Default Guideline Values (converted to mg/kg)												
DGV	1.0	-	-	-	-	-	1.5	-	80	65	-	0.15
GV-high	4.0	-	-	-	-	-	10	-	370	270	-	1.0

Metals in sediment continued.

Site	LA	MN	MO	NI	PB	SB	SE	SN	SR	TH	TI	TL	U	V	ZN
S1E	15	360	< 5	14	7	< 5	< 3	< 5	150	< 5	89	< 5	< 5	28	28
S1M	13	590	< 5	11	11	< 5	< 3	< 5	42	< 5	26	< 5	< 5	22	22
S2E	9	110	< 5	5	< 5	< 5	< 3	< 5	13	< 5	23	< 5	< 5	12	12
S2M	18	230	< 5	13	8	< 5	< 3	< 5	29	6	52	< 5	< 5	34	29
S3E	11	130	< 5	11	7	< 5	< 3	< 5	29	< 5	53	< 5	< 5	37	23
S3M	17	540	< 5	16	11	< 5	< 3	< 5	44	< 5	51	< 5	< 5	43	39
S4E	< 5	32	< 5	< 5	< 5	< 5	< 3	< 5	< 5	< 5	20	< 5	< 5	6	< 5
S4M	16	280	< 5	13	7	< 5	< 3	< 5	33	< 5	55	< 5	< 5	29	29
S5E	7	180	< 5	5	< 5	< 5	< 3	< 5	21	< 5	46	< 5	< 5	13	12
S5M	13	360	< 5	12	8	< 5	< 3	< 5	48	< 5	73	< 5	< 5	36	28
S6E	16	540	< 5	15	7	< 5	< 3	< 5	53	< 5	80	< 5	< 5	51	30
S6M	17	340	< 5	16	8	< 5	< 3	< 5	35	< 5	63	< 5	< 5	38	36
DGV	-	-	-	21	50	-	-	-	-	-	-	-	-	-	200
GV-high	-	-	-	52	220	-	-	-	-	-	-	-	-	-	400

*Green indicates no laboratory detection. ANZECC Guidelines Trigger Values for sediments are provided in Appendix 4. Dashed lines represent parameters that do not have trigger values.

3.6. Results: Pesticides / Herbicides in water and sediment

Background: Pesticides represent a large and complex group of organic toxicants because they incorporate insecticides, acaricides, herbicides, algicides and fungicides. In addition, the behaviour (e.g. persistence, partitioning) and toxicity of pesticides varies greatly, making it difficult to generalise about risks. Pesticides generally enter water from sources in the primary industry sector, primarily agriculture (ANZECC 2000).

Pesticides / Herbicides in Water

Several herbicides including metolachlor, atrazine, simazine, terbuthylazine, tebuthiuron, clopyralid, fluroxpyr were detected from the laboratory-analysed water samples, and where ANZECC guideline values were available, generally exceeded the values for 99% protection, but were below the recommended 95% protection levels (Table 10). These herbicides are consistent with agricultural / farming practices and their levels should be monitored in future.

Pesticides / Herbicides in Sediment

No herbicides or pesticides exceeded the laboratory detection levels (see attached ALS laboratory report) in sediment.

Table 10. Pesticides / Herbicides in Water and associated ANZECC guidelines trigger values (ug/L)

	Metolachlor	**Atrazine**	**Simazine**	**Terbuthylazine**	**Tebuthiuron**	**Clopyralid**	**Fluroxypyr**
	(Miscellaneous herbicides)	(Triazine herbicides)		(Herbicide)	(Urea herbicides)	(Herbicide)	(Herbicide)
S1E	0.05	0.21	0.07	0.08	0.03	0.13	0.1
S1M	0.08	0.28	0.12	0.12	0.03	0.15	0.12
S2E	0.08	0.3	0.13	0.12	0.03	0.17	0.1
S2M	0.08	0.31	0.14	0.13	0.04	0.18	0.12
S3E	0.03	0.24	0.02	0.06	0.03	0.17	0.09
S3M	0.04	0.23	0.03	0.07	0.03	0.16	0.08
S4E	0.04	0.22	0.03	0.06	0.03	0.16	0.06
S4M	0.05	0.31	0.03	0.07	0.04	0.19	0.08
S5E	0.03	0.23	0.03	0.06	0.03	0.15	0.08
S5M	0.03	0.22	0.03	0.06	0.03	0.14	0.07
S6E	0.01	0.12	< 0.02	0.04	0.03	0.1	0.05
S6M	0.01	0.11	< 0.02	0.04	0.02	0.13	0.04
ANZECC Trigger Values (ug/L)							
99%	-	0.07	0.2	-	0.02	-	-
95%	-	13	3.2	-	2.2	-	-
90%	-	45	11	-	20	-	-
80%	-	150	35	-	160	-	-

