ACTEW Corporation

Murrumbidgee Ecological Monitoring Program

Part 2: Burra Creek

Autumn 2010

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CERTIFICATE OF APPROVAL FOR ISSUE OF DOCUMENTS

Client: ACTEW CORPORATION	
Project Title: **Murrumbidgee Ecological Monitoring Program**	
Title: Burra Creek Autumn 2010	
Project No:	CN 211063
Document Status:	Final

Cover Photograph: Upper Burra Creek (within the Tinderry Nature Reserve)

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Document Revision Control

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Document Revision Control

Version	Description of Revision	Person Making Issue	Date	Approval

ABN 94 105 060 320

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List of Abbreviations

ACT – Australian Capital Territory
ACTEW – ACTEW Corporation Limited
AFDM – Ash Free Dry Mass (periphyton)
ALS – Australian Laboratory Services
ANZECC –Australian and New Zealand Environment and Conservation Council
ANOVA – Analysis of Variance (statistics)
APHA – American Public Health Association
ARMCANZ – Agriculture and Resource management Council of Australia and New Zealand
ARI – Average Recurrence Interval
AUSRIVAS – Australian River Assessment System
BACI – Before After Control Impact
CI – Confidence Interval
CMA – Catchment Management Authority
EC – Electrical Conductivity
EIS – Environmental Impact Statement
EPA – Environmental Protection Authority
GL/a – Gigalitres per annum
GPS – Global positioning system
IBT- Inter-Basin Water Transfer
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)
NSW – New South Wales
NTU – Nephlelometric Turbidity Units
QA – Quality Assurance
QC – Quality Control
SD – Standard Deviation
TN – Total Nitrogen
TP – Total Phosphorus

Executive Summary

ACTEW is committed to improving the security of the ACT water supply through the construction of an additional pumping structure and pipeline that will abstract Murrumbidgee River water from a location near Angle Crossing (southern border of the ACT). The proposed pumping system will transfer water 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 is expected to be in operation around 2011. Abstraction at Angle Crossing and its subsequent transfer and release into Burra Creek 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 transfer project (M2G).

The hydrological change will noticeably increase the baseflow of Burra Creek and, therefore requires an assessment of the response of the river and its ecology to flow variability in order to help predict potential impacts associated with such changes.

This ecological monitoring program aims to establish the baseline river condition prior to water discharges into Burra Creek over a three year period and then to continue monitoring after the commencement of the operation phase of the M2G Project to determine what changes are taking place that are attributable to water discharges from the Murrumbidgee River into Burra Creek.

The key aims of the sampling program were to:

1. *Establish the current status of the macroinvertebrate community at key sites on Burra Creek and the nearby Queanbeyan River;*
2. *Provide ACTEW with river health assessments based on AUSRIVAS protocols at these key sites to determine how river health may be affected during and after the pipeline development and the subsequent discharges into Burra Creek;*
3. *Establish baseline periphyton data that will be used to characterise seasonal and temporal changes under baseline conditions*
4. *Report on water quality from continuous and grab sample monitoring in order to characterise baseline water quality conditions and provide data that could be used to predict impacts associated with the M2G project.*

This report presents the findings from biological sampling of Burra Creek and the Queanbeyan River conducted in autumn 2010. Sampling was conducted on the 15th and 16th of March 2010 and was based on ACT AUSRIVAS sampling protocols; but was extended to include multiple replicates from each site where specimens were identified to genus level, instead of family level.

The purpose of this protocol was to:

a) Collect biological signatures of condition at each site prior to the commencement of pumping;

b) Enable subtle changes to be detected if there are impacts associated with reduced flows; and

c) Provide within-site replication that will potentially allow hypothesis testing statistical analyses to be performed on the data as part of any impact assessment.

The key results from the autumn 2010 sampling of Burra Creek are as follows:

1. *The AUSRIVAS assessments showed that: both Queanbeyan River sites were "significantly impaired" (BAND B), indicating a decline in condition at QBYN 1 since spring and autumn 2009. While the overall site assessments from the Burra sites indicate improvement at BUR 2b, but there was a decline in the overall site assessment at BUR 1 (see Figure 1; Page 14). This was primarily due to the lack of any sensitive taxa in the riffle habitat.*
2. *The macroinvertebrate communities were dominated by taxa that are considered to be: mildly tolerant to water pollution, early colonisers following disturbance, and; resistant to sedimentation. EPT taxa were absent from the upstream, Burra Creek site, and there was an overall reduction in EPT richness and relative abundance across all sites compared to previous sampling events. These results are suggestive of two key factors. First, because surface flows have been observed to be present during periods of extended rainfall and temporarily following rainfall events, flow permanence is likely to be the limiting factor in the upstream Burra Creek sites, restricting the colonisation of sensitive EPT taxa; and secondly, a high flow event, closely followed by a second event in the Queanbeyan River may have initially flushed many of the taxa downstream, thus reducing both diversity and relative abundances of sensitive taxa and the moderate event may have been enough to disrupt the re-colonisation process.*
3. *Water quality grab samples show that nutrient guidelines were exceeded at all but one site (BUR 3) for TP, but all of the sampling sites exceeded TN guidelines. The TP concentrations recorded in autumn were approximately the same as those recorded in spring, but TN concentrations were in some cases three times higher;*
4. *The continuous water quality records indicated good quality water in both the Burra Creek and Queanbeyan catchments. Fluctuations in individual analytes indicated natural responses to rainfall events and decreasing temperatures heading into winter. Periods of high turbidity due to rainfall events were not sustained for long periods suggesting no localised problem areas in terms of sediment sources;*
5. *EC values were high at the Burra Creek sites, but remained within the guidelines. This is likely a dilution effect resulting from recent rainfall events. Turbidity was below the recommended guidelines at two of the Burra Creek sites at the time of sampling;*

Burra Creek is dynamic system in that it undergoes long periods with no surface flow, followed by short bursts of surface flow following rainfall events and periods of prolonged surface flow during the wetter months. The current sampling regime does not capture biological community responses under full range of flow conditions because sampling is conducted twice per year. Therefore, it is recommended that an investigation of the macroinvertebrate community responses following rainfall events after extended dry periods or similarly the responses to drying following extended periods of surface flow in order to help fill an important knowledge gap which will help determine likely scenarios relating to the M2G water transfers in the Burra Creek system.

It is also recommended that the water quality sampling regime be increased to include both event based sampling and baseflow sampling at regular intervals. This will help establish a water chemistry signature and determine natural trends in nutrient concentrations at a finer scale than is currently being implemented. Further, the additional nutrient data will enable the assessment of any nutrient-biotic interactions in a way that captures any lag effects owing to the cumulative response of periphyton to antecedent water quality conditions.

Despite the low taxonomic diversity and overall reduction in sensitive taxa across most sites, the fact that these patterns occurred throughout the study region indicates a response to a natural disturbance. The most likely cause was initially the $3^{1/2}$ yr ARI event in February, with the secondary event in March interrupting the re-colonisation process.

1 Introduction

The Murrumbidgee Ecological Monitoring Program (MEMP) 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. The scope of this study is to undertake sampling in spring and autumn over a three year period commencing in spring 2008.

There are four components / geographic areas considered as part of the MEMP study:

Part 1: Angle Crossing

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

Part 3: Murrumbidgee Pump Station

Part 4: Tantangara to Burrinjuck

This report focuses on Part 2: Burra Creek.

ACTEW is proposing to construct an additional pumping structure and pipeline to abstract water from the Murrumbidgee River from a location near Angle Crossing (southern border of the ACT). The proposed pumping system will transfer water 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 is expected to be in operation around 2011. Abstraction at Angle Crossing and the subsequent discharges to Burra Creek will be dictated by the level of demand for the water, and by the availability of water in the Murrumbidgee River. The proposed development is referred to as the Murrumbidgee to Googong project (M2G).

From the commencement of recording at the Burra Creek stream flow gauge in 1985 through to 2000, the mean daily flow was 14.5 ML/d, however over the last five years flows have reduced substantially due to climatic conditions, with a mean daily flow of just 1 ML/d. Since flow records began in 1985 a mean monthly flow of 100ML/d has only been exceeded 6 times, while flows in excess of 100ML/d have occurred less than 2% of the time on a daily basis.

In light of the current low flow conditions in Burra Creek, it is expected that the increased flow will have several impacts on water quality, channel and bank geomorphology and the ecology of the system (Table 1). Some favourable ecological effects could be expected in the reaches of Burra Creek between the discharge point and downstream of the confluence of the Queanbeyan River. These effects include: the main channel being more frequently utilised by fish species; increased biodiversity in macroinvertebrate communities and a reduction in the extent of macrophyte encroachment in the Burra Creek main channel. The transfer of Murrumbidgee River water into Burra Creek has the potential to negatively impact the natural biodiversity within Burra Creek because of the different physico-chemical characteristics of each system. Further, the inter-basin water transfer might also poses a risk of spreading exotic plant and fish species which could displace native biota directly through competition or indirectly through the spread of disease. Other potential impacts are highlighted in Table 1.

These potential impacts have been assessed by the relevant Government authorities through submission of Environmental Impact Statements (EIS) or similar assessments. One of the components of the EIS is to undertake an ecological monitoring program, for which this program is based.

Table 1. Potential impacts to Burra Creek following Murrumbidgee River discharges

Property	Possible impact	Source
Water Quality	Increased turbidity from Murrumbidgee water which could decrease light penetration, resulting in lower macrophyte and algal growth.	Biosis, 2009.
	The inter-basin transfer (IBT) of soft Murrumbidgee Water into the harder waters of Burra Creek are likely to change the natural biodiversity within Burra Creek.	Fraser, 2009.
	Changes in water temperature could be expected from the IBT and increased turbidity. This may effect plant growth, nutrient uptake and dissolved oxygen levels.	Biosis, 2009.
Ecology	Changes in macroinvertebrate communities and diversity through habitat loss from sedimentation, riparian vegetation and scouring of macrophytes. Changes in macroinvertebrates are also expected with an increase of flow (e.g. increased abundances of flow dependant taxa).	Bunn and Arthington, 2002.
	Potential risk of exotic species recruitment from IBT, this could displace native species in the catchment and pose a risk of the spread of disease.	Biosis, 2009; Davies *et al.* 1992.
	Infilling from fine sediment transport could threaten the quality of the hyporhiec zone, which provides important habitat for macroinvertebrates in temporary streams.	Williams and Hynes, 1974; Brunke and Gonser, 1997.
	Increased flow with improved longitudinal connectivity which potentially will provide fish with more breeding opportunities and range expansion, although this will be dependent on the proposed flow regime	Biosis, 2009.
Bank Geomorphology	Bank failure from the initial construction phase and first releases. This could result in increased sedimentation, loss of riparian vegetation and increase erosion rates from bank instability	Skinner, 2009.
Channel Geomorphology	Scouring of the river bed may result in a loss of emergent and submerged macrophyte species. This would result in a reduction of river bed stability and a change in macroinvertebrate diversity and dynamics.	Harrod, 1964.

1.1 Project objectives

The objectives of the Murrumbidgee Ecological Monitoring Program (MEMP) are to provide ACTEW with seasonal assessments of river health prior to (baseline) and during the construction and operational phases of the new pipeline and discharge into Burra Creek.

Specifically, the aims of the project are to:

1. Provide seasonal "river health" reports in accordance with ACTEW water abstraction licence requirements;
2. Collect baseline macroinvertebrate, water quality and periphyton data in order to ascertain whether the future discharges into Burra Creek from the Murrumbidgee River are likely to impact the ecology and ecological "health" of Burra Creek;
3. Collect baseline periphyton data that will be used as a guide to monitor seasonal and temporal changes
4. Report on water quality upstream and downstream of the discharge point in Burra Creek.

1.2 Project scope

The current ecological health of the sites monitored as part of the Burra Creek component of the Murrumbidgee Ecological Monitoring Program (MEMP) program has been estimated using ACT AUSRIVAS protocols for macroinvertebrate community data, combined with a suite of commonly used biological metrics and descriptors of community composition. The scope of this report is to convey the results from the autumn 2010 sampling run. Specifically, as outlined in the MEMP proposal to ACTEW Corporation (Ecowise, 2009*a*), this work includes:

- Sampling commencing in autumn 2009;
- Macroinvertebrate sampling from riffle and edge habitats;
- Riffle and edge samples collected as per the ACT AUSRIVAS protocols;
- Macroinvertebrates counted and identified to the taxonomic level of genus;
- Riffle and edge samples assessed through the appropriate AUSRIVAS model;
- Some water quality measurements to be measured *in-situ*, and nutrient samples to be collected and analysed in Australian Laboratory Services (ALS's) NATA accredited laboratory.

Prior to the commencement of this program, ALS sort advice by independent industry experts on the sampling regime and study design required for a robust interpretation of the biological data collected. The communications began six months prior to the first sampling run and were adjusted from its original design before it was finalised due to difficulties in finding appropriate control sites. An additional site was added to this program because the exact location of the Burra Creek discharge point has yet to be finalised.

1.3 Rationale for using biological indicators

Macroinvertebrates and periphyton are two of the most commonly used biological indicators in river health assessment. Macroinvertebrates are commonly used to characterise ecosystem health because they represent a continuous record of preceding environmental, chemical and physical conditions at a given site. Macroinvertebrates are also very useful indicators in determining specific stressors on freshwater ecosystems because many taxa have known tolerances to heavy metal contamination, sedimentation, and other physical or chemical changes (Chessman, 2003). Macroinvertebrate community assemblage, and two indices of community condition; the AUSRIVAS index and the proportions of three common taxa (the Ephemeroptera, Plecoptera, and Trichoptera, or EPT index), were used during this study to assess river health.

Periphyton is the matted floral and microbial community that resides on the river bed. The composition of these communities is dominated by algae but the term "periphyton" also includes fungal and bacterial matter (Biggs and Kilroy, 2000). Periphyton is important to maintaining healthy freshwater ecosystems as it absorbs nutrients from the water, adds oxygen to the ecosystem via photosynthesis, and provides a food for higher order animals. Periphyton communities respond rapidly to changes in water quality, light penetration of the water column and other disturbances, such as floods or low flow, and this makes them a valuables indicator of river health.

2 Materials and Methods

2.1 Study sites

Macroinvertebrate community composition, periphyton assemblages and water quality were monitored in Burra Creek, Cassidy's Creek and the Queanbeyan River to obtain baseline ecological information prior to the construction and implementation of the M2G pipeline. Seven sites were monitored in total, including three control sites (one each in Cassidy Creek, Burra creek and the Queanbeyan River) and four impact sites (three in Burra Creek and one in the Queanbeyan River downstream of the confluence with Burra Creek). This includes one provisional impact site (BUR2 was split into two locations), one of which might be removed or replaced by another monitoring location once the exact location of the discharge point is determined) (Table 2; Figures 1 & 2). Site photographs can be seen in APPENDIX A.

To monitor for potential impacts to the ecological condition of Burra Creek, aquatic macroinvertebrates were sampled from two habitats (riffle and pool edges) and organisms identified to family or genus level, to characterise each site. Periphyton was sampled in the riffle zones at each site and analysed for chlorophyll-a and Ash Free Dry Mass (AFDM) to provide estimates of the algal (autotrophic) biomass and total organic mass respectively based on the methods of Biggs and Kilroy (2000).

Both the riffle and edge habitats were sampled where available to provide a comprehensive assessment of each site and allow the flow related impacts to be distinguished from other disturbances. The reasoning behind this is that each habitat is likely to be effected in different ways. Riffle zones, for example, are often dry in Burra Creek because of its intermittent flow regime and are likely to be permanently by the additional flow through the channel. Further, due to the high number of no-flow days and the chain-of –ponds nature of Burra Creek, sampling the pool/edges allowed data collection when surface flow had ceased.

