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

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Centre for Applied Water Science

Institute for Applied Ecology

appliedecology.edu.au

University of Canberra, ACT 2601

Telephone: (02) 6206 8608

Facsimile: (02) 6201 5651

Authors:

Ugyen Lhendup, Ben Broadhurst and Rhian Clear

Inquiries regarding this document should be addressed to:

Ben Broadhurst

Centre for Applied Water Science

Institute for Applied Ecology

University of Canberra

Canberra 2601

Telephone: (02) 6206 8608

Facsimile: (02) 6201 5651

Email: ben.broadhurst@canberra.edu.au

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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 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 2021 and autumn 2022.

SPRING 2021 & AUTUMN 2022 RESULTS AND CONCLUSIONS

- Stream discharge at test sites was dominated by natural/flood events flow conditions as all reservoirs were full and spilling in both spring 2021 autumn 2022. Total discharge in the six months prior to sampling in spring 2021 were lower than discharge in the six months prior to sampling in autumn 2022 at all the test and reference sites. Total rainfall six months prior to sampling was greater than historical average rainfall across the entire study area in both spring 2021 and autumn 2022. Macroinvertebrate samples were only able to be safely (High discharges meant it was not safe to collect macroinvertebrates samples during the collection window) at some test sites in spring 2021 and at none of the sites in autumn 2022.
- Water quality parameters at below dam test sites were largely within guideline levels in spring 2021 and autumn 2022, with the exception of turbidity, nitrogen oxides (NO_x), Total Nitrogen (TN) and Total Phosphorus (TP) in both spring 2021 and autumn 2022, which were above guideline levels at a number of reference and test sites. The pH in spring 2021 at test site CM2 and reference site GM2 and GT1 were marginally out of the guideline levels. Click here for more information.
- All test and reference sites met the environmental flow ecological objective of <20% cover of filamentous algae in riffle habitats, except for the test sites downstream of Bendora Dam (CM2) in spring 2021. Click here for more information.
- Because of high flows during the sampling seasons, macroinvertebrate samples were not able to be collected at any test sites for either spring 2021 and autumn 2022 and therefore the ecological objective of band A macroinvertebrates community assemblages could not be assessed. Click here for more information
- All reference sites that were able to be sampled in spring 2021 were in 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, orange shading indicates environmental flow objective not met).

	Riffle filamentous algae cover (%)		AUSRIVAS band (O/E score)	
Site	**Spring 2021**	**Autumn 2022**	**Spring 2021**	**Autumn 2022**
CM1 (Corin Dam)	NA	<10	NA	NA
CM2 (Bendora Dam)	40	<10	NA	NA
CM3 (Cotter Dam)	<10	<10	NA	NA
QM2 (Googong Dam)	<10	<10	NA	NA
QM3 (Googong Dam)	<10	<10	NA	NA

PROJECT RECOMMENDATIONS

No new recommendations based on the result of the current assessment period.

INTRODUCTION

Water diversions and modified flow regimes can result in deterioration of both the ecological function and water quality of Australian streams (Arthington and 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 autumn and spring 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 is 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.

This report provides an assessment of sites downstream of the dams on the Cotter and Queanbeyan Rivers in spring 2021 and autumn 2022 and focuses on comparisons of these sites with unregulated reference sites and the results of previous assessments. Macroinvertebrate samples were not collected at test sites in spring 2021 and at any site in autumn 2022 because of flooding during the collection periods. Site summary sheets outlining the outcomes of both the spring 2021 and autumn 2022 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 2013). 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 and 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 and Nichols 2011).

Fifteen sites were sampled for biological, physical and chemical variables in spring between 17 to 21 December 2021 and in autumn between 7 to 17 June 2022 (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.

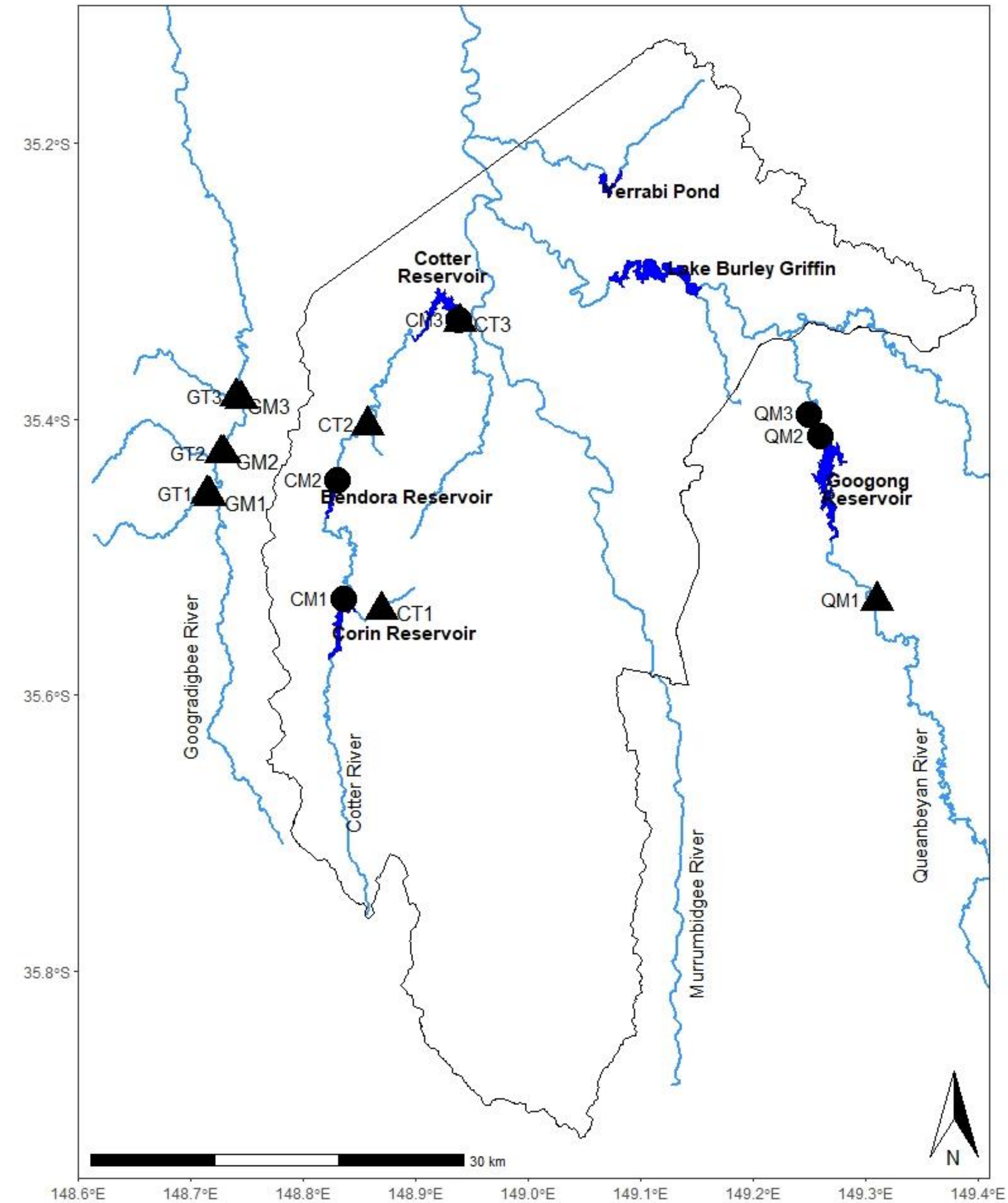


Figure 1: The location of sites on the Cotter, Goodradigbee, and Queanbeyan Rivers and tributaries for the below dams assessment program (Circles indicate test sites, triangles indicate reference tributaries).

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
QM3	Queanbeyan	2 km downstream of Googong Dam at Wickerslack Lane	600	92.6	5

HYDROMETRIC DATA

Mean daily flow data for each of the below dam test sites (provided by Icon Water) and Goodradigbee River reference sites (obtained from the NSW Department of Primary Industries Office of Water, gauging station 410088) was used to determine changes in river flow for the months preceding sampling. Daily rainfall data was obtained from ALS environmental monitoring sites 570965 (Queanbeyan Catchment), 570958 (Bendora Dam) and Bureau of Meteorology station number 07173 (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 (A.P.H.A. 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 (A.P.H.A 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. 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.* 2000, http://ausrivas.ewater.com.au/ausrivas/index.php/manuals-a-datasheets?id=54).

ASH-FREE DRY MASS AND CHLOROPHYLL-A

Only three replicate periphyton samples were collected from reference site (Goodradigbee River Sites) using a syringe sampler based on a design similar to that described by Loeb (1981). Samples from each site were measured for Ash-free dry mass (AFDM) and Chlorophyll-a content in accordance with methods described in A.P.H.A (2005). The periphyton samples were not collected from test sites due to high flow in both spring 2021 and autumn 2022.

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.* 2000; http://ausrivas.ewater.com.au/ausrivas/index.php/manuals-a-datasheets?id=54). However, because of high flows during sampling seasons, only seven sites were sampled in spring 2021 (all reference sites) and no sites were sampled in autumn 2022.

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 and 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*. 2000). QA/QC procedures were implemented for macroinvertebrate sample processing following those outlined in Nichols *et al*. (2000).

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).

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 an Open Office 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

Because of the absence of AFDM, Chlorophyll-a concentration data, and macroinvertebrate data in the spring 2021 and autumn 2022 assessments, no formal data analysis was undertaken to examine for differences between sites for these metrics.

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

Stream discharge in the months leading up to sampling in spring 2021 and autumn 2022 on the Cotter and Queanbeyan Rivers was dominated by natural/flood flow conditions. The flow regime targets were well surpassed the prescribed operational flow requirements under the environmental flow guidelines (ACT Government 2019) (

Table 4). The months leading up to both the sampling events were followed on from a wet spring and summer, with below dams sites largely operating as unregulated as reservoirs were predominantly at full supply level during this time. All below dam sites met base flow regulations.

Flow in the lead up to and during sampling was high at all sites, where the mean flow in six months prior to sampling was greater than the 93rd percentile of historical flows for the same time of year (Table 5). Similarly, the total rainfall in the lead up to and during the sampling was high at all sites, where the total rainfall six months prior to sampling was greater than the 83rd percentile of historical total rainfall for the same time of year (Table 6).

Table 4: Flow regime targets (non-drought) and releases downstream of Corin, Bendora, Cotter and Googong Dams (ACT Government 2019).