ANZECC Guidelines Trigger Values for water are available in Table 3.4.1 of the guidelines (ANZECC 2000). Grey indicates sites / results that exceed 95% trigger values. Dashed lines represent parameters that do not have trigger values.

4. Conclusion

The results presented here (in particular, the detection of moderate nutrients and herbicides) are consistent with agricultural land-use in the area but for many chemicals there are no reference concentrations in national guidelines to assess health or ecological risks. Furthermore, the detection of an algal bloom during the August sampling event suggests the establishment of an ongoing monitoring program, prior to temperatures increasing (e.g. summer) and flows declining (e.g. during drought conditions), would be a prudent action. Water and sediment quality should be monitored in future to detect longer-term trends to aid in the development of any water / sediment quality management plans for future monitoring and fish death prevention programs.

This report presents a sampling strategy for a rapid assessment of the water- and sediment quality in the Menindee Lakes / Darling River (Menindee) and outlines a sampling plan for water and sediment assessment for future applications. This involves using a combination of in-situ measurements (edge- and middle- sampling using a two water quality meters (Horiba, Sonde)) and water and sediment samples for laboratory analysis (including nutrients in water, BOD, COD, metals, herbicides and pesticides). This sampling plan (methodology) and the results presented here could be used as a rapid assessment tool and as baseline preliminary data and can be applied for future applications to monitor for future fish death events or other environmental disturbances.

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Appendix 1

Table 3.4.2 General framework for applying levels of protection for toxicants to different ecosystem conditions

Ecosystem condition	Level of protection
1 High conservation/ ecological value	• For anthropogenic toxicants, detection at any concentration could be grounds for source investigation and management intervention; for natural toxicants background concentrations should not be exceeded.[a] *Where local biological or chemical data have not yet been gathered*, apply the 99% protection levels (table 3.4.1) as default values. Any relaxation of these objectives should only occur where comprehensive biological effects and monitoring data clearly show that biodiversity would not be altered. • In the case of effluent discharges, Direct Toxicity Assessment (DTA) should also be required on the effluent. • Precautionary approach taken to assessment of post-baseline data through trend analysis or feedback triggers.
2 Slightly to moderately disturbed ecosystems	• Always preferable to use local biological effects data (including DTA) to derive guidelines. *If local biological effects data unavailable*, apply 95% protection levels (table 3.4.1) as default, low-risk trigger values.[b] 99% values are recommended for certain chemicals as noted in table 3.4.1.[c] • Precautionary approach may be required for assessment of post-baseline data through trend analysis or feedback triggers. • In the case of effluent discharges DTA may be required.
3 Highly disturbed ecosystems	• Apply the same guidelines as for slightly–moderately disturbed systems. However, the lower protection levels provided in the Guidelines may be accepted by stakeholders. • DTA could be used as an alternative approach for deriving site-specific guidelines.

a This means that indicator values at background and test sites should be statistically indistinguishable. It is acknowledged that it may not be strictly possible to meet this criterion in every situation.

b For slightly disturbed ecosystems where the management goal is no change in biodiversity, users may prefer to apply a higher protection level.

c 99% values recommended for chemicals that bioaccumulate or for which 95% provides inadequate protection for key test species. Jurisdictions may choose 99% values for some ecosystems that are more towards the slightly disturbed end of the continuum.

