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MURRUMBIDGEE ECOLOGICAL MONITORING PROGRAM

PART 2: BURRA CREEK

SPRING 2010

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CERTIFICATE OF APPROVAL FOR ISSUE OF DOCUMENTS

Client: **ActewAGL Distribution**
Project Title: Murrumbidgee Ecological Monitoring Program
Report Title: **Part 2: Burra Creek Spring 2010**

Document No: **CN**211063-S10-02
Document Status: Final
Date of Issue: June 2011

Comments:

	Position	Name	Signature	Date
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Internal Review by:	Principal Scientist	Dr Jamie Corfield		23/06/2011
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Document Revision Control

Version	Description of Revision	Person Making Issue	Date	Approval
1	Draft	Kim Piercy	28/04/2011	
2	For Review	Norm Mueller	28/05/2011	
3	Final	Norm Mueller	24/06/2011	
4	Final- Changed title Part II to Part 2, doc no. & formatting	Norm Mueller	28/06/2011	

The photo on the front cover was taken on-site during ALS project work and is © ALS Water Resources Group.

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Abbreviations

ACT	Australian Capital Territory
ACTEW	Actew Corporation Pty Ltd
ActewAGL	ActewAGL Distribution Pty Ltd
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 Corporation 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. This is known as the Murrumbidgee to Googong transfer scheme (M2G).

The system is being designed to enable pumping of up to 100 ML/d, and is expected to be in operation in 2012. Abstraction from Angle Crossing and its subsequent transfer and release into Burra Creek will be dictated by the level of demand for the water, the availability of water in the Murrumbidgee River and the M2G Operational Management Plan.

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 are to:

- Establish the current status of the macroinvertebrate community at key sites on Burra Creek and the nearby Queanbeyan River;
- 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;
- Establish baseline periphyton data that will be used to characterise seasonal and temporal changes under baseline conditions;
- 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 spring 2010.

Sampling was conducted on the 5th November 2010 and incorporated macroinvertebrate and periphyton community sampling as well as in situ water quality monitoring, laboratory analysis of water samples collecting during sampling and habitat assessment at seven sites (one in Cassidy Creek, four in Burra Creek and two in Queanbeyan River). Continuous data logger records from monitoring stations in Burra Creek and Queanbeyan River for the spring period (September 1st to November 30th 2011) were obtained and assessed as part of this study, as were rainfall and mean daily flows for these systems.

Macroinvertebrate Community

Macroinvertebrate sampling was based on ACT AUSRIVAS sampling protocols, but was extended to include multiple replicates from each site. Where possible, two replicates were collected from riffle and edge habitat per site. This was done to provide within-site replication that would potentially allow hypothesis testing statistical analyses to be performed on the data as part of any impact assessment.

However, due to the lack of riffle habitat at three sites and the complete inundation of the QBYN2 site on the Queanbeyan River at the time of sampling, this was only possible at three sites. Edge habitat samples were collected at six of the seven sites but could not be sampled from QBYN due to its inundation at the time of sampling. In addition to replicated sampling, specimens were identified to genus level, instead of family level, which is normally used for the ACT AUSRIVAS assessment. This was done to increase the resolution of detection of variation in taxonomic composition and diversity with respect to variation in flows and enable subtle changes to be detected if there are impacts associated with altered flow conditions.

Key results from the spring 2010 macroinvertebrate survey include:

- Taxa richness was variable across sites and habitats during spring 2010, although no significant difference was detected between sites located upstream to those downstream of the proposed pipeline discharge location.
- The spring AUSRIVAS results showed all sites to record an overall poorer than reference condition (BAND–B) (82% riffle, 52% edge). A number of taxa predicted by the AUSRIVAS model to occur at the sites sampled in spring were not recorded. These included taxa that are relatively pollution-sensitive such as Elmidae (SIGNAL-2 = 7), Leptophlebiidae (SIGNAL-2 = 8) and Gripopterygidae (SIGNAL-2 = 8) from riffle habitats, and Gripopterygidae and Leptophlebiidae from edge habitats.
- Riffle habitat samples were heavily dominated by Diptera (Simuliidae: *Austrosimulium* (black flies)) and sub-family *Orthocladiinae* (non-biting midges)), which are considered to be moderately sensitive to poor water quality. Other commonly recorded riffle taxa included Oligochaeta (worms) and the microcaddis (Hydroptilidae: *Oxyethiral)*. The former is a deposit feeder tolerant of pollute conditions, while the latter is a member of the sensitive EPT taxa group.
- Diptera also dominated most edge habitat samples. Chironomidae sub-family's Chironominae and Orthocladiinae (non-biting midges) were among the five most dominant taxa at all sites. Trichoptera taxa including Oxyethira (microcaddis) and the Leptocerid, *Notalina* sp., were co-dominant at QBYN1, while the baetid mayfly (*Cloeon* sp. were codominant at sites BUR2A and BUR2B. Ceinidae was the dominant taxon in edge samples at the Cassidy Creek site (CAS1), but was rare or absent at other sites.
- The overall relative abundance of macroinvertebrates from edge habitats was much higher at the Queanbeyan River site (QBYN1) than at all other sites along Burra Creek.

- The SIGNAL-2 scores were relatively well distributed amongst the samples, with the lowest score recorded in an edge sample at site BUR2b (3.00), and the highest score recorded in a riffle sample at site BUR3 (4.90). Signal-2 scores ranged between 3.00 for the BUR2b edge habitat to 4.90 for BUR3 riffle habitat. SIGNAL-2 scores for the edge habitat samples were generally lower in Burra Creek than in the Queanbeyan River. The opposite was true with respect to riffle habitat.
- Macroinvertebrates associated with riffle habitat varied significantly in taxonomic composition between sites. The main taxa differences between the Queanbeyan River site and Burra Creek sites related to several genera from the sensitive EPT taxa. *Dinotoperla* (Gripoterygidae) was only recorded at QBYN1. Several *Illiesoperla* (Plecoptera) were recorded at BUR3, but no Plecoptera taxa were recorded at BUR1. Baetidae Genus 2 occurred in low numbers in riffle habitats at QBYN1 and BUR3, but was recorded from BUR.
- Macroinvertebrates associated with edge habitat also varied significantly between all sites, though BUR2A and BUR2B were the most similar to each other. There was moderate separation between sites located upstream and downstream of the proposed pipeline discharge point in terms of edge habitat taxonomic composition. Edge habitat taxonomic composition was highly variable at upstream sites whereas this was much less so for sites downstream. There were no clearly defined taxa distinguishing edge habitat samples from different sites, but SIMPER analysis highlighted Atyid shrimp *Paratya* spp. as only being recorded from edge habitat at QBYN1, and the leptocerid caddisfly *Triplectides* sp. as being limited to edge habitat associated with upstream sites

Periphyton Community

Estimates of algal biomass were made using complementary 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. Monitoring was undertaken in riffle habitat at three sites in spring 2010. A fourth site, QBYN2 could not be sampled as it was inundated by the full supply level of Googong Dam, Twelve samples were collected along a transect at each site and then randomly assigned into two groups, one for AFDM analysis and one for chlorophyll-a analysis. Samples were analysed by the ALS Canberra laboratory following methods outlined in APHA (2005).

Mean AFDM and chlorophyll-a concentration was highest at the downstream Burra Creek site BUR3 than the upstream Burra Creek site BUR1 and the Queanbeyan River site QBYN1. Mean AFDM and Chlorophyll-a concentration for BUR1 and QBYN1 were broadly similar. There was a high level of variability in both AFDM and chlorophyll-a at BUR3 not apparent at the other two sites.

Hydrology

Two major flow events occurred through both the Burra Creek and Queanbeyan River systems in relatively quick succession after a prolonged period of below average flows. The first event, corresponding to a 1.5 year ARI event, occurred during the first week of September, with a peak flow of approximately 1100 ML/d in Burra Creek and 6000 ML/d in the Queanbeyan River. The second event, corresponding with a 3.5 year ARI event, occurred on 15 October with peak flows of

approximately 3000ML/d and 10,000ML/d respectively in Burra Creek and Queanbeyan River, 3 weeks prior to sampling.

Water Quality

- Continuous water quality measurements from the monitoring stations indicate that observed changes in water quality were coincident with the spring flow events, including a temporary spike in turbidity and a dip in EC levels. Turbidity levels quickly reduced as the high flow events receded. Conversely, EC gradually increased with reducing flows along Burra Creek between each peak flow. The Queanbeyan River water turbidity and EC levels appeared to stabilise more rapidly than Burra Creek following peak flows.
- Grab sample results showed that several upstream control sites recorded turbidity, dissolved oxygen saturation, oxidised nitrogen (NOx) and total phosphorus concentrations outside the recommended range given in the ANZECC and ARMCANZ (2000) guidelines. Downstream sites had turbidity, NOx and total phosphorus concentrations within guideline ranges, but some had slightly reduced dissolved oxygen levels and all had EC concentrations above the recommended guideline level. This was not apparent in any of the upstream control sites, though CAS1 had EC levels of 312 $\mu S/cm^{-2}$, close to the guideline trigger level. Total nitrogen was found to exceed the guidelines trigger level at all sites, with the highest concentration recorded in Cassidy Creek (CAS1).
- Monthly water quality summary statistics recorded at the water quality stations are also presented in Table 3-3. Generally, EC was higher in Burra Creek than Queanbeyan River, whilst turbidity was higher in the Queanbeyan River than in Burra Creek, though, the peak turbidity values for both systems were of a similar order in October.

Key Findings

The major flow events that occurred in spring 2010 are likely to have had a substantial influence on the results presented above. While sampling was carried out within the recommended period following high flow events, these high flow events are likely to have scour-removed macroinvertebrates from riffle and edge habitat. Hence it is likely that macroinvertebrate sampling results reflect an early recovery phase. Macroinvertebrate abundance and diversity in spring 2010 was relatively low. In addition, the dominant taxa in the spring samples included several diptera families such as Chironominae and Simuliidae taxa, and Ephemeroptera families such as Baetidae taxa that are regarded as disturbance tolerant and known for their fast recovery times following floods. There were also several taxa predicted to occur at the sites monitored. Their absence could have been due to scour-removal, the changes in water quality associated with the high flow events, or a combination of both.

While there is evidence here of slight nutrient enrichment in both the Burra Creek and Queanbeyan River system, elevated nitrate 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. Base flow period records to date indicate that the nutrient levels are generally within ANZECC and ARMCANZ (2000) guidelines and have probably had a negligible effect on the periphyton community. The highest

periphyton biomass in spring 2010 was recorded at site BUR3, but nutrient concentrations were lower at this site than the two other sites. This would suggest that local-scale factors probably contributed to the observed patterns with respect to periphyton biomass. Also, because periphyton growth is the cumulative effect of preceding water quality conditions, if there is a relationship between nutrients and growth rates, the sampling of water quality only at the time of periphyton sampling is unlikely to elicit the true nature of periphyton production-nutrient dynamics relationships.

Elevated EC levels and reduced turbidity levels in the downstream reach of Burra Creek is possibly due to the influence of groundwater in this intermittently flowing creek. Groundwater fed creeks have naturally elevated levels of salts and lower turbidity because the water is filtered through porous limestone. The influence of groundwater flows on water quality in Burra Creek requires further investigation.

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 several issues and knowledge gaps to be addressed to improve the utility of the monitoring program outputs. The following recommendations are made:

i) There were two issues identified with the current study design identified in this study. Firstly, the Cassidy's Creek has been completely encroached by vegetation and is now very different to other sites in terms of habitat structure. As such it is not representative as a control site for further monitoring. Secondly, the QBYN2 site cannot be surveyed when the Googong Dam is > 80% full. At such times, this site essentially forms part of the dam backwater and is not representative of downstream fluvial stream habitat in Burra Creek. Accordingly, these two sites should be disregarded as part of future monitoring and alternative sites located where possible.

ii) Levels of EC and turbidity in Burra Creek may reflect a groundwater influence in this system. As such, trigger values for EC and turbidity may not be suitable as guideline levels with respect to maintaining the ecology of this system. The influence of groundwater flows on water quality in Burra Creek requires further investigation. If that influence is found to be substantial, it would be worth considering developing local water quality guidelines for Burra Creek according to procedures outlined in the ANZECC and ARMCANZ (2000) guidelines.

iii) We recommend that future sampling be extended to cover summer and winter as well as the autumn and spring sampling. We also recommend event-based sampling of refugial pools to assess the nature of recovery by macroinvertebrates following spates. This will provide greater predictive capacity in terms of assessing potential impacts of the proposed M2G water transfer on macroinvertebrates in Burra Creek.

iv) The importance of the hyporheic zone (HZ) as a refuge for over-summering taxa, and during periods of flood and drought requires attention. HZ fauna are likely to be present in Burra Creek given its

intermittent flows and potential groundwater influence, yet these have not yet been considered as part of any impact assessment or monitoring to date. ALS 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.

v) Thus far, assessments as part of the M2G program have focussed on individual sampling events. This approach prevents any detailed understanding of longer-term trends (e.g. inter-annual variability), which in the long term, undermines our ability to assess the role of flow variability on the dynamics of stream biota and water quality. We recommend that an extensive temporal assessment of all baseline data collected biannually since spring 2008 be undertaken as part of the autumn 2011 reporting task.

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 constructing an additional pumping structure and pipeline to abstract water from the Murrumbidgee River from a location immediately upstream of 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 in 2012. Abstraction at Angle Crossing and the subsequent discharges to Burra Creek will be dictated by the level of demand for the water, the availability of water in the Murrumbidgee River, and the M2G Operational Management Plan. 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 100 ML/d has only been exceeded 6 times, while flows in excess of 100 ML/d have occurred less than 2 % (0.015) 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 1-1). 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 used 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 also poses a

risk of spreading exotic plant and fish species (should the screens not be fully effective) which could displace native biota directly through competition or indirectly through the spread of disease. Other potential impacts are highlighted in Table 1-1.

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 1-1: 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 transfers (IBT) of soft Murrumbidgee water into the harder water of Burra Creek may 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 hyporheic 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 ActewAGL 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:

- Provide seasonal "river health" reports in accordance with ACTEW water abstraction licence requirements;
- 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;
- Collect baseline periphyton data that will be used as a guide to monitor seasonal and temporal changes; and
- 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.

Specifically, as outlined in the MEMP proposal to ACTEW Corporation (Ecowise, 2009a), this work includes:

- Biannual sampling which commenced in autumn 2009;
- Macroinvertebrate sampling from riffle and edge habitats (where available) 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 models;
- Selected water quality measurements to be measured in-situ, and collected for analysis at Australian Laboratory Services (ALS's) NATA accredited laboratory.

The scope of this report is to convey the results from the spring 2010 sampling run.

Prior to the commencement of this program, ALS sought advice from 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 had 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 Methodology

Prior to sampling, comprehensive site assessments were carried out, including assessments of safety, suitability and access permission 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.

