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

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BACKGROUND AND STUDY OBJECTIVE

- The Cotter and Queanbeyan Rivers are regulated to supply water to the Australian Capital Territory (ACT) and Queanbeyan. Ecological assessments are undertaken in spring and autumn each year to evaluate river responses to environmental flow releases. The study design incorporates sites downstream of dams on regulated reaches, alongside a hierarchical control framework consisting of both unregulated mainstem sites (e.g. the Goodradigbee River and the Queanbeyan River upstream of Googong Dam) and paired unregulated tributary sites. Each regulated reach below a dam is matched with a comparable unregulated tributary, and each unregulated mainstem site is similarly paired with a tributary reference, providing a two-tiered control design that improves the ability to distinguish effects of flow regulation from natural variability at both local reach scales and across comparable river systems within the broader Murrumbidgee basin.
- This study fulfils the requirements of Icon Water's Licence to Take Water (WU67) by assessing the ecological effects of dam operations, water abstraction, and environmental flow releases, and informing adaptive management of the Cotter and Googong water supply catchments. It evaluates ecological condition using integrated water quality and biotic indicators, with specific performance benchmarks applied to regulated (downstream-of-dam) sites, including filamentous algae cover on riffles of <20% and an AUSRIVAS macroinvertebrate condition grading of A. A broader suite of supporting metrics—including water quality, periphyton biomass and growth (e.g. ash-free dry mass), and related indicators—is also assessed to aid interpretation of ecological responses. This report presents the outcomes of monitoring undertaken in spring 2025 and autumn 2026, providing an evidence base for evaluating flow management effectiveness.

SPRING 2025 & AUTUMN 2026 RESULTS AND CONCLUSIONS

- Flow conditions preceding sampling reflected rainfall variability across the monitored systems, with generally higher and more variable discharges during spring 2025 followed by lower and more stable flows during autumn 2026. Cumulative flows were below long-term seasonal averages in both periods at most sites. Below-dam sites experienced substantially reduced cumulative flows in autumn 2026 relative to spring 2025, while the Cotter River below Corin Dam showed comparatively higher flows prior to autumn sampling, indicating improved runoff conditions in that catchment.
- Reservoir levels followed expected seasonal patterns but reflected reduced inflows into autumn 2026. Cotter Reservoir remained near full supply through spring 2025 before declining from early 2026. Corin Reservoir peaked in October 2025 and then declined steadily, while Bendora Reservoir fluctuated but showed an overall downward trend. Googong Reservoir remained stable through spring before declining over summer and partially recovering prior to autumn sampling. These patterns are consistent with lower inflows and ongoing water supply demands.

- Water quality below dams was generally within guideline values during both monitoring periods. However, elevated nutrient concentrations were observed at several sites, particularly in autumn 2026, when Total Nitrogen, Total Phosphorus, and oxidised nitrogen exceeded guideline levels more frequently than in spring 2025. Elevated nutrients in spring were primarily associated with downstream reservoir sites, and occasional pH exceedances were also recorded. Overall, results indicate largely acceptable water quality with localised nutrient enrichment.
- The ecological objective for filamentous algae (<20% cover on riffles) was achieved at all regulated (below-dam) sites in both spring 2025 and autumn 2026, with observed cover consistently <10%. (refer to Filamentous Algae and Periphyton Results)
- Periphyton responses showed greater variability than filamentous algae cover. While filamentous algae remained low, total periphyton cover exceeded 20% at several sites in spring 2025 and persisted at CM1 into autumn 2026. Biomass indicators (AFDM and chlorophyll-a) showed no consistent differences between regulated and reference groups overall; however, elevated biomass and productivity were observed at specific sites (notably CM1, and QM2 in autumn 2026). These results indicate that, despite low filamentous algae cover, localised increases in periphyton biomass and productivity occurred at some sites.
- Macroinvertebrate condition at regulated sites did not meet ecological objectives. In spring 2025, only one below-dam site (CM1) achieved AUSRIVAS band A, with remaining sites assessed as bands B and C. Condition declined further in autumn 2026, with all below-dam sites assessed as band B or C, indicating that no sites met the band A target during this period. (refer to AUSRIVAS assessment Results)
- As observed in previous assessments, regulated sites were generally in poorer ecological condition than reference sites across both sampling periods. In spring 2025, most reference sites were assessed as AUSRIVAS band A, with several exceeding reference expectations (band X). In autumn 2026, most reference sites remained in band A, although some declines were observed (including one site in band C and one in band B), indicating that broader regional conditions also influenced ecological outcomes. (refer to AUSRIVAS assessment Results)

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 2025**	**Autumn 2026**	**Spring 2025**	**Autumn 2026**
CM1 (Corin Dam)	<10	<10	A	B
CM2 (Bendora Dam)	<10	<10	B	B
CM3 (Cotter Dam)	<10	<10	C	B
QM2 (Googong Dam)	<10	<10	B	B
QM3 (Googong Dam)	<10	<10	B	C

PROJECT CONCLUSIONS AND RECOMMENDATIONS

- Environmental flow management was effective in achieving its primary objective of limiting nuisance filamentous algal growth, with all regulated sites consistently meeting the <20% cover target. Supporting lines of evidence—including generally acceptable water quality and the absence of consistent differences in periphyton biomass (AFDM and chlorophyll-a) between regulated and reference groups—indicate that flow regimes are broadly functioning as intended at a system scale.

- Despite this, macroinvertebrate condition at regulated sites remained consistently lower than at reference sites and did not meet the target of AUSRIVAS band A. Localised increases in periphyton biomass and productivity at some sites, together with elevated nutrients and reduced flow conditions in autumn 2026, suggest that factors beyond flow alone are influencing ecological condition.

- Overall, the results indicate that while current flow management is effective in controlling nuisance algal growth, achieving broader ecological condition comparable to reference sites likely depends on the interaction of multiple drivers, including water quality, productivity dynamics, and site-specific factors.

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 2025 and autumn 2026. 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 2025 and autumn 2026 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 20 to 23 October 2025 and autumn between 2 to 5 March 2026 (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.

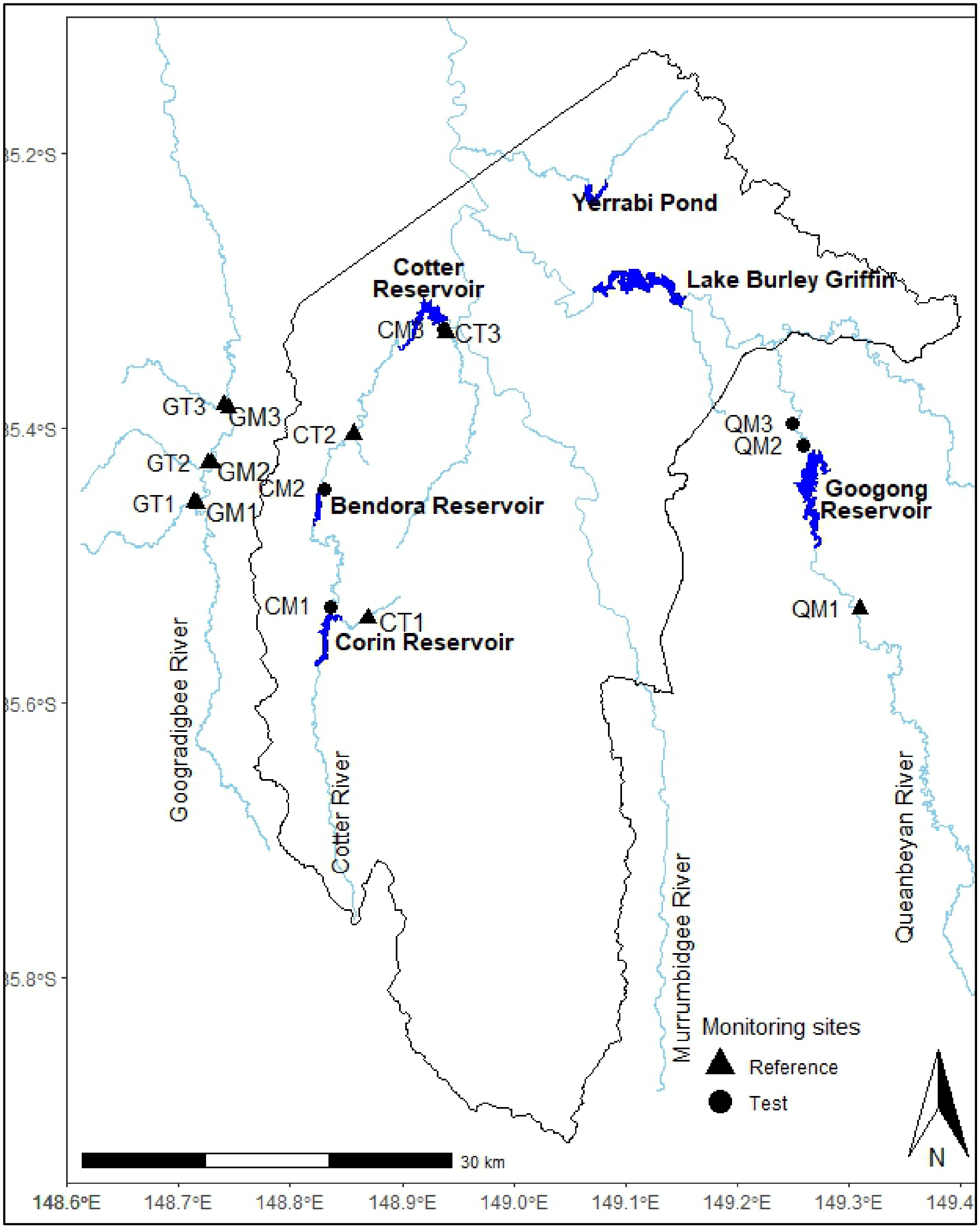

Figure 1: The location of sites on the Cotter, Goodradigbee, and Queanbeyan Rivers and tributaries for the below dams assessment program (Circles indicate test sites, triangles indicate reference tributaries).

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 2026.

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 2025 sampling, stream discharge across the below dams sites were generally below historical average conditions, with percentile flows ranging from the 34th to 58th percentile (Table 5). Flows were particularly low at the Cotter River downstream Cotter Reservoir and downstream of Corin Dam, However, Goodradigbee and Queanbeyan River remained closer to historical average conditions (Figure 2 and Table 5). Flow conditions prior to the autumn 2026 sampling showed greater variability among monitoring sites. Improved flow conditions were observed downstream of Corin Dam and within the Goodradigbee River catchment, where percentile flows increased to the 58th and 63rd percentiles, respectively. However, most other sites recorded substantially lower cumulative flows in autumn 2026 than spring 2025 (Table 5). Rainfall in the three months preceding spring 2025 was generally below to near historical average conditions across most monitoring sites, with percentile rankings ranging from the 31st to 57th percentile. In the lead-up to autumn 2026, rainfall patterns varied more substantially among catchments. Rainfall remained below average below Bendora and Cotter dam sites, where percentile rankings declined to the 38th and 20th percentiles, respectively. In contrast, the Queanbeyan and Goodradigbee catchments recorded notably higher rainfall than historical autumn averages, with percentile rankings ranging from the 72nd to 83rd percentile (Table 6). Overall, flow conditions across the study period were generally below long-term seasonal averages at most sites, with reduced cumulative flows in autumn 2026 compared to spring 2025 and some localised variability among catchments.

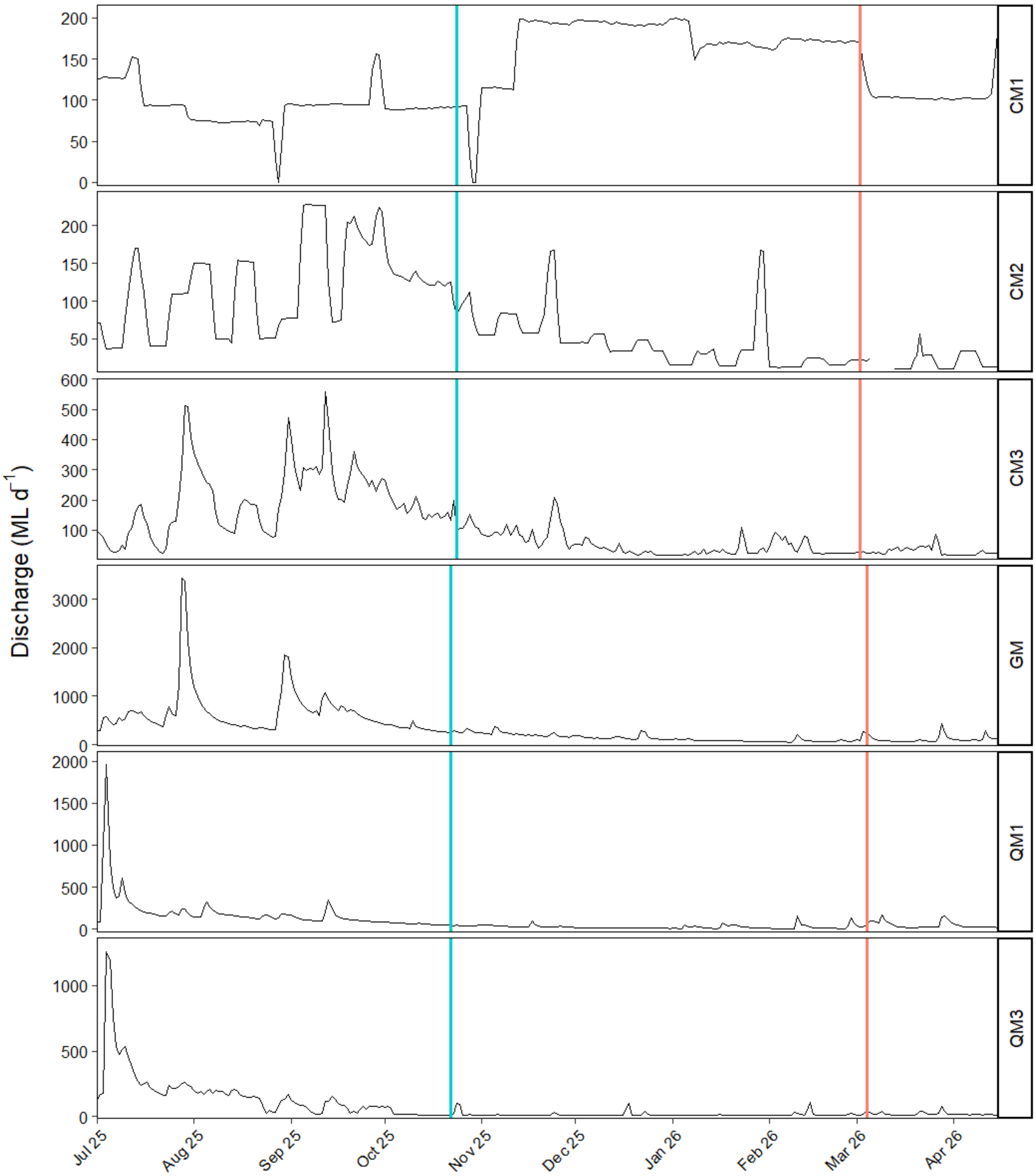

Figure 2: Mean daily discharge below Corin (CM1, station 410752), Bendora (CM2, station 410747), and Cotter (CM3, station 410700) Dams and in the Goodradigbee River (GM, station 410088) and Googong Dam (QM3, station 410760) and the Queanbeyan River upstream of Googong Reservoir (QM1, station 410781) from July 2025 to April 2026. **NOTE:** Blue bar corresponds to spring 2025 sampling and orange bar corresponds to autumn 2026 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 2025 sampling (ML)	Cumulative flow in three months prior to autumn 2026 sampling (ML)	Historical mean flow in spring (ML)	Historical mean flow in autumn (ML)	Percentile mean flow in spring 2025 (ML/Day)	Percentile mean flow in autumn 2026 (ML/Day)
CM2, CT2	11924.7	2912.6	16266 ± 2371	7649.1 ± 2056	52nd	53rd
CM1, CT1	7903.2	16301.7	17115.1 ± 2330	16632.1 ± 1202	38th	58th
CM3, CT3	20386	3190.8	49806.7 ± 4212	15394 ± 2003	34th	24th
GM1, GM2, GM2, GT1, GT2, Gt3	62106.4	18749.8	65869 ± 5098	22267 ± 2574	58th	63rd
QM1	12034.4	2254.9	14906 ± 2762	11811 ± 3020	58th	22nd
QM2, QM3	9070.5	1463	22680 ± 5064	13842 ± 3097	57th	30th

