BIOLOGICAL RESPONSE TO FLOWS DOWNSTREAM OF CORIN, BENDORA, COTTER AND GOOGONG DAMS

Annual report July 2025

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EXECUTIVE SUMMARY

BACKGROUND AND STUDY OBJECTIVE

- The Cotter and Queanbeyan Rivers are regulated to supply water to the Australian Capital Territory (ACT) and Queanbeyan. Ecological assessment is undertaken in spring and autumn each year to evaluate river response to environmental flow releases to the Cotter and Queanbeyan Rivers. Sites below dams are assessed and compared with sites on the unregulated Goodradigbee River and Queanbeyan River (upstream of Googong Dam) to evaluate ecological change and responses attributed to the flow regulation.
- This study addresses the needs of Icon Water's License to Take Water (WU67) to assess the effects of dam operation, water abstraction, and environmental flows, and to provide information for the adaptive management of the Cotter and Googong water supply catchments. This study specifically focuses on assessing the ecological status of river habitats by investigating water quality and biotic characteristics. This report is the results of assessments undertaken in spring 2024 and autumn 2025.

SPRING 2024 & AUTUMN 2025 RESULTS AND CONCLUSIONS

- Flows leading up to sampling in both spring 2024 and autumn 2025 generally reflected rainfall variability across the monitored catchments. In spring 2024, cumulative flows were consistently lower than the historical spring mean flows at all stations. Conversely, in autumn 2025, while most stations still showed lower cumulative flows than historical autumn means, Cotter River at D/S Corin Dam and Goodradigbee River at Brindabella had relatively higher flows compared to spring 2024, indicating some catchments experienced improved runoff conditions during autumn 2025.
- Cotter Reservoir remained close to full supply throughout the assessment period, including before both spring 2024 and autumn 2025 sampling. Corin Reservoir had a steady decline from June 2024, reaching its lowest level in May 2025, indicating sustained outflows and limited replenishment. Bendora Reservoir fluctuated more, with levels dropping in mid-2024, peaking briefly in December, and then declining again. These trends suggest a mix of natural inflow and regulated releases, with most reservoirs approaching full supply in July and temporarily again around January.
- Water quality below the Dams were generally within guideline levels during spring 2024 and autumn 2025. However, elevated nutrient concentrations were noted, particularly below Googong Reservoir, where Total Nitrogen and Total Phosphorus were high in both seasons. Sites downstream of Bendora and Cotter reservoirs also had increased nitrogen oxides in autumn 2025. While most sites were within guidelines, nutrient enrichment at some locations suggests site-specific water quality issues.
- The ecological objective of maintaining a filamentous algae cover of less than 20% in riffle habitats was achieved at all test sites in spring 2024 and autumn 2025. Click here for more information.
- As per previous assessments, test sites were generally in poorer condition than reference sites for both spring 2024 and autumn 2025 assessments.
- In spring 2024, site QM2 was the only below-dam site to achieve AUSRIVAS band A. By autumn 2025, QM2 declined to band B, while site QM3 improved to Band A, developing

as the only below-dam site to meet ecological objectives in both seasons. Click here for more information

- All reference sites in spring 2024 (except CT3 and QM1 in autumn 2025) were all assessed as band A biological condition (similar to reference). Click here for more information

Table 1A: Filamentous algae cover and AUSRIVAS band scores for the test sites (green shading indicates environmental flow objective met, red shading indicates environmental flow objective not met).

	Riffle filamentous algae cover (%)		AUSRIVAS band (O/E score)	
Site	Spring 2024	Autumn 2025	Spring 2024	Autumn 2025
CM1 (Corin Dam)	<10	<10	B	B
CM2 (Bendora Dam)	20	<10	B	B
CM3 (Cotter Dam)	<10	<10	C	B
QM2 (Googong Dam)	<10	<10	A	B
QM3 (Googong Dam)	<10	<10	B	A

PROJECT RECOMMENDATIONS

The drivers of the continued differential biological condition between test and reference sites in this program (test sites generally in worse biological condition that reference sites) appear to be site and season specific. It is recommended that a more thorough investigation to determine what is contributing to the long-term lower condition at test sites, and what possible remediation action may be taken to more consistently meet band A should be undertaken.

INTRODUCTION

Water diversions and modified flow regimes can result in deterioration of both the ecological function and water quality of Australian streams (Arthington & Pusey, 2003). Many of the aquatic ecosystems in the Australian Capital Territory (ACT) are subject to flow regulation. Environmental flow guidelines were introduced in 1999 as part of the Water Resources Act 1998 and redefined in 2006, 2013 and 2019 (ACT Government, 2019). The Environmental Flow Guidelines identify the components of the flow regime that are necessary for maintaining stream health and set the ecological objectives for the environmental flow regime (ACT Government, 2019). The ecological objectives for environmental flows are 1) for the Cotter and Queanbeyan Rivers to reach an Australian River Assessment System (AUSRIVAS) observed/expected band A grade (similar to reference condition) and 2) to have <20% filamentous algal cover in riffles for 95% of the time (ACT Government, 2019). Ecological assessment evaluates the effectiveness of the flow regime for meeting the ecological objectives and provides the scientific basis to inform decisions about refinements to future environmental flow releases to ensure that these objectives are met.

This assessment is based on the ecological objectives of environmental flow regimes in the ACT, has been ongoing at fixed sampling sites since 2001 and is based on bi-annual assessments of macroinvertebrate assemblages, algae (periphyton and filamentous algae) and water quality. Sampling is conducted during spring and autumn of each year to evaluate the condition of river habitat downstream of dams on both the Cotter and Queanbeyan Rivers. A comparison is made with the condition of reference sites on the unregulated Goodradigbee River and the Queanbeyan River upstream of Googong Dam.

Tributaries of the Cotter and Goodradigbee Rivers are also sampled to determine whether impacts on biological condition in these rivers are being caused by catchment or river regulation effects. For example, if Cotter River tributaries are assessed in poorer biological condition than reference tributaries on the Goodradigbee River, then catchment condition may be driving instream biological condition at Cotter River test sites regardless of river regulation effects. However, if Cotter and Goodradigbee River tributaries are in similar biological condition, then differences in biological condition between Goodradigbee and Cotter River sites may be attributed to river regulation effects.

This sampling and reporting program satisfies Icon Water's Licence to Take Water (WU67) and the requirement to provide an assessment of the effects of dam operation and the effectiveness of environmental flows. The information from the assessment informs the adaptive management framework applied in the water supply catchments.

The present report evaluates the sites located downstream of the dams on the Cotter and Queanbeyan Rivers in spring 2024 and autumn 2025. The assessment primarily concentrates on comparing these sites with unregulated reference sites and the findings of previous assessments. Site summary sheets outlining the outcomes of both the spring 2024 and autumn 2025 assessments for each of the test sites CM1 (Corin Dam), CM2 (Bendora Dam), CM3 (Cotter Dam), QM2 (Googong Dam), and QM3 (downstream of QM2) are included as Appendix 1.

FIELD AND LABORATORY METHODS

STUDY AREA

The study area includes the Cotter and Goodradigbee Rivers, which are situated to the east and west of the western border of the ACT, respectively, and the Queanbeyan River to the east of the ACT (Figure 1).

The Cotter River is a fifth order stream (below Cotter Dam) with a catchment area of approximately 480 km^2. The Cotter River is a major source of drinking water for Canberra and Queanbeyan, with the principal management outcome to ensure a secure water supply (ACT Government, 2019). Conservation of ecological values of the river is an important consideration in the ongoing management of the Cotter River. The river is regulated by three dams, the Cotter Dam, Bendora Dam and Corin Dam.

The Cotter River catchment is largely free of pollutants and human disturbance aside from regulation, which provides the opportunity to study the effects of flow releases from the dams with minimal confounding from other factors often present in environmental investigations (Chester & Norris, 2006; Nichols et al., 2006). The Murrumbidgee to Cotter pumping augmentation (M2C) project has been implemented to provide an environmental flow transfer capability (up to 40ML d^{-1}) for the Cotter River reach below Cotter Dam by pumping water from Murrumbidgee River when releases from the Cotter Dam are unavailable.

The Queanbeyan River is a fifth order stream (at all sampling sites) and is regulated by Googong Dam approximately 90 km from its source to secure the water supply for the ACT and Queanbeyan. Compared to the Cotter River catchment, the Googong catchment is less protected and is therefore subject to disturbance in addition to flow regulation.

The Goodradigbee River is also a fifth order stream (at all sampling sites) and remains largely unregulated until it reaches Burrinjuck Dam (approximately 50 km downstream of the study area). This river constitutes an appropriate reference site for the study because it has similar environmental characteristics (substrate and chemistry) but is largely unregulated (Norris & Nichols, 2011)

Fifteen sites were sampled for biological, physical and chemical variables in spring between 09 to 22 October and autumn between 12 March and 1 April 2025 (Table 1). Site characteristics including latitude, longitude, altitude, stream order, catchment area, and distance from source were obtained from 1:100 000 topographic maps. Latitude and longitude were confirmed in the field using a Global Positioning System.

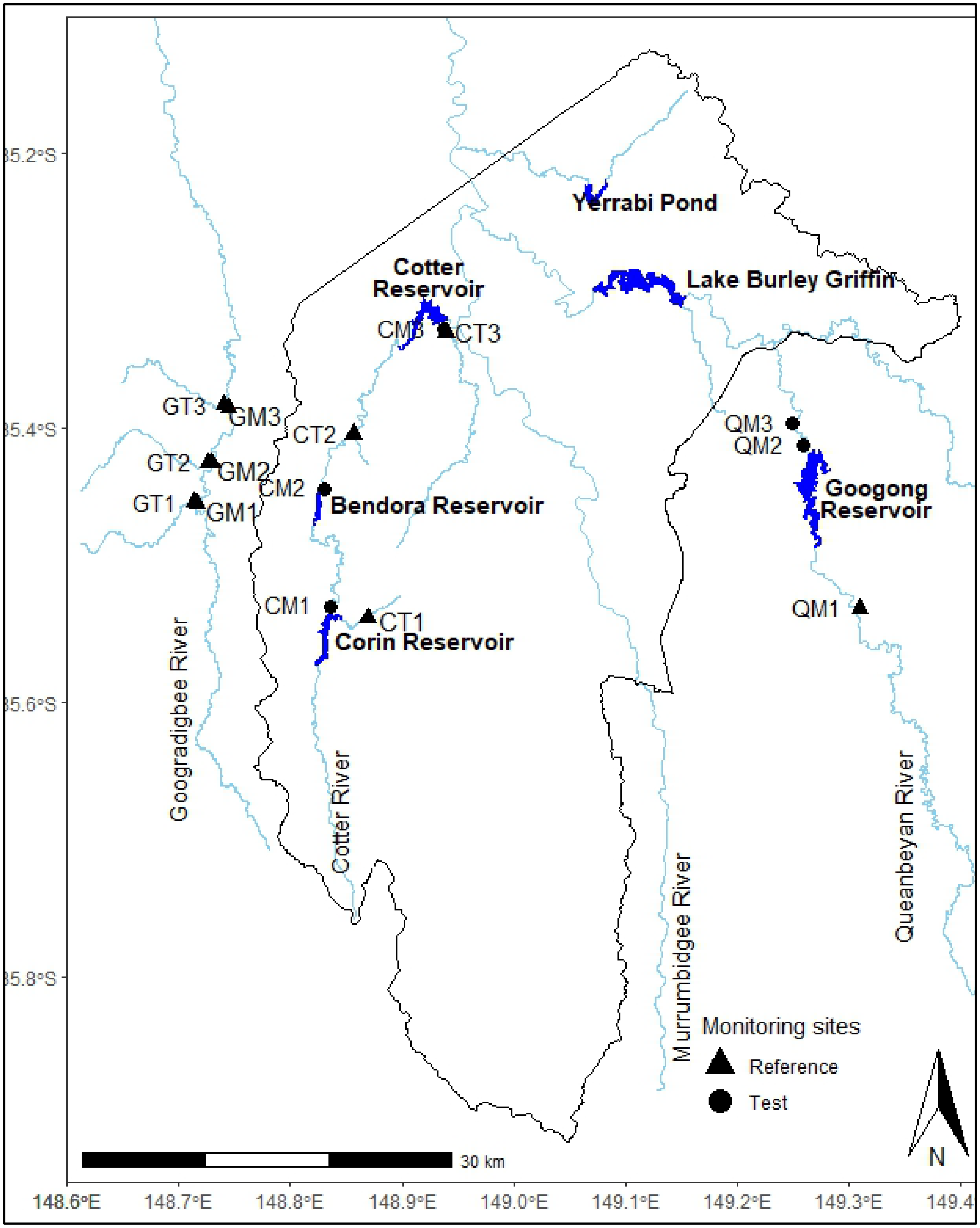

Figure 1: The location of sites on the Cotter, Goodradigbee, and Queanbeyan Rivers and tributaries for the below dams assessment program (Circles indicate test sites, triangles indicate reference tributaries).

Table 1: Cotter, Goodradigbee and Queanbeyan River sites sampled for the below dams assessment program.

Site	River	Location	Altitude (m)	Distance from source (km)	Stream order
CM1	Cotter	500m downstream of Corin Dam	900	31	4
CM2	Cotter	500 m downstream of Bendora Dam	700	51	4
CM3	Cotter	100m upstream Paddy's River confluence	500	75	5
CT1	Kangaroo Ck	50m downstream Corin Road crossing	900	7.3	3
CT2	Burkes Ck	50 m upstream of confluence with Cotter River	680	4.5	3
CT3	Paddys	500 m upstream of confluence with Cotter River	500	48	4
GM1	Goodradigbee	20 m upstream of confluence with Cooleman Ck	680	38	5
GM2	Goodradigbee	20 m upstream of confluence with Bull Flat Ck	650	42	5
GM3	Goodradigbee	100 m upstream of Brindabella Bridge	620	48	5
GT1	Cooleman Ck	50 m upstream of Long Plain Road crossing	680	17.9	4
GT2	Bull Flat Ck	Immediately upstream of Crace Lane crossing	650	15.6	4
GT3	Bramina Ck	30 m upstream of Brindabella Road crossing	630	18	5
QM1	Queanbeyan	12 km upstream of Googong Dam near 'Hayshed Pool'	720	72	5
QM2	Queanbeyan	1 km downstream of Googong Dam	590	91.6	5

HYDROMETRIC DATA

To analyse the variations in river flow leading up to the sampling period, mean daily flow data for each of the below dam test sites (ALS) and the Goodradigbee River reference sites (WaterNSW, gauging station 410088) were utilised. Daily rainfall data was gathered from various environmental monitoring sites, including ALS site 570816 and 570983 in the Queanbeyan Catchment, ALS site 570958 at Bendora Dam, ALS site 570825 in Peirces Creek, and Bureau of Meteorology station number 071073 located in Brindabella.

PHYSICAL AND CHEMICAL WATER QUALITY ASSESSMENT

Water temperature, pH, electrical conductivity and turbidity were measured at all sites using a calibrated Horiba U-52 water quality meter and dissolved oxygen was measured using a Hach portable DO meter. Total alkalinity was calculated by field titration to an end point of pH 4.5 (Association & Association, 2005). Two 50ml water samples were collected from each site to measure ammonium, nitrogen oxide, total nitrogen and total phosphorus concentrations. Samples were analysed following methods from the Standard Methods for the Examination of Water and Wastewater (Association & Association, 2005).

Water quality guideline values for the Cotter, Googong and Goodradigbee catchments were based on the most conservative values from the Environment Protection Regulations SL2005-38 (which cover a variety of water uses and environmental values for each river reach in the ACT), and the ANZECC and ARMCANZ (2000) water quality guidelines for aquatic ecosystem protection in south-east Australian upland rivers (ANZECC & ARMCANZ, 2000). While comparisons with water quality guidelines are not required as part of the environmental flow guidelines, and are used only as a guide, they provide a useful tool for the protection of ecosystems (which is a primary objective of environmental flows). Only the upper guideline value for conductivity was used because concentrations below the minimum guideline level are unlikely to impact on the ecological condition of streams.

Table 2: Water quality guideline values from the Environment Protection Regulations SL2005-38* and ANZECC and ARMCANZ (2000)**. N/A *= guideline value not available*.

Measure	Units	Guideline value
Alkalinity	mg L^{-1}	N/A
Temperature	ºC	N/A
Conductivity**	µS cm^{-1}	<350
pH**	N/A	6.5-8
Dissolved oxygen *	mg L^{-1}	>6
Turbidity*	NTU	<10
Ammonium (NH_4^+)**	mg L^{-1}	<0.13
Nitrogen oxides**	mg L^{-1}	<0.015
Total phosphorus**	mg L^{-1}	<0.02
Total nitrogen**	mg L^{-1}	<0.25

PERIPHYTON AND FILAMENTOUS ALGAE

VISUAL OBSERVATIONS

Periphyton and filamentous algae visual observations within riffle habitats were recorded following methods outlined in the ACT AUSRIVAS sampling and processing manual (Nichols et al., 2000a; Nichols et al., 2000b) http://ausrivas.ewater.com.au/ausrivas/index.php/manuals-a-datasheets?id=54).

ASH-FREE DRY MASS AND CHLOROPHYLL-A

Six replicate periphyton samples were collected at each of the Cotter and Goodradigbee River sites and site QM2 on the Queanbeyan River using a syringe sampler based on a design similar to that described by Loeb (Loeb, 1981). Samples from each site were measured for Ash-free dry mass (AFDM) and Chlorophyll-a content in accordance with methods described in (Association & Association, 2005).

MACROINVERTEBRATE SAMPLE COLLECTION AND PROCESSING

Benthic macroinvertebrates were sampled from the riffle habitat following National River Health Program protocols presented in the ACT AUSRIVAS sampling and processing manual (Nichols et al., 2000a) http://ausrivas.ewater.com.au/ausrivas/index.php/manuals-a-datasheets?id=54). Macroinvertebrate samples from the site CT2 (Burkes Creek, upstream of confluence with Cotter River) could not be collected due to lack of flow at the site in autumn 2025.

