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ACTEW Water

Murrumbidgee Ecological Monitoring Program

Part 2: Burra Creek

Autumn 2012

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List of Abbreviations

ACT – Australian Capital Territory
ACTEW – ACTEW Corporation Limited
AFDM – Ash Free Dry Mass (periphyton)
ALS – Australian Laboratory Services
ANOSIM – Analysis of similarities
ANOVA – Analysis of Variance (statistics)
ANZECC –Australian and New Zealand Environment and Conservation Council
APHA – American Public Health Association
ARMCANZ – Agriculture and Resource management Council of Australia and New Zealand
AUSRIVAS – Australian River Assessment System
BACI – Before After Control Impact
CMA – Catchment Management Authority
CPOM – Coarse Particulate Organic Matter
CRCFE – Cooperative Research Centre for Freshwater Ecology
EC – Electrical Conductivity
EIS – Environmental Impact Statement
EPA – Environmental Protection Authority
EPT – Ephemeroptera, Plecoptera and Trichoptera taxa
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
PERMANOVA – PERMutational Multiple Analysis Of Variance
QA – Quality Assurance
QC – Quality Control
SIMPER – Similarity Percentages
TN – Total Nitrogen
TP – Total Phosphorus

Executive Summary

ACTEW Water 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. The pumping system will transfer water through an underground pipeline into Burra Creek, and then transfer the water by 'run of river' flows into the Googong Reservoir. The system is designed to enable pumping of up to 100 ML/d, and is to be operational in August 2012. Abstraction from the Murrumbidgee River and its subsequent transfer and release into Burra Creek will be primarily dictated by the level of demand for the water, the availability of water and whether the Murrumbidgee River water quality complies with the EPA trigger levels. The project is referred to as Murrumbidgee to Googong transfer project (M2G).

The transfer of water will increase the base flow of Burra Creek noticeably, 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, if any, are attributable to water discharges from the Murrumbidgee River into Burra Creek.

The key aims of the sampling program are to:

- *Provide ACTEW Water with river health assessments based on AUSRIVAS protocols at sites upstream and downstream of the M2G discharge point in Burra Creek and the nearby control site on the Queanbeyan River;*
- *Build upon current baseline periphyton data (predominately algae and organic material attached to rocks and cobbles on the streambed) that will help characterise seasonal changes prior to the operation of M2G;*
- *Report on water quality monitoring from continuous in-situ sensors and collected individual samples. This will enable surface water characteristics to be established in Burra Creek, which could be used predict impacts associated with the release of Murrumbidgee River water into Burra Creek during the operation of the M2G transfer.*

This report presents the findings from the biological (macroinvertebrates and periphyton) and water quality sampling of Burra Creek and the Queanbeyan River in autumn 2012. Sampling was conducted on the 3rd and 4th of May 2012. Macroinvertebrate collection was undertaken to establish biological signatures upstream and downstream of the discharge point prior to the commencement of the M2G operation. Identification of genus level macroinvertebrates will allow for subtle flow-related impacts to be identified.

The key results from the autumn 2012 sampling run are that:

1) In the first week of March a rain event in Burra Creek created a peak flow of 2200 ML/d at the gauging station (410774; just downstream of Burra Rd) and approximately 10 days later another peak at approximately 200 Ml/d occurred. These events are thought to have impacted macroinvertebrate communities by flushing some of the more sensitive taxa out of sites where protection may have been limited. There was also some evidence of streambed movement, within some reaches (eg. near London bridge) leaving new sand deposits in the riffle habitat;

2) Nitrogen values (TN and NOx, a key nutrient source) were outside the ANZECC & ARMCANZ guidelines at all monitoring sites. Concentrations were highest downstream of the Williamsdale Road bridge at site BUR 2a;

3) Significantly higher chlorophyll-a concentrations (predictor of algae growth) were found downstream of Williamsdale Road Bridge compared to the upstream sites. These concentrations were found to be correlated to nitrogen concentrations and it is suggested that if increased levels persist in the creek downstream of the discharge point, that an investigation be undertaken to determine the source and assess possible mitigation measures (outside current project scope);

4) pH levels exceeded the upper threshold of the ANZECC guidelines at all sampling sites including the Burra Creek native site and the Queanbeyan River site. These values were between 0.1 to 0.3 pH units above the current limits, but it should be noted that these values still fall within the current natural range for Burra Creek. Since the drought broke, there has been a progressive increase in the median pH in Burra Creek, which is likely due to increased groundwater contribution from the local limestone geology;

5) Sites BUR 1a (upstream Burra Ck) and QBYN 1 (Queanbeyan River) tended to have higher taxonomic richness and more sensitive taxa compared to the downstream sites suggesting overall that habitat and water quality is of a relatively high standard at these sites.

6) AUSRIVAS assessments allocated all sites on Burra Creek to Band B. The Queanbeyan River site dropped from Band A in spring 2011 to Band B also, although all of the Burra Creek sites remained consistent with the previous two sampling runs.

7) There were no obvious signs of any aquatic impact from the M2G construction based on the macroinvertebrate samples. None of the missing but expected taxa showed any location or site specific patterns to suggest that the current condition is related to M2G. The key factor driving the patterns seen in this round of sampling appear to be differences in habitat quality between BUR 1a, QBYN 1 and the remaining Burra Creek sites combined with differences in the impacts and recolonisation patterns following the high flow event in early March.

8) Following the high flow events at the beginning of March, there was a reduction in the number of sensitive macroinvertebrate taxa meaning the communities were dominated by moderately to highly tolerant taxa compared to previous sampling runs. None of the taxa identified as missing from the AUSRIVAS model point to a specific impact and this is primarily because for the most part, the missing taxa were not missing from one specific site or location; rather they were missing across most of the sampling sites indicating a large scale impact as opposed to a specific cause.

9) Several recommendations from previous reports have been actioned, including winter and summer macroinvertebrate monitoring, and determination of the approximate depth of oxygen exchange in the subsurface of Burra Creek. All recommendations from previous reports have been compiled into a summary document (ALS, 2012).

Included in this document is the need to review the water quality guideline trigger levels within Burra Creek, which are discussed in section 4.1 of this report.

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. The programme is being undertaken as part of the ACT water supply security infrastructure upgrade. The scope of this study was to undertake biannual sampling in spring and autumn which commenced in Burra Creek in autumn 2009.

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

- Part 1: Angle Crossing
- **Part 2: Burra Creek**
- Part 3: Murrumbidgee Pump Station
- Part 4: Tantangara to Burrinjuck

This report focuses on Part 2: Burra Creek, specifically the results from the autumn 2012 sampling round.

The Murrumbidgee to Googong (M2G) transfer system will pump water from the Murrumbidgee River adjacent to Angle Crossing (southern border of the ACT), through an underground pipeline discharging into Burra Creek, at which point the water will then, travelling by 'run of river,' flow into the Googong Reservoir. The system is designed to enable pumping of up to 100 ML/d, and construction was completed in August 2012. Abstraction from the Murrumbidgee River and the subsequent discharges to Burra Creek will be dictated by the Operational Environment Management Plan (OEMP).

In light of the natural low flow conditions in Burra Creek compared to the maximum pumping rate of 100 ML/d , it is expected that the increased flow due to the discharge from the Murrumbidgee River may have several impacts on water quality, channel and bank geomorphology and the ecology of the system (Table 1). Some favourable ecological effects might occur in the reaches of Burra Creek between the discharge point (just upstream of Williamsdale Road) to downstream of the confluence of the Queanbeyan River.

These may include, but are not limited to:

- The main channel being more frequently used by fish species due to increased flow permanence and longitudinal connectivity between pools;
- Increased biodiversity in macroinvertebrate communities; and
- A reduction in the extent of macrophyte encroachment in the Burra Creek main channel.