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

Relevant monitoring site/s	Total rainfall in three months prior to spring 2025 sampling (mm)	Total rainfall in three months prior to autumn 2026 sampling (mm)	Historical total rainfall in spring (mm)	Historical total rainfall in autumn (mm)	Percentile total rainfall in spring 2025 (mm)	Percentile total rainfall in autumn 2026 (mm)
CM1, CM2, CT1, CT2	263.8	179.2	301 ± 16.5	232 ± 13.1	41st	38th
CM3, CT3	203	133.8	196.3 ± 17.4	199.7 ± 15.9	57th	20th
QM2, QM3	113.4	192.6	151.7 ± 10.6	164.2 ± 8.6	36th	72nd
QM1	106.6	228.6	152.8 ± 12.5	192.4 ± 15.1	31st	83rd
GM1, GM2, GM3, GT1, GT2, GT3	257.6	237	254.2 ± 20.5	176.9 ± 13.7	53rd	76th

WATER QUALITY

Water quality across both test and reference sites during the spring 2025 and autumn 2026 assessments was generally within guideline levels, although several exceedances were recorded. In spring 2025, elevated pH was observed at QM2, QM3, QM1, and GM3, while elevated NOx concentrations were recorded at CM1, QM2, and GM3. Total Nitrogen exceeded guideline levels at QM2 and QM3, and Total Phosphorus was elevated at QM3, CT3, QM1, and GT3 (Table 7 and Table 8). In autumn 2026, nutrient enrichment was more widespread, with elevated NOx concentrations recorded at QM2, QM3, CT3, QM1, and GM3, including noticeably elevated concentrations at CT3 and QM3. Total Nitrogen exceeded guideline levels at CM2, CM3, QM2, QM3, GM3, GT1, GT2, and GT3, while Total Phosphorus concentrations were elevated at CM3, CT3, QM1, GT2, and GT3. Higher turbidity was also recorded at QM1 and GT3 (Table 7 and Table 8). Water quality parameters at below-dam sites were generally within guideline levels during both the spring 2025 and autumn 2026 assessments, although several nutrient exceedances were recorded, particularly during autumn 2026. Importantly, these exceedances were observed across both regulated and reference sites, indicating no consistent pattern of nutrient enrichment attributable solely to flow regulation.

Table 6. Water quality parameters measured at each of the test and reference sites in spring 2025. Values outside guideline levels are shaded orange.

		Temp. (^oC)	EC ($\mu s\ cm^{-1}$)	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**	10.01	27	7.72	10.26	0.0	10	0.01	0.024	0.09	0.01
	CM2	10.73	25	7.74	10.24	0.0	8	0.01	0.005	0.08	0.01
	CM3	15.41	40	7.24	9.25	0.0	14	0.00	0.008	0.13	0.02
	QM2	14.65	103	8.18	9.98	0.0	36	0.01	0.021	0.35	0.02
	QM3	16.85	126	8.38	9.15	0.0	42	0.01	0.008	0.37	0.03
Reference sites	**CT1**	15.64	50	7.68	8.36	0.0	20	0.01	0.006	0.06	0.02
	CT2	14.97	34	7.63	9.17	0	14	0.00	0.005	<0.05	0.02
	CT3	17.18	89	7.74	9.22	0.0	32	0.00	0.012	0.1	0.03
	QM1	16.55	89	8.05	8.97	5.0	30	0.01	<0.002	0.23	0.03
	GM1	13.79	97	7.96	9.28	0	0	0.01	0.006	0.06	0.01
	GM2	13.93	92	7.82	9.13	0.0	30	0.01	0.008	0.06	0.02
	GM3	14.82	92	8.11	9.23	0.0	40	0.01	0.019	0.09	0.02
	GT1	12.84	59	7.57	9.41	0	26	0.01	0.005	0.09	0.02
	GT2	13.19	59	7.61	9.21	0.1	24	0.00	0.006	0.09	0.02
	GT3	13.41	54	7.93	9.31	0.0	23	0.01	<0.002	0.09	0.03

Table 7: Water quality parameters measured at each of the test and reference sites in autumn 2026. Values outside guideline levels are shaded orange.

		Temp. (^{o}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	19.43	29	7.64	8.37	0.0	8	0.01	<0.004	0.08	<0.002
	CM2	19.55	29	6.60	8.47	0.0	8	0.01	0.011	0.28	0.02
	CM3	21.77	170	7.05	8.11	0.0	44	<0.004	0.013	0.42	0.03
	QM2	22.19	121	7.76	9.09	0.0	40	0.01	0.018	0.26	0.01
	QM3	23.3	260	7.97	8.66	0.0	69	0.01	0.045	0.44	0.02
Reference sites	CT1	15.63	57	7.13	8.59	0.0	4	<0.004	<0.004	0.14	0.02
	CT2						0				
	CT3	20.87	104	7.45	9.42	0.0	38	0.01	0.059	0.21	0.04
	QM1	21.67	107	7.38	7.24	12.2	35	0.07	0.026	0.54	0.05
	GM1	19.23	99	7.81	8.79	0	32	0.01	0.006	0.22	0.02
	GM2	18.99	89	7.31	8.49	0.0	28	0.01	0.005	0.1	0.01
	GM3	19.29	91	7.67	8.51	0.0	22	0.01	0.017	0.27	0.02
	GT1	18.21	64	7.68	8.95	0	23	0.01	<0.004	0.28	0.02
	GT2	17.93	72	7.19	8.77	0.0	8	0.01	<0.004	0.33	0.03
	GT3	17.64	64	7.01	8.94	17.0	12	0.01	<0.004	0.53	0.06

FILAMENTOUS ALGAE AND PERIPHYTON

The environmental flow ecological objective of maintaining filamentous algae cover below 20% in riffle habitats was achieved at all below-dam test sites during both the spring 2025 and autumn 2026 assessments (Table 9). In contrast, periphyton cover in riffle habitats exceeded 20% at several sites during the monitoring period. In spring 2025, elevated periphyton cover was recorded at CM1 (D/S Corin Reservoir), CM2 (D/S Bendora Reservoir), QM3 (D/S Googong Dam), and QM1 (U/S Googong Dam), with cover ranging from 30–40%. In autumn 2026, elevated periphyton cover persisted only at CM1, where cover increased to 35%, while all other sites remained below the 20% threshold (Table 9).

There was no significant difference in AFDM in both spring 2025 and autumn 2026, between reference site group and below dams site group ($\beta = 0.308$, $t5 = 0.570$, $p = .593$) in spring 2025 and ($\beta = 0.089$, $t5 = 0.229$, $p = .828$) in autumn 2026, although below dams sites had a higher mean AFDM. Pairwise comparisons between sites in spring 2025 revealed that the below-dams site CM1 had significantly higher AFDM compared to all reference sites (GM1: $\beta = -1.2652$, $t = -4.287$, $p = 0.0024$; GM2: $\beta = -1.5094$, $t = -5.115$, $p =$

0.0002; GM3: $\beta = -1.5637$, $t = -5.299$, $p = 0.0001$). Similar, CM1 had significantly higher AFDM than the other below-dam sites CM2 ($\beta = 1.0257$, $t = 3.476$, $p = 0.0212$), CM3 ($\beta = 1.3381$, $t = 4.535$, $p = 0.0012$), and QM2 ($\beta = 2.1893$, $t = 7.419$, $p < 0.0001$). Additionally, CM2 had significantly higher AFDM than QM2 in spring 2025 ($\beta = 1.1636$, $t = 3.943$, $p = 0.0062$), and GM1 had significantly lower AFDM than QM2 ($\beta = 0.9241$, $t = 3.132$, $p = 0.0493$). In Autumn 2026, there were no significant differences, with the exception of CM2 having significantly higher AFDM than QM2 ($\beta = -1.3758$, $t = -3.572$, $p = 0.0166$). No statistically significant differences were detected between any other reference site pairs or between below-dams site pairs in either season.

In Spring 2025, there was no significant difference in chlorophyll-a concentrations between the monitoring sites ($\beta = 1.6772$, $t_5 = 1.759$, $p = 0.139$). Similarly, in Autumn 2026, there was no statistically significant difference in chlorophyll-a between monitoring sites ($\beta = 1.6560$, $t_5 = 2.300$, $p = 0.0696$). In Spring 2025, pairwise comparisons between sites revealed that the below-dams site CM1 had significantly higher chlorophyll-a than all three reference sites (GM1: $\beta = -2.4385$, $t = -5.233$, $p = 0.0001$; GM2: $\beta = -4.0712$, $t = -8.736$, $p < 0.0001$; GM3: $\beta = -4.1495$, $t = -8.905$, $p < 0.0001$), and was also significantly higher than the other below-dams sites CM2 ($\beta = 2.6546$, $t = 5.697$, $p < 0.0001$), CM3 ($\beta = 1.6499$, $t = 3.541$, $p = 0.0180$), and QM2 ($\beta = 3.1989$, $t = 6.865$, $p < 0.0001$). Similarly, CM3 was significantly elevated compared to GM2 ($\beta = -2.4213$, $t = -5.196$, $p = 0.0002$) and GM3 ($\beta = -2.4996$, $t = -5.364$, $p = 0.0001$), and CM2 was significantly higher than GM3 ($\beta = -1.4949$, $t = -3.208$, $p = 0.0411$). Notably, within the reference group, GM1 had significantly higher chlorophyll-a than both GM2 ($\beta = 1.6327$, $t = 3.504$, $p = 0.0197$) and GM3 ($\beta = 1.7110$, $t = 3.672$, $p = 0.0128$). In Autumn 2026, QM2 exhibited notably elevated chlorophyll-a concentrations, with levels significantly exceeding those recorded at all three reference sites. (GM1: $\beta = -2.0160$, $t = -3.195$, $p = 0.0443$; GM2: $\beta = -2.8226$, $t = -4.283$, $p = 0.0027$; GM3: $\beta = -3.5968$, $t = -5.457$, $p = 0.0001$) and above CM2 ($\beta = -2.0934$, $t = -3.317$, $p = 0.0331$). CM1 remained significantly higher than GM2 ($\beta = -2.2967$, $t = -3.640$, $p = 0.0149$) and GM3 ($\beta = -3.0710$, $t = -4.867$, $p = 0.0005$) in Autumn 2026. No other pairwise comparisons had statistical significance difference in either season (Figure 6).

Filamentous algal cover remained below the ecological objective threshold (<20%) at all regulated sites, with no clear distinction between regulated and reference conditions. Similarly, periphyton biomass indicators (AFDM and chlorophyll-a) showed no consistent differences between site groups, despite some localised site-specific elevations. Together, these findings suggest that flow management and associated conditions are broadly effective in limiting excessive algal proliferation at a system scale.

Table 8: Periphyton and filamentous algae (categorised on percent cover) in the riffle habitat at below dams sites and reference sites, from spring 2025 to autumn 2026. 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-23	Aut-24	Spr-24	Aut-25	Spr-25	Aut-26		Spr-23	Aut-24	Spr-24	Aut-25	Spr-25	Aut-26
CM1	20	<10	<10	<10	30	35		<10	<10	10	<10	10	<10
CM2	20	<10	30	<10	40	15		<10	20	<20	<10	<10	<10
CM3	<10	<10	<10	<10	<10	<10		<10	<10	10	<10	<10	<10
QM2	20	<10	<10	<10	<10	<10		20	<10	10	<10	<10	<10
QM3	30	<10	<10	<10	30	<10		<10	<10	10	<10	<10	<10
GM1	<10	NA	<10	<10	<10	<10		<10	NA	<10	15	<10	<10
GM2	<10	<10	<10	<10	<10	<10		<10	<10	<10	<10	<10	<10
GM3	20	<10	<10	<10	<10	<10		<10	<10	<10	<10	<10	<10
QM1	20	20	<10	30	30	<10		<10	<10	<10	<10	<10	<10

Test sites

Site CM1

Site CM2

Site CM3

Site QM2

Site QM3

Reference sites

Site GM1

Site GM2

Site GM3

Site QM1

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 2025.

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 2026.

