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MURRUMBIDGEE ECOLOGICAL MONITORING PROGRAM

PART 4: TANTANGARA TO BURRINJUCK

Spring 2010

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Executive Summary

The major water security program introduced by ACTEW Corporation in 2007 is in the process of upgrading existing, and developing new infrastructure to secure water for the Australian Capital Territory in light of the recent drought in the region. Included in the new water security projects is the proposed "Tantangara transfer", which will involve releasing water from the Tantangara Reservoir in the upper Murrumbidgee River to the ACT via run of river flow with the aim of providing a source of water that is less dependent on rainfall within the ACT.

The Murrumbidgee Ecological Monitoring Programme (MEMP) is designed to address potential concerns brought up by both Government and non-Government stakeholders; and provides relevant information and data regarding beneficial and/or detrimental ecological effects of the water abstraction projects. The aims of this monitoring program have been established to monitor the condition of the Murrumbidgee River in terms of water quality and ecological condition at key sites both upstream and downstream of the extraction points, before and after the proposed abstractions are implemented.

The key aims of this sampling run were to:

a. *Increase baseline macroinvertebrate data for key sites along the Murrumbidgee River, and in doing so establish a database of the existing condition prior to any releases from Tantangara reservoir;*
b. *Undertake in-situ water quality sampling – including nutrient analysis as a baseline for future condition assessments;*
c. *Provide AUSRIVAS assessments of riffle and edge habitats between Tantangara Reservoir and Burrinjuck reservoir on the Murrumbidgee River*

This report contains the results of the spring 2010 sampling event conducted on the Murrumbidgee River between Tantangara Dam and Uriarra Crossing. Historically, sites are also sampled as far downstream as Burrinjuck Dam delta. However, high rainfall throughout the spring period, including the upper Cotter Catchment, meant that the Cotter Reservoir was spilling at a much higher rate than usual. Therefore, sampling could not be safely conducted at some sites downstream of the Cotter River confluence. Despite the high rainfall throughout September, October and November, macroinvertebrate and in-situ water quality sampling (at most sites) followed a dry period of approximately 8 days.

The impacts of high flow events throughout spring were evident in the water quality and macroinvertebrate results. Several exceedances of nutrient guidelines were observed within Zone 2 and Zone 3, presumably as a result of run-off from surrounding agricultural land. Low Electrical Conductivity levels at Zone 1 sites are assumed to be due to rainfall experienced on the day of sampling. The exceedance of upper Turbidity trigger levels occurred at several of the permanent monitoring stations. Spikes of high turbidity level were usually linked to corresponding rainfall events.

Multivariate analyses determined that there were significant differences in the macroinvertebrate community collected from Riffle samples between Zone 1 and Zone 2. The macroinvertebrate community from Edge samples was seen to differ at Zone 1 sites compared to sites within Zones 2 and 3. These differences were generally considered to be related to higher flow occurring in Zones 2 and 3 compared to Zone 1.

Macroinvertebrate richness was comparable to previous sampling events, considering the high flow conditions. However, the proportion of sensitive taxa was reduced by comparison to previous sampling events. There was no difference in SIGNAL-2 or EPT richness between zones.

AUSRIVAS results varied between "reference condition" and "severely impaired". The poor ratings received at some sites were due to habitat changes caused by high flows or potential eutrophication resulting from run-off. These results must be treated with caution given the flooding conditions that were experienced during sampling. Further sampling at baseflow conditions is required to accurately assess the relationships between flow and "ecological health" within the Murrumbidgee River.

Based on the results of this study, ACTEW should continue with the current monitoring design to cover as much hydrological variation in the six-monthly sampling as possible in order to obtain a robust data set of biological and water quality parameters prior to the Tantangara transfer project is operational. Additional multivariate analyses have been included in this study to address the relationships between environmental parameters and macroinvertebrate communities. It is recommended that this component of the Tantangara to Burrinjuck monitoring program is maintained, but expanded to include a suite of hydrological variables such as time since disturbance and mean seasonal flows for example, which could be used to predict responses of certain indicator taxa and ma may have important ramifications in ACTEWS ability to predict likely responses to various flow regimes in the Murrumbidgee River prior to the Tantangara Transfer.

List of abbreviations

ACT – Australian Capital Territory

ACTEW – ACTEW Corporation Limited

ANZECC – Australian and New Zealand Environment and conservation Council

ANOSIM – Analysis of Similarities (statistics)

ANOVA – Analysis of Variance (statistics)

ARI – Annual Recurrence Interval

ARMCANZ - Agriculture and Resource Management Council of Australia and New Zealand

AUSRIVAS – Australian River Assessment System

CPOM – Coarse Particulate Organic Matter

CRCFE – Cooperative Research Centre for Freshwater Ecology

EC – Electrical Conductivity

ECD – Enlarged Cotter Dam

EIS – Environmental Impact Statement

EPA – Environmental Protection Authority

EPT – Ephemeroptera, Plecoptera, Trichoptera

D.O. – Dissolved Oxygen

GL/a – Gigalitres per annum

GPS – Global Positioning System

LMWQCC – Lower Molonglo Water Quality Control Centre

LWD – Large Woody Debris

M2G – Murrumbidgee to Googong

MEMP – Murrumbidgee Ecological Monitoring Program

ML/d – Megalitres per day

NATA – National Association of Testing Authorities

NMDS – Non-metric Multidimensional Scaling (statistics)

O/E Family – Observed to Expected ratio of macroinvertebrate families

PCA – Principal Components Analysis

Q – Daily flow (ML/d)

QA – Quality Assurance

QC – Quality Control

RBA – Rapid BioAssessment

SIGNAL – Stream Invertebrate Grade Number – Average Level

SIMPER – Similarity Percentage (statistics)

TN – Total Nitrogen

TP – Total Phosphorus

Temp. - Water temperature (℃)

WAE – Water Allocation Entitlement

WL – Water Level

1 Introduction

The Murrumbidgee Ecological Monitoring Program was set up by ACTEW Corporation to evaluate the potential impacts of water abstraction from the Murrumbidgee River. It is being undertaken as part of the ACT water supply security infrastructure upgrade. There are four component areas being considered:

Part 1: Angle Crossing;

Part 2: Burra Creek (discharge point for Angle Crossing abstraction);

Part 3: Murrumbidgee Pump Station; and

Part 4: Tantangara to Burrinjuck.

This report focuses on Part 4: Tantangara to Burrinjuck.

The major water security program introduced by ACTEW Corporation in 2007 involves upgrading existing, and developing new infrastructure to secure water for the Australian Capital Territory in light of continuing drought in the region. Included in the new water security projects is the "Tantangara transfer" which will involve transferring water from the Tantangara Reservoir in the upper Murrumbidgee River to the ACT via run of river flow with the aim of increasing water security for the region.

ACTEW is committed to the construction of a river offtake pumping structure, and pipeline from a location near Angle Crossing (southern border of the ACT). The proposed pumping system will transfer water, initially released from Tantangara Reservoir into the Murrumbidgee River, from Angle Crossing through an underground pipeline into Burra Creek, and then transfer the water by Run of River flows into the Googong Reservoir. The system is being designed to enable pumping of up to 100 ML/d, and to be in operation by around 2011. Abstraction will be dictated by the level of demand for the water, and by the availability of water in the Murrumbidgee River. The proposal is referred to as Murrumbidgee to Googong project (M2G). A schematic overview of the proposed operations is given in Appendix A.

Water abstractions will be regulated through the *2006 Environmental Flows Guidelines*. ACT & NSW Government agencies, and recreational and rural users in the regional Murrumbidgee River reach (both upstream and downstream of Angle Crossing), are key stakeholders in the M2G project.

The Murrumbidgee River Ecological Monitoring Program (MEMP) is designed to address concerns raised by both Government and non-Government stakeholders; and provide ACTEW Corporation with relevant information regarding any beneficial and/or detrimental ecological effects of the project. The project is to be implemented prior to the commencement of the M2G project, allowing ACTEW to collect pre- and post-abstraction data.

1.1 Objectives

The overall objectives of the MEMP are to monitor the physical, biological and water quality indicators along the length of the upper Murrumbidgee River from Tantangara to Burrinjuck reservoirs (details are given in Ecowise, 2009). The intention of the first season of sampling was to establish baseline macroinvertebrate data for key sites along the Murrumbidgee River and in doing so, establish a database of the existing condition prior to any releases from Tantangara Reservoir. The baseline monitoring incorporates water quality monitoring (including nutrient analysis) and macroinvertebrate monitoring based on the Australian River Assessment System (AUSRIVAS) sampling and assessment framework.

With these procedures in place, ALS will be able to provide ACTEW with appropriate information to further develop knowledge and understanding of environmental flows and ecosystem thresholds. The information derived from this program will also support ACTEW's adaptive management approach to water abstraction and environmental flow provision in the ACT. Frequent assessments of the program will ensure that the monitoring program put in place has the capacity to adapt to changing environmental, social and economic conditions, with regard to ACTEW's operations and requirements.

1.2 Scope of Work

The works outlined in the proposal to ACTEW Corporation (Ecowise, 2009) included the following:

- Bi-annual sampling to commence in spring 2008;
- Macroinvertebrate sampling of both the riffle and edge habitats as per ACT AUSRIVAS protocols;
- Macroinvertebrates to be identified to the taxonomic level of family;
- In-situ water quality measurements to be collected and analysed; and
- Nutrient analysis to be conducted in ALS's NATA accredited laboratory.

2 Materials and Methods

2.1 Study Sites

As stated in the objectives of this program, macroinvertebrate community composition and water quality is to be monitored along the Murrumbidgee River between the Tantangara and Burrinjuck reservoirs, with the aim of obtaining baseline information about ecological condition. Ecological monitoring was conducted in accordance with ANZECC and ARMCANZ (2000) guidelines.

The upper Murrumbidgee River is impacted by a range of land-use practices throughout the catchment. Consequently, it was important to sample a sufficiently large number of sites to provide a realistic snap-shot of the current macroinvertebrate community across all existing land-use types. Both riffle and edge habitats were sampled, where possible, to provide a more complete picture of the macroinvertebrate community at each site.

Sites were chosen based on several criteria which included:

1. Accessibility – safe and with approvals from land owners;
2. Sites which have representative habitats (i.e. riffle / pool sequences). If both habitats were not present then riffle zones took priority as the they are the most likely to be affected by water abstractions;
3. Sites which have historical ecological data sets (e.g. Keen, 2001) took precedence over "new sites" – thus allowing comparisons through time to help assess natural variability through the system.

Potential sites were identified initially from topographic maps and then visited prior to sampling to assess suitability. In total, 23 sites fulfilled the above criteria. These sites include 10 sites upstream of Angle Crossing (NSW) and 13 sites downstream. The sites include locations up and downstream of the major abstraction site at Angle Crossing, locations upstream and downstream of the Lower Molonglo Water Quality Control Centre (LMWQCC) and several of the Murrumbidgee Rivers major tributaries (Table 1; Figure 1).

The sites were divided into four macro-reaches (zones) representing geographic or hydrological changes (Allan and Castillo, 2008) throughout the system; and obvious changes in land-use, erosional processes and/or other potential anthropogenic impacts. These classifications are to some extent subjective, but are based on previous frameworks which have suggested methods for such classifications (e.g. Hynes, 1970; Frissell et al., 1986; Allan and Castillo, 2008). Details of the four zones are provided in Table 2.

Table 1: Sampling site locations and details

Site Code	Location	Alt. (m)	Landuse	Habitat sampled
Mur 1	D/S Tantangara Reservoir	1200	Native	Edge
Mur 2	Yaouk Bridge	1070	Grazing	Riffle and Edge
Mur 3	Bobeyan Road Bridge	968	Grazing	Riffle and Edge
Mur 4	Camp ground off Bobeyan Road	968	Recreation / Grazing	Edge only
Mur 6	D/S STP Pilot Creek Road	743	Native / Residential	Riffle and Edge
Mur 9	Murrells Crossing	723	Grazing	Riffle and Edge
Mur 12	Through Bredbo township	698	Grazing / Residential / Recreation	Riffle and Edge
Mur 15	Near Colinton - Bumbalong Road	658	Grazing / Recreation	Riffle and Edge
Mur 16	The Willows - Near Michelago	646	Grazing / Recreation	Riffle and Edge
Mur 18	U/S Angle Crossing	608	Grazing	Riffle and Edge
Mur 19	D/S Angle Crossing	608	Grazing / Recreation	Riffle and Edge
Mur 22	Tharwa Bridge	572	Recreation / Grazing / Residential	Riffle and Edge
Mur 23	Point Hut Crossing	561	Recreation / Residential	Riffle and Edge
Mur 27	Kambah Pool	519	Recreation / Residential	Riffle and Edge
Mur 931	“Fairvale” ~4km U/S of the Cotter Confluence	480	Grazing	Not sampled
Mur 28	U/S Cotter River confluence	468	Grazing	Not sampled
Mur 935	Casuarina sands	471	Grazing	Not sampled
Mur 937	Mt. MacDonald ~5km D/S of the Cotter Confluence	460	Grazing / ex-forestry/ Recreation	Not sampled
Mur 29	Uriarra Crossing	445	Grazing	Riffle and Edge
Mur 30	U/S Molonglo Confluence	445	Grazing	Not sampled
Mur 31	D/S Molonglo Confluence	443	Grazing	Not sampled
Mur 34	Halls Crossing	393	Grazing	Not sampled
Mur 37	Boambolo Road	370	Grazing	Not sampled