On the other hand, there is potential for the transfer of Murrumbidgee River water into Burra Creek to adversely affect the natural biodiversity within Burra Creek due to the different physico-chemical characteristics of water in each system (particularly with regards to EC). Furthermore, the inter-basin water transfer also poses a risk of spreading exotic plant and fish species which could displace native biota directly through competition or indirectly through the spread of disease. Other potential impacts are highlighted in Table 1.

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

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

Property	Possible impact	Source
Water Quality	Increased turbidity from Murrumbidgee water which could decrease light penetration, resulting in lower macrophyte and algal growth.	(Martin and Rutlidge, 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 affect plant growth, nutrient uptake and dissolved oxygen levels and ultimately compromise the quality of fish habitat.	(Martin and Rutlidge, 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.	(Davies*, et al.*, 1992), (Martin and Rutlidge, 2009)
	Infilling from fine sediment transport could threaten the quality of the hyporheic zone (sub-surface region below the invert of the stream channel), which provides important habitat for macroinvertebrates in temporary streams.	(Brunke and Gonser, 1997)
	Increased flow with improved longitudinal connectivity which will potentially provide fish with more breeding opportunities and range expansion, although this will be dependent on the flow regime.	(Martin and Rutlidge, 2009)
Bank Geomorphology	Bank failure from the initial construction phase and first releases. This could result in increased sedimentation, loss of riparian vegetation and increased 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 and Scope

The objectives of the Murrumbidgee Ecological Monitoring Programme (MEMP) are to provide ACTEW Water with seasonal assessments of river health prior to, and during the construction and operational phases of the new pipeline and discharge into Burra Creek. Specifically, the aims of the project are to:

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

The current ecological health of the sites monitored as part of the Burra Creek component of the Murrumbidgee Ecological Monitoring Programme (MEMP) 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. As outlined in the MEMP proposal to ACTEW Water (GHD, 2012) this work includes:

1. Biannual sampling which commenced in autumn 2009;
2. Macroinvertebrate sampling from riffle and edge habitats (where available) as per the ACT AUSRIVAS protocols;
3. Macroinvertebrates counted and identified to the taxonomic level of genus;
4. Riffle and edge samples assessed through the appropriate AUSRIVAS models;
5. Selected water quality measurements to be measured *in situ*, and collected for analysis at Australian Laboratory Services (ALS's) NATA accredited laboratory in Canberra.

Six months prior to the commencement of this program, GHD (formally 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 program was adjusted from its original design before it was finalised due to difficulties in finding appropriate control sites.

1.2 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 (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). 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 and shelter 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 valuable indicator of river health.

2. Materials and Methods

2.1 Study Sites

Prior to the 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.

Seven sites were initially selected, including three control sites and four impact sites. This design previously had BUR 2a listed as a control site, because the exact location of the discharge was unknown. The discharge point has been confirmed to be located just upstream of Williamsdale Bridge. Accordingly, site BUR 2a is now included as an impact site on Burra Creek (Figure 1; Table 2).

Since the inception of the Burra Creek monitoring programme, the original designated sampling sites have gone through several changes (Figure 1; Table 2); which include:

- Site QBYN 2 and BUR 3 are currently not sampled because both sites are inundated by Googong dam;
- BUR 2c has been included as an alternative site for BUR 3 during periods of inundation by Googong dam. Both sites share similar physical characteristics;
- Cassidy Creek (CAS 1) been removed from the programme, because since its selection, it has been dry or choked by *Typha sp*. and collecting representative samples has continued to be problematic;
- BUR 1b was included to balance the design of the programme and was to serve as an additional upstream control site. Access was originally given through private land in early 2011; however the landowners have since withdrawn this permission.

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 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 more permanent habitats downstream of the release point due to the additional flow being provided. Furthermore, due to the high number of no-flow days and the chain-of–ponds nature of Burra Creek, sampling the pool/edges allows data collection when surface flow has ceased. In any case, edge habitat would be affected by the M2G project in that edge habitat would be increasingly (and artificially) maintained in terms of water level downstream of the release point, so the potential effects on edge habitat are certainly worth monitoring in their own right.

Table 2. Sampling site details for the Burra Creek monitoring programme

Site code	Site name and Location	Notes	Purpose	Latitude	Longitude
QBYN 1	Queanbeyan River at Flynn's Crossing		Perennial Control	-35.524317	149.303300
QBYN 2	Queanbeyan River, downstream of Burra Creek confluence	Sampling has not been possible since autumn 2010 because of inundation by Googong dam	Perennial Impact	-35.498951	149.265700
BUR 1a	Burra Creek, upstream Cassidy Creek confluence		Upstream Control	-35.598461	149.228868
BUR 1b	Burra Creek, ~1.5km upstream of Williamsdale Bridge	Initial access permission revoked by landowner	Upstream Control	-35.583224	149.228421
BUR 1c	Upstream of Williamsdale Bridge		Upstream Control	-35.556511	149.221238
BUR 2a	Downstream of Williamsdale Bridge	This site was originally considered a control site, but since the location of the Burra Creek discharge weir was decided upon at Williamsdale Road, this site is now acting as a downstream impact site. This will not affect the future interpretation of future data collection.	Downstream impact	-35.554345	149.224477
BUR 2b	Burra Creek, downstream of Burra Road bridge		Downstream impact	-35.541985	149.230407
BUR 2c	Burra Creek upstream of London Bridge	With the inundation of BUR 3 for the foreseeable future, BUR 2c serves as its replacement	Downstream impact	-35.517894	149.261452
BUR 3	Burra Creek, downstream of London Bridge	Sampling has not been possible since autumn 2010 because of inundation by Googong dam	Downstream impact	-35.510333	149.264351
CAS 1	Cassidy Creek, Upstream of the Burra Creek confluence	Discontinued in 2011	Control	-35.598515	149.227171