In the laboratory, preserved samples were placed in a sub-sampling box comprising of 100 cells (Marchant 1989) and agitated until evenly distributed. Contents of each cell were removed until approximately 200 animals from each sample were identified (Parsons & Norris, 1996). Macroinvertebrates were identified to the family taxonomic level using keys listed by (Hawking, 2000), except Chironomidae, which were identified to sub-family, aquatic worms (Oligochaeta) and mites (Acarina), which were identified to class. After the ~200 macroinvertebrates were sub-sampled, the remaining unsorted sample was visually scanned to identify taxa which were not found in the ~200 animal sub-sample (Nichols et al., 2000a) QA/QC procedures were implemented for macroinvertebrate sample processing following those outlined in (Nichols et al., 2000a).

AUSRIVAS (AUSTRALIAN RIVER ASSESSMENT SYSTEM)

AUSRIVAS predicts the macroinvertebrate fauna expected to occur at a site with specific environmental characteristics, in the absence of environmental stress. The fauna observed (O) at a site can then be compared to fauna expected (E), with the deviation between the two providing an indication of biological condition (Coysh et al., 2000) http://ausrivas.ewater.com.au). A site displaying no biological impairment should have an O/E ratio close to one. The O/E ratio will generally decrease as the macroinvertebrate assemblage and richness are adversely affected.

The AUSRIVAS predictive model used to assess the biological condition of sites was the ACT spring and the ACT autumn riffle models. The AUSRIVAS software and User's Manual (Coysh et al., 2000) is available online at: http://ausrivas.ewater.com.au . The ACT spring and ACT autumn riffle models use a set of 12 habitat variables to predict the macroinvertebrate fauna expected to occur at each site in the absence of disturbance.

AUSRIVAS allocates test site O/E taxa scores to category bands that represent a range in biological conditions to aid interpretation. AUSRIVAS uses five bands, designated X, A, B, C, and D (Table 3). The derivation of model bandwidths is based on the distribution of O/E scores of the reference sites used to create each AUSRIVAS model (Coysh et al., 2000) http://ausrivas.ewater.com.au).

To evaluate differences in macroinvertebrate community composition between Test and Reference sites, a multivariate statistical approach was employed. Taxonomic abundance data were fourth-root transformed to reduce the influence of dominant taxa while preserving ecological gradients. Bray-Curtis dissimilarity was used to quantify pairwise compositional differences among sites, appropriate for zero-inflated ecological count data. Non-metric multidimensional scaling (nMDS) was used to visualize community structure in two dimensions, with taxa vectors overlaid based on Pearson correlations with the ordination axes. Hierarchical clustering using average linkage was applied to the Bray-Curtis matrix, and clusters were delineated at a visually assessed for natural groupings on the similarity threshold for each season and visualized using convex hulls.

To statistically test for differences in community composition between treatment groups, a permutational multivariate analysis of variance (PERMANOVA) was conducted using the adonis2() function from the vegan package. The model tested the effect of the categorical variable Group (below dams vs Reference) on the Bray-Curtis dissimilarity matrix. The analysis used 999 unrestricted permutations under a reduced model to assess significance.

SIGNAL 2 GRADES

Habitat disturbance and pollution sensitivity grades (SIGNAL 2) range from 1 to 10, with sensitive taxa receiving higher grades than tolerant taxa. The sensitivity grades are based on taxa tolerance to common pollution types (Chessman, 2003).

DATA ENTRY AND STORAGE

Water quality, habitat, and macroinvertebrate data were entered into the University of Canberra database. The layout of the database matches the field data sheets to minimise transcription errors. All data were checked for transcription errors using standard two person checking procedures. A backup of files was carried out daily.

DATA ANALYSIS

To evaluate differences in chlorophyll-a and Ash free dry concentrations across sampling sites and between site classifications (below dams group vs. reference group), a linear mixed-effects modeling approach was employed using R (version 4.4.1). Data were first assessed for normality and homogeneity of variance. Due to heteroscedasticity observed in residual diagnostics, chlorophyll-a concentrations were log-transformed to stabilize variance. A mixed-effects model was then fitted using the lme4 and lmerTest packages, with group (test/reference) included as a fixed effect and site as a random effect to account for site-level variability. Estimated marginal means (EMMs) were computed using the emmeans package to compare group-level differences. To explore differences among individual sites, a separate model was fitted using lm() with site treated as a fixed effect, allowing for pairwise comparisons with Tukey adjustment. Model diagnostics were conducted using the DHARMa and performance packages to assess residual patterns, variance structure, and model fit. The similarity in macroinvertebrate community structure between sites was evaluated by utilizing the Bray-Curtis similarity measure and the group average method, focusing on the relative abundance data.

Table 3: ACT autumn and spring riffle AUSRIVAS model band descriptions, band width and interpretation.

Band	Band description	Band width	Interpretation
X	More biologically diverse than reference	**>1.12** (autumn) **>1.14** (spring)	More taxa found than expected. Potential biodiversity hot-spot. Possible mild organic enrichment.
A	Similar to reference	**0.88-1.12** (autumn) **0.86-1.14** (spring)	Water quality and/or habitat condition roughly equivalent to reference sites.
B	Significantly impaired	**0.64-0.87** (autumn) **0.57-0.85** (spring)	Potential impact either on water quality or habitat quality or both, resulting in loss of taxa.
C	Severely impaired	**0.40-0.63** (autumn) **0.28-0.56** (spring)	Loss of macroinvertebrate biodiversity due to substantial impacts on water and/or habitat quality.
D	Extremely impaired	**0-0.39** (autumn) **0-0.27 (** spring)	Extremely poor water and/or habitat quality. Highly degraded.

RESULTS

HYDROMETRIC DATA

In the three months preceding the spring 2024 sampling, stream discharge at sites downstream of dams on the Cotter and Queanbeyan Rivers was generally below the historical average, with flows primarily influenced by regulated releases (Table 5). Similarly, the Goodradigbee River recorded significantly lower cumulative flows compared to its historical mean, reflecting widespread reduced streamflow conditions across the region (Figure 2 and Table 5). In contrast, streamflows in the lead-up to the autumn 2025 sampling were generally comparable to or only slightly below historical averages, depending on the site, and were shaped by a combination of natural events and regulated releases. For example, moderate flows were observed at Cotter River downstream of Corin Dam and Queanbeyan River upstream of Googong Dam, while sites such as Cotter River at Kiosk and Downstream of Googong Reservoir remained well below average (Table 5). Rainfall in the three months prior to spring 2024 was well below average across all monitoring sites. In contrast, rainfall in the three months before autumn 2025 showed a marked improvement compared to spring 2024 but lower than historical mean rainfall in the same period, reflecting a return to more typical seasonal patterns and contributing to improved streamflow conditions (Table 6).

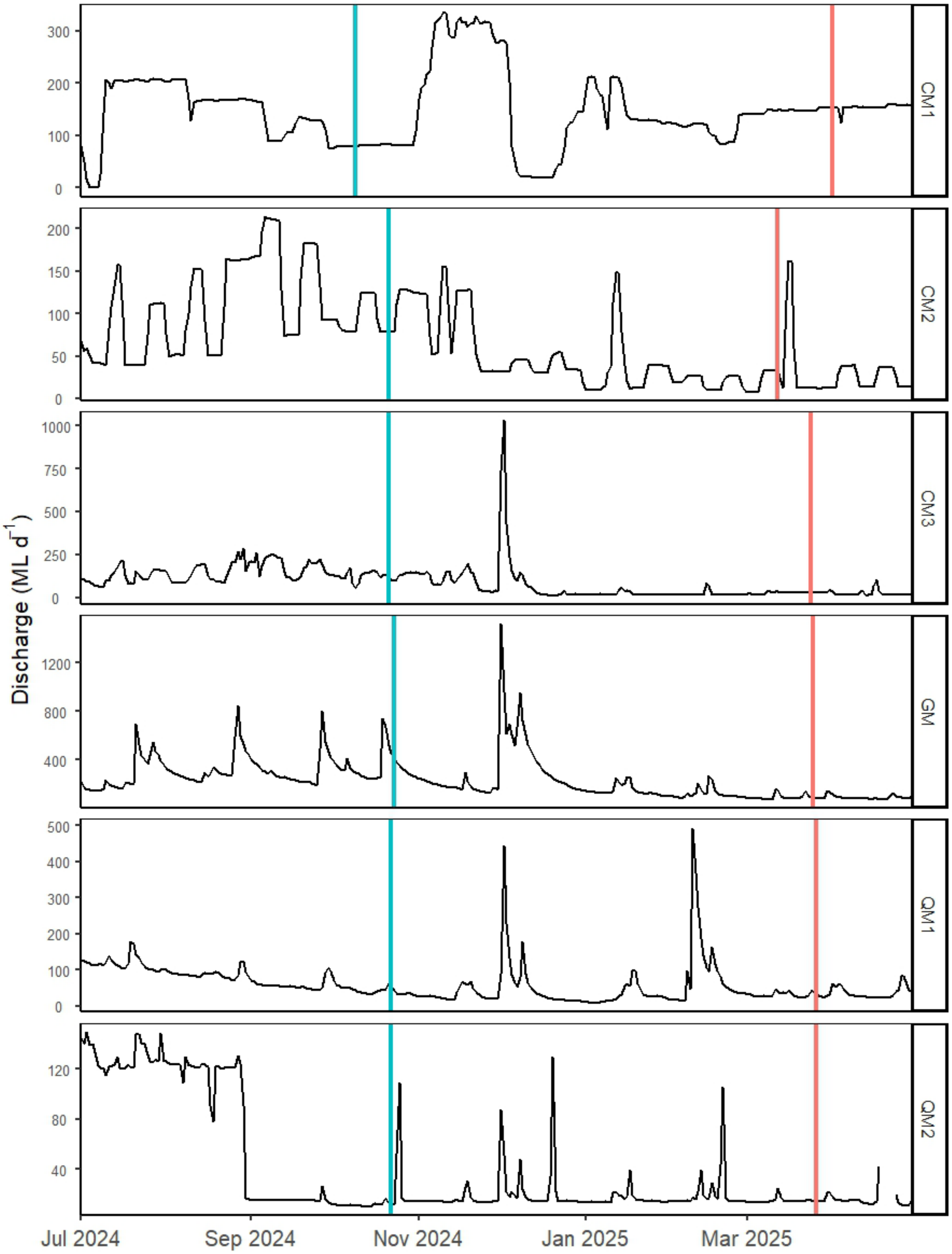

Figure 2: Mean daily discharge below Corin (CM1, station 410752), Bendora (CM2, station 410747), and Cotter (CM3, station 410700) Dams and in the Goodradigbee River (GM, station 410088) and Googong Dam (QM3, station 410760) and the Queanbeyan River upstream of Googong Reservoir (QM1, station 410781) from June 2024 to May 2025. **NOTE:** Blue bar corresponds to spring 2024 sampling and orange bar corresponds to autumn 2025 sampling.

Table 4: Discharge summary for monitoring sites (Data: NSW water and ALS).

Relevant monitoring site/s	Cumulative flow in three months prior to spring 2024 sampling (ML)	Cumulative flow in three months prior to autumn 2025 sampling (ML)	Historical mean flow in spring (ML)	Historical mean flow in autumn (ML)	Percentile mean flow in spring 2024 (ML/Day)	Percentile mean flow in autumn 2025 (ML/Day)
CM2, CT2	10561	2681	16054 ± 2363	6725 ± 1749	47th	52th
CM1, CT1	14093	12739	15840 ± 2186	15586 ± 1432	67th	35th
CM3, CT3	13957	2107	50075 ± 4223	13021 ± 1818	23rd	22nd
GM1, GM2, GM2, GT1, GT2, Gt3	30935	11516	65852 ± 5170	18722 ± 2920	20th	48th
QM1	6385	4658	14811 ± 2735	11459 ± 3072	43rd	53rd
QM2, QM3	5246	1556	22796 ± 5106	13666 ± 3187	40th	33rd

Table 5: Rainfall summary for monitoring sites (Data: BOM and ALS).

Relevant monitoring site/s	Total rainfall in three months prior to spring 2024 sampling (mm)	Total rainfall in three months prior to autumn 2025 sampling (mm)	Historical total rainfall in spring (mm)	Historical total rainfall in autumn (mm)	Percentile total rainfall in spring 2024 (mm)	Percentile total rainfall in autumn 2025 (mm)
CM1, CM2, CT1, CT2	176	211	305 ± 17.4	230 ± 13.3	19th	41st
CM3, CT3	78	175	197 ± 18.0	195 ± 18.2	10th	48th
QM2, QM3	61.2	179	152 ± 10.6	164 ± 8.4	10th	65th
QM1	83	212	153 ± 12.5	180 ± 13.3	14th	71st
GM1, GM2, GM3, GT1, GT2, GT3	143	165	254 ± 20.9	179 ± 14.5	23rd	53th

WATER QUALITY

Water quality across both test and reference sites during the spring 2024 and autumn 2025 assessments were largely within guideline levels, with some exceedances observed. In spring 2024, the pH in test site QM2 and QM3, NOx at test site QM2 and reference site QM1, TN at test site QM2 and QM3 and CT1 were slightly higher than guideline levels. In autumn 2025, NOx at test site CM3 and QM2 and reference site CT2; Total Nitrogen at test site CM3, and QM3 and Total Phosphorus at test site CM3 and reference site GT3 (Table 7 and Table 8).

Table 6. Water quality parameters measured at each of the test and reference sites in spring 2024. Values outside guideline levels are shaded orange.

		Temp. (^{0}C)	EC (µs cm^{-1})	pH	D.O. (mg L^{-1})	Turbidity (NTU)	Alkalinity (mg L^{-1})	NH_3 N (mg L^{-1})	NO_x (mg L^{-1})	Total Nitrogen (mg L^{-1})	Total phosphorus (mg L^{-1})
		Guideline level									
		NA	<350	6.5-8	>6	<10	NA	<0.13	<0.015	<0.25	<0.02
Below dam test sites	CM1	12.3	19	6.77	9.56	0.0	10	0.004	0.004	0.06	0.006
	CM2	13.54	18	7.60	11.12	0.0	10	<0.002	0.003	0.08	0.003
	CM3	15.11	30	7.48	9.91	0.0	14	0.005	0.005	0.11	0.006
	QM2	17.27	105	8.23	10.92	0.0	35	0.004	0.017	0.38	0.016
	QM3	20.8	234	8.24	9.74	0.0	75	0.008	0.013	0.40	0.017
Reference sites	CT1	12.52	39	7.25	9.59	0.0	20	0.005	<0.002	0.25	0.018
	CT2	14.81	29	7.49	9.65	0	10	0.004	<0.002	<0.05	0.016
	CT3	15.21	72	7.97	10.59	7.3	25	0.003	0.023	0.07	<0.002
	QM1	17.36	95	7.70	9.07	9.4	35	0.007	0.039	0.19	0.013
	GM1	14.12	69	7.81	9.79	0.0	30	0.003	0.002	0.08	0.011
	GM2	13.84	67	7.37	9.95	0.0	30	0.005	0.002	0.10	0.012
	GM3	14.35	69	7.69	10.02	0.3	0	0.005	0.004	0.09	0.004
	GT1	13.31	51	7.65	9.98	0.0	22	0.007	<0.002	0.10	0.015
	GT2	13.86	55	7.36	9.79	0.0	24	0.024	<0.002	0.13	0.015
	GT3	14.01	52	7.56	9.83	0.0	28	0.007	<0.002	0.13	0.016

Table 7: Water quality parameters measured at each of the test and reference sites in autumn 2025. Values outside guideline levels are shaded orange.

		Temp. (^{0}C)	EC (µs cm^{-1})	pH	D.O. (mg L^{-1})	Turbidity (NTU)	Alkalinity (mg L^{-1})	NH_3 N (mg L^{-1})	NO_x (mg L^{-1})	Total Nitrogen (mg L^{-1})	Total phosphorus (mg L^{-1})
		Guideline level									
		NA	<350	6.5-8	>6	<10	NA	<0.13	<0.015	<0.25	<0.02
Below dam test sites	**CM1**	18.62	22	6.99	8.86	0.9	12	0.011	0.006	0.10	0.006
	CM2	19.58	21	6.53	8.73	0.9	10	0.006	0.006	0.09	0.003
	CM3	22.27	149	7.03	7.89	3.0	37	0.012	0.019	0.36	0.028
	QM2	21.86	110	7.94	9.46	0.0	31	0.016	0.026	0.25	0.016
	QM3	24.25	166	7.98	8.62	0.8	47	0.015	0.003	0.35	0.014
Reference sites	**CT1**	13.54	45	7.29	9.28	0.1	20	0.038	0.006	0.06	0.017
	CT2	18.07	37	6.53	7.7	0.5	13	0.005	0.019	0.09	0.010
	CT3	21.24	94	7.26	8.59	0.5	31	0.006	0.005	<0.05	0.010
	QM1	21.22	88	7.46	8.06	3.1	36	0.008	<0.002	0.19	0.019
	GM1	18.99	138	8.14	9.52	0	63	0.026	0.006	<0.05	0.009
	GM2	19.31	132	7.75	8.68	0.7	54	0.011	0.002	0.05	0.009
	GM3	19.99	129	7.75	8.85	0.6	53	0.011	0.010	0.07	0.012
	GT1	19.3	66	7.72	8.96	1.5	29	0.007	0.004	0.10	0.014
	GT2	18.13	81	7.65	8.92	2.8	35	0.012	0.005	0.18	0.020
	GT3	18.12	66	7.81	9.08	1.1	28	0.008	<0.002	0.07	0.022

FILAMENTOUS ALGAE AND PERIPHYTON

The environmental flow ecological objective of <20% cover of filamentous algae in riffle habitats was achieved at all below dam test sites in both spring 2024 and autumn 2025 assessments (Table 9). In contrast, field observations of periphyton cover of riffle habitats were >20% at below dams site CM2 (D/S Bendora Reservoir) in spring 2024 and reference site QM1 (upstream of Googong Reservoir) in autumn 2025, which had higher percentage of periphyton cover of riffle habitat.