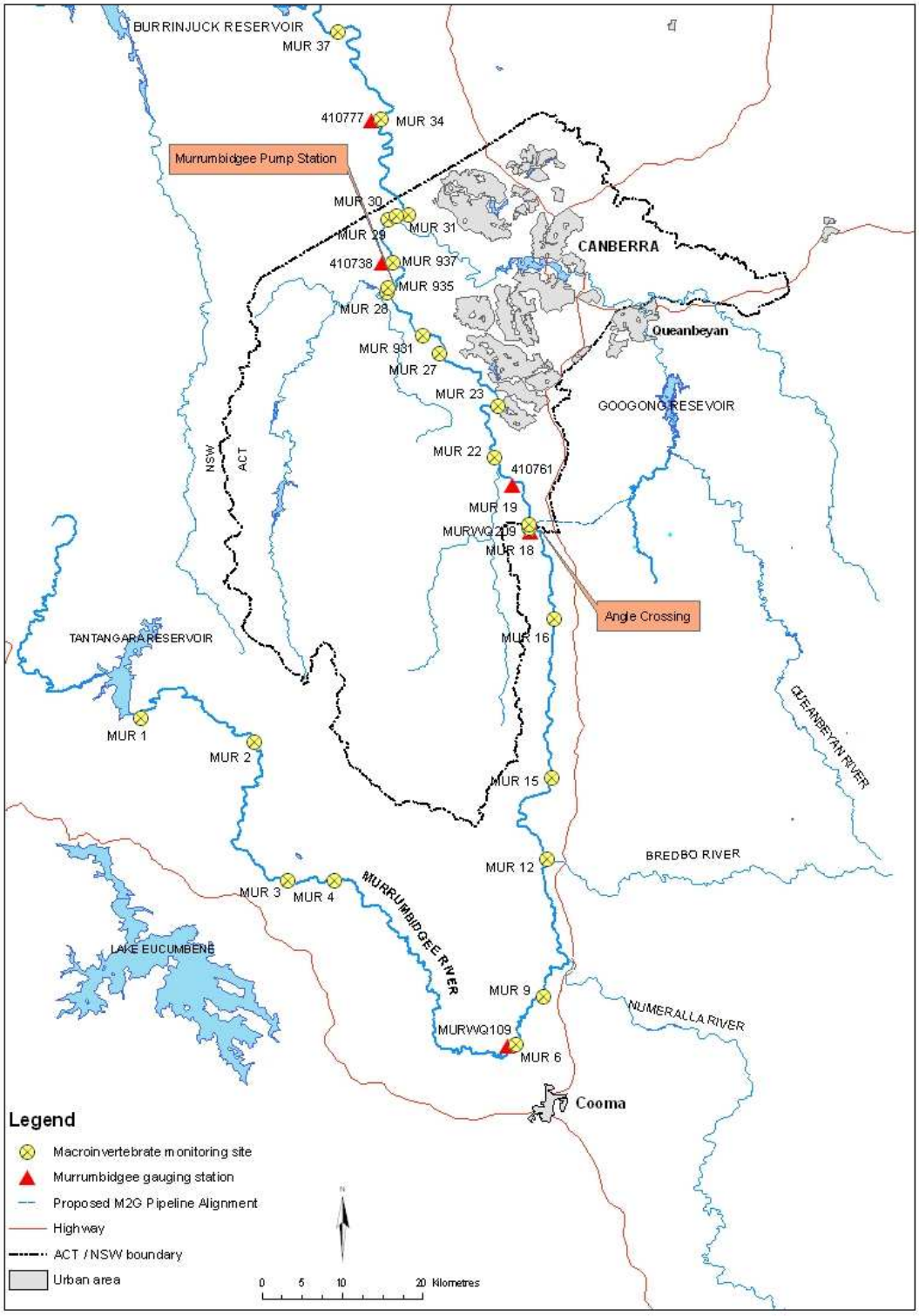

Figure 1: Location map of macroinvertebrate monitoring sites on the Murrumbidgee River

Table 2: Zone structure of sites along the Murrumbidgee River

Macro-reach	Zone	Sites included	Land use
Tantangara - Cooma	1	MUR 1 - 4	Native. Reservoir within national park. Recreation. Agricultural land downstream of Yaouk
Cooma – Angle Crossing	2	MUR 6 - 18	Agriculture dominant. Some urbanization. STP present upstream of MUR 6.
Angle Crossing - LMWQCC	3	MUR 19 - 30	Residential and residential / urban development increases. Less grazing than in the Tantangara – Cooma and LMWQCC – Taemas Bridge macro-reaches
LMWQCC – Taemas bridge	4*	MUR 31 - 37	Intensive agricultural land use. Downstream of LMWQCC. Previous work has shown a marked change in water quality downstream of the treatment plant

*Zone 4 sites could not be sampled in spring 2010

2.2 Hydrology and rainfall

River flows and rainfall for the sampling period were recorded at gauging stations operated and maintained by ALS located at: upstream of Angle Crossing (MURWQ09); Lobb's Hole (downstream of Angle Crossing: 410761); Mount MacDonald (downstream of the Cotter River Confluence: 410738) and Halls Crossing (located at MUR 34: 410777). Gauging locations and codes are given in Table 3. Stations are calibrated monthly and data is downloaded and verified before quality coding and storage in the database. Water level data is manually verified by comparing the logger value to staff gauge value and adjusted accordingly. Rain gauges are calibrated and adjusted as required. Records are stored on the HYDSTRA© database software and downloaded for each sampling period.

Table 3: River flow monitoring locations and parameters

Site	Site Code	Location/Notes	Parameters*	Latitude	Longitude
1	MURWQ09	M'bidgee River, upstream of Angle Crossing	WL, Q, pH, EC, D.O., Temp, Turb, Rainfall	S 35.5907	E 149.1179
2	410761	M'bidgee River @ Lobb's Hole (D/S of Angle Crossing)	WL, Q, pH, EC, D.O., Temp, Turb, Rainfall	S 35.5398	E 149.1015
3	410738	M'bidgee River @ Mt. MacDonald	WL, Q	S 35.2917	E 148.9565
4	410777	M'bidgee River @ Hall's Crossing	WL, Q, pH, EC, D.O., Temp, Turb, Rainfall	S 35.13277	E 148.9425

* WL = Water Level; Q = Rated Discharge; EC = Electrical Conductivity; D.O. = Dissolved Oxygen; Temp = Temperature; Turb = Turbidity; Rainfall = Rainfall (min. 0.2 mm).

2.3 Water quality

In-situ physico-chemical parameters including temperature, pH, electrical conductivity, turbidity and dissolved oxygen were recorded using a multiprobe HYDROLAB® Minisonde 5 and Surveyor meter. The Minisonde and Surveyor unit were calibrated in accordance with ALS QA procedures and the manufactures requirements prior to sampling.

From each site, grab samples were taken in accordance with the AUSRIVAS protocols (Coysh et al., 2000b) for HYDROLAB® verification and nutrient analysis. All samples were placed on ice, returned to the ALS laboratory and analysed for nitrogen oxides (total NOx), total nitrogen and phosphorus in accordance with the protocols outlined in A.P.H.A (2005). Collectively, this information on the water quality parameters will assist in the interpretation of biological data and provide a basis to gauge changes that can potentially be linked to flow reductions at these key sites following water abstractions.

2.4 Macroinvertebrate sampling

Macroinvertebrate samples were collected and analysed in accordance with the ACT AUSRIVAS protocols for Riffle and Edge habitats (Coysh et al., 2000). Samples were collected using a framed net (350 mm wide) with 250 µm mesh. Riffle habitat (flowing broken water over gravel, pebble, cobble or boulder, with a depth greater than 10cm) (Coysh et al., 2000). Sampling began at the downstream end of each riffle. The net was held perpendicular to the substrate with the opening facing upstream. The stream directly upstream of the net opening was disturbed by vigorously kicking and agitating the stream bed, allowing any dislodged material to be carried into the net. The process continued, working upstream over 10 metres of riffle habitat. Edge habitat was sampled by sweeping the collection net along the edge habitat at the sampling site with the operator working systematically over a ten metre section and sampling where there was overhanging vegetation, submerged snags, macrophyte beds, overhanging banks and areas with trailing vegetation. The samples were then preserved in the field using 70% ethanol in clearly labelled containers showing site codes, habitat and date information.

The purpose of this seasonal report is to convey the results of the macroinvertebrate and water quality sampling from Tantangara Reservoir to Burrinjuck Reservoir in spring 2010. Several sites within this report are also key components of the three main sub-sections of the Murrumbidgee Ecological Monitoring Program (MEMP), including monitoring for the Murrumbidgee Pump Station (MPS) upgrade and the impact assessment of the construction and operation of the Angle Crossing pump station and pipeline, which includes the eventual discharge into Burra Creek. The sampling regime for these sub-sections differs slightly to those reported here, mainly in that multiple replicates were collected for ecological assessment in the other sub-sections. This means that a more comprehensive list of macroinvertebrate taxa captured is likely for those sub-sections. For the purposes of consistency, the results for this component of the project were only compared with the first sub-sample from the first replicate analysed as part of monitoring in the other sub-sections. As such, it should be recognised that there are small discrepancies between the taxonomic inventories, taxonomic richness measurements and presence / absence of taxa reported here and those reported in relation to other sub-sections of the MEMP.

2.5 Sample processing

In the laboratory, the preserved macroinvertebrate samples were placed in a sub-sampler, comprising of 100 (10 X 10) cells (Marchant, 1989). The sub-sampler was then agitated to evenly distribute the sample. The contents of randomly selected cells were extracted, one at a time, until a total of 200 animals were collected. If 200 animals were identified before a cell had been completely analysed, identification continued until all animals within the cell were identified. Macroinvertebrates were examined under a microscope and identified to family level except for some groups such as Chironomidae (identified to sub-family), Oligochaeta (identified to class) and Acarina (identified to order). Macroinvertebrate identification was undertaken using a range of published and working keys. QA/QC procedures for macroinvertebrate sample processing are described in Section 2.5.

Upon the completion of macroinvertebrate identification, the samples were transferred to robust vials with evaporation-proof rubber seals for long-term archiving. Samples can be re-examined at a later date if required (e.g. if the taxonomy changes significantly during the course of a long term monitoring program).

2.6 Data analysis

2.6.1 Water quality

Principal Components Analysis (PCA) was used to determine which physico–chemical variables were most strongly associated with differences among sites. PCA was used in this component of the MEMP because of its capability of illustrating broad-scale spatial patterns in an ordination plot. This analysis provides a means of visualising the relationships between sites and zones based on changes in the physico-chemical and nutrient data which can help describe patterns that may otherwise have been missed.

PCA is a multivariate analysis technique that is commonly used on environmental data as an exploratory procedure. It compresses a set of variables – in this case water quality- into a smaller number of derived variables, called components. These components are linear combinations of the original variables that help explain as much of the variation in the data matrix as possible (Quinn and Keough, 2002); PCA summarises the data in a way which best explains the variance within the data set, so is similar to a multivariate extension of linear regression.

The output from the PCA includes a two or three dimensional plot similar to those produced by non-metric multidimensional scaling (NMDS) and a list of eigenvalues and eigenvectors. The eigenvalues represent the amount of the original variance explained by each new component and the eigenvectors are coefficients or weights that show how much each original variable contributes to each new, derived variable, or component.

Principal Components Analysis was performed in PRIMER version 6 (Clarke and Gorley, 2006) using normalised and log transformed (except pH) water quality variables collected

in spring 2010. The analysis began with 14 variables; Total NOx, nitrate, nitrite and ammonia records were removed from the analysis because most values were censored (i.e. their values were below detectable limits) and could not be reliably analysed in PRIMER.

Water quality parameters were also examined for compliance with ANZECC water guidelines for healthy ecosystems in upland streams (ANZECC and ARMCANZ, 2000).

2.6.2 AUSRIVAS assessment

AUSRIVAS is a prediction system that uses macroinvertebrates to assess the biological health of rivers and streams. The model uses site-specific information to predict the macroinvertebrate fauna expected (E) in the absence of environmental stressors. The expected fauna from sites with similar sets of predictor variables (physical and chemical characteristics which cannot be influenced by human activities e.g. altitude) are then compared to the observed fauna (O) and the ratio derived is used to indicate the extent of any impact (O/E). The ratios derived from this analysis are converted to Bandwidths (i.e. X, A-D; Table 4) which indicate the overall health of each site (Coysh et al. 2000). Data is presented using the AUSRIVAS O/E 50 ratio (Observed/Expected score for taxa with a >50% probability of occurrence) and the previously mentioned rating bands (Table 4).

The site assessments are based on the results from both the riffle and edge samples. The overall site assessment is based on the furthest band from reference in a particular habitat at a particular site. For example, a site that had an A assessment in the edge and a B Band in the riffle would be given an overall site assessment of B (Coysh et al., 2000b).

The use of the O/E 50 scores is standard in AUSRIVAS. However it should be noted that this restricts the inclusion of rare taxa and influences the sensitivity of the model. Taxa that are expected less than 50% of the time are not included in the O/E scores produced by the model. This could potentially limit the inclusion of rare and sensitive taxa and might also reduce the ability of the model to detect any changes in macroinvertebrate community composition over time (Cao et. al., 2001). However, it should be noted that the presence or absence of rare taxa does vary over time and in some circumstances the inclusion of these taxa in the model might indicate false changes in the site classification; the presence or absence of these taxa might be a function of sampling effort rather than truly reflecting ecological change.

Table 4: AUSRIVAS Band-widths and interpretations for the ACT spring edge and riffle models

Band	O/E Band Width		Explanation
	RIFFLE	EDGE	
X	>1.14	>1.13	More diverse than expected. Potential enrichment or naturally biologically rich.
A	0.86-1.14	0.87-1.13	Similar to reference. Water quality and / or habitat in good condition.
B	0.57-0.85	0.61-0.86	Significantly impaired. Water quality and/ or habitat potentially impacted resulting in loss of taxa.
C	0.28-0.56	0.35-0.60	Severely impaired. Water quality and/or habitat compromised significantly, resulting in a loss of biodiversity.
D	0-0.27	0-0.34	Extremely impaired. Highly degraded. Water and /or habitat quality is very low and very few of the expected taxa remain.

This might occur where the anthropogenic activities in question provide habitat that might not occur naturally or an enhanced food supply.

2.6.3 SIGNAL-2 (Stream Invertebrate Grade Number – Average Level)

Stream Invertebrate Grade Number – Average Level (SIGNAL) is a biotic index based on pollution sensitivity values (grade numbers) assigned to aquatic macroinvertebrate families. The sensitivity values for each family have been determined from published and unpublished information on their tolerance to pollutants, such as sewage and nitrification (Chessman, 2003). Each family in a sample is assigned a grade between 1 (most tolerant) and 10 (most sensitive). Sensitivity grades are also given in the AUSRIVAS output which can then be used as complimentary information to these assigned Bandwidths to aid the interpretation of each site assessment.

2.6.4 Univariate indices

Several additional metrics to the AUSRIVAS and SIGNAL-2 were utilised. The number of taxa (taxa richness) was counted for each site and other descriptive metrics such as the relative abundances of sensitive taxa (e.g. Ephemeroptera, Plecoptera and Trichoptera or EPT) and tolerant taxa, i.e. Oligochaeta and Chironomids were examined. Differences in SIGNAL-2 scores and O/E 50 ratios were determined between zones using separate one-way ANOVAs coding “Zone” and “Habitat” as fixed factors. Differences between groups were assessed using a modified version of Tukey’s HSD (honestly significant differenced) test for factors with $k \geq 3$ levels with uneven sample sizes.

High taxonomic richness does not necessarily indicate better ecological condition at a given site. While in certain instances high scores can indicate favourable conditions, they can also indicate altered conditions, indicative of an anthropogenically 'enhanced' site.

2.6.5 Macroinvertebrate communities

The Macroinvertebrate data were examined separately for riffle and edge habitats. All multivariate analyses were performed using PRIMER version 6 (Clarke and Gorley, 2006). Univariate statistics were performed using STATISTICA version 6 (StatSoft Inc, 1984-2002).

Non-metric multidimensional scaling (NMDS)

Non-metric multidimensional scaling (NMDS) was performed on the macroinvertebrate community data following the initial cluster analysis. NMDS is a multivariate procedure that reduces the dimensionality of multivariate data and simplifies its interpretation. It reduces the dimensionality of the data by describing trends in the joint occurrence of taxa. The initial step in this process was to calculate a similarity matrix for all pairs of samples based on the Bray-Curtis similarity coefficient (Clarke and Warwick, 2001). The number of dimensions (axes) used in the NMDS procedure was based on the resultant Stress levels. Stress is a measure of the distortion produced by compressing multidimensional data into a reduced set of dimensions and will increase as the number of dimensions is reduced. Stress can also be considered as a measure of "goodness of fit" of the ordination plot to the original data matrix (Kruskal, 1964).