Dam	Flow regime
Corin	Maintain 75% of the 80th percentile of the monthly natural inflow, or inflow, whichever is less. Riffle maintenance flow 150 ML d^{-1} for 3 consecutive days every 2 months. Maintain a flow of >550 ML d^{-1} for 2 consecutive days between mid-July and mid-October.
Bendora	Maintain 75% of the 80th percentile of the monthly natural inflow, or inflow, whichever is less. Riffle maintenance flow 150 ML d^{-1} for 3 consecutive days every 2 months. Maintain a flow of >550 ML d^{-1} for 2 consecutive days between mid-July and mid-October.
Cotter	From Murrumbidgee to Cotter (M2C) transfer: If Murrumbidgee River flow at Mt MacDonald gauging station is greater than 80 MLd^{-1}, then M2C discharges 40 MLd^{-1}. Each month, M2C discharge flow is reduced temporarily to 20 ML d^{-1} for a 36 to 46 hour period. Cotter Dam releases bimonthly flows peaking at 100 MLd^{-1} and a flow peaking at 150 ML d^{-1} between mid-July and mid-October.
Googong	Maintain base flow average of 10 ML d^{-1} or natural inflow, whichever is less. Riffle maintenance flow of 100 ML d^{-1} for 1 day every 2 months.

Table 5: Flow information for Below Dams rivers and monitoring sites for which they are relevant; (Data: NSW water and ALS)

Station	Relevant monitoring site/s	Mean flow in six months prior to autumn 2022 sampling (ML/Day)	Mean flow in six months prior to autumn 2021 sampling (ML/Day)	Historical mean flow in autumn (ML/Day)	Percentile mean flow in autumn 2022 (ML/Day)
Cotter River at D/S Bendorra Dam (Station no. 410747)	CM2, CT2	345.27	208.49	69.18	97th
Cotter River at D/S Corin Dam (Station no. 410752)	CM1, CT1	311.43	194.89	169.47	94th
Cotter River at Kiosk (Station no. 410777)	CM3, CT3	533.48	316.654	193.11	93rd
Goodradigbee River at Brindabella (Station no. 410729)	GM1, GM2, GM2, GT1, GT2, Gt3	505.34	245.98	232.05	94th
Queanbeyan River U/S Googong Dam (Station no. 410781)	QM1	904.5	336.93	128.85	100th
Queanbeyan River Wickerslack (Station no. 410760)	QM2, QM3	1093.36	406.46	187.18	98th

Table 6: Rainfall information for Below Dams and monitoring sites for which they are relevant; (Data: BOM and ALS)

Station	Relevant monitoring site/s	Total rainfall in six months prior to autumn 2022 sampling (mm)	Total rainfall in six months prior to autumn 2021 sampling (mm)	Historical total rainfall in autumn (mm)	Percentile total rainfall in autumn 2022 (mm)
Rainfall at Bendorra Dam (Station no. 570958)	CM2, CT2	736.4	581.2	454.65	95th
Rainfall at Peirces Creek (Station no. 570825)	CM3, CT3	632.6	528.2	328.39	96th
Rainfall at Queanbeyan River Wickerslack (Station no. 570983)	QM2, QM3	490.2	397.4	288.72	98th
Rainfall at Queanbeyan River U/S Googong Dam (Station no. 570816)	QM1	641.2	412.2	305.27	100th
Rainfall at Goodradigbee at Brindabella (Station no. 71073)	GM1, GM2, GM3, GT1, GT2, GT3	549.4	463.8	355.57	83rd

WATER QUALITY

Water quality parameters were generally within guideline levels at test and reference sites in spring 2021 and autumn 2022. Notable exceptions were pH in test site CM2 and reference sites GM2 and GT1 in spring 2021 (Table 7). Turbidity was almost seventeen times higher and seven times higher than guideline values at reference site CT3 in spring 2021 and autumn 2022, respectively (Table 7 and Table 8). Turbidity was ~2.5 times higher than the guideline value for test sites CM3 and QM2 in autumn 2022 (Table 8). NO_x , total nitrogen and total phosphorus concentrations were above guideline values at test sites QM2 and QM3 for both spring 2021 and autumn 2022 assessments (Table 7 and Table 8). NO_x concentrations were above guideline levels at all test sites and two Cotter tributary sites in autumn 2022 (Table 8).

Table 7: Water quality parameters measured at each of the test and reference sites in spring 2021. Values outside guideline levels are shaded orange.

		Temp. (°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										
	CM2	18.21	20	6.32	9.55	0.0	10	0.006	0.009	0.12	0.008
	CM3	21.35	31	6.51	8.68	6.7	13	0.007	<0.002	0.16	0.010
	QM2	20.17	95	7.86	9.47	3.4	34	0.012	0.099	0.73	0.025
	QM3	19.84	195	7.96	9.07	3.5	90	0.011	0.093	0.67	0.022
Reference sites	CT1	19.17	39	7.50	8.45	6.3	18	0.006	<0.002	0.14	0.014
	CT2										
	CT3	20.78	65	6.77	9.21	172.0	32	0.061	0.024	0.57	0.049
	QM1	19.76	98	7.79	9.13	10.5	42	0.024	0.030	0.39	0.020
	GM1	19.86	85	7.49	9.05	4.4	34	0.008	<0.002	0.06	0.006
	GM2	18.95	81	8.04	9.05	6.2	37	0.004	0.007	0.06	0.006
	GM3	17.87	75	7.06	9.54	5.4	39	0.002	<0.002	0.08	0.009
	GT1	20.41	52	8.12	8.68	6.2	26	0.003	<0.002	0.09	0.009
	GT2	18.27	53	7.96	9.07	7.1	20	0.003	0.013	0.09	0.010
	GT3	17.52	49	6.89	9.22	10.6	24	0.008	0.012	0.14	0.012

Table 8: Water quality parameters measured at each of the test and reference sites in autumn 2022. Values outside guideline levels are shaded orange. **NOTE:** Turbidity for QM3 was not recorded due to instrument error and WQ parameters were not recorded due to sites being inaccessible.

		Temp. (°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	9.11	31	7.17	10.93	2.9	16	0.005	0.059	0.14	0.004
	CM2	8.99	26	7.00	11.5	5.2	14	0.003	0.037	0.12	0.004
	CM3	10.66	39	7.10	11	27.8	20	0.004	0.062	0.18	0.006
	QM2	10.8	96	7.63	11.33	27.4	42	<0.002	0.109	0.58	0.022
	QM3	10.14	181	7.85	10.78		64	0.01	0.144	0.68	0.022
Reference sites	CT1	7.62	36	6.97	10.65	6.3	18	0.002	0.004	0.05	0.007
	CT2	9.58	29	6.7	10.73	0	10	<0.002	0.148	0.24	0.004
	CT3	6.4	73	7.25	11.71	77.0	300	0.018	0.115	0.6	0.035
	QM1										
	GM1										
	GM2	7.15	73	7.28	11.43	9.2	44	0.017	0.013	0.08	0.006
	GM3	7.16	70	7.32	11.44	10.6	30	<0.002	0.024	0.09	0.004
	GT1	6.74	47	7.24	11.61	9.7	24	0.002	<0.002	0.16	0.008
	GT2	7	44	7.14	11.39	10.5	24	0.002	0.006	0.11	0.01
	GT3	6.75	42	7.20	11.7	13.5	19	<0.002	0.003	0.11	0.011

FILAMENTOUS ALGAE AND PERIPHYTON

The environmental flow ecological objective of <20% cover of filamentous algae in riffle habitats was achieved at all below dams test sites in both assessments except for CM2 in spring 2021 (Table 9). Field observations of periphyton cover of riffle habitats were <20% at all sites in both spring 2021 and autumn 2022 (Table 9).

Table 9: Periphyton and filamentous algae (categorised on percent cover) in the riffle habitat at below dams sites and reference sites, from spring 2019 to autumn 2022. 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-19	Aut-20	Spr-20	Aut-21	Spr-21	Aut-22	Spr-19	Aut-20	Spr-20	Aut-21	Spr-21	Aut-22
CM1	<30	<10	<20	<10	NA	<10	<30	<10	<10	<10	NA	<10
CM2	<10	<10	<30	30	15	<10	<10	<10	40	<10	40	<10
CM3	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
QM2	<10	30	<10	20	<10	<10	<10	40	<10	30	<10	<10
QM3	<10	20	<20	<10	<10	<10	<10	20	<10	<10	<10	<10
GM1	NA	<10	<10	<10	<10	NA	NA	<10	<10	<10	<10	NA
GM2	<10	<10	<20	<10	<10	<10	<10	<10	<10	<10	<10	<10
GM3	<30	<10	<30	35	15	<10	<20	<10	<10	<10	<10	<10
QM1	<10	<20	<20	<10	<10	NA	<10	<20	<10	<10	<10	NA

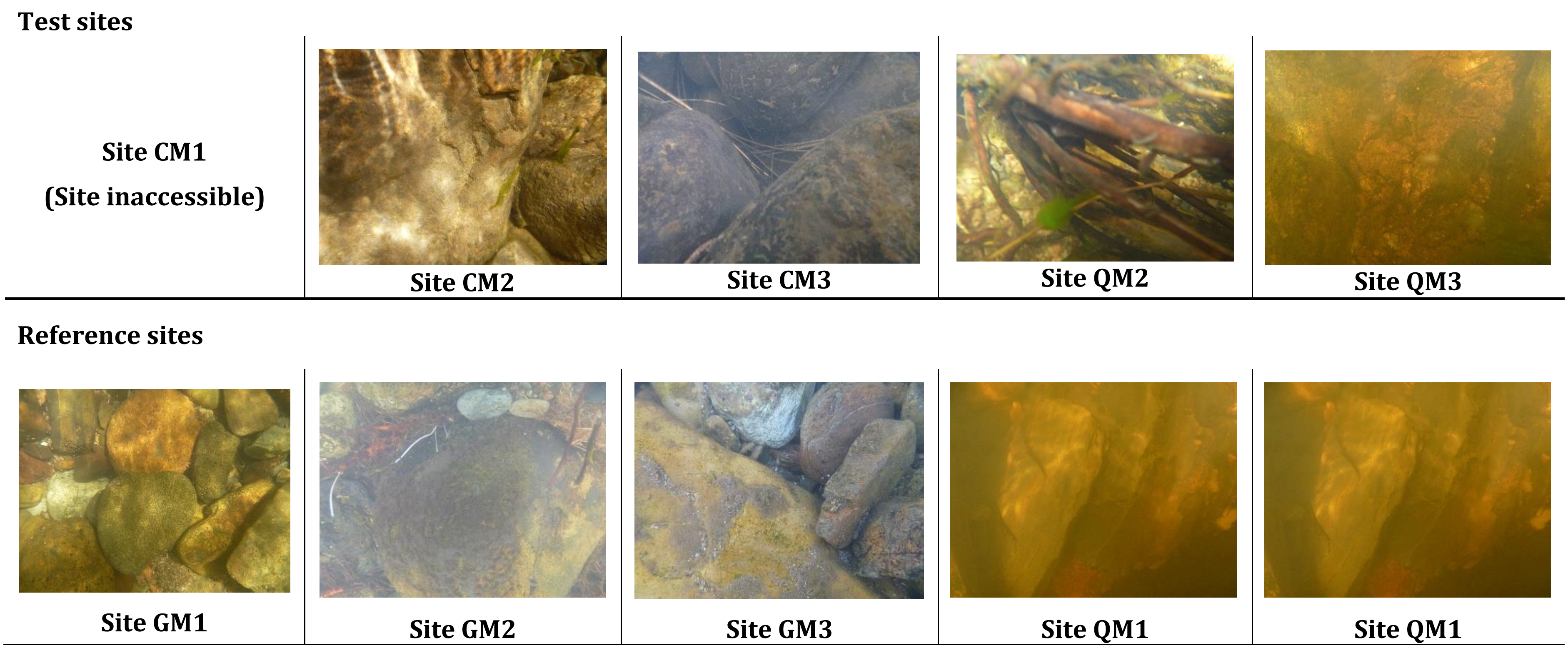


Figure 2. Filamentous algae and periphyton cover of riffle bed sediments at below dam test sites and corresponding reference sites on the Cotter, Goodradigbee and Queanbeyan Rivers in spring 2021.