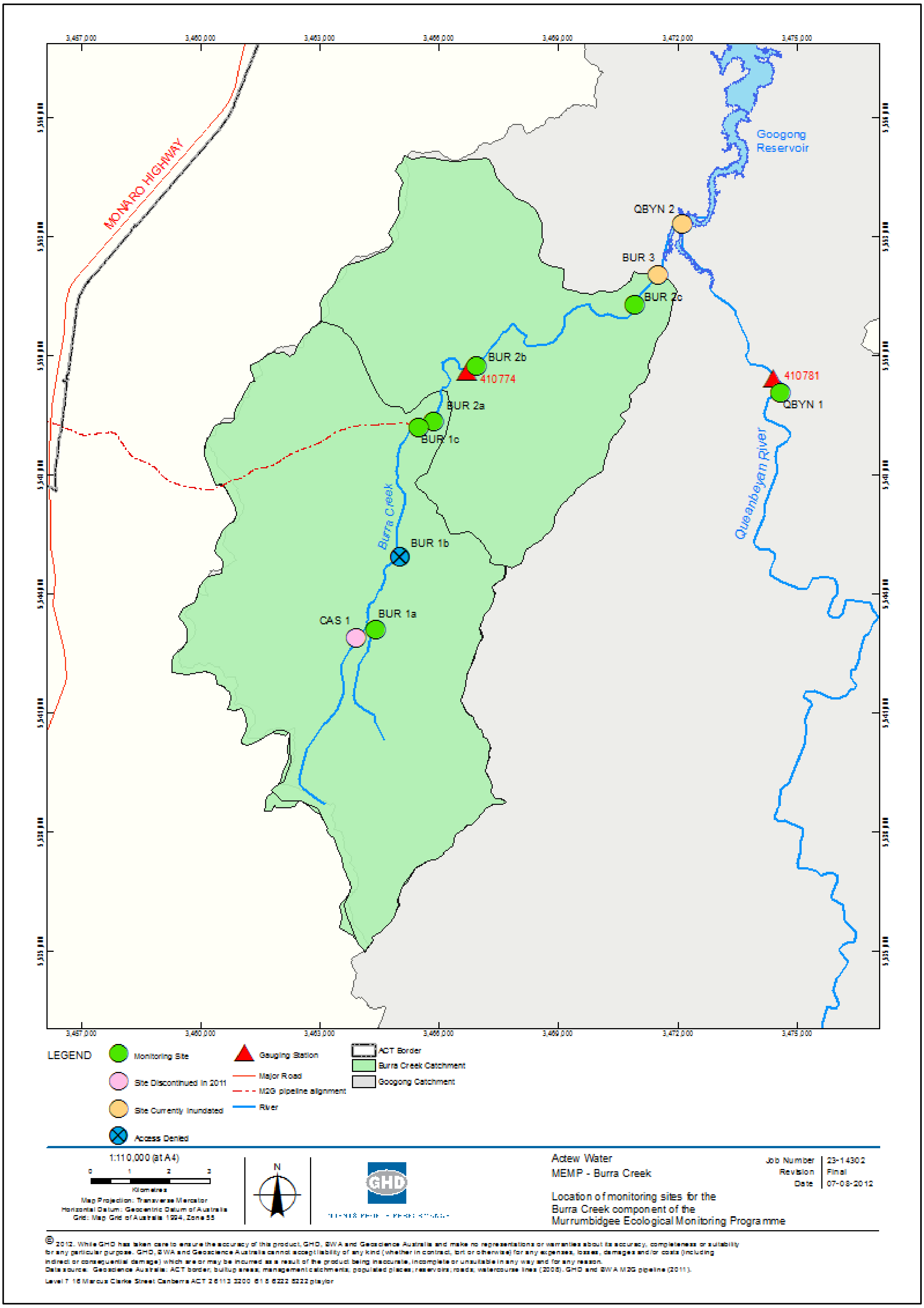


Figure 1. Location of the monitoring sites and gauging stations for the Burra Creek monitoring programme

2.2 Hydrology and Rainfall

River flows and rainfall 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 for the gauging stations are given in Table 3.

Table 3. Stream flow and water quality monitoring site locations

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

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

2.3 Water Quality

Baseline *in situ* physico-chemical parameters including temperature, pH, electrical conductivity, turbidity, and dissolved oxygen were recorded at each sampling site using a multiprobe Hydrolab® Minisonde 5a Surveyor. The Surveyor was calibrated in accordance with GHD 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 and nutrient analysis.

Nutrient analysis included nitrogen oxides (total NOx), total nitrogen (TN) and total phosphorus (TP) in accordance with the protocols outlined in APHA (2005). This information will assist in the interpretation of biological data and provide a basis to gauge changes that can potentially be linked to increased flow and potential changes in the Burra Creek system due to inter-basin water transfers from the donor (Murrumbidgee) system.

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

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), and as described in (Biggs and Kilroy, 2000). A one metre wide transect was established across riffles at each site. Along each transect, twelve samples were collected at regular intervals, using a sampling device consisting 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 Macroinvertebrate sampling and processing

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

Two replicate samples were collected from each of the two habitats (edge and riffle - where available) at most sites in autumn. 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 ten metres 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.

The bulk samples were placed in separate 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 bulk 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). 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

Data were analysed using both univariate and multivariate techniques. Analyses were performed in PRIMER v6 (Clarke and Gorley, 2006) and R version 2.15.1 (R Development Core Team, 2011). Descriptive statistics performed on rainfall, hydrology and continuous water quality parameters were organised in the time series data management software - HYDSTRA©.

2.6.1 Water Quality

The water quality parameters were assessed for compliance with the ANZECC & ARMCANZ (2000) water guidelines for aquatic ecosystems in upland streams of south-east Australia. These measurements were taken from two continuous water quality stations; the first located on the Queanbeyan River (410781) and the second on Burra Creek (410774).

2.6.2 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). Differences between upstream-control locations and downstream-impact locations were assessed by fitting the log-transformed chlorophyll-a and AFDM data to a mixed effects, nested analysis of variance (ANOVA). Site was nested within location and was treated as a random effect and location was considered a fixed effect. For the purposes of graphical visualisation, raw data are presented.

2.6.3 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.

Univariate Analysis

The univariate techniques performed on the macroinvertebrate data include:

- Taxa Richness and EPT taxa index (richness and relative abundance)
- SIGNAL-2 Biotic Index
- 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. 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 SIGNAL-2 model approach developed by (Chessman, 2003). These changes were introduced to improve the reliability of the SIGNAL index. 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.

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 an initial cluster analysis. NMDS is a multivariate procedure that reduces the dimensionality of multivariate data by describing trends in the joint occurrence of taxa. The initial step in this process was to transform the data (4th root) to down-weight the influence of highly abundant taxa 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 discharge point, and also between individual sites. 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).

2.6.4 AUSRIVAS Assessment

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 4) which are used to gauge the overall health of a particular site Coysh, *et al.* (2000). Data are presented using the AUSRIVAS O/E 50 ratio (Observed/Expected score for taxa with a >50% probability of occurrence) and the previously mentioned rating bands (Table 4).

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 habitats (e.g. D – A) an overall assessment is avoided due to the unreliability of the results.

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

One caveat to note in this study is that while AUSRIVAS predictions based on physical information can result in similar taxa expected to occur within different stream types (i.e. intermittent and perennial), disparities in macroinvertebrate communities are related to system–specific differences such as water chemistry and the disturbance and flows regimes, resulting in adaptations to cope with these differences

(Wallace, 1990). The AUSRIVAS model does not take the degree of flow permanence into account which could result in erroneous predictions by the model and lead to misleading outputs. It is therefore advised that caution should be given to the AUSRIVAS outputs for the Burra Creek sites.

2.7 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 will be re-identified by another senior taxonomist
- and very small, immature, damaged animals or pupae that could not be positively identified were not included in the dataset.

All procedures were performed by AUSRIVAS accredited staff.

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

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

2.8 Licences and Permits

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

All GHD field staff holds current AUSRIVAS accreditation.

3. Results

3.1 Summary of sampling conditions

Sampling of Burra Creek and the Queanbeyan River was completed on the 3rd and 4th of May. Full site condition summaries are shown in Appendix A. As has been the case during previous sampling runs both BUR 3 and QBYN 2 were not sampled due to inundation by the back waters of Googong Reservoir (Plate 1).

Plate 1. BUR 3, downstream of London Bridge showing inundation by Googong Reservoir water

Considering the large rainfall event at the beginning of March (Figures 3 & 4) the physical characteristics at all sites remained much as they were from spring 2011. There was some evidence of fresh sediment deposits at QBYN 1, mainly on the existing 'Island' splitting the main flow into several side channels. In Burra Creek there were other indications of the influence of the high flows with some new erosion at BUR 1a and 2c, scouring of the stream bed (BUR 2b and 2c) and sections of dead macrophytes and riparian grasses that were previously encroaching the main channel (this was most noticeable at BUR 1c). The number of samples collected in each habitat is presented in Table 5, with photos of each site in Plates 2 & 3.