Table 2. Sampling site locations and details

Site Code	Location	Purpose	Latitude	Longitude
CAS 1	Cassidy's Creek, upstream Burra Creek confluence	Control site	-35° 35.918	149° 13.641
BUR 1	Burra Creek, upstream Cassidy Creek confluence	Control site	-35° 35.855	149° 13.666
BUR 2*a**	Burra Creek, downstream of Williamsdale Road Bridge	Impact site	-35° 33.326	149° 13.400
BUR 2*b**	Burra Creek, downstream of Burra Road bridge	Impact site	-35° 35.571	149° 13.649
BUR 3	Burra Creek, downstream of London Bridge	Impact site	-35° 30.620	149° 15.861
QBYN 1	Queanbeyan river at Flynn's Crossing	Control site	-35° 31.459	149° 18.198
QBYN 2	Queanbeyan River, downstream of Burra Creek confluence	Impact site	-35° 29.937	149° 15.942

* Two options are given here because at the time of study design, the actual point of discharge into Burra Creek had yet to be confirmed.

2.2 Hydrology and rainfall

River flows and rainfall for the sampling period were recorded at ALS gauging stations at Burra Road (410774, downstream of the Burra Road Bridge) and the Queanbeyan River (410781, upstream of Googong reservoir). Site locations and codes are given in Table 2 (below).

Table 3. Stream flow and water quality monitoring site locations

Site code	Location	Parameters*	Latitude	Longitude
410774	Burra Creek	WL, Q, pH, EC, DO, Temp, Turb	-35.5425	149.2279
410781	Queanbeyan River US of Googong Reservoir	WL, Q, pH, EC, DO, Temp, Turb	-35.5222	149.3005

* WL = Water Level; Q = Rated Discharge; EC = Electrical Conductivity; DO = Dissolved Oxygen; Temp = Temperature; Turb = Turbidity

2.3 Water quality

Baseline *in-situ* physico-chemical parameters including temperature, pH, electrical conductivity, turbidity and dissolved oxygen were recorded at each sampling site using a multiprobe Hydrolab® Minisonde 5*a* Surveyor. The Surveyor was calibrated in accordance with ALS QA procedures and the manufacturer's requirements prior to sampling. Additionally, grab samples were taken from each site in accordance with ACT AUSRIVAS protocols (Coysh *et al.*, 2000) for Hydrolab® verification, nutrient analysis and given that all of the Burra Creek sites were able to be sampled on this occasion a full metals screen and anion: cation balance was carried out to provide a baseline for comparisons against samples collected during the construction and operational phases of the M2G Project.

All water samples were placed on ice, returned to the ALS laboratory and analysed for nitrogen oxides (total NOx), total nitrogen (TN) and total phosphorus (TP) in accordance with the protocols outlined in APHA (2005). This information will assist in the interpretation of biological data and provide a basis to gauge changes that can potentially be linked to increased flow and potential changes in the Burra Creek system due to inter-basin water transfers from the donor (Murrumbidgee) system.

2.4 Macroinvertebrate sampling

Riffle and edge habitats were sampled for macroinvertebrates and analysed using the ACT Spring riffle and edge AUSRIVAS (Australian River Assessment System) protocols (Coysh *et al.*, 2000) during autumn (March 15th and 16th) 2010.

Most of the sites in this program are limited by the amount of habitat suitable for macroinvertebrate sampling. For the majority of sites, this has meant only one replicate sample could be taken on any given sampling occasion. The Queanbeyan River is the exception, where two replicates have been sampled at each site since the inception of the monitoring program. Given that the majority of sites only had sufficient habitat available for one replicate to be taken, only one was taken across all sites in this sampling run in order to provide a balanced study design that did not bias results through differences in statistical power or permutations in the multivariate re-sampling techniques.

At each site, one sample was taken from the riffle habitat (flowing broken water over gravel, pebble, cobble or boulder, with a depth greater than 10cm; (Coysh *et al.*, 2000) using a framed net with 250 µm mesh size. Sampling began at the downstream end of each riffle. The net was held perpendicular to the substrate with the opening facing upstream. The stream bed directly upstream of the net opening was agitated by vigorously kicking, allowing dislodged invertebrates to be carried into the net by the current. The process continued, working upstream over 10 metres of riffle habitat. Samples were then preserved in 70% ethanol, clearly labelled with site code and date, then stored on ice and placed in a refrigeration unit until laboratory sorting commenced.

The edge habitat was also sampled according to the ACT AUSRIVAS protocols. One sample was taken from the edge habitat. The nets and all other associated equipment were washed thoroughly between sampling events to remove any macroinvertebrates retained on them. Samples were collected by sweeping the collection net along the edge habitat at the sampling site; the operator worked systematically over a ten metre section covering overhanging vegetation, submerged snags, macrophyte beds, overhanging banks and areas with trailing vegetation. Samples were preserved on-site as described for the riffle samples.

Prior to sampling, comprehensive site assessments were carried out, including assessments of safety, suitability and granted access from landowners. There are no suitable reference sites in the proximity for this assessment, so a Before – After / Control – Impact (BACI) design (Downes *et al.*, 2002) was adopted based on sites upstream of the abstraction point serving as Control sites and sites downstream of the abstraction / construction point serving as 'Impacted' sites. Baseline monitoring carried out as part of this study will serve as the 'Before' period for this assessment.

2.5 Periphyton

Estimates of algal biomass were made using complimentary data from both chlorophyll-*a* (which measures autotrophic biomass) and ash free dry mass (AFDM; which estimates the total organic matter in periphyton samples and includes the biomass of bacteria, fungi, small fauna and detritus in samples) measurements (Biggs, 2000).

The seven sampling sites selected for this project (Table 2, shown earlier) were sampled for periphyton in autumn in conjunction with the macroinvertebrate sampling. All periphyton (i.e. adnate and loose forms of periphyton, as well as organic/inorganic detritus in the periphyton matrix) samples were collected using the *in-situ* syringe method similar to Loeb (1981), as described in Biggs and Kilroy (2000). A 1 m wide transect was established across riffles at each site. Along each transect, twelve samples were collected at regular intervals, using a sampling device of two 60 ml syringes and a scrubbing surface of stiff nylon bristles covering an area of ~637 mm^2. The samples were divided randomly into two groups of six samples to be analysed for Ash Free Dry Mass (AFDM), and chlorophyll-a. Samples for Ash Free Dry Mass and chlorophyll-a analysis were filtered onto glass filters and frozen. Sample processing followed the methods outlined in APHA (2005).

2.6 Data analysis

Data were analysed using a mixture of uni- and multivariate techniques using both PRIMER v6 (Clarke and Gorley, 2006) and R 2.10.1. (R Development Core Team, 2008). Details of these analyses are provided below.

2.6.1 Water quality

Water quality parameters were examined for compliance with ANZECC & ARMCANZ (2000) water guidelines for healthy ecosystems in upland streams. Trend analyses of water quality parameters will be conducted at the end of the baseline collection period.

2.6.2 Macroinvertebrate communities

The macroinvertebrate data were examined separately for riffle and edge habitats. Replicates were examined individually (i.e. not averaged) at all sites because the aim is to examine within site variation as much as it is to describe patterns among sites at this stage. All multivariate analyses were performed using PRIMER version 6 (Clarke and Gorley, 2006).

Processing of the aquatic macroinvertebrate samples followed the ACT AUSRIVAS protocols. Briefly, 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 and the contents of randomly selected cells removed. Macroinvertebrates from each selected cell were identified to genus level. Specimens that could not be identified to the specified taxonomic level (i.e. immature or damaged taxa) were removed from the data set prior to analysis.

For the ACT AUSRIVAS model, all taxa were analysed at the family level except Chironomidae (identified to sub-family), Oligochaeta (class) and Acarina (order). Animals were identified using taxonomic keys published by Hawking (2000). All animals within the cell were identified. Data was entered directly into electronic spreadsheets to eliminate errors associated with manual data transfer.

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 by describing trends in the joint occurrence of taxa and aids with interpretation. 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). For the macroinvertebrate data collected during this survey, the final number of dimensions is reduced to two. How well the patterns in the 2-dimensional NMDS plot represents the multivariate data is indicated by the stress value of each plot. The stress level 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 be considered a measure of "goodness of fit" to the original data matrix (Kruskal, 1964), and when near zero suggests that NMDS patterns are very representative of the multidimensional data. Stress greater than 0.2 indicates a poor representation (Clarke and Warwick 2001).

An analysis of similarities (ANOSIM) was performed on the data to test whether macroinvertebrate communities were statistically different upstream and downstream of the proposed discharge point. Sites were unable to be nested with location in the two-way design due to a lack of replication at several of the sites. Instead, a one-way analysis examined the differences between location (up and downstream of the proposed discharge point, using site as the unit of replication) and differences between systems (Burra and Queanbeyan).

The similarity percentages (SIMPER) routine was carried out on the datasets only if the initial ANOSIM test was significant (i.e. $P<0.05$), to examine which taxa were responsible for, and explained the most variation among statistically significant groupings. This procedure was also used to describe groups (i.e. which taxa characterised each group of sites) (Clarke and Warwick, 2001)

2.6.3 AUSRIVAS assessment

AUSRIVAS is a prediction system that uses macroinvertebrates to assess the biological health of rivers and streams. Specifically, the model uses site-specific information to predict the macroinvertebrate fauna Expected (E) to be present in the absence of environmental stressors. The expected fauna from sites with similar sets of predictor variables (physical and chemical characteristics influenced by non-human characters, 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 ratio derived from this analysis is compiled into bandwidths (i.e. X, A-D; Table 4) which are used to gauge the overall health of particular 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 (Tables 4).

Site assessments are based on the results from both the riffle and edge samples. The overall site assessment was based on the furthest band from reference in a particular habitat at a particular site. For example, a site that had a Band A assessment in the edge and a Band B in the riffle would be given an overall site assessment of Band B (Coysh *et al.*, 2000). In cases where the bands deviate significantly between habitat (e.g. D – A) an overall assessment is avoided due to the unreliability of the results.

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 not predicted to occur more 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 also 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 because the presence or absence of these taxa might be a function of sampling effort rather than truly reflecting ecological change.

One caveat to note in this study, is that while AUSRIVAS predictions based on physical information can result in similar taxa expected to occur within different stream types (i.e. intermittent and perennial), disparities in macroinvertebrate communities are related to system – specific differences such as water chemistry and the disturbance and flows regimes, resulting in adaptations to cope with these differences (Wallace, 1990). The AUSRIVAS model does not take the degree of flow permanence into account which could result in erroneous predictions by the model and lead to misleading outputs. It is therefore advised that caution should be given to the AUSRIVAS outputs for the Burra Creek sites.

2.6.4 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 that have been derived 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.

Table 4. AUSRIVAS band-widths and interpretations for the ACT autumn riffle and edge models

	RIFFLE	EDGE	
BAND	O/E Band width	O/E Band width	Explanation
X	>1.12	>1.17	More diverse than expected. Potential enrichment or naturally biologically rich.
A	0.88-1.12	0.83-1.17	Similar to reference. Water quality and / or habitat in good condition.
B	0.64-0.87	0.49-0.82	Significantly impaired. Water quality and/ or habitat potentially impacted resulting in loss of taxa.
C	0.40-0.63	0.15-0.48	Severely impaired. Water quality and/or habitat compromised significantly, resulting in a loss of biodiversity.
D	0.-0.39	0-0.14	Extremely impaired. Highly degraded. Water and /or habitat quality is very low and very few of the expected taxa remain.

2.6.5 Periphyton

The raw chlorophyll-a and AFDM data were converted to estimates of concentrations and biomass per square metre respectably following the methodology outlined in Biggs and Kilroy (2000).

These data were used to test for differences between upstream-control locations versus downstream impact locations. Log-transformed chlorophyll-a and AFDM data were fitted to a mixed effects, nested analysis of variance (ANOVA). Site was nested within location and was treated as a random effect and location was considered a fixed effect. For the purposes of graphical visualisation, raw data are presented.

Exploratory analyses were also conducted on AFDM and chlorophyll-a data, which were correlated with environmental parameters to determine possible causal relationships that could be used in later experimental designs. Pearson's Correlation Coefficients were used to test the strength of the relationships. Formal testing was not conducted because mean values were used and therefore represented an insufficiently low sample size.

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. To overcome losses associated with damage to intact organisms during vial transfer, attempts were made to obtain significantly more than 200 organisms;
- Identification was performed by qualified and experienced aquatic biologists with more than 100 hours of identification experience;
- When required, taxonomic experts confirmed identification. Reference collections were also used when possible;
- 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.

All procedures were performed by AUSRIVAS accredited staff.

2.8 Licenses 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)).

ALS field staff maintains current ACT AUSRIVAS accreditation.

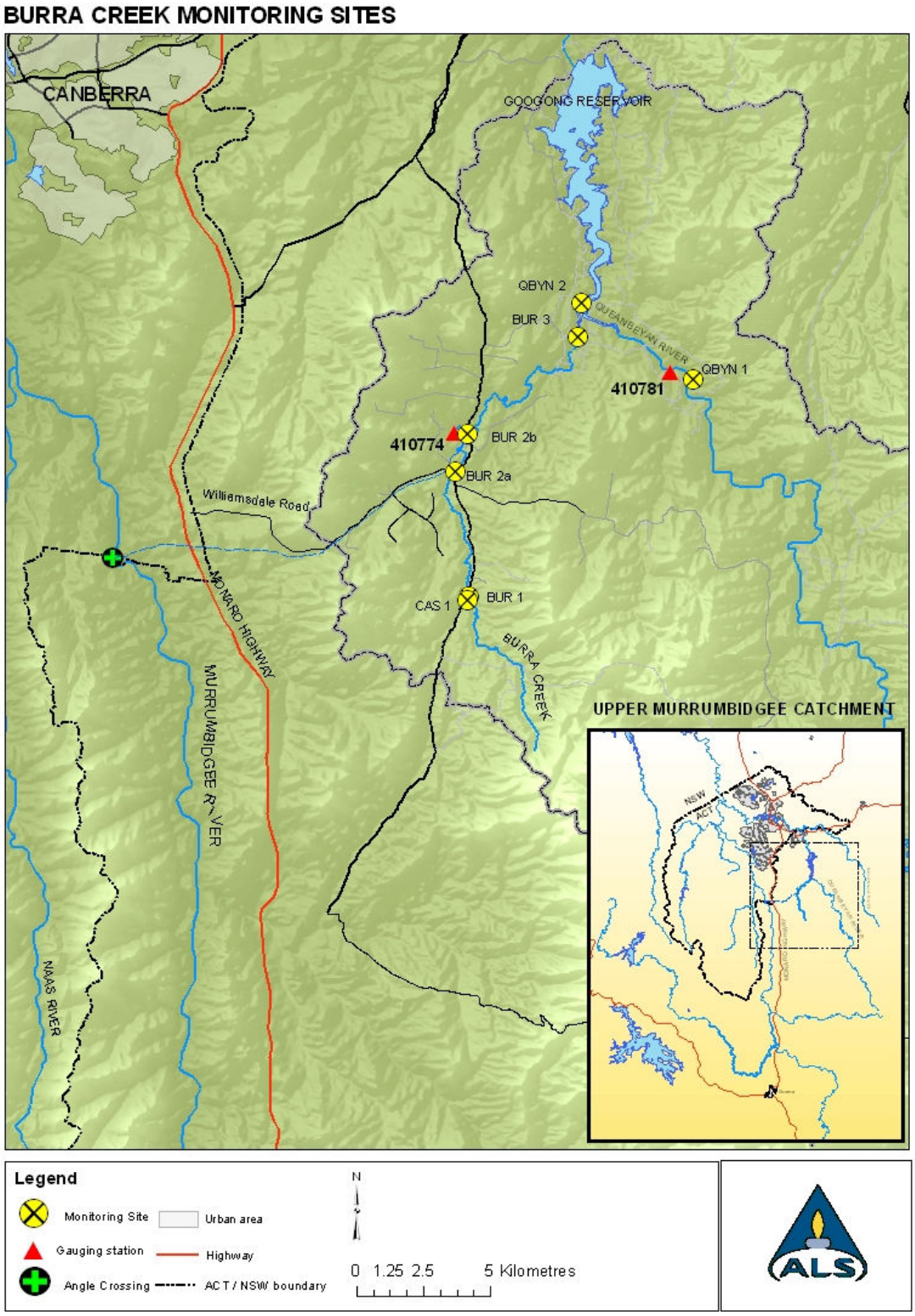

Figure 1. Locality of the monitoring sites and gauging stations for the Burra Creek monitoring program

3 Results

3.1 Sampling details

Burra Creek had less than 0.2 ML/d of surface flow during the autumn sampling run in 2009, which was insufficient for biological sampling. Therefore, sampling was conducted one week following the first event in autumn, which occurred on the 8th of March (Figure 2). During this period, Burra Creek had enough surface water to conduct biological sampling albeit receding rapidly through evaporation and infiltration. Aside from the recent rainfall event, the weather conditions during sampling were fine, the ambient temperature averaged 28°C with moderate cloud cover. Flows during sampling averaged 0.9 ML/d (for over two days) in Burra Creek and 53 ML/d in the Queanbeyan River.