2.1 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 and four impact sites. This includes a 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 2-1; Figure 2-1). 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 genus level (where practical), 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 for flow related impacts to be distinguished from other disturbances. The reason 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 become permanent habitats 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 2-1: Sampling site locations and details

Site Code	Location	Purpose	Latitude	Longitude
CAS1	Cassidy's Creek, upstream Burra Creek confluence	Control site	-35° 35.918	149° 13.641
BUR1	Burra Creek, upstream Cassidy Creek confluence	Control site	-35° 35.855	149° 13.666
BUR2*a**	Burra Creek, downstream of Williamsdale Road Bridge	Impact site	-35° 33.326	149° 13.400
BUR2*b**	Burra Creek, downstream of Burra Road bridge	Impact site	-35° 35.571	149° 13.649
BUR3	Burra Creek, downstream of London Bridge	Impact site	-35° 30.620	149° 15.861
QBYN1	Queanbeyan River at Flynn's Crossing	Control site	-35° 31.459	149° 18.198
QBYN2	Queanbeyan River, downstream of Burra Creek confluence	Impact site	-35° 29.937	149° 15.942

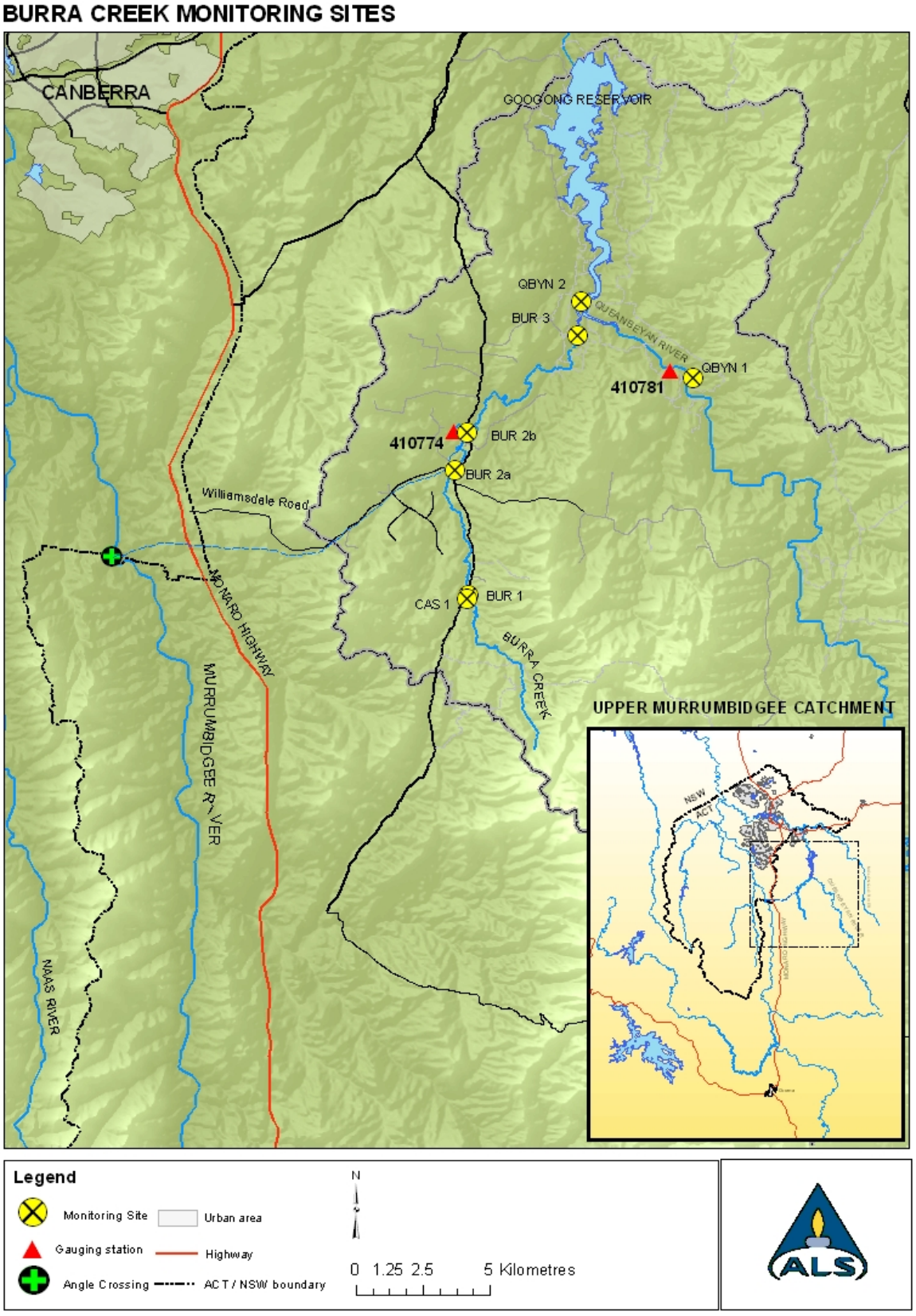


Figure 2-1: Location of the monitoring sites and gauging stations for the Burra Creek monitoring program

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 2-2.

Table 2-2: 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

**Notes: 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 5a 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 for Hydrolab® verification, nutrient analysis. Nutrient analysis included nitrogen oxides (total NOx), total nitrogen (TN) and total phosphorus (TP) in accordance with the protocols outlined in A.P.H.A (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.

All water samples were appropriately labelled and placed on ice in the field. The samples were delivered 'same day' to the ALS laboratory for analysis.

2.4 Periphyton

Estimates of algal biomass were made using complementary 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).

A total of four sites were selected for this project for periphyton assessment in spring in conjunction with the macroinvertebrate sampling program, including sites BUR1, BUR3, QBYN1 and QBYN2. Unfortunately, site QBYN2 is located within the full supply level of Googong Dam, and was inundated at the time of the program (Googong Dam at 80% capacity).

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).

2.5 Macroinvertebrates

Riffle and edge habitats were sampled for macroinvertebrates using the ACT AUSRIVAS (Australian River Assessment System) protocols (Coysh et al., 2000). The nets and all other associated equipment were washed thoroughly between habitats, sites and sampling events to remove any macroinvertebrates retained on them.

The field program occurred on 5th November 2010. Table 2-3 outlines the macroinvertebrate sample collection undertaken in spring 2011. The original aim was to collect two replicate samples each from edge and riffle habitat - where available.

This was possible at three of the seven monitoring sites in spring 2011. At CAS1 sampling was limited by the amount of habitat suitable for macroinvertebrate sampling to one edge sample only. QBYN2, which is located within the full supply level of Googong Dam, was inundated at the time of sampling (Googong Dam at 80% capacity) so was not sampled. Only edge habitat was sampled at BUR2a and BUR2b as riffle habitat was not available for sampling at these two sites.

Table 2-3: Macroinvertebrate samples collected for the Burra Creek component of MEMP, spring 2010.

Sites	Edge	Riffle
CAS1	1	N/A
BUR1	2	2
BUR2a	2	N/A
BUR2b	2	N/A
BUR3	2	2
QBYN1	2	2
QBYN2	N/S	N/S

Notes:

N/A – habitat not available.
N/S – not sampled, within Googong Dam inundation area.

Sampling of the riffle habitat (flowing broken water over gravel, pebble, cobble or boulder, with a depth greater than 10 cm; Coysh et al., 2000) involved using a framed net with 250 µm mesh size. Sampling began at the downstream end of each

riffle, with the net held perpendicular to the substrate and the opening facing upstream. The stream bed directly upstream of the net opening was agitated by vigorous kicking, allowing dislodged invertebrates to be carried into the net by the current. The process continued, working upstream over a 10 metre section of riffle habitat.

The edge habitat sample was collected by sweeping the collection net along the edge of the creek line at the sampling site, with the operator working systematically over a ten metre section covering all microhabitats such as overhanging vegetation, submerged snags, macrophyte beds, overhanging banks and areas with trailing vegetation.

Each bulk residual sample was placed in separate 1L white containers, preserved with 70% ethanol, and clearly labelled inside and out with project information, site code, date, habitat, and sampler details.

Processing of the aquatic macroinvertebrate samples followed the ACT AUSRIVAS protocols. In the laboratory, each preserved macroinvertebrate sample was 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 were removed and examined under a dissecting microscope until a minimum of 200 animals were counted. All animals within the selected cells were identified.

In order to provide additional replication within the experimental design, laboratory processing of each sample was repeated 3 times to total up to 6 samples per habitat per site (2 field replicates x 3 laboratory processed replicates). This method was possible for all samples, with the exception of site BUR3 field replicate #2 riffle sample, as the entire sample was sorted within 2 sub-samples.

Macroinvertebrates were identified to genus level (where possible) using taxonomic keys outlined in Hawking (2000) and later publications. 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.

2.6 Data analysis

2.6.1 Hydrology and rainfall

Data from the two water quality stations was extracted from the database management system Hydstra©.

2.6.2 Water quality

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

A gap existed in the continuous water quality recorded from station no. 410774 (Burra Creek) due to a sensor malfunction in September. A further malfunction

occurred in mid-October, however, only the EC sensor malfunctioned. A new water quality meter was installed at this site on the 5th November, 2011.

2.6.3 Periphyton

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

Previous assessments on this data included tests for differences between upstream-control locations versus downstream-impact locations; however, site QBYN2 was found to be inundated by the impounded water of Googong Dam during the spring 2010 event and hence was not sampled. Therefore, this type of assessment was only conducted on the Burra Creek sites (BUR1 vs BUR3), and a summary only was provided for the QBYN1 site results. BUR1 and BUR3 chlorophyll-a and AFDM data was log-transformed and compared using a one-way analysis of variance (ANOVA). The ANOVA was run using the statistics software package Statistica version 9.0.

2.6.4 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.

2.6.4.1 Univariate analysis

The univariate techniques performed on the macroinvertebrate data, include:

- Taxa Richness and PET Taxa Index
- SIGNAL-2 Biotic Index (Chessman, 2003)
- ACT AUSRIVAS O/E scores and bandings

Taxa Richness refers to the number of different taxa contained in a sample. **EPT Taxa Index** refers to the proportional representation of key macroinvertebrate taxa belonging to the Ephemeroptera, Plecoptera and Trichoptera groups.

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, 1995). Each family in a sample is assigned a grade between 1 (most tolerant) and 10 (most sensitive). The SIGNAL index is then calculated as the average grade number for all families present in the sample. The resulting index score can then be interpreted by comparison with reference and/or control sites. Recently these grades have been improved and standard errors applied under the SIGNAL2 model approach developed by Chessman (2003). These changes were introduced to improve the reliability of the SIGNAL index.

The **AUStralian RIVer Assessment System (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 2-4) 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 (Table 2-4).

Table 2-4: AUSRIVAS band- widths and interpretations for the ACT spring riffle and edge models.

BAND	O/E Band width	O/E Band width	Explanation
	RIFFLE	EDGE	
X	>1.14	>1.13	More diverse than expected. Potential enrichment or naturally biologically rich.
A	0.86-1.14	0.87-1.13	Similar to reference. Water quality and / or habitat in good condition.
B	0.57-0.85	0.61-0.86	Significantly impaired. Water quality and/ or habitat potentially impacted resulting in loss of taxa.
C	0.28-0.56	0.35-0.6	Severely impaired. Water quality and / or habitat compromised significantly, resulting in a loss of biodiversity.
D	0-0.27	0-0.34	Extremely impaired. Highly degraded. Water and /or habitat quality is very low and very few of the expected taxa remain.

Macroinvertebrate results were simplified to family level to allow for an AUSRIVAS assessment, except for Chironomidae (identified to sub-family), Oligochaeta (class) and Acarina (order) groups, as is the required approach for input to the ACT AUSRIVAS models.

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.

The variation in the above univariate indices between location ('upstream' versus 'downstream' site groups) and also individual sites was assessed using analysis of variance (ANOVA) methods. As the univariate index results did not meet the normal assumptions of ANOVA, a non-parametric Kruskal-Wallis test was used to analyse the ranked data. ANOVAs were performed using Statistica version 9.0.

2.6.4.2 Multivariate analysis

All multivariate analyses were performed using PRIMER version 6 (Clarke and Gorley, 2006).

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 log(y+1) transform the data and 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 represent 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 highly representative of the multidimensional data. Stress values greater than 0.2 indicates a poor representation (Clarke and Warwick 2001).

An **ANalysis Of SIMilarities (ANOSIM)** test is a non-parametric permutation procedure, applied to the similarity matrix underlying the NMDS. This test was performed on the data to determine whether macroinvertebrate communities were statistically different upstream and downstream of the proposed discharge point, and also between individual sites. Outputs are expressed as R-values (multivariate equivalent of an F-test result) and p-values. Significance was defined as being at the 5% probability level ($p<0.05$).

The SIMilarity PERcentages (SIMPER) routine was carried out on the datasets 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).

2.7 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 Licences and permits

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

ALS field staff maintain current AUSRIVAS accreditation.

3 Results

3.1 Sampling conditions

Sampling was conducted on 5th November, at which time Burra Creek recorded a mean flow of 3.7 ML/d. Flow through Burra Creek had remained stable (<10 ML/d) for approximately 2 weeks preceding the sampling event. A major flow event was recorded prior to this period, with flows peaking at 3000 ML/d on the 15th of October 2010.

Queanbeyan River recorded a flow of 108 ML/d on the day of sampling, and similar to Burra Creek, recorded relatively stable conditions for the two weeks preceding sampling (<200 ML/d).

The weather condition during sampling was overcast with light drizzle and a cool ambient air temperature of approximately 10ºC.

3.2 Hydrology and rainfall

Four major flow events were recorded by the monitoring stations on Burra Creek and Queanbeyan River in spring 2010 (Figure 3-1). The September high flow event for Burra Creek had an Average Recurrence Interval (ARI) of approximately 1.5 years, based on results of the Log-Pearson Type III analysis in Hydstra©; whilst the Queanbeyan River system recorded an ARI of 5 years for the same event.

The second event during on 15 October was the most intense across the spring period; with the Burra Creek system recording a peak of approximately 3000 ML/d instantaneous flow, and an ARI of 3.5 years. This event was mirrored within the Queanbeyan River system, although much larger, peaking at approximately 10,500 ML/d, and an ARI of approximately 7.5 years.

The two events recorded in November were each of smaller magnitude than the first two events, although together produced the highest monthly median flow over the spring period for both systems.

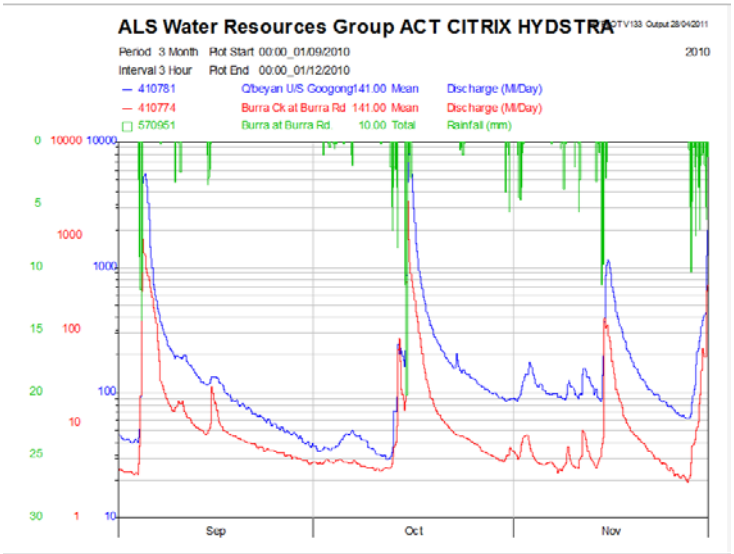


Figure 3-1: Spring hydrograph from the Burra Creek and Queanbeyan River gauging stations.

The Burra Creek monitoring station recorded a total of 34 days of rain, with a total of 337 mm recorded between September and November. Whilst November recorded the highest rainfall over the month, it was the high intensity storm event in mid-October which resulted in a higher mean flow (Table 3-1).

The Queanbeyan River monitoring station recorded 32 days of rain, with a total of 354 mm over the spring period. Similar flow patterns were recorded within the Queanbeyan River, as was observed in Burra Creek, with more rainfall recorded in November, but a higher intensity storm event recording the maximum peak flow mid-October (Table 3-1).

Table 3-1: Monthly flow and rainfall statistics for Burra Creek at Burra Road (410774) and Queanbeyan River upstream of Googong Reservoir (410781) spring 2010.

Station	Burra Creek		Queanbeyan River	
	Rainfall Total (mm)	Mean Flow (ML/d)	Rainfall Total (mm)	Mean Flow (ML/d)
September	73.0	38.99 [412]	72.8	297.8 [3640]
October	117.4	43.82 [780]	112.5	404.6 [4450]
November	146.8	13.52 [114]	169.0	186.2 [940]
Spring	337.2	32.11	354.3	888.6

Notes:

Monthly maximums are shown in yellow

3.3 Water quality

Continuous water quality records were collected from Burra Creek (Station number: 410774) (Figure 3-2) and the Queanbeyan River (Station number: 410781) (Figure 3-3). These records are useful for highlighting the variability in water quality and timing of major fluctuations in relation to major flow events. The major flow events which occurred mid-October and mid-November are coincident with the rapid changes in water quality of Burra Creek. Turbidity was immediately influenced with each flow event, with reducing turbidity as flows receded; conversely, EC was found to gradually increase with reducing flows along Burra Creek between each peak flow period. The Queanbeyan River water quality results, although still influenced by the major flow events, appeared to stabilise more rapidly than Burra Creek i.e. EC remained less than 100 µS/cm between high flow periods.

Grab samples collected at the time of the biological sample collection are reported on in relation to ANZECC and ARMCANZ (2000) guidelines in Table 3-2. The results present EC concentrations higher in the Burra Creek system downstream of the confluence with Cassidy Creek, with evidence that the control site along Cassidy Creek is of similar concentration in the upper reaches of the catchment. In addition, total nitrogen was found to exceed the guidelines across all sites, with the highest concentration recorded in Cassidy Creek (CAS1).

Monthly water quality summary statistics recorded at the water quality stations are also presented in Table 3-3. Generally, EC was higher in Burra Creek than Queanbeyan River, whilst turbidity was higher in the Queanbeyan River than in Burra Creek, though, the peak turbidity values for both systems were of a similar order in October.