Cluster analysis

Cluster analysis is a mathematical method of grouping entities according to the relative similarity of their attributes. In an ecological setting these techniques can be used to group sites according to how similar their macroinvertebrate community is. The key to this technique is the Bray-Curtis similarity matrix which is constructed from the individual similarities between all possible pairs of sites (Bray & Curtis, 1957; Clifford & Stephenson, 1975). From this matrix, a classification using Hierarchical Agglomerative Clustering is obtained and represented visually as a dendrogram. The dendrogram displays sites in groups of varying size according to the similarities between them. In other words, sites which are similar in macroinvertebrate assemblage will be grouped together on the dendrogram.

Cluster analysis can be useful in detecting patterns within complex data sets but it is not without limitations. The nature of this technique is such that linkages will often be made between sites based on chance similarities. The SIMPROF test (described below) can be used in conjunction with the cluster analysis to prevent misinterpretation of random similarities as "true" patterns.

SIMPROF (SIMilarity PROFile)

The SIMPROF test determines whether a dataset contains a "multivariate structure. It can be used as a safeguard against misinterpreting chance similarities as meaningful patterns. SIMPROF works by rearranging observations (i.e. taxa counts) across the samples to simulate random data and then recalculating the similarities between the samples. The similarities from the 'random' data are then compared to the similarities from the observed data. This process is replicated several times, each time with the observed data being compared to a different 'random' set of data. If the similarities calculated from the actual observations are found to be significantly different from those calculated from the simulated 'random' data then it is concluded that any pattern detected is 'real' and not

just a chance occurrence (Clarke and Warwick, 2001). When used in conjunction with cluster analysis, the SIMPROF test will indicate meaningful clusters within the dendrogram by outlining them in red.

ANOSIM (ANalysis of SIMilarity)

Analysis of Similarity (ANOSIM) was used to test for differences in the macroinvertebrate communities between groups (Zones). ANOSIM is a test of significance between groups which have been defined *a-priori* (Clarke, 1993) and is based on the rank order of the dissimilarity measures used to describe the relationships between groups of samples. The ANOSIM procedure tests the null hypothesis that there are no differences between the members of the various groups. The Similarity Percentages (SIMPER) routine was carried out on the datasets following a significant ANOSIM test to examine which taxa were responsible for, and explained the most variation among statistically significant groupings (Clarke and Warwick, 2001). This analysis procedure was also used to describe which taxa characterised each group of sites.

SIMPER (SIMilarity PERcentages)

The SIMPER routine was used to identify taxa that contributed strongly to the average dissimilarity between site groups identified from the cluster analysis (classification). SIMPER computes the average dissimilarity (Bray-Curtis) between all pairs of inter-group samples (every sample in Group 1 with every sample in Group 2 etc.) and then breaks this average down into the separate contributions from each taxon. In addition to calculating the average dissimilarity between groups, SIMPER also calculates the average similarity within a group.

BEST

BEST is a multivariate statistical technique that allows the user to evaluate the match between the community assemblage data and a set of corresponding environmental variables. It does this by determining all possible combinations of environmental variables (each on its own, each paired with one other, each paired with two others etc.) and calculating the similarities for each combination. Each matrix of environmental variable similarities is then correlated with the resemblance matrix of biotic assemblage. The BEST procedure selects the subset of environmental variables which produces the highest correlation coefficient. These variables are those which best explain the community composition seen across the sites (Clarke *et. al*., 2008). This technique was only employed where cluster (and SIMPROF) analysis suggested a difference between zones.

For all univariate and multivariate analyses, alpha was set to 5% (i.e. significance was based on $p<0.05$).

2.7 Macroinvertebrate quality control procedures

A number of Quality Control Procedures were undertaken during the identification phase of this program including:

- Organisms that were heavily damaged were not selected during sorting. Attempts were made to obtain significantly more than 200 organisms, to overcome losses associated with damage to intact organisms during vial transfer.
- Identification was performed by qualified and experienced aquatic biologists who had more than 100 hours of identification experience.
- When required, taxonomic experts performed confirmations of identification. Reference collections were also used when required.
- ACT AUSRIVAS QA/QC protocols were followed.
- An additional 10% of samples were re-identified by another senior taxonomist.
- Very small, immature, or damaged animals or pupae that could not be positively identified were not included in the dataset.
- Characteristics of geological and in-stream attributes were documented according to AUSRIVAS methods. These characteristics were cross-checked between sites with similar characteristics to ensure that habitat descriptions were consistent (some of the attributes involve percentage estimates, and are subjective by definition).
- All procedures were performed by AUSRIVAS accredited staff.

2.8 Licences and permits

All sampling was carried out with current NSW scientific research permits under section 37 of the Fisheries Management Act 1994 (permit number P01/0081(C))-03.

ALS field staff maintains current ACT AUSRIVAS accreditation.

3 RESULTS

Sampling was completed between the 20th and the 30th of November 2010. During spring 2010, heavy rainfall across the region resulted in increased flows at many of the targeted systems. Sites below the Cotter Dam (except MUR29) could not be sampled safely in during the spring sampling event. No sites from Zone 4 were sampled in spring 2010.

3.1 Hydrology and rainfall

Figure 2 below shows flows during spring 2010 at the four river flow monitoring locations (Table 3). This hydrograph also indicates rainfall in the area. For clarity, total rainfall (mm) is only shown from the Lobb's Hole gauging site. Rainfall records are highly correlated between Lobb's Hole, Angle Crossing and Halls Crossing (average R^2 = 0.86) indicating the records from Lobb's Hole are a fair representation of the broad scale patterns occurring during spring. Individual station statistics are presented in Table 5.

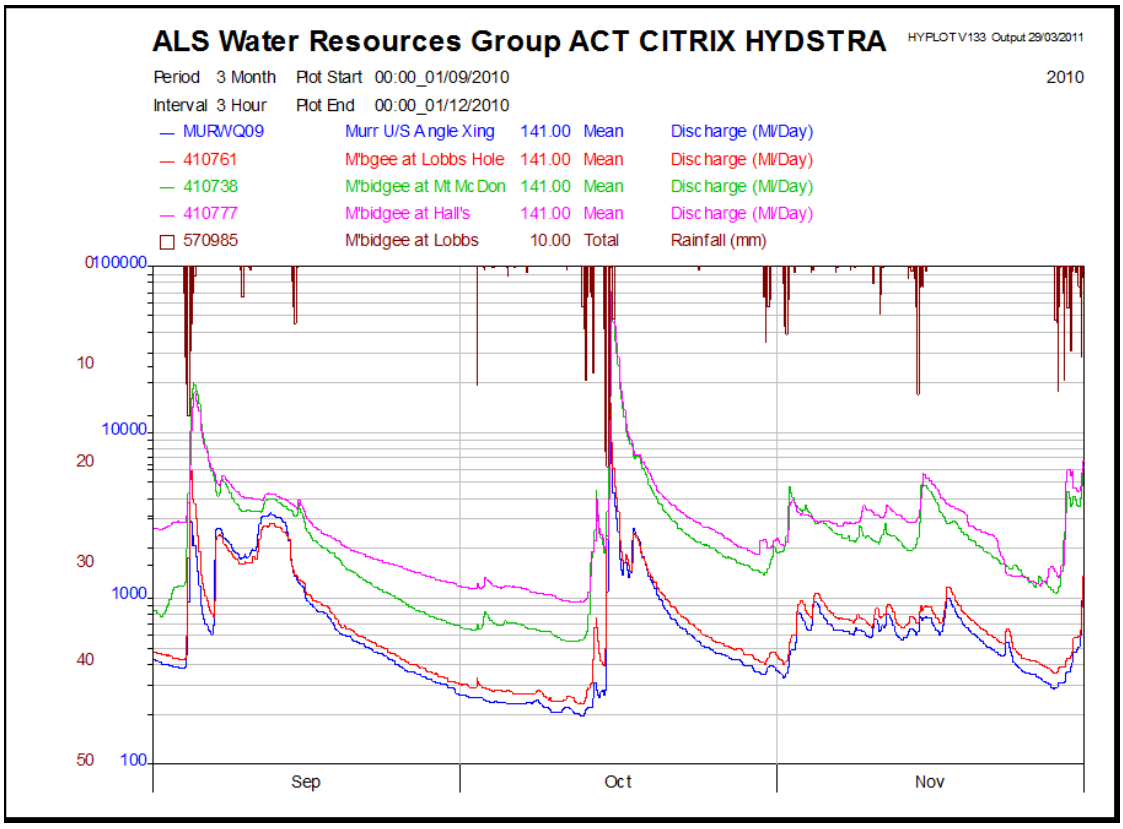

Figure 2: Spring hydrograph of the Murrumbidgee River at Angle Crossing (upstream) (blue); Lobb's Hole (red), Mount MacDonald (green) and Halls Crossing (pink)

During spring 2010 there were several periods of high rainfall. Rainfall was recorded for a total of 34 days at Lobb's Hole station and 39 days at MURWQ09. The rain was spread fairly evenly across the three month period with a spring rainfall total of 355 mm and 333 mm at Lobb's Hole and MURWQ09, respectively. Rain was usually concentrated to

a period of three or four days with dry days in between. From the hydrograph above, the most significant rainfall event occurred between 14th and 17th of October. Over this period, approximately 30 % of the total spring rainfall occurred at both stations. Other significant rainfall events were between 5th to 7th September, 14th to 16th of November and between 29th and 30th November.

The hydrograph in Figure 2 also indicates that patterns in flow closely mirrored the rainfall patterns. Nearly identical patterns were evident between the four stations, although the magnitude varied. In general, discharge was higher at Mt MacDonald and Lobb's Hole than at Hall's Crossing and Angle Crossing. Flow peaked on 15th of October, corresponding with the highest rainfall for the period. However, average flow was higher in September than the other two months of spring.

Table 5: Average monthly flow and rainfall statistics for spring 2010 at MURWQ09, Lobb's Hole, Mount MacDonald and Hall's Crossing. Flow values are averages (ML/Day). Rainfall values are totals (mm). N/A indicates no rainfall gauges are currently installed at these sites.

Site Code * ALS Site	September Average flow (ML/d)	October Average flow (ML/d)	November Average flow (ML/d)	 Rainfall (mm) (spring total)
Upstream of Angle Crossing (MURWQ09)	1079	710.8	585.5	333.99
Lobb's Hole (410761)	1119	858.6	689.9	355.89
Mt. MacDonald (410738)	2831	3487	2482	N/A
Hall's Crossing (410777)	3316	3946	2933	N/A

As a result of the high rainfall occurring over the entire region throughout spring (Figure 2), the Cotter Reservoir spilled at a much higher rate than usual (Appendix D) at the time of sampling. Although rainfall receded by late November when sampling was conducted, the hydrograph in Appendix D shows that daily discharge from Cotter Reservoir in November 2010 was still significantly greater than that observed over most of 2010 (i.e. between January and July 2010). As a result, flow and river depth was high at sites downstream of Cotter Dam (downstream of MUR 27). As macroinvertebrate sampling requires field staff to wade into the water body, sampling could not be conducted safely while flows were high. Accordingly, sampling could not be successfully completed at any site downstream of Cotter Dam in spring 2010.

3.2 Water Quality

3.2.1 Grab samples

Water quality results analysed from grab samples are presented in Table 6. All Turbidity and pH levels were within the range recommended by ANZECC and ARMCANZ (2000) water quality guidelines. Turbidity levels appeared to be generally lower in Zone 1 and higher in Zone 3. EC, Temperature and Alkalinity levels generally increased between the upstream sites of Zone 1 and the downstream sites of Zone 3 (except for MUR 28 and MUR 29). EC was lower than recommended between MUR1 and MUR 3. EC was below 100 µs/cm at all sites during spring 2010.

D.O. (% saturation) was lower than recommended in all Zone 1 sites and MUR6, MUR9, MUR 12 and MUR 15 within Zone 2. NOX was above the ANZECC and ARMCANZ (2000) trigger value at MUR 1 and MUR 12. NOX and Nitrate was higher at MUR 1 and MUR 12 than at any other sites. TP was higher than recommended at MUR 4 and all sites within Zone 2 and Zone 3. TN values were above the trigger level at all sites except MUR 1 and MUR 2.

The results of Principal Components Analysis conducted on the *in-situ* water quality results are shown in the ordination plot in Figure 3.

The two principal components shown in Figure 3 account for approximately 87.2% of the variation in the water quality results. The PCA ordination plot shows a separation in the water quality between the three zones along both axes. Axis 1 (PC1) represents decreasing Temperature, EC, Alkalinity and Turbidity. Axis 2 (PC2) of the PCA is characterised by decreasing Ammonia and TSS and increasing D.O. (% saturation) and pH. Therefore, this plot indicates that Temperature, EC, Alkalinity and Turbidity are lower at sites within in Zone 1 compared to Zones 2 and 3. It is also indicates that pH and D.O. is highest at Zone 3 sites followed by Zone 1 sites and then Zone 2 sites. Conversely, TSS and Ammonia levels are lowest within Zone 3 and highest within Zone 1 sites with intermediate levels of these parameters within Zone 2.

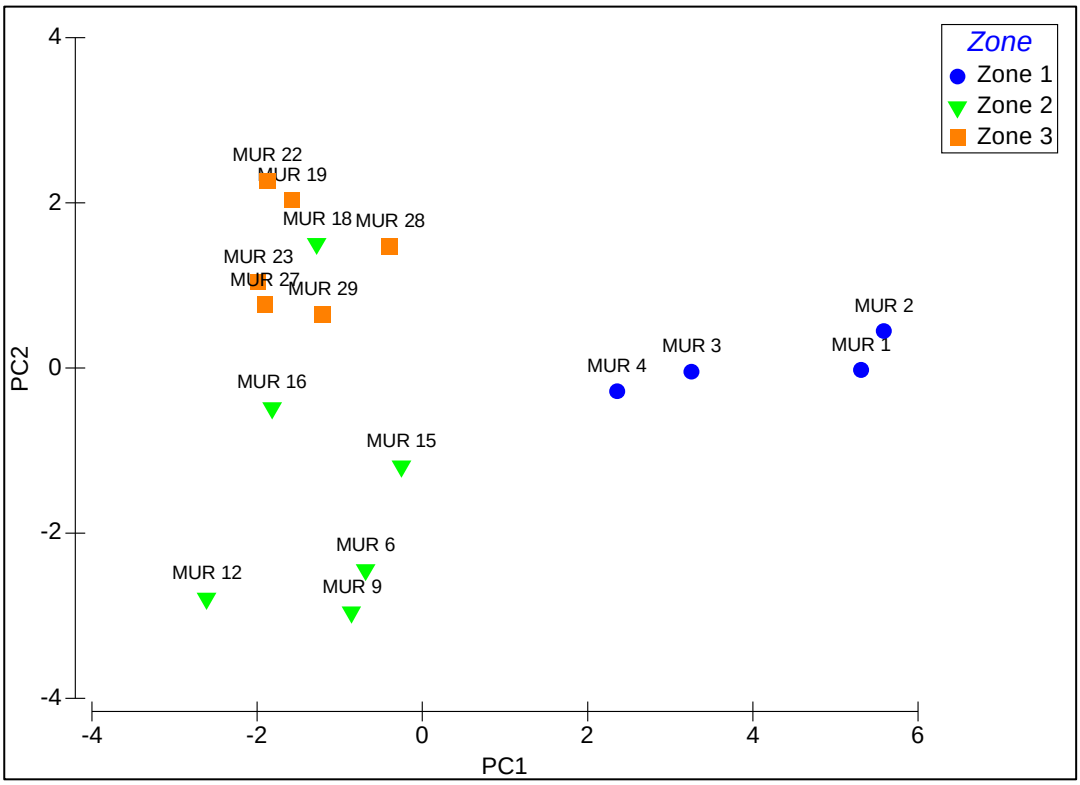

Figure 3: Correlation based Principal Components Analysis on water quality data collected in spring 2010

Table 6: *In-situ* water quality results for spring 2010. ANZECC & ARMCANZ guidelines are in bold parentheses. Values outside recommended guideline levels are highlighted yellow.