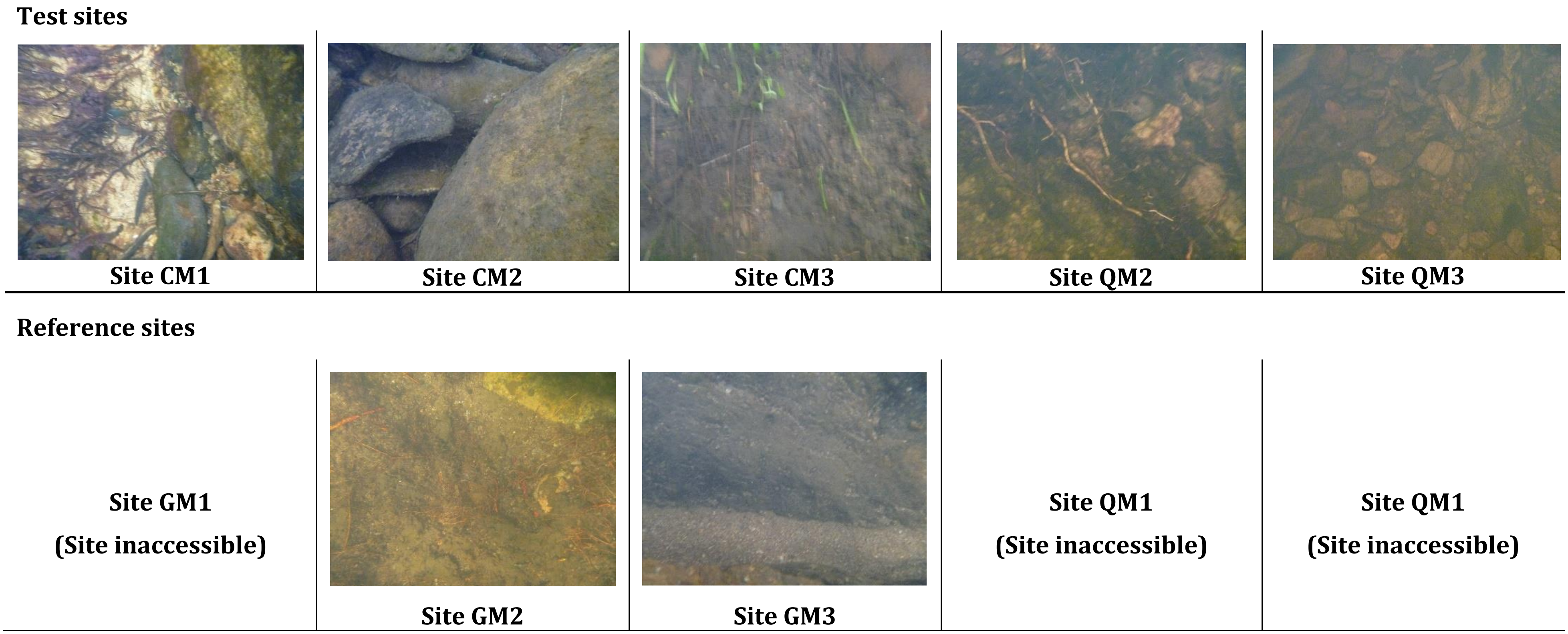


Figure 3: Filamentous algae and periphyton cover of riffle bed sediments at below dam test sites and corresponding reference sites on the Cotter, Goodradigbee and Queanbeyan Rivers in autumn 2022.

High river flows prevented AFDM and Chlorophyll-a from being collected and analysed at tests sites in spring2021 and all sites in autumn 2022 (Figure 4 and Figure 5).

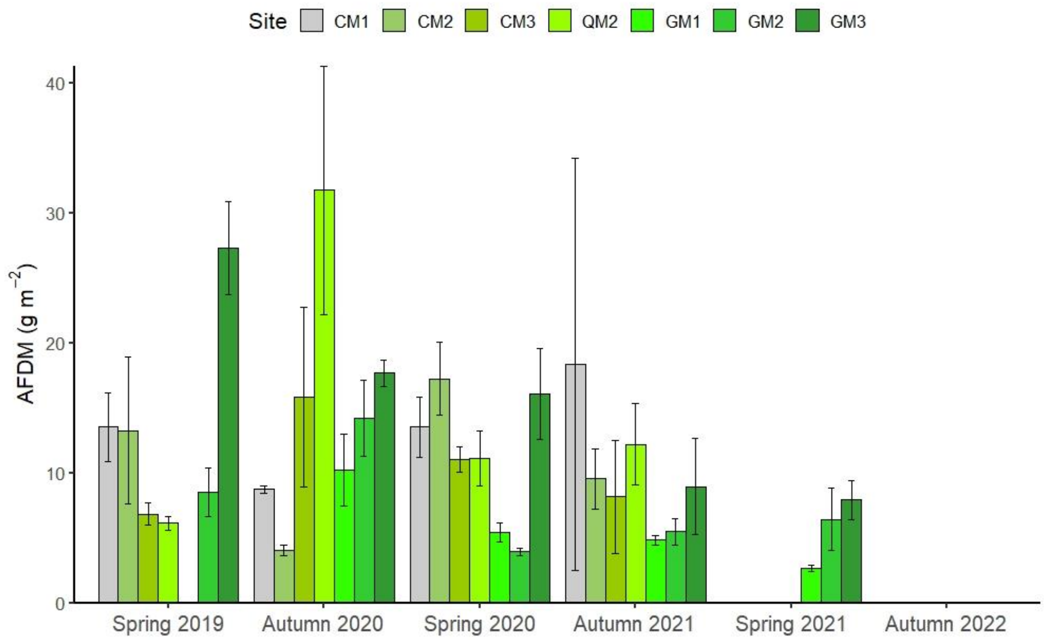


Figure 4: Mean AFDM (g m^{-2}) at below dam test sites and reference sites on the Goodradigbee River from spring 2019 to autumn 2022. Error bars represent +/- 1 standard error. **NOTE**: Only three sites were assessed in spring 2021 and none in autumn 2022 due to high flow during the sampling.

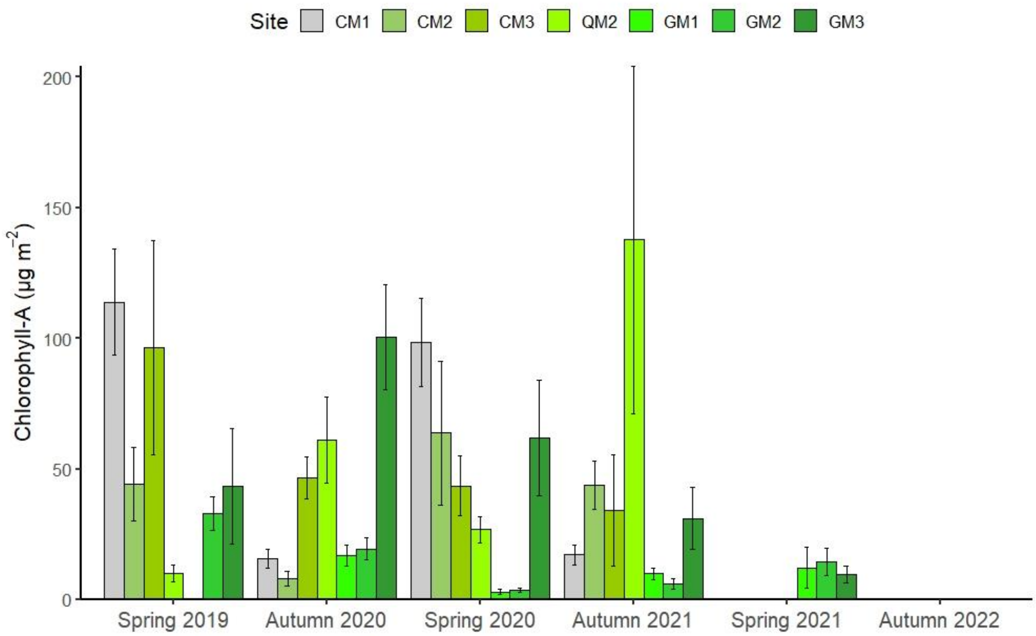


Figure 5: Mean Chlorophyll-a (µg m-2) at below dam test sites and reference sites on the Goodradigbee River from spring 2019 to autumn 2022. Error bars represent +/- 1 standard error. NOTE: Only three sites were assessed in spring 2021 and none in autumn 2022 due to high flow during the sampling.

BENTHIC MACROINVERTEBRATES

AUSRIVAS ASSESSMENT

Macroinvertebrate samples were only collected from reference sites Kangaroo Creek (CT1), and Goodradigbee River reference site (GM1, GM2, GM3, GT1, GT2 and GT3) in spring 2021 and at no sites in autumn 2022 due high flow during the sampling periods. Therefore, the biological condition of the sites cannot be compared between years and sites. Therefore, no analysis of macroinvertebrate assemblages (other than AUSRIVAS band scores below) will be presented for spring 2021 and autumn 2022. Interestingly, despite high flows, all sites that were able to be sampled in spring 2021 were assessed as band A (similar to reference) (

Table 10).

Table 10: AUSRIVAS band and Observed/Expected taxa score for each site from autumn 2019 to autumn 2022. NOTE: N/A represents absence of data due to inaccessible sites.

	Below dams sites					Reference sites									
	CM1	CM2	CM3	QM2	QM3	CT1	CT2	CT3	QM1	GM1	GM2	GM3	GT1	GT2	GT3
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)

DISCUSSION

WATER QUALITY

Water quality and nutrient levels at below dam test sites and unregulated reference sites were generally within guideline levels in both spring 2021 and autumn 2022. Parameters outside of guideline levels were pH, Turbidity, Nitrogen Oxides (NOx), Total Nitrogen (TN) and Total Phosphorus (Table 7 and Table 8).

Turbidity at reference site CT3 (Paddy's River above Cotter River Junction) exceeded the guideline level of <10 NTU in both spring 2021 and autumn 2022 assessment. The higher level of turbidity is because of instream sedimentation caused by catchment land use (predominantly forestry, rural and large density of unsealed roads) and a large flood event which occurred prior to sampling.

Nitrogen oxides (NO_x) had exceeded guideline level at the sites QM2 and QM3 and reference sites CT3 and QM1 in spring 2021 and all the test sites and reference sites CT2 and CT3 in autumn 2022. High Nitrogen levels and denitrification within the reservoir and flood events prior the sampling could be the cause of elevated NOx concentrations at sites directly below reservoirs and the high concentrations experienced in autumn 2022 are not likely related to the environmental flow regime (Saunders and Kalff 2001).