3.2 Hydrology and rainfall

The March flow event, which affected both river systems assessed in this study, had an Average Recurrence Interval (ARI) of approximately 1 year, based on the results of the Log-Pearson Type III analysis in Hydstra©. Approximately one month prior to this event, a larger event, peaking at 2125 ML/d with an ARI of 3.5 years was recorded in the Queanbeyan River (410781) (APPENDIX B) resulting from 145 mm of rainfall over a period of 5 days. This February flow event resulted in 108 mm of rain falling in the Burra catchment, but had a much lesser effect on surface flows, probably as a result of high infiltration following extended periods of zero flow.

There 22 wet days in the Burra Creek catchment during autumn resulted in 204 mm of rain for the season in this catchment (Table 5). This rainfall resulted in 0.87% runoff with average monthly flows for autumn of 1.4 ML/d. Highest flows were in March with an average for the month of 3.8 ML/d, the highest since March 1993. Peak flows occurred on March 8th (310 ML/d) and returned rapidly to baseflow conditions after this (Figure 2). March was the wettest month in the Burra Creek catchment during autumn with approximately 105 mm rainfall occurring. May recorded a further 81 mm, which was predominantly in the last week of autumn.

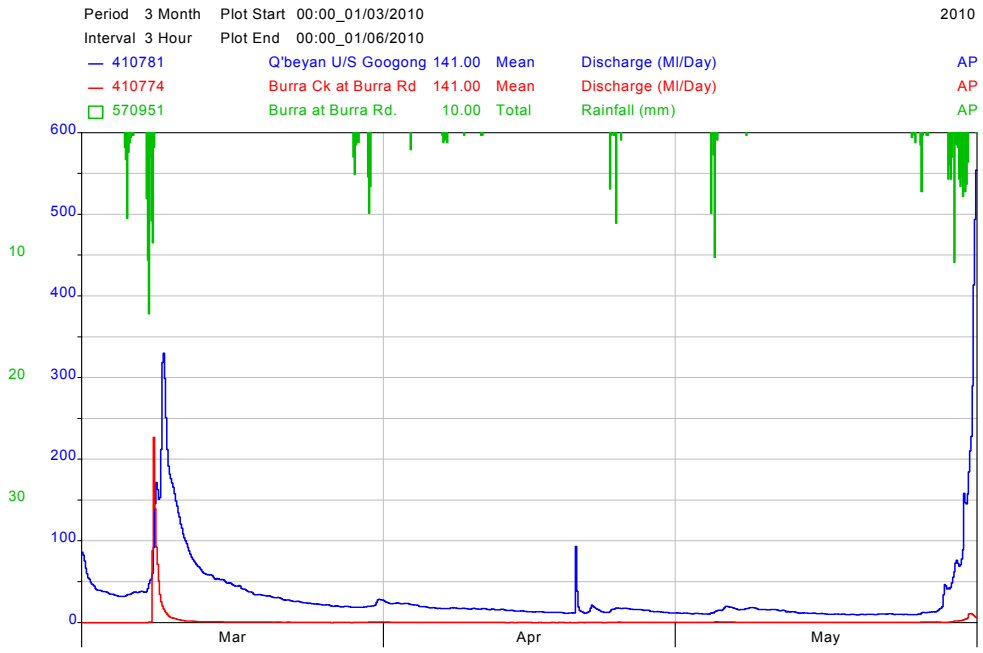

Figure 2. Autumn hydrograph from the Burra Creek and Queanbeyan River gauging stations

Table 5. Monthly flow and rainfall statistics for autumn 2010 at Burra Road (410774) and Queanbeyan River upstream of Googong reservoir (410781).

Monthly maximums are shown in yellow

Station	Burra Creek		Queanbeyan River	
	Rainfall Total (mm)	Mean Flow (ML/d)	Rainfall Total (mm)	Mean Flow (ML/d)
March	105.6	3.8 [310]	66.8	51.6 [335]
April	17.6	0.18 [0.47]	15	16.5 [175]
May	81.2	0.32 [1.2]	87.2	27.0 [569]
Autumn	204.4	1.4	169	31.7

3.3 Water quality

Continuous water quality records were collected from Burra Creek (Station number: 410774) (Figure 3) and the Queanbeyan River (Station number: 410781). Time series plots of water quality parameters logged at 410781 - u/s Googong Reservoir on the Queanbeyan River, are provided in APPENDIX C. Monthly water quality summary statistics are presented in Table 6. Grab sample results collected at the time of the biological sample collection are also reported on in relation to ANZECC and ARMCANZ (2000) guidelines (Table 7). The results of the full metals screen, and the anion: cation balance are provided in APPENDIX D.

During autumn, turbidity was above ANZECC and ARMCANZ (2000) guidelines (based on daily means) for two days early March (Figure 2), which followed four days of continuous rainfall. Mean daily turbidity readings were below the recommended lower bounds (2 NTU) for 18 days in autumn. The instant maximum following the March event was 386 NTU, which returned to within the guideline limits of 25 NTU within 36 hours.

pH in Burra Creek was consistent throughout autumn ranging from 7.1 – 7.7 (mean= 7.3 ± 0.13 SD) High values were related to decreasing flows and increasing water temperatures throughout May (Table 6).

Electrical conductivity was negatively related to flow ($R = -0.68$; $P<0.05$). Prior to the event in early March, the daily EC values were averaging between 560 $\mu s/cm^{-2}$ and 530 $\mu s/cm^{-2}$ there was a sharp decline to approximately 290 $\mu s/cm^{-2}$ once the surface flows increased (Figure 3).

Dissolved oxygen (% saturation) was low in autumn, as it was for spring 2009. The diurnal range increased as flows decreased but there was also showed and overall increase in dissolved oxygen saturation as water temperatures increased. Daily maximums ranged from 85-97% and usually peaked between 1400 and 1700 hours.

Nitrogen concentration guidelines were exceeded at all sites during autumn (Table 7). There were 1.6 to 2.7 fold increases seen across all sites between spring 2009 and autumn 2010. Queanbeyan 2 (downstream of the Burra confluence: Table 2; Figure 1) had the highest concentration of TN with 0.91 mg/L, followed by Burra 1 with 0.89 mg/L and Queanbeyan 1 (0.77 mg/L). The largest change occurred at Burra 2a (Table 2; Figure 1), showing a 2.7 fold increase since spring 2009. Total Phosphorus (TP) was also outside of the guideline values at 4 of the 7 sites (Cas 1; Burra 1; Qbyn 1 and Qbyn 2) while two of the sites were right on the threshold value of 0.2 mg/L (Bur 2a and Bur 2b). Bur 3 was within the guideline for total phosphorus.

Turbidity was under the recommended lower limit at two Burra creek sites, but as discussed in Ecowise (2009b) there is an argument for reviewing these guidelines, given that Burra Creek, being a limestone stream with surface water being made up of a high proportion of groundwater have naturally low turbidity readings and EC levels. EC levels in Burra Creek were within the guidelines when in-situ physico-chemical readings were taken (Table 7) but these results are in contrast to the long term records and the seasonal time series plot for EC in this catchment (Figure 3).

Table 6. Monthly water quality statistics from Burra Creek (410774) and the Queanbeyan River (410781).

All values are means. Monthly maximum turbidity values are in yellow

Station	Burra Creek				Queanbeyan River			
Analyte	temp.	EC	pH	turbidity	temp.	EC	pH	turbidity
March	17.9	458	7.2	9.4 [386]	19.5	98	7.2	12 [58]
April	13.7	537	7.3	3.3 [47]	15.2	95	7.3	12 [153]
May	10.5	466	7.5	1.5 na	9.2	70	7.8	9 [96]
Autumn	14	489	7.3	4.7	14.6	64	7.4	11

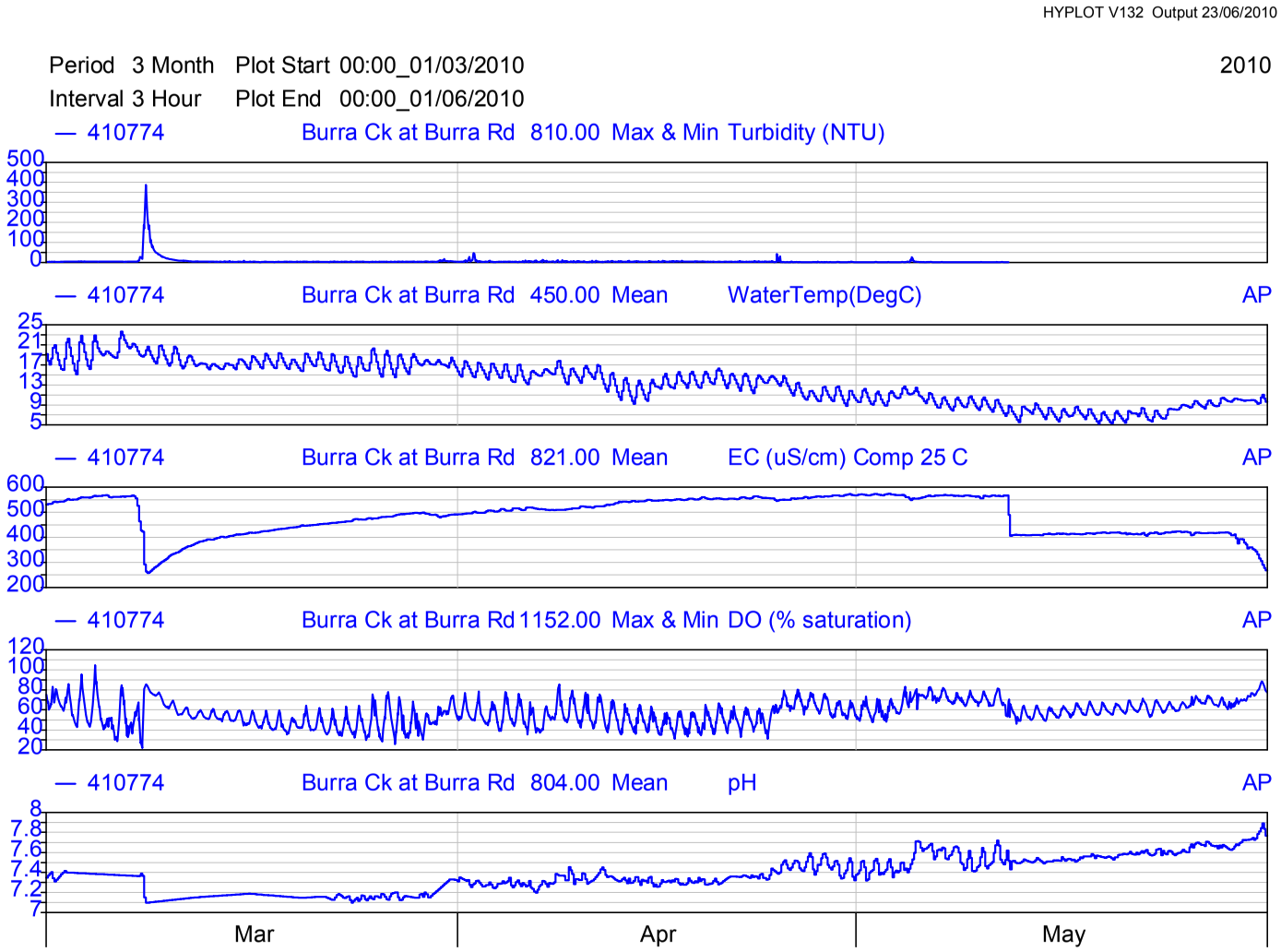

Figure 3. Water quality records from Burra Creek (410774) during Spring 2009

Table 7. *In-situ* water quality results: autumn 2010

(ANZECC & ARMCANZ guidelines are in red). Yellow cells indicate values outside guidelines. Refer to Table 2 for site location details. † Indicates water sample taken from pool/edge. Further details are provided in APPENDIX B

Location	Site	Time	Temp. (°C)	EC (µs/cm) (30-350)	Turbidity (NTU) (2-25)	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)	Total Phosphorus (mg/L) (0.02)	Total Nitrogen (mg/L) (0.25)
Control sites	Cas 1†	*11.30*	17.2	174.1	7.4	6.7	22.6	2	168	<0.01	<0.01	<0.01	0.04	0.63
	Bur 1	*10.10*	15.7	46.9	20	6.5	77.8	7.3	29	<0.01	<0.01	<0.01	0.05	0.89
	Qbyn 1	*13.50*	20.7	42.4	11	7.2	99.8	8.4	39	0.04	0.04	<0.01	0.06	0.77
Downstream sites	Bur 2a†	*15.00*	20.8	151.6	2.7	7.01	38.9	3.6	125	<0.01	<0.01	<0.01	0.02	0.61
	Bur 2b†	*13.00*	17.5	160.5	1	7.2	52	4.7	139	<0.01	<0.01	<0.01	0.02	0.69
	Bur 3	*15.45*	24.7	176.9	1.4	7.8	108.9	8.3	151	<0.01	<0.01	<0.01	0.01	0.53
	Qbyn 2	*10.00*	18.9	46	13	7.5	99.6	8.6	41	0.10	0.10	<0.01	0.06	0.91

3.4 Periphyton

Chlorophyll-*a* concentrations ranged considerably, both within, and between sites (Figure 4). Average concentrations (ug/m^{-2}) ranged from and average of 5003 ± 4068 (95% CI) at Bur 3 to 106876 (± 22911 95% CI) at Bur 1. Despite the large differences in mean values, there were no significant location effects determined by the nested ANOVA ($F_{1,2}$ = 6.35; P=0.12) (Table 8).

Ash Free Dry Mass (AFDM) showed much less between site variability (Figure 5). Average AFDM was highest at Bur 3 (5520 mg/m^{-2} ± 898 95% CI) lowest at Qbyn 1 (3378 mg/m^{-2} ± 1257 95% CI). There was no location effect of AFDM found in this study ($F_{1,2}$ = 6.35; P=0.82) (Table 8).

Small sample size has restricted reliable statistical testing of chlorophyll-*a* and AFDM in response to water quality parameters. Exploratory techniques found no apparent relationship between any of the water quality parameters in this study.

Exploratory analyses of habitat-related parameters show strong relationships between mean chlorophyll-a and the level of shading (Pearson correlation coefficient: R = 0.86) indicating that as shading increases so does chlorophyll-*a*, implying that the chlorophyll-a content is detrital rather than algal in origin (Table 9). The minor relationship between the AFDM and chlorophyll-a (r=0.16) samples supports this hypothesis. There were also moderate relationships between mean velocity and the percent coverage of sand and bedrock within the riffle habitat, but this generally applied to chlorophyll-a samples. Most of the habitat variables investigated showed very weak correlations with AFDM (Table 9).