ZONE	Site	Time	Temp. (℃)	EC (µs/cm) (30-350)	Turbidity (NTU) (2-25)	TSS mg/L	pH (6.5-8)	D.O. (% Sat.) (90-110)	D.O. (mg/L)	Alkalinity	NOX (mg/L) (0.015)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L) (0.02)	TN (mg/L) (0.25)
Tantangara - Cooma	MUR 1	11:00	13.2	20.1	2	5	6.95	84.9	9.22	13	0.02	0.02	<0.01	0.01	0.02	0.2
	MUR 2	13:20	12	20.5	3	3	7.1	85.5	9.54	15	<0.01	<0.01	<0.01	0.03	0.01	0.15
	MUR 3	15:40	13.2	28.3	9	6	6.95	87.8	9.15	17	<0.01	<0.01	<0.01	0.03	0.02	0.33
	MUR 4	14:40	13.4	33.6	9	10	6.95	86.6	8.95	20	<0.01	<0.01	<0.01	0.02	0.03	0.39
Cooma – Angle Crossing	MUR 6	11:00	21.2	37.4	16	29	7.2	85.7	7.82	21	<0.01	<0.01	<0.01	0.07	0.05	0.35
	MUR 9	12:00	21.5	38	19	24	7.1	86.6	7.9	21	<0.01	<0.01	<0.01	0.11	0.05	0.32
	MUR 12	13:00	21.9	54.2	25	35	7.3	87.6	7.95	27	0.02	0.02	<0.01	0.11	0.07	0.42
	MUR 15	09:50	22.2	51.4	9.8	14	6.95	89.3	8.06	26	<0.01	<0.01	<0.01	0.07	0.04	0.37
	MUR 16	12;00	23.2	64.7	16	36	7.03	94.4	8.37	31	<0.01	<0.01	<0.01	0.04	0.05	0.51
	MUR 18	14:30	24.4	69.7	10	12	7.5	99.3	8.58	33	<0.01	<0.01	<0.01	0.04	0.04	0.46
Angle Crossing – LMWQCC	MUR 19	15:30	24.6	70.1	12	11	7.92	98.8	8.52	33	<0.01	<0.01	<0.01	0.03	0.04	0.46
	MUR 22	14:30	25.4	76.5	13.9	8	7.88	100.7	8.55	37	<0.01	<0.01	<0.01	0.04	0.04	0.47
	MUR 23	13:10	24.1	79	12	14	7.7	95.4	8.32	38	<0.01	<0.01	<0.01	0.06	0.04	0.47
	MUR 27	11:55	24.5	82.3	11	13	7.5	94.6	8.17	38	<0.01	<0.01	<0.01	0.06	0.04	0.48
	MUR 28	09:00	22.1	67.7	14	11	7.32	100.1	9.06	33	<0.01	<0.01	<0.01	0.05	0.03	0.34
	MUR 29	10:30	23	70	15	16	7.3	98.6	8.69	35	<0.01	<0.01	<0.01	0.06	0.04	0.35

3.2.2 Continuous water quality

Water quality results measured continuously at Lobb's Hole monitoring station are outlined in Figure 4. No data were available between the 2nd and 7th of October (shaded area) due to probe damage from a lightning strike. Dissolved Oxygen (% saturation), Electrical Conductivity and pH levels were within the recommended ANZECC and ARMCANZ (2000) range across the entire spring 2010 period. Turbidity levels at Lobb's Hole were lower than recommended on the 8th, 9th and 10th of October. Turbidity levels were higher than recommended between 4th and 14th of September, 14th to 21st October and on 13th, 15th and 30th of November. Average Water Temperature was 12.51°C, 17.12°C and 20.19°C in September, October and November, respectively.

Water quality parameters were measured continuously at Angle Crossing in spring 2010 (Figure 5).

Average water temperature at Angle Crossing was 12.40°C, 16.75°C and 20.02°C in September, October and November, respectively. pH levels were within the recommended range (ANZECC and ARMCANZ, 2000) except between the 1st and 5th of October when levels were slightly higher than recommended. Turbidity levels were higher than recommended between 4th and 17th September and the 14th to 21st October. Turbidity was extremely high (>200) on several days across spring 2010.

Dissolved Oxygen was below recommended levels on 7th, 12th and between 20th and 30th of September. Dissolved Oxygen levels were also lower than recommended between 21st and 31st of October. Within November 2010, D.O. was lower than recommended between 1st and 4th, 8th and 15th and on the 17th. D.O. values were extremely low (<10 % saturation) on 28th and 29th of September and between late October and early November. These periods of particularly low D.O., indicated by shading in the diagram, have been attributed to silt build up on the probe and should therefore be interpreted with caution. EC levels were within the recommended range across all three months of spring.

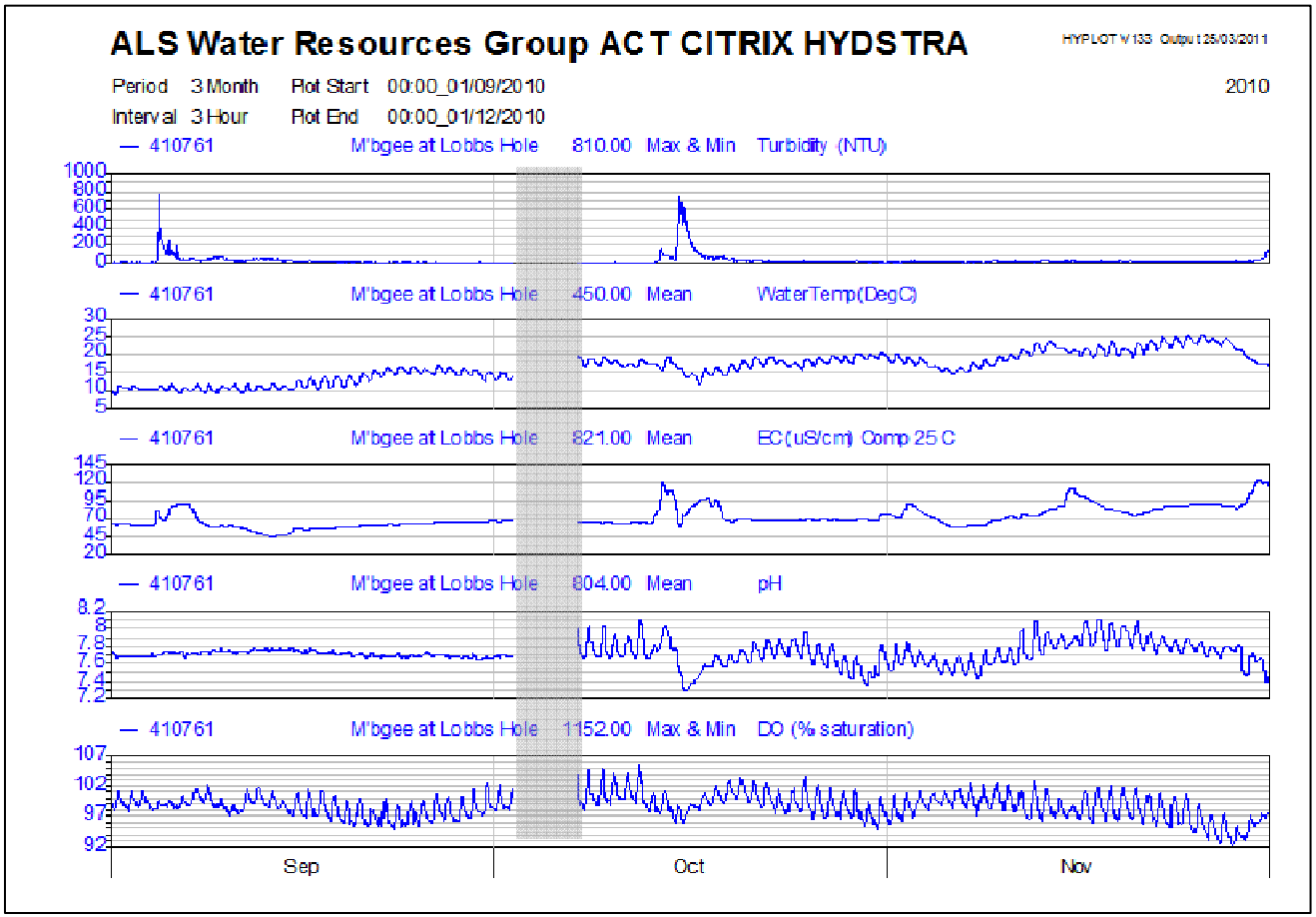

Figure 4: Continuous water quality results for spring 2010 (Lobb's Hole: 410761). The shaded region indicates a period during which probes were covered by silt.

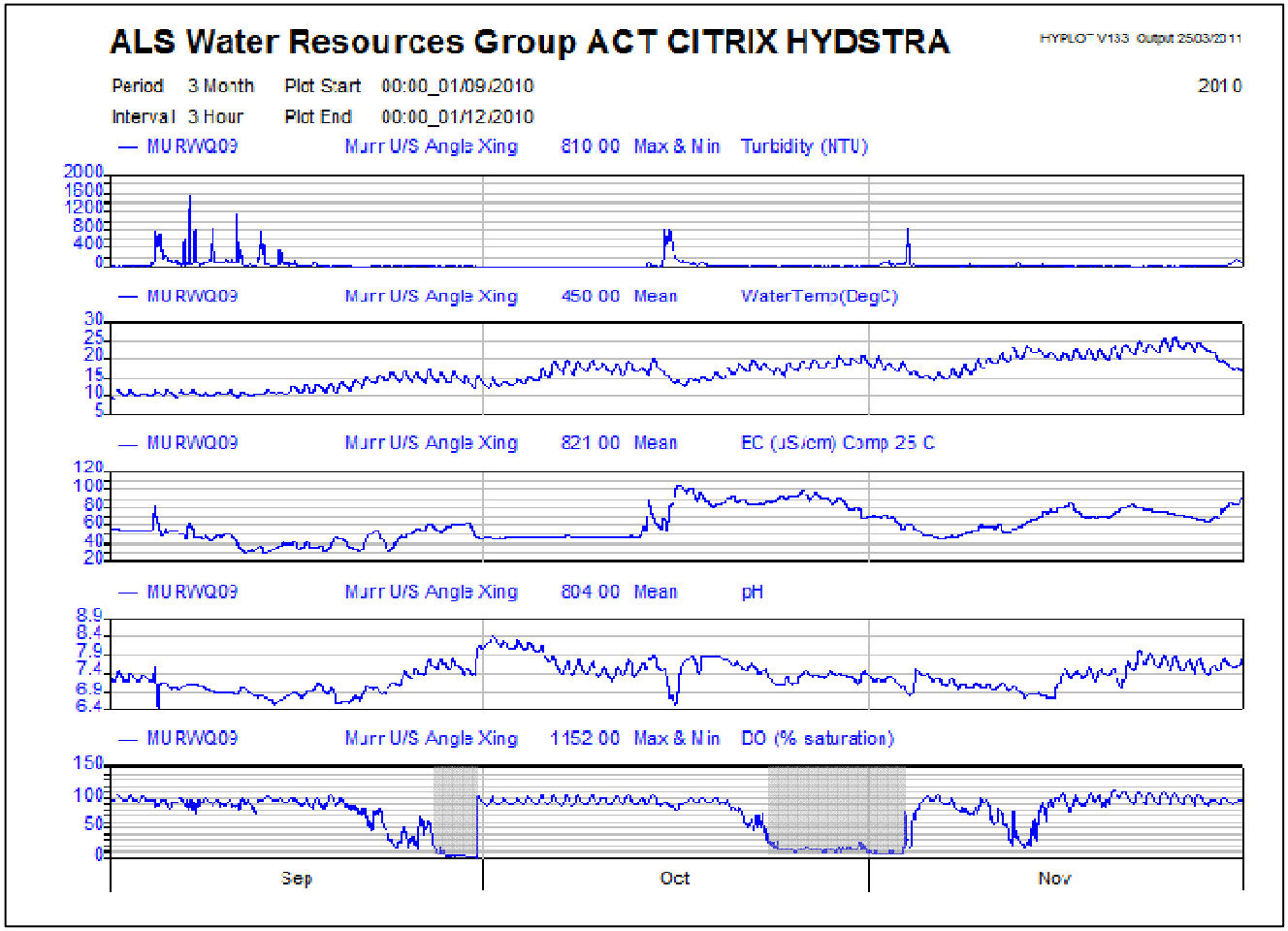

Figure 5: Continuous water quality results for spring 2010 (Upstream Angle Crossing: MURWQ09). The shaded regions indicate periods during which probes were covered by silt**.**

3.3 Macroinvertebrate communities

Cluster analysis was used to analyse differences in Riffle macroinvertebrate communities between samples. The dendrogram in Figure 6 below provides the results of the cluster analysis. A SIMPROF test was conducted to determine the significance of any grouping identified in the Cluster analysis. Significant groupings are those which contain "true" multivariate structure rather than chance similarities. The SIMPROF tests indicates only one significant grouping (outlined in red) which encompasses all sites except MUR 1 and MUR 29. All sites within this group are a minimum of 63% similar. There is no clear separation of zones in the diagram below. However, some small groupings within zones are indicated. The most similar Riffle samples are those from MUR 16 (Zone 2) and MUR 23 (Zone 3). Some stronger linkages are indicated between adjacent sites, regardless of Zone (e.g. MUR 6 and MUR 9; MUR 15, MUR 16 and MUR 18).