Table 5. Macroinvertebrate samples collected during the autumn sampling run

Site	Edge	Riffle	Notes
QBYN1	2	2	
BUR1a	2	2	
BUR1c	2	1	Limited riffle habitat available. Only one sample was possible
BUR2a	2	1	Limited riffle habitat available. Only one sample was possible
BUR2b	2	2	
BUR2c	2	2	Replacement for BUR 3 while it is inundated


BUR 1a – looking downstream showing minimal riffle habitat (left) and further upstream showing a run leading into a pool


BUR 1c – facing upstream. Dying macrophytes encroaching riffle habitat (left) and looking downstream to the head of a pool


BUR 2a – looking upstream through very limited riffle habitat and right, facing downstream from the same point

Plate 2. Site photographs looking upstream and downstream at sites BUR 1a, 1c and 2a


BUR 2b – Large boulders and bedrock are common features through this reach


BUR 2c – At BUR 2c the riparian zone is limited to a few shrubs and exotic grasses. High banks with almost no shrubs or trees make this section vulnerable to erosion.


QBYN 1 – Flynn's Crossing. The riffle habitat features good substrate diversity, cool fast flowing waters and has typical riffle/pool sequences throughout the reach. Deep pools with good native riparian vegetation make the edge/pool habitat ideal for macroinvertebrate diversity and abundance.

Plate 3. Site photographs looking upstream and downstream at sites BUR 2b, BUR 2c and QBYN 1

3.2 Hydrology and Rainfall

Burra Creek stream flow data from 1985 through to 2012 (as of 31st May) shows the mean daily flow as 10.2 ML/d (median = 1.4 ML/d). However, over the last five years flows have reduced to 8.76 ML/d (median = 0.42 ML/d) compared to the long term conditions. Since flow records began in 1985 a mean monthly flow of 100 ML/d has only been exceeded 8 times, while flows in excess of 100 ML/d have occurred less than 2% of the time on a daily basis.

In the first week of March, 140 mm of rain fell in the Burra Creek Catchment (172.3 mm for the month; Figure 2) with similar patterns seen in the Queanbeyan River catchment area (Table 6). Flow peaks during autumn corresponded to these periods of high rainfall (Figures 3 and 4). The main March event in Burra Creek peaked at 2200 ML/d on 1st March with a second peak of 2000 ML/d 3 days later. A small event occurred on the 9th March peaking at 200 Ml/d. Flows stabilised towards mid-April at approximately 5 ML/d, which is what the base flow was at the time of sampling and for the remainder of the autumn period.

The hydrograph for Queanbeyan River shows similar responses although it has a shallower recession limb following the initial March event (Figure 3), which reflects the size difference between catchments. Average flow in the Queanbeyan River in autumn was approximately 730 ML/d and was 150 ML/d on the day of sampling.

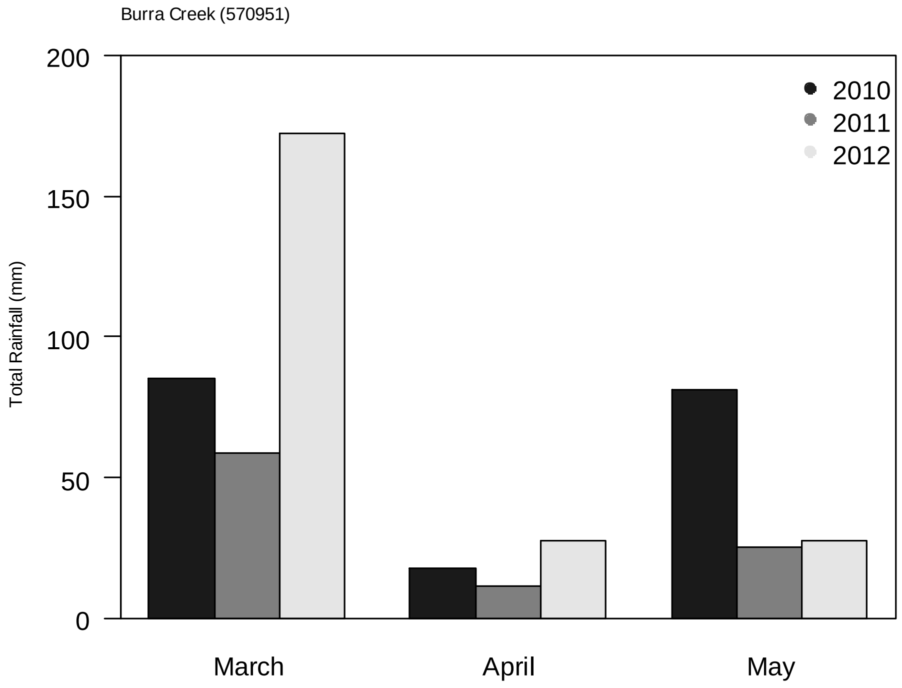


Figure 2. Annual comparisons of monthly rainfall (mm) recorded at Burra Creek (570951)

Table 6. Autumn rainfall and flow summaries for Burra Creek and the Queanbeyan River
Flow values are monthly means; rainfall is monthly total (mm)

	Burra Creek (410774)		Queanbeyan River (410781)	
	Rainfall	Mean Flow (ML/d)	Rainfall	Mean Flow (ML/d)
March	172.3	149	183.0	1870
April	27.8	6.11	28.0	210
May	27.8	4.30	19.0	123
Autumn Total	227.9	53.1	76.7	734