Test sites QM2 and QM3 and reference sites QM1 and CT3 in spring 2021 and test sites QM2 and QM3 in autumn 2022 had high level of Total Nitrogen (TN) and exceeded guideline levels. This high level of nutrients may have been triggered as a result from runoff due to higher rainfall and big flow events that occurred prior to sampling in spring 2021 and autumn 2022 (**Error! Reference source not found.**).

Total Phosphorus concentration at test sites QM2 and QM3 (below Googong Dam) and reference site CT3 and QM1 were marginally higher than guideline level (0.005 mgL^{-1}, 0.002 mgL^{-1} and 0.029 mgL^{-1} respectively) in spring 2021; below Googong Dam (QM2 and QM3) with (0.002 mgL^{-1} and 0.002 mgL^{-1} respectively) This increase in TP concentrations cannot be attributed by the dam operations but it is likely due to the result of water carrying increased sediment load from runoff in the surrounding catchment (Harrison *et al.* 2010) due to flow events in the months leading to sampling.

FILAMENTOUS ALGAE AND PERIPHYTON

Filamentous algae cover in riffle habitats was well below the environmental flow ecological objective of <20% cover at all sites except the test sites below Bendora dam in spring 2021 and autumn 2022. The current flood event is effective in achieving the environmental flow ecological objective to control filamentous algae accumulation downstream of dams on the Cotter and mostly on the Queanbeyan Rivers during spring and autumn.

Comparisons of ash free dry mass (AFDM) and chlorophyll-a concentrations between sites for both the spring 2021 and autumn 2022 assessments were not able to be discussed due to absence of data (was not able to be collected due to high flow during sampling seasons).

BENTHIC MACROINVERTEBRATES

Due to the absence of test site data, macroinvertebrate assemblages will not be discussed in detail. It is worth noting that all reference sites were assessed as band A (similar to refence) in spring 2021. This indicates that these sites have robust resilient macroinvertebrate communities, able to either withstand disturbance, or rapidly recover following a disturbance.

CONCLUSION

Water quality parameters at below dam test sites were largely within guideline levels in spring 2021 and autumn 2022, with the exception of pH, nitrogen oxides (NOx) in all the test sites in both assessment seasons and total nitrogen (TN), total phosphorus (TP) and turbidity in a few sites. Despite some increased nutrient availability, filamentous algae coverage of riffle habitats remained well within environmental flow ecological objective levels at all test sites for both assessments, except for CM2 spring 2021.

REFERENCES

ACT Government (2019). *2019 Environmental Flow Guidelines*.

ANZECC and ARMCANZ (2000). National water quality management strategy: Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Australian and New Zealand Environment and Conservation Council and the Agriculture and Resource Management Council of Australia and New Zealand.

A.P.H.A. (2005). Standard methods for the examination of water and wastewater. 21st edition. American Public Health Association: Washington.

Arthington, A. H., and Pusey, B. J. (2003). Flow Restoration and Protection in Australian Rivers. *River Research and Applications* 19: 377-395.

Belmar, O., Velasco, J., Canovas, C., Diaz, A., Millan, A. and Wood, P.J. (2013), The influence of flow regimes on macroinvertebrate assemblages in a semiarid Mediterranean basin, *Ecohydrology*, Volume 6, pp. 363-379, Spain.

Broadhurst, B. (2016)*. Biological response to flows downstream of Corin, Bendora, Cotter and Googong Dams: Autumn 2016 report to Icon Water*. Institute for Applied Ecology, Canberra

Bernot M.J. and Dodds, W.K. (2005) Nitrogen retention, removal, and saturation in lotic ecosystems. *Ecosystems* 8:442–453.

Chessman, B. C. (2003). New sensitivity grades for Australian river macroinvertebrates. Marine and Freshwater Research 54:95-103.

Chester, H. and Norris, R. (2006). Dams and flow in the Cotter River, Australia: effects on instream trophic structure and benthic metabolism. *Hydrobiologia*, 572: 275–286

Clarke, K. R. and Warwick, R. M. (2001). Change in Marine Communities: An Approach to Statistical Analysis and Interpretation. 2nd edition. Plymouth Marine Laboratory, Plymouth.

Connell, J. H. (1978). Diversity in tropical rainforests and coral reefs. *Science* 199: 1302 – 1310.

Cornish, P. M. (2001). The effects of roading, harvesting and forest regeneration on streamwater turbidity levels in a moist eucalypt forest, *Forest Ecology and Management*, Volume 152, pp. 293 – 312, Australia.

Coysh, J. L., Nichols, S. J., Simpson, J. C., Norris, R. H., Barmuta, L. A., Chessman, B. C. and Blackman, P. (2000). AUStralian RIVer Assessment System (AUSRIVAS) National River Health Program Predictive Model Manual. Cooperative Research Centre for Freshwater Ecology, Building 15, University of Canberra, ACT, 2601

Death, R.G., 2008. The effect of floods on aquatic invertebrate communities. *Aquatic insects: challenges to populations*, pp.103-121.

Environment Protection Regulations SL2005-38. *Environment Protection regulation 2005 made under the Environment Protection ACT 1997*. Australian Capital Territory Government.

Harrison, E., Wright, D. and Nichols, S. (2010). *Biological response to environmental flows below Corin, Bendora, Cotter and Googong Dams. Spring 2010*. Report ACTEW Corporation.

Hawking, J. (2000). *Key to keys, 2nd edition. Identification guide No. 2*. Cooperative Research Centre for Freshwater Ecology, Canberra, Australia.

Lhendup, U., Broadhurst, B. and Clear, R. (2018). *Biological response to flows downstream of Corin, Bendora, Cotter and Googong Dams: Autumn 2018 report to Icon Water*. Institute for Applied Ecology, Canberra

Loeb, S. L. (1981). An in situ method for measuring the primary productivity and standing crop of the epilithic periphyton community in lentic systems. *Limnology and Oceanography*, 26: 394-400.

Marchant, R. (1989). A sub-sampler for samples of benthic invertebrates. *Bulletin of the Australian Society of Limnology* 12: 49-52.

Nichols, S.J., Coysh, J.L., Sloane, P. I. W., Williams, C. C., and Norris, R. H. (2000). *Australian Capital Territory (ACT), AUStralian RIVer Assessment System* (*AUSRIVAS), Sampling and Processing Manual.* Cooperative Research Centre for Freshwater Ecology, Building 15, University of Canberra, ACT, 2601.

Nichols, S., Norris, R., Maher, W., and Thoms, M., (2006). Ecological Effects of serial impoundment on the Cotter River, Australia. *Hydrobiologia,* 572: 255-273.

Norris, R. And Nichols, S. (2011). Environmental flows: achieving outcomes in variable environments. In Grafton, Q. and Hussey, K. (Eds) *Water Resources and Planning. Cambridge University Press*, London.

Nowlin, W. H., Evarts, J. L. and Vanni, M. J. (2005), Release rates and potential fates of nitrogen and phosphorus from sediments in a eutrophic reservoir. *Freshwater Biology*, 50: 301–322.

Parsons, M. and Norris, R. H. (1996). The effect of habitat-specific sampling on biological assessment of water quality using a predictive model. *Freshwater Biology* 36: 419-434.

Robinson, C.T., Uehlinger, U. and Monaghan, M.T. (2003) Effects of a multi-year experimental flood regime on macroinvertebrates downstream of a reservoir. *Aquatic Sciences* 65, 210–222.

Saunders DL, Kalff J (2001) Nitrogen retention in wetlands, lakes and reservoirs. *Hydrobiologia* 443:205–212.

White, H., Deschasequx, E. and Norris, R. (2009). Biological response to environmental flows below Corin, Bendora and Googong Dams ad low flows below the Cotter Dam. Autumn 2009. Report to ACTEW Water.

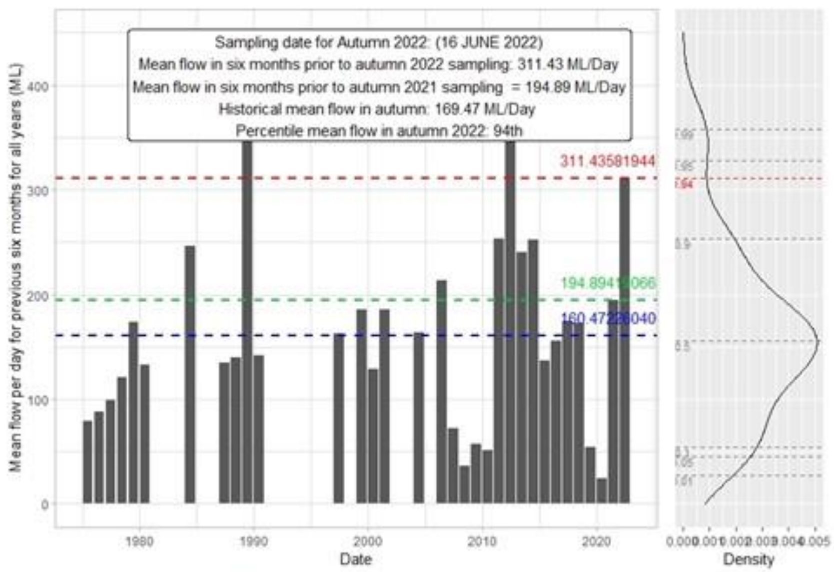
APPENDIX 1: BELOW DAM SITE SUMMARY SHEETS

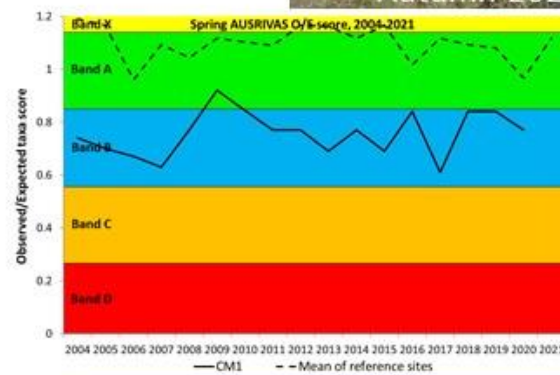
CM1 - Spring 2021 - Autumn 2022

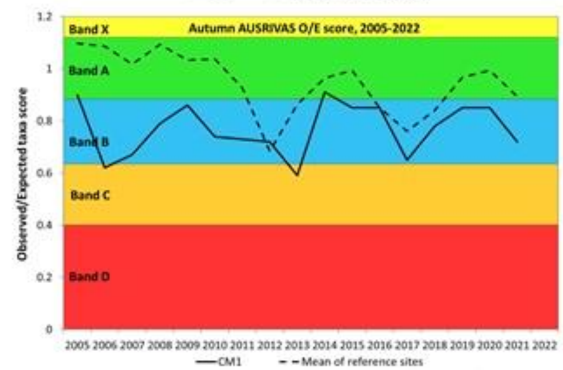
Downstream of Corin Dam

Environmental flow ecological objective	Spring 2021	Autumn 2022	Objective met?
AUSRIVAS band A	Not assessed	Not assessed	N/A
<20% filamentous algae cover in riffle habitat	<10%	<10%	Yes in both seasons