Table 8. One-way nested analysis of variance results for Cholorophyll-a and ash free dry mass densities

Response	Source	DF	F-value	P-value
Chlorophyll-*a* (log)	Location	1	6.35	0.12
	Residuals	20	419.37	
AFDM	Location	1	0.08	0.82
	Residuals	20	52.07	

Table 9. Pearson's correlation coefficients between AFDM and Chlorophyll-a and environmental variables

Periphyton	Environmental variable				
	Mean riffle depth	Mean velocity	Sand	Shading	Bedrock
Mean Chlorophyll-a	-0.32	-0.42	-0.45	0.87	0.25
Mean AFDM	-0.33	-0.31	<0.2	<0.2	<0.2

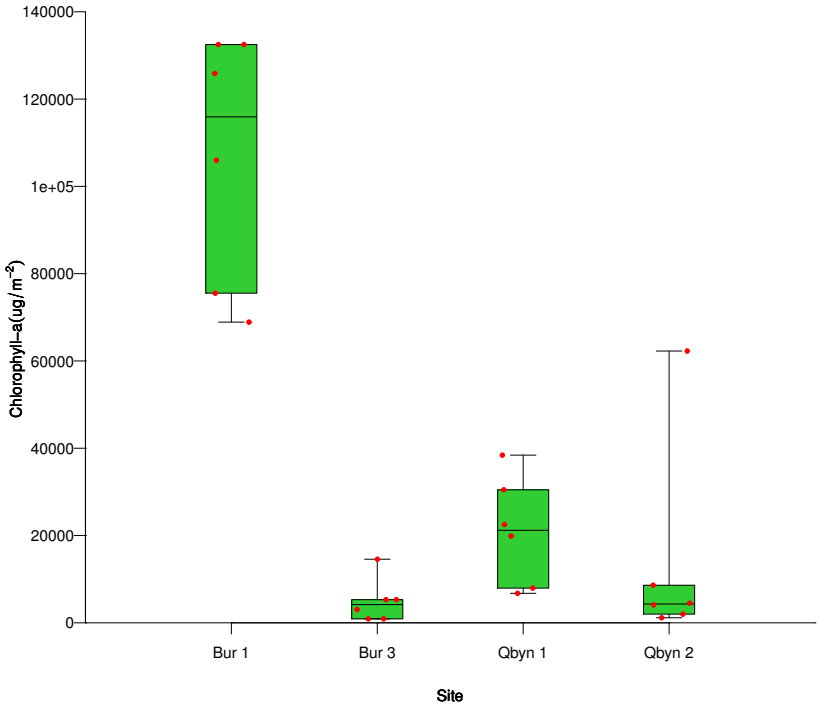

Figure 4. Periphyton chlorophyll-*a* concentrations from upstream (BUR 1 and QBYN 1) and downstream (BUR 3 and QBYN 2) locations

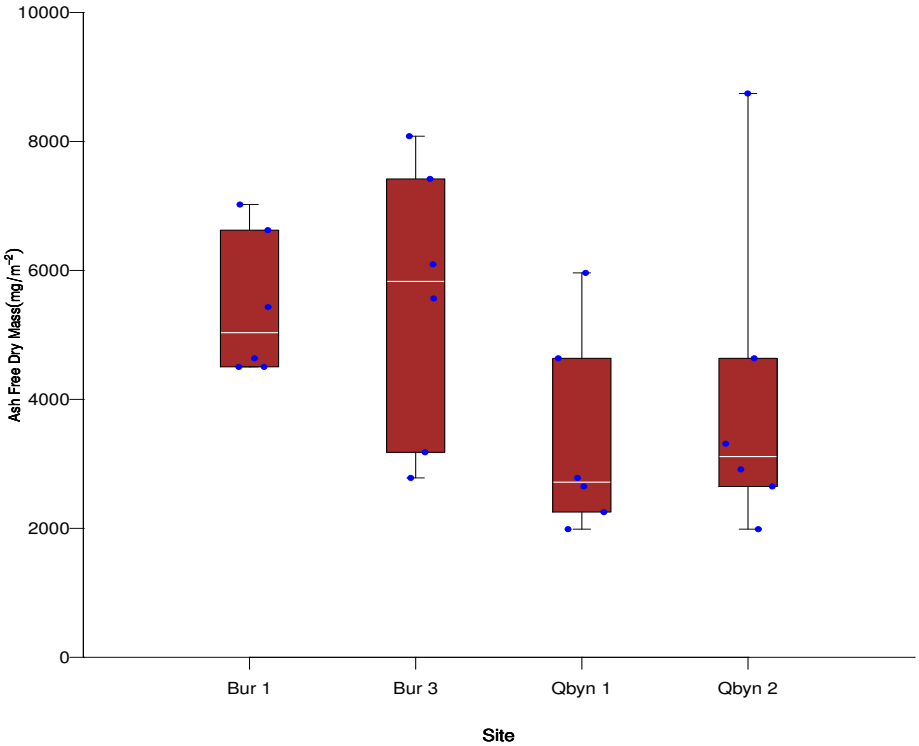

Figure 5. Periphyton Ash Free Dry Mass (AFDM) from upstream and downstream locations **Strip chart values in red (top) and blue (above) represent raw data points. See APPENDIX E for and explanation on how to interpret box and whisker plots**

3.5 Macroinvertebrate communities

3.5.1 Patterns in community structure

The ANOSIM detected significant differences in the riffle macroinvertebrate communities between sites (R=1; P=0.01) and between macroinvertebrate edge samples (R=0.9; P=0.01). The separation between the riffle samples can been seen in Figure 6.

The NMDS solution in figure 6 is known as a degenerate solution because all of the within site samples have collapsed onto a single point. This happens when all of dissimilarities within each site are smaller than all of the between site similarities (Anderson *et al.*, 2008). The result is a very low stress value but the result fails to include very little structural information in the data set. For the purposes of clarity, one of the recommended approaches is to subset the NMDS plot where more than one site has collapsed into one, as is the case in Figure 6. An NMDS subset was performed on the Queanbeyan River sites and the resulting solution was again, degenerate. The best approach in this situation is to recognize this structure, but to interpret the relationships between sites using the cluster analysis (Figure 7).

The relationship between the edge samples are shown in Figures 8 and 9. The cluster analysis of the riffle samples shows three main groups, consistent with the NMDS plot. The first split separates BUR 1 from BUR 3 and both Queanbeyan River sites at 42% similarity between these groups. The next division in the dendrogram shows that BUR 3 separates from the Queanbeyan River sites at approximately 50% similarity and the final division between the Queanbeyan River sites at 80% indicate a high degree of shared taxa between these site.

A full inventory of the macroinvertebrate taxa collected in autumn 2010 is given in APPENDIX F.

3.5.1.1 Riffle

The highest number of families was found at BUR 3 (19), with 33 genera and the least were collected from QBYN 1 with 15 families and 19 genera (Table 10). The taxonomic richness estimates represented a 60% decline in the number of families collected in autumn 2009 (37) and 73% decline in the number of genera collected (70). Downstream at QBYN 2, the number of taxa were more similar to the number collected in autumn 2009, with only a 25% decrease in the number of genera and a 6% decrease in the number families. Comparisons are not available for Burra Creek as it was dry during the autumn run in 2009.

The most notable feature of the riffle communities is the lack of EPT taxa across all of the sampling sites (APPENDIX F). EPT taxa were completely absent from BUR 1 (Table 10). The highest number of EPT taxa were collected at QBYN 2, with 5 families and 8 genera followed by QBYN 1 with 4 families and 6 genera and then BUR 3 with 4 families and 5 genera. The estimated relative abundance of EPT was very low across all sites ranging from 0.5% at BUR 1 to 13.3% at QBYN 2. The low estimated relative abundances reflect the very high abundances of Dipterans in the samples. Individual EPT numbers were similar between QBYN 1 and QBYN 2 but the lower estimated relative abundance at QBYN 1 is because that estimated total abundance of macroinvertebrates was approximately 3 times higher at this site, thereby down weighting the contribution of the EPT taxa present.

The most abundant EPT taxa were *Atalophlebia sp.* (Leptophlebiidae: SIGNAL =8) at QBYN 1 and *Tasmanocoenis sp.* (Caenidae: SIGNAL = 4) at QBYN 2.

Taxa discriminating between the various sites showed little variation between site pairs. For the most part, these taxa included the same taxa but with differences in their ranked importance between site pairs. This is because the same suite of dominant taxa occurred across most sites. Most pair-wise comparisons involving BUR 1 however, included EPT taxa owing to their complete absence at BUR 1. For example, *Hellyethira sp*. (Hydroptilidae: SIGNAL =4 was influential in separating BUR 1 and BUR 3; while increased abundances of both *Baetis sp.* (Baetidae: SIGNAL=5) and Tasmanocoenis (Caenidae: SIGNAL =4) separated BUR 1 with BUR 3 and QYBN 2. The five most influential taxa characterising each site, (which are also the most dominant) was determined through the SIMPER analysis from each site show that in most cases account from approximately 80% of the total abundance at each site (Figure 10). The results show that Simulids (SIGNAL=5), Chironomids and Oligochaetes are the key dominant taxa in the riffle samples – in most cases accounting for approximately 80% of the total abundance in each sample (Figure 10). The only exception to this was the inclusion of Tasmanocoenis *sp.* at QBYN 2, which accounted for approximately 6% of the total abundance (Figure 10).

3.5.1.2 Edges

The highest number of families in the edge samples was recorded at QBYN 1. QBYN 1 had a total of 32 families and 42 genera collected which represents a reduction of 15% and 30% respectively since autumn 2009. The three Burra Creek sites, downstream of Williamsdale bridge had similar taxa richness scores for both genus and family level (Table 10). These three sites are grouped together at 58% similarity in the NMDS plot (Figure 8). These three sites shared many of the same taxa. The main differences between them appear to be related to the abundances of the most dominant taxa (Figure 11) and higher EPT richness at BUR 3 (Table 10).

The edge samples had a higher diversity of EPT taxa than the riffle samples (Table 10); however the differences were only in the order of 1 or 2 families and 2 to 4 genera. Both of the Queanbeyan River sites and BUR 3 had the richest EPT fauna at the family and genus level, with 6 families being collected from, each site and 9 and 10 genera collected from QBYN2, BUR 3 and QBYN 1 respectively.

At the Cassidy Creek site in spring, none of the EPT fauna were collected. However, in this sampling run, the were 3 families and six genera collected – the most abundant of these were *Baetis sp.* Baetis sp. were also abundant at BUR 2a, BUR 3 and QBYN 1 (Figure 11). The general trend across all of the edge samples is the dominance of 1 or 2 taxa followed by smaller contributions of the remaining macroinvertebrates from the sample. Chironominae (SIGNAL = 3) is an example of this, where at BUR 1, BUR 2b & BUR 3 and QBYN 2, this taxa contributed between 35-57% of the total community abundance (Figure 11).

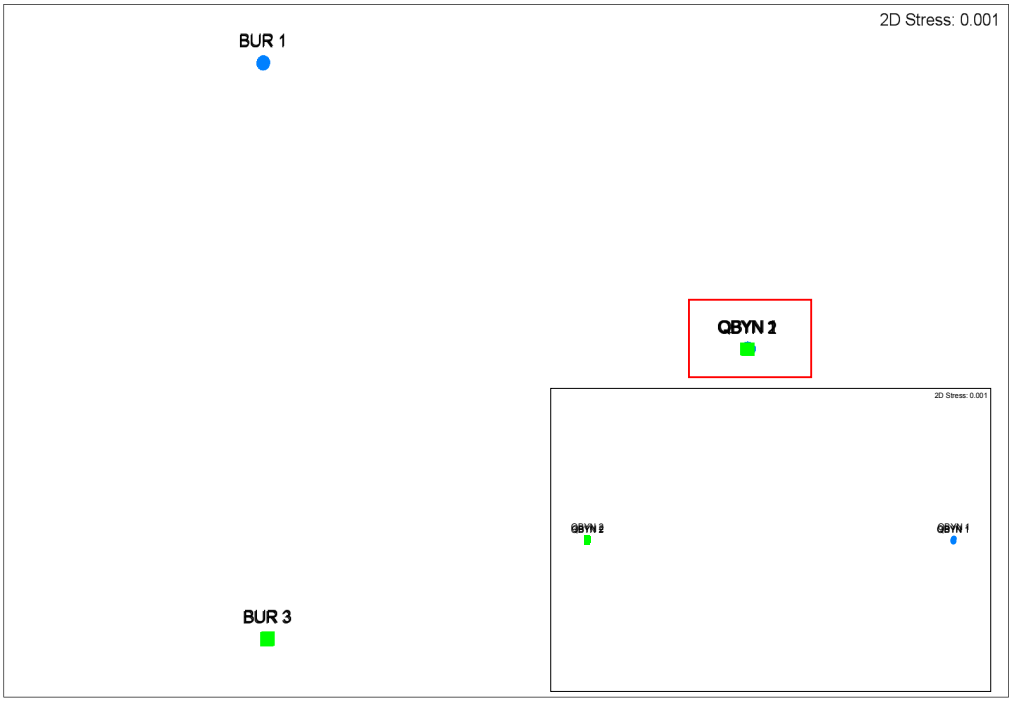

Figure 6. Non-metric multidimensional scaling (NMDS) of genus data from autumn riffle samples. Green squares are sites downstream of the proposed discharge point; blue circles are upstream (control) sites. The NMDS subset (sites the this was performed on are enclosed in the red box).. The subset also shows a degenerate solution.

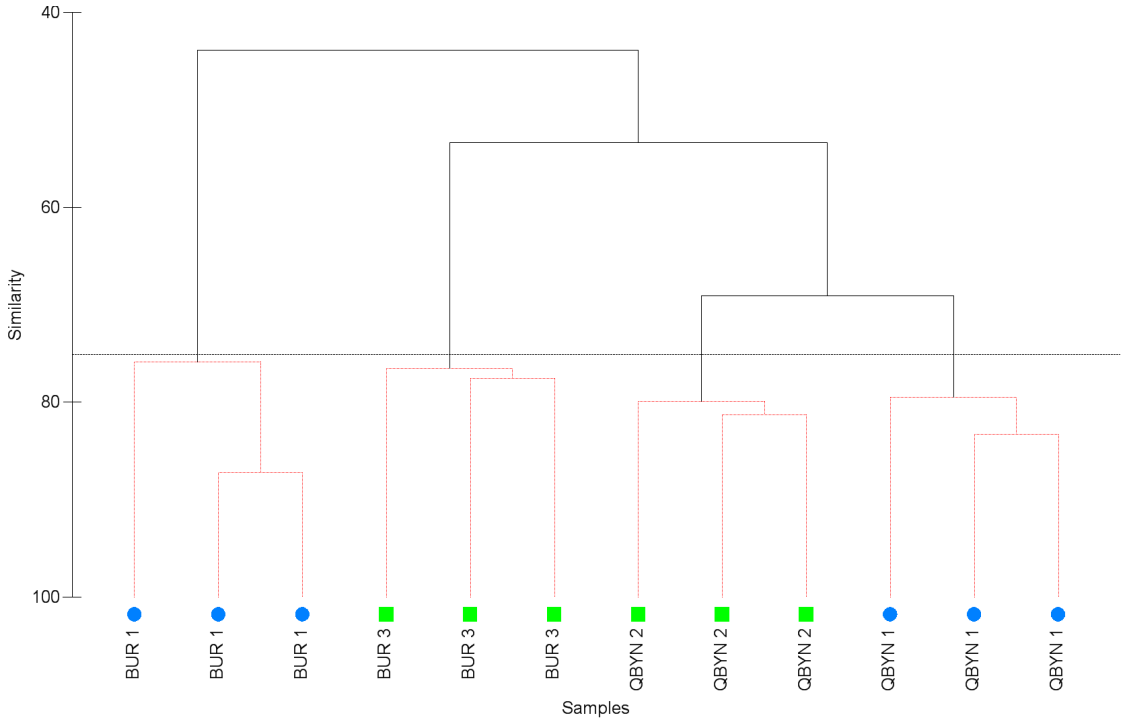

Figure 7. Cluster analysis based on genus level data for autumn riffle samples. Green squares are sites downstream of the proposed discharge point; blue circles are upstream (control) sites.