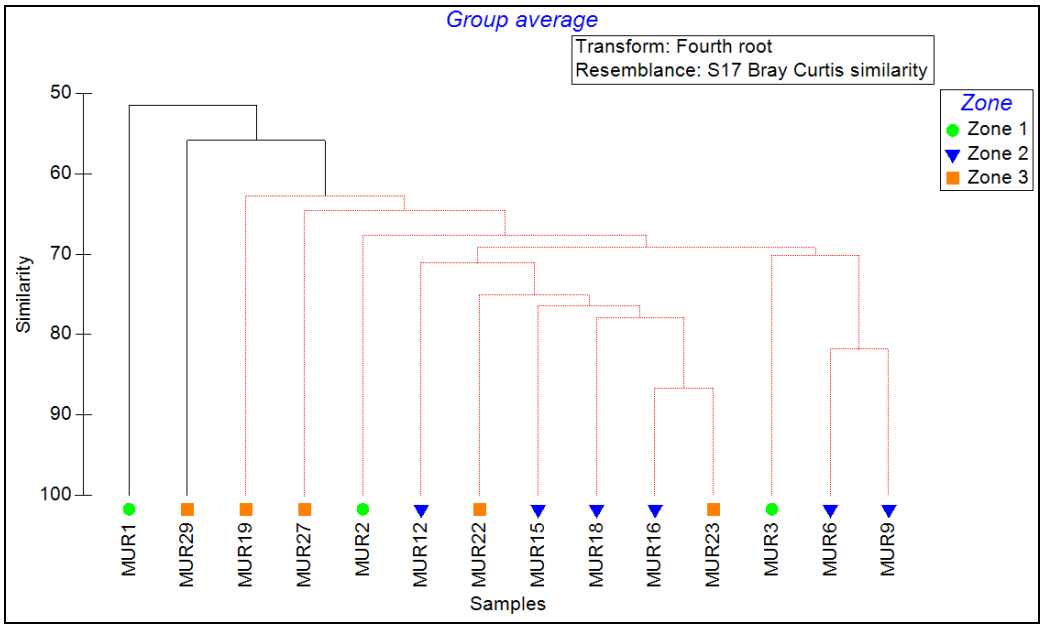

Figure 6: Cluster analysis of family level data for the spring Riffle samples. Branches marked in red denote significant groupings based on SIMPROF.

The MDS plot in Figure 7 provides a visual representation of the between-sample differences in the macroinvertebrate community collected from Riffle habitat. As with the Cluster diagram, no clear separation can be seen between the three zones. However, this plot does indicate a higher degree of within-group similarity between Zone 2 sites compared that seen for Zone 1 and Zone 3. Samples collected from Zone 2 seem to be clumping although with interference from MUR 22 and MUR 23 of Zone 3. The 60% similarity between all samples (except for MUR 1 and MUR 29) that was seen in Figure 6 is again indicated.

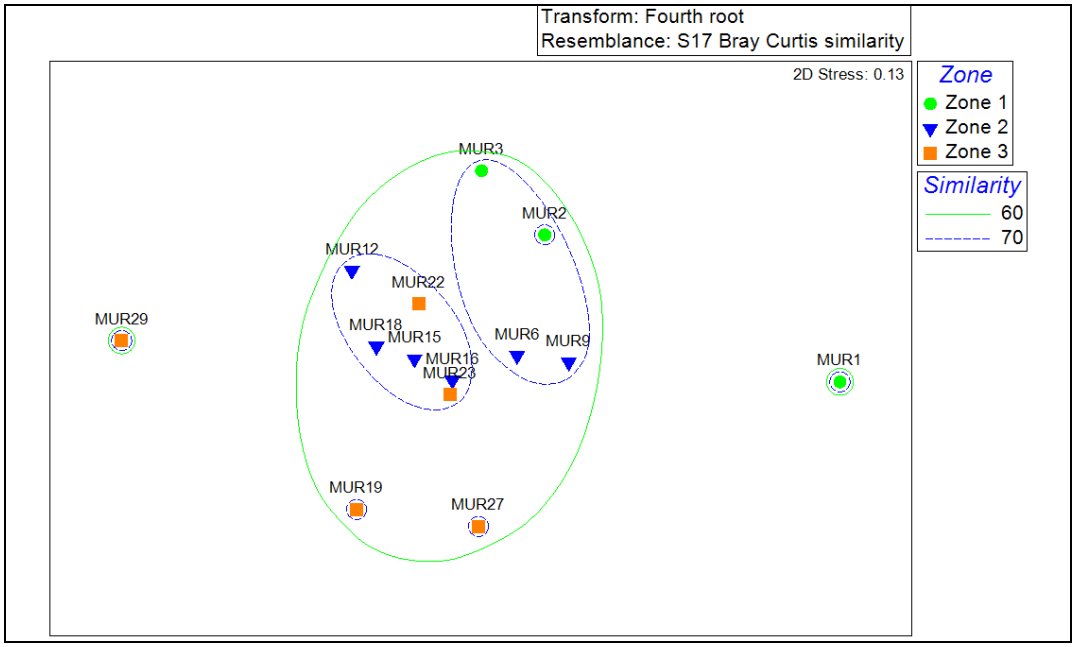

Figure 7: Non-metric multidimensional scaling of family level data for the spring riffle samples. Ellipses represent the 60% and 70% similarity groupings superimposed from the cluster analysis.

ANOSIM was used to examine differences in the macroinvertebrate community of Riffle habitat between zones. There was found to be a significant (p<0.05) difference in Riffle macroinvertebrates between zones. Table 7 indicates the results of pairwise comparisons between the three zones. Pairwise tests revealed significant differences in the macroinvertebrate community of Riffle habitats only between Zone 1 and Zone 2.

Table 7: Pairwise ANOSIM comparison of Riffle macroinvertebrate community. Significant values are highlighted in red (p<0.05)

Zone	*R*-statistic	*p*-value (>F)
1,2	0.562	**0.012**
1,3	0.374	0.071
2,3	0.179	0.058

SIMPER analysis was used to identify the key taxa which contribute to the differences between Zone 1 and Zone 2. There were no taxa that were responsible for a particularly large percentage of the variation between Zone 1 and Zone 2. The five most influential taxa are outlined in Table 8 below. This table suggests that a higher average abundance of Simuliidae at Zone 2 compared to Zone 1 is the most important difference between the zones. Also noted were higher numbers of Oligochaeta and lower numbers of Baetidae and Hydropsychidae at Zone 1 sites compared to Zone 2 sites. No Empididae were collected from Zone 1 sites, whereas an average of two Empididae was collected in samples from Zone 2.

Table 8: Differentiating taxa between Zone 1 and Zone 2 in Riffle samples

Family	Av abundance		% contribution to group differences
	Zone 1	Zone 2	
Simuliidae	65	589	6.58
Oligochaeta sp.	1001	309	5.77
Empididae	0	43	5.7
Baetidae	240	64	5.46
Hydropsychidae	81	325	5.31

The BEST analysis of Riffle samples was not significant.

Figure 8 represents the similarity in macroinvertebrate community composition for Edge habitat between sites and zones. The cluster diagram indicates that Zone 1 Edge samples are separated from all other samples. SIMPROF was used to test the significance of the observed groupings. The results of SIMPROF are indicated below by the red lines. This technique has identified four groups within the fifteen sites. The cluster of Zone 1 sites is further separated into two groups, the first comprised of MUR 1 and MUR 2 and the second of MUR 3 and MUR 4. The other two clusters include a mixture of Zone 2 and Zone 3 sites. However, within these groups, adjacent sites are often grouped together (i.e. MUR 18 and MUR 19; MUR 6 and MUR 9; MUR 15 and MUR 16; MUR 22 and MUR23). Similarity between sites was variable. The most closely related sites, MUR 22 and MUR 23, were only 75% similar. The similarity of Zone 1 sites from Zone 2 and 3 sites is only 50%.

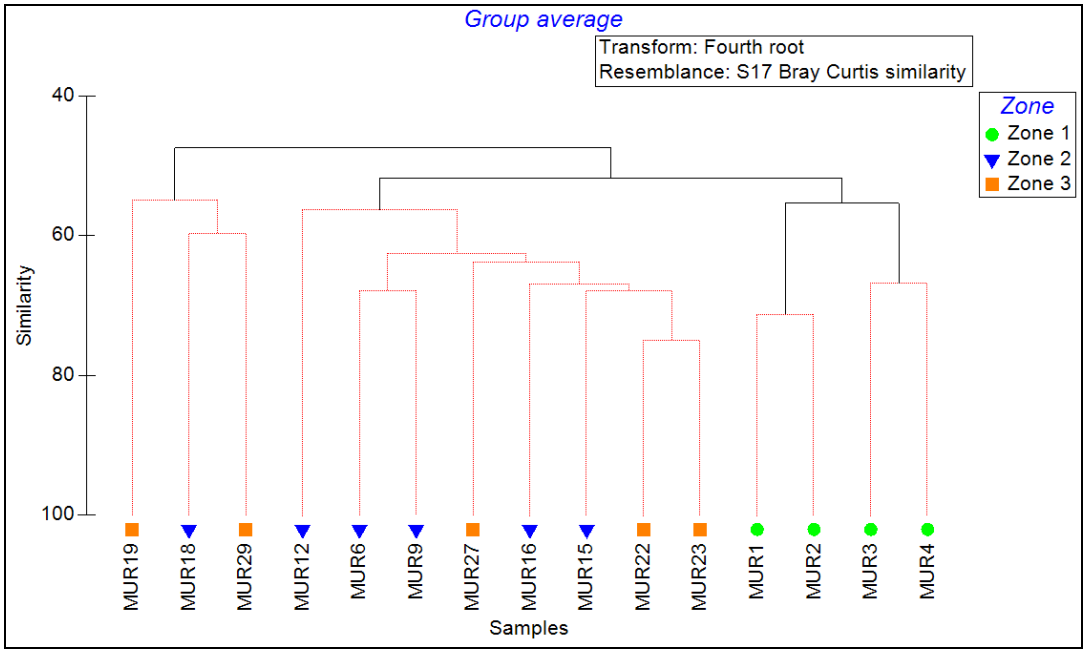

Figure 8: Cluster analysis of family level data for the spring edge samples. Branches marked in red denote significant groupings based on SIMPROF

The MDS plot in Figure 9 shows grouping that are almost identical to those identified in the cluster plot above for Edge samples. Zone 1 sites were separated from other sites and the Zone 2 and 3 sites were interchanged within the remaining two groupings. The smaller pairs of more similar sites indicated by the cluster diagram above can be seen more clearly in the MDS plot. This diagram also highlights the variation between sites within Zone 1 which were less noticeable in Figure 8.

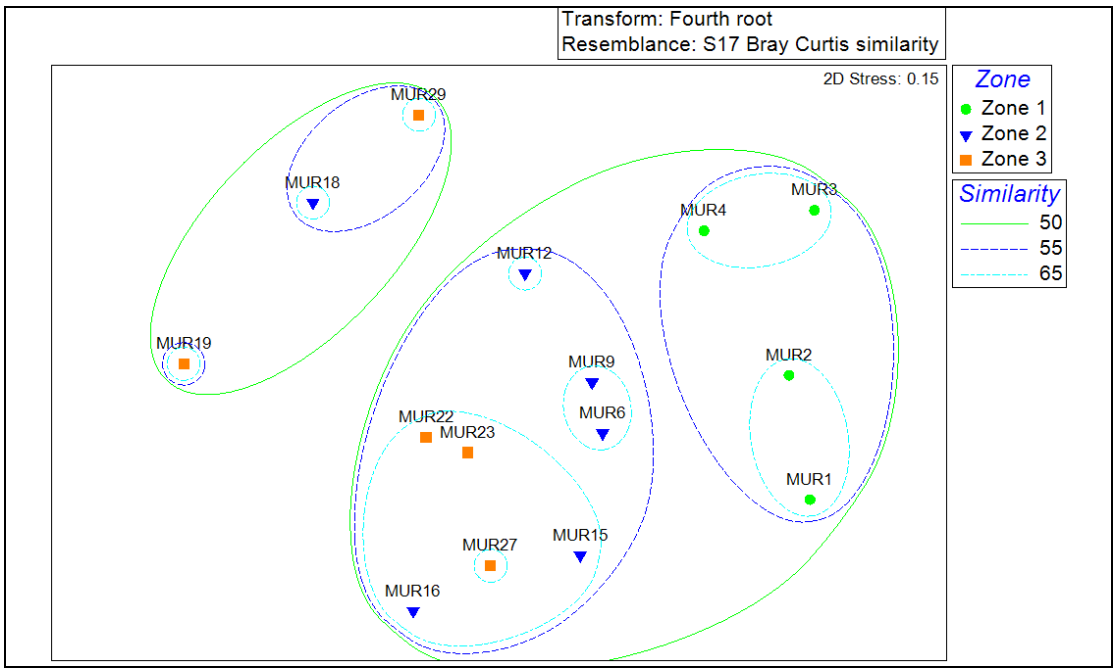

Figure 9: Non-metric multidimensional scaling of family level data for the spring edge samples. Ellipses represent the 50%, 55 and 65% similarity groupings superimposed from the cluster analysis.

ANOSIM compared the Edge community between zones. There are significant (p=0.013) differences in the macroinvertebrate community between the three zones. Table 9 indicates the results of pairwise ANOSIM analyses. The macroinvertebrate community of Edge habitat is different in Zone 1 compared to the other two zones. There was no difference detected between Zones 2 and 3.

Table 9: Pairwise ANOSIM comparison of Edge macroinvertebrate community. Significant *p*-values are highlighted in red (<5%)

Zone	*R*-statistic	*p*-value (>F)
1,2	0.353	**0.014**
1,3	0.763	**0.008**
2,3	-0.051	0.682

SIMPER analysis was performed to determine the taxa most responsible for the differences detected between the three zones. The five most influential taxa on the differences between Zone 1 and Zone 2 are provided in Table 10. The most glaring difference between Zones is in the numbers of Simuliidae and Lymnaeidae. Large numbers of Lymnaeids were collected from Zone 1 sites compared to a small number from Zone 2 sites. The pattern was reversed for Simuliidae. There were no Veliidae detected in Zone 2.

Table 10: Notable taxa differing between Zone 1 and Zone 2 Edge samples

Family	Av abundance		% contribution to group differences
	Zone 1	Zone 2	
Lymnaeidae	707	19	6.11
Simuliidae	9	444	5.44
Physidae	95	16	3.8
Veliidae	37	0	3.66
Dytiscidae	35	3	3.64

The major taxa contributing to differences in Zone 1 and Zone 3 sites are outlined in Table 11. This shows the same patterns of Lymnaeidae and Simuliidae that was observed between Zone 1 and Zone 2. Additionally, zero Palaemonidae were observed in Zone 1 sites while a moderate number were collected at Zone 3 sites.

Table 11: Notable taxa differing between Zone 1 and Zone 3 Edge samples

Family	Av abundance		% contribution to group differences
	Zone 1	Zone 3	
Lymnaeidae	707	0	7.27
Simuliidae	9	2227	6.68
Physidae	95	3	4.51
Palaemonidae	0	36	4.27
Baetidae	71	310	3.63

BEST analysis examined the relationship between *in-situ* water quality and macroinvertebrate community. The BEST analysis of Edge samples was significant (p=0. 009). For samples collected in Edge environments, D.O. and Water Temperature were the most influential parameters on macroinvertebrate communities. The raw data shows that D.O. is higher at MUR 16, MUR 19 and all Zone 3 sites compared to all other sites. Water Temperature generally increased between MUR 1 and MUR 29. The full results of BEST analysis are presented in Appendix C.

3.4 AUSRIVAS assessment

Table 12 provides the average SIGNAL-2 score, O/E50 score and AUSRIVAS banding for macroinvertebrate samples collected during spring 2010. Average SIGNAL-2 at Riffle habitat was highest at MUR1 and lowest at MUR23. The average SIGNAL-2 at Edge habitat was highest at MUR1 and lowest at MUR19. SIGNAL-2 scores were higher in general at Riffle sites compared to Edge sites.