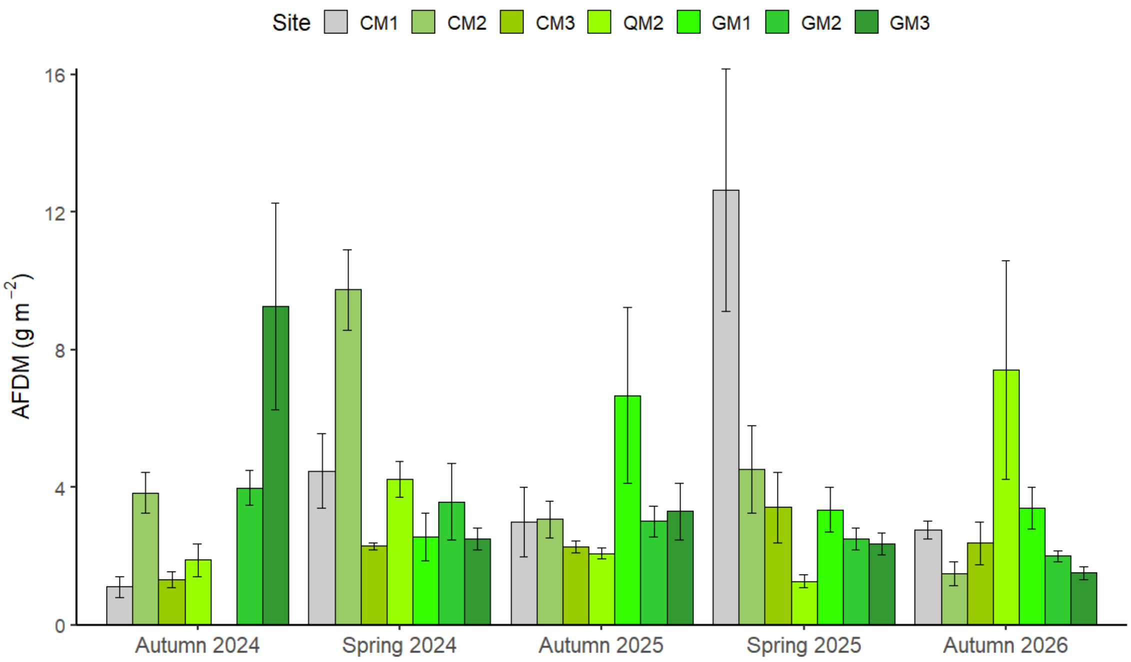

Figure 5: Mean AFDM (g m^{-2}) at below dam test sites and reference sites on the Goodradigbee River from autumn 2024 to autumn 2026. Error bars represent +/- 1 standard error. **NOTE**: AFDM samples were not collected in autumn 2024 at site GM1 due to site being inaccessible during the sampling season.

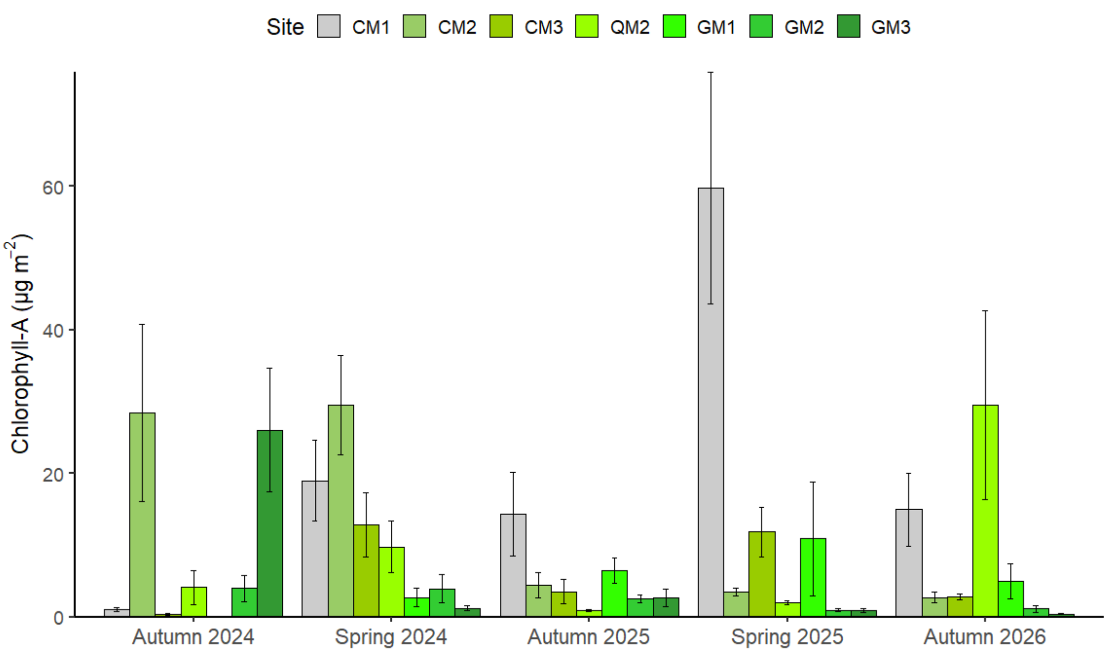

Figure 6: Mean Chlorophyll-a (µg m^{-2}) at below dam test sites and reference sites on the Goodradigbee River from autumn 2024 to autumn 2026. Error bars represent +/- 1 standard error. **NOTE:** samples were not collected in autumn 2024 at site GM1 due to site being inaccessible during the sampling season.

BENTHIC MACROINVERTEBRATES

AUSRIVAS ASSESSMENT

Below-dams test sites were generally in poorer biological condition than reference sites in both spring 2025 and Autumn 2026, continuing a persistent long-term trend (Table 10). In Spring 2025, all below-dams sites scored band B or lower, with QM3 recording the poorest condition (band C), while reference sites largely maintained band A or above. This pattern persisted in Autumn 2026, with below-dams sites remaining predominantly in band B and reference sites retaining healthy band A. Since Autumn 2023, below-dams sites have achieved band A or above on only 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 autumn 2026 and declined its biological condition from being assessed as band A (similar to reference) in spring 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 – 0.85 (Table 10). The dominant taxa at this site in spring 2025 and autumn 2026 were Orthocladiinae and Hydroptilidae respectively (Appendix 2). No taxa were detected 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 2025 and autumn 2026.

Condition of the Cotter River below Bendora Dam (CM2) was assessed as band B (significantly impaired) in both spring 2025 and autumn 2026 (Table 10). This site has been stable with band B since spring 2024 (Table 10). The macroinvertebrate community at CM2 was characterised by a high abundance of Orthocladiinae in spring 2025 and Simuliidae in autumn 2026 (Appendix 2). The taxa Hydrobiosidae 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 autumn 2026. No taxon had been detected in spring 2025 in the 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 autumn 2026 but improved its biological condition from being assessed as band C (severely impaired) in spring 2025. (Table 10). Taxa Oligochaeta was the dominant taxon at the site in spring 2025, while Simuliidae dominated in autumn 2026 (Appendix 2). From taxa that were predicted to have a ≥50% chance of occurrence by the AUSRIVAS model taxa Psephenidae, Baetidae and Leptophlebiidae were detected in the whole sample scan in spring 2025, suggesting that this taxon was present, but in low abundances at this site. No taxon had been detected in autumn 2026 in the whole sample scan for this site (Table 11).

The site below Googong Dam (QM2) did not change its biological condition from being assessed as band B (significantly impaired) between spring 2025 and autumn 2025 (Table 10). In contrast, site QM3 has declined its biological condition from being assessed as band B (significantly impaired) in spring 2025 to band C (severely impaired) in autumn 2026.

Condition of both of these sites has varied over the past several years, varying condition bands of A to C (Table 10). The sites have been characterized by high abundances of tolerant Orthocladiinae and Chironominae in spring 2025 respectively and Simuliidae in autumn 2026 in both the sites (Appendix 2). Taxon Psephenidae in QM2, Hydrobiosidae and Hydropsychidae in 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 2026.

The biological condition of reference sites varied within and in between spring 2025 and autumn 2026, although most sites remained within band A, indicating conditions similar to reference. In spring 2025, most reference sites were assessed as band A, with CT2, GT1 and GT3 assessed as band X (more biologically diverse than reference) (Table 10). In autumn 2026, reference site condition showed greater variability, with CT3 assessed as band C (severely impaired) and QM1 assessed as band B (significantly impaired), while CT2 was not assessed and GM3 was assessed as band X. Overall, biological condition at reference sites in autumn 2026 was slightly poorer than in spring 2025, particularly within the Cotter and Queanbeyan River catchments. In contrast, reference sites within the Goodradigbee River catchment generally maintained better biological condition, with GM1 and GM2 remaining in band A across both seasons (Table 10). In spring 2025, the dominant taxa at the reference sites included Gripopterygidae CT1, GT1, GT2 and Gt3, Leptophlebiidae at CT2, GM1 and GM2, Simuliidae at CT3, and Oligochaeta at GM3 and QM1. In autumn, the dominant taxa reference site were Leptophlebiidae at CT1, GM1, GM2 and CT2, Simuliidae at CT3, Baetidae at GM and GT1, Leptoceridae at GT3 and Chironominae at QM1. Taxa Psephenidae at CT3, GM2 and GM3 and Hydropsychidae at GT3 and QM1 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 2025. Similarly, Tipulidae at CT1, Psephenidae at GT3 and Gomphidae at QM1 were 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 2026.

Macroinvertebrate condition exhibited a consistent and persistent difference between regulated and reference sites, with below-dam sites generally supporting poorer biological condition and greater dominance of tolerant taxa. This pattern was evident across both sampling periods and reflects a longer-term trend within the system.

Table 9: AUSRIVAS band and Observed/Expected taxa score for each site from autumn 2015 to autumn 2026. 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 2026	B (0.85)	B (0.79)	B (0.78)	B (0.84)	C (0.62)	A (1.07)	N/A	C (0.62)	B (0.81)	A (1.05)	A (1.05)	X (1.19)	A (1.05)	A (0.98)	A (0.88)
Spring 2025	A (1.00)	B (0.59)	C (0.37)	B (0.80)	B (0.77)	A (0.89)	X (1.15)	A (0.88)	A (1.04)	A (1.04)	A (0.89)	A (1.13)	X (1.20)	A (1.05)	X (1.20)
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)

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 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 spring 2025																
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									
Acarina	6		X									X				
Elmidae	7		X			X										
Psephenidae	6		X	X	X	X			X		X	X				
Tipulidae	5		X	X	X							X				
Simuliidae	5			X							X					
Tanypodinae	4	X	X	X						X		X				
Chironominae	3			X			X									
Baetidae	5		X	X	X											
Leptophlebiidae	8	X	X	X	X											
Caenidae	4		X	X		X			X						X	
Notonemouridae	6						X									
Hydrobiosidae	8	X		X	X	X	X			X					X	
Glossosomatidae	9	X	X	X	X	X	X	X	X				X	X		
Hydropsychidae	6			X		X		X	X	X	X	X	X		X	X
Conoesucidae	7			X	X	X			X							
Calocidae	9						X									
Leptoceridae	6						X									
TOTAL TAXA		**4**	**9**	**12**	**7**	**7**	**7**	**2**	**5**	**3**	**3**	**5**	**2**	**1**	**3**	**1**

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 2026 (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 flow during sampling	X	X						
Ancylidae	4				X	X			X	X						
Acarina	6					X			X			X				
Scirtidae	6	X												X		
Elmidae	7		X													
Psephenidae	6	X		X											X	
Tipulidae	5		X				X									
Podonominae	6		X	X	X	X	X		X	X	X	X	X		X	X
Tanypodinae	4	X	X			X			X	X						
Coloburiscidae	8	X												X		
Leptophlebiidae	8		X		X	X			X							
Gomphidae	5			X												X
Gripopterygidae	8			X							X					
Hydrobiosidae	8	X	X	X	X	X			X	X	X	X	X			X
Glossosomatidae	9	X					X							X		
Hydroptilidae	4					X			X	X					X	X
Hydropsychidae	6														X	
Leptoceridae	6		X		X	X			X							
TOTAL TAXA		**6**	**7**	**5**	**6**	**9**	**3**		**9**	**6**	**3**	**3**	**2**	**3**	**4**	**4**

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 2025 (Figure 7). Below dams sites showed some improvement with increases in EPT composition, especially at most upstream Cotter River CM1 and Queanbeyan river sites QM2 and QM3, in autumn 2026 (Figure 8). Reference sites were generally dominated by EPT taxa in both the spring 2025 and autumn 2026 assessments, except for site CT3, GM3 and QM1 in spring 2025 which had higher OC and EPT (Figure 7, Figure 8).

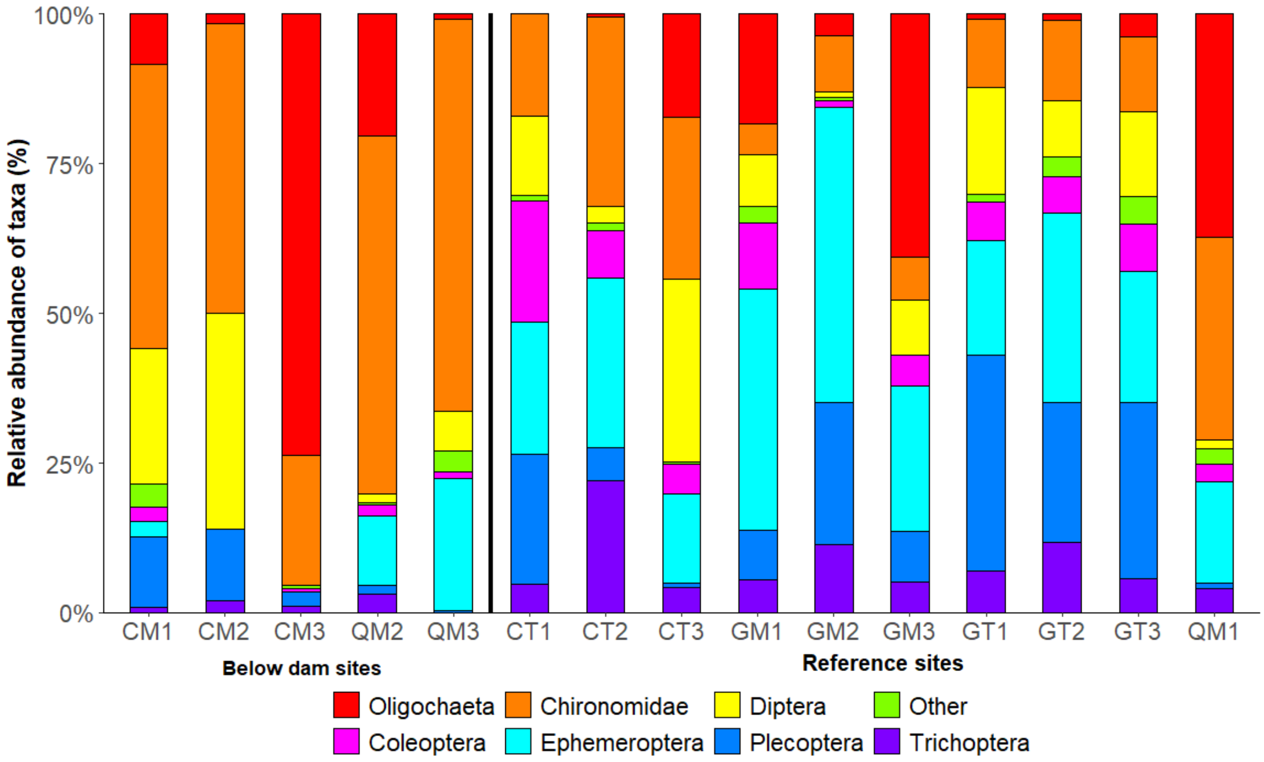

Figure 7: Relative abundance of macroinvertebrate taxonomic groups from samples collected in spring 2025.