In spring 2024, There was no significant difference in AFDM between reference site group and below dams site group ($\beta = 0.563$, $t_5 = 1.584$, $p = .174$), although below dams sites had a higher mean AFDM. Pairwise comparisons between sites revealed that below dams site CM2 had significantly higher AFDM compared to all other sites except for below dams site QM2 in spring 2024. In autumn 2025, there was no statistically significant difference in AFDM between reference site group and below dams site group ($\beta = - 0.2816$, $t_5 = 1.583$, $p = .1752$), although below dams sites showed a trend toward lower AFDM values. Despite a high mean AFDM concentration at GM1, pairwise comparisons between sites revealed no statistically significant differences in AFDM between any site pairs (Tukey-adjusted $p > 0.05$) (Figure 5).

In spring 2024, there was no significant difference in chlorophyll-a concentrations at reference site group and below dams site group ($\beta = -1.049$, $t_5 = -0.790$, $p = 0.474$). Pairwise comparisons between sites showed that below dams sites CM2, and to a lesser extent CM1 and CM3, had significantly elevated chlorophyll-a concentration compared to reference sites. In autumn 2025, there was no statistically significant difference in chlorophyll-a concentration between reference site group and below dams site group ($\beta = -0.0434$, $t_5 = -0.064$, $p = 0.951$). Pairwise comparisons revealed significant differences between some sites. Notably, QM2 had lower chlorophyll-a than CM1 and GM1, and CM1 had higher levels than GM3 (Figure 6).

Table 8: Periphyton and filamentous algae (categorised on percent cover) in the riffle habitat at below dams sites and reference sites, from spring 2024 to autumn 2025. Filamentous algae observations greater than the environmental flow ecological objective of <20% cover are shaded orange. NA represents sites inaccessible.

% cover of riffle habitat													
	Periphyton							Filamentous algae					
	Spr-22	Aut-23	Spr-23	Aut-24	Spr-24	Aut-25		Spr-22	Aut-23	Spr-23	Aut-24	Spr-24	Aut-25
CM1	<10	40	20	<10	<10	<10		<10	<10	<10	<10	10	<10
CM2	15	40	20	<10	30	<10		<10	<10	<10	20	<20	<10
CM3	<10	20	<10	<10	<10	<10		<10	<10	<10	<10	10	<10
QM2	20	30	20	<10	<10	<10		<10	<10	20	<10	10	<10
QM3	30	40	30	<10	<10	<10		<10	<10	<10	<10	10	<10
GM1	NA	10	<10	NA	<10	<10		NA	<10	<10	NA	<10	15
GM2	<10	15	<10	<10	<10	<10		<10	<10	<10	<10	<10	<10
GM3	<10	20	20	<10	<10	<10		<10	<10	<10	<10	<10	<10
QM1	NA	10	20	20	<10	30		NA	<10	<10	<10	<10	<10

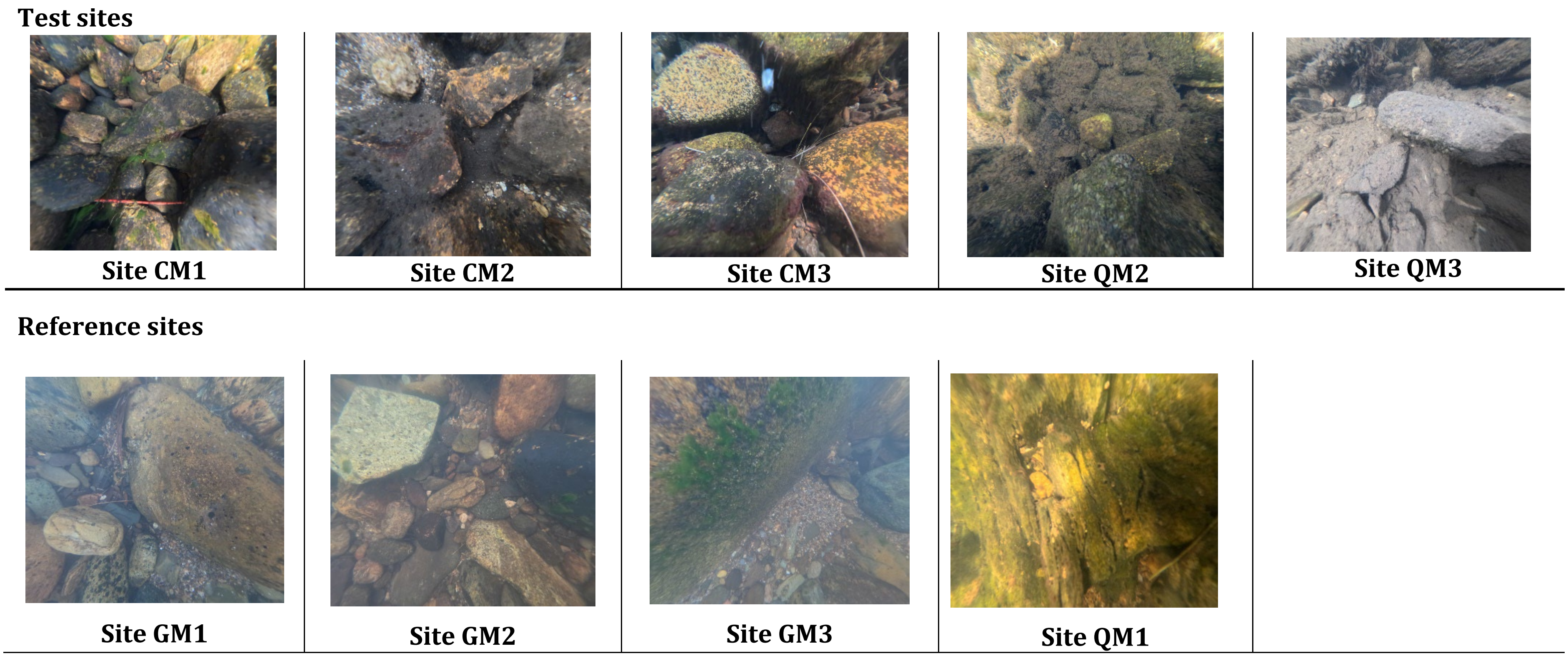

Figure 3. Filamentous algae and periphyton cover of riffle bed sediments at below dam test sites and corresponding reference sites on the Cotter, Goodradigbee and Queanbeyan Rivers in spring 2024.

Test sites

Site CM1

Site CM2

Site CM3

Site QM2

Site QM3

Reference sites

Site GM1

Site GM2

Site GM3

Site QM1

Figure 4: Filamentous algae and periphyton cover of riffle bed sediments at below dam test sites and corresponding reference sites on the Cotter, Goodradigbee and Queanbeyan Rivers in autumn 2025.

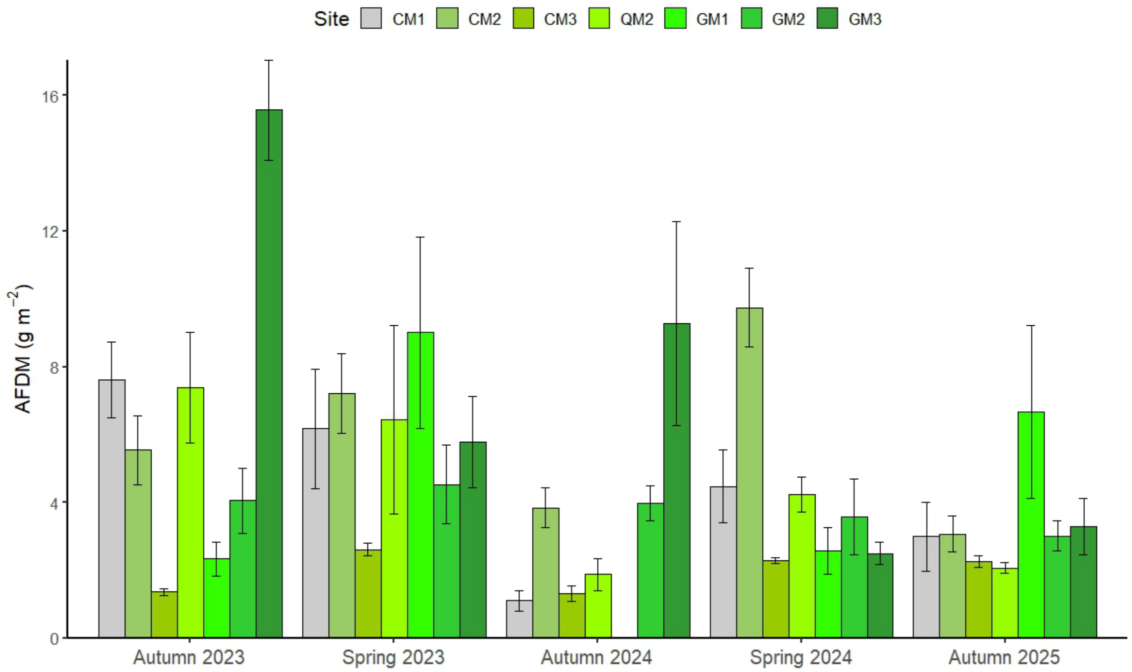

Figure 5: Mean AFDM (g m^{-2}) at below dam test sites and reference sites on the Goodradigbee River from autumn 2023 to autumn 2025. Error bars represent +/- 1 standard error. **NOTE**: AFDM samples were not collected in autumn 2024 at site GM1 due to site being inaccessible during the sampling season.

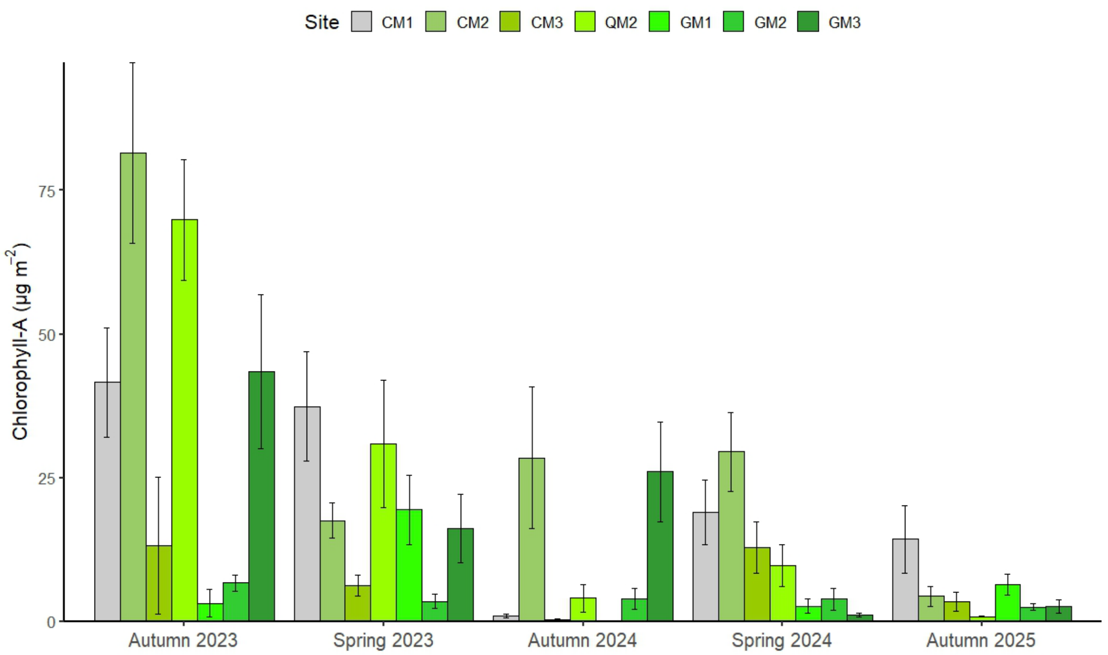

Figure 6: Mean Chlorophyll-a (µg m^{-2}) at below dam test sites and reference sites on the Goodradigbee River from autumn 2023 to autumn 2025. Error bars represent +/- 1 standard error. **NOTE:** samples were not collected in autumn 2024 at site GM1 due to site being inaccessible during the sampling season.

BENTHIC MACROINVERTEBRATES

AUSRIVAS ASSESSMENT

Below dam test sites were generally in poorer biological condition than reference sites based on AUSRIVAS assessment in both spring 2024 and autumn 2025 assessments (Table 10), as observed in autumn 2025. This continues a longer-lasting trend of below dams sites being generally in poorer condition than reference sites. Since autumn 2023, across all sites, below dams sites have only achieved condition band A or above on 24% of occasions, compared to 80% for reference sites (Table 10).

Cotter River below Corin Dam (CM1) was assessed as significantly impaired (band B) in both spring 2024 and autumn 2025 (Table 10). This site has remained in band B for the past several assessments with a relatively stable O/E score of around 0.72 – 0.84 (Table 10). The dominant taxa at this site in spring 2024 and autumn 2025 were environmentally tolerant Orthocladiinae and Oligochaeta, respectively (Appendix 2). Taxa Psephenidae and Hydrobiosidae were the only taxa predicted to have a ≥50% chance of occurrence by the AUSRIVAS model were detected in the whole sample scan (Table 11 and Table 12), but not in the subsample that were processed, suggesting that this taxa were present, but in low abundances at this site in both spring 2024 and autumn 2025.

Condition of the Cotter River below Bendora Dam (CM2) was assessed as band B (significantly impaired) in both spring 2024 and autumn 2025 (Table 10). This site has been alternating between band A and B since autumn 2021, though generally A in autumn and B in spring (Table 10). The macroinvertebrate community at CM2 was characterised by a high abundance of Orthocladiinae in spring 2024 and Simuliidae in autumn 2025 (Appendix 2). The taxa Conoesucidae was only taxa that was predicted to have a ≥50% chance of occurrence by the AUSRIVAS model was detected in the whole sample scan (Table 11), but not in the subsample that was processed, suggesting that this taxon was present, but in low abundances at this site in spring 2024. No taxon had been detected in autumn 2025 whole sample scan for this site.

The condition of the Cotter River below Cotter Dam (CM3) has been assessed as band B (significantly impaired) in both spring 2024 and autumn 2025. However, the site's O/E score increased from 0.59 in spring 2024 to 0.75 in autumn 2025 (Table 10). The site was consistently dominated by environmentally tolerant taxa (OC) over environmentally sensitive taxa (EPT) in both spring 2024 and autumn 2025 (Figure 7, Figure 8). Oligochaeta was the dominant taxon at the site in spring 2024, while Orthocladiinae dominated in autumn 2025 (Appendix 2). The taxa Psephenidae, Tipulidae, Gripopterygidae, Hydrobiosidae and Hydropsychidae in spring 2024 and taxa Psephenidae and Gripopterygidae in autumn 2025 were predicted to have a ≥50% chance of occurrence by the AUSRIVAS model was detected in the whole sample scan (Table 11), but not in the subsample that was processed, suggesting that this taxon was present, but in low abundances at this site.

The site below Googong Dam (QM2) has decreased in biological condition from being assessed as band A (similar to reference) in spring 2024 to band B (significantly impaired) in autumn 2025 (Table 10). In contrast, site QM3 has increased its biological condition from being assessed as band B (significantly impaired) in spring 2024 to band A (similar to reference) in autumn 2025. Coindition of both of these sites has varied over the past several years, raining in condition bands of A to C (Table 10). The sites have been characterized by high abundances of tolerant Chironominae in spring 2024 and Simuliidae in autumn 2025 (Appendix 2). Tipulidae and Hydrobiosidae at QM3 were the only taxa that were predicted to have a ≥50% chance of occurrence by the AUSRIVAS model was detected in the whole sample scan (Table 11), but not in the subsample that was processed, suggesting that this taxa were present, but in low abundances at this site in spring 2024. None of the taxa were detected in whole sample scan in autumn 2025.

The biological condition of reference sites varied within and between the seasons of spring 2024 and autumn 2025, though generally were assessed as being similar to reference. Only two of the reference sites have been assessed as band B (significantly impaired) in autumn 2025. Overall, the biological condition of the reference sites in autumn 2025 was poorer compared to spring 2024 (Table 10). A consistent pattern observed at reference sites within the Goodradigbee River catchment generally exhibited better biological condition (band A) in both spring and autumn 2025 compared to those in the Cotter and Queanbeyan River catchments (Table 10). The macroinvertebrate community at all the reference sites were dominated by Leptophlebiidae at site CT1, CT2, GM1, GM2 and GM3. Simuliidae at CT3 and Chironominae at GT2, GT3 and QM1 in spring 2024 and taxa Leptophlebiidae at site CT1, GM1 and GT3, Baetidae at CT3, Chironominae GM2, GT1 and GT2, Simuliidae at site GM3 and QM1 in autumn 2025. Taxa Elmidae at site CT3, Psephenidae at sites CT2, CT3, GM3, GT2 and GT3, Tipulidae at sites CT2 and GM3, Caenidae at site GT3, both Hydrobiosidae and Hydropsychidae at sites GM1 and GT1 were predicted to have a ≥50% chance of occurrence by the AUSRIVAS model were detected in the whole sample scan (Table 11) but not in the subsample that was processed, suggesting those taxa were present, but in relatively low abundances at reference sites in spring 2024. Similarly, taxa Psephenidae at sites GT1 and GT2, Gomphidae at site GM3 and Hydrobiosidae at site CT1 predicted to have a ≥50% chance of occurrence by the AUSRIVAS model were detected in the whole sample scan (Table 11, Table 12) but not in the subsample that was processed, suggesting those taxa were present, but in relatively low abundances at reference sites in autumn 2025.

Table 9: AUSRIVAS band and Observed/Expected taxa score for each site from autumn 2021 to autumn 2025. NOTE: N/A represents absence of data due to inaccessible sites or due to low flow during the sampling day.