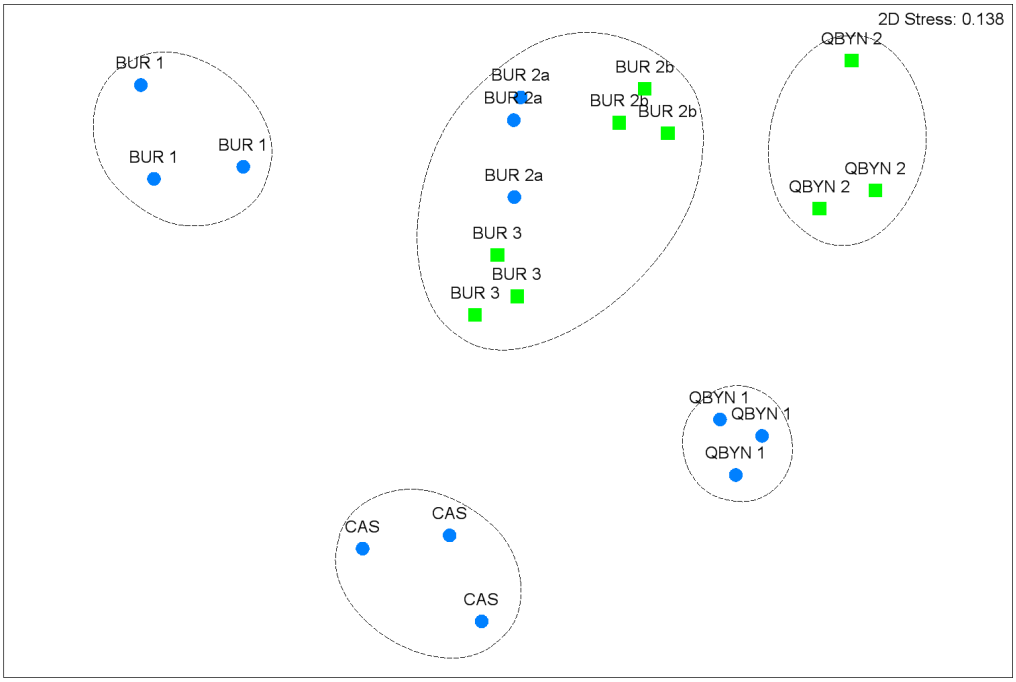

Figure 8. Non-metric multidimensional scaling (NMDS) of genus data from autumn edge samples. Green squares are sites downstream of the proposed discharge point; blue circles are upstream (control) sites. Ellipses represent 58% similarity cut-points.

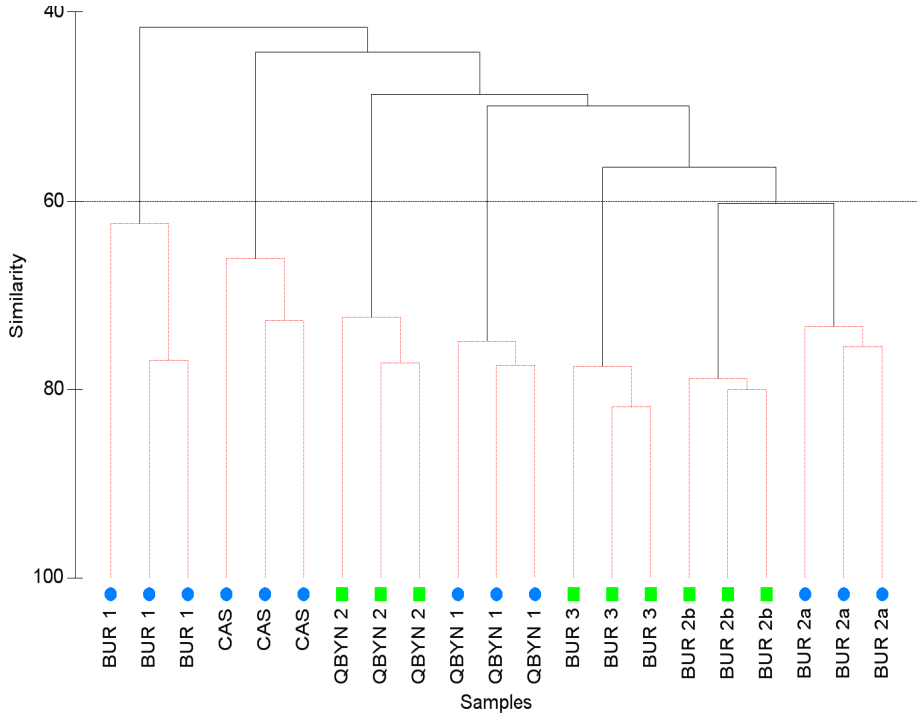

Figure 9. Cluster analysis based on genus level data for autumn edge samples. Green squares are sites downstream of the proposed discharge point; blue circles are upstream (control) sites

Table 10. Summary of biological metrics used for riffle and edge macroinvertebrate samples

Location	Site	Family richness		Genus richness		Relative abundance sensitive taxa (riffle)	Relative abundance tolerant taxa (riffle)	EPT richness: Family (genus)	
		riffle	edge	riffle	edge			riffle	edge
Control sites	Cas 1	/	28	/	36	/	/	/	3 (6)
	Bur 1	16	18	21	27	0.5 %	96 %	0 (0)	2 (3)
	Qbyn 1	15	32	19	42	3.5 %	95.5 %	4 (6)	6 (10)
Downstream sites	Bur 2a	/	26	/	32	/	/	/	2 (4)
	Bur 2b	/	25	/	34	/	/	/	5 (6)
	Bur 3	19	25	26	33	3 %	94.5%	4 (5)	6 (9)
	Qbyn 2	16	28	22	32	13.3 %	85 %	5 (8)	6 (9)

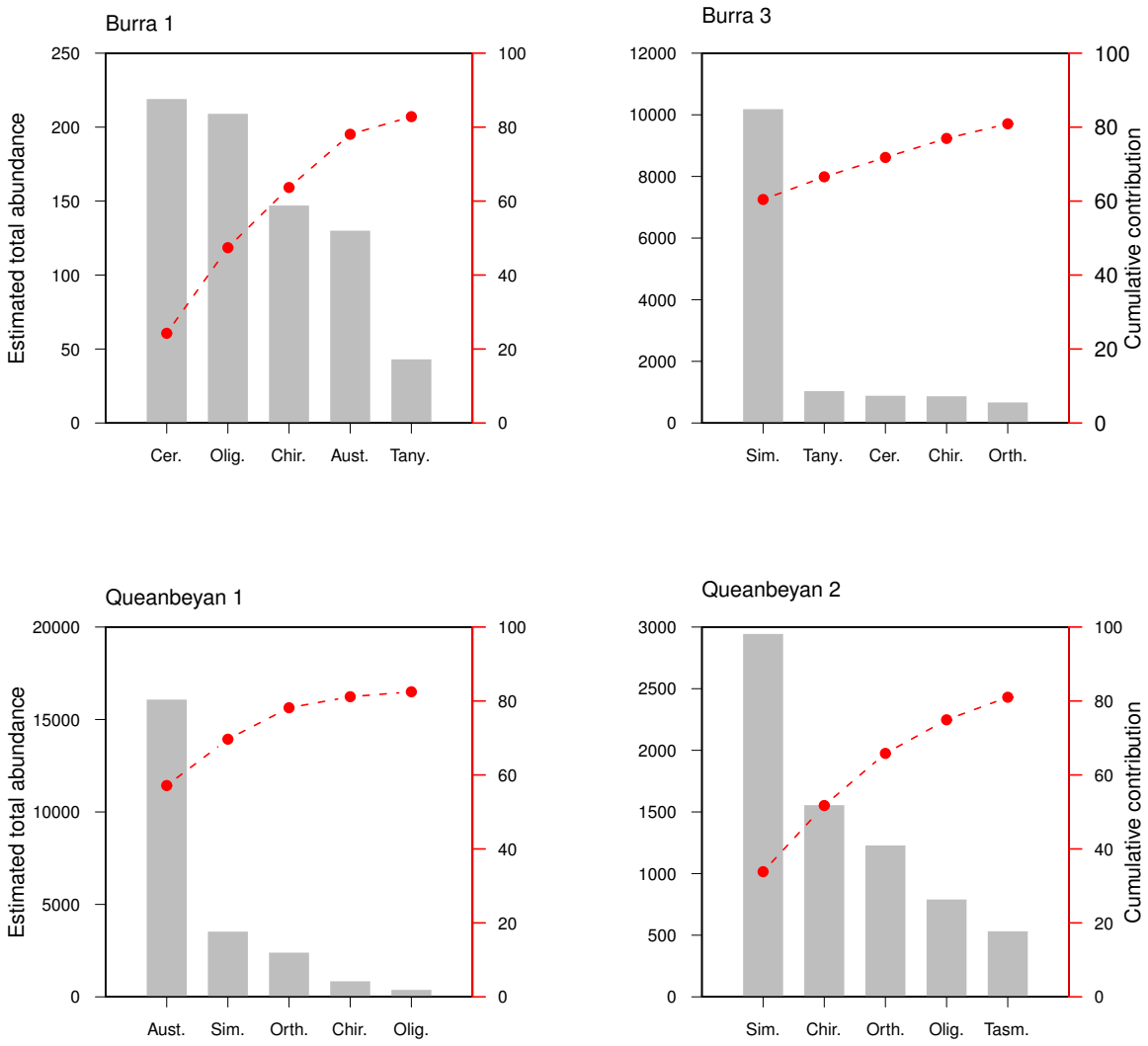

Figure 10. The average abundance of the five most abundant taxa from the rifle samples determined from the SIMPER analysis at each site with cumulative frequency curves overlaid.

The key table below indicates taxa names corresponding to abbreviations, their higher level taxonomy and their SIGNAL scores.

Abbreviation	Order [CLASS]	Family (*sub-family*)	Genus	SIGNAL - 2
Cer.	Diptera	*Ceratopogonidae*	-	4
Chir.	Diptera	*Chironominae*	-	3
Olig.	OLIGOCHAETA	-	-	2
Orth.	Diptera	*Orthocladiinae*		4
Tany.	Diptera	*Tanypodinae*		4
Sim.	Diptera	Simuliidae	*Simulium*	5
Aust.	Diptera	Simuliidae	*Austrosimulium*	5
Tas.	Ephemeroptera	Caenis	*Tasmanocoenis*	4

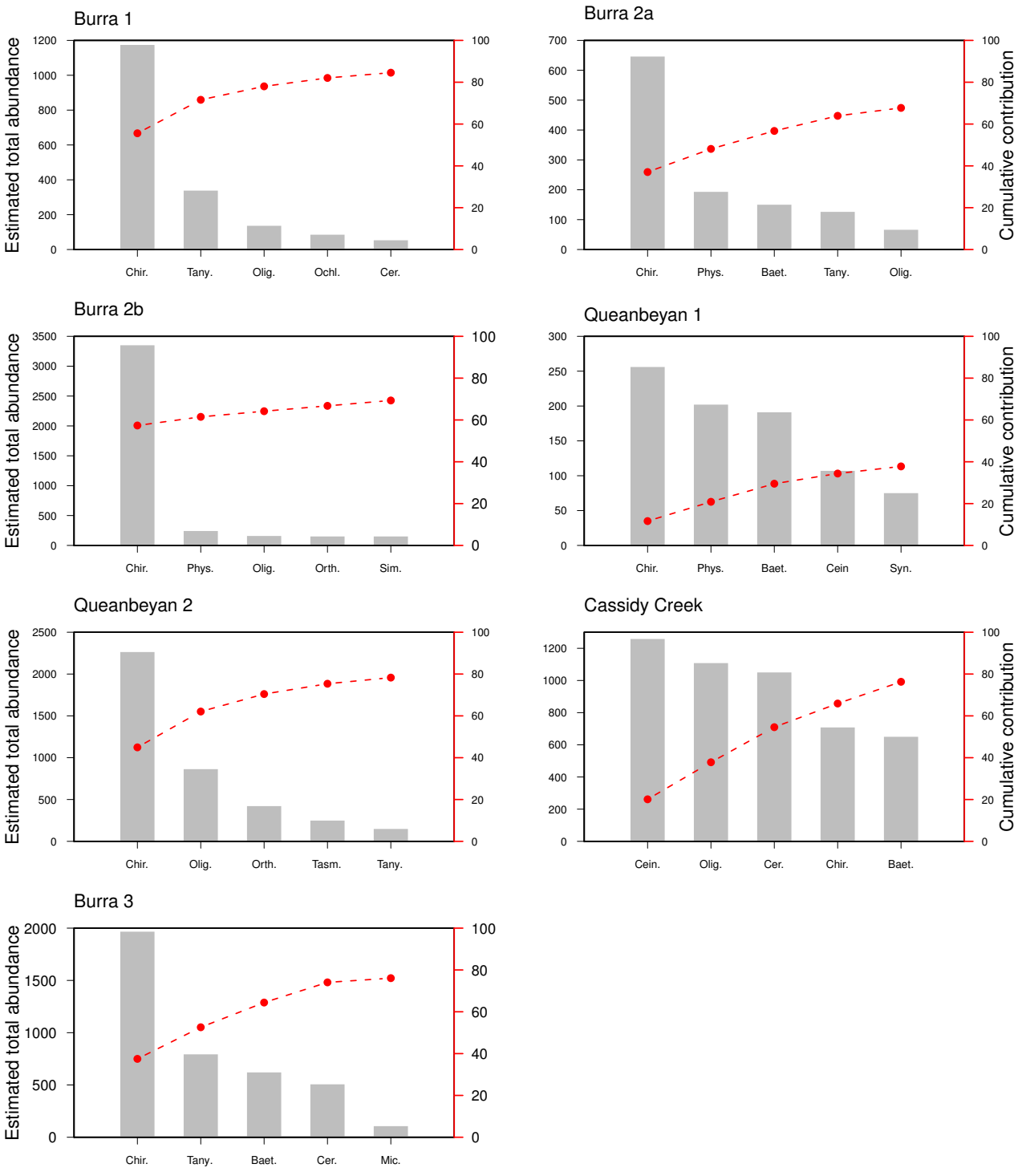

Figure 11. The average abundance of the five most abundant taxa from the edge samples determined from the SIMPER analysis at each site with cumulative frequency curves overlaid.

The key table over (←) indicates taxa names corresponding to abbreviations, their higher level taxonomy and their SIGNAL scores.

Abbreviation	Order [CLASS]	Family (*sub-family*)	Genus	SIGNAL – 2 (Family)
Baet.	Ephemeroptera	Baetidae	Baetis	5
Cer.	Diptera	*Ceratopogonidae*	-	4
Chir.	Diptera	*Chironominae*	-	3
Olig.	OLIGOCHAETA	-	-	2
Orth.	Diptera	*Orthocladiinae*	-	4
Tany.	Diptera	*Tanypodinae*	-	4
Ochl.	Diptera	Culicidae	*Ochlerotatus*	1
Cein.	Amphipoda	Ceinidae	-	2
Mic.	Hemiptera	Corixidae	*Micronecta*	2
Sim.	Diptera	Simuliidae	*Simulium*	5
Phys.	Gastropoda	Physidae	*Physa*	1
Tasm.	Trichoptera	Caenidae	*Tasmanocoenis*	4
Syn.	Zygoptera	Synlestidae	-	7

3.5.2 AUSRIVAS assessment

The AUSRIVAS results show that most of the sites assessed in autumn 2010 were assigned BAND-B (Table 11). The only site to deviate from this was BUR 1 which, because of the absence of EPT taxa was assigned to a BAND –C assessment. Comparisons to previous seasons suggest that these results show an improvement at QBYN 2 in the riffle habitat, moving from a BAND –C to BAND-B since autumn 2009 and a decline in the edge habitat at QBYN 1 shifting from a BAND-A to BAND – B since autumn 2009. There was no assessment given to any of the Burra Creek sites in autumn 2009, so between-year comparisons cannot be made for between Burra Creek sites.

3.5.2.3 Riffles

Since spring, there has been no change in assessment between QBYN 1, QBYN 2 and BUR 3, with all of these sites previously being assessed as BAND-B. There was a high degree of consistency in the sub-samples from all of the sites in terms of the taxa predicted but missing and abundances (APPENDIX G).

BUR 1 was assessed as BAND-C, showing strong departures from the reference condition. There were 9 missing taxa from this site, all either having high SIGNAL scores or belonging to the EPT suite of taxa. Of these predicted taxa, 67% were EPT taxa and the remaining three were: Gomphidae (SIGNAL=5); Elmidae (SIGNAL =7) and Podonominae (SIGNAL=6). The taxa that were present, were generally species that are considered to be tolerant to poor or lowered water quality, or be early colonizers following disturbance. This is shown also by the low average SIGNAL scores for this site (Table 11).

The remaining sites were assessed as BAND –B . QBYN 1 had the most missing taxa (10), but also because of its location in the catchment, also had a higher number predicted than the other sites. Of the missing taxa at QBYN 1, 90% were also listed as missing in the autumn 2009 sampling run. Similarly, QBYN 2 had 70% of the taxa that were missing in autumn 2009. Leptophlebiidae (SIGNAL =8) and Caenidae (SIGNAL =4) were collected in this sampling run from QBYN 2, which were both previously absent. SIGNAL -2 scores at both Queanbeyan River sites, while still rather low, were higher on average than both Burra Creek sites.