Spring 2021
Photo NA







* 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 2021	Data not available									
Autumn 2022	9.11	31	7.17	10.93	2.9	16	0.005	0.059	0.14	0.004

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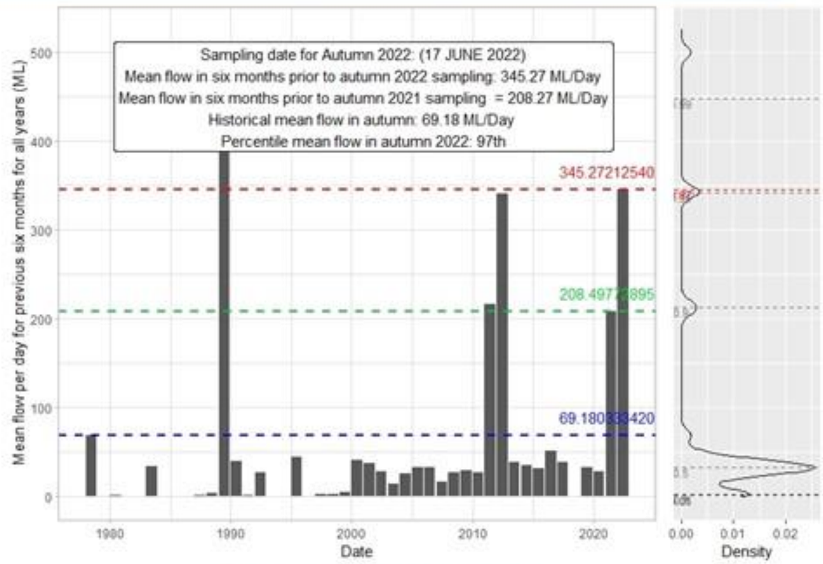
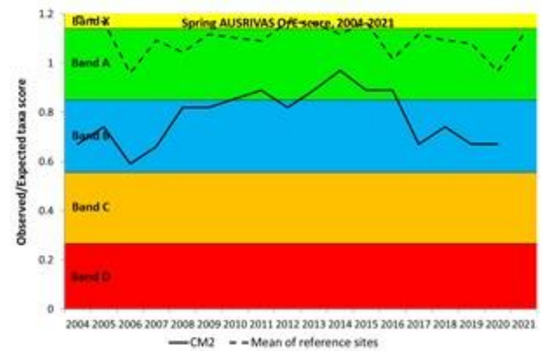
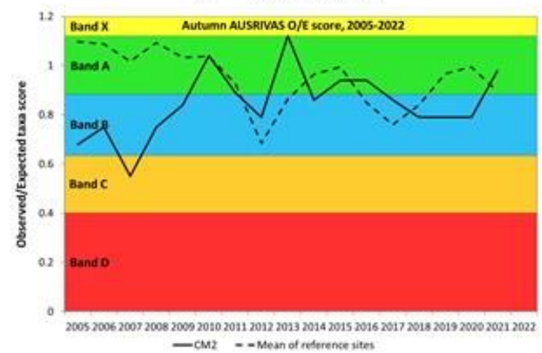
CM2 - Spring 2021 - Autumn 2022

Downstream of Bendora Dam

Environmental flow ecological objective	Spring 2021	Autumn 2022	Objective met?
AUSRIVAS band A	Not assessed	Not assessed	N/A
<20% filamentous algae cover in riffle habitat	30%	<10%	No in Spring 2021 and Yes in autumn 2022







* Denotes values outside guideline levels

Sampling season	Temp. (^{o}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 2021	18.21	20	6.32	9.55	0.0	10	0.006	0.009	0.12	0.008
Autumn 2022	8.99	26	7.00	11.5	5.2	14	0.003	0.037	0.12	0.004

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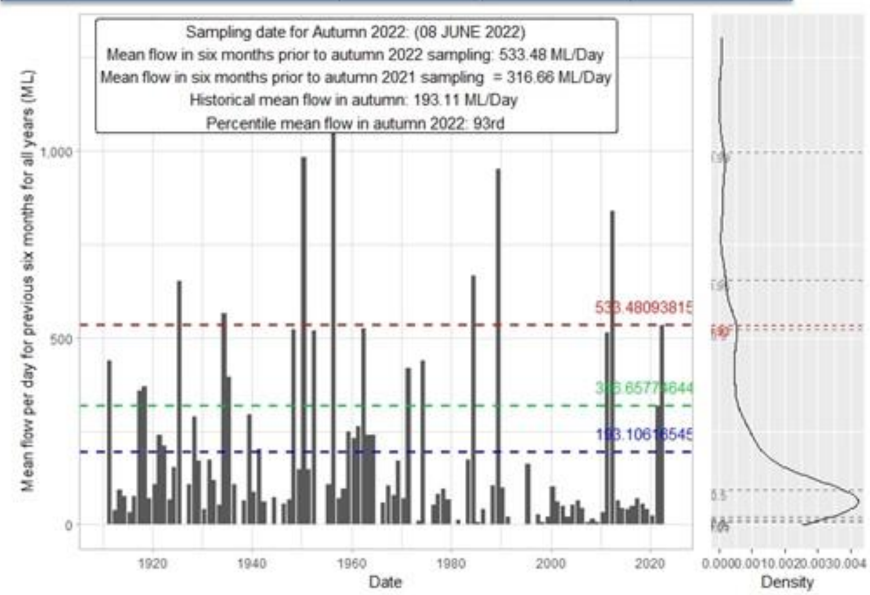
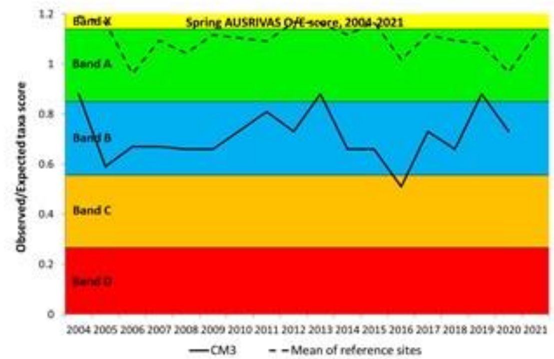
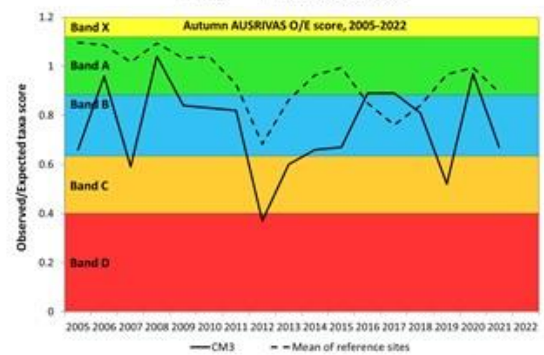
CM3 - Spring 2021 - Autumn 2022

Downstream of Cotter Dam

Environmental flow ecological objective	Spring 2021	Autumn 2022	Objective met?
AUSRIVAS band A	Not assessed	Not assessed	N/A
<20% filamentous algae cover in riffle habitat	<10%	<10%	Yes in both seasons







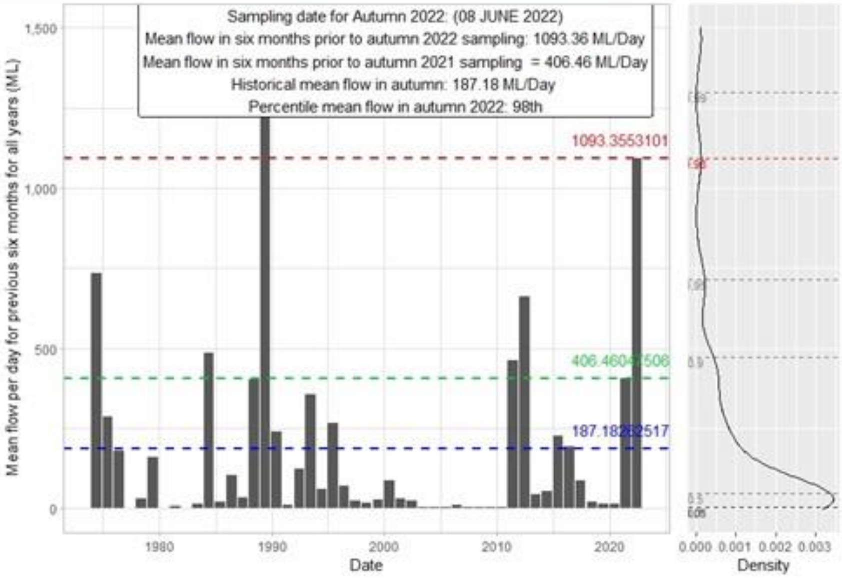
* Denotes values outside guideline levels

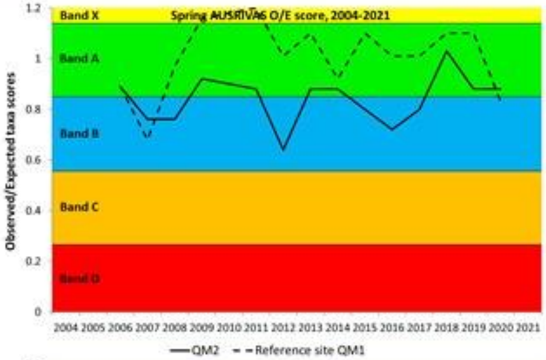
Sampling season	Temp. (ºC)	EC (µs cm⁻¹)	pH	D.O. (mg l⁻¹)	Turbidity (NTU)	Alkalinity (mg L⁻¹)	NH₄⁺ (mg L⁻¹)	NOx (mg L⁻¹)	TN (mg L⁻¹)	TP (mg L⁻¹)
Spring 2021	21.35	31	6.51	8.68	6.7	13	0.007	<0.002	0.16	0.010
Autumn 2022	10.66	39	7.10	11	27.8	20	0.004	0.062	0.18	0.006

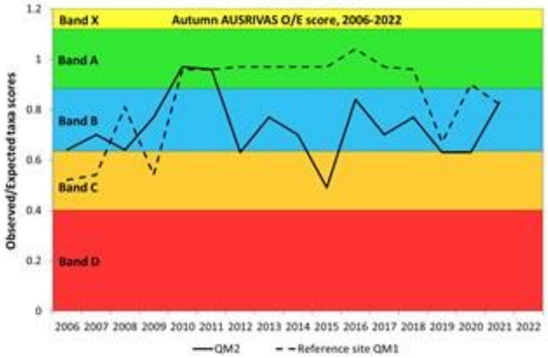
QM2 - Spring 2021 - Autumn 2022

Downstream of Googong Dam

Environmental flow ecological objective	Spring 2021	Autumn 2022	Objective met?
AUSRIVAS band A	Not assessed	Not assessed	N/A
<20% filamentous algae cover in riffle habitat	<10%	<10%	Yes in both seasons