An AUSRIVAS band of B was assigned for the Riffle samples collected from MUR1 and MUR27. The Riffle sample from MUR29 was awarded a C assessment. All other Riffle samples were given an AUSRIVAS assessment of A. AUSRIVAS band was more variable between Edge samples. Of all Edge samples, only MUR9 was given an X rating. An A rating was awarded to MUR 2, MUR 3, MUR6, MUR22, MUR23 and MUR29. An AUSRIVAS B rating was given to MUR1, MUR4, MUR12, MUR15, MUR16 and MUR27. MUR18 and MUR19 were given a C rating.

The overall site assessment is based on the lowest rating of Edge and Riffle sample for each site. An overall A was awarded to MUR2, MUR3, MUR6, MUR9, MUR22 and MUR23. The overall AUSRIVAS band of B was given to MUR1, MUR4, MUR12, MUR15, MUR16, and MUR27. The remaining sites, MUR18, MUR19 and MUR29 were rated as C. There is no obvious pattern in AUSRIVAS bands between Zones. However, the rating appears to decline between MUR12 (Bredbo township) and MUR19 (d/s Angle Crossing). These sites were rated either B or C. The remaining C rating was given to MUR29 (Uriarra Crossing).

Table 12: AUSRIVAS and SIGNAL scores for spring 2010

Site	Location	SIGNAL-2		AUSRIVAS O/E50 score		AUSRIVAS BAND		Overall site assessment
		Riffle	Edge	Riffle	Edge	Riffle	Edge	
MUR 1	D/S Tantangara Reservoir	5.67	5.10	0.84	0.69	B	B	B
MUR 2	Yaouk Bridge	5.09	4.60	1.05	1.11	A	A	A
MUR 3	Bobeyan Road Bridge	5.31	4.25	0.93	0.89	A	A	A
MUR 4	Camp ground off Bobeyan Road	N/A	4.00	N/A	0.70	N/S	B	B
MUR 6	D/S STP Pilot Creek Road	5.23	4.22	1.03	1.00	A	A	A
MUR 9	Murrells Crossing	5.38	4.55	1.00	1.22	A	X	A
MUR 12	Through Bredbo township	5.25	3.71	0.90	0.78	A	B	B
MUR 15	Near Colinton - Bumbalong Road	4.92	4.17	1.10	0.66	A	B	B
MUR 16	The Willows - Near Michelago	4.92	3.86	1.01	0.78	A	B	B
MUR 18	U/S Angle Crossing	5.00	4.40	0.87	0.55	A	C	C
MUR 19	D/S Angle Crossing	5.09	3.60	0.86	0.55	A	C	C
MUR 22	Tharwa Bridge	5.15	4.22	0.98	1.00	A	A	A
MUR 23	Point Hut Crossing	4.64	4.44	1.06	1.00	A	A	A
MUR 27	Kambah Pool	5.36	4.43	0.82	0.78	B	B	B
MUR 29	Uriarra Crossing	5.43	4.00	0.52	0.89	C	A	C

Notes: N/S = not sampled due to high flows

3.5 Univariate indices

ANOVA was used to explore differences in O/E family score between Zones and Habitats. O/E represents the ratio of Observed taxa to Expected taxa. No significant difference was detected in O/E score between Zones or Habitats (Table 13).

Table 13: Results from the ANOVA model of O/E family scores

O/E Family	df	Sum of squares	Mean squares	F value	*p*-value (>F)
Zone	2	0.02218	0.01109	0.3264	0.73
Habitat	1	0.04741	0.04741	1.3951	0.26
Zone*Habitat	2	0.03047	0.01524	0.4484	0.64
Residual	23	0.78151	0.03398		

The results of an ANOVA comparing SIGNAL2 scores between Zones and Habitats are shown in Table 14. There was no significant difference in SIGNAL2 score between Zones. However, SIGNAL2 was significantly higher ($p<0.05$) on average within Riffle habitats compared to Edge habitats.

Table 14: ANOVA of SIGNAL2 scores between Zones and Habitats. Significant results highlighted in red.

SIGNAL2	df	Sum of squares	Mean squares	F value	*p*-value (>F)
Zone	2	0.4309	0.2154	2.042	0.15
Habitat	1	6.0834	6.0834	57.666	**<0.001**
Zone*Habitat	2	0.0171	0.0086	0.081	0.92
Residual	23	2.4264	0.1055		

The number of sensitive (EPT) families compared to total richness can be visualised for Edge and Riffle habitat in Figure 10 and Figure 11, respectively. Figure 10 shows that the highest number of sensitive families was detected in the Edge habitat at MUR3. Overall richness was also higher at MUR2 and MUR4 compared to other sites. There appears to be a higher number of families within Zone 1 sites compared to sites from other Zones. Overall richness and EPT richness of Edge habitats was particularly low at MUR18 and MUR19.

No main pattern was evident in overall richness of EPT between Zones (Figure 11). Overall richness was lowest in MUR29 and highest in MUR22. EPT richness was lowest at MUR27 and MUR1 and highest at MUR2 and MUR15.

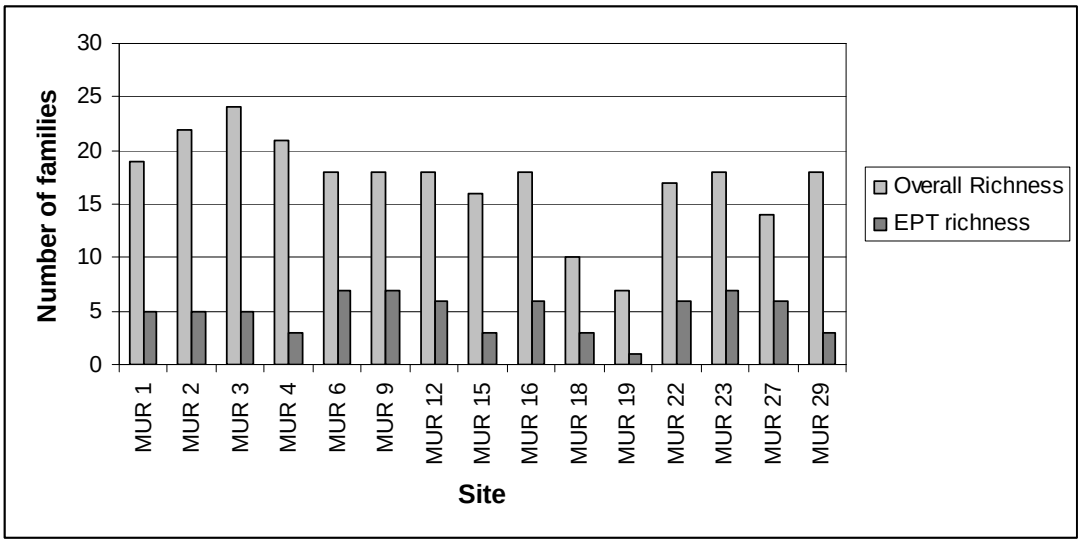

Figure 10: Relative number of families and sensitive taxa within Edge samples

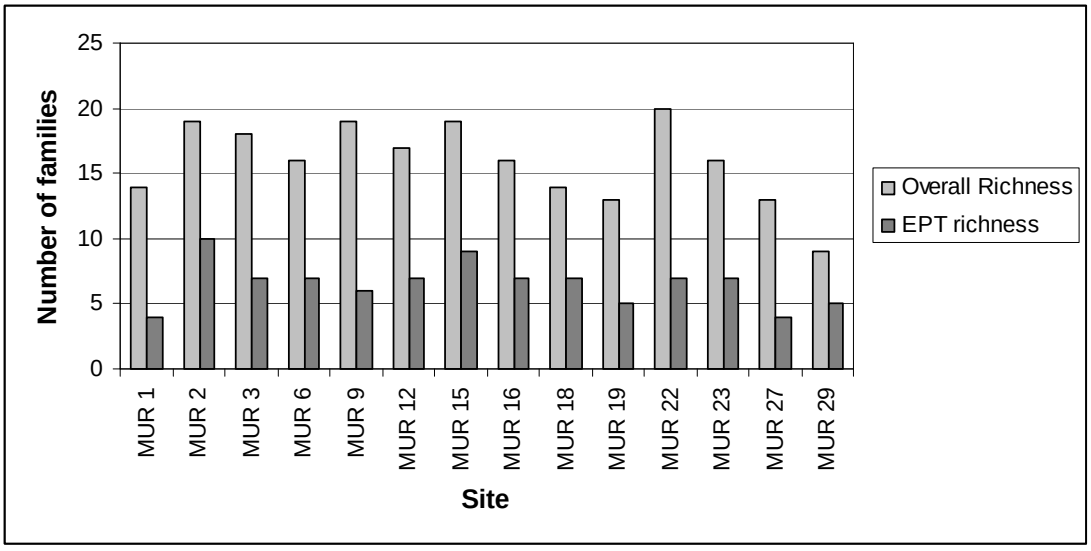

Figure 11: Relative number of families and sensitive taxa within Riffle samples

The result of an ANOVA comparing overall taxa richness is provided in Table 15. This table shows that no significant difference was detected between Habitats. However, a significant (p<0.05) difference was determined between zones (Table 15). A Tukey test was used to evaluate pairwise differences between zones. Overall taxa richness was found to be significantly higher within Zone 1 sites than Zone 3 sites (Table 14). This supports the graph in Figure 8. Taxa richness was no different between Zone 2 and Zone 3 sites.

Table 15: Results from the ANOVA model of Overall Taxa Richness scores. Significant results highlighted in red.

Richness	df	Sum of squares	Mean squares	F value	*p*-value (>F)
Zone	2	91.940	45.970	4.2163	**0.027**
Habitat	1	16.071	16.071	1.4740	0.237
Zone*Habitat	2	28.115	14.058	1.2894	0.294
Residual	23	250.767	10.903		

Table 16. Tukey's HSD *post-hoc* analysis of Zone comparisons for Overall taxa Richness scores across zones. Text in red indicates significance at the 5% level.

Zone	1	2	3
1			
2	0.161		
3	**0.012**	0.324	

Table 17 provides the results of the ANOVA in EPT richness between Habitats and Zones. The *p*-values indicate that there is no significant difference in EPT richness between Zones. However, there were a significantly higher number of EPT families found in Riffle habitat compared to Edge habitat.

Table 17: ANOVA of EPT Richness scores between Zones and Habitats. Significant results highlighted in red**.**

EPT Richness	df	Sum of squares	Mean squares	F value	P value (>F)
Zone	2	101.03	50.51	0.19163	0.83
Habitat	1	1328.82	1328.82	5.04082	**0.03**
Zone*Habitat	2	141.05	70.52	0.26753	0.76
Residual	23	6063.06	263.61		

4 Discussion

4.1 Water Quality

Electrical conductivity levels were below ANZECC trigger values at the three furthest upstream sites of Zone 1. This is consistent with results collected in autumn 2010. EC levels were particularly low during this sampling event probably due to the high levels of freshwater inflows from rainfall across the region. The increasing gradient of EC, Alkalinity and Water Temperature between upstream sites and downstream sites of Murrumbidgee River has been noted in previous sampling events. This gradient of water quality suggests varying degrees of local impact within each Zone. Zone 1 generally exhibited the best water quality which is most likely a reflection of this Zone having the least grazing and agricultural land use and urbanisation compared to Zones 2 and 3. The land use in Zone 2 is noted to be largely agriculture. Whilst agricultural practices are less predominant in Zone 3, urban influences are greater. Agriculture and urbanisation have both been seen to increase nutrients and EC levels as well as decreasing D.O. levels (Wang et al., 2003). Influences can be direct, by the use of chemicals/fertilisers that are then washed into the waterways, or indirectly by the clearing of land for grazing which leads to increased run-off and sedimentation. Cattle are also a major source of disturbance which can influence water quality.

Large amounts of rainfall can have a strong influence on water quality due to increased run-off which can add nutrients, sediments and organic matter to waterways (Moss, 2006). Despite very high flows at times throughout spring, macroinvertebrate and water quality sampling followed several dry days (except for Zone 1 sites and MUR6). The increased run-off from flooding would be expected to cause increased turbidity and nutrient levels. Total Phosphorus and Nitrogen was present in measurable concentrations at all sites excluding the furthest upstream sites of Zone 1. Total Phosphorus exceeded guidelines across more sites compared to autumn 2010. Turbidity levels were all within the normal range suggesting that the days of dry weather prior to sampling provided an opportunity for particulates to settle. However, a marked increase in Turbidity and TSS occurred between sites near Cooma downstream to sites around Angle Crossing. This could be a result of influences from the Sewage Treatment Plant (STP) situated upstream of MUR6 or possible impacts from urbanisation. Regardless, as Turbidity levels did not exceed the trigger value the increased levels were not of immediate concern. Surprisingly, Turbidity was lowest at Zone 1 sites despite the rainfall that was falling on the day of sampling. Continuous water quality monitoring at Lobb's Hole and Angle Crossing indicated that there were several spikes in Turbidity during which the levels were far above those recommended under ANZECC and ARMCANZ (2000) guidelines. These spikes can be matched to rainfall events in most cases.

Continuous Dissolved Oxygen readings at Angle Crossing were lower than recommended for a period of 11-12 days at the end of September and October. Low D.O. was also noted for four days at the start of November and between the 8th and 15th November, as well as other scattered instances. These particularly low D.O. readings were attributed to silt build up on the probe following the major rainfall events.

Multivariate analysis of physico-chemical data revealed an interesting trend gradient of increasing Water Temperature, Alkalinity, EC and Turbidity from the upstream Murrumbidgee River sites towards the furthest downstream Murrumbidgee sites. These longitudinal trends are attributed to altitude, changing geology, land use practices and contributing catchment area and are not considered to be outside of the normal parameter limits that have been observed throughout this project.

4.2 Patterns in macroinvertebrate communities

The grouping of Edge macroinvertebrate samples into pairs of adjacent sites (regardless of zone) gives evidence to suggest that the differences between sites are due to the longitudinal cumulative effects of increasing water quality parameters and flow rather than distinct differences at the Zone scale. Edge samples collected from Zone 1 sites were clumped together. Although similarity between these sites was only moderately strong, the degree of within zone similarity was markedly higher than between Zones 1 and Zone 2/Zone 3. Given the clear differences seen in water quality of Zone 1 compared to other zones, it is not surprising to find a difference in macroinvertebrate assemblage of Zone 1 sites. The BEST analysis confirmed a link between water quality and the macroinvertebrates of Edge habitats. Of the physico-chemical variables collected, Dissolved Oxygen and Water Temperature had the closest correlation with the Edge taxa. It is not surprising that Dissolved Oxygen correlated to the presence/absence of Edge taxa. Edge habitats are defined as areas of little or no flow. As low flow environments tend to be lower in D.O. as well, Edge taxa are often those that are robust against low D.O. environments. The connection between high Dissolved Oxygen saturation and low Water Temperature is also well known. It is interesting to note that Water Temperature was one of several variables that followed a near-linear gradient of change between upstream and downstream sites of Murrumbidgee River.