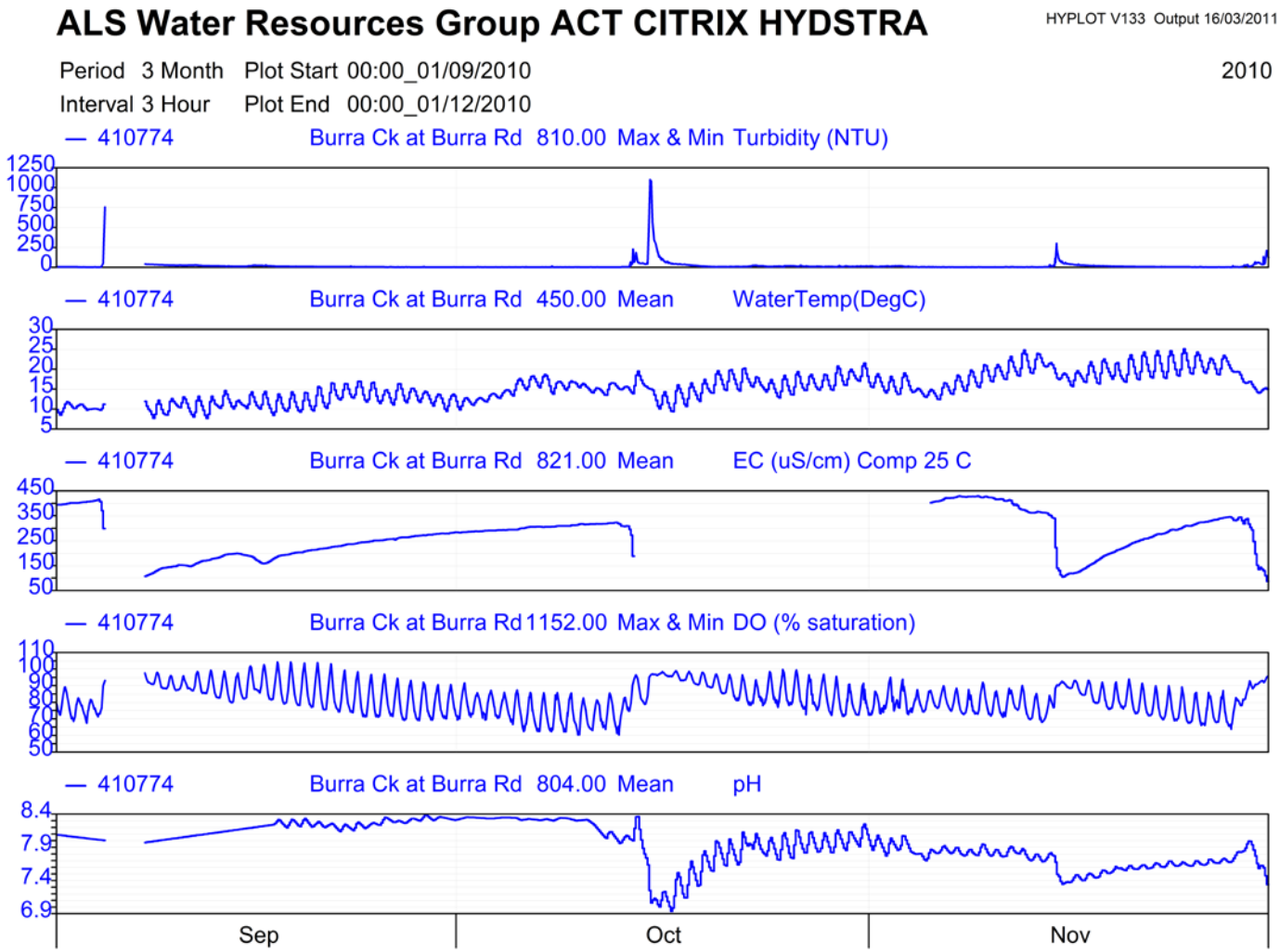


Figure 3-2: Water quality records from Burra Creek (410774) during spring 2010.

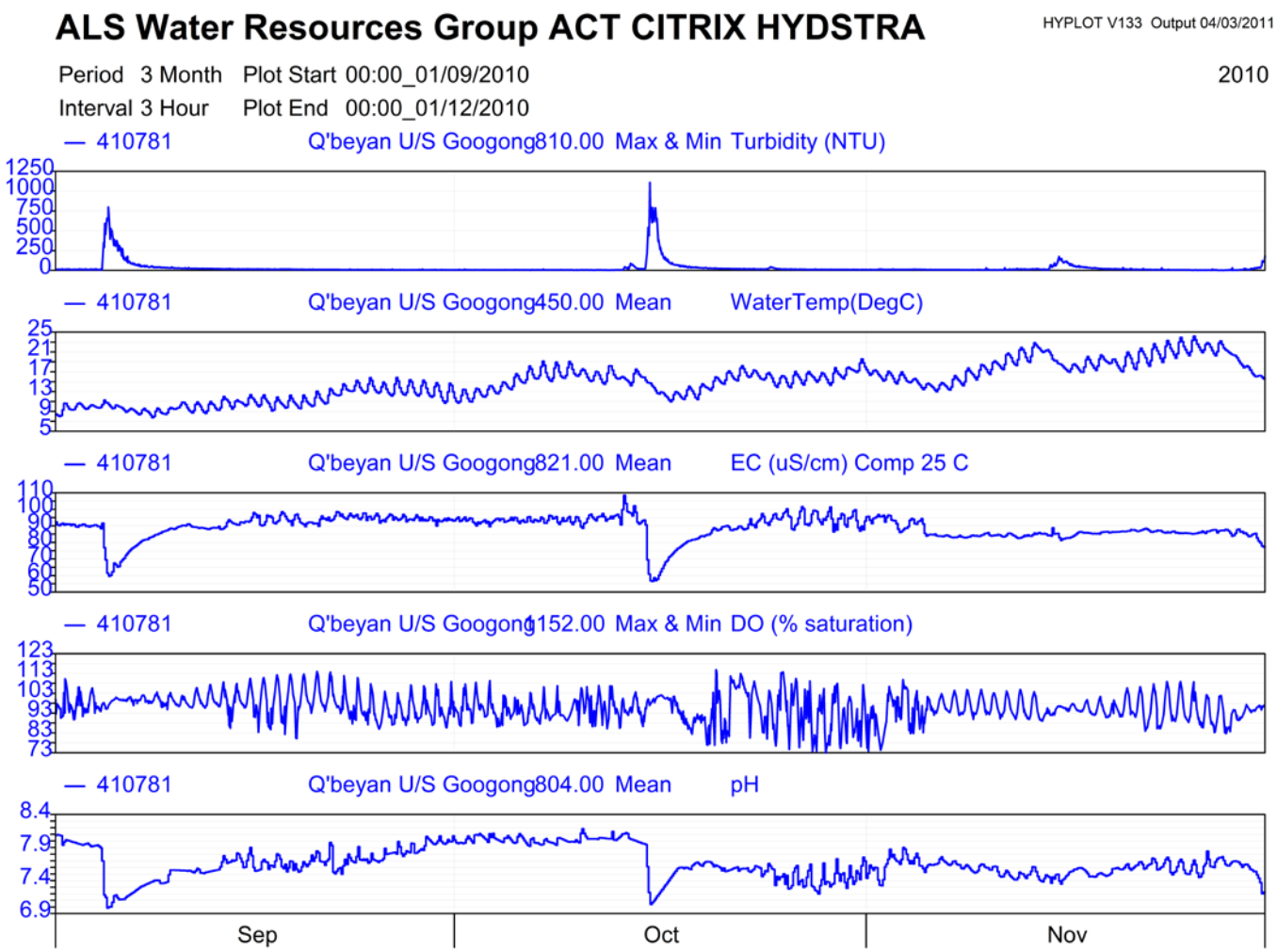


Figure 3-3: Water quality records from Queanbeyan Creek (410781) during spring 2010.

Table 3-2: Grab sample water quality results, spring 2010.

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)	Total Alkalinity (mg/L)	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	CAS1	14:10	14.70	312.0	36	7.80	73.6	7.69	135	<0.01	<0.01	<0.01	0.04	0.65
	BUR1	13:00	13.76	90.1	6	7.22	86.3	9.26	18	0.04	0.04	<0.01	0.03	0.63
	QBYN1	9:15	13.50	75.8	33	7.48	90.6	9.70	34	0.06	0.06	<0.01	0.03	0.42
Downstream sites	BUR2a	14:30	15.00	351.3	4	7.6	86.5	9.92	147	<0.01	<0.01	<0.01	0.01	0.44
	BUR2b	15:00	15.10	356.4	4	7.67	91.3	9.42	147	0.01	0.01	<0.01	<0.01	0.39
	BUR3	10:30	14.90	387.9	6	8.07	84.8	8.84	170	<0.01	<0.01	<0.01	<0.01	0.35
	QBYN2	*N/S*	*N/S*	*N/S*	*N/S*	*N/S*	*N/S*	*N/S*	*N/S*	*N/S*	*N/S*	*N/S*	*N/S*	*N/S*

Notes:

ANZECC & ARMCANZ (2000) guideline values are indicated in the headings in red.
Yellow cells indicate values recorded outside guideline values.
N/S – not sampled, site within Googong Dam inundation area.

Table 3-3: Monthly water quality statistics recorded from Burra Creek (410774) and the Queanbeyan River (410781) water quality stations.

Station	Burra Creek					Queanbeyan River				
Analyte	Temp.	EC[1]	pH	D.O [min-max].	Turbidity	Temp.	EC	pH	D.O [min-max]	Turbidity
September	11.96	232.3	8.19	75.4-93.4	10.9 [33.2]	11.13	90.0	7.67	92.4-102.6	37.4 [356]
October	15.47	303.3	7.99	70.5-96.8	25.5 [352.3]	15.21	90.3	7.74	88-107.3	37.7 [372.6]
November	18.62	300.6	7.72	73.7-92.6	13.2 [88.9]	18.47	86.3	7.58	87-98.9	16.9 [102.3]
Spring	15.35	278.7	7.97	73.2-94.1	16.5	14.94	88.9	7.66	89.1-102.9	30.7

Notes

Based upon 13 records only, EC equipment malfunction from 14th October – 5th November, 2010.
All values are means, except D.O which is expressed as mean monthly maximum and minimums
Monthly maximum turbidity values are in yellow

3.4 Periphyton assessment

The raw periphyton results are presented in APPENDIX B.

The chlorophyll-*a* samples recorded variable concentrations at site BUR3, with results ranging from 1391 – 12 587 mg/m^3; in comparison to the upstream sites BUR1 and QBYN1 where concentrations did not exceed 3300 mg/m^3 (Figure 3-4). The high variability within site BUR3 contributed to a significantly different result when compared to BUR1 ($F_{1,10}$= 8.14; p=0.017) (Table 3-4).

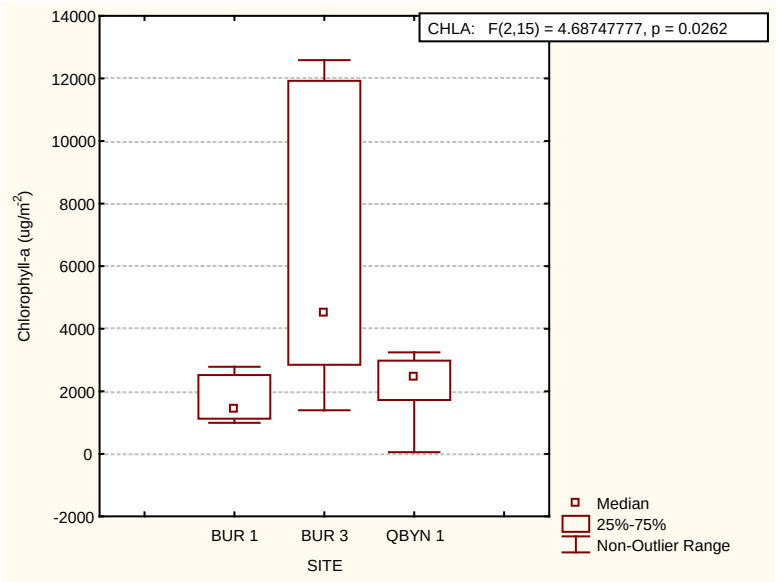


Figure 3-4: Periphyton chlorophyll- a concentrations from upstream (BUR1 and QBYN1) and downstream (BUR3) locations.

The trend reflected in chlorophyll-a results was also apparent in the ash free dry mass (AFDM) results, which recorded a large variability within the BUR3 site samples, and similar results amongst samples collected from BUR1 and QBYN1 (Figure 3-5). The high variability within site BUR3 contributed to a significantly different result when compared to BUR1 ($F_{1,10}$= 5.06; p=0.048) (Table 3-4).

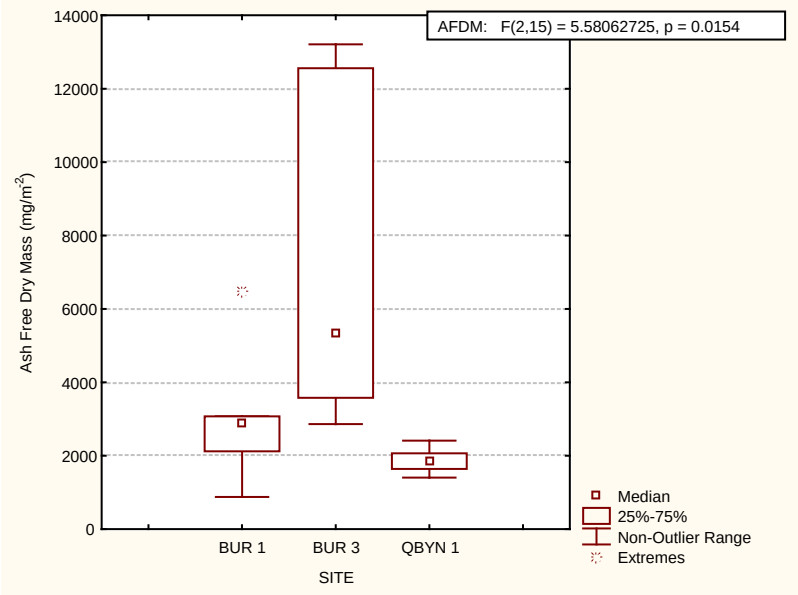


Figure 3-5: Periphyton Ash Free Dry Mass from upstream (BUR1 and QBYN1) and downstream (BUR3) locations.

Table 3-4: One- way analysis of variance results for Chlorophyll- a and ash free dry mass densities between sites BUR1 and BUR3.

Parameter	SS	DF	MS	F	P- value
Chlorophyll- a (log)					
SITE	0.686	1	0.686	8.14	0.017
error	0.843	10	0.084		
AFDM (log)					
SITE	0.3975	1	0.3975	5.06	0.048
error	0.786	10	0.0786		

As in previous events, there was a low correlation between the chlorophyll-a results and AFDM ($r = 0.442$, $p = 0.066$).

3.5 Macroinvertebrate communities

3.5.1 Univariate analysis

The results of all univariate indices across all sites and samples are presented in Table 3-5. Taxa richness was lower in the riffle habitats at all sites compared to the edge habitats, with the exception of one sample from QBYN1 which recorded the same number of taxa at the family and genus level of identification.

The highest taxa richness results for the riffle and edge habitats were recorded from QBYN1 and BUR3, respectively. In addition, these two sites also recorded the highest EPT richness for the riffle and edge habitats, although not within the same sample. The EPT taxa formed 33% of all generic level taxa within the edge sample at BUR3, whereas the EPT taxa made up 47% of all generic level taxa within the riffle sample at QBYN1 (Table 3-5).

Table 3-5: Univariate results for spring 2010.