* 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 2021	20.17	95	7.86	9.47	3.4	34	0.012	0.099	0.73	0.025
Autumn 2022	10.8	96	7.63	11.33	27.4	42	<0.002	0.109	0.58	0.022

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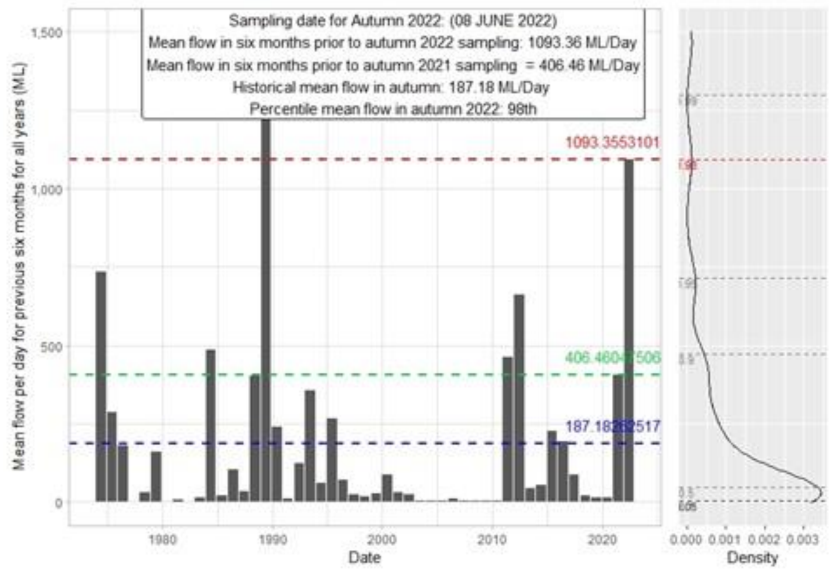
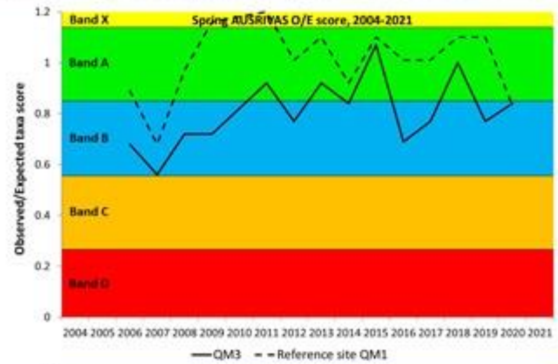
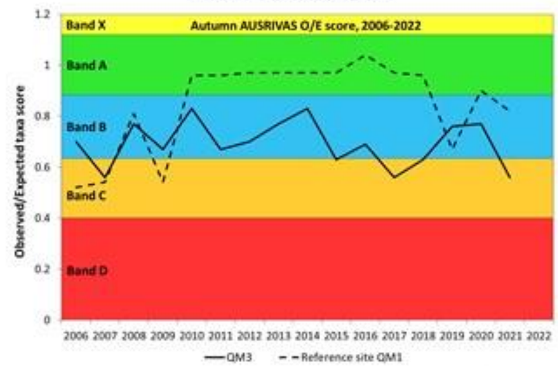
QM3 - Spring 2021 - Autumn 2022

2km Downstream of Googong Dam

Environmental flow ecological objective	Spring 2021	Autumn 2022	Objective met?
AUSRIVAS band A	Not assessed	Not assessed	N/A
<20% filamentous algae cover in riffle habitat	<10%	<10%	Yes in both seasons







* 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 2021	19.84	195	7.96	9.07	3.5	90	0.011	0.093	0.67	0.022
Autumn 2022	10.14	181	7.85	10.78		64	0.01	0.144	0.68	0.022

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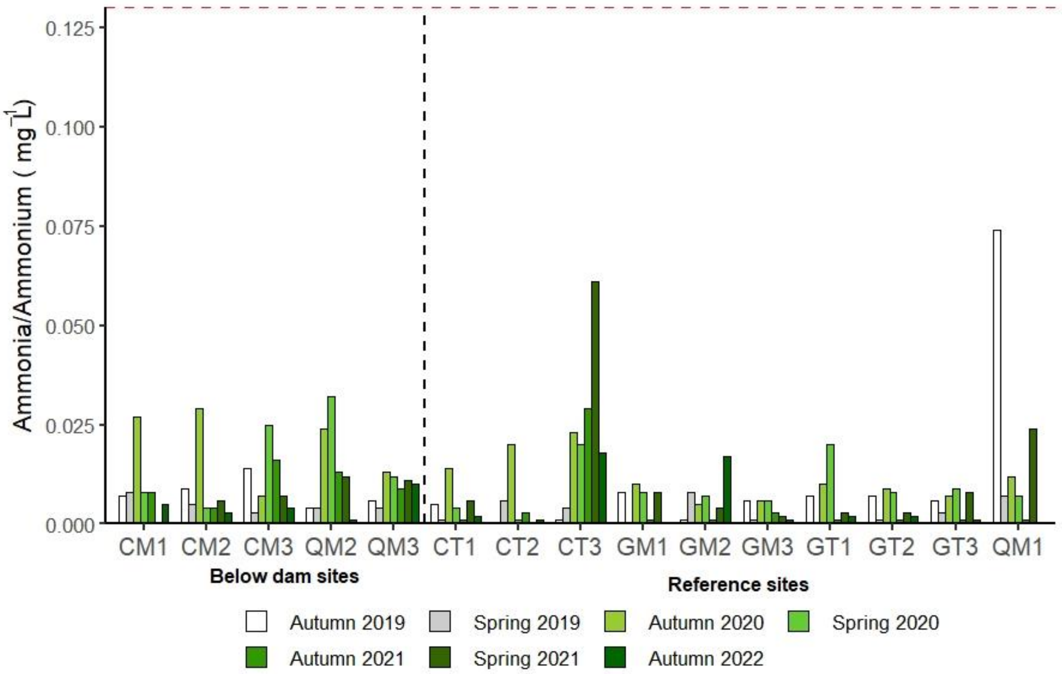
APPENDIX 2: MACROINVERTEBRATE TAXA SPRING 2021

Macroinvertebrate taxa and their sensitivity grade (SIGNAL 2) (Chessman, 2003) collected from sub-samples in spring 2021 at each of the study sites.

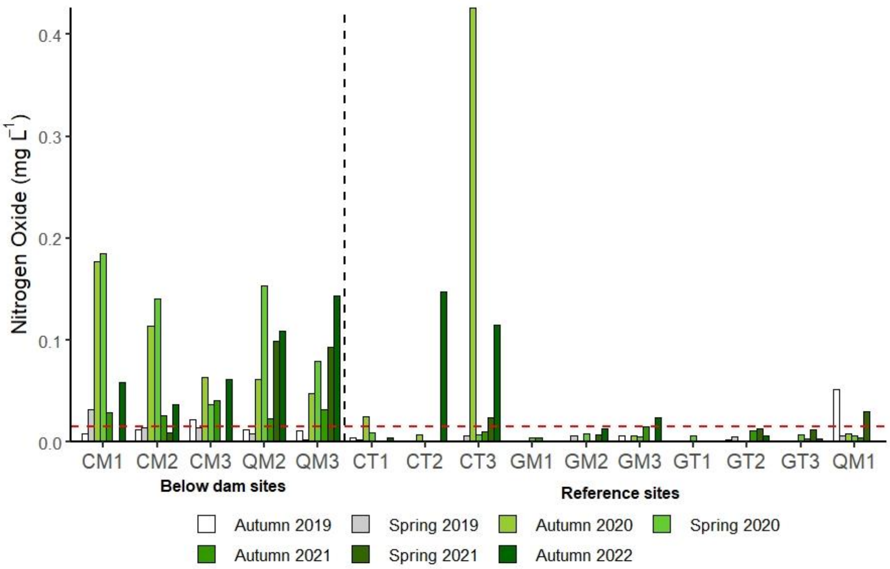
CLASS **Order** Family *Sub-family*	**Signal 2 Grade**	**Test sites**					**Reference sites**									
		CM1	**CM2**	**CM3**	**QM2**	**QM3**	**CT1**	**CT2**	**CT3**	**GM1**	**GM2**	**GM3**	**GT1**	**GT2**	**GT3**	**QM1**
Gastropoda																
Planorbidae	4									1						
Sphaeriidae	5											1				
OLIGOCHAETA	2						1			15	17	2	3	8	4	
ACARINA	6						2			5	1		1	15		
Coleoptera																
Scirtidae Sp.	6						1				1		1	1		
Elmidae (Adult)	7						1			7		1	1	4	2	
Elmidae (Larvae)	7						23			3	2	3	6	5	3	
Psephenidae	6									10	3	3	1	1	1	
Ptilodactylidae	10						2									
Diptera																
Tanyderidae	6														1	
Tipulidae	5						5				3	2	8	21	10	
Ceratopogonidae	4														1	
Simuliidae	5						2				4	4	2	1	4	
Athericidae	8						5					1		1	2	
Aphroteniinae	8						2							2		
Podonominae	6										1				3	
Tanypodinae	4									1			2	2		
Orthocladiinae	4						29			9	20	51	46	22	21	
Chironominae	3						10			3	7	2	2	4	1	
Ephemeroptera																
Baetidae	5						25			26	10	78	59	27	31	
Coloburiscidae	8						10			5	12	2			6	
Leptophlebiidae	8						10			18	68	25	18	52	40	
Caenidae	4									8	3	1		6		
Hemiptera															2	
Veliidae	3														2	
Megaloptera																
Corydalidae	7						1								3	
Odonata																
Aeshnidae	4						5									
Gomphidae	5										1				1	
Telephlebiidae	9												1		2	
Plecoptera																
Gripopterygidae	8						20			14	26	7	16	5	16	
Eustheniidae	10						2									
Trichoptera																
Hydrobiosidae	8						3			3	2	4	5	3		
Glossosomatidae	9									1		1				
Hydroptilidae	8						1						5			
Philopotamidae	8						3			11			1		1	
Hydropsychidae	6						10			1	2	1	2		1	
Ecnomidae	4						4			5	9	4	1	2	1	
Conoesucidae	8						21			47	13	21	16	12	39	
Helicopsychidae	8												1	1		
Leptoceridae	6									3	1	1	6	5		
No. of individuals							198			193	205	214	197	194	198	
No. of taxa							25			20	20	20	21	20	25	
% of sub-sample							14			8	7	5	8	6	28	
Whole sample estimate							**1414**			**2413**	**2929**	**4280**	**2463**	**3233**	**707.1**	