Differences in the macroinvertebrate community collected from Edge habitat between Zones 1 and 2 were attributed to the relative abundance of several taxa with no clearly dominating taxa. However, the most notable difference was in the number of Simuliidae and Lymnaeidae between the two zones. Simuliidae are almost solely restricted to the fast-flowing conditions of Riffle habitat while Lymnaeidae usually prefer areas of little or no flow. Therefore, the relatively high numbers of Simuliidae and low numbers of Lymnaeidae found in Zone 2 compared to Zone 1 suggests that flows were increased at this site. The monitoring station closest to Zone 2 sites (Lobb's Hole) does suggest increased flows when compared to the monitoring station closest to Zone 1 (upstream of Angle Crossing). Due to recent rainfall events, flows would have increased above baseline levels. Therefore, the habitat sampled at Zone 2 during the spring 2010 sampling event was probably not reflective of "true" Edge conditions.

Macroinvertebrate samples collected from Riffle habitat were less variable than those collected from Edge habitat. Most sites shared at least 60% of the same taxa (ignoring the influence of abundance). No pattern in Riffle macroinvertebrates was easily detectable between sites of Zones. However, multivariate techniques identified a significant difference in Riffle macroinvertebrate community composition between Zone 1 and Zone 2. The differences between samples in the two Zones were attributed to a series of changes in taxa abundance between Zones. No one taxon was found to be responsible for the differences. However, the markedly lower abundance of Simuliidae and Hydropsychidae observed at Zone 1 sites was an important distinction. These taxa are

common to the fast flowing riffle habitats. The very small numbers of these animals at Zone 1 could indicate displacement of some taxa at these upstream reaches of the Murrumbidgee River due to scouring by high flows (Rutherford et al. 2000). Alternatively, the difference in numbers between sites may reflect the reduced flow in Zone 1 (see Figure 2 for MURQW09 flows) compared to Zone 2.

4.3 River Health (AUSRIVAS Assessment & univariate indices)

High flow events such as those experienced in spring 2010 can lead to a reduction in diversity and abundance of macroinvertebrates and significant changes in taxa assemblage (Kroon et al., 2010). A reduction in richness/abundance can occur due to the direct impacts of death or washing animals downstream or by indirect impacts such as scouring of habitat. Abundances were high within spring 2010 samples. However, the most abundant taxa were tolerant groups such as Chironomidae, Simuliidae and Hydropsychidae, which not are not only capable of withstanding the increased shear stress exerted by high flow events, but are also noted as being early colonisers following such disturbances.

Richness levels were reasonable for most sites given the high flow conditions experienced prior to sampling. Overall taxa richness within Edge samples was higher within Zone 1 sites compared to the other zones. This could be due to be a combination of lower flow and better water quality within this zone. However, the low proportion of EPT richness at these sites suggests that Zone 1 sites are not as “healthy” as indicated by the water quality. In autumn 2010, a trend was discovered whereby the proportion of sensitive taxa to tolerant taxa decreased between upstream and downstream sites. This pattern was not replicated in spring 2010. In spring 2010, the proportion of EPT taxa was variable between sites with no significant difference evident between zones. By far the lowest richness was observed at MUR19 (downstream of Angle Crossing) and MUR 18 (upstream of Angle Crossing). This suggests some type of local disturbance around Angle Crossing which is impacting on both MUR 18 and MUR 19. However, the proportion of sensitive taxa was particularly high at MUR 19 in autumn 2010. Therefore, any disturbance impacting on this site in spring, such as sedimentation due to heavy rainfall, may be temporary. This seems a likely cause of the generally low proportion of sensitive taxa detected throughout the Murrumbidgee sites in spring 2010.

As expected, average SIGNAL-2 score was higher within Riffle samples compared to Edge samples. This is usually attributed to the greater heterogeneity or habitat and flow conditions as well as increased Dissolved Oxygen levels. Average SIGNAL2 score did not differ between Zones. This provides further evidence that the reduction of sensitive taxa collected in spring 2010 samples is due to the blanketing influence of high flows.

AUSRIVAS results were quite consistent between Edge and Riffle samples of Zone 1 sites. Within Zones 2 and 3, AUSRIVAS bandings varied between the Edge and Riffle habitats of most sites. AUSRIVAS banding was generally higher within Riffle samples than Edge samples across Zones 2 and 3. A BAND X rating was given to the Edge sample for MUR 9 (Murrells Crossing) indicating that more taxa were observed than expected within this site. This generally indicates either a biodiversity “hotspot” or nutrient enrichment at the site. The water quality results indicate increased levels of Total Phosphorus and Total Nitrogen at MUR 9. Therefore, the enhanced diversity within the

Edge sample is considered to be due to nutrient enrichment, probably as a result of run-off from adjacent agricultural land.

Overall AUSRIVAS assessment indicated that most sites were either in “reference condition” (40% of samples) or “significantly impaired” (40% of sites). There was no discernable pattern in the grades between zones. Twenty per cent of sites were labelled as “severely impaired” indicating that the water quality and habitat of these sites are significantly compromised. These sites were MUR 18, MUR 19 and MUR 29. Once again, MUR18 and MUR 19 were highlighted at sites with poor macroinvertebrate community health. However, the individual habitat assessments for these sites showed that only the Edge sample was graded poorly for each. Raw taxa counts for the MUR 18 Edge sample suggest that a lack of common Edge taxa such as Acarina, Tipulidae, and Corixidae are responsible for the poor grade. The raw taxa counts for the MUR 19 Edge sample indicate that the most dominant taxa by far were Simuliidae. This suggests that sampling conditions were not consistent with the criteria for Edge habitat, and therefore, explains the poor assessment for this site. Given the obvious impacts of high flows at the time of sampling, a larger number of C grade sites would not have been surprising. It should be noted that AUSRIVAS protocols discourage sampling during a flood event (Coysh et al, 2000a). Therefore AUSRIVAS health assessments should be viewed with caution.

5 Conclusion and recommendations

The spring 2010 sampling event was complicated by high rainfall events scattered across the three month period. The influence of increased rainfall is evident in flow levels and water quality results. Continuous monitoring indicated fluctuations of Turbidity, Electrical Conductivity and pH at both monitoring sites in response to rainfall events. Turbidity exceeded the upper guideline values at several points is connection with these events.

A period of approximately eight dry days preceded spring 2010 macroinvertebrate sampling (except for Zone 1 sites). Turbidity was within the recommended level at the time of *in-situ* water quality sampling. However, there were several exceedances of guideline values for Total Nitrogen and Total Phosphorus, mostly within Zone 2 and 3 sites. A small number of NOx exceedances were also observed. The increased number of nutrient related exceedances in spring 2010 compared to the previous sampling event can most likely be attributed to increased run-off from recent rainfall. Overall water quality appeared to be better within Zone 1 compared to Zones 2 and 3.

Macroinvertebrate samples collected within Edge habitats were different in Zone 1 compared the other two zones. The differences were attributed to the relatively small numbers of Simuliidae and large numbers of Lymnaeidae in Zone 1 compared to Zones 2 and 3. The large number of Simuliidae in the Edge samples of Zone 2 suggests that flows in Zone 2 are faster than is appropriate for the targeted habitat. Within Riffle samples, low numbers of Simuliidae and Hydropsychidae were found in Zone 1 samples compared to Zone 2 samples. Hydropsychidae are also known to frequent fast flowing waters. Therefore, the low numbers of these common Riffle taxa within Zone 1 samples could indicate that flows within Zone 1 during sampling were lower than the optimum threshold for these taxa. Another possibility is that these animals were displaced from the site through the scouring effects of flooding. The discrepancies between the actual sampled conditions and AUSRIVAS protocols for Edge and Riffle habitats are likely to be a result of micro-habitat changes due to increased rainfall in spring 2010.

Despite changes that were evident in water quality and flow between zones, no difference was detected in the EPT richness, average SIGNAL2 score or overall AUSRIVAS assessment between them. The proportion of sensitive taxa was generally low although overall richness was moderate. Overall health of most sites, as assessed by AUSRIVAS modelling, ranged between “reference condition” and “significantly impaired” with only a few sites being marked as “severely impaired”. However, these results must be interpreted with caution due to high flows throughout the Murrumbidgee River in the months prior to sampling.

Overall, Zone 1 was seen to be different in terms of water quality and macroinvertebrate community compared to Zones 2 and 3. Water quality was generally better within Zone 1 sites. This may be due to the land use of native forest and only light grazing/recreation within this zone. Although some differences were found between Zone 2 and Zone 3, they appeared to be largely similar it terms of site condition. This is probably a reflection of the shared influences of grazing and urbanisation or the upstream catchment.

Although some meaningful relationships have been detected between macroinvertebrates and environmental/habitat/physical parameters, the results of the spring 2010 were complicated by high rainfall events in the months preceding sampling. Similar flooding events have been experienced in the autumn 2010 sampling season. Therefore, it is recommended that sampling continue until enough data is collected without the influence of rainfall to allow for the "true" baseline conditions to be determined.

6 References

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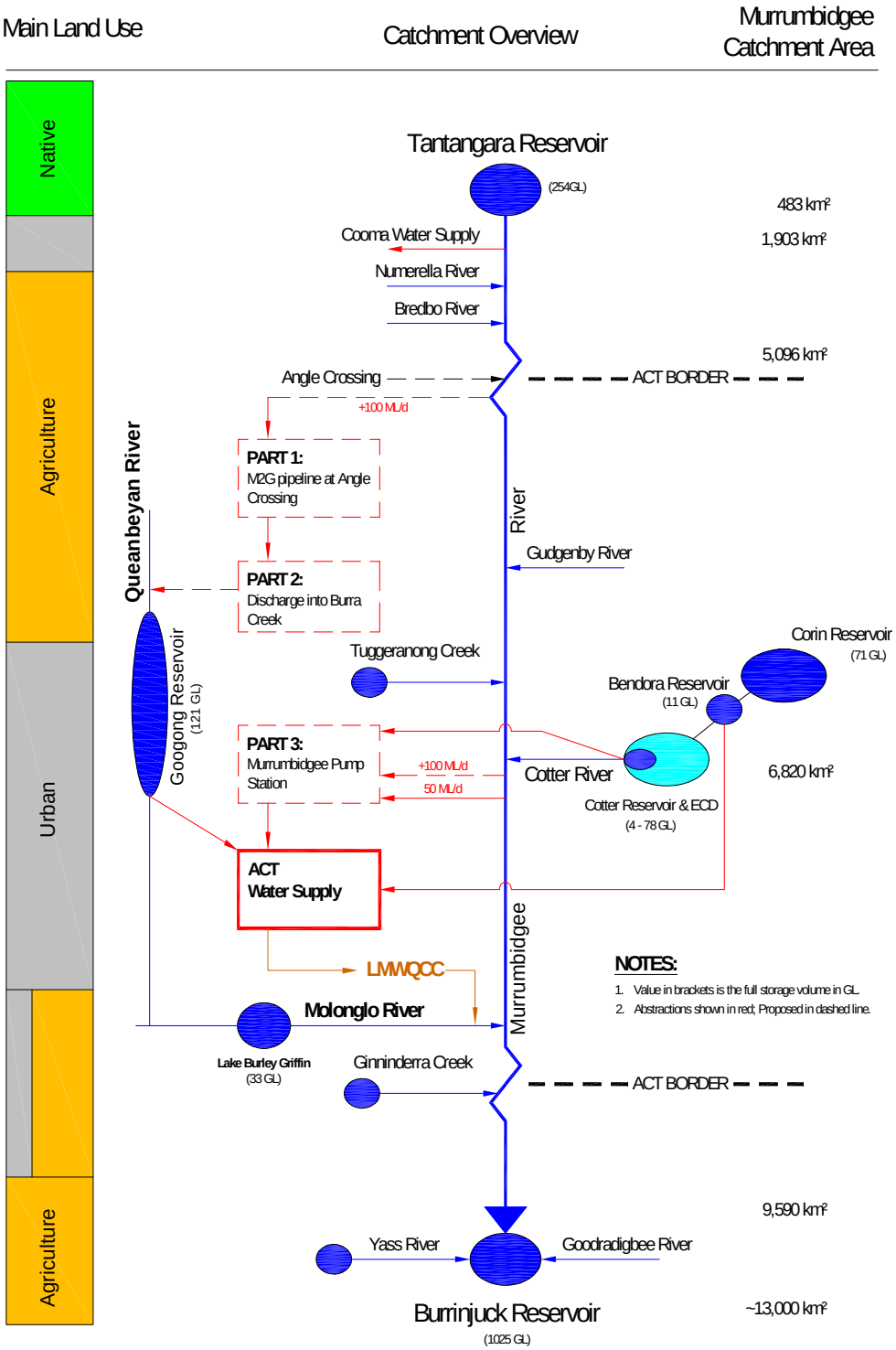
Appendix A - Schematic representation of the Murrumbidgee Catchment and ACTEW's major water projects


Main Land Use
Catchment Overview
Murrumbidgee Catchment Area
Native
Agriculture
Urban
Agriculture
Tantangara Reservoir
(254GL)
483 km²
Cooma Water Supply
1,903 km²
Numerella River
Bredbo River
5,096 km²
Angle Crossing
ACT BORDER
+100 ML/d
PART 1:
M2G pipeline at Angle Crossing
PART 2:
Discharge into Burra Creek
Queanbeyan River
River
Gudgenby River
Googong Reservoir
(121 GL)
Tuggeranong Creek
Corin Reservoir
(71 GL)
Bendora Reservoir
(11 GL)
PART 3:
Murrumbidgee Pump Station
+100 ML/d
50 ML/d
Cotter River
6,820 km²
Cotter Reservoir & ECD
(4 - 78 GL)
ACT
Water Supply
LMWQCC
Murrumbidgee
NOTES:
1. Value in brackets is the full storage volume in GL.
2. Abstractions shown in red; Proposed in dashed line.
Molonglo River
Lake Burley Griffin
(33 GL)
Ginninderra Creek
ACT BORDER
9,590 km²
Yass River
Goodradigbee River
Burrinjuck Reservoir
(1025 GL)
~13,000 km²

Appendix B -
Principal Components Analysis of water quality variables

PCA
Principal Component Analysis

Data worksheet
Name: Data3
Data type: Environmental
Sample selection: All
Variable selection: All

Eigenvalues

PC	Eigenvalues	%Variation	Cum.%Variation
1	6.92	62.9	62.9
2	2.68	24.3	87.2
3	0.531	4.8	92.1
4	0.366	3.3	95.4
5	0.228	2.1	97.5

Eigenvectors
(Coefficients in the linear combinations of variables making up PC's)

Variable	PC1	PC2	PC3	PC4	PC5
Water temp.	-0.362	0.091	-0.163	0.001	-0.425
EC	-0.343	0.240	0.061	-0.146	-0.190
pH	-0.226	0.369	-0.535	0.470	0.429
D.O (mg/L)	0.291	0.329	0.132	-0.422	0.355
D.O (% Sat.)	-0.232	0.457	0.020	-0.366	-0.063
Turbidity	-0.331	-0.175	0.105	-0.346	0.626
Alkalinity	-0.334	0.266	0.017	-0.184	-0.157
Ammonia	-0.224	-0.401	-0.535	-0.348	0.005
TP	-0.320	-0.289	0.041	0.180	0.163
TN	-0.324	0.130	0.514	0.368	0.148
TSS	-0.289	-0.345	0.322	-0.060	-0.055