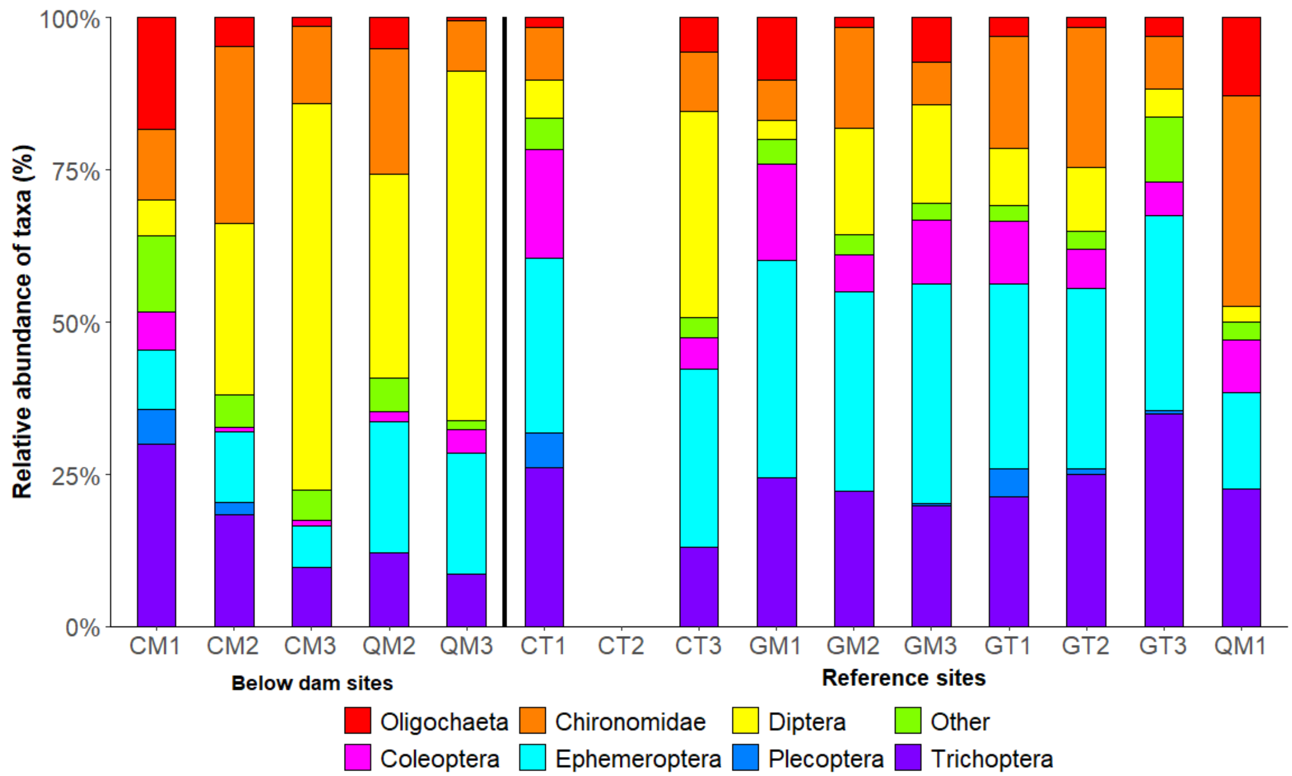

Figure 8: Relative abundance of macroinvertebrate taxonomic groups from samples collected in autumn 2026.
Note: The sites without a bar graph indicates unavailability of data due to low flow during sampling.

MACROINVERTEBRATE ASSEMBLAGE SIMILARITY

Macroinvertebrate community composition differed significantly between below dams sites and reference sites in both the spring 2025 assessment (PERMANOVA: $F_{1,13} = 4.72$, $R^2 = 0.27$, $p = 0.001$) and the autumn 2026 assessment (PERMANOVA: $F_{1,12} = 2.78$, $R^2 = 0.19$, $p = 0.016$), indicating clear differences in assemblage structure between regulated and reference river sites. The separation between below dams and reference sites was more pronounced in spring 2025 compared to autumn 2026, reflecting stronger seasonal differences in macroinvertebrate communities during spring (Figure 9).

In spring 2025, reference sites were more strongly associated with environmentally sensitive taxa including Baetidae, Leptophlebiidae, Gripopterygidae, Conoesucidae and Aphroteniinae, whereas below dams sites had stronger associations with Tanypodinae and revealed reduced correlation with several sensitive taxa (Figure 9). In autumn 2026, reference sites were associated with taxa such as Leptophlebiidae, Helicopsychidae and Calocidae, while below dams sites were more closely associated with Simuliidae, Hydrophilidae and Hydroptilidae (Figure 10).

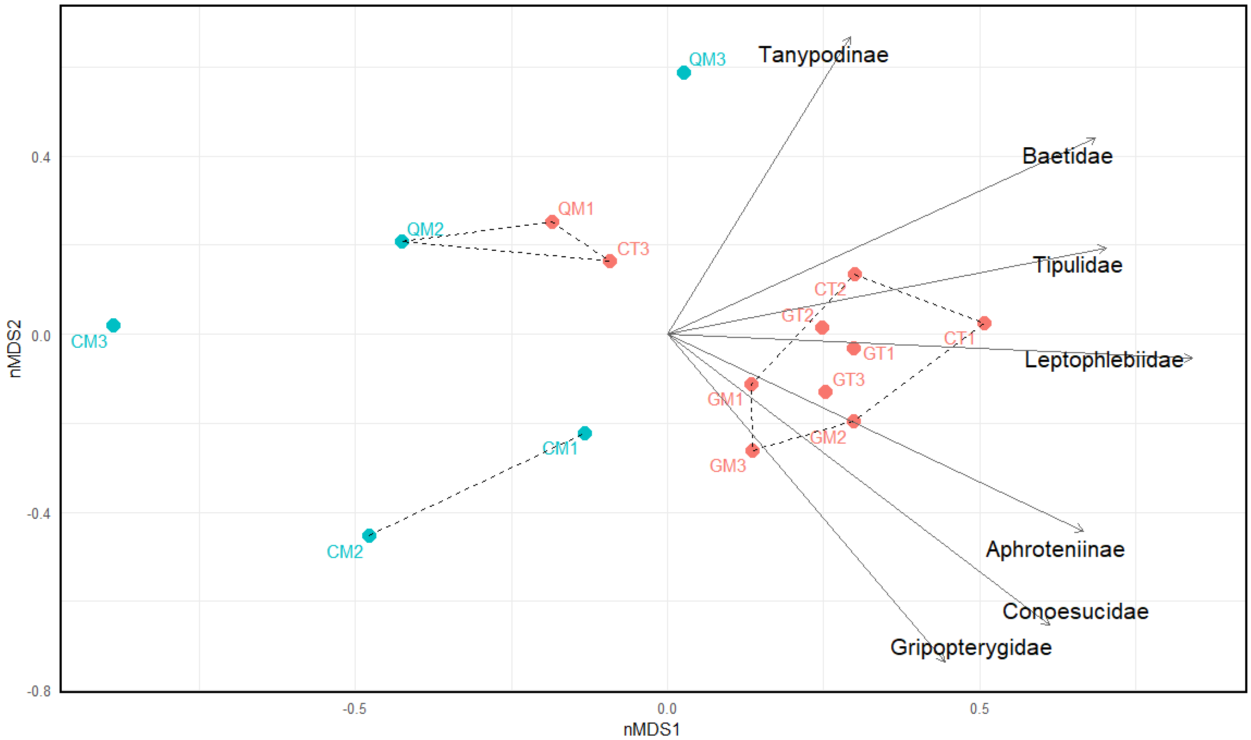

Figure 9. nMDS ordination of 40% similarity between macroinvertebrate samples collected in spring 2025 for the below dams assessment program (polygon with dashed line). Similarity is based on macroinvertebrate relative abundance. Macroinvertebrate taxa with Pearson correlations greater than 0.75 (i.e. 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.

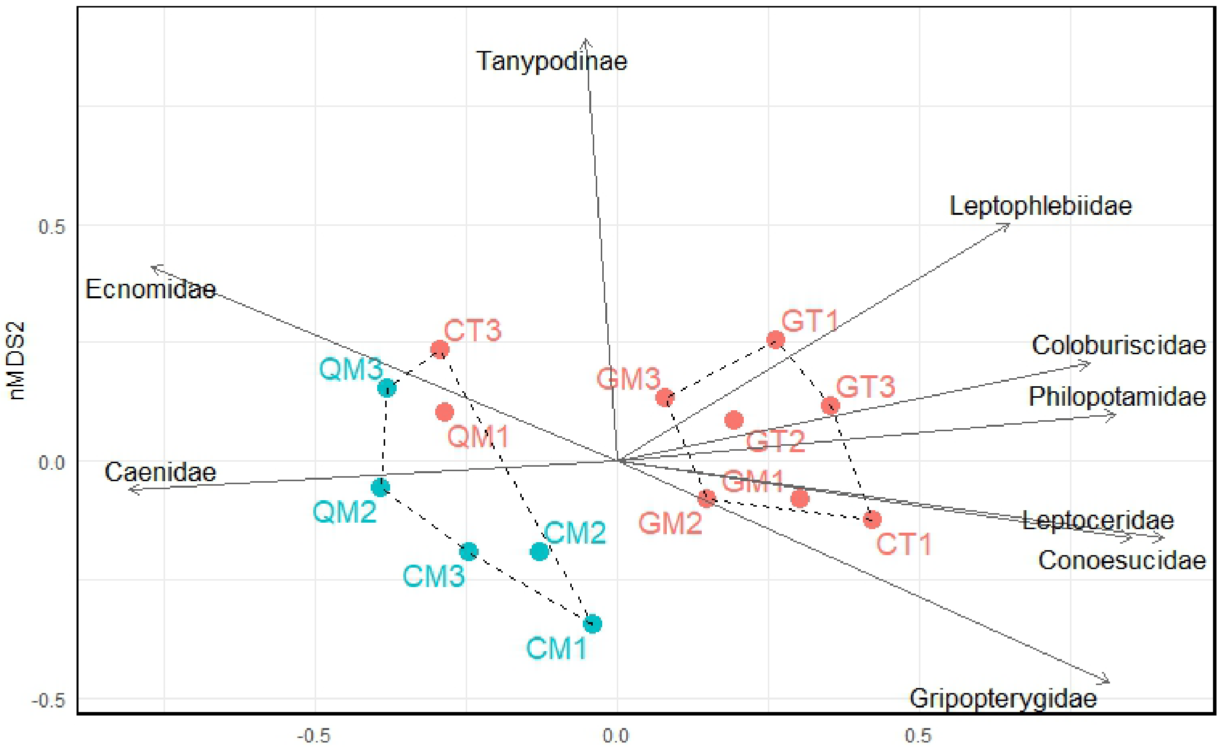

Figure 10. nMDS ordination of 40% similarity between macroinvertebrate samples collected in autumn 2026 for the below dams assessment program (polygon with dashed line). Similarity is based on macroinvertebrate relative abundance. Macroinvertebrate taxa with Pearson correlations greater than 0.75 (i.e. 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.

DISCUSSION

Across the monitored indicators, results showed a clear contrast in the consistency of responses between regulated and reference sites. Flow conditions and water quality were broadly comparable across sites and seasons, with only localised variation and no consistent pattern attributable to regulation. Filamentous algal cover remained consistently below ecological thresholds at all sites, and periphyton biomass and productivity exhibited spatial and temporal variability but no systematic differences between regulated and reference groups. In contrast, macroinvertebrate condition showed a persistent and consistent divergence, with below-dam sites generally supporting poorer biological condition and a greater dominance of tolerant taxa relative to reference sites. Taken together, these findings indicate that while current flow regimes are effective in achieving algal-based objectives and maintaining broadly acceptable physicochemical conditions, they do not translate to equivalent biological condition, suggesting that additional factors beyond flow and nutrient dynamics are influencing ecological outcomes downstream of dams. This pattern of indicator decoupling — where physical and chemical indicators may meet management objectives while biological condition remains impaired — is increasingly recognised in the regulated river literature as a fundamental challenge for environmental flow programs (A. J. Brooks et al., 2024; Calapez et al., 2021; Feio et al., 2021)

WATER QUALITY

Water quality was generally within guideline ranges across both regulated and reference sites, with nutrient exceedances observed in both groups, particularly during autumn 2026. The lack of a consistent difference between regulated and reference sites indicates that nutrient enrichment is not solely attributable to regulation and likely reflects a combination of catchment-scale inputs and reservoir-related processes. While some exceedances were more frequent downstream of dams, the overall pattern suggests that water quality differences are unlikely, in isolation, to explain the observed differences in biological condition. This finding is consistent with broader evidence that catchment-scale nutrient loads can override reach-scale regulation signals, making it difficult to attribute water quality variation to dam operation alone (Calderon et al., 2023). Multiple-stressor research has further demonstrated that biological impairment in rivers is frequently explained by the interaction of nutrient enrichment with altered flow and habitat condition, rather than by any single variable (Fanelli et al., 2022).

FILAMENTOUS ALGAE AND PERIPHYTON

Filamentous algae objectives were consistently met at all regulated sites, demonstrating that current flow regimes are effective in limiting excessive filamentous growth in riffle habitats. This outcome aligns with established understanding that managed flow variability, particularly the inclusion of periodic higher-velocity releases, can suppress filamentous algal development by promoting scouring and reducing biomass accrual (Biggs et al., 2008; Uehlinger et al., 2003). The maintenance of algal objectives through flow management is encouraging and confirms that the flow regime is achieving one of its primary ecological targets.