3.5.2.4 Edges

The average O/E family scores from the AUSRIVAS output indicate that the condition in the edge samples, as has been the case in both previous sampling runs, is in better condition than the riffle samples. At 4 of the 7 sites in this sampling run, at least one subsample was assessed as BAND –A (Table 11). However, the standard procedure is to take the lowest reading (furthest from reference condition BANAD-A) in these circumstances (Barmuta *et al.*, 2003) and as such, all of the edge sites are assessed as BAND-B.

The number of missing taxa ranged from 2 at QBYN 2 to 8 at BUR 2a. The majority of the missing taxa had high SIGNAL scores. For example, Elmidae: SIGNAL=7 and Leptophlebiidae: SIGNAL =8), but also included some moderately tolerant mayflies, such as Caenidae (SIGNAL =4) and Caddisflies such as Ecnomidae (SIGNAL=4). These results are also reflected in the low average SIGNAL scores (Table 11). Taxa, with tolerances to low water quality, (dissolved oxygen in particular) were common across all samples. For example, Oligochaeta (SIGNAL=2); Dytiscidae (SIGNAL=2), while *Physa sp.* (SIGNAL =2) and other Gastropods also featured at all sites.

Table 11. AUSRIVAS and SIGNAL-2 scores for autumn 2010

SITE	Rep.	SIGNAL-2		AUSRIVAS O/E score		AUSRIVAS Band		Overall habitat assessment		Overall site assessment
		Riffle	*Edge*	*Riffle*	*Edge*	*Riffle*	*Edge*	*Riffle*	*Edge*	
CAS	1	*na*	*3.75*	*na*	*0.78*	*na*	**B**			
CAS	2	*na*	*4*	*na*	*0.78*	*na*	**B**	***na***	**B**	**B**
CAS	3	*na*	*3.43*	*na*	*0.45*	*na*	**C**			
BUR 1	1	*4*	*3.33*	*0.59*	*0.59*	**C**	**B**			
BUR 1	2	*4*	*3.14*	*0.69*	*0.69*	**C**	**B**	**C**	**B**	**C**
BUR 1	3	*4*	*3.14*	*0.69*	*0.69*	**C**	**B**			
BUR 2a	1	*na*	*3.11*	*na*	*0.73*	*na*	**B**			
BUR 2a	2	*na*	*3.11*	*na*	*0.73*	*na*	**B**	***na***	**B**	**B**
BUR 2a	3	*na*	*3.25*	*na*	*0.65*	*na*	**B**			
BUR 2b	1	*na*	*3.78*	*na*	*0.82*	*na*	**A**			
BUR 2b	2	*na*	*3.56*	*na*	*0.82*	*na*	**A**	***na***	**B**	**B**
BUR 2b	3	*na*	*4*	*na*	*0.64*	*na*	**B**			
BUR 3	1	*4.2*	*3.56*	*0.74*	*0.82*	**B**	**A**			
BUR 3	2	*4.4*	*3.56*	*0.74*	*0.82*	**B**	**A**	**B**	**B**	**B**
BUR 3	3	*4.3*	*3.11*	*0.74*	*0.80*	**B**	**B**			
QBYN 1	1	*4.8*	*3.82*	*0.64*	*0.85*	**B**	**A**			
QBYN 1	2	*4.8*	*4*	*0.64*	*0.78*	**B**	**B**	**B**	**B**	**B**
QBYN 1	3	*4.8*	*3.8*	*0.64*	*0.78*	**B**	**B**			
QBYN 2	1	*4.58*	*3.67*	*0.83*	*0.77*	**B**	**B**			
QBYN 2	2	*4.58*	*3.88*	*0.83*	*0.68*	**B**	**B**	**B**	**B**	**B**
QBYN 2	3	*4.58*	*3.85*	*0.83*	*1.11*	**B**	**A**			

4 Discussion

4.1 Water quality and periphyton

Water samples were collected approximately one week after a rainfall event that caused a peak flow of over 200 ML/d in Burra Creek and >300 ML/d in the Queanbeyan River (Figure 2). Sampling occurred on the falling limb of the hydrograph in the Queanbeyan River when flows were 50 ML/d. The event was missed in Burra Creek, although there was still surface water flowing at approximately 0.2ML/d. The nutrient levels were higher than samples that have previously been collected during prolonged dry periods at base flow levels, suggesting surface runoff from surrounding farm land as the primary source.

One of the chief concerns regarding nutrient enrichment in the Burra Creek system is the response to these increases by filamentous green algae and cyanobacteria (blue-green algae) whose growth rates are determined partly by the level of nutrients in the water. Proliferations can cause problems to water storages, alter water quality in lentic and lotic systems, lower the aesthetic value, cause operational difficulties (i.e. clogging intake valves) (Biggs and Kilroy, 2000) and have been linked to reducing the number and abundance of sensitive macroinvertebrate taxa (Suren and Jowett, 2006).

Although nutrients are often limiting to algal growth (Biggs, 1989; Bowes *et al.*, 2007), the concentrations of chlorophyll-a pigment and AFDM have been found to be unrelated, or show very weak correlations to the nutrient concentrations found in this program to date. There are several explanations for this. First, the sampling frequency is likely to be insufficient to detect such trends, as over the period of six months, other environmental factors are likely to be influential to the growth rates and standing stock and separating these factors from the observed periphyton. Further, as described in Ecowise (2009a), because periphyton is the cumulative effect of preceding water quality conditions, if there is a relationship between the two factors, the sampling water quality only at the time of biological sampling is unlikely to pick up these relationships.

Analyses of AFDM and chlorophyll-a found no differences between locations (Figures 4 & 5; Table 8). However, there were elevated concentrations of chlorophyll- a in the Burra control site (BUR 1). These concentrations were highly correlated to the increased shading in the reach (Table 8), which might indicate that the source of chlorophyll-a is allochthonous (i.e. from riparian leaf litter) rather than from algal material. This is further supported by the low correlation between AFDM and chlorophyll-a, a high correlation would indicate that the pigment is algal derived. The differences in shading are most apparent when considering the site photographs in APPNEDIX A. Identifying the source of chlorophyll-a will help understand the dynamics of the ecosystem in Burra Creek and provide a context for evaluating future periphyton results.

While there is evidence here of slight nutrient enrichment in the Burra Creek system, elevated concentrations usually follow wet periods, and are thus most likely due to surface runoff from the surrounding landscape - which include farm land and sealed roads – rather than background levels in the system. In fact, during base flow however, our records to date indicate that the nutrient levels are below ANZECC and ARMCANZ (2000) guidelines and as such have probably had a negligible effect on the periphyton community. The upshot of this is that under ‘normal’ conditions in Burra Creek, it is unlikely that that algal proliferations would occur because, nutrient supply and shading at some sites are likely to limit algal growth. The other consideration is that these base flow periods are short lived and desiccation is likely to impact the standing crop before populations respond to increased nutrients. The response of periphyton to ‘run of river’ releases may differ from this, however, because Murrumbidgee River water may have a different nutrient status and because surface flows in Burra creek are likely to extend for longer periods. In addition, more consistent flows over the periphyton matrix may promote nutrient uptake.

Outside of the elevated nutrient concentrations, the water quality parameters show no long-term deviation from normal temporal trends apparent in this program or indeed the long term records. Dissolved oxygen levels are quite low in the pools which would account for the high iron and manganese concentrations (APPENDIX D); and EC values have shown rapid decreases with increased surface flow. However, since these water quality changes are short - term responses to natural changes in the system they are unlikely to be the factor determining the current AUSRIVAS river health assessments, given that localised adaptations to this type of variation are expected (Boulton and Lake, 1992).

4.2 River health and patterns in macroinvertebrate communities

The autumn results show that all sites were in poorer condition than reference (Table 4). BUR 1, the upstream control site on Burra Creek, was assessed as being in the poorest ecological condition, with a BAND–C assessment. The remaining sites all had overall site assessments of BAND–B. Downstream of the Burra Road bridge at BUR 2b, all of the Burra Creek sites had at least one subsample with a BAND-A assessment. All sites had several taxa missing from the prediction of the AUSRIVAS model (APPENDIX G).

The majority of taxa missing from the riffle samples were from the EPT suite of macroinvertebrates and other sensitive taxa (APPENDIX G), such as Elmidae (SIGNAL =7) and Psephenidae (SIGNAL= 6). While in previous seasons we have found similar AUSRIVAS assessments to the assessments in this study, the results presented here had a particularly high number of sensitive taxa absent from the riffle samples, and to a lesser degree in the edge samples, which is further highlighted by the low average SIGNAL -2 scores at each site and habitat (Table 4). The macroinvertebrate communities were dominated by three main taxonomic groups – Chironomids, Oligochaetes and Simulids (Figure 10 & 11) – making up to 80% of the total abundance at all but one of the sites sampled. All of these groups have moderate to low signal scores and are regarded to be tolerant to poor water quality and resistant to, or rapid colonisers of, high flow events (Radar *et al.*, 2008).

The macroinvertebrate community at BUR 1 was in the poorest condition in this study. BUR 1 had an overall site assessment of BAND-C despite the BAND – B assessment given to the edge habitat (Table 10). There were 9 taxa missing from the riffle habitat; 78% of these were from the EPT suit of taxa and 88% had SIGNAL scores of ≥ 5 (APPENDIX G). The macroinvertebrate community from the riffle samples at BUR 1 was dominated by Chironomids, Oligochaetes and Simulids (Figure 10). Taxa richness and abundance was low and EPT taxa were completely absent (Table 10). These findings are consistent with Stubbington *et al.* (2009) who found very low richness and abundances of macroinvertebrate taxa (mainly Chironomids and Oligochaetes) 5 days after flow reactivation in the upper reaches of an intermittent stream of a similar order to Burra Creek. Different degrees of flow permanence were argued to be the major driver of the high abundances and richness in communities downstream (i.e. with higher flow permanence). Similarly in this study, BUR 3, downstream of BUR 1 had macroinvertebrate abundances in several orders of magnitude higher than found at BUR1, richness was higher as was the number of EPT taxa (Table 9). During previous site visits, BUR 3 has been flowing on 70% of occasions, whereas during this sampling program, this was only the second time BUR 1 has contained surface flow in the riffle habitat.

Up until the autumn sampling run, surface flow at BUR 3 had been maintained since the February event meaning a period of sustained, but diminishing flow over the 4 week period leading up to the autumn sampling run. In contrast, BUR 1 had dried within two days of the February event (*P.Taylor - Pers. obs*) suggesting that this site is subject to flashy episodes of unsustained flow following rainfall events. Due to the nature of this site, it is not surprising therefore that the majority of taxa collected were opportunist in nature. The re-colonisation of these sites is also likely to be determined by the life-history strategies employed individual taxa during periods of drought. Stubbington *et al.* (2009) found that core samples of the sediment at the intermittent sites contained very high abundances of

macroinvertebrates and high diversity, indicating that the hyporhiec zone is probably and important refuge for prolonged dry periods at intermittent sites for certain macroinvertebrate taxa.

If the hyporhiec zone at the Burra Creek sites provide refuge during dry periods, the absence of sensitive taxa at BUR 1 could be due to delays in hatching times (Hynes, 1970a) or the observed communities are a consequence of the samples being taken very early on (7 days) after rewetting; indicating that later stage successional species have not yet had the opportunity to re-establish. Flow permanence could explain why several EPT taxa were found downstream at BUR 3. The four week period since re-wetting would have provided enough time for the establishment of a greater diversity of taxa at this site (e.g. Suren and Jowett, 2006). This however, does not explain why many of the sensitive taxa previously found at this site were missing.

One explanation is that, prior to the March event (Figure 1) the four week period of surface flow at BUR 3 allowed recolonisation stages to proceed to a point where many of the sensitive taxa were present in the community. The high flow event came through on March 7th and through the combined effects of bed load movement and high shear stress, much of the community was dislodged. This scenario has been found elsewhere (e.g. Hynes, 1970a; Miller and Gollady, 1996; Suren and Jowett, 2006). However, without pre-high flow event data these explanations cannot be confirmed.

Increasing temperatures with streambed drying could also account for the absent of sensitive taxa and specifically for the complete absence of Plecopterans in this study given their preference for cool fast flowing water (Gooderham and Tsyrlin, 2005). High water temperatures were indicated as a reason for the absence of highly sensitive taxa from the spring 2009 samples (Ecowise, 2009b). Although water pollution is known to have similar impacts on sensitive taxa as high flow events by reducing abundances and richness (Griffith *et al.*, 2005), the indication from the water quality parameters in this study are not suggestive of water quality related impacts (albeit that macroinvertebrate communities reflect a cumulative response to water quality, whereas correlations tested in this study were between macroinvertebrate and water quality results collected at the same time) (Table 7; Figure 3). Furthermore, although in much reduced abundances, some highly water-quality sensitive taxa were collected from the Quenbeyan River sites such as: Leptophlebiidae (SIGNAL =8); and Elmidae (SIGNAL =7); suggesting effects other than poor water quality were responsible for the patterns found in this study.

In the edge samples, there were slight increases in the abundance of Leptophlebiidae (SIGNAL =8), which might suggest that the edges are functioning as a refuge during high flow events and during receding flows in Burra Creek. These highly sensitive mayflies have previously been founding high numbers in both Burra Creek and the Queanbeyan River. In this study the were only found in the riffle samples taken from QBYN 1, but were present in the edge samples at QBYN 1, QBYN 2, and BUR 3. Boulton (1989) found that pools can act as refuges over summer in an intermittent stream so it is equally as feasible that they utilise this habitat during periods of high flows. Other taxa utilising this habitat as a refuge are not obvious at this stage.

The decline in richness, abundance and sensitive taxa at the Queanbeyan River sites warrants a separate explanation despite the similar community assemblage patterns to Burra Creek (Figures 10 & 11). The results from the Queanbeyan River in this study suggest that the two events preceding sampling in February and March (Figure 2; APPENDIX B) had a compounding impact on the macroinvertebrate samples collected in the Queanbeyan River. The event in February peaked at over 2000 ML/d with an ARI of 3.5 years. This was the largest event in the Queanbeyan River since 2007. A similar size event in the Murrumbidgee River in spring was thought to be responsible for declines of up to 30% of family richness and up 5-fold decreases of macroinvertebrate abundance (Ecowise, 2009b), which correspond to the declines seen in this study since the last sampling run.

Recovery rates post-high flow events vary considerably (Hynes, 1970a; Niemi *et al.*, 1990; Miller and Gollady, 1996; Collier and Quinn, 2003; Fritz and Dodds, 2004) and depend on various factors including the time since the last event, the magnitude of the event and recolonisation rates. While there would have been some recovery at these sites – as 4 weeks had passed since the February event - the second event, albeit of a much lower magnitude, could have disrupted this process by removing colonising sensitive taxa.

Seasonal differences in taxonomic composition, through differences in life histories, changes in water quality parameters and flow regimes are all likely to influence the community composition. However, taking seasonality into account, the results from this study still indicate high flow responses as the key factor. If seasonal variation played a role in the sharp declines in sensitive taxa and overall abundances, then the results from this study should be comparable to the samples collected in autumn 2009. Despite only having two sites for comparison (QBYN 1 and QBYN 2) there was a 60% decrease in family richness at QBYN 1 suggesting that the decline in taxa is not directly related to seasonal variation, but other factors such as the impacts of high flow events are also likely to explain these patterns.

5 Conclusion

The current assessment indicates a that the majority of sites are considered to be in a poorer condition to the reference condition (BAND –B). The upstream control site had an overall site assessment of BAND –C, reflecting the complete absence of sensitive EPT taxa in the riffle habitat. The BAND –B assessment at the remaining sites reflects the absence of several tolerant and sensitive taxa in each sample. Some caution needs to be placed on these bandings based on the fact that the AUSRIVAS model does not take into account the permanency of flow conditions and sites in the Burra Creek catchment are subject to intermittent flows.

The assessments given to the Burra Creek sites in this study are suggestive of responses to high flows in the lower sections of the river. Upstream of Williamsdale bridge, the macroinvertebrate community resembles those described by other authors where flow permanence is often the limiting factor to successful colonization following prolonged dry periods and subsequent re-wetting. The similar community assemblages (in terms of the dominant taxa) in the Quenbeyan River to the Burra Creek communities reflect communities impacted by high flow events. A small one year ARI event occurred a week before autumn sampling. However, it was probably the initial impact of the 3.5 year ARI event in February and the drying phase that followed this which had the largest impact on the results.