Appendix C -
BEST analysis – Edge output

BEST
Biota and/or Environment matching

Data worksheet
Name: env trans norm
Data type: Environmental
Sample selection: All
Variable selection: All

Resemblance worksheet
Name: Edge(2)
Data type: Similarity
Selection: All

Parameters
Rank correlation method: Spearman
Method: BIOENV
Maximum number of variables: 5
Resemblance:
Analyse between: Samples
Resemblance measure: D1 Euclidean distance

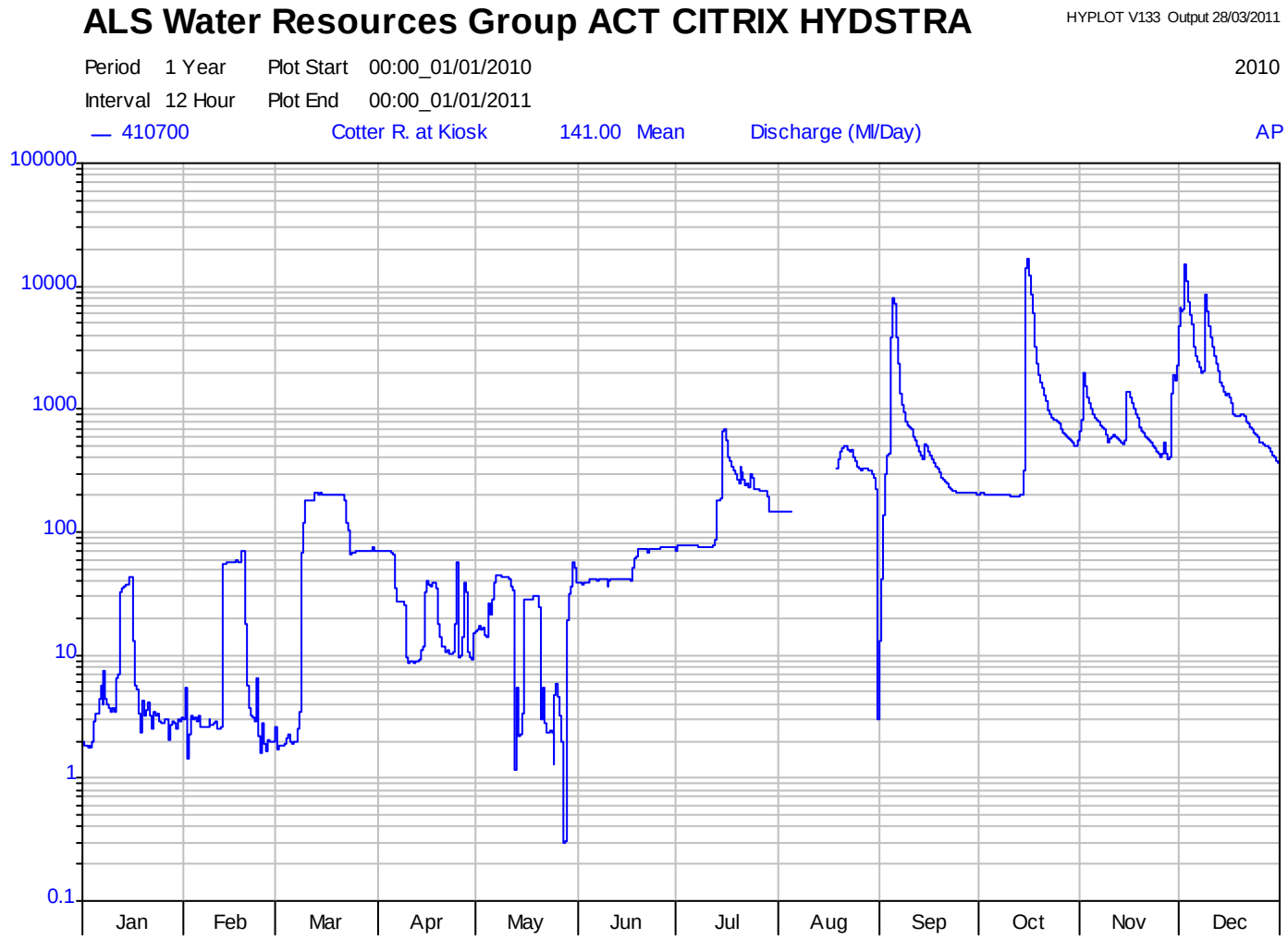
Variables
1 Water temp.
2 EC
3 pH
4 D.O (mg/L)
5 D.O (% Sat.)
6 Turbidity
7 Alkalinity
8 Ammonia
9 TP
10 TN
11 TSS

Global Test
Sample statistic (Rho): 0.499
Significance level of sample statistic: 0.9%
Number of permutations: 999 (Random sample)
Number of permuted statistics greater than or equal to Rho: 8

Best results

No.Vars	Corr.	Selections
2	0.499	1,5
3	0.452	1,5,6
4	0.452	1,5,7,9
3	0.451	1,5,9
3	0.449	1,5,7
5	0.443	1,2,4-6
3	0.442	1,2,5
4	0.441	1,2,5,9
4	0.440	1,5,9,10
4	0.440	1,4,5,10

Appendix D -
Discharge from Cotter Reservoir during spring 2010


ALS Water Resources Group ACT CITRIX HYDSTRA
HYPLOT V133 Output 28/03/2011
Period 1 Year
Plot Start 00:00_01/01/2010
2010
Interval 12 Hour
Plot End 00:00_01/01/2011
410700
Cotter R. at Kiosk
141.00 Mean
Discharge (Ml/Day)
AP
100000
10000
1000
100
10
1
0.1
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Appendix E - Raw taxa counts for macroinvertebrates collected in riffle and edge habitats: spring 2010

Appendix D. Taxonomic inventory of the macroinvertebrate taxa collected in the EDGE spring 2010.

Class/Order	Family/Subfamily	MUR1	MUR2	MUR3	MUR4	MUR6	MUR9	MUR12	MUR15	MUR16	MUR18	MUR19	MUR22	MUR23	MUR27	MUR29
Acarina	Sp.	0	43	50	40	0	57	0	60	14	0	0	50	60	14	0
Amphipoda	Ceinidae	140	14	0	0	0	0	0	0	0	0	0	0	0	0	0
Amphipoda	Talitridae	60	200	0	0	0	0	0	0	0	0	0	0	0	0	0
Bivalvia	Sphaeriidae	0	14	0	7	0	0	0	0	0	0	0	0	0	0	0
Coleoptera	Dytiscidae	60	29	0	53	0	0	17	0	0	0	0	0	0	0	17
Coleoptera	Elmidae	0	0	17	7	0	0	0	0	0	0	0	0	0	0	0
Coleoptera	Gyrinidae	0	0	0	0	0	0	50	20	0	0	0	30	20	0	0
Coleoptera	Hydrophilidae	0	14	100	13	0	0	0	0	0	7	0	0	0	0	0
Coleoptera	Staphylinidae	0	14	0	0	0	0	0	0	0	0	0	0	0	0	0
Decapoda	Atyidae	0	0	0	13	0	43	0	0	0	7	0	0	20	0	67
Decapoda	Palaemonidae	0	0	0	0	0	0	0	0	7	0	50	10	40	29	50
Decapoda	Parastacidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17
Diptera	Ceratopogonidae	20	29	0	0	0	14	0	20	0	0	0	20	20	0	17
Diptera	Culicidae	0	0	17	0	0	0	0	0	0	0	0	0	0	0	17
Diptera	Empididae	20	0	50	7	20	0	0	20	21	0	0	0	20	14	0
Diptera	Psychodidae	0	0	33	0	0	0	0	0	0	0	0	0	0	0	17
Diptera	s-f Chironominae	280	271	67	153	800	443	533	180	50	900	100	190	700	1100	1850
Diptera	s-f Orthocladiinae	1540	714	33	213	860	1029	1200	1120	407	421	900	490	1920	614	900
Diptera	s-f Tanypodinae	20	29	33	40	160	286	0	80	21	0	50	20	120	143	83
Diptera	Simuliidae	20	0	17	0	220	0	33	1880	464	64	10550	250	300	0	33
Diptera	Tipulidae	0	0	0	7	0	0	0	20	14	0	0	20	0	0	0
Ephemeroptera	Baetidae	0	14	117	153	80	14	50	0	0	36	100	790	560	0	100
Ephemeroptera	Caenidae	0	0	0	0	40	29	17	0	14	0	0	0	80	43	0

Class/Order	Family/Subfamily	MUR1	MUR2	MUR3	MUR4	MUR6	MUR9	MUR12	MUR15	MUR16	MUR18	MUR19	MUR22	MUR23	MUR27	MUR29
Ephemeroptera	Leptophlebiidae	280	57	0	0	0	29	0	0	0	14	0	20	0	14	17
Gastropoda	Ancylidae	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0
Gastropoda	Lymnaeidae	80	371	2350	27	80	14	0	20	0	0	0	0	0	0	0
Gastropoda	Physidae	80	214	67	20	60	0	17	20	0	0	0	0	0	14	0
Gastropoda	Planorbidae	140	43	0	0	20	0	0	0	0	0	0	0	0	0	0
Hemiptera	Corixidae	0	57	17	7	20	100	517	0	7	0	0	10	0	0	17
Hemiptera	Hydrometridae	0	0	17	0	0	0	0	0	0	0	0	0	0	0	0
Hemiptera	Notonectidae	0	0	17	7	0	0	0	0	0	0	0	0	0	0	33
Hemiptera	Veliidae	20	0	117	13	0	0	0	0	0	0	0	0	0	0	0
Odonata	Coenagrionidae	0	0	0	0	0	14	0	0	0	0	0	0	0	0	0
Odonata	Zygoptera sp.	0	14	0	0	0	14	0	0	0	0	0	0	0	0	0
Oligochaeta	sp.	1320	329	517	340	1200	286	1383	160	21	107	250	250	600	186	33
Plecoptera	Gripopterygidae	100	57	17	0	120	100	0	20	29	0	0	0	120	0	0
Trichoptera	Conoesucidae	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trichoptera	Ecnomidae	0	0	0	0	0	0	17	0	14	0	0	10	20	314	0
Trichoptera	Hydrobiosidae	0	0	17	0	20	0	17	0	43	0	0	0	0	0	0
Trichoptera	Hydropsychidae	0	0	0	0	20	43	0	20	143	0	0	150	40	300	0
Trichoptera	Hydroptilidae	20	329	250	267	880	357	317	55	141	25	0	150	10	114	25
Trichoptera	Leptoceridae	40	29	17	7	20	86	50	0	0	0	0	30	40	29	0
Turbellaria	Dugesiidae	0	0	0	0	0	0	17	0	0	0	0	0	0	0	17
Turbellaria	**Temnocephalidae**	**0**	**0**	**17**	**0**	**20**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**17**

Appendix D. Taxonomic inventory of the macroinvertebrate taxa collected in the RIFFLE spring 2010

Class/Order	Family/Subfamily	MUR1	MUR2	MUR3	MUR6	MUR9	MUR12	MUR15	MUR16	MUR18	MUR19	MUR22	MUR23	MUR27	MUR29
Acarina	Acarina	14	25	29	43	21	20	37	89	63	100	13	150	100	0
Amphipoda	Ceinidae	29	0	7	0	0	0	0	0	0	0	0	0	0	0
Bivalvia	Corbiculidae	0	0	0	0	0	0	4	0	0	0	0	0	0	0
Bivalvia	Sphaeriidae	0	0	71	0	14	0	0	0	0	0	0	0	0	0
Coleoptera	Dytiscidae	0	0	0	0	0	20	0	0	0	0	0	0	0	0
Coleoptera	Elmidae	29	50	0	0	21	0	0	0	0	0	67	0	20	0
Coleoptera	Gyrinidae	0	0	0	0	0	40	0	0	0	0	7	0	0	0
Coleoptera	Hydrophilidae	0	0	14	0	0	0	0	0	0	0	7	0	0	0
Coleoptera	Psephenidae	0	0	14	0	0	0	0	0	0	0	0	0	0	0
Coleoptera	Scirtidae	14	50	0	0	0	0	0	0	0	0	0	0	0	0
Decapoda	Parastacidae	0	0	0	0	0	0	0	0	0	0	0	25	0	0
Diptera	Ceratopogonidae	14	0	0	0	0	40	11	33	0	0	27	25	0	14
Diptera	Empididae	0	0	0	14	14	0	70	44	113	0	0	0	20	0
Diptera	s-f Chironominae	43	700	57	357	86	40	15	344	113	33	227	1375	380	0
Diptera	s-f Orthocladiinae	1600	575	150	357	250	820	233	789	425	250	107	1300	1320	771
Diptera	s-f Tanypodinae	14	125	57	29	21	20	19	111	138	33	13	50	0	0
Diptera	Simuliidae	0	175	21	14	86	2140	74	33	1188	2650	267	125	140	3129
Diptera	Tipulidae	14	0	0	14	14	0	4	122	0	17	7	50	60	0
Ephemeroptera	Baetidae	0	500	221	86	0	100	44	89	63	50	187	100	20	86
Ephemeroptera	Caenidae	0	125	93	143	100	40	78	56	88	0	73	200	0	0

Class/Order	Family/Subfamily	MUR1	MUR2	MUR3	MUR6	MUR9	MUR12	MUR15	MUR16	MUR18	MUR19	MUR22	MUR23	MUR27	MUR29
Ephemeroptera	Coloburiscidae	0	50	0	0	0	0	0	0	0	0	0	0	0	0
Ephemeroptera	Leptophlebiidae	157	625	279	29	50	60	11	133	338	33	233	300	20	14
Gastropoda	Ancylidae	0	0	0	14	14	0	0	0	0	0	0	0	0	0
Hemiptera	Corixidae	0	0	0	0	7	20	0	0	0	33	7	0	0	0
Megaloptera	Corydalidae	0	0	0	0	7	0	0	0	0	0	0	0	0	0
Odonata	Gomphidae	0	25	14	0	0	0	0	0	0	0	0	0	0	0
Oligochaeta	Oligochaeta	1171	1675	157	1129	471	140	15	89	13	550	80	225	160	29
Plecoptera	Gripopterygidae	57	100	7	29	36	20	4	0	0	17	0	0	0	0
Trichoptera	Conoesucidae	29	0	0	0	0	0	0	0	0	0	0	0	0	0
Trichoptera	Ecnomidae	0	50	0	0	0	0	7	89	25	17	13	75	120	0
Trichoptera	Hydrobiosidae	100	50	7	43	21	120	15	44	13	0	20	25	20	14
Trichoptera	Hydropsychidae	0	100	143	200	129	940	252	378	50	50	113	775	2120	57
Trichoptera	Hydroptilidae	0	75	121	729	157	120	26	61	56	0	53	31	0	7
Trichoptera	Leptoceridae	0	0	0	0	0	0	4	0	0	0	0	0	0	0
Trichoptera	Tasimiidae	0	25	0	0	0	0	0	0	0	0	0	0	0	0
Turbellaria	Dugesiidae	0	0	0	0	0	0	0	0	0	33	0	0	0	0