Season	Below dams sites					Reference sites									
	CM1	CM2	CM3	QM2	QM3	CT1	CT2	CT3	QM1	GM1	GM2	GM3	GT1	GT2	GT3
Autumn 2025	B (0.78)	B (0.79)	B (0.75)	B (0.77)	A (0.90)	A (1.00)	N/A	B (0.83)	B (0.84)	A (0.96)	A (0.96)	A (0.94)	A (1.06)	A (1.05)	A (1.12)
Spring 2024	B (0.84)	B (0.67)	B (0.59)	A (1.11)	B (0.84)	A (1.1)	A (0.92)	A (0.96)	X (1.29)	A (1.12)	X (1.19)	A (1.04)	A (1.06)	A (1.05)	A (1.13)
Autumn 2024	B (0.72)	A (1.01)	B (0.67)	C (0.56)	C (0.49)	A (0.92)	A (1.03)	B (0.69)	B (0.75)	NA	A (0.97)	A (1.04)	NA	A (1.06)	A (0.97)
Spring 2023	B (0.84)	B (0.74)	C (0.44)	A (0.88)	A (0.92)	A (0.96)	A (1.07)	B (0.66)	A (1.01)	A (0.97)	B (0.82)	A (1.04)	X (1.21)	X (1.28)	A (1.05)
Autumn 2023	B (0.72)	A (0.91)	B (0.74)	C (0.49)	B (0.69)	A (0.93)	A (0.96)	A (0.90)	A (0962)	B (0.85)	A (0.89)	A (1.04)	A (1.01)	A (0.99)	A (1.05)
Spring 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Autumn 2022	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Spring 2021	N/A	N/A	N/A	N/A	N/A	A (0.96)	N/A	N/A	N/A	A (1.12)	A (1.11)	A (1.12)	A (1.13)	A (1.13)	A (0.90)
Autumn 2021	B (0.72)	A (0.98)	B (0.67)	B (0.83)	C (0.56)	A (1.00)	B (0.77)	C (0.62)	B (0.82)	B (0.81)	A (0.90)	A (0.97)	A (1.09)	A (1.06)	A (1.05)
Spring 2020	B (0.77)	B (0.67)	B (0.73)	A (0.88)	B (0.84)	B (0.82)	A (1.00)	B (0.66)	B (0.83)	A (1.04)	A (0.97)	A (0.89)	X (1.21)	A (1.13)	A (0.98)
Autumn 2020	B (0.85)	B (0.79)	A (0.97)	C (0.63)	B (0.77)	A (0.96)	B (0.64)	B (0.76)	A (0.90)	A (1.12)	A (1.04)	B (0.82)	A (1.08)	B (0.85)	X (1.13)
Spring 2019	B (0.84)	B (0.67)	A (0.88)	A (0.88)	B (0.77)	A (0.96)	Not sampled	B (0.74)	A (1.10)	Not sampled	X (1.19)	A (0.97)	Not sampled	A (1.05)	A (1.13)
Autumn 2019	B (0.85)	B (0.79)	C (0.52)	C (0.63)	B (0.76)	A (1.08)	Not sampled	B (0.76)	B (0.67)	A (1.05)	A (1.04)	B (0.81)	X (1.23)	B (0.86)	X (1.28)
Spring 2018	B (0.84)	B (0.74)	B (0.66)	A (1.03)	A (1.00)	A (1.10)	Not sampled	A (1.11)	A (1.10)	X (1.19)	A (0.97)	A (1.12)	A (0.98)	A (1.13)	A (1.13)
Autumn 2018	B (0.78)	B (0.79)	B (0.81)	B (0.77)	C (0.63)	A (1.00)	Not sampled	A (0.9)	A (0.96)	A (0.99)	B (0.64)	A (0.89)	B (0.87)	X (1.18)	A (0.9)
Spring 2017	B (0.61)	B (0.67)	B (0.73)	B (0.80)	B (0.77)	X (1.23)	A (1.00)	A (1.11)	A (1.01)	A (1.12)	A (1.11)	A (1.12)	X (1.21)	X (1.28)	A (0.98)
Autumn 2017	B (0.65)	B (0.86)	A (0.89)	B (0.70)	C (0.56)	B (0.85)	B (0.71)	A (0.90)	A (0.97)	B (0.73)	B (0.67)	A (0.88)	X (1.26)	A (1.12)	A (0.97)
Spring 2016	B (0.84)	A (0.89)	C (0.51)	B (0.72)	B (0.69)	B (0.75)	A (1.07)	A (0.88)	A (1.01)	A (1.04)	A (1.04)	A (0.97)	A (1.13)	A (1.07)	A (0.88)
Autumn 2016	B (0.85)	A (0.94)	A (0.89)	B (0.84)	B (0.69)	X (1.16)	Not sampled	A (0.90)	A (1.04)	B (0.84)	A (0.97)	B (0.74)	A (1.12)	A (0.93)	A (0.97)
Spring 2015	B (0.69)	A (0.89)	B (0.66)	B (0.80)	A (1.07)	A (0.96)	X (1.15)	A (0.96)	A (1.1)	X (1.27)	A (1.04)	X (1.19)	X (0.91)	A (0.98)	A (1.21)
Autumn 2015	B (0.85)	A (0.94)	B (0.67)	C (0.49)	C (0.63)	A (0.93)	B (0.77)	B (0.70)	A (0.97)	B (0.81)	A (1.05)	A (1.12)	X (1.16)	A (1.05)	A (1.05)
Spring 2014	B (0.77)	A (0.97)	B (0.66)	A (0.88)	B (0.84)	A (1.03)	A (1.07)	A (0.96)	A (0.92)	A (1.12)	A (1.11)	A (1.12)	A (1.13)	A (0.98)	A (1.05)
Autumn 2014	A (0.91)	B (0.86)	B (0.66)	B (0.70)	B (0.83)	A (0.96)	A (0.90)	B (0.84)	A (0.97)	A (0.88)	A (1.04)	A (0.97)	X (1.19)	A (1.12)	A (1.05)

Table 10: Macroinvertebrate taxa that were expected with a ≥ 50% chance of occurrence by the AUSRIVAS ACT autumn riffle model but were missing from sub-samples for each of the study sites in spring 2024 (Indicated by an "X") and their SIGNAL 2 grade (Chessman 2003). Orange shading indicates missing taxa that were identified in the whole of sample scan (which indicates taxa that were present, though at relatively low abundances).

Missing taxa in spring 2024																
Taxon Name	Signal Score	Test sites					Reference sites									
		CM1	CM2	CM3	QM2	QM3	CT1	CT2	CT3	GM1	GM2	GM3	GT1	GT2	GT3	QM1
Oligochaeta	2						X							X		
Scirtidae	6						X									
Elmidae	7		X						X							
Psephenidae	6	X	X	X	X	X		X	X			X		X	X	
Tipulidae	5	X	X	X		X		X				X				
Simuliidae	5							X								
Tanypodinae	4	X	X	X					X							
Chironominae	3	X														
Baetidae	5		X													
Leptophlebiidae	8		X	X		X										
Caenidae	4							X					X		X	
Gripopterygidae	8			X												
Hydrobiosidae	8	X		X		X				X			X			
Glossosomatidae	9	X	X	X	X	X		X								
Hydropsychidae	6			X					X	X	X	X	X	X		
Conoesucidae	7		X	X	X	X										
Total taxa		**6**	**8**	**9**	**3**	**6**	**2**	**5**	**4**	**2**	**1**	**3**	**3**	**3**	**2**	**0**

Table 11: Macroinvertebrate taxa that were expected with a ≥ 50% chance of occurrence by the AUSRIVAS ACT autumn riffle model but were missing from sub-samples for each of the study sites in autumn 2025 (Indicated by an "X") and their SIGNAL 2 grade (Chessman 2003). Orange shading indicates missing taxa that were identified in the whole of sample scan (which indicates taxa that were present, though at relatively low abundances).

Missing taxa in Autumn 2025																
Taxon Name	**Signal Score**	**Test sites**					**Reference sites**									
		CM1	**CM2**	**CM3**	**QM2**	**QM3**	**CT1**	**CT2**	**CT3**	**GM1**	**GM2**	**GM3**	**GT1**	**GT2**	**GT3**	**QM1**
Hydrobiidae	4				X	X		No data due to low flow during sampling	X	X		X				
Ancylidae	4					X			X	X						
Scirtidae	6	X												X		
Elmidae	7		X													
Psephenidae	6	X	X	X									X	X	X	
Podonominae	6		X	X	X	X	X		X	X	X	X	X		X	X
Tanypodinae	4	X	X	X	X		X			X	X					
Coloburiscidae	8	X												X		
Leptophlebiidae	8	X	X	X	X											
Caenidae	4									X			X			
Gomphidae	5			X	X	X			X	X	X	X			X	
Gripopterygidae	8			X												
Hydrobiosidae	8	X					X									
Glossosomatidae	9	X														
Hydroptilidae	4		X		X				X			X	X			
Hydropsychidae	6												X			
Conoesucidae	7			X												
Leptoceridae	6		X		X	X			X							
Total taxa		**7**	**7**	**7**	**7**	**5**	**3**		**6**	**6**	**3**	**4**	**5**	**3**	**3**	**1**

TAXONOMIC RELATIVE ABUNDANCE

Below dams sites were dominated by environmentally tolerant Oligochaeta and Chironomidae (OC) taxa compared to environmentally sensitive Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa in spring 2024 (Figure 7). Below dams sites showed some improvement with increases in EPT composition, especially at Queanbeyan river sites QM2 and QM3, in autumn 2025 (Figure 8). Reference sites were generally dominated by EPT taxa in both the spring 2024 and autumn 2025 assessments (Figure 7, Figure 8). Notable deviations from this are CT3 in spring 2024, and TG1 and GT2 in autumn 2025, which were dominated by OC taxa (Figure 7, Figure 8).

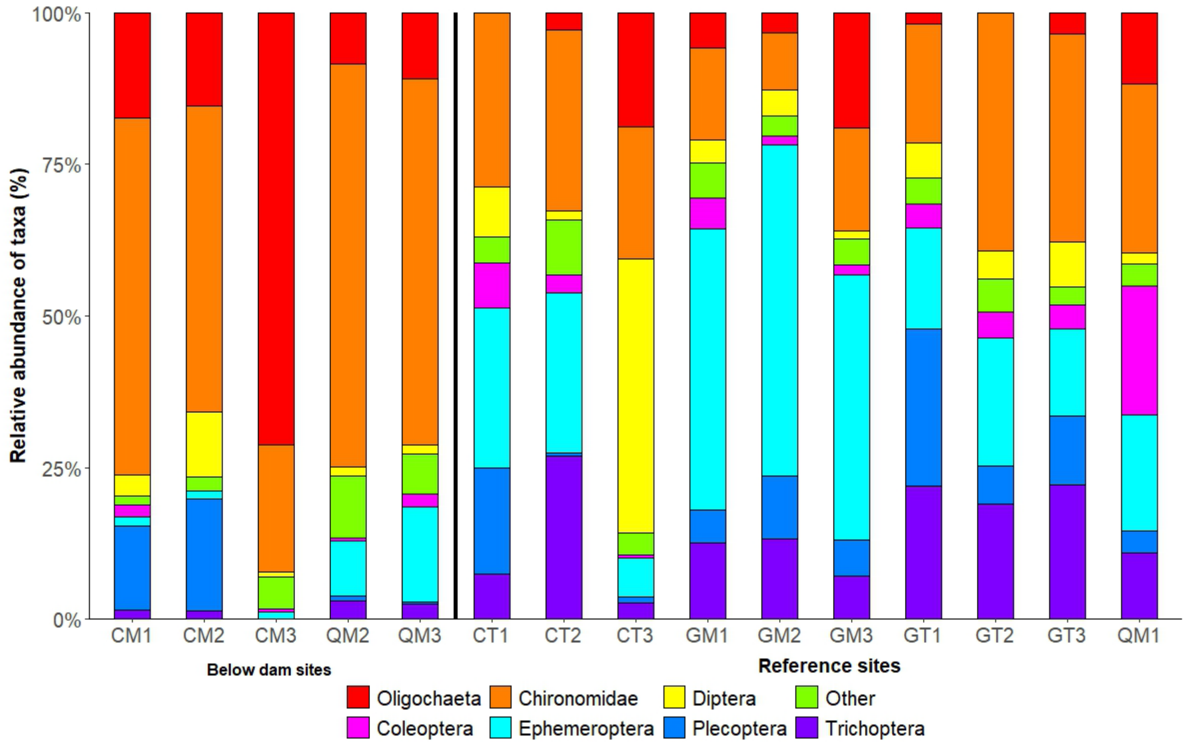

Figure 7: Relative abundance of macroinvertebrate taxonomic groups from samples collected in spring 2024.

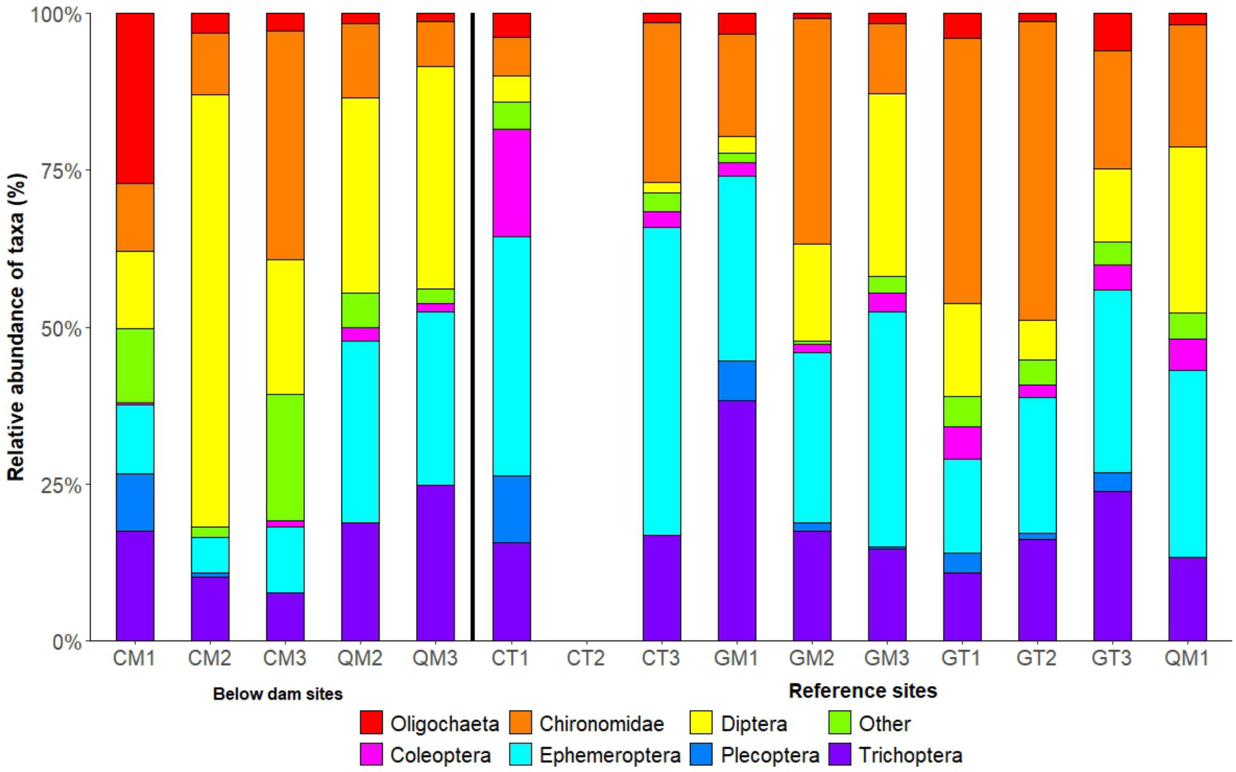

Figure 8: Relative abundance of macroinvertebrate taxonomic groups from samples collected in autumn 2025. **Note:** The sites without a bar graph indicates unavailability of data due to low flow during sampling.

MACROINVERTEBRATE ASSEMBLAGE SIMILARITY

Macroinvetebrate community comspoition was significantly different between below dams sites and references sites in both the spring 2024 assessment ($F_{1,13} = 7.1367$, $R^2 = 0.35$, $p = 0.002$) and the autumn 2025 assessment ($F_{1,12} = 3.62$, $R^2 = 0.232$, $p = 0.014$). In spring 2024, reference sites were more strongly associated with taxa such as Baetidae, Leptoceridae, Conoesucidae, Leptophlebiidae, Glossosomatidae and Gripopterygidae which are environmentally sensitive taxa. In contrast, below dams sites showed reduced correlation with these taxa, suggesting a lower abundance or absence of environmentally sensitive taxa and potential dominance of more tolerant taxa like Orthocladiinae (Figure 9).