In contrast, periphyton cover and biomass displayed considerable spatial and temporal variability, including localised elevated values at some sites (notably CM1 and QM2), but without consistent differences between regulated and reference groups. The absence of a clear system-level difference in periphyton biomass (AFDM and chlorophyll-a) suggests that dam operations are not driving persistent increases in benthic productivity. Instead, observed variability is more likely driven by site-specific factors such as nutrient availability, light, substrate stability, and short-term flow conditions. These findings are consistent with global analyses showing that periphyton accrual is controlled by the interaction of flow velocity, nutrient bioavailability, light regime, and local substrate characteristics, rather than by flow regulation per se (De Silva & Hodson, 2020; Young & Collier, 2009). Site-specific nutrient limitation, in particular, can decouple periphyton responses from broader system-level drivers (Moulton et al., 2004). These findings indicate that algal-based objectives are being achieved, but that biomass-based responses are more variable and not strongly structured by regulation at the scale of this study.

BENTHIC MACROINVERTEBRATES

In contrast to the physical and primary producer responses, macroinvertebrate assemblages showed a clear and persistent difference between regulated and reference sites. Below-dam sites remained predominantly within AUSRIVAS bands B and C, while reference sites were largely within band A, consistent with long-term patterns observed in the program. This outcome is consistent with the established performance of AUSRIVAS predictive models in detecting macroinvertebrate impairment downstream of dams in south-eastern Australia, where depressed observed-to-expected (O/E) ratios have been reported across multiple regulated systems (Marchant & Hehir, 2002; Nichols et al., 2000a) Assemblages at regulated sites were characterised by higher dominance of tolerant taxa and reduced representation of sensitive EPT taxa (Ephemeroptera, Plecoptera and Trichoptera), although some seasonal improvement was observed in autumn 2026 at selected sites. Reductions in EPT richness and relative abundance are among the most consistently reported biological responses to flow regulation globally, reflecting the sensitivity of these taxa to altered hydrological variability, habitat structure, and substrate conditions (Calapez et al., 2021; Calderon et al., 2023; HAN et al., 2012).

The consistency of this difference, despite broadly similar water quality and periphyton responses, indicates that macroinvertebrate condition is influenced by factors not captured by algal or water quality indicators alone. Altered flow regimes remain a plausible driver, particularly through effects on habitat structure, hydraulic variability, and substrate stability, which are known to influence macroinvertebrate communities. Dams interrupt longitudinal sediment continuity, creating sediment-starved downstream reaches characterised by altered substrate composition, reduced habitat heterogeneity and modified channel morphology — conditions that can reduce macroinvertebrate diversity even in the absence of detectable water quality impairment (Calderon et al., 2023; Katano et al., 2021). In the context of Australian regulated rivers, (Chessman et al., 2022) demonstrated that hydraulic velocity preferences of macroinvertebrate families are strongly structured by flow conditions downstream of dams, further supporting the inference that flow-mediated habitat change is an important driver of assemblage composition, independent of water quality.

However, the absence of consistent differences in other response variables suggests that flow alone does not fully explain the observed patterns. Rather, the results point to the influence of interacting drivers, including local habitat conditions, site-specific geomorphology, and seasonal variability, which may constrain the recovery or persistence of sensitive taxa. This interpretation is reinforced by a growing body of multiple-stressor research demonstrating that biological impairment in regulated systems often arises from the non-additive interaction of flow alteration with other catchment and reach-scale stressors, such that ameliorating flow alone may not be sufficient to restore macroinvertebrate condition to reference-equivalent states (Fanelli et al., 2022; van Klink et al., 2024). Evidence from long-term monitoring programs in Australia similarly suggests that meaningful improvement in benthic invertebrate assemblages requires sustained high-flow delivery over many years, sufficient to mobilise fine sediment accumulations and restore hydraulic habitat diversity (A. Brooks et al., 2024).

SITE SPECIFIC BIOLOGICAL CONDITION

Site-level responses further support the importance of local controls on ecological condition. Sites such as CM1 and QM2 exhibited elevated periphyton biomass at times but did not consistently support improved macroinvertebrate condition, while other sites showed variability in biological condition independent of clear changes in water quality or algal metrics. This decoupling between indicators is consistent with broader findings that macroinvertebrate condition is a more integrative and temporally lagged response variable than water quality or algal metrics, reflecting accumulated effects of habitat structure, hydrological history and colonisation dynamics rather than immediate physicochemical conditions (Calapez et al., 2021; Wang et al., 2023). The observed site-level variation also highlights the role of local geomorphology in mediating ecological outcomes: sites embedded within distinct substrate or channel configurations may respond differently to the same flow regime, irrespective of broader system-level management actions. These findings reinforce the need to consider site-scale processes alongside system-scale drivers in the design and interpretation of ecological monitoring programs for regulated rivers.

CONCLUSION

Environmental flow management has been effective in achieving its primary objective: all regulated sites consistently met the filamentous algae cover target in both spring 2025 and autumn 2026, demonstrating that the flow regime is functioning as intended with respect to algal growth control. Water quality was broadly within guideline ranges, and periphyton biomass showed no systemic differences between regulated and reference groups, further supporting the conclusion that flow management is achieving its physicochemical objectives at a system scale.

However, macroinvertebrate condition at regulated sites remained consistently and substantially lower than at reference sites, and no below-dam sites met the Band A ecological objective in autumn 2026. This pattern is persistent, having been observed across multiple assessment periods, and is not explained by the current suite of water quality or algal indicators. The weight of evidence suggests that macroinvertebrate impairment reflects the interaction of multiple drivers — including altered flow regime, modified substrate and in-stream habitat structure, and catchment-scale nutrient dynamics — rather than any single stressor. Achieving macroinvertebrate condition comparable to reference sites is unlikely to be possible through flow management alone and will require a more detailed understanding of the specific drivers operating at each regulated site.

Targeted investigative work is recommended to diagnose the causes of persistent macroinvertebrate impairment. This should prioritise systematic physical habitat and substrate assessment at regulated and reference sites, functional trait analysis of existing macroinvertebrate datasets, and evaluation of the hydrological, geomorphic, and connectivity conditions at each site. The outcomes of this work would provide a stronger evidence base for evaluating whether adaptive management of the current flow regime, or complementary non-flow interventions, are required to achieve the program's biological condition objectives.

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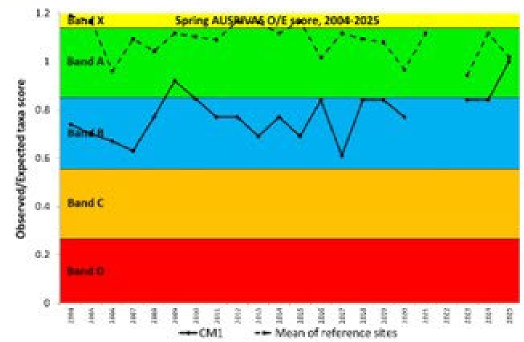
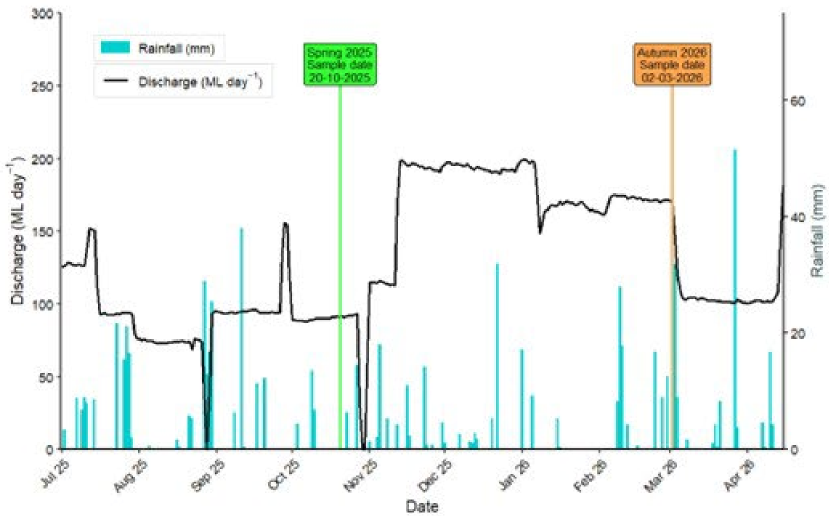
APPENDIX 1: BELOW DAM SITE SUMMARY SHEETS

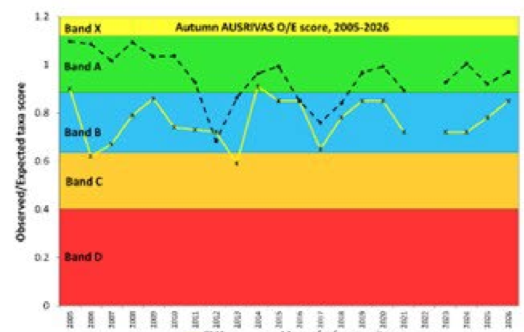
CM1 - Spring 2025 - Autumn 2026

Downstream of Corin Dam

Environmental flow ecological objective	Spring 2025	Autumn 2026	Objective met?
AUSRIVAS band A	Band A	Band B	Only for Spring 2025
<20% filamentous algae cover in riffle habitat	<10%	<10%	Yes, for both assessment







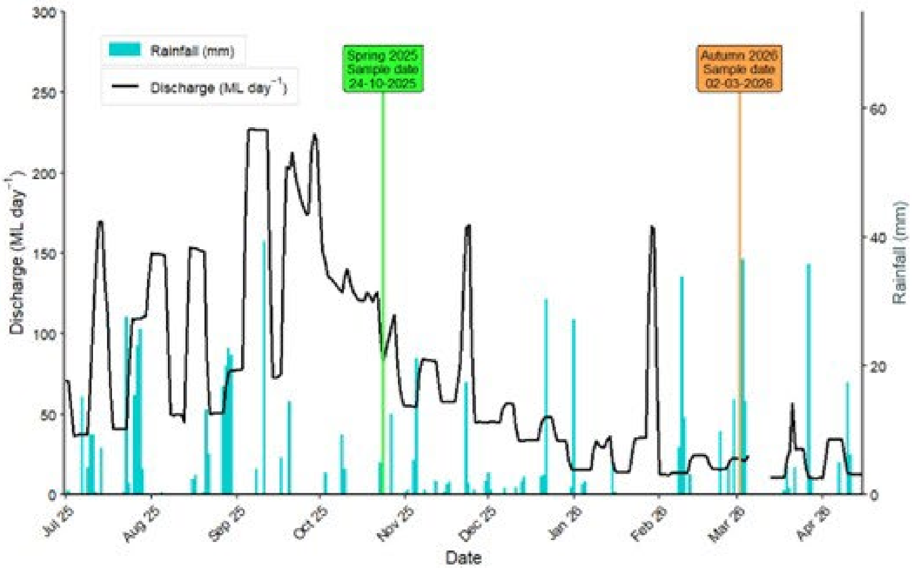
* Denotes values outside guideline levels

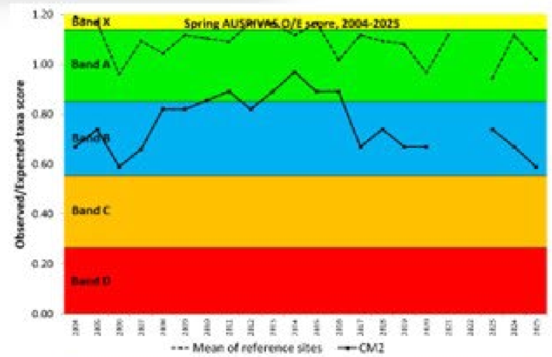
Sampling season	Temp. (°C)	EC (µs cm^{-1})	pH	D.O. (mg l^{-1})	Turbidity (NTU)	Alkalinity (mg L^{-1})	NH_4^+ (mg L^{-1})	NOx (mg L^{-1})	TN (mg L^{-1})	TP (mg L^{-1})
Spring 2025	10.01	27	7.72	10.26	0.0	10	0.01	0.024	0.09	0.01
Autumn 2026	19.43	29	7.64	8.37	0.0	8	0.01	<0.004	0.08	<0.002

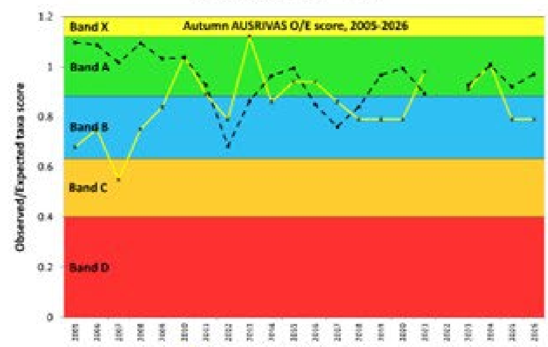
CM2 - Spring 2025 - Autumn 2026

Downstream of Bendora Dam

Environmental flow ecological objective	Spring 2025	Autumn 2026	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 2025	10.73	25	7.74	10.24	0.0	8	0.01	0.005	0.08	0.01
Autumn 2026	19.55	29	6.60	8.47	0.0	8	0.01	0.011	**0.28**	0.02

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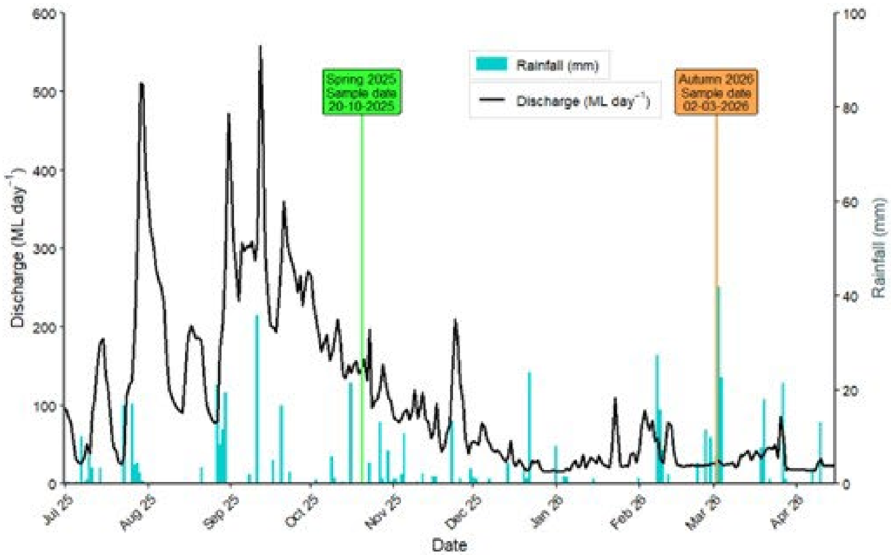
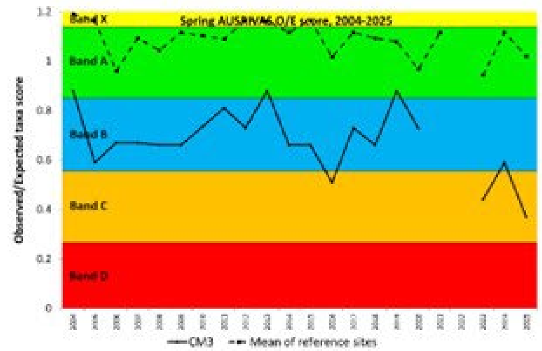
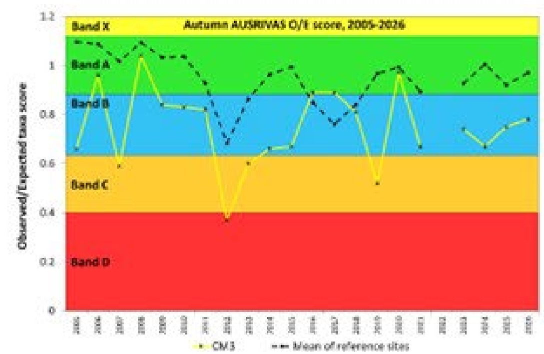
CM3 - Spring 2025 - Autumn 2026