Site	Field Rep.	Lab Rep.	Taxa richness: Family (genus)		EPT richness: Family (genus)		SIGNAL- 2 index		AUSRIVAS O/E score		AUSRIVAS Band		Overall habitat assessment		Overall site assessment
			Riffle	Edge	Riffle	Edge	Riffle	Edge	Riffle	Edge	Riffle	Edge	Riffle	Edge	
CAS1	1	1		13 (14)		2 (2)		3.46		0.78		B			
		2		15 (17)		4 (4)		3.67		0.89		A		B	B
		3		14 (15)		3 (3)		3.79		0.78		B			
BUR1	1	1	9 (10)	20 (25)	3 (3)	4 (7)	4.33	3.65	0.64	0.98	B	A			
		2	12 (13)	20 (23)	3 (3)	4 (5)	4.17	3.55	0.74	0.98	B	A	B	A	B
		3	11 (12)	19 (21)	3 (3)	4 (4)	4.18	3.84	0.64	0.87	B	A			
	2	1	11 (12)	15 (19)	2 (2)	3 (4)	4.46	3.6	0.74	0.76	B	B			
		2	13 (14)	15 (18)	3 (3)	3 (5)	3.85	3.73	0.64	0.65	B	B	B	B	B
		3	12 (13)	13 (15)	3 (3)	4 (5)	4.17	4.08	0.64	0.76	B	B			
BUR2A	1	1		13 (13)		3 (3)		3.54		0.63		B			
		2		16 (17)		5 (6)		3.38		0.72		B		B	B
		3		16 (17)		5 (5)		3.69		0.81		B			
	2	1		15 (15)		4 (4)		3.13		0.63		B			
		2		17 (19)		5 (6)		3.76		0.90		A		B	B
		3		18 (19)		5 (6)		3.72		0.90		A			
BUR2B	1	1		15 (16)		2 (2)		3.07		0.70		B			
		2		13 (15)		3 (3)		3.00		0.70		B		B	B
		3		16 (17)		3 (3)		3.25		0.82		B			
	2	1		11 (15)		4 (4)		3.91		0.82		B			
		2		13 (15)		4 (4)		3.62		0.93		A		B	B
		3		20 (21)		5 (6)		3.35		1.05		A			

Site	Field Rep.	Lab Rep.	Taxa richness: Family (genus)		EPT richness: Family (genus)		SIGNAL- 2 index		AUSRIVAS O/E score		AUSRIVAS Band		Overall habitat assessment		Overall site assessment
			Riffle	Edge	Riffle	Edge	Riffle	Edge	Riffle	Edge	Riffle	Edge	Riffle	Edge	
BUR3	1	1	10 (11)	20 (24)	4 (4)	5 (8)	4.90	3.65	0.65	1.05	B	A	B	A	B
		2	10 (12)	19 (22)	3 (4)	4 (5)	4.50	3.26	0.74	0.93	B	A			
		3	13 (15)	22 (23)	3 (4)	5 (6)	4.69	3.59	0.83	1.05	B	A			
	2	1	14 (16)	21 (22)	6 (7)	5 (5)	4.79	3.19	1.02	0.93	A	A	B	A	B
		2	11 (12)	19 (19)	3 (4)	4 (4)	4.64	3.42	0.83	0.93	B	A			
		3		20 (24)		4 (6)		3.20		0.93		A			
QBYN1	1	1	16 (18)	12 (14)	6 (7)	4 (5)	4.44	3.83	0.92	0.76	A	B	B	B	B
		2	12 (13)	12 (13)	5 (5)	4 (5)	4.67	4.17	0.92	0.76	A	B			
		3	12 (13)	13 (15)	4 (5)	4 (5)	4.67	4.15	0.83	0.76	B	B			
	2	1	12 (14)	20 22)	5 (6)	5 (6)	4.67	3.65	0.83	0.98	B	A	B	B	B
		2	13 (17)	16 (19)	5 (8)	5 (7)	4.54	3.63	0.83	0.76	B	B			
		3	12 (13)	20 (21)	5 (5)	6 (7)	4.67	3.9	0.83	0.98	B	A			

There was no significant difference between the taxa richness of riffle habitats for the treatment 'location' between upstream sites (QBYN1 & BUR1) and downstream sites (BUR3), although this assessment only includes the one downstream site. This outcome applied to both the generic level identification (KW-H [1,17] = 0.289, p = 0.591) and simplified family level results (KW-H (1,17) = 0.294, p = 0.588).

There was also no significant difference between the taxa richness of riffle habitats when comparing individual sites at both levels of taxonomic resolution (Figure 3-6).

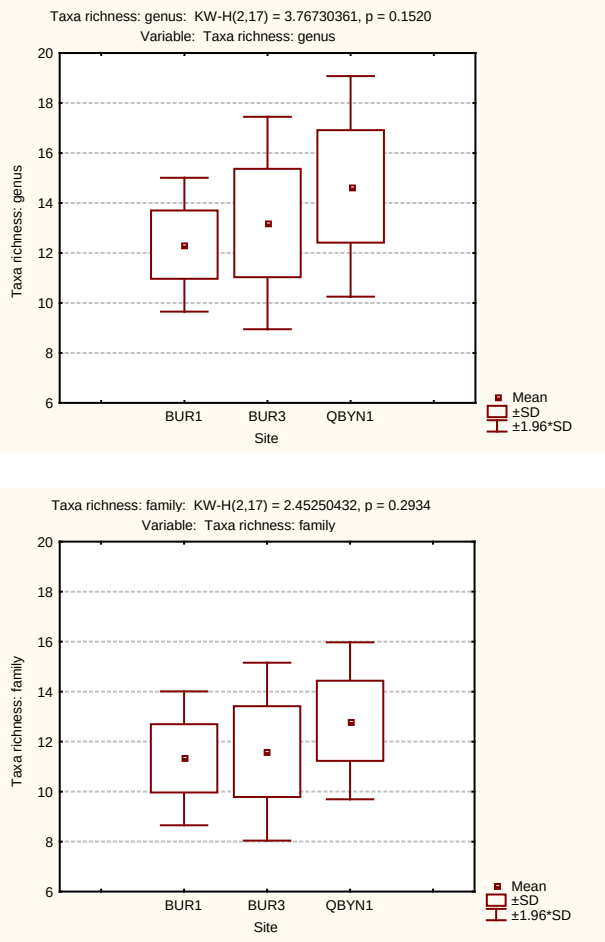


Figure 3-6: Average ranked genus (upper) and Family (lower) taxonomic richness for riffle habitat across sites, spring 2010.

There was no significant difference between the taxa richness edge habitat results for the treatment 'location' between upstream sites (QBYN1, CAS1 & BUR1) to downstream sites (BUR2A, BUR2B and BUR3). This applied to both the generic level identification (KW-H [1,33] = 0.242, p = 0.623) and simplified family level results (KW-H [1,33] = 1.123, p = 0.289).

There was, however, a significant difference in taxa richness results when compared between individual sites, with similar patterns exhibited for both generic level and family level identification (Figure 3-7).

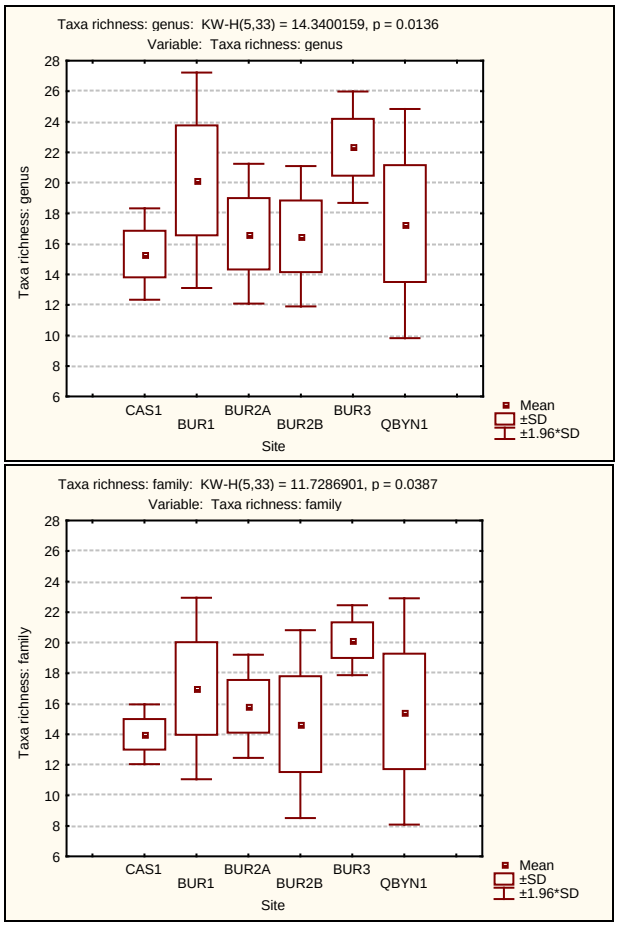


Figure 3-7: Average ranked genus (upper) and Family (lower) taxonomic richness for edge habitat across sites, spring 2010.

Whilst most taxa richness results appeared comparable, the main difference was between site BUR3 and CAS1, with a mean generic level taxa richness of 22 to 15, respectively. These sites recorded similar results across all samples in comparison to a wider distribution of results within the other sites suggesting a higher level of intra-site variability.

A review of the distribution of taxa recorded within the samples is presented as cumulative dominance graphs below for the riffle (Figure 3-8) and edge (Figure 3-9) habitats. Whilst site QBYN1 and BUR3 recorded the most abundant taxa dominating approximately 30% of the riffle samples, site BUR1 recorded samples with one taxon making up between 50-60% of the total abundance recorded in riffle samples (Figure 3-8). There was also evidence of unevenness in taxa distribution within the edge samples, with QBYN1 samples recording over 60% of the abundance from a single taxon.

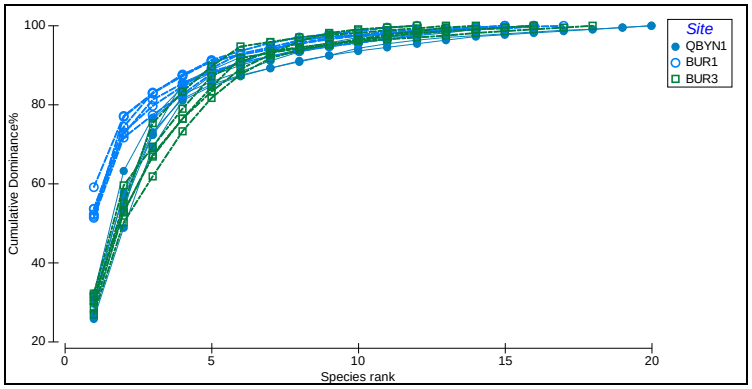


Figure 3-8: Cumulative dominance of taxa (generic level) within the riffle samples, spring 2010. *Green squares are sites downstream of the proposed discharge point; blue circles are upstream sites.*

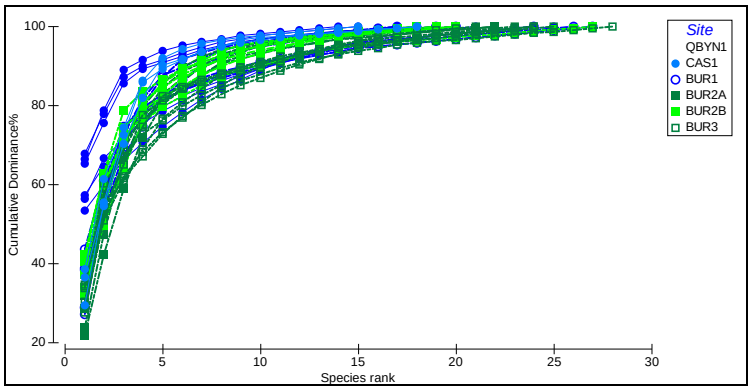


Figure 3-9: Cumulative dominance of taxa (generic level) within the edge samples, spring 2010. *Green squares are sites downstream of the proposed discharge point; blue circles are upstream sites.*

Further investigation into the taxa dominating the samples found Diptera taxa to be present in high numbers across all riffle samples (Figure 3-10) with Simuliidae *Austrosimulium* (black flies) and the Chironomidae sub-family *Orthocladiinae* (non-biting midges) to be the most dominant (>50%) at all sites. These taxa, although common, are considered to be moderately sensitive to poor water quality as indicated by the SIGNAL-2 score of 5 and 4, respectively.

Only two other taxa not from the order Diptera were listed in the top five most dominant taxa for the riffle samples, including Oligochaeta (worms) and Hydroptilidae *Oxyethira* (microcaddis). Hydroptilidae taxa are within the Trichoptera order, and are part of the sensitive EPT taxa groupings.

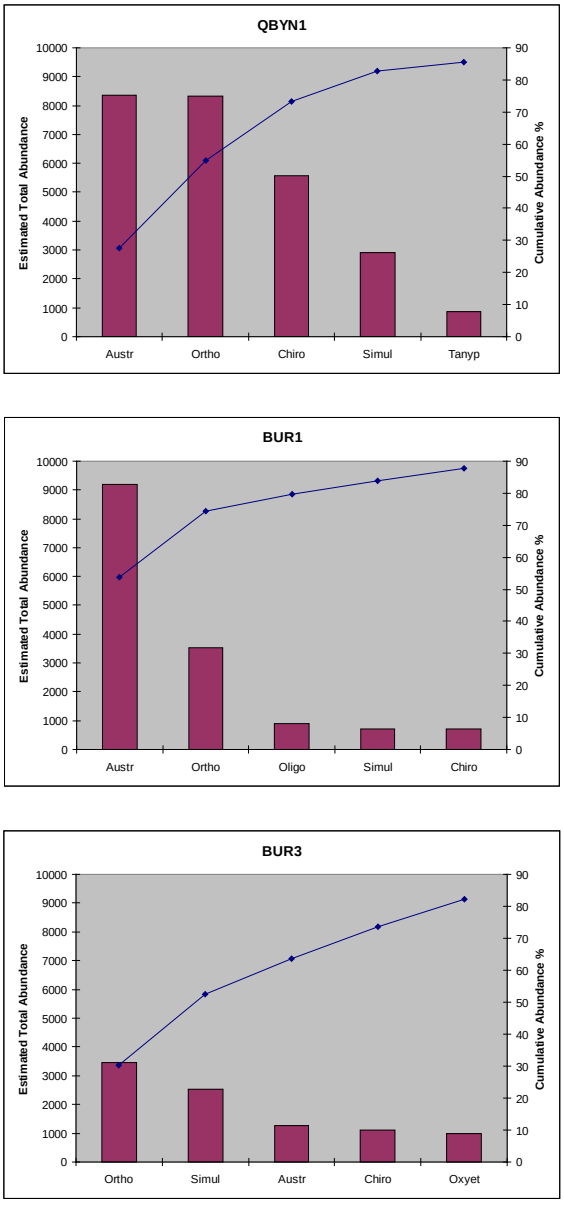


Figure 3-10: The estimated total abundance (3.5m^{-2}) and cumulative percentage of the five most abundant taxa within riffle samples from each site. See Table 3-6 for taxa abbreviation explanation.

Table 3-6: Key to abbreviated taxa names in Figure 3- 10 and 3- 11

Taxa from the EPT group are highlighted within the thicker border.

Abbreviation	Order [CLASS]	Family (*sub- family*)	*Genus*	SIGNAL- 2 score
Chiro	Diptera	*Chironominae*	*sp.*	3
Ortho	Diptera	*Orthocladiinae*	*sp.*	4
Tanyp	Diptera	*Tanypodinae*	*sp.*	4
Austr	Diptera	Simuliidae	*Austrosimulium*	5
Simul	Diptera	Simuliidae	*sp.*	5
Cloeo	Ephemeroptera	Baetidae	*Cloeon*	5
Baeti	Ephemeroptera	Baetidae	*sp.*	5
Notal	Trichoptera	Leptoceridae	*Notalina*	6
Oxyet	Trichoptera	Hydroptilidae	*Oxyethira*	4
Helly	Trichoptera	Hydroptilidae	*Hellyethira*	4
Physa	GASTROPODA	Physidae	*Physa*	1
Oligo	OLIGOCHAETA	--	--	2
Ceini	Amphipoda	Ceinidae	*sp.*	2

The most abundant animals in the edge samples included many Diptera taxa, with the Chironomidae sub-family's *Chironominae* and *Orthocladiinae* (non-biting midges) present in the five most dominant taxa at all sites.

Chironominae represented 65% of the abundance at site QBYN1, although this site also recorded two Trichoptera taxa within the top five most dominant, including Hydroptilidae *Oxyethira* (microcaddis) and Leptoceridae *Notalina* (stick caddis). Other dominant EPT taxa included the Baetidae taxa *Cloeon* and an unidentified *sp.* at sites BUR2A and BUR2B.

Ceinidae was the dominant taxon in edge samples at the Cassidy Creek site (CAS1), where it comprised >30 % of the community. However, this taxon was rare or absent at other sites, making up less than 1 % of individuals in the invertebrate assemblage.