APPENDIX 3: WATER QUALITY FIGURES

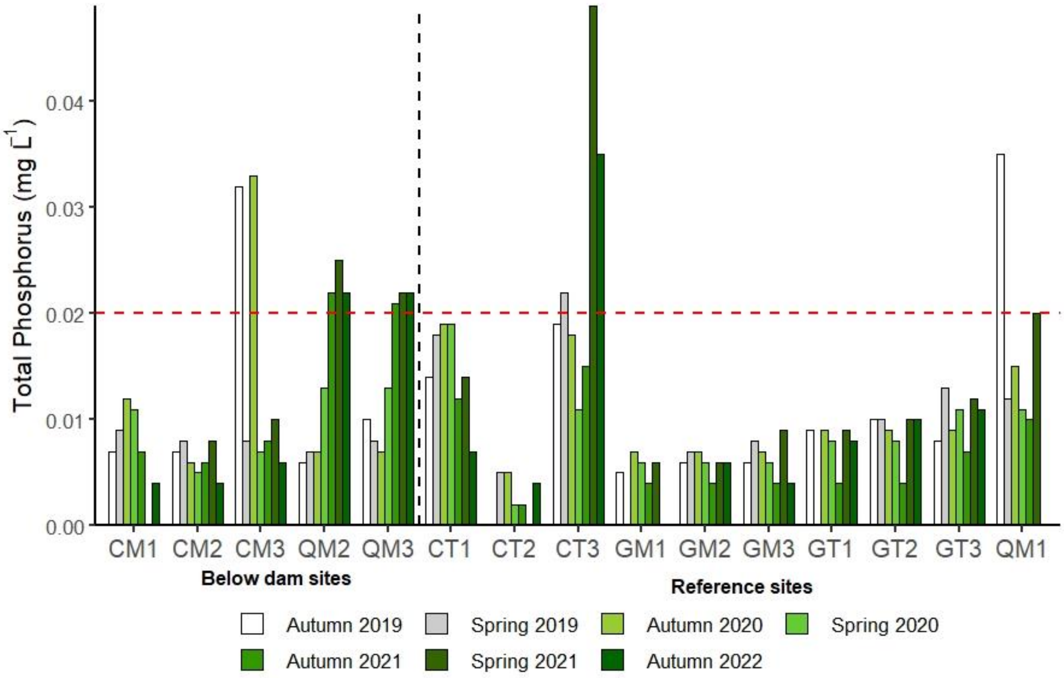
(Note: There was no flow during sampling and water samples could not be collected at site CT2 (Burkes Creek at above Pipeline Crossing).



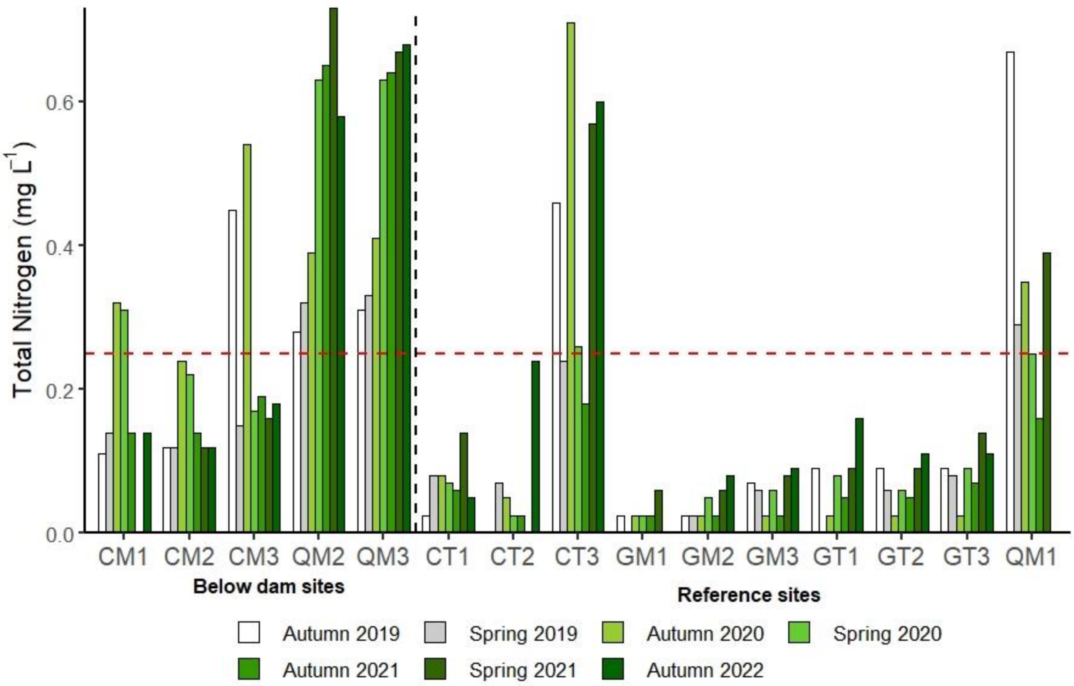
Ammonium (NH_4^+) concentration at all sites from autumn 2019 to autumn 2022. Values below the minimum detectable limit of 0.002 mg L^{-1} are shown at 0.001 mg L^{-1}. The ANZECC/ARMCANZ (2000) guideline maximum concentration for ammonium (NH_4^+) is dashed line and shaded red.



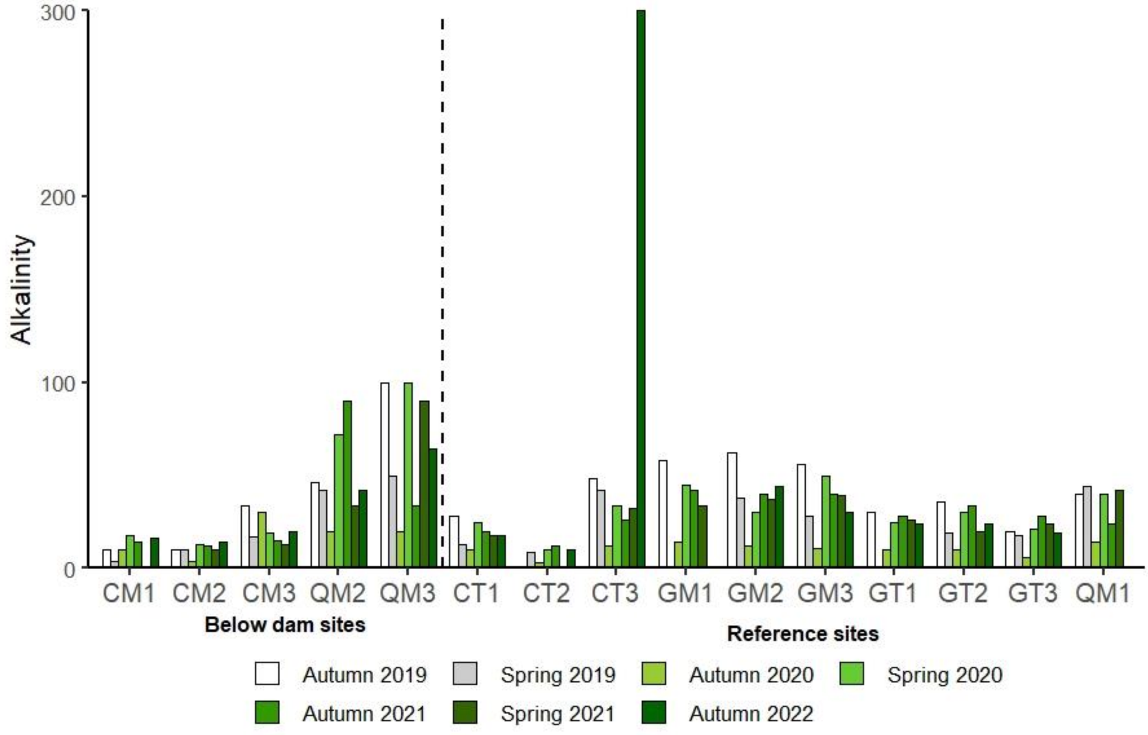
Nitrogen oxide concentrations at all sites from autumn 2019 to autumn 2022. Values below the minimum detectable limit of 0.002 mg L-1 are shown at 0.001 mg L-1. The ANZECC/ARMCANZ (2000) guideline maximum concentration for nitrogen oxide is dashed line and shaded red.



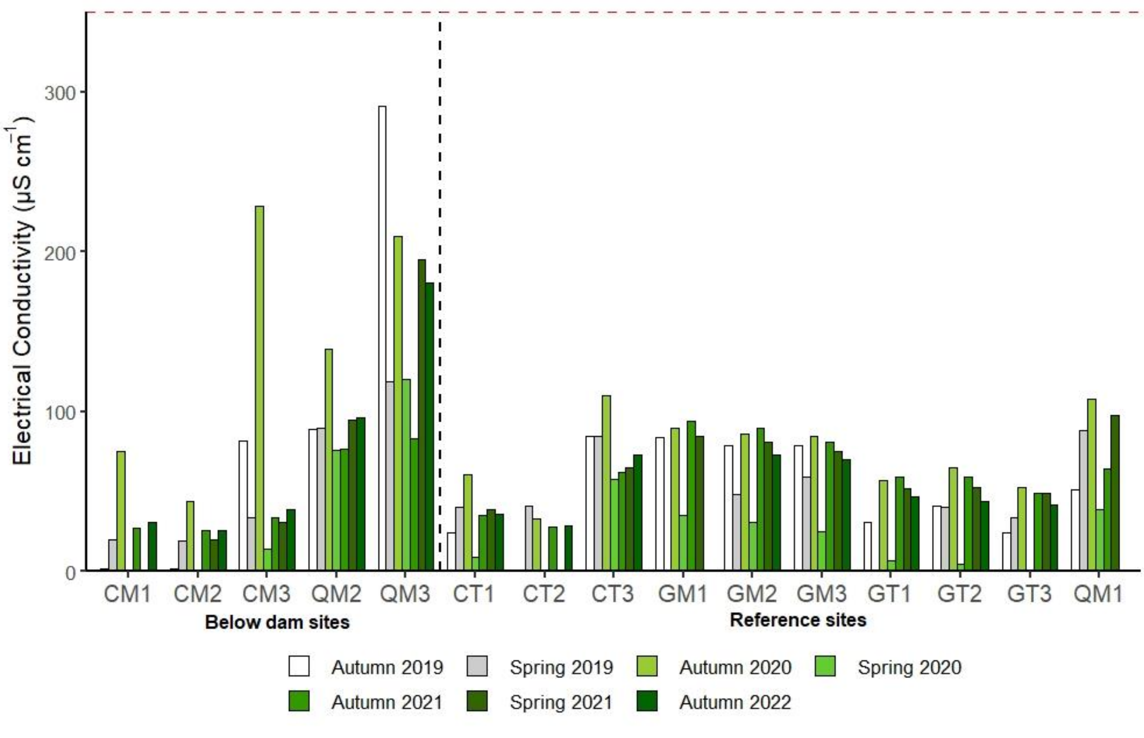
Total phosphorus concentrations at all sites from autumn 2019 to autumn 2022. Values below the minimum detectable limit of 0.01 mg L-1 are shown at 0.005 mg L-1. The ANZECC/ARMCANZ (2000) guideline maximum concentration for total phosphorus is dashed line and shaded red.