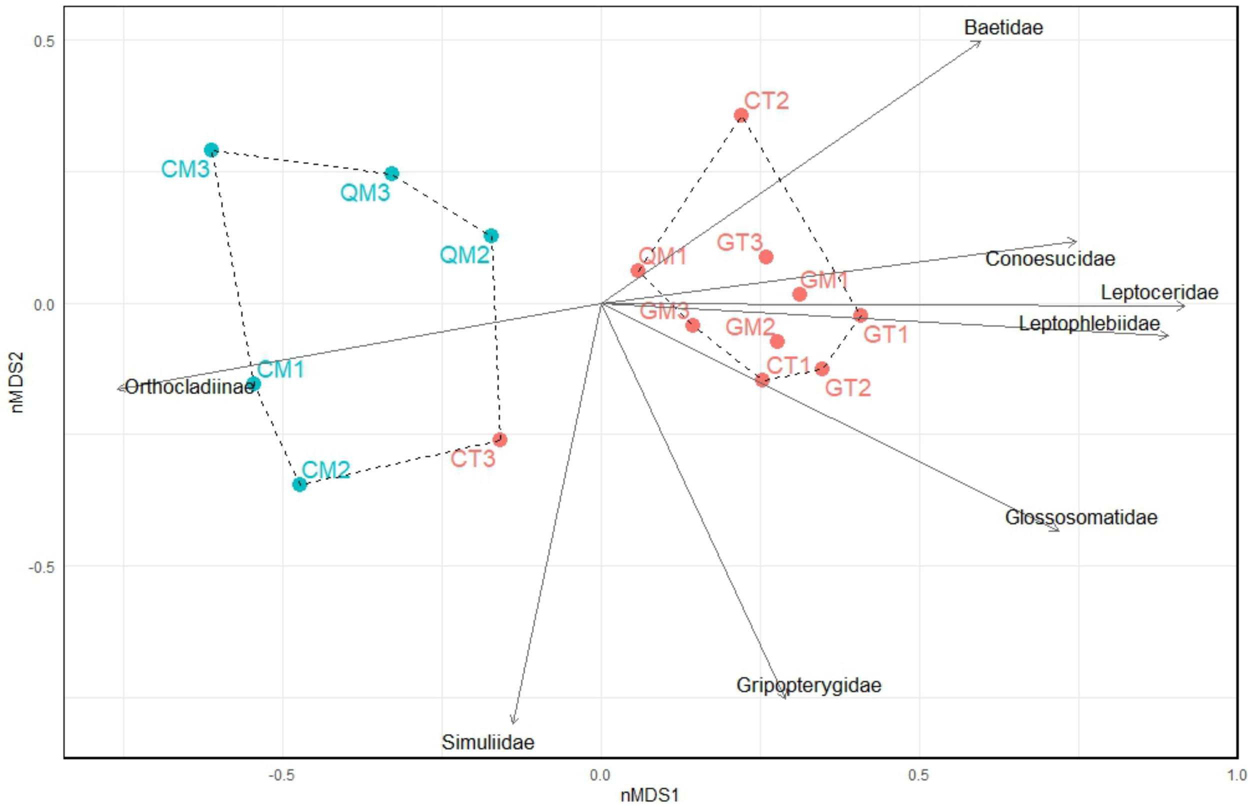

Figure 9. nMDS ordination of 45% similarity between macroinvertebrate samples collected in spring 2024 for the below dams assessment program (polygon with dashed line). Similarity is based on macroinvertebrate relative abundance. Macroinvertebrate taxa with Pearson correlations greater than 0.75 (i.e. taxa that discriminate between the groups of sites) are overlayed on the nMDS ordination. Blue points are below dams sites and red points are reference sites.

In autumn 2025, reference sites were more strongly associated with sensitive taxa such as Leptophlebiidae, Coloburiscidae, Philopotamidae, Leptoceridae, Conoesucidae, and Gripopterygidae, which are environmentally sensitive taxa. Below dams sites show reduced correlation with these taxa and are positioned closer to vectors such as Tanypodinae, Caenidae, and Ecnomidae, which are generally more environmentally tolerant (Figure 10).

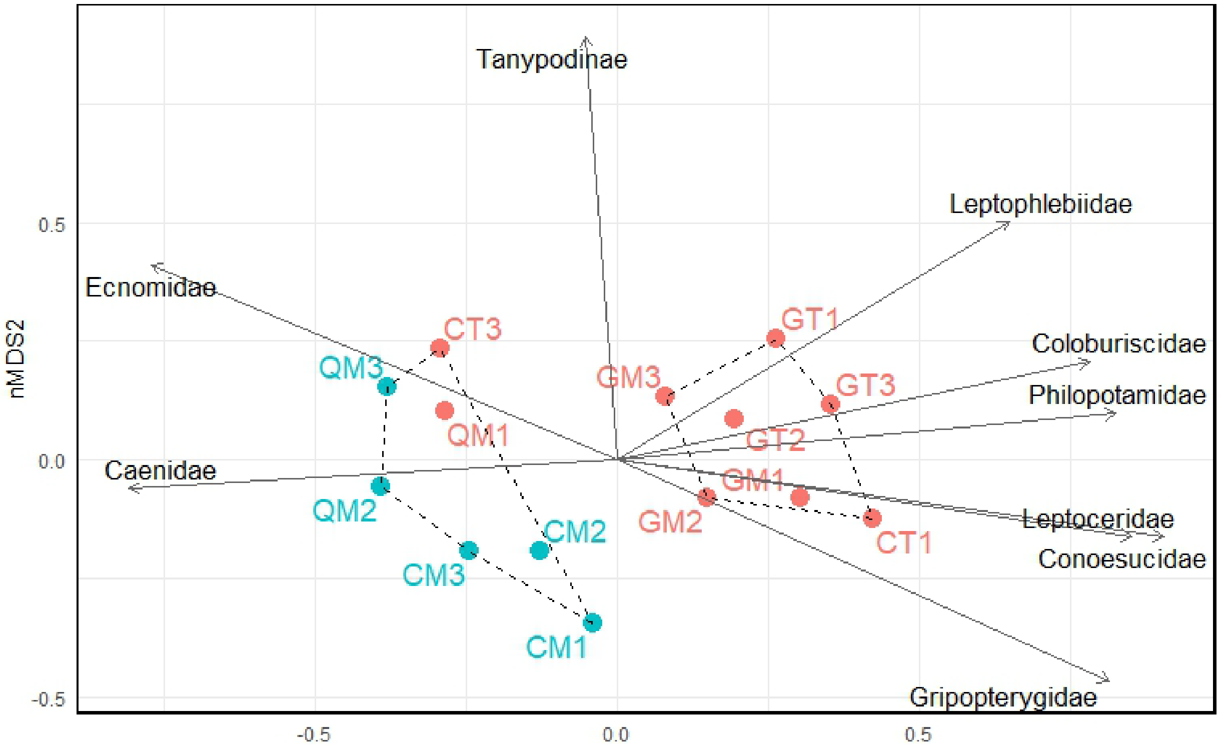

Figure 10. nMDS ordination of 40% similarity between macroinvertebrate samples collected in autumn 2025 for the below dams assessment program (polygon with dashed line). Similarity is based on macroinvertebrate relative abundance. Macroinvertebrate taxa with Pearson correlations greater than 0.70 (i.e. taxa that discriminate between the groups of sites) are overlayed on the MDS ordination. Blue points are below dams sites and red points are reference sites.

DISCUSSION

WATER QUALITY

During the spring 2024 and autumn 2025 assessment periods, water quality parameters at both test and reference sites were generally within guideline levels. However, exceedances in nutrient concentrations were observed, predominantly at below dams sites and were predominately associated with nutrient concentrations. These exceedances highlight localised nutrient enrichment and potential water quality concerns, particularly at test sites. This higher level of nutrients, suggest localised nutrient enrichment, particularly at test sites, which may be indicative of anthropogenic influences or due to modified catchment. There are a couple of likely sources of the elevated nitrogen at the test sites. Firstly, denitrification within the reservoir could be the cause of elevated NOx concentrations at sites directly below reservoirs and the high concentrations experienced in autumn 2025 (Saunders & Kalff, 2001). Secondly, heavy rainfall events contribute to increased runoff, which can lead to elevated transport of nutrients from the surrounding landscape into water bodies (Rattan et al., 2017).

FILAMENTOUS ALGAE AND PERIPHYTON

Filamentous algae coverage in riffle habitats remained well below the ecological objective of 20% at all monitored sites during both spring 2024 and autumn 2025. These results are congruent with previous assessments and suggest that both natural flow events (e.g., overtopping) and regulated flow regimes are effectively limiting the accumulation of filamentous algae downstream of dams.

In spring 2024, although no statistically significant difference in AFDM was observed between below dams site group and reference site group, though below sites exhibited slightly higher average values (largely driven by very high concentrations at CM2). Similarly, AFDM levels were not significantly different between below dams site group and reference site group, with below dams sites showing a trend toward lower values in autumn 2025, compared to reference sites. Site-level variation was minimal, and no significant differences were observed between sites. This seasonal contrast may reflect temporal variability in biomass concentration dynamics or a temporary reduction in nutrients at previously impacted sites.

Despite some site level differences, there was not significant difference in chlorophyll-a concentrations between below dams site group and reference site group in either spring 2024 or autumn 2025. Site level differences were not consistent through time, indicating some short-lived fluctuations in Chlorophyll-a concentrations at the site level. Importantly, the observed differences in both AFDM and Chlorophyll-a concentrations were independent of site categorisation (below dams vs. reference), indicating that these variations were not likely to be directly attributable to dam operations. Instead, the sites reflect natural spatial variability across the catchments. Continued monitoring and further investigation are recommended to better understand the underlying drivers of these patterns and their potential ecological implications.

BENTHIC MACROINVERTEBRATES

AUSRIVAS assessments from spring 2024 and autumn 2025 indicated that, with few exceptions, below dam sites exhibited significantly poorer biological condition compared to reference sites. The AUSRIVAS assessments at below dam test sites from Autumn 2023 to Autumn 2025, suggest that these sites have been consistently biologically impaired. Out of all recorded assessments during this period, only 25% achieved band A (similar to reference). The remaining assessments predominantly fell into band B and band C, reflecting moderate to significant ecological degradation. This finding supports the conclusion that below dam sites continue to be significantly impaired, with only occasional recovery to reference condition and underscores the ongoing ecological impact of dam regulation on downstream aquatic ecosystems. In contrast, 80% of recorded assessments at reference sites achieved band A or above (similar to reference). Only a few instances showed lower bands (B). These results suggests that reference sites generally reflect stable and healthy biological conditions.

More likely, differences in macroinvertebrate communities above and below dams can be attributed to flow regime and / or physical habitat (that may be influenced by flow regime) (Growns & Growns, 2001; Krajenbrink et al., 2019; Mbaka & Wanjiru Mwaniki, 2015). Impacts of altered flow regimes from regulation can be taxa specific (Growns & Growns, 2001), with some taxa being negatively impacted, while others positively impacted. The main drivers of the hydrology impacted by dams that may be driving macroinvertebrate communities is base flow and daily rate of change (both generally reduced in regulated streams) (Growns & Growns, 2001). The drivers of the continued differential biological condition between test and reference sites in this program appear to be site and season specific. It is recommended that a more thorough investigation to determine what is contributing to the long-term lower condition at test sites, and what possible remediation action may be taken to more consistently meet band A should be undertaken.

SITE SPECIFIC BIOLOGICAL CONDITION

Cotter River below Corin Dam (CM1) was assessed as significantly impaired (band B) in both spring 2024 and autumn 2025, consistent with its long-term condition. Since autumn 2014, CM1 has remained in band B and has only achieved a biological condition equivalent to reference condition (band A) on two occasions since spring 2008, representing just 7% of assessments. However, from autumn 2020 onwards, the site's Observed/Expected (O/E) scores have been remarkably stable, with several values approaching the band A threshold (0.88–1.12 for autumn; 0.86–1.14 for spring), indicating a trend toward improved ecological condition despite not fully reaching reference condition (Table 10). The dominance of tolerant taxa like Orthocladiinae and Oligochaeta at CM1 suggests adaptation to altered flows. Low detection of sensitive taxa such as Psephenidae and Hydrobiosidae indicated limited habitat suitability or due to regulated flows reducing habitat complexity (Jowett & Duncan, 1990).

Cotter River below Bendora Dam (CM2) did not change its biological condition between spring 2024 and autumn 2025. Historically, the site has exhibited a distinct seasonal pattern, consistently achieving band A (similar to reference) during autumn assessments, while being assessed as band B (significantly impaired) in spring from autumn 2021. This pattern suggests a stable but seasonally influenced ecological condition at CM2, with autumn scores regularly falling within the AUSRIVAS Band A range (0.88–1.12), and spring scores slightly lower, yet still relatively stable. Low and regulated flows downstream of dams reduce habitat complexity, alter temperature and oxygen levels, and disrupt food sources. These changes stress sensitive taxa, reduce biodiversity, and favor tolerant taxa, leading to degraded ecological conditions and shifts in community composition (de Wit, 2022). The dominance of tolerant taxa like Orthocladiinae and Simuliidae at CM2 suggests adaptation to stable but altered flow conditions. The low abundance of sensitive taxa such as Conoesucidae, detected only in whole sample scans, indicates limited habitat suitability or episodic recolonization under regulated flow regimes (Feld et al., 2002).

Cotter River below Cotter Reservoir (CM3) has been improving its biological condition, moving from Band C (severely impaired) in spring 2023 to Band B (significantly impaired) through to autumn 2025. Over the past four years (excluding non-sampling years), the site's condition has fluctuated considerably, with assessments ranging from band C to band B. This variability reflects a highly dynamic ecological state at CM3, though the recent shift away from severe impairment suggests a positive trend in biological recovery. Notably, the site has previously achieved band A as early as autumn 2011, demonstrating the site's capacity to support better biological condition under favourable environmental conditions. The dominance of tolerant taxa and low detection of sensitive species at CM3 suggests ongoing ecological stress from regulated flows, which reduce habitat diversity and alter water conditions. Sensitive taxa in whole samples but absent in subsamples indicate low abundance, likely due to suboptimal habitat or intermittent recolonization (Jowett & Duncan, 1990).

The macroinvertebrate assemblages at these below dams sites differed from those of reference sites primarily because of a higher abundance of environmentally tolerant taxa Orthocladiinae, in spring 2024 and Caenidae, and Ecnomidae, in autumn 2025, although these sites had reasonable taxonomic richness in both the seasons (Appendix 2).

The fluctuating biological condition at Googong Dam sites (QM2 and QM3), alternating between bands A, B, and C, indicated ecological instability likely driven by variable flow regimes and occasional water quality exceedances, highlighting spatial and temporal variability in ecosystem responses. The consistent dominance of tolerant taxa such as Chironominae and Simuliidae, coupled with the low detection of sensitive taxa like Tipulidae and Hydrobiosidae, suggests limited habitat suitability and potential stress from altered hydrological conditions. These patterns are consistent with findings by (Martínez et al., 2013), who reported reduced macroinvertebrate diversity and functional traits downstream of small dams due to disrupted flow and habitat heterogeneity. Although periphyton cover at QM2 and QM3 met ecological objectives in spring 2024 and autumn 2025. Similarly, AFDM and Chlorophyll-a concentrations were not elevated in those sites. This suggests nutrient enrichment was not a key driver of biological condition, with flow variability or habitat factors were likely playing a more significant role in shaping macroinvertebrate communities (Szeles et al., 2025). These results underscore the importance of integrated flow and nutrient management to maintain ecological stability and support sensitive aquatic communities downstream of dams.

The biological condition of reference sites varied between spring 2024 and autumn 2025, with a general decline observed in autumn 2025. Two sites were assessed as band B in autumn 2025, contrasting with their typically better condition. Reference sites in the Goodradigbee River catchment consistently showed stronger biological condition (band A) than those in the Cotter and Queanbeyan catchments. While environmentally sensitive taxa such as Leptophlebiidae were dominant at many sites, environmentally tolerant taxa like Chironominae and Simuliidae were more common at sites with lower condition. The presence of environmentally sensitive taxa in whole sample scans but not in processed subsamples suggests low abundance, possibly due to habitat degradation or occasional recolonisation. These patterns support findings that local habitat and flow conditions often exert greater influence on macroinvertebrate communities than broader environmental or climatic factors (Leszczyńska et al., 2017; Santos et al., 2024).

CONCLUSION

The water quality parameters at below-dam sites were largely within guideline levels during both the spring 2024 and autumn 2025 assessments. Despite some elevated nutrient concentrations at certain sites, filamentous algae cover in riffle habitats remained well below the environmental flow ecological objective threshold (<20%), indicating that water quality management efforts have been largely effective in preventing excessive algal growth and supporting ecosystem function.

However, AUSRIVAS assessments revealed a continued trend of impairment at below dams sites compared to reference sites. With few exceptions (e.g., QM2 in spring 2024 and QM3 in autumn 2025), most below dams sites were assessed as biologically impaired (band B), while reference sites generally maintained better ecological condition (band A). This pattern is consistent with previous assessments, reinforcing the long-term observation that sites downstream of dams tend to exhibit reduced biological condition. The persistence of impairment at test sites, despite acceptable water quality and periphyton levels, suggests that other factors, such as altered flow regimes, habitat degradation, or sediment dynamics may be contributing to ecological stress. The site and season specific nature of impairment further highlights the complexity of these systems. Continued investigation into the underlying drivers of biological condition at test sites is recommended to inform targeted management and restoration strategies.