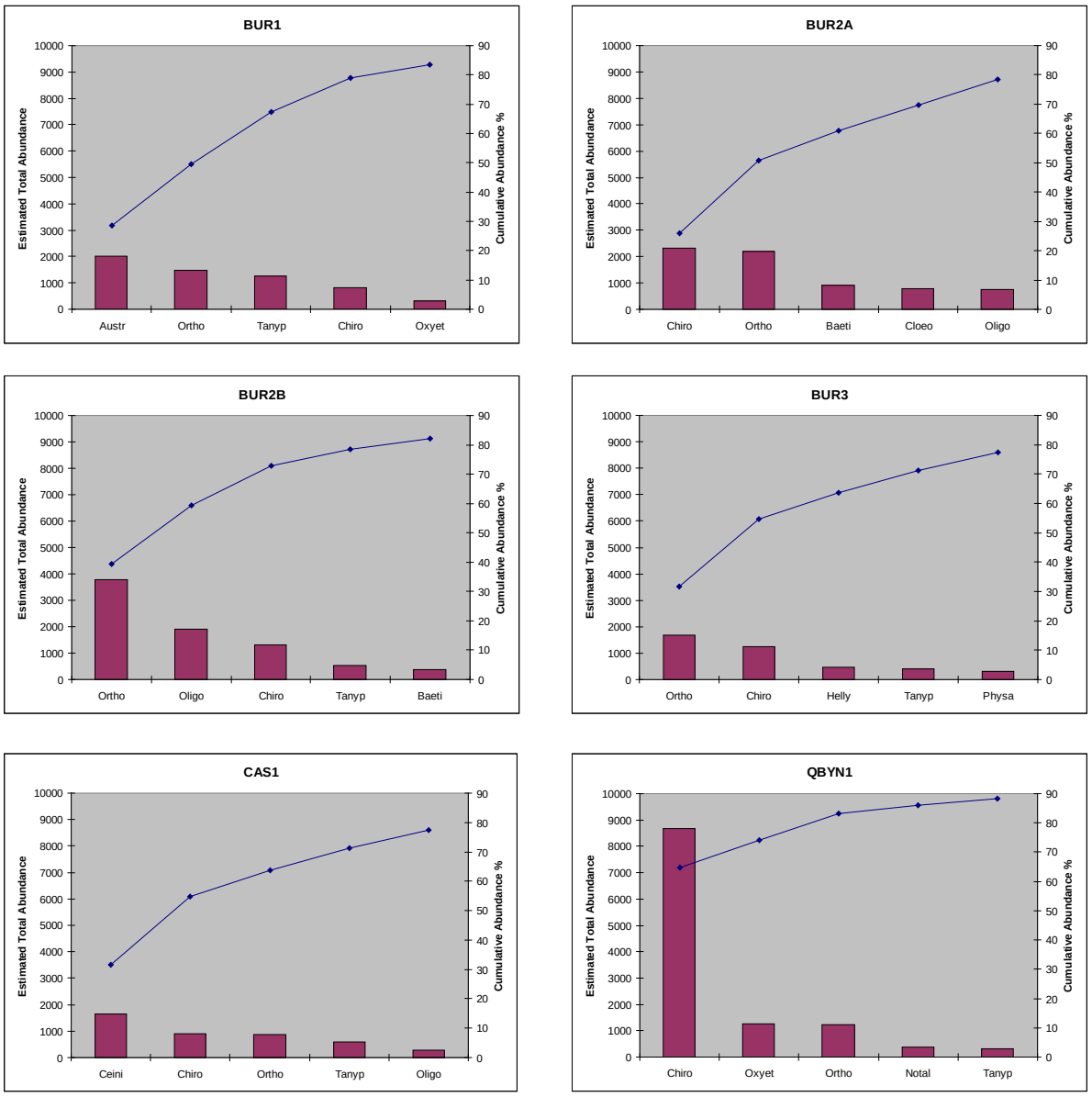


Figure 3-11: The total abundance (3.5m^{-2}) and cumulative percentage of the five most abundant taxa within edge samples from each site. See Table 3-6 for taxa abbreviation explanation.

The overall relative abundance of macroinvertebrates from edge habitats was much higher at the Queanbeyan River site (QBYN1) than at all other sites along Burra Creek. The QBYN1 samples contained an estimated 13000 animals compared to approximately 5400 from BUR3.

The SIGNAL-2 scores were relatively well distributed amongst the samples, with the lowest score recorded in an edge sample at site BUR2b (3.00), and the highest score recorded in a riffle sample at site BUR3 (4.90). Signal scores for the edge habitat

samples were generally lower in Burra Creek, although only one site was sampled along the Queanbeyan River.

The SIGNAL-2 scores were higher in the upstream sites than the sites downstream of the proposed pipeline discharge point (Figure 3-12).

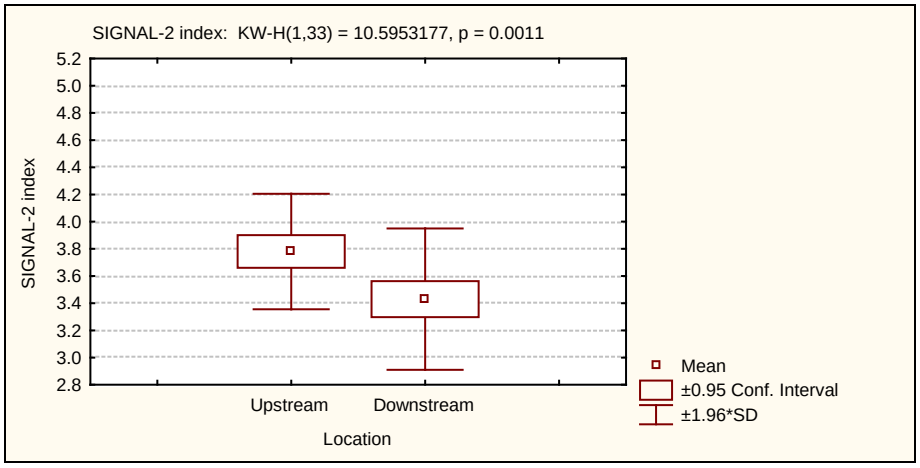


Figure 3-12: Ranked SIGNAL- 2 scores for edge samples grouped into upstream and downstream locations of the proposed pipeline discharge site.

Conversely, SIGNAL-2 scores for the riffle habitats recorded the opposite trend with the downstream site (BUR3) recording higher SIGNAL-2 scores than the upstream sites (QBYN1 and BUR1) (Figure 3-13).

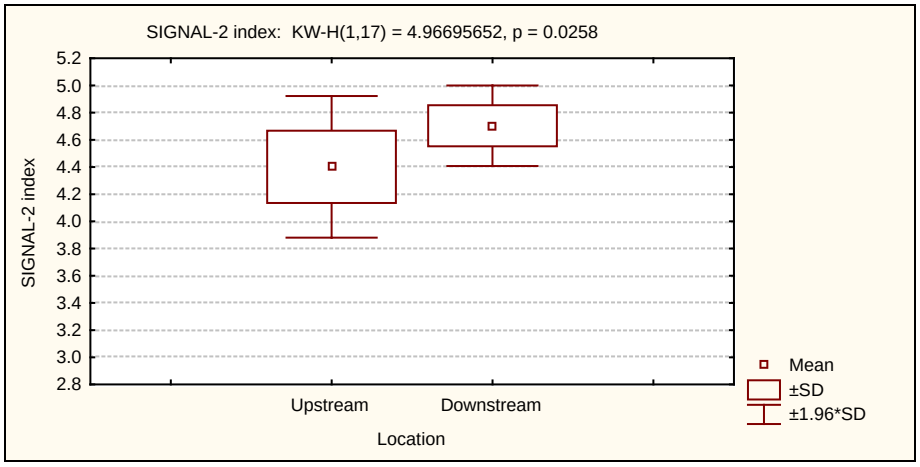


Figure 3-13: Ranked SIGNAL- 2 scores from riffle samples grouped into upstream and downstream locations of the proposed pipeline discharge site.

Most of the samples were within AUSRIVAS Band B (82% riffle, 52% edge), suggesting the sites were significantly impaired. However, the remaining samples all recorded a Band A, with site BUR3 recording the highest O/E50 scores for samples from both riffle and edge habitats. All sites recorded a mixture of Band A and B results across the samples, with no one dominant level of assessment.

The AUSRIVAS output for the riffle samples indicated several taxa with a greater than 50% likelihood of being present, but which were not collected during spring (Table 3-7). The greatest number of taxa absent from samples was from site BUR1, with 6 of the 9 taxa absent from all sample replicates for that site. Included in the absent taxa were families from the sensitive EPT groups, including Leptophlebiidae and Caenidae (Ephemeroptera), Gripopterygidae (Plecoptera), and Hydropsychidae (Trichoptera) (Table 3-7). Leptophlebiidae and Elmidae (Coleoptera) taxa were only collected in two samples, whereas Sphaeriidae (bivalves) and Hydropsychidae were not collected in any samples, yet all of these taxa are considered to be relatively common families in riffle environments.

Table 3-7: Taxa predicted with at least a 50% chance to be present within each sample, but which were not collected, riffle habitat spring 2010. Figures in table represent likelihood of occurrence.

Taxon Name	Sphaeriidae	Acarina	Elmidae	Ceratopogonidae	Tanypodinae	Leptophlebiidae	Caenidae	Gripopterygidae	Hydropsychidae
Signal Score	5	6	7	4	4	8	4	8	6
BUR1_K1_L1	0.56	0.71	0.91			0.77	0.86	0.82	0.51
BUR1_K1_L2	0.56		0.91			0.77	0.86	0.82	0.51
BUR1_K1_L3	0.56		0.91	0.5		0.77	0.86	0.82	0.51
BUR1_K2_L1	0.56		0.91			0.77	0.86	0.82	0.51
BUR1_K2_L2	0.56	0.71	0.91			0.77	0.86	0.82	0.51
BUR1_K2_L3	0.56	0.71	0.91			0.77	0.86	0.82	0.51
BUR3_K1_L1	0.5	0.73	0.92		0.75	0.79	0.87		0.52
BUR3_K1_L2	0.5		0.92			0.79	0.87	0.84	0.52
BUR3_K1_L3	0.5					0.79	0.87	0.84	0.52
BUR3_K2_L1	0.5		0.92						0.52
BUR3_K2_L2	0.5		0.92			0.79	0.87		0.52
QBYN1_K1_L1	0.52			0.51		0.78			0.52
QBYN1_K1_L2	0.52		0.91	0.51					0.52
QBYN1_K1_L3	0.52		0.91			0.78	0.87		0.52
QBYN1_K2_L1	0.52		0.91	0.51		0.78			0.52
QBYN1_K2_L2	0.52		0.91	0.51		0.78			0.52
QBYN1_K2_L3	0.52		0.91	0.51		0.78			0.52

The most common taxa predicted by the AUSRIVAS model which were not collected within the edge habitat samples across the sites were from the sensitive EPT taxa groupings, Gripopterygidae (Plecoptera), Caenidae and Leptophlebiidae (Ephemeroptera), and Leptoceridae (Trichoptera) (Table 3-8). Gripopterygidae were only recorded in 3 samples (2 x QBYN1, 1 x BUR2A), but were expected (>60%) at all sites. This family, and also Leptophlebiidae, are highly sensitive taxa as indicated by the signal score of 8 (Table 3-8). The remaining three sensitive taxa were also collected at varying abundances within a scatter of samples, but were all predicted at over 85% to occur at these sites. Most of the predicted taxa indicated in Table 3-8 were not collected from the upstream sites of BUR1 and QBYN1 (20 individuals).

Table 3-8: Taxa with at least a 50 % chance of occurring in each sample, but which were not collected, edge habitat spring 2010. Figures in table represent likelihood of occurrence.

Taxon Name	Oligochaeta	Acarina	Ceratopogonidae	Leptophlebiidae	Caenidae	Gripopterygidae	Leptoceridae
Signal Score	2	6	4	8	4	8	6
BUR1_E1_L1					0.93	0.75	
BUR1_E1_L2					0.93	0.75	
BUR1_E1_L3		0.55			0.93	0.75	
BUR1_E2_L1		0.55			0.93	0.75	0.89
BUR1_E2_L2		0.55		0.87	0.93	0.75	0.89
BUR1_E2_L3		0.55		0.87	0.93	0.75	
BUR2A_E1_L1			0.59	0.92	0.87	0.88	
BUR2A_E1_L2		0.7	0.59			0.88	
BUR2A_E1_L3			0.59			0.88	
BUR2A_E2_L1		0.7	0.59	0.92		0.88	
BUR2A_E2_L2							0.91
BUR2A_E2_L3						0.88	
BUR2B_E1_L1				0.85	0.94	0.69	0.89
BUR2B_E1_L2			0.63	0.85		0.69	0.89
BUR2B_E1_L3				0.85	0.94	0.69	
BUR2B_E2_L1			0.63			0.69	0.89
BUR2B_E2_L2		0.47				0.69	0.89
BUR2B_E2_L3						0.69	
BUR3_E1_L1						0.7	
BUR3_E1_L2					0.94	0.7	
BUR3_E1_L3						0.7	
BUR3_E2_L1			0.63			0.7	
BUR3_E2_L2		0.49				0.7	0.89
BUR3_E2_L3		0.49		0.85		0.7	
CAS1_E1_L1		0.38	0.65		0.94	0.62	0.88
CAS1_E1_L2			0.65			0.62	0.88
CAS1_E1_L3			0.65		0.94	0.62	0.88
QBYN1_E1_L1		0.57	0.61	0.87	0.94		
QBYN1_E1_L2	1		0.61		0.94	0.76	
QBYN1_E1_L3	1		0.61	0.87	0.94		
QBYN1_E2_L1	1					0.76	
QBYN1_E2_L2		0.57	0.61	0.87		0.76	
QBYN1_E2_L3	1					0.76	

3.5.2 Multivariate analysis

3.5.2.1 Riffle habitat

The ANOSIM test did detect differences between individual sites with the Global R statistic = 0.723 (p = 0.001), and pairwise tests indicated macroinvertebrate communities at sites QBYN1 and BUR1 were highly similar (R = 0.957; p=0.002), whilst comparisons with site BUR3 less so (R = 0.664, p = 0.002 QBYN1; R = 0.645, p=0.002 BUR1). This result was supported by the cluster dendrogram (Figure 3-14) and NMDS plot (Figure 3-15) for the riffle samples.

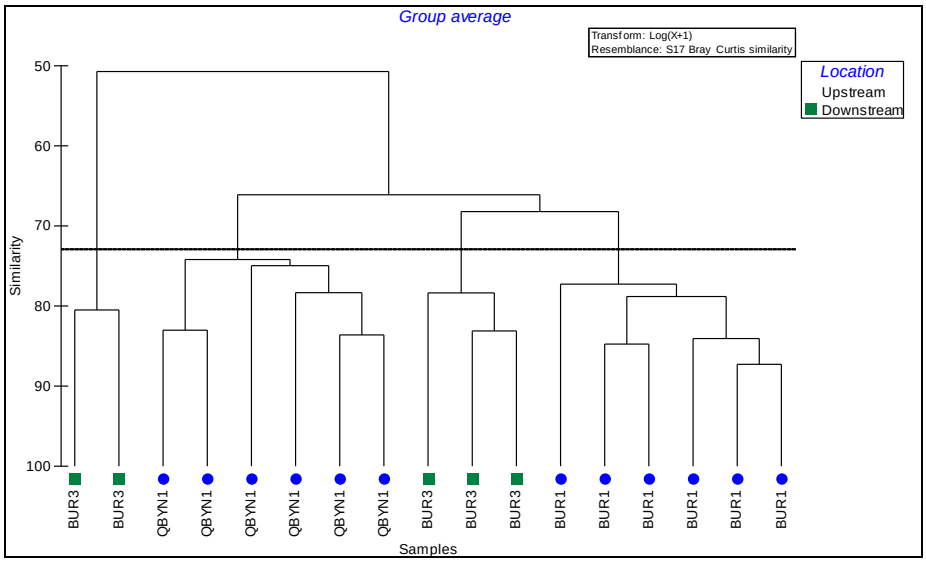


Figure 3-14: Cluster analysis based on genus level data for spring riffle samples. ***Green squares - downstream; blue circles - upstream. Slice line is at the 73% similarity level.***

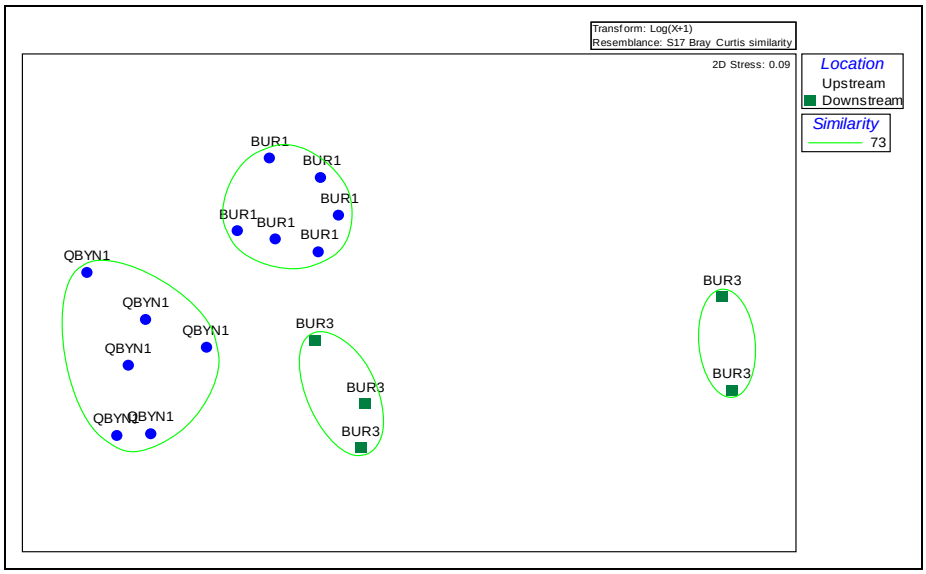


Figure 3-15: Non- metric multidimensional scaling (NMDS) of genus data for spring riffle samples. ***Green squares - downstream; blue circles - upstream. Ellipses are at the 73% similarity level.***