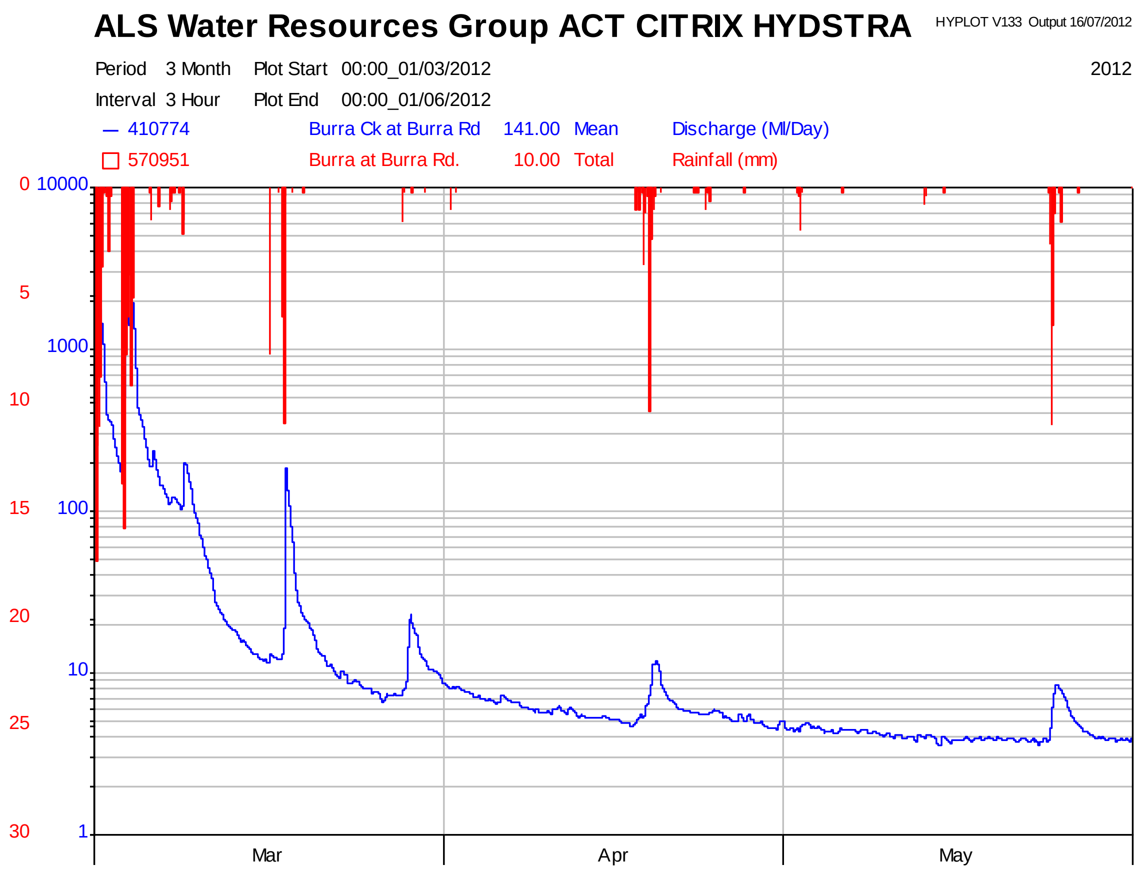


Figure 3. Hydrograph and rainfall for Burra Creek during autumn 2012

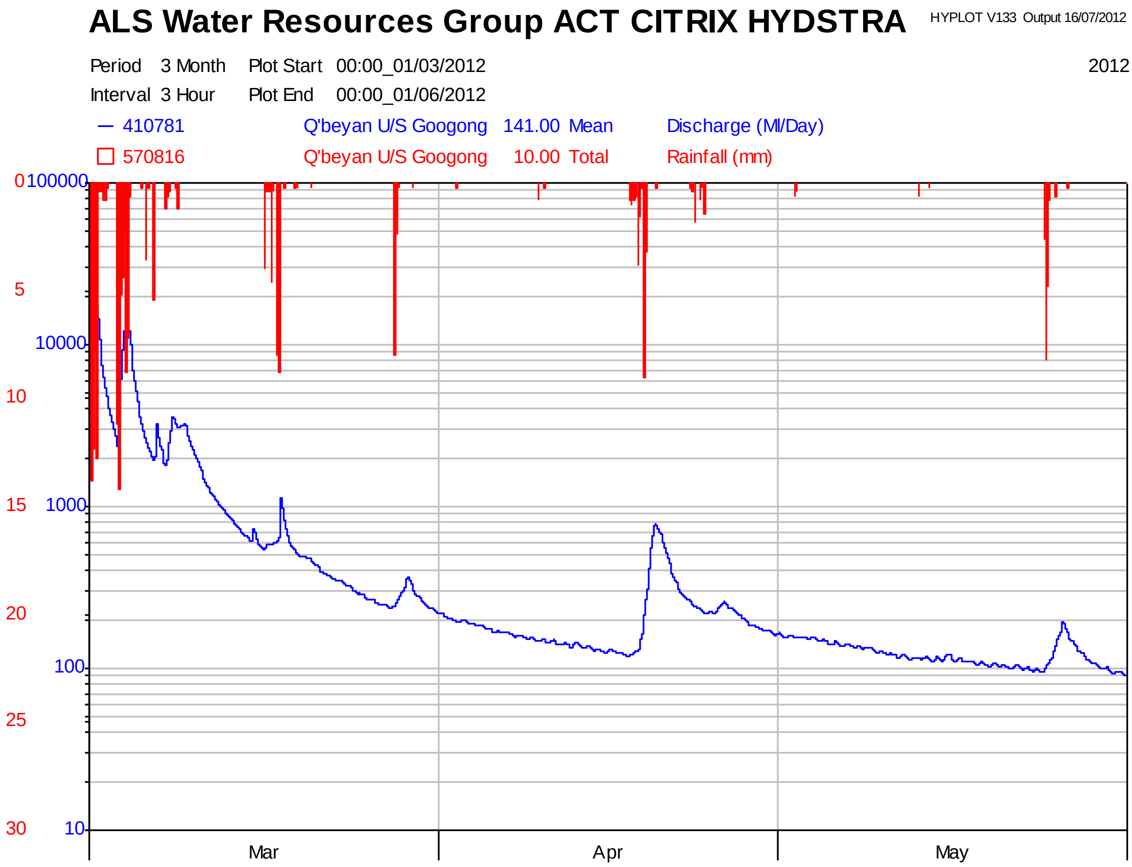


Figure 4. Autumn hydrograph and rainfall for the Queanbeyan River (upstream of Googong reservoir)

3.3 Water Quality

3.3.1 Grab samples

The results from the grab samples and the *in situ* water quality measurements are shown in Table 7.

Water quality in the Queanbeyan River was within the ANZECC & ARMCANZ (2000) guideline levels for all parameters with the exception of total nitrogen (TN). Temperatures in Burra Creek ranged from 7.2°C at BUR 1a to 14.6°C at BUR 2c. With the exception of BUR 1a all sites, including QBYN 1, showed super saturated dissolved oxygen (DO) levels. pH ranged from 7.2 – 8.3 and exceeded the ANZECC & ARMCANZ (2000) guidelines at Bur 1c, 2a, 2b and 2c (Table 7). BUR 1a and QBYN 1 were both within the guidelines for pH.

Electrical conductivity (EC) levels exceeded the upper threshold of the guidelines at all sampling locations expect QBYN 1 and BUR 1a. These values fall outside of the recommended ANZECC & ARMCANZ (2000) because of the catchment geology. Although the values are outside guidelines they are within the 80^{th} and 20^{th} percentiles (390 µs/cm^{-1} and 600 µs/cm^{-1}) based on the period of record data collected from the Burra Road weir (410774).

Total Nitrogen was above the guideline upper limits at all sites. However, there appeared to be a spike at BUR 2a (Table 7). The source of the elevated TN was found to be Holdens Creek, confirmed from additional water sample testing.

3.3.2 Continuous water quality

The readings from the continuous water quality monitoring station on Burra Creek (410774) are displayed in Figure 5. All parameters were influenced by the high flow event at the beginning of March. Turbidity was elevated for much of the first week in March. Maximum readings exceed 1000 NTU and daily mean turbidity readings remained outside the upper limit of the ANZECC and ARMCANZ (2000) guidelines for 14 days in March. However, turbidity guidelines were met 100% of the time for the remainder of autumn once base-flows had returned to below 10 ML/d.

Dissolved oxygen (DO) showed distinct diurnal patterns which was less prominent at the beginning of autumn during the high flow events. Daily means dropped by 2-3% at the beginning of May meaning they fell under the lower guideline threshold for this period. The range throughout autumn was 85-98% (based on daily means). Elevated electrical conductivity (EC) was above the upper guideline level. As mentioned in section 3.3.1, these concentrations are not unusual for the Burra Creek catchment downstream of Cassidy Creek Bridge and although falling outside of the ANZECC and ARMCANZ (2000) guidelines they are within the 80^{th} and 20^{th} percentile range for this system.

The pH levels were also elevated beyond the guideline levels for 72% of the autumn period (based on daily means). However, all values were within the long term 80^{th} and 20^{th} percentile range of 8.12 and 7.34 respectively. Surface water temperatures decreased steadily for the duration of autumn in line with decreasing ambient temperatures towards the beginning of winter.

The pH probe at the gauging station on the Queanbeyan River upstream of Googong Reservoir (410781) has not been repaired since lightning damage in mid-January 2012. The remaining parameters followed a similar trend as those seen in the Burra Creek catchment. Turbidity peaked at 935 NTU at the beginning of March, which then returned to meet the guidelines in the second week of March (Figure 6).

EC in the Queanbeyan River was within the ANZECC & ARMCANZ (2000) guideline levels for the whole season (Figure 6). Dissolved oxygen was within guidelines for 84% of the season (based on daily means).