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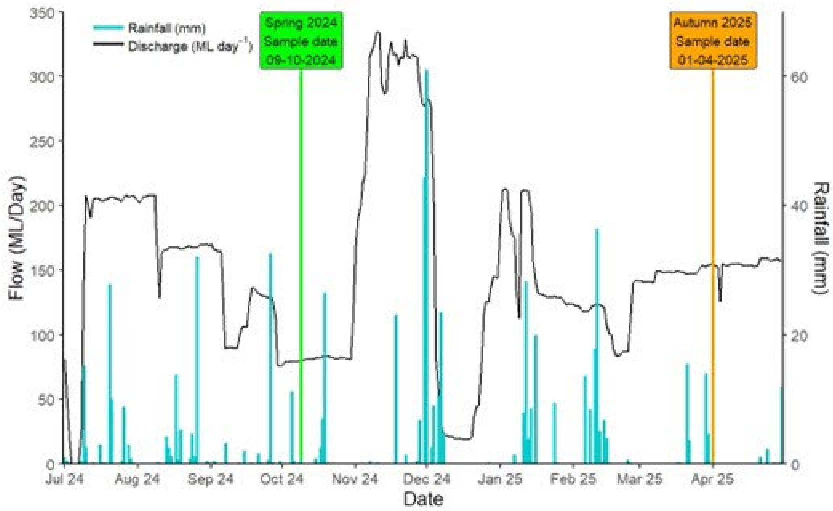
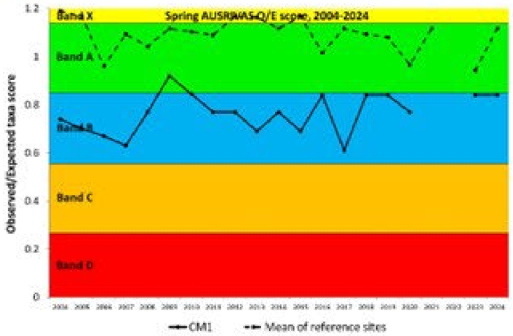
APPENDIX 1: BELOW DAM SITE SUMMARY SHEETS

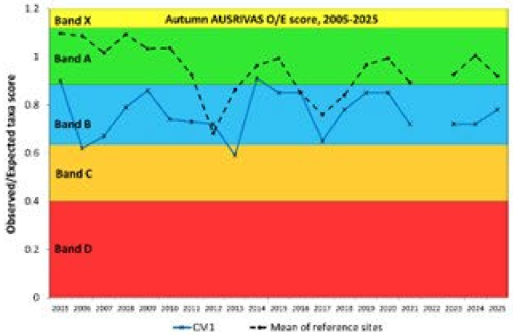
CM1 - Spring 2024 - Autumn 2025

Downstream of Corin Dam

Environmental flow ecological objective	Spring 2024	Autumn 2025	Objective met?
AUSRIVAS band A	Band B	Band B	Not for either assessment
<20% filamentous algae cover in riffle habitat	<10%	<10%	Yes, for both assessment







* Denotes values outside guideline levels

Sampling season	Temp. (°C)	EC (µs cm^{-1})	pH	D.O. (mg l^{-1})	Turbidity (NTU)	Alkalinity (mg L^{-1})	NH_4^+ (mg L^{-1})	NOx (mg L^{-1})	TN (mg L^{-1})	TP (mg L^{-1})
Spring 2024	12.3	19	6.77	9.56	0.0	10	0.004	0.004	0.06	0.006
Autumn 2025	18.62	22	6.99	8.86	0.9	12	0.011	0.006	0.10	0.006

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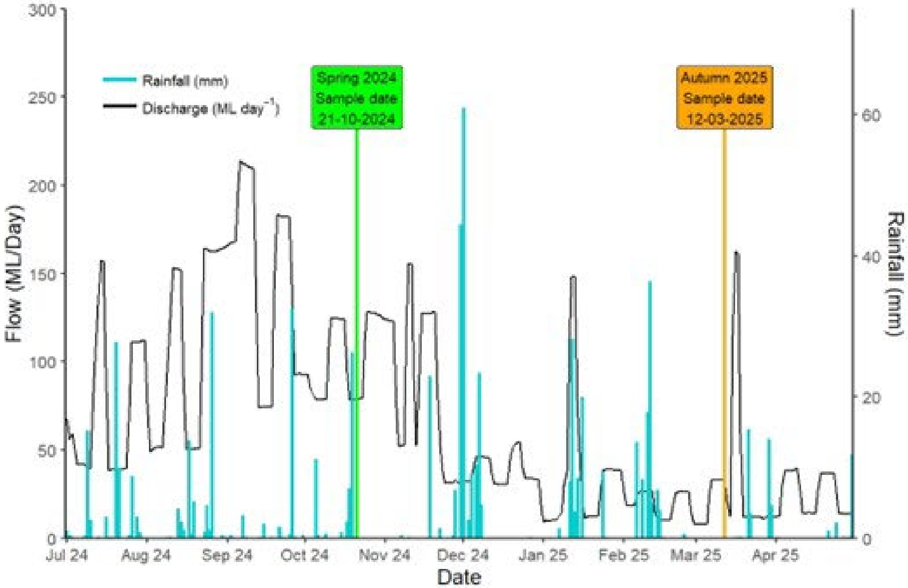
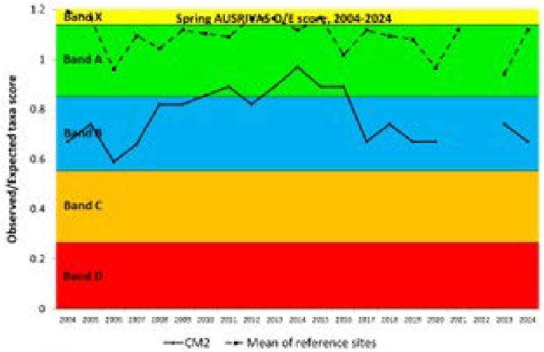
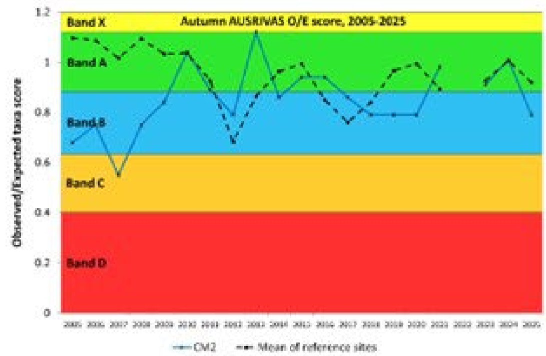
CM2 - Spring 2024 - Autumn 2025

Downstream of Bendora Dam

Environmental flow ecological objective	Spring 2024	Autumn 2025	Objective met?
AUSRIVAS band A	Band B	Band B	Not for either assessment
<20% filamentous algae cover in riffle habitat	20%	<10%	Yes, for both assessment







* Denotes values outside guideline levels

Sampling season	Temp. (°C)	EC (µs cm-1)	pH	D.O. (mg l-1)	Turbidity (NTU)	Alkalinity (mg L-1)	NH_4^+ (mg L-1)	NOx (mg L-1)	TN (mg L-1)	TP (mg L-1)
Spring 2024	13.54	18	7.60	11.12	0.0	10	<0.002	0.003	0.08	0.003
Autumn 2025	19.58	21	6.53	8.73	0.9	10	0.006	0.006	0.09	0.003

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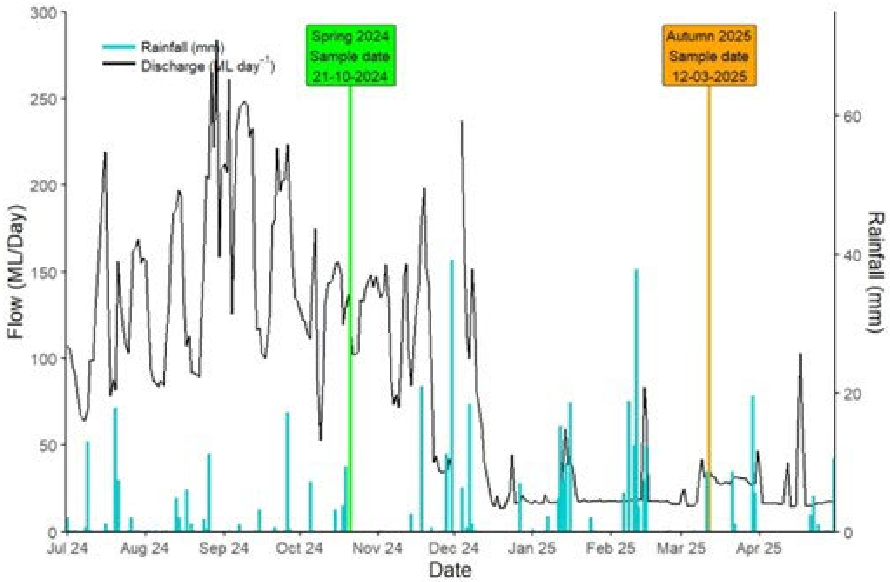
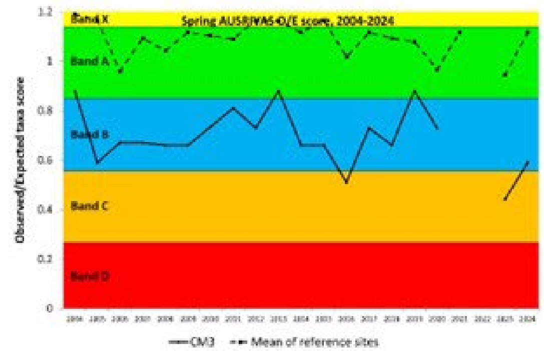
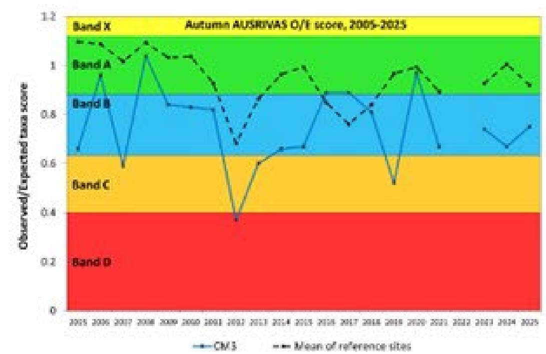
CM3 - Spring 2024 - Autumn 2025

Downstream of Cotter Dam

Environmental flow ecological objective	Spring 2024	Autumn 2025	Objective met?
AUSRIVAS band A	Band B	Band B	Not for either assessment
<20% filamentous algae cover in riffle habitat	<10%	<10%	Yes, for both assessment







* Denotes values outside guideline levels

Sampling season	Temp. (°C)	EC (µs cm⁻¹)	pH	D.O. (mg l⁻¹)	Turbidity (NTU)	Alkalinity (mg L⁻¹)	NH_4^+ (mg L⁻¹)	NOx (mg L⁻¹)	TN (mg L⁻¹)	TP (mg L⁻¹)
Spring 2024	15.11	30	7.48	9.91	0.0	14	0.005	0.005	0.11	0.006
Autumn 2025	22.27	149	7.03	7.89	3.0	37	0.012	0.019	0.36	0.028

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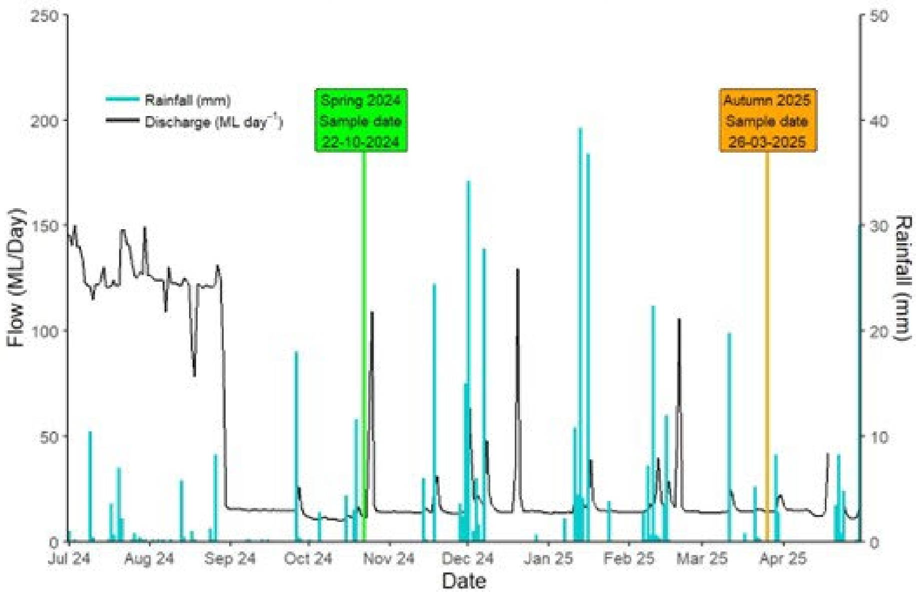
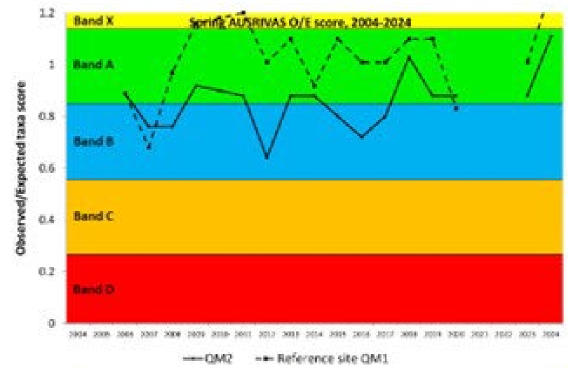
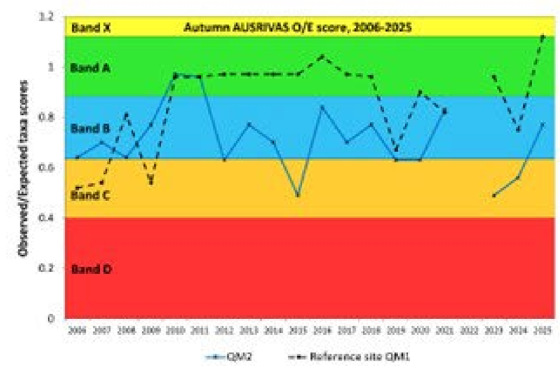
QM2 - Spring 2024 - Autumn 2025

Downstream of Googong Dam

Environmental flow ecological objective	Spring 2024	Autumn 2025	Objective met?
AUSRIVAS band A	Band A	Band B	Only for spring 2024
<20% filamentous algae cover in riffle habitat	<10%	<10%	Yes, for both assessment







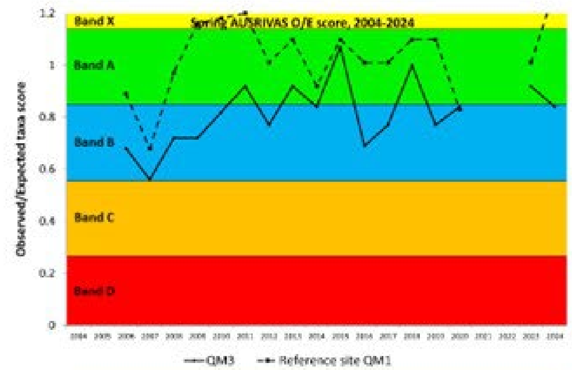
* Denotes values outside guideline levels

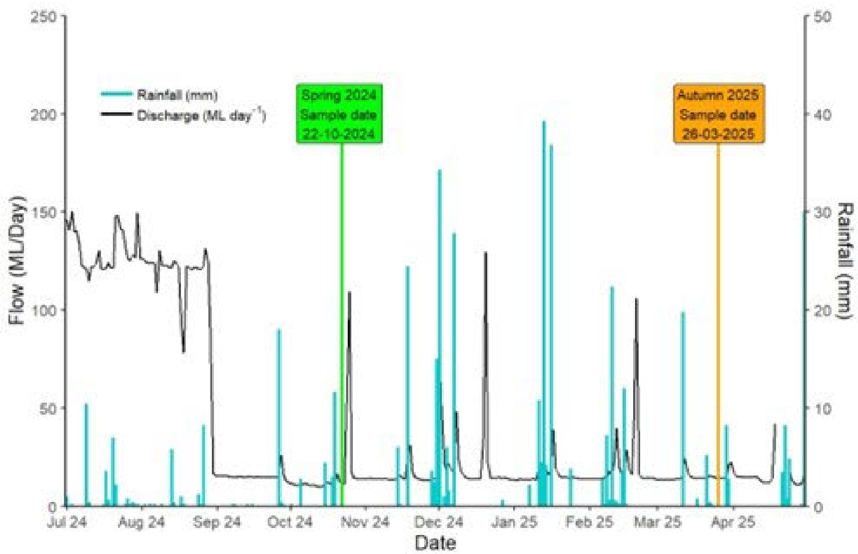
Sampling season	Temp. (°C)	EC (µs cm^{-1})	pH	D.O. (mg l^{-1})	Turbidity (NTU)	Alkalinity (mg L^{-1})	NH_4^+ (mg L^{-1})	NOx (mg L^{-1})	TN (mg L^{-1})	TP (mg L^{-1})
Spring 2024	17.27	105	8.23	10.92	0.0	35	0.004	0.017	0.38	0.016
Autumn 2025	21.86	110	7.94	9.46	0.0	31	0.016	0.026	0.25	0.016

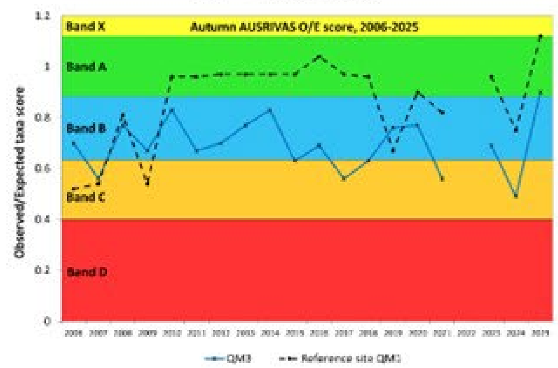
QM3 - Spring 2024 - Autumn 2025

2km Downstream of Googong Dam

Environmental flow ecological objective	Spring 2024	Autumn 2025	Objective met?
AUSRIVAS band A	Band B	Band A	Only for autumn 2025
<20% filamentous algae cover in riffle habitat	<10%	<10%	Yes, for both assessment







* Denotes values outside guideline levels

Sampling season	Temp. (°C)	EC (µs cm⁻¹)	pH	D.O. (mg l⁻¹)	Turbidity (NTU)	Alkalinity (mg L⁻¹)	NH_4^+ (mg L⁻¹)	NOx (mg L⁻¹)	TN (mg L⁻¹)	TP (mg L⁻¹)
Spring 2024	20.8	234	8.24	9.74	0.0	75	0.008	0.013	0.40	0.017
Autumn 2025	24.25	166	7.98	8.62	0.8	47	0.015	0.003	0.35	0.014

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APPENDIX 2: MACROINVERTEBRATE TAXA SPRING 2024

Macroinvertebrate taxa and their sensitivity grade (SIGNAL 2) (Chessman, 2003) collected from sub-samples in spring 2024 at each of the study sites. **NOTE:** Orange highlight indicates maximum taxa of the site for the sampling season.