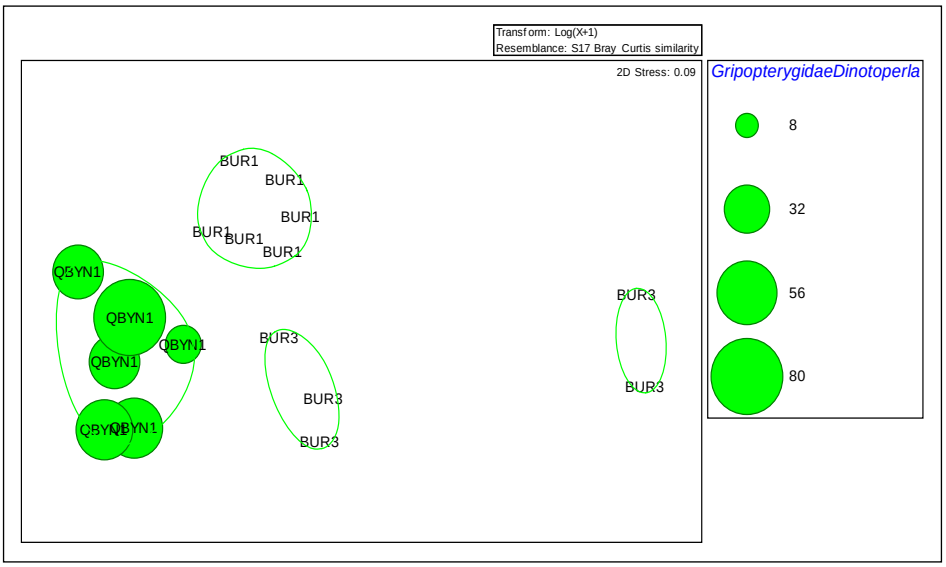
The multivariate analyses indicate a high level of intra-site variability at site BUR3, with two replicate samples containing approximately 50% similarity in macroinvertebrate community composition when compared to all other riffle samples. These two outlier replicates were the two laboratory sorted samples from the same field sample. All of the remaining samples group into site-specific clusters at the 73% similarity level. There are too few samples to determine any real separation between the site groupings of upstream and downstream locations. Unlike edge habitat sampling, downstream riffle habitat data is only available for a single site, BUR3. That site has high within-site variability in taxonomic composition making it difficult to tell whether the separation between the sample scores for upstream and downstream sites in Figure 3-15 represent real differences in community structure between upstream and downstream reaches or some local scale factor operating at site BUR3. As riffle habitat is limited at other downstream monitoring sites, new riffle sampling sites in the downstream reach may be required to allow for improved upstream-downstream comparisons as part of future rounds of monitoring. Whether or not such sites exist to allow for this still needs to be determined.

The SIMPER analysis results for riffle samples within-site, and also between-sites are presented in Table 3-9. Site BUR1 samples recorded the least dissimilarity, with approximately 80% of animals recorded at this site present within all replicate samples. QBYN1 recorded a 76% similarity in macroinvertebrate composition across replicate samples, whilst BUR3 recorded 65%.

Table 3-9: SIMPER results for samples collected from riffle habitats across sites, spring 2010.

	QBYN1	BUR1	BUR3
QBYN1	76.13		
BUR1	65.99	79.97	
BUR3	58.52	61.93	65.35

The main taxa differences between the Queanbeyan River site and Burra Creek sites related to several genera from the sensitive EPT orders. The major taxa differences are presented as bubble plots in whereby taxa abundances were superimposed on an NMDS as circles of varying diameters reflecting the abundance changes for those taxa across all samples. *Dinotoperla* (Gripoterygidae) was only recorded at QBYN1, and although several *Illiesoperla* were recorded at BUR3, no Plecoptera taxa were recorded at BUR1. *Baetidae Genus 2* also occurred in low numbers across riffle habitats. This genus was not identified from the samples at BUR1, but there were large numbers of early instar or damaged Baetids that it was not possible to identify beyond Family. Therefore, it is still possible that *Baetidae Genus 2* was present at BUR1, though undetected, in these specimens.



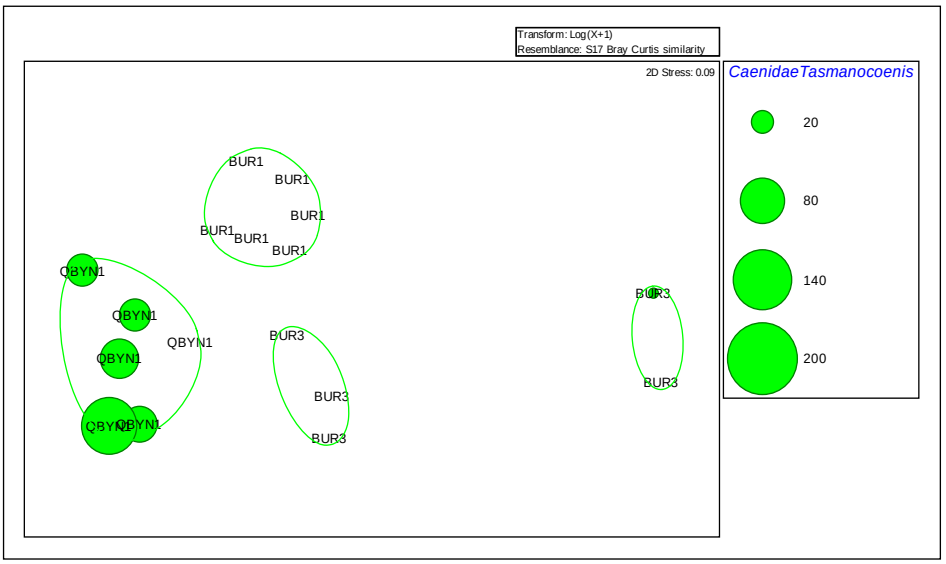


Figure 3-16: Bubble plots of selected taxa abundance across riffle samples, spring 2010.

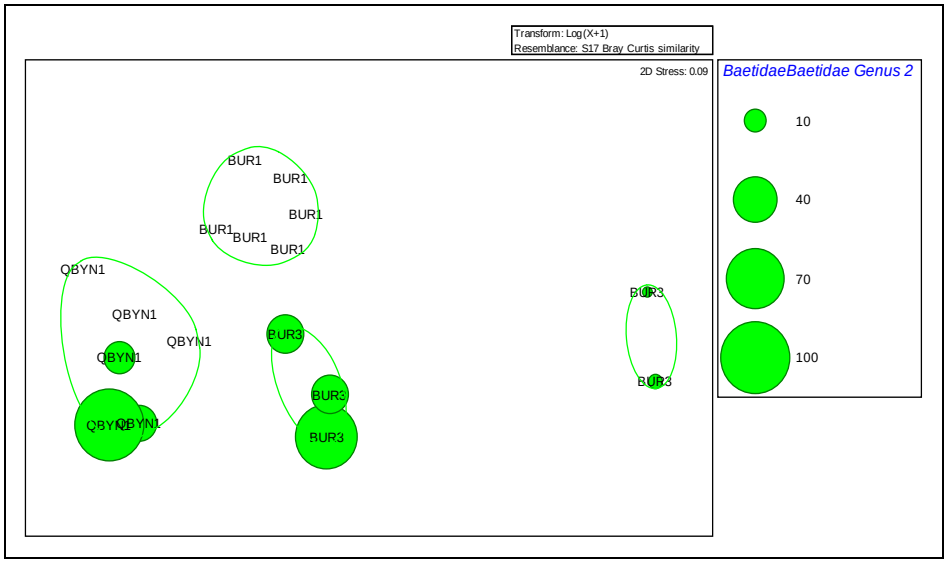


Figure 3-16 cont'd: Bubble plots of selected taxa abundance across riffle samples, spring 2010.

3.5.2.2 Edge habitat

The ANOSIM test on the edge samples detected significant differences between individual sites with the Global R statistic = 0.803 (p = 0.001), and pairwise tests indicated most within-site samples were highly similar in macroinvertebrate community composition and separate between sites, with the exception of BUR2A and BUR2B which although considered to be significant, resulted in a R statistic = 0.47 suggesting only moderate separation between samples. This result was further supported by the cluster dendrogram (Figure 3-17) and NMDS plot (Figure 3-15) for the edge samples.

There did appear to be a moderate separation in those sites located upstream and downstream of the proposed pipeline discharge point, although this separation occurred at the 60% level of similarity, suggesting more than half of the taxa collected were similar across all sites. Sites upstream appeared to be highly variable whereas sites downstream grouped quite closely within the multidimensional space.

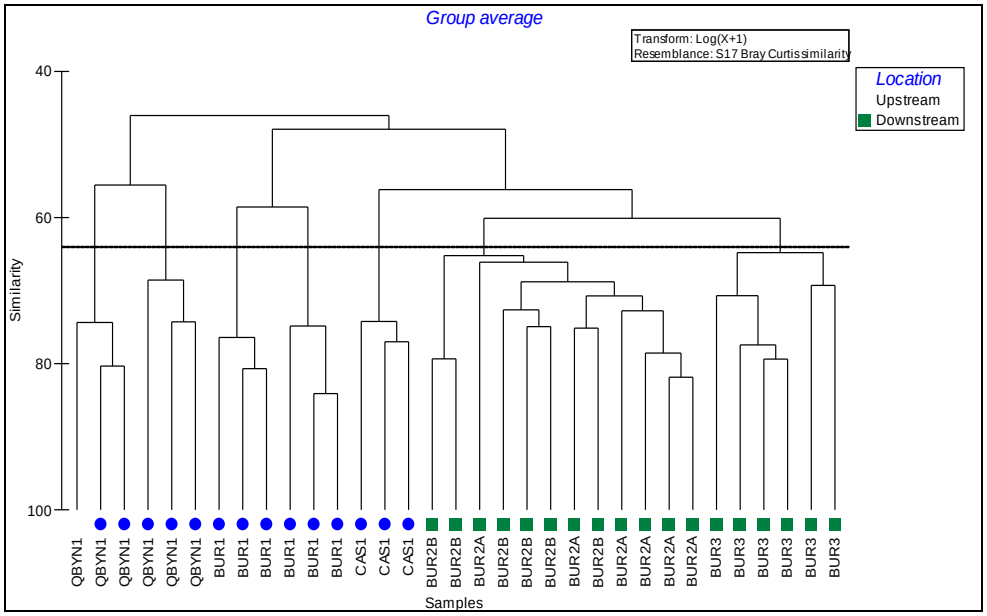


Figure 3-17: Cluster analysis based on genus level data for spring edge samples. ***Green squares - downstream; blue circles - upstream. Slice line is at 64% similarity.***

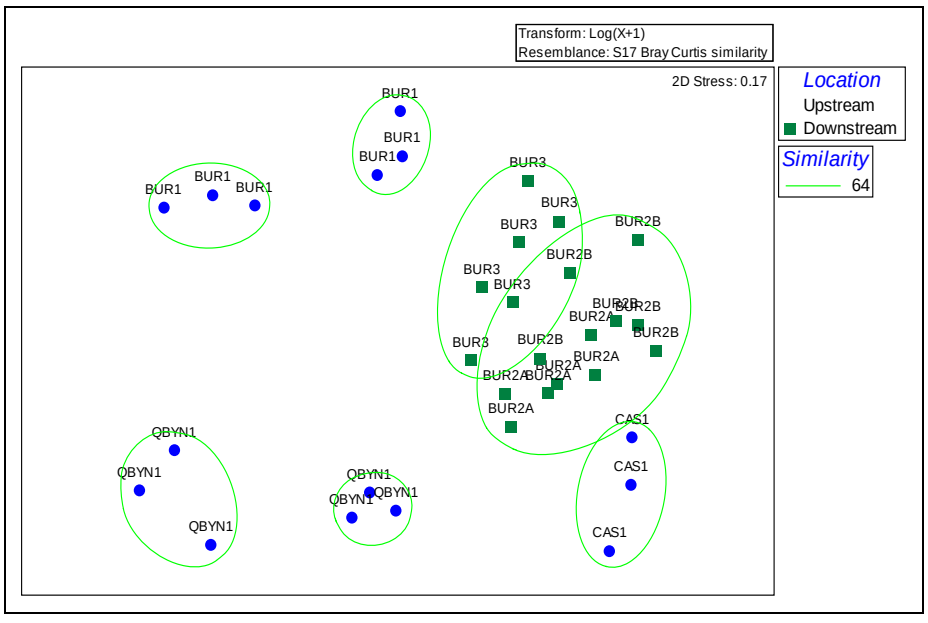


Figure 3-18: Non- metric multidimensional scaling (NMDS) of genus data from spring edge samples. ***Green squares – downstream; blue circles - upstream. Ellipses represent 64% similarity.***

The SIMPER analysis results for edge samples within-site, and also between-sites are presented in Table 3-10. Site CAS1 samples recorded the greatest similarity, with approximately 75% of animals recorded at this site present within all replicate samples. In contrast to the riffle samples, QBYN1 recorded the least within-site similarity (62%) in macroinvertebrate composition across replicate samples.

Table 3-10: SIMPER results for samples collected from edge habitats across sites, spring 2010.

	QBYN1	CAS1	BUR1	BUR2A	BUR2B	BUR3
QBYN1	62.64					
CAS1	42.48	75.12				
BUR1	45.67	45.49	66.24			
BUR2A	49.40	57.55	47.70	72.32		
BUR2B	43.45	57.64	47.51	66.66	69.86	
BUR3	47.06	53.16	49.48	59.59	60.50	68.89

While there were no clearly defined taxa separating out most of the groups of sites, SIMPER highlighted the Atyidae *Paratya* genera to be present only in the QBYN1 samples, and that Leptoceridae *Triplectides* was limited to the upstream sites (Figure 3-19).

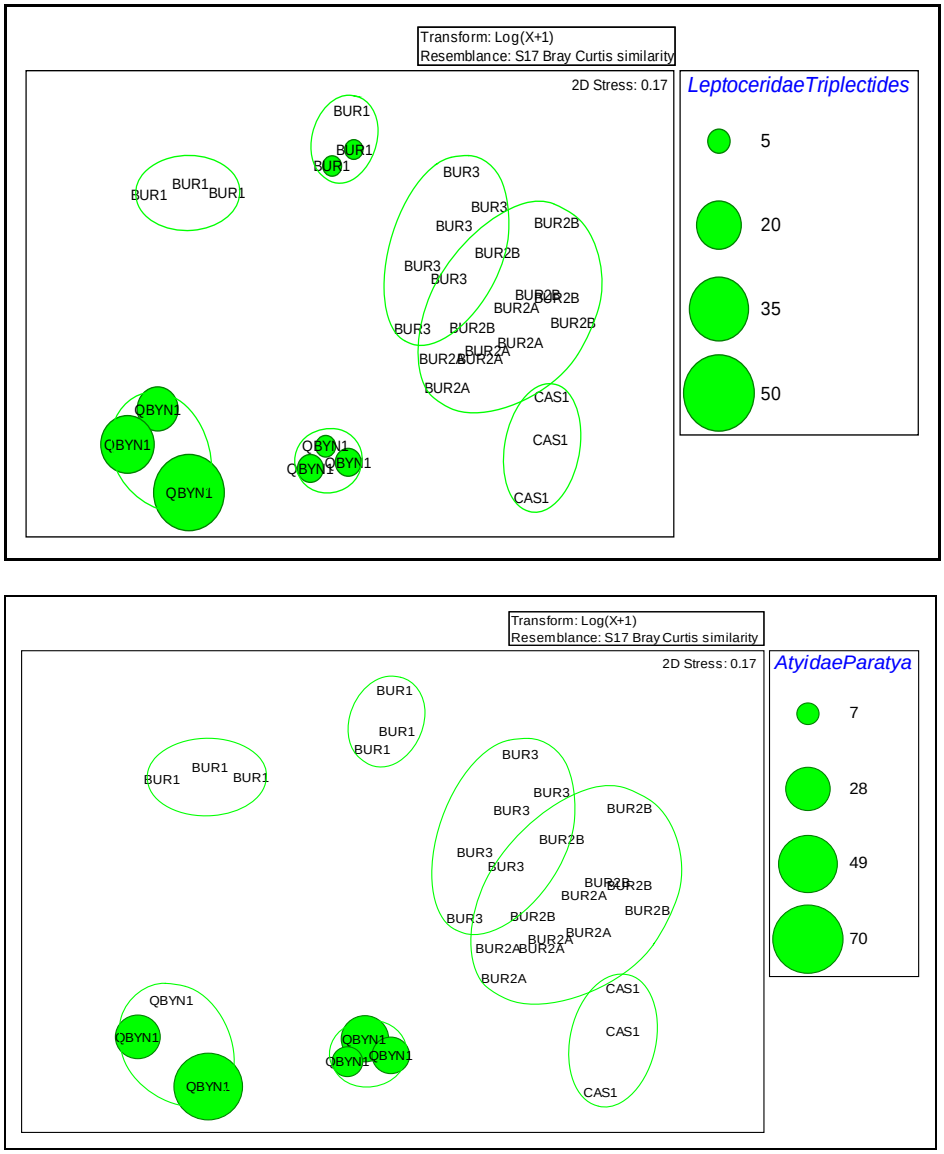


Figure 3-19: Bubble plots of selected taxa abundance across edge samples, spring 2010.