Appendix 2

Table 3.3.2 Default trigger values for physical and chemical stressors for south-east Australia for slightly disturbed ecosystems. Trigger values are used to assess risk of adverse effects due to nutrients, biodegradable organic matter and pH in various ecosystem types. Data derived from trigger values supplied by Australian states and territories. Chl *a* = chlorophyll *a*, TP = total phosphorus, FRP = filterable reactive phosphate, TN = total nitrogen, NO_x = oxides of nitrogen, NH_4^+ = ammonium, DO = dissolved oxygen.

Ecosystem type	Chl *a*	TP	FRP	TN	NO_x	NH_4^+	DO (% saturation)[l]		pH	
	($\mu g\ L^{-1}$)	($\mu g\ P\ L^{-1}$)	($\mu g\ P\ L^{-1}$)	($\mu g\ N\ L^{-1}$)	($\mu g\ N\ L^{-1}$)	($\mu g\ N\ L^{-1}$)	Lower limit	Upper limit	Lower limit	Upper limit
Upland river	na[a]	20[b]	15[g]	250[c]	15[h]	13[i]	90	110	6.5	7.5[m]
Lowland river[d]	5	50	20	500	40[o]	20	85	110	6.5	8.0
Freshwater lakes & Reservoirs	5[e]	10	5	350	10	10	90	110	6.5	8.0[m]
Wetlands	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data
Estuaries[p]	4[f]	30	5[j]	300	15	15	80	110	7.0	8.5
Marine[p]	1[n]	25[n]	10	120	5[k]	15[k]	90	110	8.0	8.4

na = not applicable;
a = monitoring of periphyton and not phytoplankton biomass is recommended in upland rivers — values for periphyton biomass (mg Chl *a* m^{-2}) to be developed;
b = values are 30 μgL^{-1} for Qld rivers, 10 μgL^{-1} for Vic. alpine streams and 13 μgL^{-1} for Tas. rivers;
c = values are 100 μgL^{-1} for Vic. alpine streams and 480 μgL^{-1} for Tas. rivers;
d = values are 3 μgL^{-1} for Chl *a*, 25 μgL^{-1} for TP and 350 μgL^{-1} for TN for NSW & Vic. east flowing coastal rivers;
e = values are 3 μgL^{-1} for Tas. lakes;
f = value is 5 μgL^{-1} for Qld estuaries;
g = value is 5 μgL^{-1} for Vic. alpine streams and Tas. rivers;
h = value is 190 μgL^{-1} for Tas. rivers;
i = value is 10 μgL^{-1} for Qld. rivers;
j = value is 15 μgL^{-1} for Qld. estuaries;
k = values of 25 μgL^{-1} for NO_x and 20 μgL^{-1} for NH_4^+ for NSW are elevated due to frequent upwelling events;
l = dissolved oxygen values were derived from daytime measurements. Dissolved oxygen concentrations may vary diurnally and with depth. Monitoring programs should assess this potential variability (see Section 3.3.3.2);
m = values for NSW upland rivers are 6.5–8.0, for NSW lowland rivers 6.5–8.5, for humic rich Tas. lakes and rivers 4.0-6.5;
n = values are 20 μgL^{-1} for TP for offshore waters and 1.5 μgL^{-1} for Chl *a* for Qld inshore waters;
o = value is 60 μgL^{-1} for Qld rivers;
p = no data available for Tasmanian estuarine and marine waters. A precautionary approach should be adopted when applying default trigger values to these systems.

NON-METALLIC INORGANICS									
Ammonia	D	320	900 [C]	1430 [C]	2300 [A]	500	910	1200	1700
Chlorine	E	0.4	3	6 [A]	13 [A]	ID	ID	ID	ID
Cyanide	F	4	7	11	18	2	4	7	14
Nitrate	J	17	700	3400 [C]	17000 [A]	ID	ID	ID	ID
Hydrogen sulfide	G	0.5	1.0	1.5	2.6	ID	ID	ID	ID

Appendix 3

Page 3.4-5: ANZECC Guidelines Trigger Values

https://www.waterquality.gov.au/sites/default/files/documents/anzecc-armcanz-2000-guidelines-vol1.pdf

Table 3.4.1 Trigger values for toxicants at alternative levels of protection. Values in grey shading are the trigger values applying to typical *slightly–moderately disturbed systems*; see table 3.4.2 and Section 3.4.2.4 for guidance on applying these levels to different ecosystem conditions.