Downstream of Cotter Dam

Environmental flow ecological objective	Spring 2025	Autumn 2026	Objective met?
AUSRIVAS band A	Band C	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 2025	15.41	40	7.24	9.25	0.0	14	0.00	0.008	0.13	0.02
Autumn 2026	21.77	170	7.05	8.11	0.0	44	<0.004	0.013	0.42	0.03

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QM2

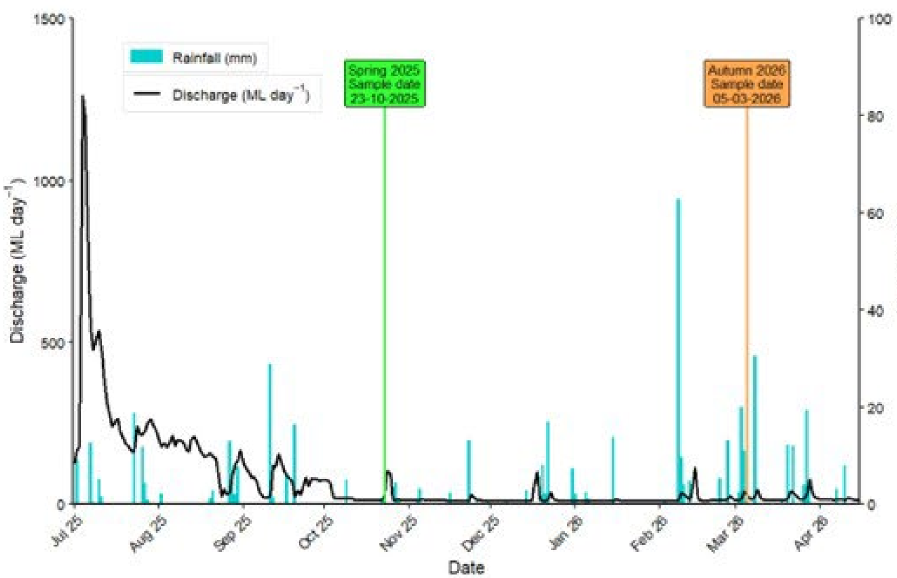
- Spring 2025
- Autumn 2026

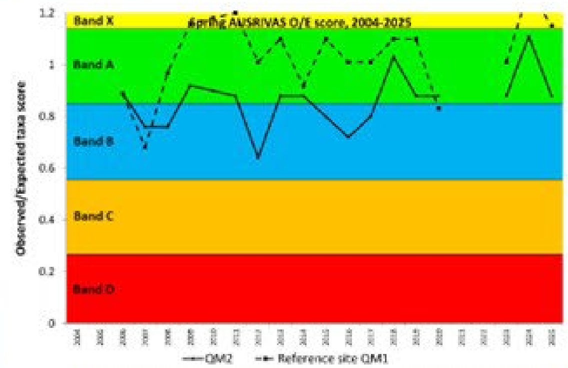
Downstream of Googong Dam

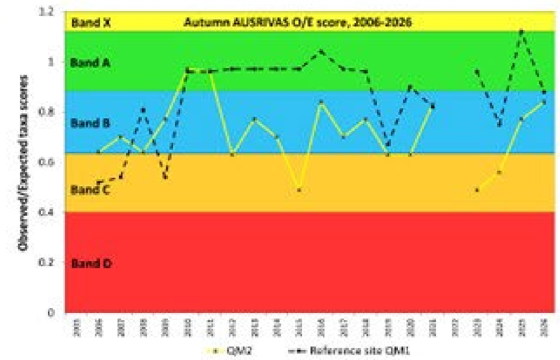
Environmental flow ecological objective	Spring 2025	Autumn 2026	Objective met?
AUSRIVAS band A	Band B	Band B	Not for either assessment
<20% filamentous algae cover in riffle habitat	<10%	<10%	Yes, for both assessment


Spring 2025


Autumn 2026







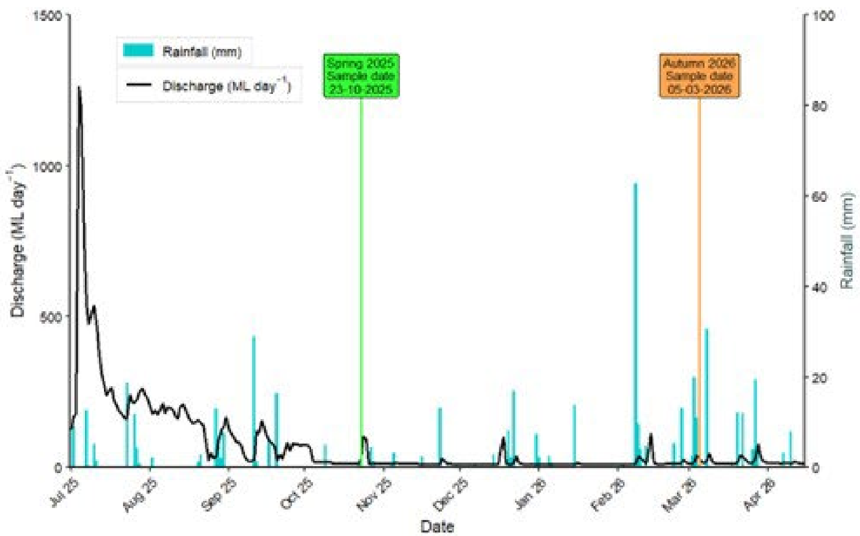
* Denotes values outside guideline levels

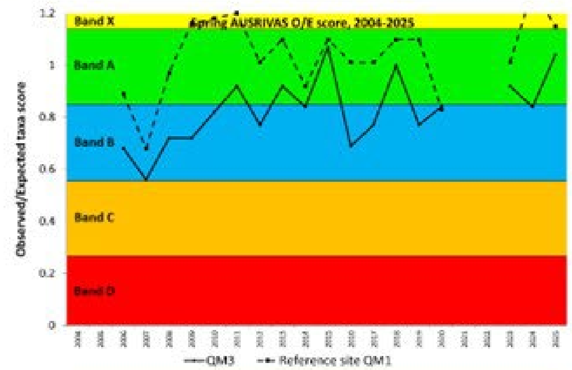
Sampling season	Temp. (°C)	EC (µs cm^{-1})	pH	D.O. (mg l^{-1})	Turbidity (NTU)	Alkalinity (mg L^{-1})	NH_4^+ (mg L^{-1})	NOx (mg L^{-1})	TN (mg L^{-1})	TP (mg L^{-1})
Spring 2025	14.65	103	**8.18**	9.98	0.0	36	0.01	**0.021**	**0.35**	0.02
Autumn 2026	22.19	121	7.76	9.09	0.0	40	0.01	**0.018**	**0.26**	0.01

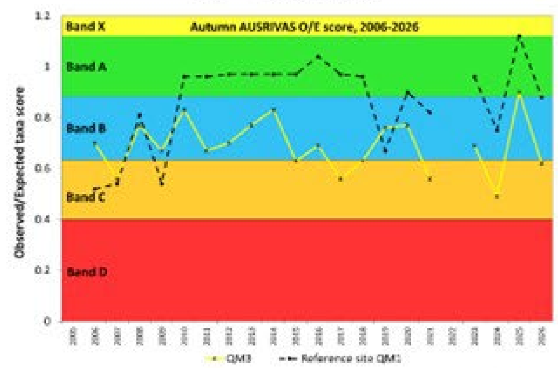
QM3 - Spring 2025 - Autumn 2026

2km Downstream of Googong Dam

Environmental flow ecological objective	Spring 2025	Autumn 2026	Objective met?
AUSRIVAS band A	Band B	Band C	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 2025	16.85	126	8.38	9.15	0.0	42	0.01	0.008	0.37	0.03
Autumn 2026	23.3	260	7.97	8.66	0.0	69	0.01	0.045	0.44	0.02

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APPENDIX 2: MACROINVERTEBRATE TAXA SPRING 2025

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

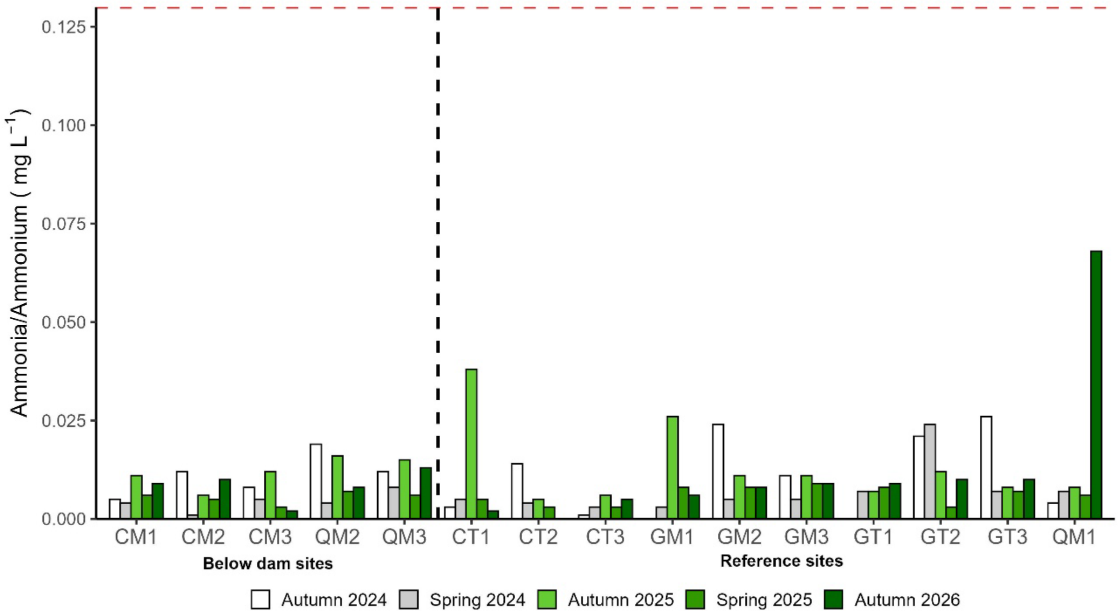
CLASS **Order** Family *Sub-family*	**Signal 2 Grade**	**Test sites**					**Reference sites**									
		CM1	**CM2**	**CM3**	**QM2**	**QM3**	**CT1**	**CT2**	**CT3**	**GM1**	**GM2**	**GM3**	**GT1**	**GT2**	**GT3**	**QM1**
Gastropoda																
Physidae	**1**															1
Lymnaeidae	**1**	2														
Bivalvia																
Sphaeriidae	**5**					7								1		
OLIGOCHAETA	**2**	17	3	145	45	2		1	45	40	7	87	2	2	8	75
ACARINA	**6**	4		1	1	1	1	1	1	1	1		2	4	6	3
Coleoptera																
Scirtidae Sp.	**6**						1	5					1			
Dytiscidae	**2**					3										
Elmidae (Adult)	**7**						14		1	5		1	4	1	4	1
Elmidae (Larvae)	**7**	3		1	4		23	8	12	8	2	9	9	11	12	5
Gyrinidae	**4**											1				
Psephenidae	**6**	2					4	4		11			1	1	1	
Ptilodactylidae	**10**						1									
Diptera																
Tipulidae	**5**	2				5	10	4	1	16	1		1	6	10	
Ceratopogonidae	**4**				1				3					2		2
Simuliidae	**5**	42	69		1	12	4	1	74	2		20	40	8	20	1
Athericidae	**8**	1					13		2	1	1			4		
Empididae	**5**	1	1				1	1								
Diamesinae	**6**														5	
Aphroteniinae	**8**	1					4	5			7	4	2	5	1	
Tanypodinae	**4**				3	2	1	11	2		2		2	2	3	11
Orthocladiinae	**4**	95	93	43	121	49	31	33	43	10	6	8	12	16	14	27
Chironominae	**3**	1	1		9	124		19	26	1	3	3	10	6	4	30
Podonominae	**6**							1								
Psychodidae	**3**				1	1										
Ephemeroptera																
Baetidae	**5**	2				58	4	19	24	17	12	16	23	24	3	2
Coloburiscidae	**8**						5				12	1	1		1	
Leptophlebiidae	**8**					1	36	42	15	66	67	29	13	37	43	5
Caenidae	**5**	3			26		2	1		5	5	6	7	7		27
Megaloptera																
Corydalidae	**7**	2						1		2				1	2	
Odonata																
Telephlebiidae	**9**					1	1						1	1		
Gomphidae	**5**									3					2	1
Aeshnidae	**4**							1								
Plecoptera																
Gripopterygidae	**8**	24	23	5	3	1	46	12	2	18	46	18	83	50	63	2
Trichoptera																
Hydrobiosidae	**8**		1					4	10		1	4	1	2		3
Glossosomatidae	**9**									2	5	1			1	1
Helicopsychidae	**8**							14		1	1	1	1	2	1	
Hydroptilidae	**8**						2	3	1							1
Philopotamidae	**8**			2										1	2	
Hydropsychidae	**6**	1	2		3		1							1		
Ecnomidae	**4**				4			3		1				5		3
Conoesucidae	**8**	1	1				7	22		8	9	3	5	3	6	
Calamoceratidae	**7**							2						6	1	
Tasimiidae	**8**												1			
Leptoceridae	**6**										6	2	8	5	1	
No. of individuals		204	194	197	222	267	212	218	262	218	194	214	230	214	214	201
No. of taxa		18	9	6	13	14	22	25	16	20	19	18	23	28	24	19
% of sub-sample		8	2	6	4	2	7	7	4	9	4	2	3	5	5	2
Whole sample estimate		**2550**	**9700**	**3283**	**5550**	**13350**	**3029**	**3114**	**6550**	**2422**	**4850**	**10700**	**7667**	**4280**	**4280**	**10050**