4 Discussion

4.1 Sampling conditions

The main influence on results from the spring program was the major flow events through both the Burra Creek and Queanbeyan River systems in relatively quick succession after a prolonged period of below average flows. The first event occurred during the first week of September, sustaining a flow of almost 900 ML over 3 days through the Burra Creek system and 6000 ML over 3 days in the Queanbeyan River system, with the second event occurring in mid-October approximately 3 weeks prior to sampling.

Sampling was completed on 5th November, at which time Burra Creek recorded flow of 3.7 ML/day and had remained stable (<10 ML/day) for approximately 16 days preceding the sampling event. The major flow event was recorded to peak at 780 ML/day on 15th October 2010 in Burra Creek before rapidly receding back to 10 ML/day within 7 days. Queanbeyan River recorded flow of 108.4 ML/day on the day of sampling, and similar to Burra Creek, recorded relatively stable conditions for several weeks preceding sampling (<200 ML/day). Usually, it is suggested that macroinvertebrate sampling be deferred for a minimum of 2-4 weeks post flooding (Turak et al, 2004; Nichols et al, 2000), which was the approach used for this sampling event. Consequently, due to the magnitude of the floods, it would be expected that some influence is likely to be observed on the macroinvertebrate communities within this set of results.

The influence these high intensity flooding flows have had on water quality, aquatic habitat quality, and macroinvertebrate community composition for this sampling round is further investigated below.

Of worthy note is the location of site QBYN2 below the full supply level of Googong Dam (Figure 4-1). While Googong Dam remains above the 80 % supply level this site will not service this project as a downstream site. It is recommended this site be removed from the program and another site established upstream of the full supply level influence if possible.

Figure 4-1: Site QBYN2 inundated by impounded water from Googong Dam at time of sampling for the spring 2010 event.

4.2 Water quality and periphyton

Continuous measurements indicated that changes in water quality, particularly spikes in turbidity coincided with the spring flow events.. Turbidity can influence aquatic ecosystems by reducing light penetration, and as a consequence, affect primary production (Kirk, 1985) and interfere with the breathing an feeding mechanisms of taxa (i.e. clogging of gills or feeding appendages) (Hellawell, 1986). However, since these spikes in turbidity were of a short duration they are unlikely to be the fundamental factor determining the current ecological river health assessment, given that localised adaptations by stream biota to short term spikes in turbidity associated with flow events are expected (Boulton and Lake, 1992).

Nutrient concentrations from some of the grab samples exceed the ANZECC and ARMCANZ (2000) Guidelines, including total nitrogen concentrations at all sites. One of the chief concerns regarding nutrient enrichment in the Burra Creek system is the potential for increased filamentous green algae and cyanobacteria (blue-green algae) growth, the rate at which is 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 reduced numbers sensitive macroinvertebrate taxa (Suren and Jowett, 2006). The control sites of BUR1 and QBYN1 recorded comparably low chlorophyll-a and AFDM measurements, but BUR3 recorded significantly higher concentrations for both parameters. This was not surprising given high percentage of growth observed on the substrate at this site (Figure 4-2).

Figure 4-2: periphyton growth observed at site BUR3 during spring 2010 sampling event.

While there is evidence here of slight nutrient enrichment in both the Burra Creek and Queanbeyan River system, elevated nitrate 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, the records to date indicate that the nutrient levels are below ANZECC and ARMCANZ (2000) guidelines and 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 associated with the drying phase of Burra Creek hydrology would limit the temporal extent of increased periphyton production in response to nutrient enhancement associated with high flow events.

Although nutrients are often limiting to algal growth (Biggs, 1989; Bowes et al., 2007), the sampling frequency applied in this study is likely to be insufficient to detect such trends. Over a period of six months, other environmental factors are likely to be influential to the growth rates and standing stock separating these factors from the observed periphyton. Further, as described in Ecowise (2009a), because periphyton growth is the cumulative effect of preceding water quality conditions, if there is a relationship between nutrients and growth rates, the sampling of water quality only at the time of biological sampling is unlikely to pick up these relationships.

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; although further investigations into the temporal trends will form part of the block assessment of baseline data post autumn 2011 program.

4.3 River health and patterns in macroinvertebrate communities

Taxa richness was variable across sites and habitats during the spring 2010 event, although no significant difference was detected between sites located upstream to those downstream of the proposed pipeline discharge location. There was a measurable difference between sites BUR3 and CAS1 for taxa collected from the edge habitats only, of which CAS1 recorded a significantly lower richness score than further downstream at BUR3. Noteworthy is the presence of a considerably different aquatic habitat structure between these two sites (Figure 4-3), where Cassidy's Creek has been completely encroached by vegetation.

Figure 4-3: Variable aquatic habitat present between CAS1 (left) and BUR3 (right), spring 2010.

Dominant taxa in the spring samples include several Diptera families such as Chironominae and Simuliidae taxa, and Ephemeroptera families such as Baetidae taxa. These taxa are disturbance tolerant with fast recovery times following floods (Robinson et al, 2004). However, the two floods in relatively quick succession are likely to have had a cumulative impact on the ecological response of biota of both systems, although the impact was probably greater in the smaller Burra Creek system. Consequently, the presence of taxa within each of the EPT groupings (albeit in reduced abundance) across both Burra and Queanbeyan systems indicated the resilience of many groups to recolonise within a couple of weeks after the mid-October event.

The spring AUSRIVAS results showed all sites had an overall poorer than reference condition (BAND–B) (82% riffle, 52% edge), with fewer taxa than expected by the AUSRIVAS model. Of those taxa predicted to occur in the riffle habitats, Elmidae (SIGNAL-2 = 7), Leptophlebiidae (SIGNAL-2 = 8) and Gripopterygidae (SIGNAL-2 = 8) would be considered to be the most sensitive to changes in the environment. These three taxa were not collected in any replicate samples from site BUR1, whilst they were present (albeit only in a select few samples) in samples from the remaining two sites. Gripopterygidae and Leptophlebiidae were also predicted to occur within the edge habitats, of which Gripopterygidae taxa were only collected in three samples (11%).

Flood magnitude obviously played an important role in dictating the kinds and amounts of refugia in the channels of streams (e.g. Cobb et al., 1992). For instance, the earlier flood may have increased the susceptibility of particular substrate patches to disturbance by the later flood, perhaps as suggested by Robinson et al (2004) by reducing the amount of fine sediments that can armour stream bottoms. The second flood in October was more intense than the previous September flood, most likely disturbing areas that were refugia during the smaller flood, thus causing a reduction in sources of potential colonists. Peterson et al. (1994) suggests that recovery of benthos may be influenced by the degree of disturbance in connection with the timing from a previous disturbance and the composition of the community in response to previous floods.

A similar size event in the Murrumbidgee River in spring 2009 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 low diversities seen in this study. 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 3 weeks had passed since the October event – the second event would have disrupted this process by removing colonising sensitive taxa.

In addition, because of the relatively rapid peak flow periods and minimal change in the continuously monitored water quality parameters, the relatively low richness and abundance taxa measurements may be the function of the high flows on scouring bedload transport and sheer forces (i.e. increased water velocities). For example, the turbidity results suggested fine material was mobilized during the flood peaks and remained mobile for several days following peak flow. Lawrence and Ward (1982) found a significant relationship between sediment release from a reservoir and decreases in macroinvertebrate abundances.

The abrupt flow increases by flooding also typically results in a major increase in drifting organisms (Irvine and Henriques, 1984; Imbert and Perry, 2000), an activity whereby taxa enter the water column and are transported downstream by the current. The displacement of individuals downstream during higher flows would likely contribute to the lower taxa abundance and richness results at upstream sites recorded in spring 2010. It could be assumed the receding flows of the post-September event would have allowed recolonisation to proceed to a point where many of the sensitive taxa may have been present in the community. However, the high intensity flow event which occurred mid-October coupled with the combined effects of bed load movement and high shear stress, would have dislodged much of the community. This scenario has been found elsewhere (e.g. Hynes, 1970a; Miller and Gollady, 1996; Suren and Jowett, 2006). However, with sampling not having been undertaken immediately prior to the high flow event community data these explanations cannot be confirmed.

The taxa richness recorded in the edge habitats was consistently higher at all sites in comparison to the riffle habitat samples. Boulton (1989) found that pools can act as refuges over summer in intermittent streams so it is equally feasible that they use the edge and backwater habitats as a refuge during periods of high flows. However, riffle habitats usually support a more diverse taxa community due to greater habitat heterogeneity, particle size, stream velocity and marginally higher

oxygen content (Thorp & Covich, 2001). With this in mind, it would be worth expanding the sampling program to include more riffle habitats within the experimental design as this habitat will be the most affected by the hydrological changes through the Burra Creek system from the M2G transfer.

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 of disturbance during this event.

5 Conclusions

The Burra Creek ecological monitoring program aims to establish the baseline river condition prior to water discharges into Burra Creek over a three year period, of which this report presents the findings of the Spring 2010 sampling event (5th baseline sampling). The main outcomes concluded from this sampling event are as follows:

Two major flow events occurred through both the Burra Creek and Queanbeyan River systems in relatively quick succession after a prolonged period of below average flows. The first event occurred during the first week of September, with a peak flow of approximately 1100 ML/d in Burra Creek and 6000 ML/d in the Queanbeyan River, with the second event occurring on 15 October with peak flows of approximately 3000ML/d and 10,000ML/d respectively, 3 weeks prior to sampling.

Site QBYN2 was located within the full supply level of Googong Dam, and will no longer service this project as a downstream site along that system should Googong Dam remain above the 80% supply level.

Continuous water quality measurements from the monitoring stations indicate changes in water quality results were coincident with the spring flow events, including a temporarily spike in turbidity. Consequently, since these water quality changes are short - term responses to natural changes in the system, they are unlikely to be the fundamental factor determining the current ecological river health assessment.

Some sediment nutrient concentrations exceeded the ANZECC and ARMCANZ (2000) Guidelines, including total nitrogen concentrations at all sites.

One of the chief concerns regarding nutrient enrichment in the Burra Creek system is the potential for increased filamentous green algae and cyanobacteria (blue-green algae) growth, the rate at which is determined partly by the level of nutrients in the water. The control sites of BUR1 and QBYN1 recorded comparably low periphyton results (chlorophyll-a and AFDM); however, BUR3 recorded significantly higher concentrations for both parameters.

Taxa richness was found to be variable across sites and habitats during the spring 2010 event. Although no significant difference was detected between sites located upstream to those downstream of the proposed pipeline discharge location.

Dominant taxa present in the spring samples included several Diptera families such as Chironominae and Simuliidae taxa, and Ephemeroptera families such as Baetidae taxa; all of which are known to be disturbance tolerant with fast recovery times following flooding flows; in addition to EPT groupings (albeit in reduced abundance) across both Burra and Queanbeyan systems indicated the resilience of many groups to recolonise within a couple of weeks after the mid-October event.

The spring AUSRIVAS results showed all sites to record an overall poorer than reference condition (BAND–B) (82% riffle, 52% edge), and a number of taxa predicted by the AUSRIVAS model but not recorded during this sampling event, including Elmidae (SIGNAL-2 = 7), Leptophlebiidae (SIGNAL-2 = 8) and Gripopterygidae (SIGNAL-2 = 8) from riffle habitats, and Gripopterygidae and Leptophlebiidae from edge habitats.

Flood magnitude obviously played a role in dictating the level of disturbance to stream bed habitat in terms of scouring. Recovery of benthos was likely influenced by flood magnitude and timing in relation to previous disturbance and the composition of the community at the time of the floods.

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 is 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. Groundwater 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 hyporheic zone (HZ) as a refuge for over-summering taxa, and during periods of flood and 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 in turn could impact upon the hyporheic fauna. It is recommended to undertake a pilot program collecting baseline survey data of the 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 hyporheic 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 ALS 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 AUSRIVAS sampling);
- Responses to various flow regimes, including large spates and increasing number of flow days since re-wetting

A comprehensive understanding of this system in relation to changing flow would involve a more intensive sampling regime, but would provide ActewAGL with a more

detailed assessment which would fill a large knowledge gap existing in this system at present. We recommend that future sampling be extended to cover summer and winter as well as the autumn and spring sampling. We also recommend event based sampling of refugial pools to assess the nature of recovery by macroinvertebrates following spates. This will provide greater predictive capacity in terms of assessing potential impacts of the proposed M2G water transfer on macroinvertebrates in Burra Creek.

In addition to the recommendations above, other recommendations are highlighted as an outcome from this most recent sampling event, including:

4) The necessity to locate additional riffle habitat sites in downstream reaches of Burra Creek as they usually support a more diverse taxa community and therefore would respond to fluctuations hydrological changes through the Burra Creek system from the M2G transfer and currently upstream-downstream comparisons based on riffle habitat community data is somewhat limited..

5) Undertake an extensive temporal assessment of all baseline data collected biannually since spring 2008 as part of the autumn 2011 reporting task. A total of 6 sampling events would be completed providing a robust dataset prior to the commencement of water transfers.

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APPENDIX A-
Site Photos

BURRA 1

Looking upstream into the Tinderry nature reserve

Limited edge habitat

CASSIDY CREEK

A view looking south-west from the confluence bridge highlighting the extent of channel inundation

Isolated pool, inundated with *Typha sp.*

BURRA 2a

Looking downstream from Williamsdale Bridge

Looking upstream of Williamsdale Bridge

BURRA 2b

Looking downstream from Burra Road bridge

Sampling edge habitat, downstream of Burra Road bridge

BURRA 3

Riffle Habitat

Looking downstream towards Draw down Crossing

QUEANBEYAN 1

Riffle habitat

Looking downstream from Flynn's Crossing

APPENDIX B-
Periphyton Results

SITE	location	Impact	logCHLA	logAFDM	CHLA	AFDM
BUR 1	Burra	u	3.40094	2.94419	2517.331	879.4081
BUR 1	Burra	u	3.201368	3.460643	1589.893	2888.306
BUR 1	Burra	u	2.997248	3.487675	993.6834	3073.794
BUR 1	Burra	u	3.444406	3.456641	2782.313	2861.808
BUR 1	Burra	u	3.122187	3.813268	1324.911	6505.314
BUR 1	Burra	u	3.051606	3.326307	1126.174	2119.858
BUR 3	Burra	d	4.09991	3.658745	12586.66	4557.694
BUR 3	Burra	d	4.076429	4.120882	11924.2	13209.36
BUR 3	Burra	d	3.640701	3.553551	4372.207	3577.26
BUR 3	Burra	d	3.143376	4.098995	1391.157	12560.16
BUR 3	Burra	d	3.672415	3.783999	4703.435	6081.342
BUR 3	Burra	d	3.454625	3.456641	2848.559	2861.808
QBYN 1	Queanbeyan	u	3.423217	3.215608	2649.822	1642.89
QBYN 1	Queanbeyan	u	3.23613	3.315311	1722.384	2066.861
QBYN 1	Queanbeyan	u	3.352636	3.382258	2252.349	2411.338
QBYN 1	Queanbeyan	u	3.474369	3.147493	2981.05	1404.406
QBYN 1	Queanbeyan	u	1.724247	3.262066	52.99645	1828.377
QBYN 1	Queanbeyan	u	3.511353	3.277523	3246.032	1894.623
QBYN 2	Queanbeyan	d	ns	ns	ns	ns
QBYN 2	Queanbeyan	d	ns	ns	ns	ns
QBYN 2	Queanbeyan	d	ns	ns	ns	ns
QBYN 2	Queanbeyan	d	ns	ns	ns	ns
QBYN 2	Queanbeyan	d	ns	ns	ns	ns
QBYN 2	Queanbeyan	d	ns	ns	ns	ns