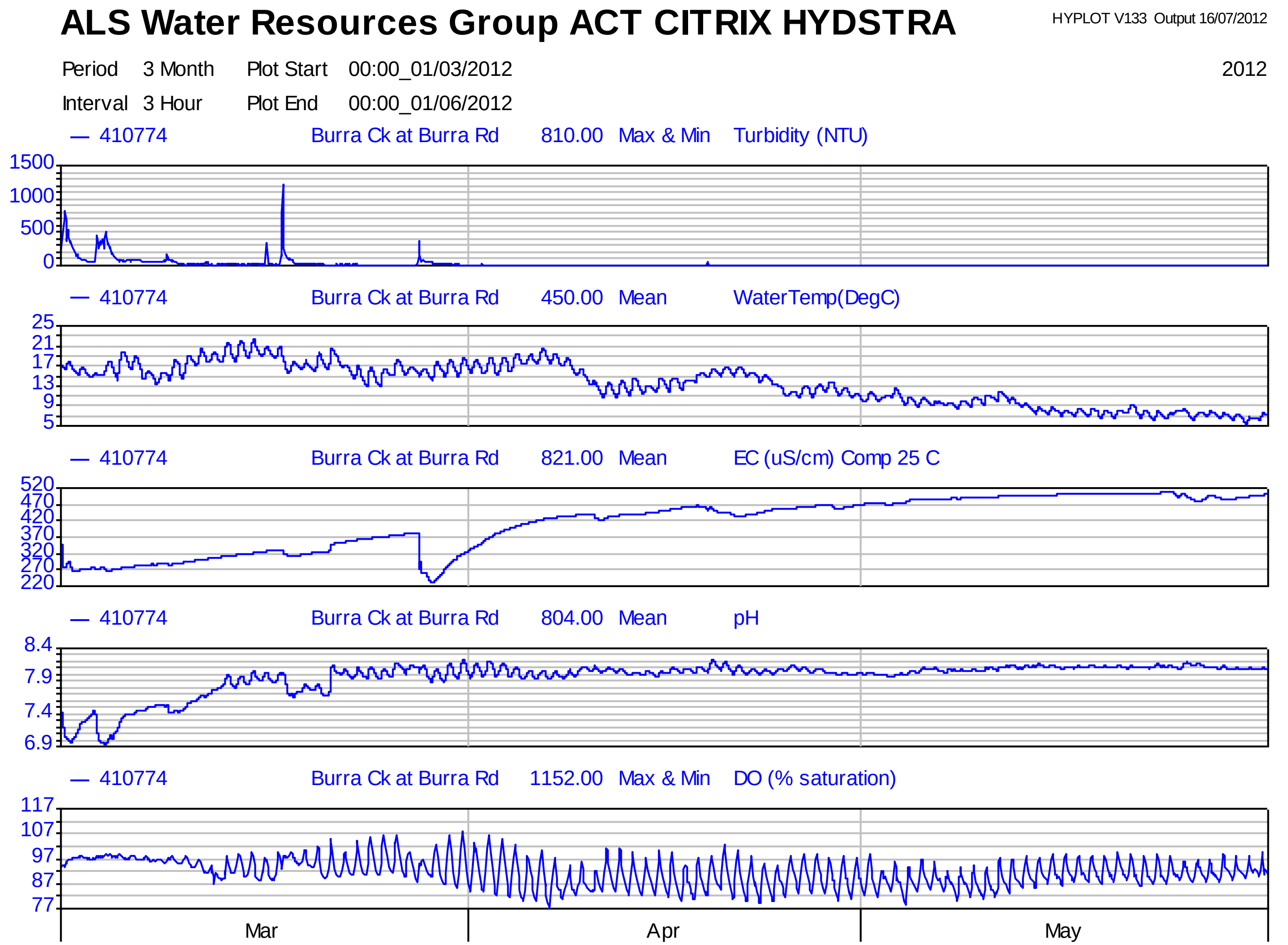


Figure 5. Continuous water quality records from Burra Creek (410774) for autumn 2012

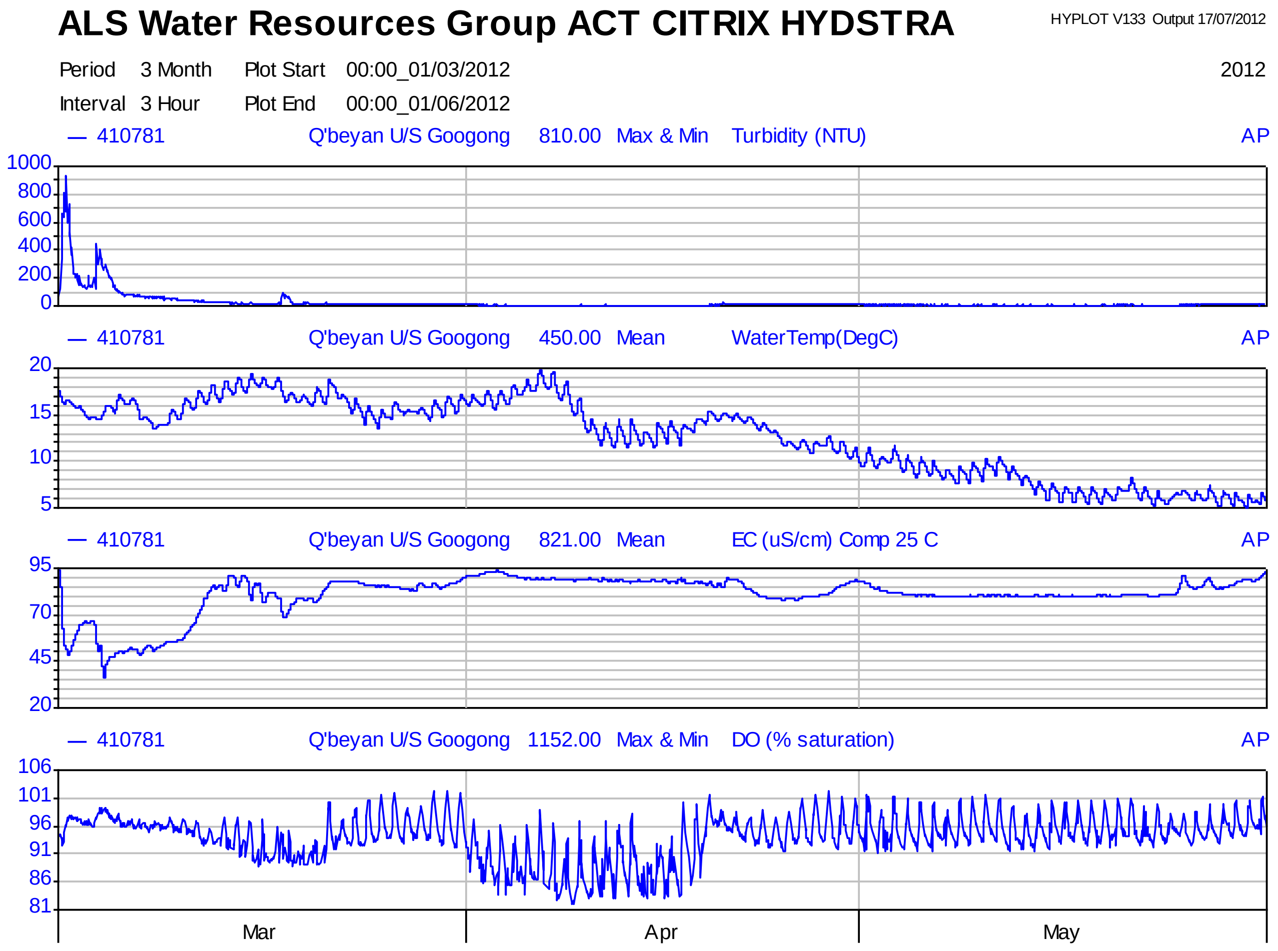


Figure 6. Continuous water quality records from the Queanbeyan river (upstream of Googong Reservoir: 410781) for autumn 2012

Table 7. *In situ* water quality results from Autumn 2011

ANZECC guidelines are in red bold parentheses, yellow cells indicate values outside of ANZECC and ARMCANZ (2000) guidelines, orange cells indicate value is on the cusp of the guideline