APPENDIX 2: MACROINVERTEBRATE TAXA AUTUMN 2026

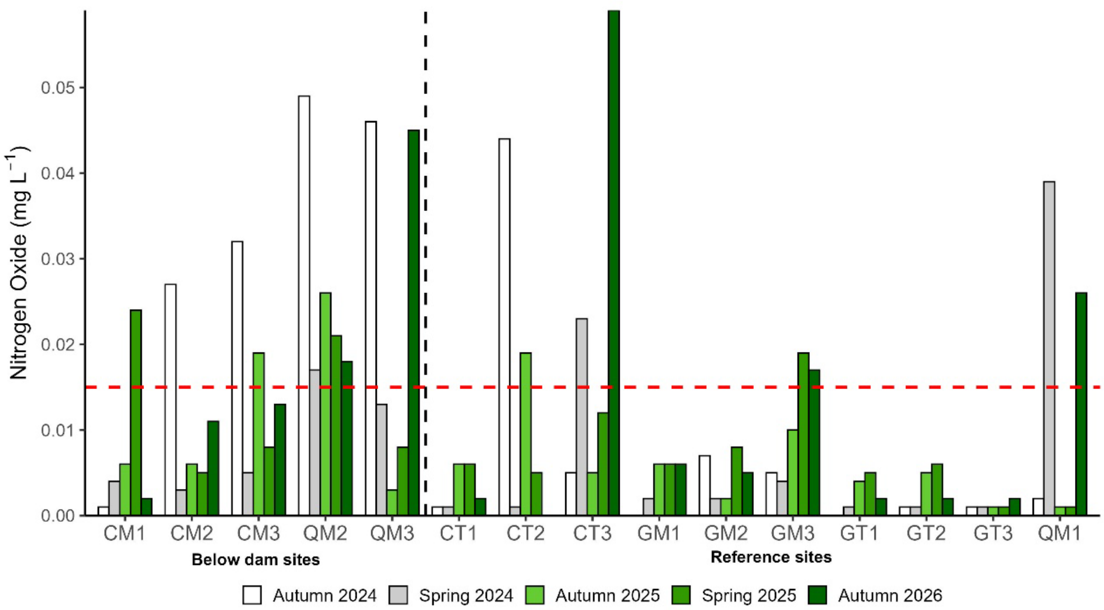
Macroinvertebrate taxa and their sensitivity grade (SIGNAL 2) (Chessman, 2003) collected from sub-samples in autumn 2026 at each of the study sites. **NOTE:** Orange highlight indicates maximum taxa of the site for the sampling season.

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								**No flow during sampling**								
Physidae	1	1														
Bivalvia																
Sphaeriidae	5	1	1	2	1	2	4					4	1	4	2	5
Cyrenidae	4		7													
OLIGOCHAETA	2	38	12	3	12	1	3		12	20	4	18	6	3	6	30
ACARINA	6	17		5	4		4			6	3		3	2	14	2
Coleoptera																
Scirtidae Sp.	6			1						2	1					
Elmidae (Adult.)	7	3			1	4	3		1	1		1	1		1	8
Elmidae (Larvae)	7	3		1		4	27		3	23	5	17	14	10	10	12
Psephenidae	6		1		1		3		5	5	9	8	3	2		
Ptilodactylidae	10						2									
Hydrophilidae	2	7	1		2				2				3			
Chrysomelidae	2													1		
Diptera																
Dolichopodidae	3											1				
Tipulidae	5	7			2	2			3	3		1	1	1	1	3
Ceratopogonidaen	4				1				1				1			
Dixidae	7					1										
Simuliidae	5	5	73	130	77	116	11		69	3	40	38	14	19	8	3
Athericidae	8						1				2		3	1		
Aphroteniinae	**8**			1											1	
Tanypodinae	**4**			2	1		1				1	3	1	3	2	13
Orthocladiinae	**4**	23	18	4	17	9	7		17	11	13	10	3	17	5	11
Chironominae	**3**	1	58	19	31	8	9		4	2	26	4	33	26	9	57
Ephemeroptera																
Baetidae	5	2	23	9	18	10	6		27	12	24	61	36	6	26	14
Coloburiscidae	8						2				6	4			2	
Leptophlebiidae	8	1		1			41			46	47	12	11	43	26	2
Caenidae	5	17	7	4	33	31	7		36	12	2	12	14	10	9	21
Hemiptera																
Micronectidae	2											1				
Megaloptera																
Corydalidae	7	5	6	3	5		1		1		2	1	1		1	
Odonata																
Telephlebiidae	9				1		1			1					3	
Gomphidae	5				1	1			6	1	3	1				
Aeshnidae	4	2			1										1	
Plecoptera																
Gripopterygidae	8	12	5				11					1	9	2	1	
Trichoptera																
Hydrobiosidae	8						1							1	1	
Helicopsychidae	8						1			5				2	2	
Hydroptilidae	8	44	13		1		9				1	5	4	1		
Philopotamidae	8		4	1	1	1			1	4	24	2	7	10	9	1
Hydropsychidae	6	8	20	16	18	10	28		25	11	20	28	3	1		39
Ecnomidae	4	4	7	3	9	7			1	2	1	6		2	4	13
Conoesucidae	8	5	4				4		1	18	7	8	6	2	4	
Calocidae	9						8			2			3		1	
Calamoceratidae	7									2	1		2	11	12	
Leptoceridae	6	1								4			18	20	36	
No. of individuals		207	260	205	238	207	195		215	196	242	247	201	200	197	234
No. of taxa		22	17	17	22	15	25		18	23	22	24	26	25	27	16
% of sub-sample		4	2	2	2	2	2		4	1	2	3	2	2	7	3
Whole sample estimate		5175	13000	10250	11900	10350	9750		5375	19600	12100	8233	10050	10000	2814	7800

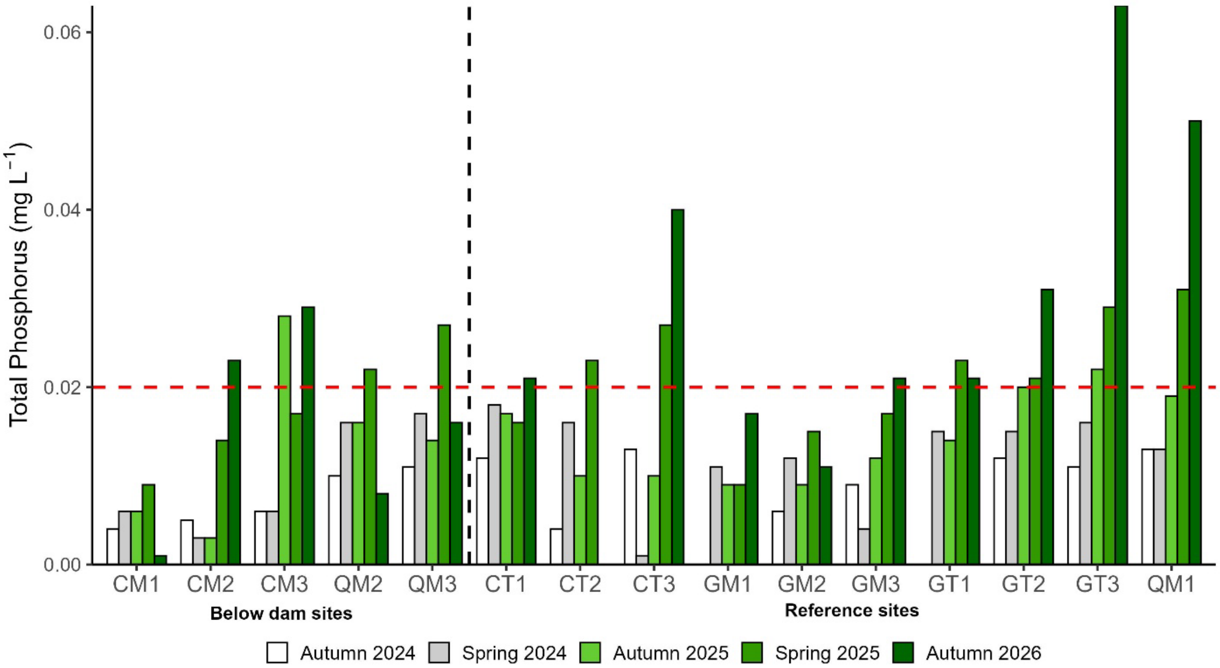
APPENDIX 3: WATER QUALITY FIGURES



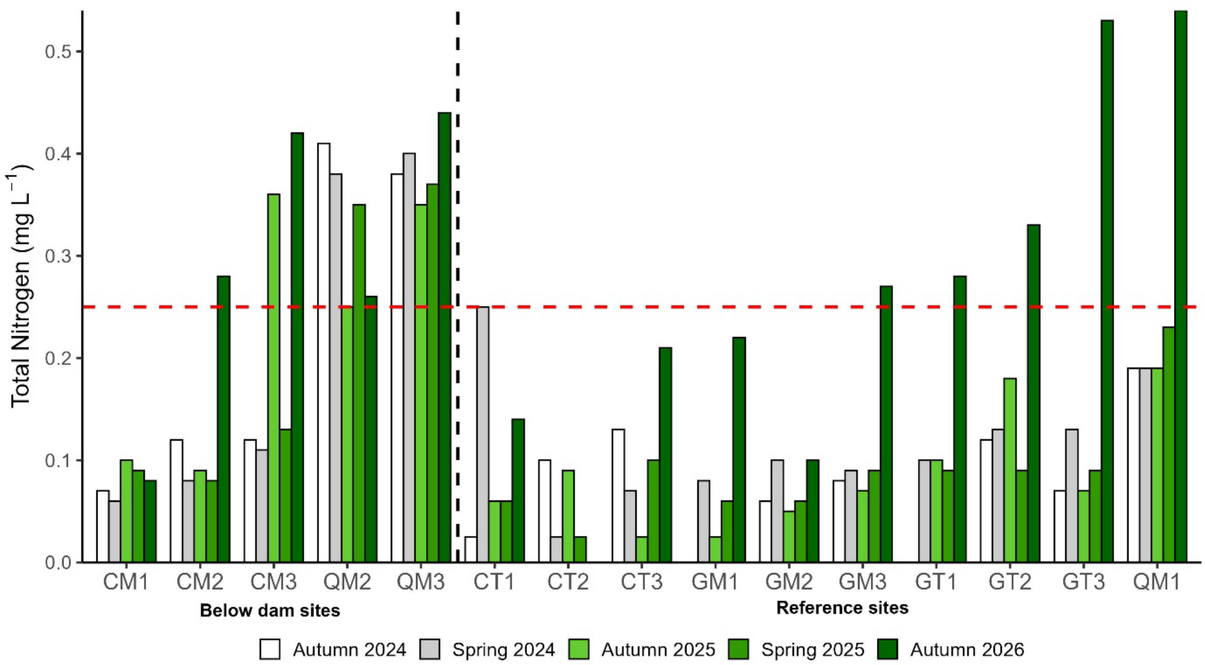
Ammonium (NH_4^+) concentration at all sites from autumn 2023 to autumn 2026. Values below the minimum detectable limit of 0.002 mg L^{-1} are shown at 0.001 mg L^{-1}. The ANZECC/ARMCANZ (2000) guideline maximum concentration for ammonium (NH_4^+) is dashed line and shaded red.



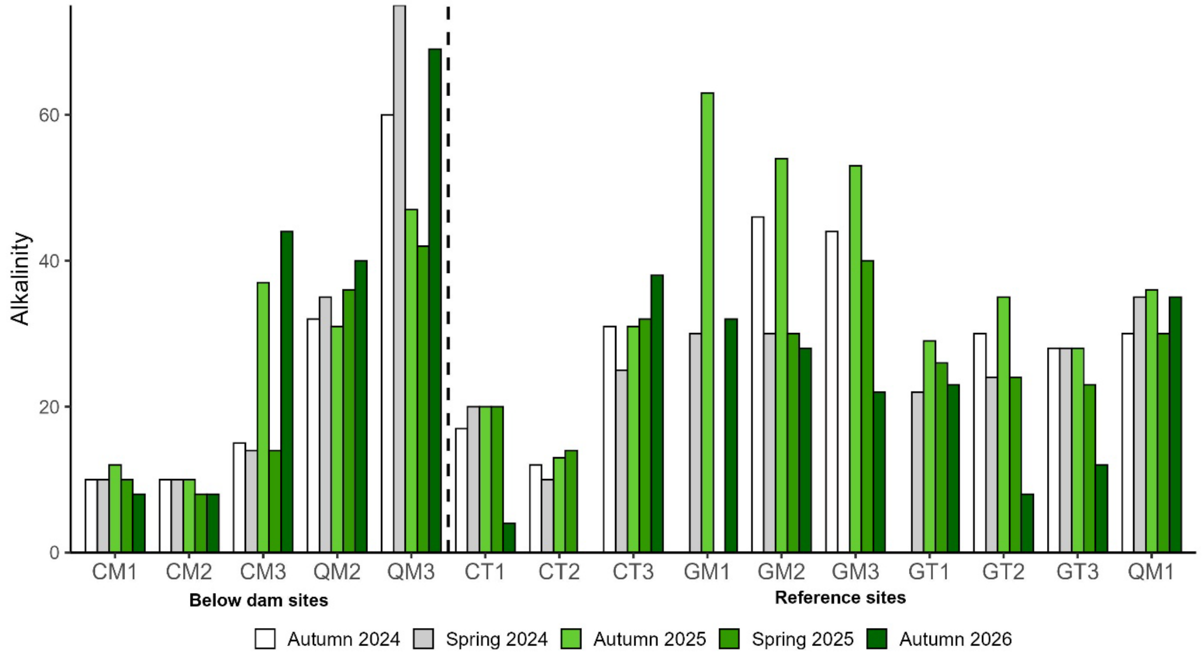
Nitrogen oxide concentrations at all sites from autumn 2023 to autumn 2026. Values below the minimum detectable limit of 0.002 mg L-1 are shown at 0.001 mg L-1. The ANZECC/ARMCANZ (2000) guideline maximum concentration for nitrogen oxide is dashed line and shaded red.