Responses to various flow events and periods of drought are evident from the data collected to date. However, the main limitation to this work is the inability to draw firm conclusions from the current sampling regime. The ability to understand the seasonal dynamics and responses to flow regimes will require a more intensive sampling program outside of the prescribed autumn / spring sampling under the current AUSRIVAS protocols.

6 Recommendations

A condition stated in the Burra Creek monitoring proposal (section 1) is that the program is to agree to an adaptive management approach; so that the methodology, site selection and analyses are periodically reviewed so that the objectives of the program are being met to ACTEW Corporation's requirements. The results from this study suggest that there are similar knowledge gaps that were outlined in the spring 2009 study (Ecowise, 2009b). Based on this, the same suite of recommendations are put forward here, which are as follows:

1) If compliance monitoring is to take place following the collection of baseline data, it recommended that current trigger levels be revised for Burra Creek. Ground water fed creeks such as Burra Creek have naturally elevated levels of salts and lower turbidity because the water is filtered through porous limestone. Both these parameters are often outside the bounds of the current guidelines, which would give the impression of guideline breeches when the values are likely to be within the natural boundaries of the system. Procedures for determining local water quality objectives are outlined in the ANZECC and ARMCANZ (2000) guidelines.

2) The importance of the hyporhiec zone (HZ) as a refuge for over-summering taxa, and during periods of drought is highlighted by several authors (Hynes, 1970b; Williams and Hynes, 1977; Boulton, 1989) and its importance within the Burra Creek system is poorly understood. The proposed M2G transfer has the potential to change the substratum, surface water quality and potentially the groundwater quality within the system which could in turn impact upon the hyporhiec fauna. We recommend collecting baseline survey data of hyporheic community at each site. This information will allow ACTEW to make informed decisions regarding this component of the ecosystem, but would mean an expansion to the scope of the project to include such sampling.

Adding the HZ to the existing program as a third habitat (i.e. riffle, pool/edge, and hyporhiec zone) would also mean that even in periods when there is no surface flow, there would be the opportunity to collect representative data from a given site. This would require a period of intensive sampling in the early stages to develop a comprehensive baseline of existing taxa (Hancock, *Pers. Comm.*). One advantage of this approach, however, is that Ecowise has already collected samples from the hyporheic zone in Burra Creek as part of an ActewAGL funded R &D program to investigate the suitability of hyporheic communities for indicating the ecological health of ephemeral streams; so the potential for these protocols to be explored could be done so with minimal additional cost.

3) Baseline data are now available for Burra Creek. Although this information will provide seasonal assessments on a site-specific basis, it lacks the ability to make inferences relating to the dynamics of the macroinvertebrate communities in Burra Creek, especially in relation to:

- Seasonal patterns in community turnover (outside of the standard autumn/spring AUISRIVAS sampling);
- Responses to various flow regimes, including large spates and increasing number of flow days since re-wetting (this would involve pre-event and event based sampling in refugial pools on top of any additional sampling that may or may not be deemed necessary)

A comprehensive understanding of this system in relation to changing flow would involve a more intensive sampling regime, but would provide ACTEW with a more detailed assessment which would fill a large knowledge gap existing in this system at present.

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APPENDIX A – SITE PHOTOGRAPHS

BURRA 1

Looking upstream into the Tinderry nature reserve

Looking downstream towards Cassidy creek confluence

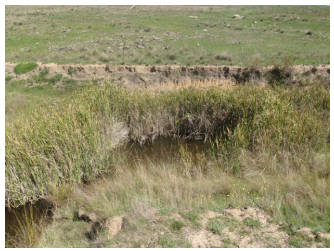
Riffle habitat; approximately 500m upstream of Cassidy Creek confluence

Looking downstream

Limited edge habitat

Riparian cover, approximately 200m upstream of the confluence

Cassidy Creek



Isolated pool, inundated with *Typha sp.*

A view looking south west from the confluence bridge

Looking upstream from the bridge highlighting the extent of the channel inundation

Burra 2a

Looking downstream from the Williamsdale Road bridge

Sampling a pool/edge just downstream of the bridge

BURRA 2b

Looking downstream from the Burra Road bridge

Downstream of Burra Road Bridge

Typha sp. on the true right bank

Myriophyllum spp.

General habitat looking north (D/S) from the Burr Road Bridge

Flow over bedrock. 800m downstream of the Burra Road bridge

BURRA 3

Main channel, looking upstream towards London Bridge

Substrate at BURRA 3

Looking downstream towards drawdown crossing

Drawdown crossing

Queanbeyan 1

Looking upstream from Flynn's Crossing

Riffle habitat

Queanbeyan 2

General habitat looking upstream towards the Burra Creek confluence (yellow arrow)

Looking downstream

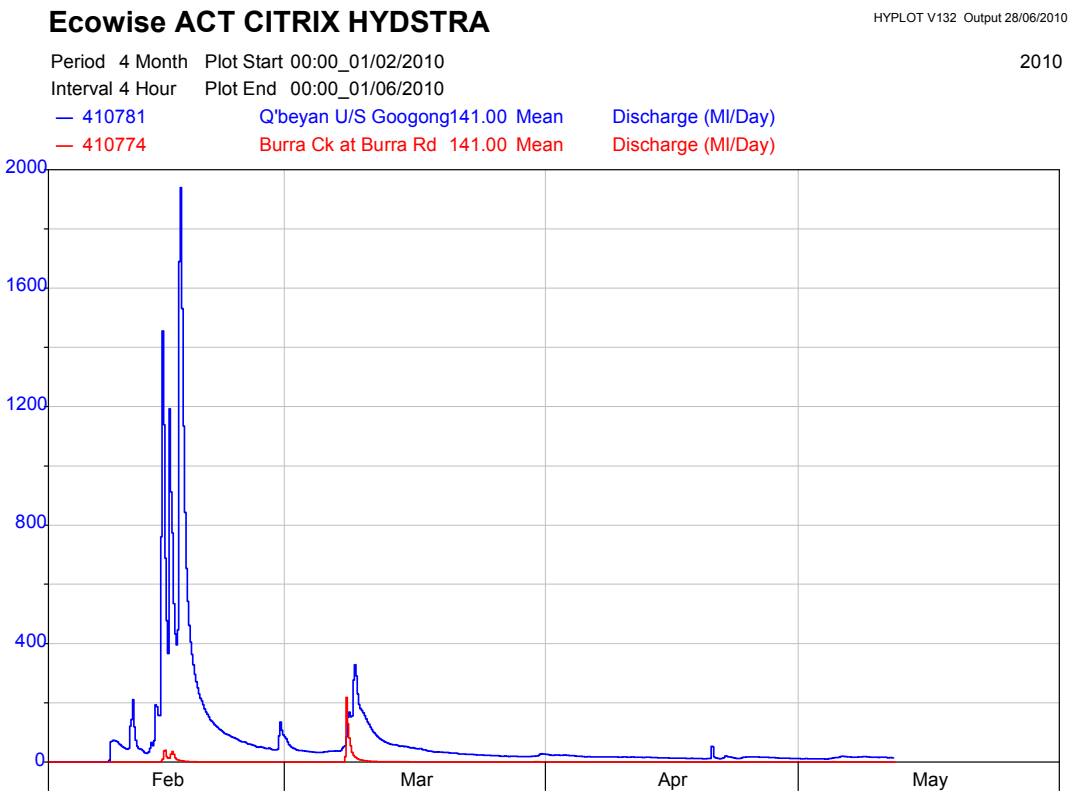
Looking towards the true left bank

Sampling periphyton

Just downstream of the Burra Confluence (arrow) looking upstream to the Queanbeyan River

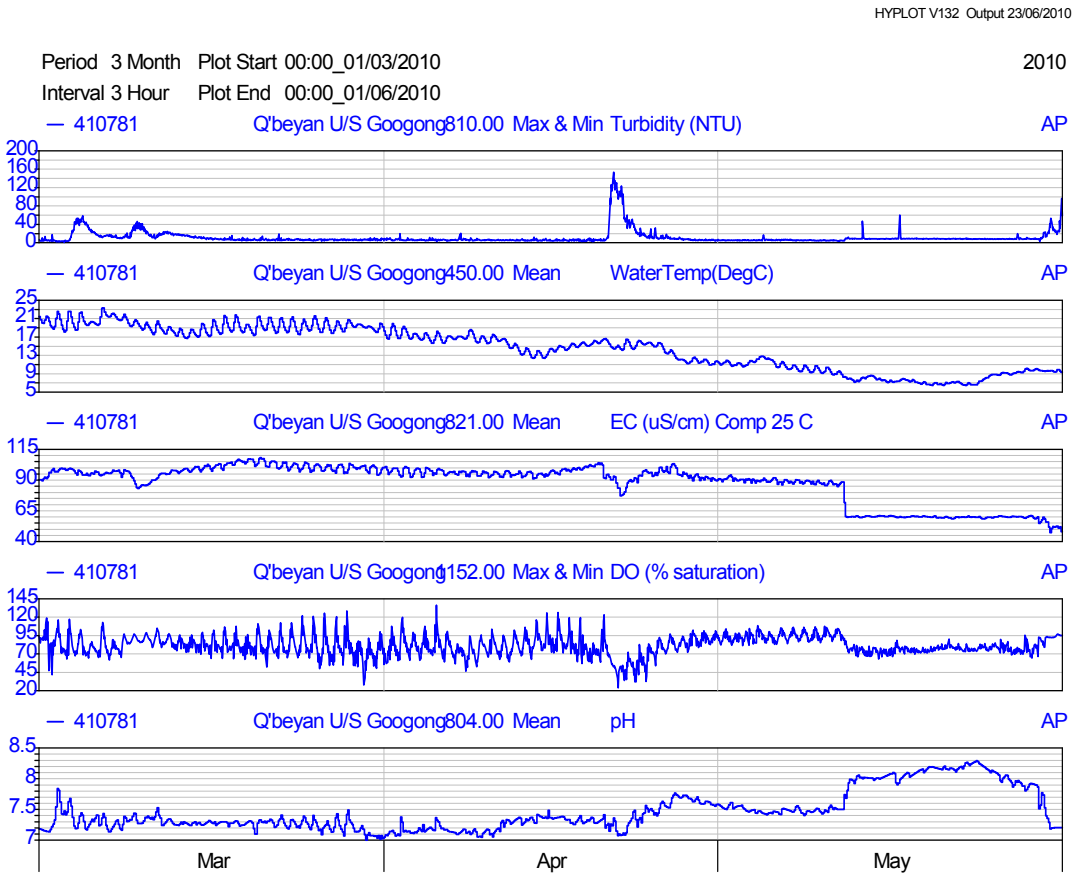
APPENDIX B – HYDROGRAPH OF BURRA CREEK AND QUEANBEYAN RIVER STATIONS

APPENDIX B. Hydrograph of Burra Creek (410774) and the Queanbeyan River (410781) stations for the period February 2010- May 2010.



APPENDIX C – CONTINUOUS WATER QUALITY RECORDS FROM 410781 (U/S GOOGONG RESERVOIR) FOR AUTUMN 2010

APPENDIX C. Continuous water quality records from 410781 (u/s Googong reservoir) for autumn 2010.



APPENDIX D – LABORATORY WATER QUALITY RESULTS AUTUMN 2010

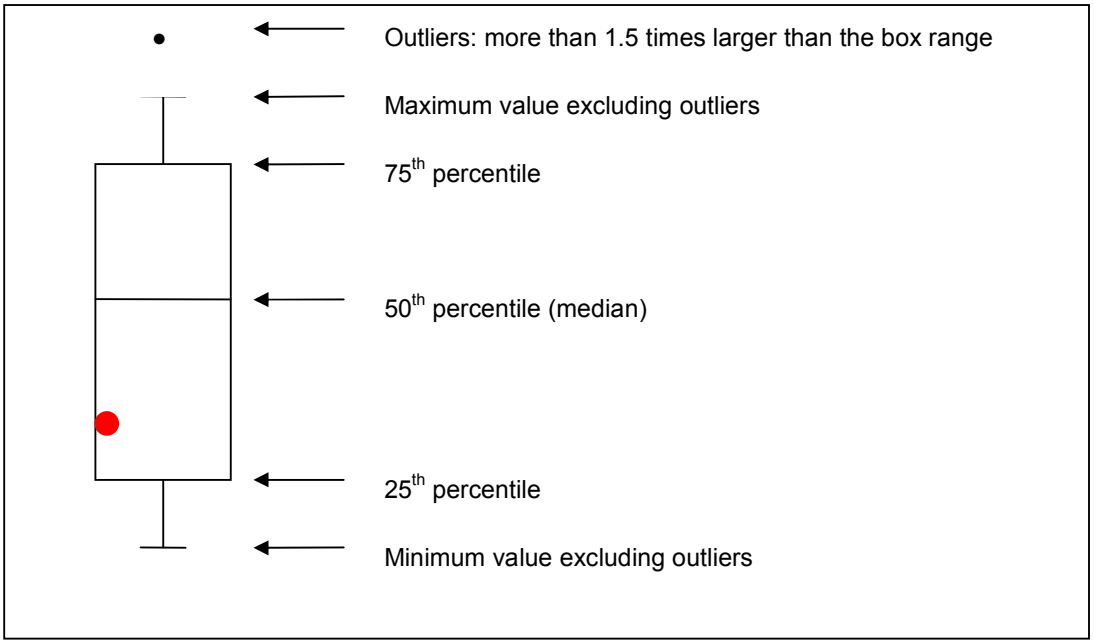
APPENDIX D. Laboratory water quality results 2010.

SITE			QBYN 1	QBYN 2	BURRA 3	CAS - 1	BURRA 2a	BURRA 2b	BURRA 1
TEST	ANALYTE	UNIT							
Alkal.(CaCO3)	Bicarb	mg/L	38.8	40.9	151	168	125	139	28.8
	Carb	mg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	Hydrox	mg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	Total	mg/L	39	41	151	168	125	139	29
Ammonia (asN)	Ammonia	mg/L N	0.08	0.08	0.04	0.04	0.05	0.03	0.03
Anions Screen	Bromide	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	Chloride	mg/L	5	6	15	23	24	20	8
	Fluoride	mg/L	<0.10	0.11	0.25	0.32	0.27	0.39	<0.10
	Nitrate	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
	Nitrite	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Phosphate	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	Sulphate	mg/L	2	3	16	3	12	11	9
Conductivity	SpC	uS/cm	94	100	360	380	340	350	110
Diss. Calcium	Diss_Ca	mg/L	6.4	7.4	36	34	24	26	2.4
Diss. Magnesium	Diss_Mg	mg/L	3.6	3.8	12	12	12	13	5.9
Diss. Potassium	Diss_K	mg/L	2.4	2.6	1.7	1.4	1.6	1.8	0.8
Diss. Sodium	Diss_Na	mg/L	5.5	5.4	18	20	22	21	7.2
DOC (as NPOC)	DOC	mg/L	11	11	9	7	11	12	17
Nitrate (asN)	Nitrate	mg/L N	0.04	0.1	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrite (asN)	Nitrite	mg/L N	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
pH	pH	pH units	7.7	7.7	8.2	7.5	7.7	7.9	7.1
Silica (as SiO2)	Silica	mg SiO2/L	12	12	14	21	17	21	17
Susp.Solids	Susp_solids	mg/L	4	6	<2	20	5	3	20
T.Diss Solids	TDS	mg/L	100	110	230	250	220	240	140
T.Oxid Nit(asN)	Oxidised_N	mg/L N	0.04	0.1	<0.01	<0.01	<0.01	<0.01	<0.01
TOC (as NPOC)	TOC	mg/L	12	12	11	7	11	13	19
Tot.Phosp (asP)	Total_P	mg/L P	0.06	0.06	0.01	0.04	0.02	0.02	0.05
Total Iron	Total_Fe	mg/L	1.5	1.5	0.25	2.4	0.9	0.28	1.4
Total Mercury	Total_Hg	ug/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Total Metals	Aluminium	ug/L	450	500	32	110	67	21	1200
	Antimony	ug/L	<3	<3	<3	<3	<3	<3	<3
	Arsenic	ug/L	2	2	<1	<1	1	<1	<1
	Barium	ug/L	11	13	28	69	47	40	18
	Beryllium	ug/L	0.2	0.1	<0.1	<0.1	<0.1	<0.1	0.3
	Cadmium	ug/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Chromium	ug/L	<2	<2	<2	<2	<2	<2	<2
	Cobalt	ug/L	0.4	0.4	0.2	1.6	1.1	0.3	1.8
	Copper	ug/L	2	2	1	2	<1	1	5
	Lead	ug/L	0.6	0.6	<0.2	<0.2	<0.2	<0.2	0.6
	Manganese	ug/L	44	42	27	2500	250	56	75
	Molybdenum	ug/L	<1	<1	<1	<1	<1	<1	<1
	Nickel	ug/L	1	2	2	2	2	2	4
	Selenium	ug/L	<2	<2	<2	<2	<2	<2	<2
	Silver	ug/L	<1	<1	<1	<1	<1	<1	<1
	Zinc	ug/L	5	6	<5	<5	<5	6	25
Total Nitrogen	Total_N	mg/L N	0.77	0.91	0.53	0.63	0.61	0.69	0.89
True Colour	True	Pt-Co	130	140	58	48	65	64	150
Turbidity	Turbidity	NTU	11	13	1.4	7.4	2.7	1	20

APPENDIX E - INTERPRETING BOX AND WHISKER PLOTS

Appendix E. Interpreting box and whisker plots.