	Site	Date	Time	Temp. (°C)	EC (µs/cm) (30-350)	Turbidity (NTU) (2-25)	TSS mg/L	pH (6.5-8)	D.O.(% Sat.) (90-110)	D.O. (mg/L)	Alkalinity (mg/L)	NOx (mg/L) (0.015)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L) (0.02)	TN (mg/L) (0.25)
Upstream	BUR 1A	4/5	10.25	7.2	98	7.7	<2	7.2	91.4	9.6	25	0.003	0.001	<0.002	0.004	0.010	0.26
	BUR 1C	4/5	12.00	11.2	410	5.4	9	8.1	102.1	9.9	165	0.006	0.004	<0.002	0.002	0.008	0.27
Downstream	BUR 2a	4/5	13.30	11.1	480	6.6	3	8.1	103.7	10.2	198	0.18	0.178	<0.002	0.003	0.008	0.40
	BUR 2b	4/5	15.00	12.4	480	5.9	2	8.3	107.5	10.3	202	0.037	0.035	<0.002	0.003	0.009	0.27
	BUR 2c	3/5	13.55	14.6	490	2.75	<2	8.2	109.4	11.2	210	0.041	0.039	<0.001	0.002	0.006	0.28
Control	QBYN 1	3/5	12.20	11.7	85	4.2	5	7.8	109.4	12.0	37	<0.002	<0.001	<0.002	0.003	0.018	0.28

EC = Electrical conductivity; TSS = Total suspended solids; D.O = Dissolved oxygen; TP = phosphorus; TN = total nitrogen

3.4 Periphyton

Chlorophyll-a derived from the periphyton samples were higher in the Queanbeyan River and Burra (downstream of Williamsdale Bridge) compared to the Burra Creek sites located upstream of the discharge point at Williamsdale Road ($F_{2,35}$ = 10.8; *P*=0.04; Table 8; Figure 7). Values ranged from 99 µg/m^{-2} at QBYN 1 to 27633 µg/m^{-2} at BUR 2b. Mean values were highest at the BUR 2 sites (i.e. downstream of the discharge point (mean = 10366 µg/m^{-2}) followed by the Queanbeyan River control site (mean = 7137 µg/m^{-2}) and lowest on average upstream of the discharge point on Burra Creek (mean = 3397 µg/m^{-2}). Overall, the variation between locations (control vs. upstream vs. downstream) explained 28.7 % of the total variation in the data, site to site variation explained 2.65 % and within site variation accounted for 68.6 %.

Biomass (estimated by AFDM) did not differ between sampling locations ($F_{2,35}$ = 1.22; *P*=0.41; Table 8; Figure 8) despite the mean concentrations being higher at the downstream sites in Burra Creek (mean = 5491 mg/m^{-2}) compared to both the upstream sites in Burra Creek (mean = 3268 mg/m^{-2}) and the perennial control at Flynn's Crossing (mean = 3709 mg/m^{-2}). These values are considerably lower than those recorded in spring 2011, especially BUR 1c where there has been approximately a tenfold decrease in the estimated biomass at that site.

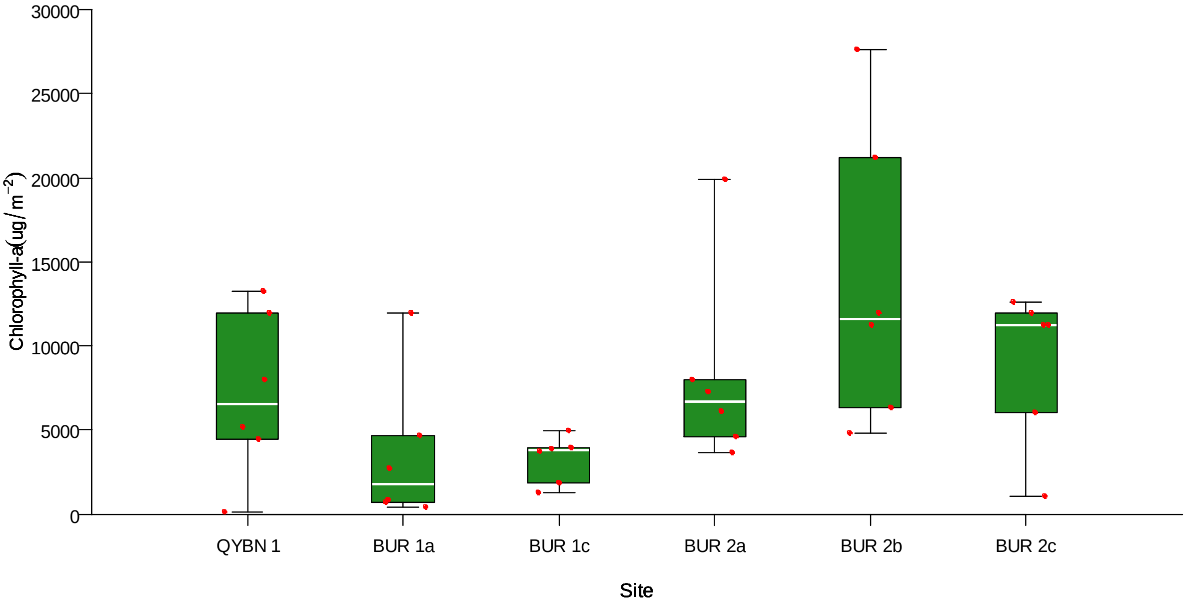


Figure 7. Chlorophyll-a concentrations in Burra Creek and the Queanbeyan River. Red dots represent the raw values (n=6) at each site.

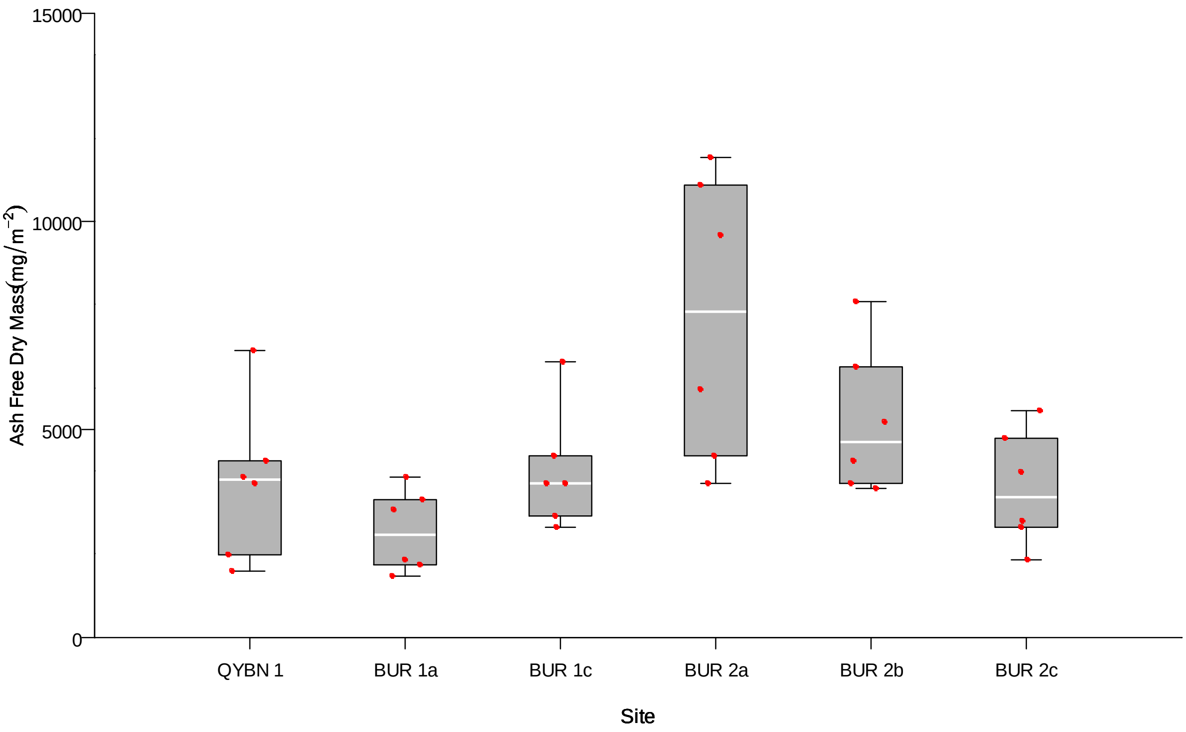


Figure 8. Ash Free Dry Mass (AFDM) concentrations in Burra Creek and the Queanbeyan River