APPENDIX C-
Macroinvertebrate Results

EDGE TAXA

Taxa	QBYN1_E1_L1	QBYN1_E1_L2	QBYN1_E1_L3	QBYN1_E2_L1	QBYN1_E2_L2	QBYN1_E2_L3	BUR1_E1_L1	BUR1_E1_L2	BUR1_E1_L3	BUR1_E2_L1	BUR1_E2_L2	BUR1_E2_L3	BUR2A_E1_L1	BUR2A_E1_L2	BUR2A_E1_L3	BUR2A_E2_L1	BUR2A_E2_L2	BUR2A_E2_L3	BUR2B_E1_L1	BUR2B_E1_L2	BUR2B_E1_L3	BUR2B_E2_L1	BUR2B_E2_L2	BUR2B_E2_L3	BUR3_E1_L1	BUR3_E1_L2	BUR3_E1_L3	BUR3_E2_L1	BUR3_E2_L2	BUR3_E2_L3	CAS1_E1_L1	CAS1_E1_L2	CAS1_E1_L3
Acarinasp.	0	33	29	8	0	3	4	3	0	0	0	0	5	0	6	0	12	7	20	27	8	5	0	13	3	3	3	5	0	0	0	6	7
AeschnidaeBrevyistyla	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	3	0	0	0	0	0	0
AeshnidaeAnox Papuensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	5	4	0	0	0	0	0	0	0	0	0
AmphipodaCeinidae	0	0	14	24	20	20	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	4	7	3	7	25	0	9	463	650	520
AncylidaeFerrissia	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0
AtyidaeParatya	67	0	29	32	20	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BaetidaeCloeon	0	0	0	8	7	3	4	0	3	0	0	0	74	213	150	147	82	107	40	55	17	55	40	25	7	20	20	5	10	9	16	25	27
CaenidaeTasmanocoenis	0	0	0	8	13	7	0	0	0	0	0	0	0	7	6	7	0	7	0	9	0	5	25	4	3	0	3	10	30	5	0	6	0
CalamatoceridaeAnisocentropus	0	0	0	0	10	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CeratopogonidaeCeratopoginae	0	0	0	20	0	7	18	10	3	17	6	20	0	0	0	0	6	7	10	0	8	0	10	4	10	10	17	0	15	9	0	0	0
CoenagrionidaeIschnura	0	0	0	4	10	13	0	0	0	0	0	0	5	13	17	27	0	13	30	0	50	0	15	8	13	10	10	15	15	0	0	0	0
ColeopteraCurculionidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0
ColeopteraDytiscidae	0	0	0	0	0	0	11	7	3	0	0	0	5	0	0	27	0	0	0	36	17	5	10	13	30	10	13	20	0	0	0	0	7
ColeopteraElmidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0
ColeopteraHydrophilidae	0	0	0	0	0	0	0	0	0	6	6	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ColeopteraScirtidae	0	0	0	0	0	0	14	3	13	11	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0
Collembolasp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	9	0	0	0	0	0	0	0	0	0	0	0	0	0
Copepodasp.	0	0	0	0	0	0	0	0	0	0	0	0	11	20	6	7	0	0	30	27	0	5	5	4	0	0	0	0	5	0	0	0	7
CorixidaeMicronecta	0	0	0	0	0	0	0	0	0	0	0	0	0	7	11	0	0	13	0	0	0	0	0	4	13	13	7	0	0	0	5	0	0
DipteraChironomidae	0	0	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	8	0	0	0	0	0	0	0	0	0	0	0	0
DipteraChironominae	2567	2517	2343	464	403	393	132	127	147	100	169	140	295	333	272	393	476	540	260	336	242	115	190	167	190	197	200	200	250	195	142	319	453
DipteraCulicidae	0	0	0	0	0	0	0	0	7	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DipteraCulicidae	0	0	0	28	7	7	11	27	10	6	6	7	0	0	0	0	0	0	60	9	17	5	0	4	7	0	0	5	20	41	5	0	0
DipteraDixidae	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	10	14	11	6	40
DipteraOrthocladiinae	350	383	357	56	33	37	232	197	237	206	338	260	358	360	350	307	329	480	920	891	808	390	390	367	230	253	183	365	370	291	274	281	300
DipteraPsychodidae	0	0	0	0	0	0	0	3	10	0	6	0	0	0	0	0	0	0	10	0	8	0	0	0	0	0	0	5	20	14	0	0	0
DipteraSciomyzidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	10	0	0	0	0	0	0
DipteraSimuliidae	0	17	57	0	7	0	0	0	3	72	25	33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	10	0	0	0	0
DipteraTanypodinae	50	33	57	56	73	50	229	193	227	217	225	173	111	140	83	127	135	67	50	18	100	100	130	125	30	40	40	100	120	77	158	206	233
DipteraTipulidae	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DytiscidaeAntiporus	0	0	0	0	0	0	4	3	7	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	5	0	0	5	6	0
DytiscidaeHydrovatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0
DytiscidaeNecterosoma	0	0	0	0	0	0	21	17	7	6	6	0	21	20	6	20	0	7	60	27	42	25	20	13	3	27	0	10	20	32	0	6	0
DytiscidaePlatynectes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	0	0	0	5	0	0	0
DytiscidaeRhantus	0	0	0	0	0	0	0	3	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0
EphemeropteraBaetidae	33	33	14	20	10	10	4	3	7	50	81	33	174	273	178	67	59	167	70	100	100	25	40	29	7	0	13	10	5	0	26	31	33
EphemeropteraCaenidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EphemeropteraLeptophlebiidae	0	0	0	4	0	0	4	3	3	6	0	0	0	0	0	0	6	20	0	0	0	5	5	4	3	3	0	5	0	0	5	13	13

Taxa	QBYN1_E1_L1	QBYN1_E1_L2	QBYN1_E1_L3	QBYN1_E2_L1	QBYN1_E2_L2	QBYN1_E2_L3	BUR1_E1_L1	BUR1_E1_L2	BUR1_E1_L3	BUR1_E2_L1	BUR1_E2_L2	BUR1_E2_L3	BUR2A_E1_L1	BUR2A_E1_L2	BUR2A_E1_L3	BUR2A_E2_L1	BUR2A_E2_L2	BUR2A_E2_L3	BUR2B_E1_L1	BUR2B_E1_L2	BUR2B_E1_L3	BUR2B_E2_L1	BUR2B_E2_L2	BUR2B_E2_L3	BUR3_E1_L1	BUR3_E1_L2	BUR3_E1_L3	BUR3_E2_L1	BUR3_E2_L2	BUR3_E2_L3	CAS1_E1_L1	CAS1_E1_L2	CAS1_E1_L3
GastropodaLymnaeidae	33	0	14	4	0	3	11	7	0	11	0	0	0	7	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0	5	0	0	7
GastropodaPlanorbidae	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gastropodasp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0
GripopterygidaeDinotoperla	67	0	14	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HemipteraCorixidae	0	0	0	0	0	0	7	17	0	0	0	0	0	7	0	13	12	0	0	9	0	0	0	4	0	0	0	0	0	0	0	31	7
HemipteraNotonectidae	0	0	0	0	0	0	11	10	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	20	33	5	10	14	0	25	0
HydraenidaeHydraena	0	17	43	0	0	0	4	10	7	22	19	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0
HydrochidaeHydrochus	0	0	0	0	0	0	0	0	3	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HydrophilidaeBerosus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0
HydroptilidaeHellyethira	0	0	0	0	3	0	7	10	17	0	6	0	5	60	28	40	29	67	30	64	50	15	5	17	77	53	63	120	95	73	0	6	7
HydroptilidaeOxyethira	383	467	371	20	17	10	7	0	0	100	125	87	0	0	0	0	6	13	0	0	0	0	0	4	10	3	7	0	0	9	0	0	0
LeptoceridaeNotalina	100	100	57	36	30	47	0	0	0	0	0	0	0	7	6	7	0	13	0	0	8	0	0	13	13	27	10	15	0	5	0	0	0
LeptoceridaeOecetis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0
LeptoceridaeTriaenodes	0	0	0	0	0	0	7	3	17	0	0	13	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
LeptoceridaeTriplectides	50	17	29	4	7	7	4	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LeptophlebiidaeAtalophlebia	0	0	0	4	0	7	0	0	0	0	0	0	0	7	6	0	0	27	0	0	0	0	0	4	3	0	3	10	5	0	0	0	13
LeptophlebiidaeJappa	0	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LymnaeidaePseudosuccinea	0	50	0	0	0	3	0	0	0	0	0	0	0	0	0	0	6	7	0	0	8	0	0	8	0	10	10	5	10	0	5	6	0
NotonectidaeEnithares	0	0	0	4	0	0	0	0	3	0	0	0	0	0	6	0	6	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
NotonectidaeParanisops	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	7	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OdonataEpiproctophora	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0
OdonataGomphidae	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OdonataLibellulidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	5	0	0	0	0
OdonataZygoptera	0	0	0	4	10	3	0	0	0	0	0	0	37	13	11	0	6	7	0	9	0	35	10	29	0	0	0	0	0	5	11	6	13
Oligochaetasp.	17	0	0	0	13	0	4	10	3	33	25	13	47	53	22	387	194	53	450	427	383	235	260	154	40	10	20	15	10	32	68	144	60
ParastacidaeCherax	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0
PhysidaePhysa	17	17	0	36	13	20	4	7	7	0	0	0	63	53	50	40	35	53	100	36	92	0	15	42	50	20	40	80	40	95	0	0	0
Planorbidae/physidaesp.	0	0	14	0	0	3	0	0	0	0	19	7	11	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PlanorbidaeGlyptophysa	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PlanorbidaePygmanisus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0
PlecopteraGripopterygidae	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plecopterasp.	0	0	0	0	0	0	4	0	0	11	6	13	0	7	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
SialidaeStenosialis	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SimuliidaeAustrosimulium	17	83	129	12	3	10	36	47	40	556	688	660	11	13	6	7	6	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SimuliidaeSimulium	0	0	0	0	0	0	4	0	3	6	0	0	0	0	6	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
StratiomyidaeOdontomyia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0
SynlestidaeSynlestes	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TrichopteraHydrobiosidae	0	0	0	0	0	0	0	0	0	0	6	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TrichopteraHydroptilidae	0	0	0	0	0	0	0	0	0	0	0	27	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0
TrichopteraLeptoceridae	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Taxa	QBYN1_E1_L1	QBYN1_E1_L2	QBYN1_E1_L3	QBYN1_E2_L1	QBYN1_E2_L2	QBYN1_E2_L3	BUR1_E1_L1	BUR1_E1_L2	BUR1_E1_L3	BUR1_E2_L1	BUR1_E2_L2	BUR1_E2_L3	BUR2A_E1_L1	BUR2A_E1_L2	BUR2A_E1_L3	BUR2A_E2_L1	BUR2A_E2_L2	BUR2A_E2_L3	BUR2B_E1_L1	BUR2B_E1_L2	BUR2B_E1_L3	BUR2B_E2_L1	BUR2B_E2_L2	BUR2B_E2_L3	BUR3_E1_L1	BUR3_E1_L2	BUR3_E1_L3	BUR3_E2_L1	BUR3_E2_L2	BUR3_E2_L3	CAS1_E1_L1	CAS1_E1_L2	CAS1_E1_L3
Trichopterasp.	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TurbellariaDugesiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Veliidaeimmature/damaged	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	5	0	0	0	0	7
abundance	3783	3783	3586	868	713	687	796	723	817	1444	1769	1507	1247	1640	1222	1640	1424	1687	2190	2100	1983	1045	1195	1071	800	747	723	1050	1075	955	1200	1775	1753

RIFFLE TAXA	QBYN1_K1_L1	QBYN1_K1_L2	QBYN1_K1_L3	QBYN1_K2_L1	QBYN1_K2_L2	QBYN1_K2_L3	BUR1 _K1_L1	BUR1 _K1_L2	BUR1 _K1_L3	BUR1_K2_L1	BUR1_K2_L2	BUR1_K2_L3	BUR3_K1_L1	BUR3_K1_L2	BUR3_K1_L3	BUR3_K2_L1	BUR3_K2_L2
Acarinasp.	20	40	60	25	50	40	0	13	11	10	0	0	0	43	29	2	2
AtyidaeParatya	0	0	0	0	0	0	0	13	0	0	0	0	0	0	0	0	0
BaetidaeBaetidae Genus 2	0	20	0	25	100	0	0	0	0	0	0	0	80	29	29	2	4
BaetidaeCloeon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0
CaenidaeTasmanocoenis	40	60	0	50	125	40	0	0	0	0	0	0	0	0	0	4	0
CeratopogonidaeCeratopogin ae	0	0	20	0	0	0	38	13	0	30	30	30	280	271	114	34	18
ColeopteraDytiscidae	0	0	0	0	0	0	0	0	11	0	0	0	0	0	0	0	0
ColeopteraGyrinidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0
ColeopteraScirtidae	0	0	0	0	0	0	0	0	0	10	0	10	20	0	0	0	2
Copepodasp.	0	0	0	0	0	0	0	0	0	10	0	10	0	0	0	0	0
DipteraChironominae	680	660	720	1300	1400	820	113	175	122	120	40	130	240	371	314	100	86
DipteraDolichopodidae	40	20	20	0	0	20	0	0	0	0	10	0	0	0	0	0	0

DipteraEmpididae	0	0	0	0	25	0	0	0	0	0	0	0	0	0	0	0	0
DipteraOrthocladiinae	1360	1520	1520	1550	1225	1160	525	625	511	600	570	690	1320	886	1014	120	106
DipteraPsychodidae	0	0	0	0	0	0	0	0	11	0	0	0	0	0	0	0	0
DipteraSimuliidae	380	380	620	350	725	440	163	163	167	40	90	90	900	757	857	4	2
DipteraTabanidae	0	0	0	25	0	0	0	0	0	0	0	0	0	0	0	0	0
DipteraTanypodinae	80	120	160	150	225	120	138	163	111	110	120	50	0	43	29	30	28
DipteraTipulidae	0	0	0	0	0	0	0	0	0	0	30	0	0	0	14	0	0
DytiscidaeNecterosoma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
DytiscidaePlatynectes	20	0	0	0	0	0	0	13	0	10	30	10	0	0	0	2	0
EcnomidaeEcnomus	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ElmidaeAustrolimnius	20	0	0	0	0	0	0	0	0	0	0	0	0	0	29	0	0
EphemeropteraBaetidae	60	60	40	75	25	40	25	88	44	30	50	40	0	14	0	0	0
EphemeropteraCaenidae	0	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EphemeropteraLeptophlebiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
GastropodaLymnaeidae	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0

GripopterygidaeDinotoperla	40	40	20	50	50	80	0	0	0	0	0	0	0	0	0	0	0
GripopterygidaeIlliesoperla	0	0	20	125	75	0	0	0	0	0	0	0	20	0	0	2	2
HydraenidaeHydraena	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0
HydrobiosidaeAustrochorema	0	0	0	100	25	0	0	0	0	0	0	0	0	0	0	0	0
HydrobiosidaePsyllobetina	0	0	0	0	0	40	0	13	0	30	0	0	0	0	0	0	0
HydrobiosidaeTaschorema	0	0	20	0	25	0	0	0	11	0	10	20	0	0	0	6	0
HydrobiosidaeUlmerochorem a	0	0	0	0	25	0	0	0	0	0	0	0	0	0	0	0	0
HydroptilidaeHellyethira	20	0	0	0	0	0	0	0	0	0	0	0	0	43	0	4	4
HydroptilidaeOxyethira	80	180	60	150	100	260	25	25	22	0	30	20	400	200	257	60	70
LeptophlebiidaeAtalophlebia	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
LymnaeidaePseudosuccinea	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0
Oligochaetasp.	100	80	140	175	150	40	63	88	89	250	260	160	160	129	86	38	22
PhysidaePhysa	0	0	0	0	25	0	0	0	0	0	0	0	0	0	0	0	0
PlanorbidaePygmanisus	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PlecopteraGripopterygidae	0	0	60	0	0	20	0	0	0	0	0	0	0	0	0	0	0

Plecopterasp.	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SimuliidaeAustrosimulium	1220	1580	1160	1450	1575	1380	1725	1588	1300	1560	1610	1420	580	386	300	0	2
SimuliidaeSimulium	160	60	0	25	100	100	63	88	44	50	70	40	140	71	29	2	0
TrichopteraHydrobiosidae	60	0	60	0	25	40	13	13	11	40	30	10	40	29	14	0	0
TrichopteraHydroptilidae	0	0	0	0	0	0	25	13	11	0	0	0	0	0	0	0	0
abundance	4460	4900	4700	5625	6075	4640	2913	3088	2478	2900	3000	2740	4180	3271	3143	416	348