Chemical		**Trigger values for freshwater (µgL⁻¹)**				**Trigger values for marine water (µgL⁻¹)**			
		Level of protection (% species)				**Level of protection (% species)**			
		99%	**95%**	**90%**	**80%**	**99%**	**95%**	**90%**	**80%**
METALS & METALLOIDS									
Aluminium	pH >6.5	27	55	80	150	ID	ID	ID	ID
Aluminium	pH <6.5	ID	ID	ID	ID	ID	ID	ID	ID
Antimony		ID	ID	ID	ID	ID	ID	ID	ID
Arsenic (As III)		1	24	94 [C]	360 [C]	ID	ID	ID	ID
Arsenic (AsV)		0.8	13	42	140 [C]	ID	ID	ID	ID
Beryllium		ID	ID	ID	ID	ID	ID	ID	ID
Bismuth		ID	ID	ID	ID	ID	ID	ID	ID
Boron		90	370 [C]	680 [C]	1300 [C]	ID	ID	ID	ID
Cadmium	H	0.06	0.2	0.4	0.8 [C]	0.7 [B]	5.5 [B, C]	14 [B, C]	36 [B, A]
Chromium (Cr III)	H	ID	ID	ID	ID	7.7	27.4	48.6	90.6
Chromium (CrVI)		0.01	1.0 [C]	6 [A]	40 [A]	0.14	4.4	20 [C]	85 [C]
Cobalt		ID	ID	ID	ID	0.005	1	14	150 [C]
Copper	H	1.0	1.4	1.8 [C]	2.5 [C]	0.3	1.3	3 [C]	8 [A]
Gallium		ID	ID	ID	ID	ID	ID	ID	ID
Iron		ID	ID	ID	ID	ID	ID	ID	ID
Lanthanum		ID	ID	ID	ID	ID	ID	ID	ID
Lead	H	1.0	3.4	5.6	9.4 [C]	2.2	4.4	6.6 [C]	12 [C]
Manganese		1200	1900 [C]	2500 [C]	3600 [C]	ID	ID	ID	ID
Mercury (inorganic)	B	0.06	0.6	1.9 [C]	5.4 [A]	0.1	0.4 [C]	0.7 [C]	1.4 [C]
Mercury (methyl)		ID	ID	ID	ID	ID	ID	ID	ID
Molybdenum		ID	ID	ID	ID	ID	ID	ID	ID
Nickel	H	8	11	13	17 [C]	7	70 [C]	200 [A]	560 [A]
Selenium (Total)	B	5	11	18	34	ID	ID	ID	ID
Selenium (SeIV)	B	ID	ID	ID	ID	ID	ID	ID	ID
Silver		0.02	0.05	0.1	0.2 [C]	0.8	1.4	1.8	2.6 [C]
Thallium		ID	ID	ID	ID	ID	ID	ID	ID
Tin (inorganic, SnIV)		ID	ID	ID	ID	ID	ID	ID	ID
Tributyltin (as µg/L Sn)		ID	ID	ID	ID	0.0004	0.006 [C]	0.02 [C]	0.05 [C]
Uranium		ID	ID	ID	ID	ID	ID	ID	ID
Vanadium		ID	ID	ID	ID	50	100	160	280
Zinc	H	2.4	8.0 [C]	15 [C]	31 [C]	7	15 [C]	23 [C]	43 [C]

Appendix 4

Recommended default guideline values for toxicants in sediment

Table 1 Recommended toxicant default guideline values for sediment quality

Type of toxicant	Toxicant	DGV	GV-high
Metals (mg/kg dry weight)[a]	Antimony	2.0	25
	Cadmium	1.5	10
	Chromium	80	370
	Copper	65	270
	Lead	50	220
	Mercury	0.15	1.0
	Nickel	21	52
	Silver	1.0	4.0
	Zinc	200	410

Source: https://www.waterquality.gov.au/anz-guidelines/guideline-values/default/sediment-quality-toxicants