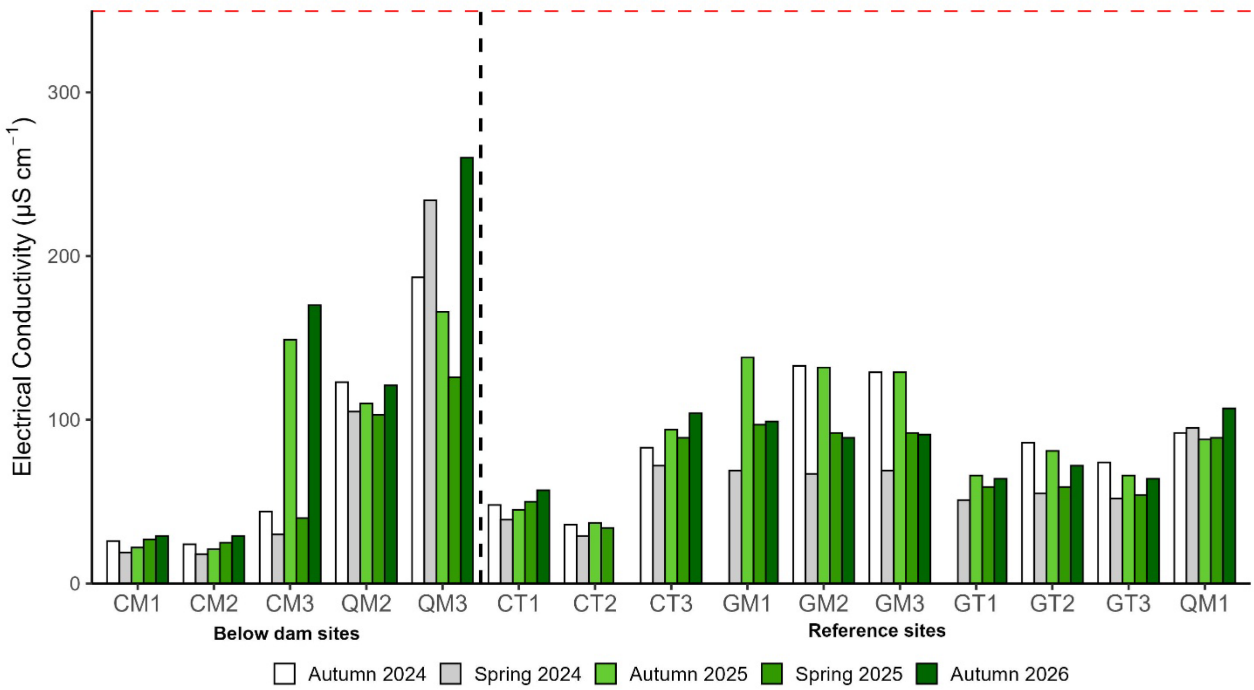
Total phosphorus concentrations at all sites from autumn 2023 to autumn 2026. Values below the minimum detectable limit of 0.01 mg L-1 are shown at 0.005 mg L-1. The ANZECC/ARMCANZ (2000) guideline maximum concentration for total phosphorus is dashed line and shaded red.



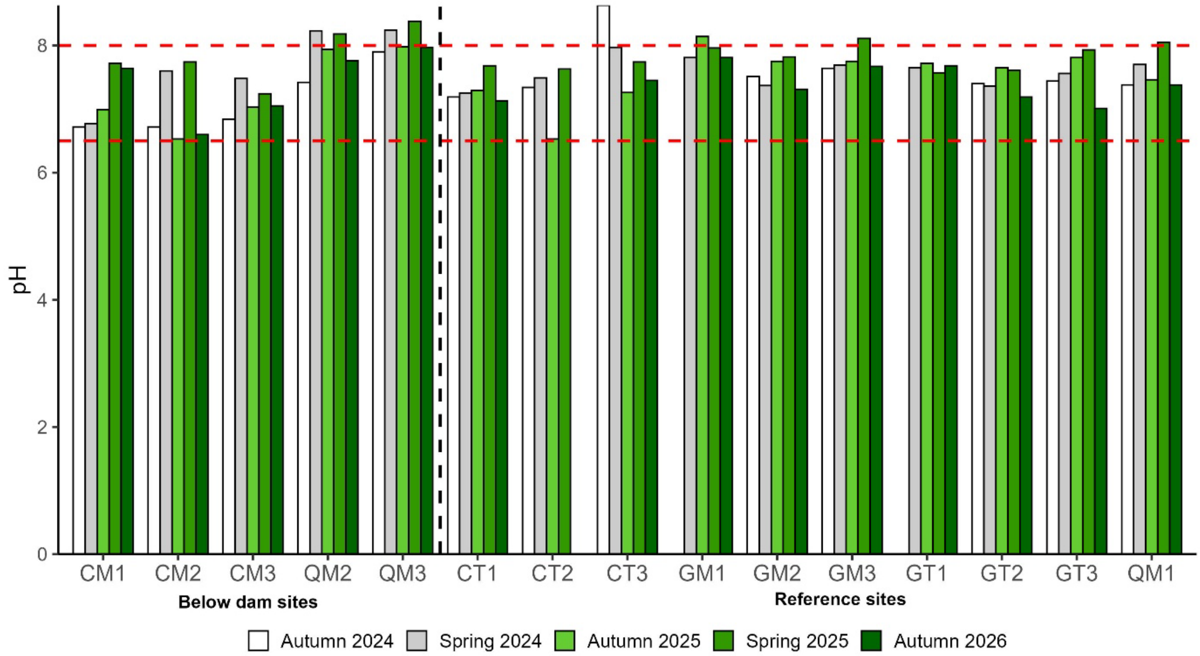
Total nitrogen concentrations at all sites from autumn 2023 to autumn 2026. Values below the minimum detectable limit of 0.01 mg L-1 are shown at 0.005 mg L-1. The ANZECC/ARMCANZ (2000) guideline maximum concentration for total nitrogen is dashed line and shaded red.



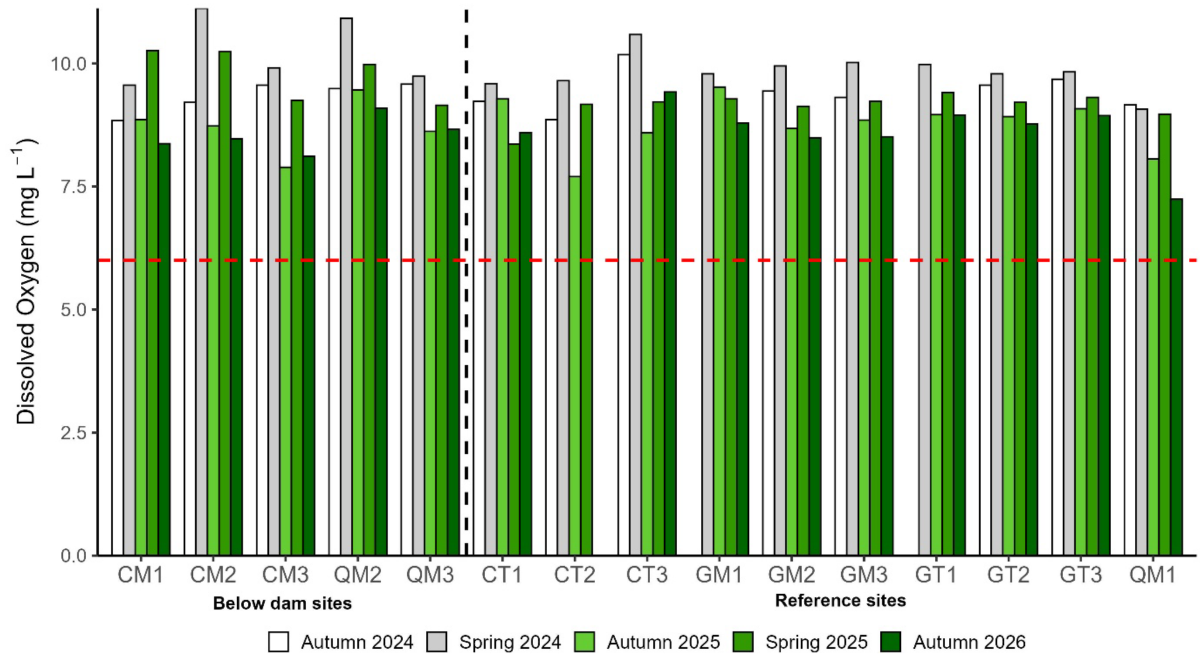
Alkalinity at all sites from autumn 2023 to autumn 2026.



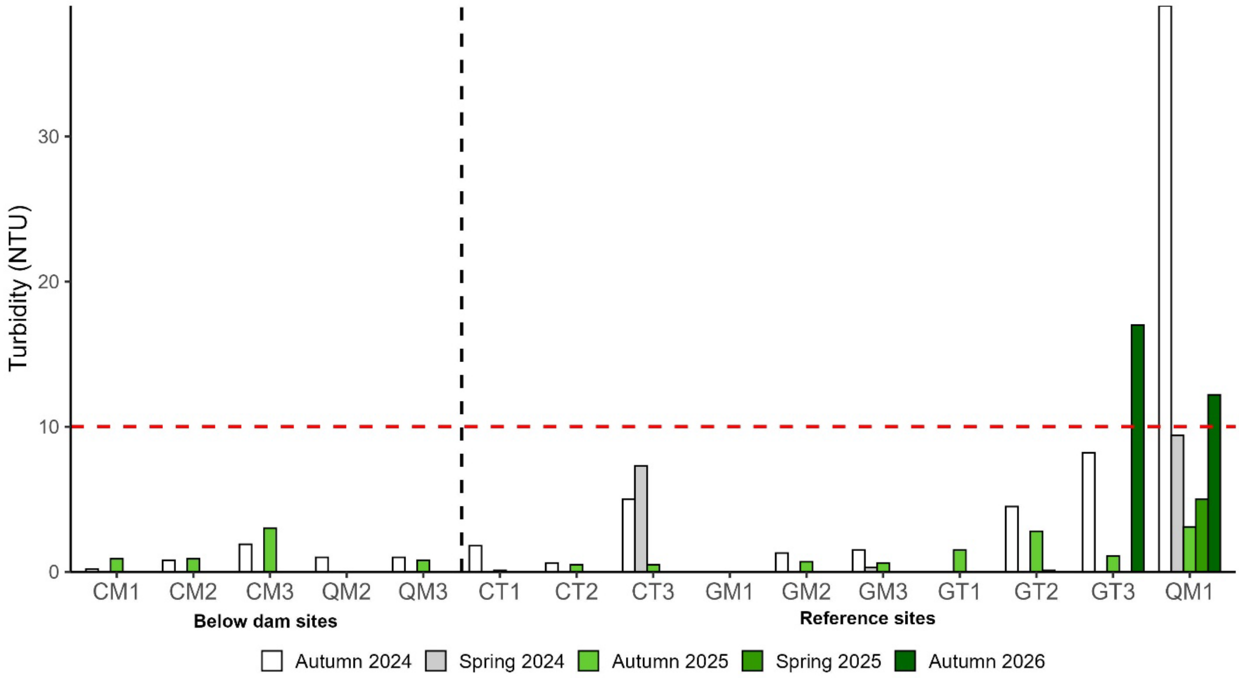
Electrical conductivity at all sites from autumn 2023 to autumn 2026. The ANZECC/ARMCANZ (2000) guideline for maximum electrical conductivity is dashed line and shaded red.



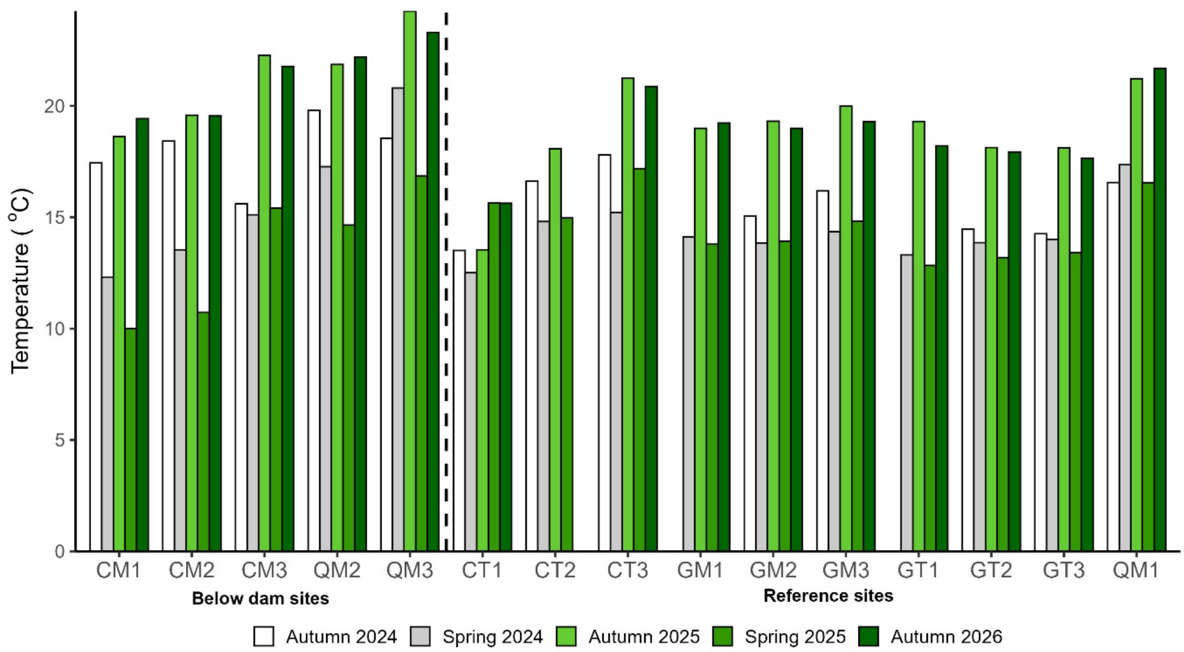
pH at all sites from autumn 2023 to autumn 2026. The ANZECC/ARMCANZ (2000) guideline range for pH are dashed lines and shaded red.



Dissolved oxygen concentration at all sites from autumn 2023 to autumn 2026. The minimum guideline for dissolved oxygen is dashed line and shaded red (Environment Protection Regulation SL2005-38).



Turbidity at all sites from autumn 2023 to autumn 2026. The guideline for maximum turbidity is dashed line and shaded red (Environment Protection Regulation SL2005-38).



Water temperature at all sites from autumn 2023 to autumn 2026.