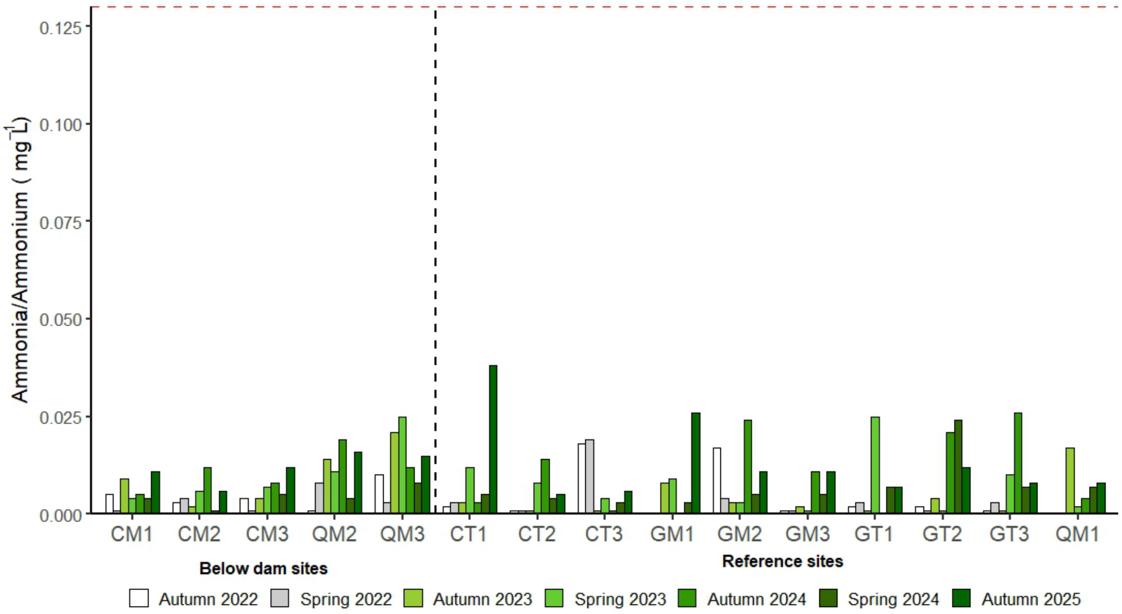
CLASS **Order** Family *Sub-family*	**Signal 2 Grade**	**Test sites**					**Reference sites**									
		CM1	**CM2**	**CM3**	**QM2**	**QM3**	**CT1**	**CT2**	**CT3**	**GM1**	**GM2**	**GM3**	**GT1**	**GT2**	**GT3**	**QM1**
Gastropoda																
Planorbidae	**2**												1			
Ancylidae	**4**	2				3		15	2						1	1
Lymnaeidae	**1**			1						1						
Bivalvia																
Sphaeridae	**5**															
Corbiculidae	**4**		1											1		
Tricladida																
Dugesiidae	**2**				2	1		1		3			1			1
OLIGOCHAETA	**2**	35	34	174	22	30		6	41	14	7	45	4		9	26
ACARINA	**6**	1	4	11	25	13	8	3	5	10	7	10	7	11	7	6
Coleoptera																
Scirtidae Sp.	**6**							1	1					2	1	
Elmidae	**7**					1	3			1		1	1		2	3
Elmidae (Larvae)	**7**	4		1	1	5	13	5		9	2	3	5	8	7	44
Psephenidae	**6**									2	1		2			
Diptera																
Tanyderidae	**6**														1	
Tipulidae	**5**				1		2		3	7	3		3	8	6	1
Ceratopogonidae	**4**				1	1		1							1	1
Psychodidae	**3**			1				1			1					
Simuliidae	**5**	7	21	1	2	3	4		94	2	5	3	6	3	5	1
Athericidae	**8**						8									
Empididae	**5**		3				4	1	1				3		6	1
Diamesinae	**6**	3						2								
Aphroteniinae	**8**						1	5		9	6	4	2		8	
Podonominae	**6**						5				1		1	1	3	
Tanypodinae	**4**				6	22	1	2		4	1	5	5	2	5	2
Orthocladiinae	**4**	115	98	27	41	29	29	41	26	5	2	4	2	6	9	12
Chironominae	**3**		14	24	127	115	26	12	21	18	10	27	31	84	63	47
Ephemeroptera																
Baetidae	**5**	1		2	3	6	3	11	3	21	16	22	12	16	5	1
Coloburiscidae	**8**						4		2	5	3	2	3			
Leptophlebiidae	**8**	1			1		49	44	2	72	94	62	20	26	32	38
Caenidae	**4**	1	3	1	20	37	1		7	13	2	17		8		3
Megaloptera																
Corydalidae	**7**			1		1			1							
Odonata																
Telephlebiidae	**9**						1							1		
Plecoptera																
Gripopterygidae	**8**	28	41		2	1	38	1	2	13	22	14	54	15	29	8
Trichoptera																
Hydrobiosidae	**8**		2		3		3	3	3		1	3		1	4	7
Glossosomatidae	**9**						1		1	2	4	2	8	4	10	3
Helicopsychidae	**8**								1				1	1	1	
Hydroptilidae	**8**				3		1	7		2	2		1	4		8
Philopotamidae	**8**						2			1						1
Hydropsychidae	**6**	2	1		2	7	1	1							1	2
Philorheithridae	**8**									1			1			1
Conoesucidae	**8**	1					6	39	1	5	4	7	3	2	21	1
Calamoceratidae	**7**							2		5		1	1	1	1	
Tasimiidae	**8**							1						1		
Leptoceridae	**6**						2	3		14	17	4	31	31	19	1
No. of individuals		201	222	244	262	275	216	208	217	239	211	236	209	237	257	220
No. of taxa		13	11	11	17	16	25	24	19	25	22	19	26	23	26	25
% of sub-sample		3	4	2	2	2	6	3	3	6	3	7	6	3	4	3
Whole sample estimate		**6700**	**5550**	**12200**	**13100**	**13750**	**3600**	**6933**	**7233**	**3983**	**7033**	**3371**	**3483**	**7900**	**6425**	**7333**

APPENDIX 2: MACROINVERTEBRATE TAXA AUTUMN 2025

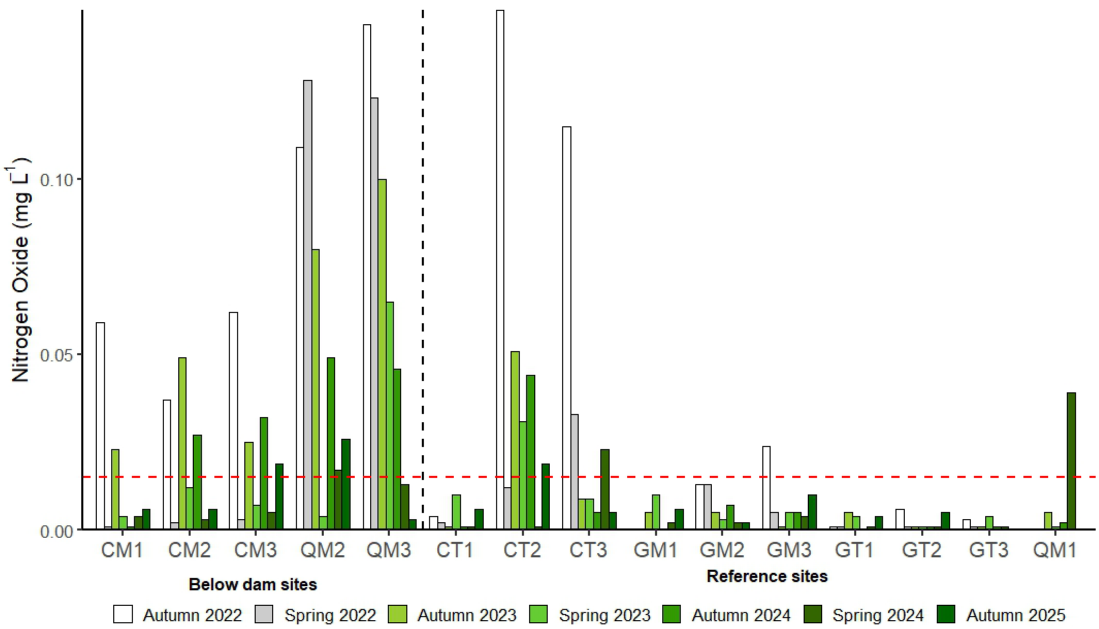
Macroinvertebrate taxa and their sensitivity grade (SIGNAL 2) (Chessman, 2003) collected from sub-samples in autumn 2025 at each of the study sites. **NOTE:** Orange highlight indicates maximum taxa of the site for the sampling season.

CLASS / **Order** / Family / *Sub-family*	**Signal 2 Grade**	**Test sites**					**Reference sites**									
		CM1	**CM2**	**CM3**	**QM2**	**QM3**	**CT1**	**CT2**	**CT3**	**GM1**	**GM2**	**GM3**	**GT1**	**GT2**	**GT3**	**QM1**
Gastropoda								**Macroinvertebrate samples not collected due to low flow**								
Physidae	**1**				1											
Ancylidae	**4**		1		1		1					2	4	6	1	
Lymnaeidae	**1**	1														
Bivalvia																
Corbiculidae						4										5
Tricladidae																
Dugesiidae	**2**			3	1		2									
OLIGOCHAETA	**2**	62	8	6	3	3	11		3	9	2	5	10	4	18	5
ACARINA	**6**	26	2	34	4	1	9		6	4	1	6	7	5	9	5
Coleoptera																
Scirtidae Sp.	**6**									1					1	
Elmidae (Adult)	**7**				3		3		2	2	1				1	
Elmidae (Larvae)	**7**	1		2	1	3	43		3	3	2	9	13	6	10	13
Psephenidae	**6**						2									
Diptera																
Tanyderidae	**6**									1					4	
Tipulidae	**5**	1	1	1	1		3			1	1		3	2	6	1
Ceratopogonidae	**4**			1											1	1
Dixidae															2	
Simuliidae	**5**	26	169	40	57	80	2		3	4	33	87	34	15	22	67
Athericidae	**8**						6									
Empididae	**5**	1		3			1			1				1		
Aphroteniinae	**8**						2						1		4	
Tanypodinae	**4**					6			6			2	3	5	3	3
Orthocladiinae	**4**	19	9	44	14	6	12		16	3	3	3	9	6	8	22
Chironominae	**3**	6	15	32	8	4	3		28	41	75	28	92	124	42	26
Ephemeroptera																
Baetidae	**5**	9	6	17	20	6	15		65	7	2	66	34	13	9	12
Coloburiscidae	**8**						13			1	1	6	1		3	
Leptophlebiidae	**8**					2	76		3	71	55	38	2	43	75	4
Caenidae	**5**	16	8	5	34	54	3		28		1	1		5	1	62
Megaloptera																
Corydalidae	**7**		1	5	3											
Odonata																
Telephlebiidae	**9**														1	
Gomphidae	**5**												1			1
Plecoptera																
Gripopterygidae	**8**	21	2				30			17	3	1	8	3	9	
Trichoptera																
Hydrobiosidae	**8**		2	1	2	3			4	2	1	1	1	2	5	1
Glossosomatidae	**9**						2					1		1	7	
Helicopsychidae	**8**												5	1	1	
Hydroptilidae	**8**	11		3		2	3			2	1			2	4	9
Philopotamidae	**8**		1	3			8			3	2	5	7	10	9	
Hydropsychidae	**6**	22	21	7	31	50	3		22	15	23	31		1	11	22
Ecnomidae	**4**			1	2	1			7							3
Philorheithridae	**8**						2			4	8					
Conoesucidae	**8**	1	1				21			69	1	5	5	2	12	
Calamoceratidae	**7**													9	11	
Tasimiidae	**8**														1	
Leptoceridae	**6**	6		1			5			8	2	1	9	18	11	
No. of individuals		229	247	209	186	225	281		196	269	218	298	249	284	302	262
No. of taxa		16	15	19	17	15	26		14	22	20	19	20	23	31	18
% of sub-sample		2	1	2	2	1	3		3	1	1	2	2	2	5	2
Whole sample estimate		11450	24700	10450	9300	22500	9367		6533	26900	21800	14900	12450	14200	6040	13100

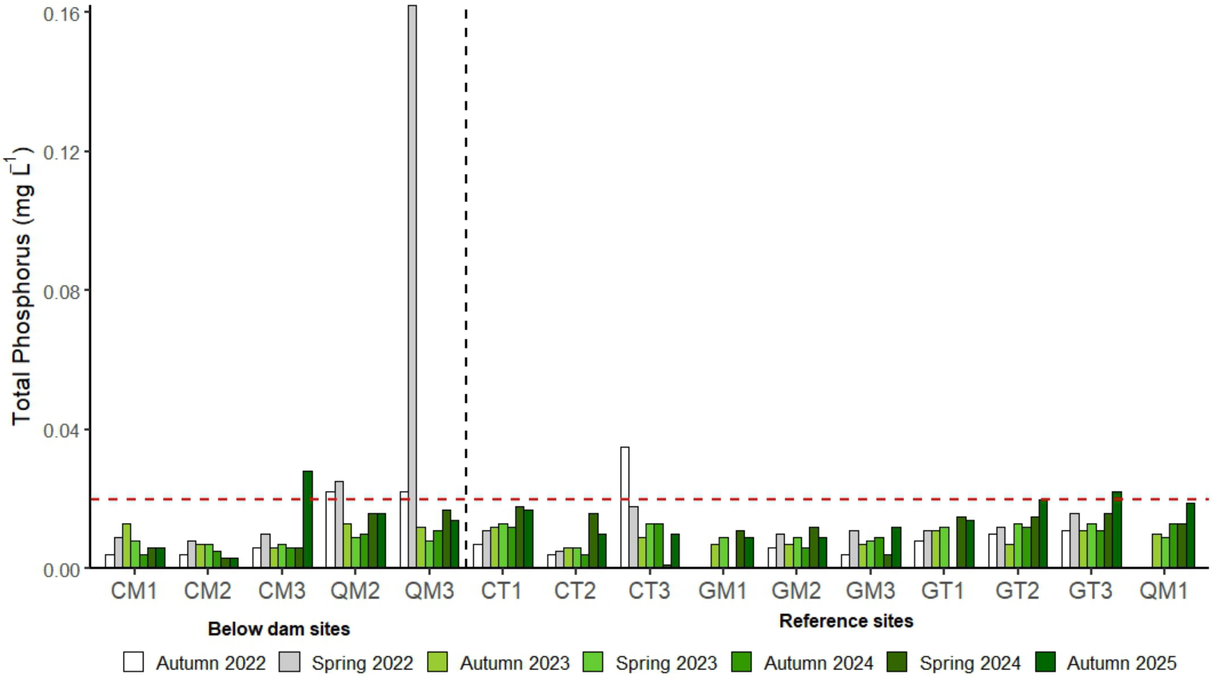
APPENDIX 3: WATER QUALITY FIGURES



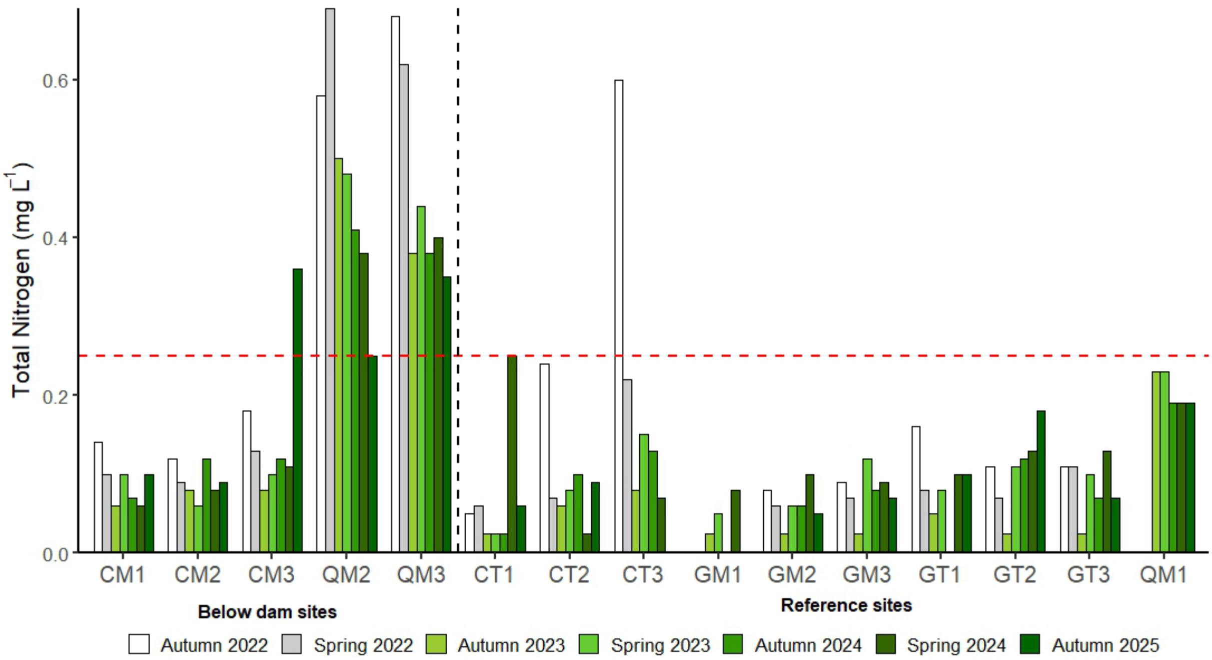
Ammonium (NH_4^+) concentration at all sites from autumn 2022 to autumn 2025. Values below the minimum detectable limit of 0.002 mg L^{-1} are shown at 0.001 mg L^{-1}. The ANZECC/ARMCANZ (2000) guideline maximum concentration for ammonium (NH_4^+) is dashed line and shaded red.