Box and whisker plots are intended as an exploratory tool to help describe the distribution of the data. The strip chart (red points) on the inside of the plot area indicate the raw data values that make up the distribution portrayed in the boxplot. The plot below explains how the box and whisker plots should be read.



* The interquartile (IQR) range is the difference between the 25th and 75th percentile. This value is important when two sets of data are being compared. The closer the values are to the median, the smaller the IQR. Conversely, the more spread out the values are, the larger the IQR.

APPENDIX F – TAXONOMIC INVENTORY OF THE AUTUMN 2010 RIFFLE AND EDGE MACROINVERTENRATE SAMPLE

CLASS Order	Family *Subfamily*	Genus	RIFFLE BUR 1	RIFFLE BUR 3	RIFFLE QBYN 1	RIFFLE QBYN 2
Acarina	Acarina	Acarina	✓	✓	✓	
BIVALVIA	Sphaeriidae	Sphaeriidae				✓
Coleoptera	Dytiscidae	Platynectes	✓	✓	✓	
Coleoptera	Dytiscidae	Dytiscidae	✓	✓		
Coleoptera	Elmidae	Elmidae		✓		
Coleoptera	Hydrophilidae	Hydrophilidae	✓			
COLLEMBOLA				✓		
Diptera	*Ceratopogonidae*	Ceratopogoninae	✓	✓	✓	✓
Diptera	*Ceratopogonidae*	Dasyhelinae				✓
Diptera	*Ceratopogonidae*	Forcipomyiinae	✓			
Diptera	Chironomidae	Chironomidae	✓	✓	✓	✓
Diptera	*Chironominae*	Chironominae	✓	✓	✓	✓
Diptera	Culicidae	Ochlerotataus	✓			
Diptera	Culicidae	Culicidae	✓			
Diptera	Dolichopodidae	Dolichopodidae	✓		✓	
Diptera	Muscidae	Muscidae	✓			
Diptera	*Orthocladiinae*	Orthocladiinae	✓	✓	✓	✓
Diptera	Psychodidae	Psychodidae	✓			
Diptera	Simuliidae	Austrosimulium	✓	✓	✓	✓
Diptera	Simuliidae	Cnephia				
Diptera	Simuliidae	Simulium	✓	✓	✓	✓
Diptera	Simuliidae	Simuliidae	✓	✓	✓	✓
Diptera	Stratiomyidae	Odontomyia		✓		
Diptera	*Tanypodinae*	Tanypodinae	✓	✓	✓	✓
Diptera	Tipulidae	Tipulidae	✓			
Ephemeroptera	Baetidae	Baetidae		✓	✓	✓
Ephemeroptera	Caenidae	Tasmanocoenis			✓	✓
Ephemeroptera	Caenidae	Caenidae			✓	✓
Ephemeroptera	Leptophlebiidae	Atalophlebia			✓	
Gastropoda	Lymnaeidae	Pseudosuccinea		✓		
Gastropoda	Physidae	Physa			✓	
Gastropoda	Planorbidae	Pygmanisus		✓		
Gastropoda	Planorbidae	Planorbidae		✓		
Gastropoda	Gastropoda	Gastropoda		✓		✓
Odonata	Epiproctophora	Epiproctophora		✓		✓
Odonata	Gomphidae	Hemigomphus				✓
OLIGOCHAETA			✓	✓	✓	✓
Trichoptera	Ecnomidae	Ecnomidae				✓
Trichoptera	Hydropsychidae	Cheumatopsyche			✓	✓
Trichoptera	Hydropsychidae	Diplectrona				✓
Trichoptera	Hydropsychidae	Hydropsychidae		✓		✓
Trichoptera	Hydroptilidae	Hellyethira		✓		✓
Trichoptera	Hydroptilidae	Hydroptilidae		✓		

CLASS Order	Family *Subfamily*	Genus	EDGE BUR 1	EDGE BUR 2a	EDGE BUR 2b	EDGE BUR 3	EDGE CAS	EDGE QBYN 1	EDGE QBYN 2
Acarina	Acarina	Acarina	✓	✓	✓		✓	✓	✓
Amphipoda	Ceinidae	Austrochiltonia					✓	✓	
BIVALVIA	Sphaeriidae	Sphaeriidae					✓		
Coleoptera	Dytiscidae	Antiporus			✓				
Coleoptera	Dytiscidae	Hyphydrus	✓			✓			
Coleoptera	Dytiscidae	Necterosoma	✓	✓		✓	✓	✓	
Coleoptera	Dytiscidae	Platynectes				✓			
Coleoptera	Dytiscidae	Rhantus	✓						
Coleoptera	Dytiscidae	Sternopriscus		✓					
Coleoptera	Dytiscidae	Dytiscidae	✓	✓	✓	✓	✓		
Coleoptera	Hydraenidae	Hydraena	✓						✓
Coleoptera	Hydrophilidae	Berosus	✓		✓				
Coleoptera	Hydrophilidae	Berosus					✓		
Coleoptera	Hydrophilidae	Hydrophilidae	✓	✓	✓	✓	✓		✓
Coleoptera	Scirtidae	Scirtidae			✓	✓	✓	✓	
COLLEMBOLA				✓	✓				✓
Decapoda	Atyidae	Paratya						✓	✓
Decapoda	Parastacidae	Cherax	✓						
Decapoda	Parastacidae	Parastacidae	✓	✓	✓		✓		
Decapoda	Decapoda	Decapoda							
Diptera	Ceratopogonidae	Ceratopogoninae	✓	✓	✓	✓	✓	✓	✓
Diptera	Ceratopogonidae	Forcipomyiinae	✓						
Diptera	Chironomidae	Chironomidae			✓		✓		
Diptera	Chironominae	Chironominae	✓	✓	✓	✓	✓	✓	✓
Diptera	Culicidae	Ochlerotataus	✓		✓	✓		✓	
Diptera	Culicidae	Culex					✓		
Diptera	Culicidae	Culicidae	✓						
Diptera	Dolichopodidae	Dolichopodidae	✓						
Diptera	Muscidae	Muscidae			✓	✓			
Diptera	Orthocladiinae	Orthocladiinae	✓	✓	✓	✓	✓	✓	✓
Diptera	Psychodidae	Psychodidae	✓	✓					
Diptera	Sciomyzidae	Sciomyzidae			✓				
Diptera	Simuliidae	Austrosimulium		✓				✓	
Diptera	Simuliidae	Simulium		✓		✓		✓	
Diptera	Simuliidae	Simuliidae	✓	✓	✓	✓		✓	✓
Diptera	Stratiomyidae	Odontomyia		✓	✓		✓	✓	
Diptera	Tanypodinae	Tanypodinae	✓	✓	✓	✓	✓	✓	✓
Diptera	Tipulidae	Tipulidae	✓						
Ephemeroptera	Baetidae	Cloeon	✓	✓		✓	✓	✓	
Ephemeroptera	Baetidae	Baetidae	✓	✓	✓	✓	✓	✓	✓
Ephemeroptera	Caenidae	Tasmanocoenis						✓	✓
Ephemeroptera	Caenidae	Caenidae			✓				✓

Ephemeroptera	Leptophlebiidae	Atalophlebia				✓	✓	✓	✓
CLASS Order	Family *Subfamily*	Genus	EDGE BUR 1	EDGE BUR 2a	EDGE BUR 2b	EDGE BUR 3	EDGE CAS	EDGE QBYN 1	EDGE QBYN 2
Gastropoda	Ancylidae	Ferrissia		✓	✓		✓		
Gastropoda	Lymnaeidae	Pseudosuccinea		✓	✓	✓		✓	✓
Gastropoda	Physidae	Physa		✓	✓	✓		✓	✓
Gastropoda	Planorbidae	Pygmanisus	✓	✓	✓	✓			
Gastropoda	Planorbidae/physidae	Planorbidae/physidae		✓	✓	✓		✓	✓
Hemiptera	Corixidae	Micronecta	✓	✓		✓	✓	✓	✓
Hemiptera	Corixidae	Sigara					✓	✓	
Hemiptera	Corixidae	Corixidae		✓	✓	✓	✓	✓	
Hemiptera	Mesoveliidae	sp.		✓				✓	
Hemiptera	Notonectidae	Enithares			✓		✓		
Hemiptera	Notonectidae	Paranisops						✓	
Hemiptera	Notonectidae	Notonectidae				✓	✓	✓	
Hemiptera	Pleidae	Plea					✓		
Hemiptera	Veliidae	Veliidae					✓	✓	
Lepidoptera	Pyralidae	Pyralidae						✓	
Odonata	Aeschnidae	Brevyistyla					✓		
Odonata	Coenagrionidae	Ischnura						✓	
Odonata	Coenagrionidae	Coenagrionidae			✓				
Odonata	Epiproctophora	Epiproctophora		✓	✓	✓	✓	✓	✓
Odonata	Gomphidae	Gomphidae							✓
Odonata	Hemicorduliidae	Hemicorduliidae				✓	✓		
Odonata	Synthemistidae	Synthemis					✓		
Odonata	Telephlebiidae	Telephlebiidae				✓	✓		
Odonata	Zygoptera			✓	✓	✓	✓	✓	✓
OLIGOCAHETA			✓	✓	✓	✓	✓	✓	✓
Trichoptera	Ecnomidae	Ecnomus						✓	
Trichoptera	Ecnomidae	Ecnomidae							✓
Trichoptera	Hydroptilidae	Hellyethira		✓	✓	✓	✓	✓	✓
Trichoptera	Hydroptilidae	Hydroptilidae		✓	✓	✓	✓	✓	✓
Trichoptera	Leptoceridae	Notalina				✓			✓
Trichoptera	Leptoceridae	Triplectides	✓					✓	
Trichoptera	Leptoceridae	Leptoceridae				✓		✓	✓
Turbellaria	Dugesiidae	Dugesia			✓			✓	✓

APPENDIX G – TAXA PREDICTED WITH >50% PROBABILITY, BUT WERE MISSING FROM THE AUTUMN 2010 SAMPLES

Appendix G. Macroinvertebrates predicted to occur with >50% probability by the AUSRIVAS model but were absent from edge samples. Number in cells represents their given probability of occurrence at a given site. Blank cells indicate they were collected at this site.

Edge

SITE		BUR 1	BUR 1	BUR 1	BUR 2a	BUR 2a	BUR 2a	BUR 2b	BUR 2b	BUR 2b	CAS	CAS	CAS
TAXON	*Signal*	1	2	3	1	2	3	1	2	3	1	2	3
Elmidae	7	0.71	0.71	0.71	0.67	0.67	0.67	0.73	0.73	0.73	0.7	0.7	0.7
Corixidae	2	0.64					0.64			0.66			
Hydrophilidae	2							0.76		0.76		0.65	0.65
Leptophlebiidae	8	0.95	0.95	0.95	0.96	0.96	0.96	0.96	0.96	0.96			
Caenidae	4	0.97	0.97	0.97	1	1	1	1	1	1	0.99	0.99	0.99
Gripopterygidae	8				0.53	0.53	0.53						
Ecnomidae	4				0.53	0.53	0.53						0.5
Hydroptilidae	4	0.5	0.5	0.5							0.54		
Hydrobiidae	4												0.5
Conoesucidae	7				0.5	0.5	0.5						
Leptoceridae	6	0.96	0.96	0.96	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
Psephenidae	6												
Total Number Of Missing Taxa		6	5	5	7	7	8	5	4	6	4	4	6

Appendix G (cntd.). Macroinvertebrates predicted to occur with >50% probability by the AUSRIVAS model but were absent from edge samples. Number in cells represents their given probability of occurrence at a given site. Blank cells indicate they were collected at this site.

SITE		BUR 3	BUR 3	BUR 3	QBYN 1	QBYN 1	QBYN 1	QBYN 2	QBYN 2	QBYN 2
TAXON	*Signal*	1	2	3	1	2	3	1	2	3
Ancylidae	4									
Acarina	6	0.6	0.6							
Elmidae	7	0.73	0.73	0.73	0.62	0.62	0.62	0.68	0.68	0.68
Synlestidae	7				0.65	0.65	0.65			
Hydrophilidae	2							0.54	0.54	
Baetidae	5							0.91	0.91	
Leptophlebiidae	8	0.95	0.95	0.95						
Caenidae	4	1	1	1		1				
Ecnomidae	4			0.51		0.59	0.59	0.5	0.5	
Corixidae	2								0.63	
Gripopterygidae	8				0.69	0.69	0.69	0.51	0.51	0.51
Hydrobiosidae	8									
Glossosomatidae	9									
Hydroptilidae	4									
Philopotamidae	8									
Hydropsychidae	6									
Conoesucidae	7				0.59	0.59	0.59			
Leptoceridae	6			0.97	0.97		0.97	0.96	0.96	
Psephenidae	6									
Total Number Of Missing Taxa		4	4	5	5	5	6	6	7	2

Appendix G (cntd). Macroinvertebrates predicted to occur with >50% probability by the AUSRIVAS model but were absent from the riffle samples. Number in cells represents their given probability of occurrence at a given site. Probability of occurrence are given in each cell.

SITE		BUR 1	BUR 1	BUR 1	BUR 3	BUR 3	BUR 3	QBYN 1	QBYN 1	QBYN 1	QBYN 2	QBYN 2	QBYN 2
TAXON	*Signal*	1	2	3	1	2	3	1	2	3	1	2	3
Ancylidae	4					0.51	0.51						
Acarina	6					0.61							
Elmidae	7	0.99	0.99	0.99	0.99						1	1	1
Podonominae	6	0.57	0.57	0.57	0.57	0.57	0.57	0.59	0.59	0.59	0.57	0.57	0.57
Tanypodinae	4										0.7	0.7	
Baetidae	5	0.99	0.99	0.99	0.99		0.99						
Leptophlebiidae	8	0.87	0.87	0.87	0.87	0.87	0.87						
Caenidae	4	0.94	0.94	0.94	0.94	0.94							
Corydalidae	7							0.55	0.55	0.55	0.5	0.5	0.5
Gomphidae	5	0.52	0.52	0.52	0.52	0.52	0.52	0.63	0.63	0.63			
Gripopterygidae	8							0.83	0.83	0.83			
Hydrobiosidae	8	0.81	0.81	0.81	0.82	0.82	0.82	0.57	0.57	0.57	0.86	0.86	0.86
Glossosomatidae	9							0.6	0.6	0.6			
Hydroptilidae	4	0.68	0.68	0.68				0.6	0.6	0.6			0.7
Philopotamidae	8							0.63	0.63	0.63			
Hydropsychidae	6	0.91	0.91	0.91			0.91						
Conoesucidae	7							0.82	0.82	0.82			
Leptoceridae	6										0.53	0.53	0.53
Psephenidae	6							0.83	0.83	0.83			
Total Number Of Missing Taxa		9	9	9	7	7	7	10	10	10	6	6	6