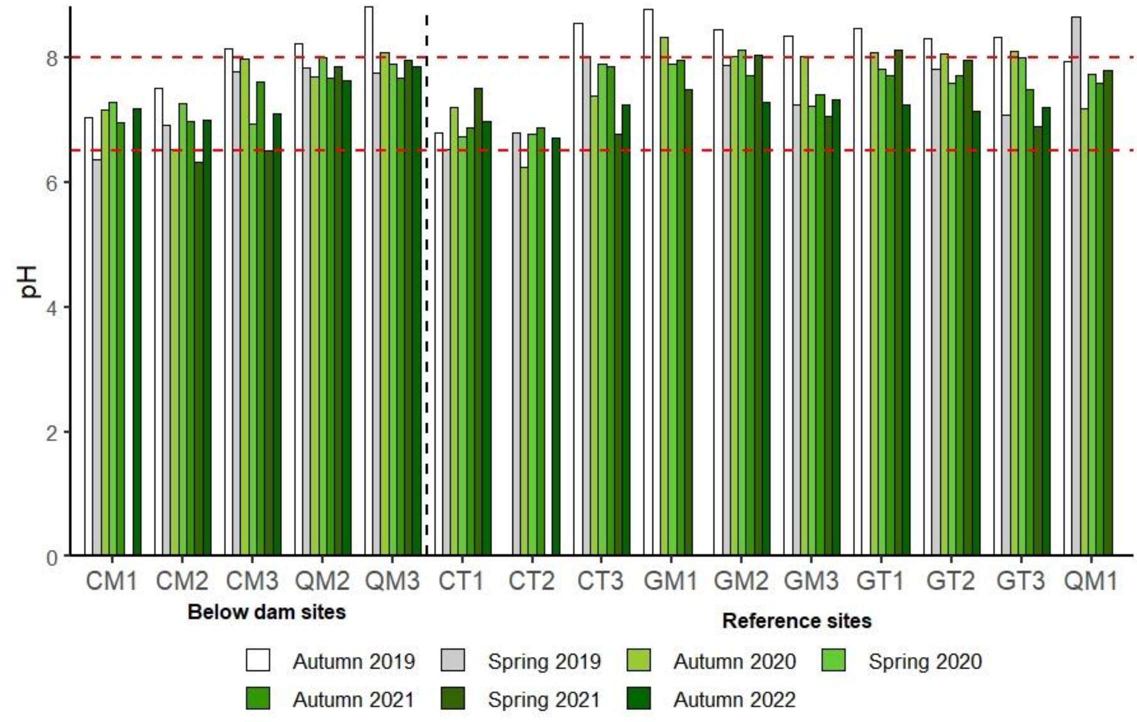
Total nitrogen concentrations at all sites from autumn 2019 to autumn 2022. Values below the minimum detectable limit of 0.01 mg L-1 are shown at 0.005 mg L-1. The ANZECC/ARMCANZ (2000) guideline maximum concentration for total nitrogen is dashed line and shaded red.



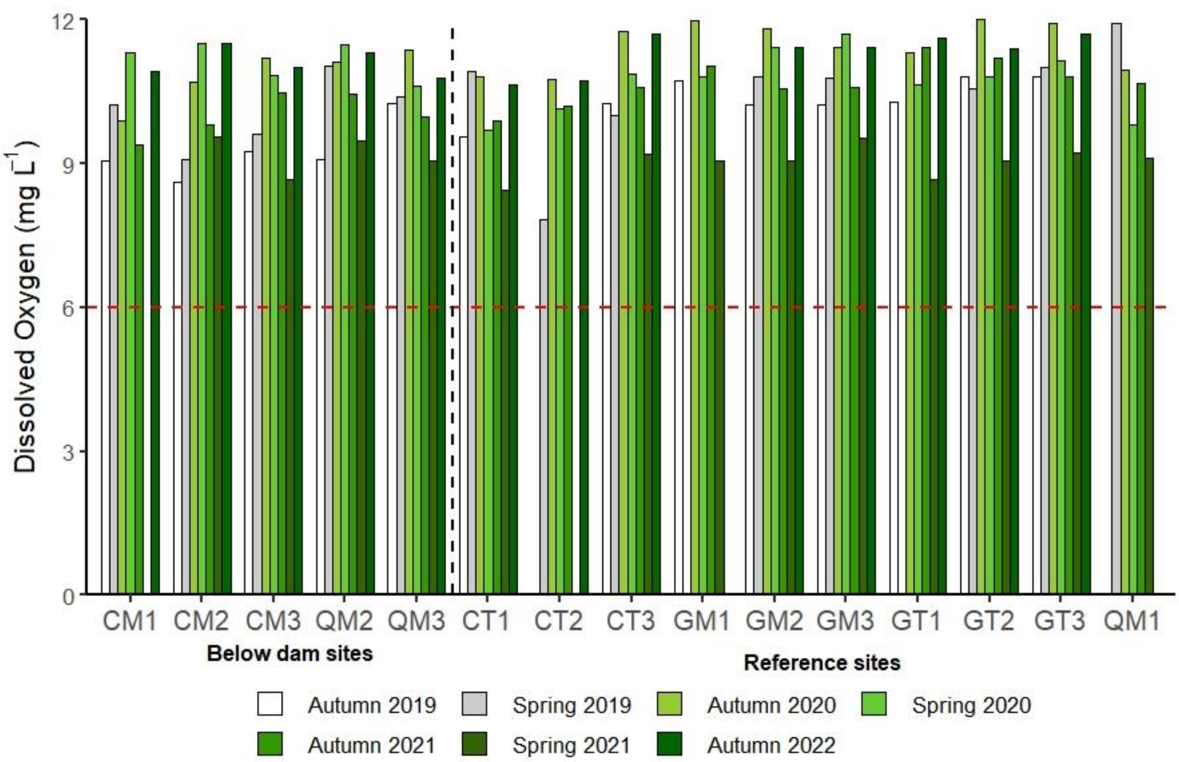
Alkalinity at all sites from autumn 2019 to autumn 2022.



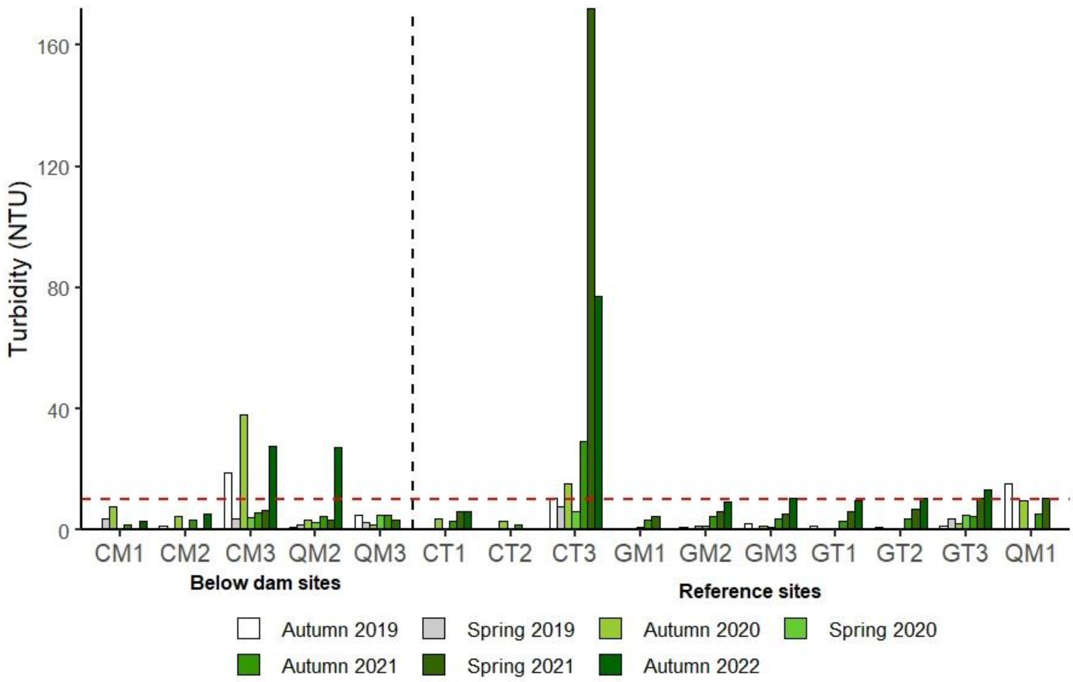
Electrical conductivity at all sites from autumn 2019 to autumn 2022. The ANZECC/ARMCANZ (2000) guideline for maximum electrical conductivity is dashed line and shaded red.



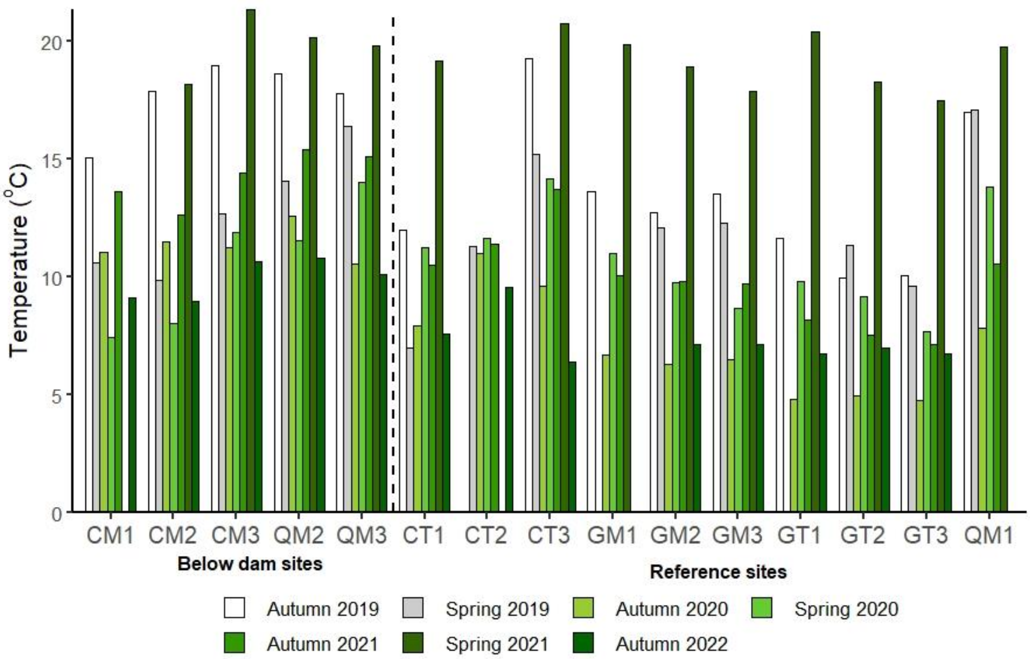
pH at all sites from autumn 2019 to autumn 2022. The ANZECC/ARMCANZ (2000) guideline range for pH are dashed lines and shaded red.



Dissolved oxygen concentration at all sites from autumn 2019 to autumn 2022. The minimum guideline for dissolved oxygen is dashed line and shaded red (Environment Protection Regulation SL2005-38).



Turbidity at all sites from autumn 2019 to autumn 2022. The guideline for maximum turbidity is dashed line and shaded red (Environment Protection Regulation SL2005-38).



Water temperature at all sites from autumn 2019 to autumn 2022.