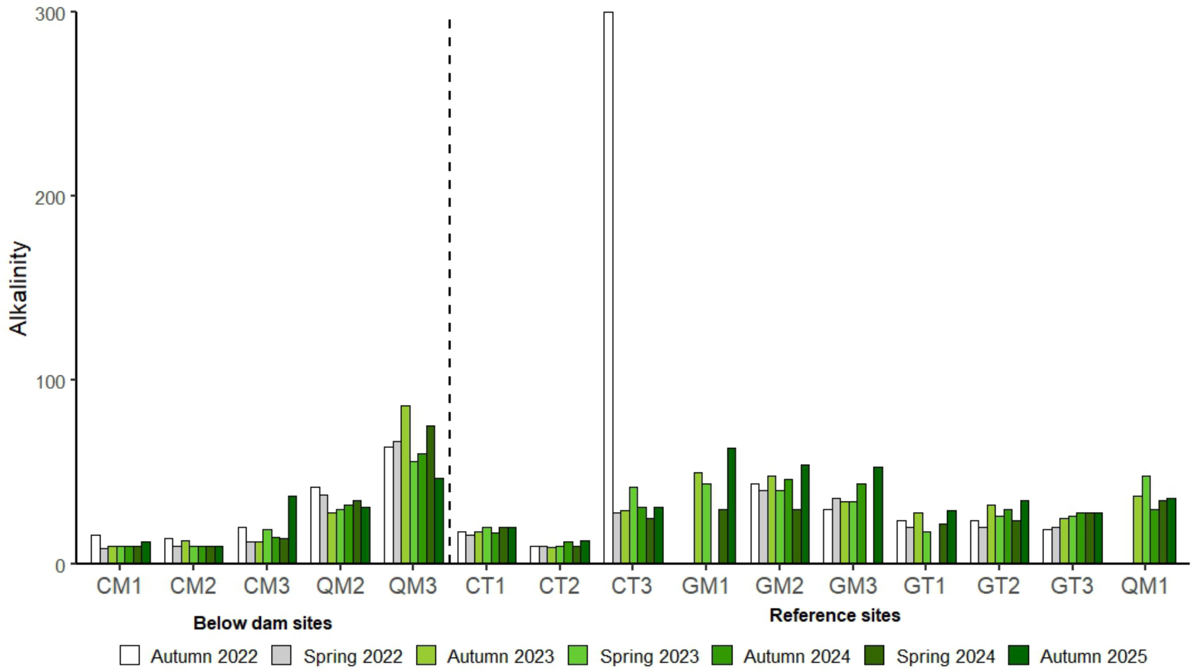
Nitrogen oxide concentrations at all sites from autumn 2022 to autumn 2025. Values below the minimum detectable limit of 0.002 mg L-1 are shown at 0.001 mg L-1. The ANZECC/ARMCANZ (2000) guideline maximum concentration for nitrogen oxide is dashed line and shaded red.



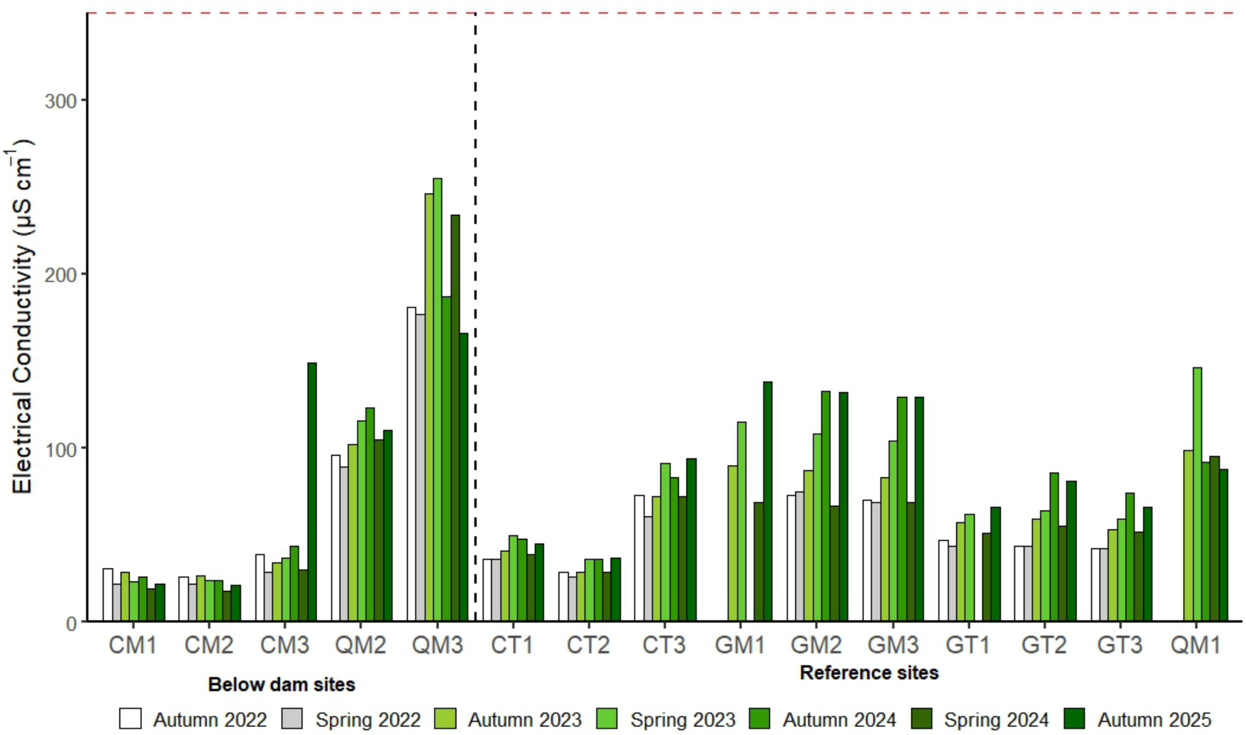
Total phosphorus concentrations at all sites from autumn 2022 to autumn 2025. Values below the minimum detectable limit of 0.01 mg L-1 are shown at 0.005 mg L-1. The ANZECC/ARMCANZ (2000) guideline maximum concentration for total phosphorus is dashed line and shaded red.



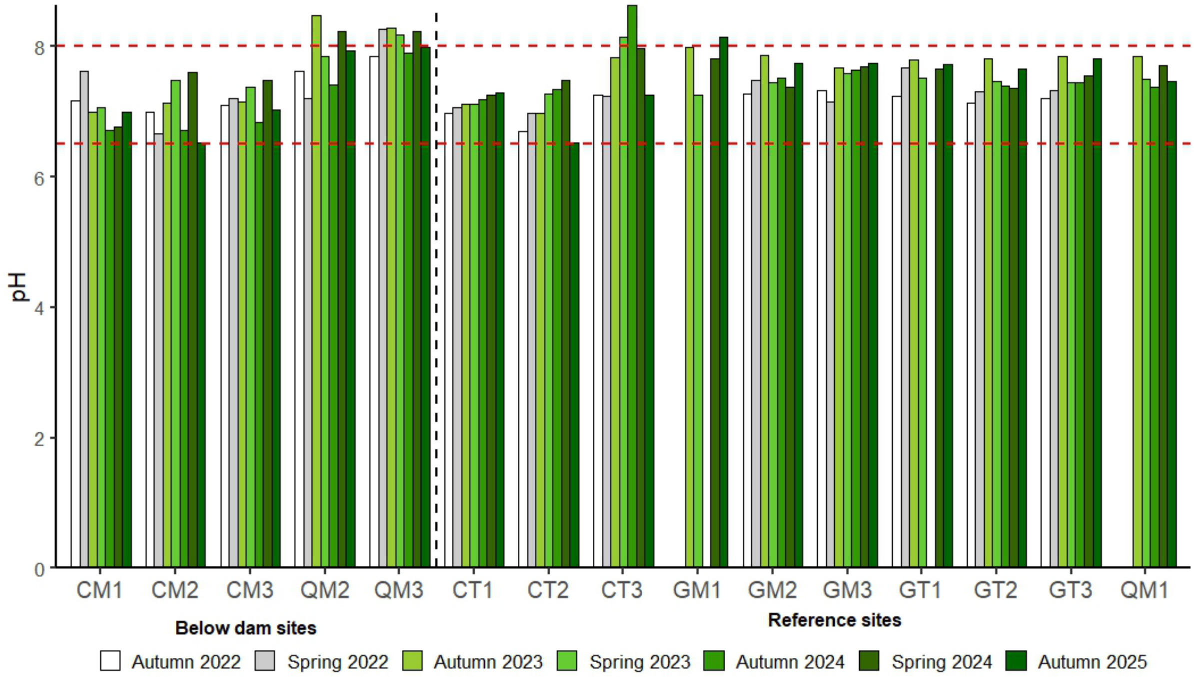
Total nitrogen concentrations at all sites from autumn 2024 to autumn 2025. Values below the minimum detectable limit of 0.01 mg L-1 are shown at 0.005 mg L-1. The ANZECC/ARMCANZ (2000) guideline maximum concentration for total nitrogen is dashed line and shaded red.



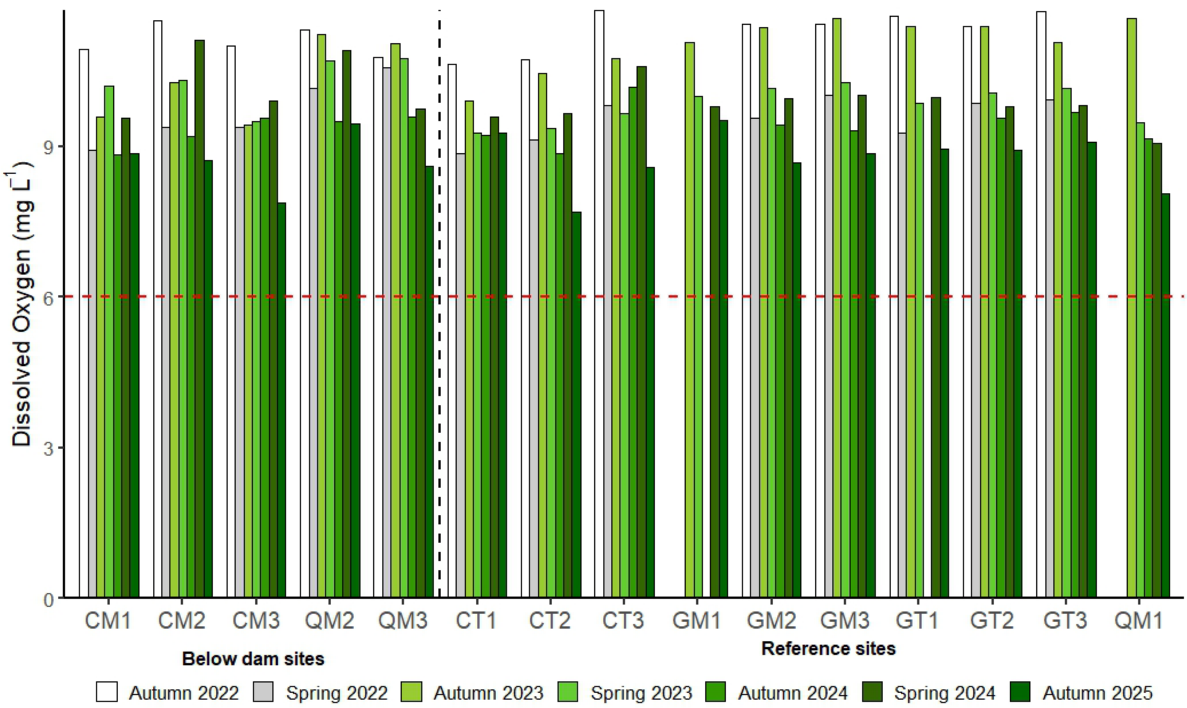
Alkalinity at all sites from autumn 2022 to autumn 2025.



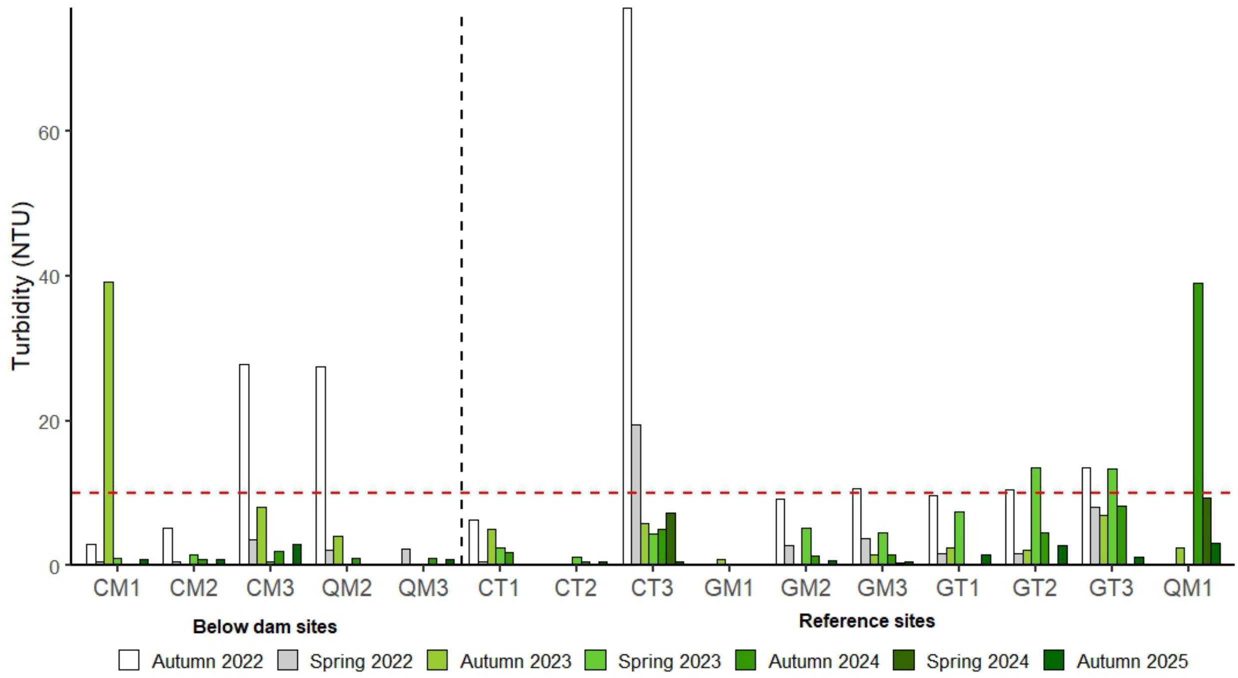
Electrical conductivity at all sites from autumn 2022 to autumn 2025. The ANZECC/ARMCANZ (2000) guideline for maximum electrical conductivity is dashed line and shaded red.



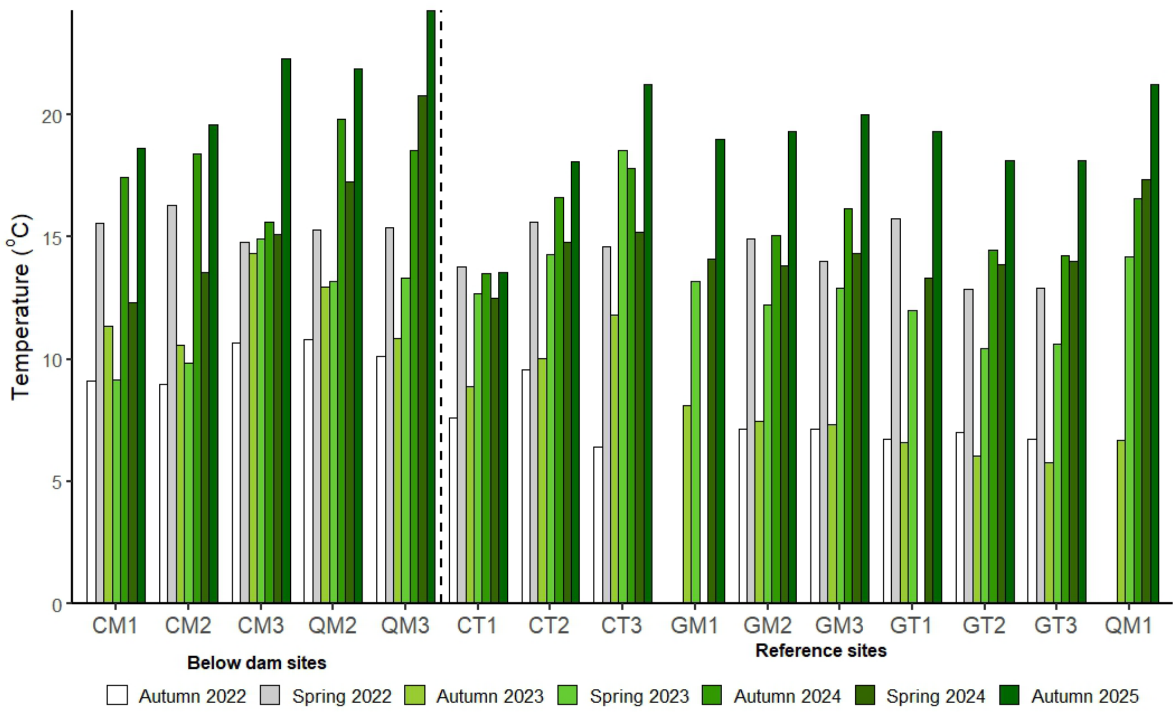
pH at all sites from autumn 2022 to autumn 2025. The ANZECC/ARMCANZ (2000) guideline range for pH are dashed lines and shaded red.



Dissolved oxygen concentration at all sites from autumn 2022 to autumn 2025. The minimum guideline for dissolved oxygen is dashed line and shaded red (Environment Protection Regulation SL2005-38).



Turbidity at all sites from autumn 2022 to autumn 2025. The guideline for maximum turbidity is dashed line and shaded red (Environment Protection Regulation SL2005-38).



Water temperature at all sites from autumn 2022 to autumn 2025.