Strip chart values (in red) represent the raw data values (n=6) for each site. See APPENDIX B for an explanation of how to interpret box and whisker plot

Table 8. Nested analysis of variance results for chlorophyll-a and AFDM concentrations

Response	Source	DF	F-value	P-value
Chlorophyll-a	Location	2	10.81	0.04
	Site [Location]	3	0.27	0.70
	Residual	35		
AFDM	Location	2	1.22	0.41
	Site [Location]	3	4.33	0.02
	Residual	35		

3.5 Macroinvertebrate Communities

3.5.1 Riffles

The multivariate structure of the riffle macroinvertebrate communities is comparable to the patterns seen in spring 2011. The most obvious feature of this plot is the grouping structure of both the Queanbeyan control site and BUR 1a which is located within the Tinderry Nature Reserve. The remaining two groups contain BUR 2b & BUR 2c and Bur 1c & BUR 2a (Figure 9). Although this grouping structure is distinctive, the ANOSIM results suggest that these groups are not significantly different (R=0.18; *P*=0.32; Appendix C), which is explained by the location of BUR 1c, whose community structure is more similar to BUR 2a and QBYN 1 than to the other upstream site (BUR 1a).

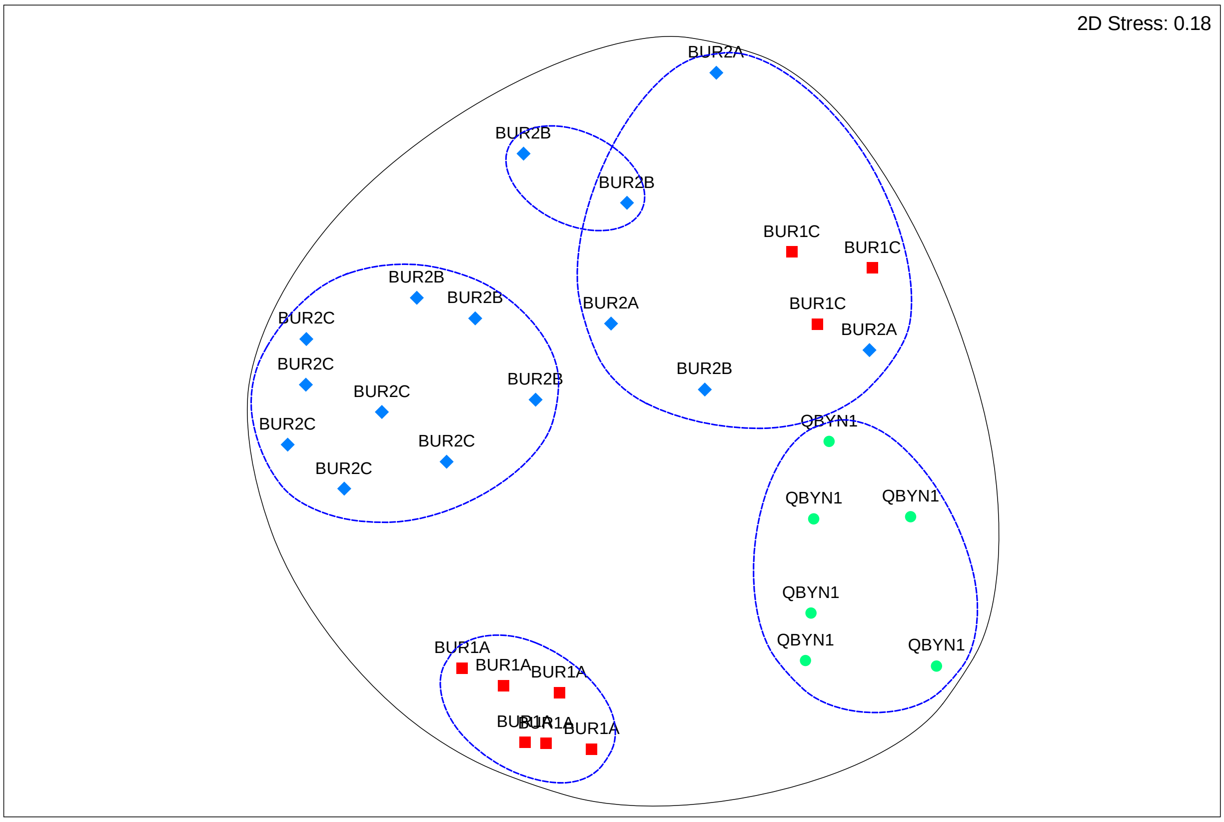


Figure 9. Non-metric multidimensional scaling ordination plot of genus level macroinvertebrates from the autumn riffle samples

Ellipses represent 60% (black) and 65 % (blue) similarity groupings. Red squares show sites on Burra Creek upstream of the discharge point, blue diamond's indicate sites downstream of the discharge point. Green circles show samples from the perennial control sites on the Queanbeyan River.

Compared to the samples collected in spring 2011, there was a notable decline in the presence/absence of Plecoptera (Stoneflies) from the samples. This was most notable at the Burra Creek sites BUR 1c through to BUR 2c. Stoneflies were collected at QBYN 1 and BUR 1a but in lower numbers than in spring. After scrutinising our data base it appears that a similar pattern occurred in autumn 2011 indicating that these changes are most probably seasonal. Other taxa characterising the Queanbeyan River included: *Austrosimulium sp*. (Simuliidae; SIGNAL = 5), Orthocladiinae (SIGNAL=4); Baetidae (SIGNAL = 5) and the sensitive mayfly family – Leptophlebiidae (SIGNAL = 8). Sites upstream of the discharge point on Burra Creek were also characterised by *Austrosimulium sp*. (Simuliidae; SIGNAL = 5) and Orthocladiinae (SIGNAL = 4). However, there were fewer highly sensitive mayflies such as Leptophlebiidae at BUR 1a and BUR 1c, although Baetidae numbers were high relative to other groups of taxa particularly at BUR 1a which is reflected in the increase in the relative abundance of sensitive taxa (i.e. EPT) at that site (Figure 10). Downstream of the discharge point similar taxa to those already mentioned characterised these sites, although there were varying orders of numerical dominance. Hydropsychidae (SIGNAL = 6) also featured, especially at BUR 2c where, combined with high numbers of Baetids, resulted in the highest relative abundance of sensitive taxa (i.e. the EPT group) amongst all of the sampling sites (Figure 10).

Sites immediately upstream and downstream of the discharge point tended to have lower relative abundances of sensitive taxa and lower overall taxa richness (Figures 10 & 11). Taxonomic richness was highest at BUR 2c, with 29 genera within 24 families and was lowest at BUR 1c with 18 genera within 15 families. The highest number of EPT families (9) occurred at QBYN 1, BUR 1a and BUR 2b while genus richness was highest at BUR 2b and BUR 2c (16) (Figure 12).

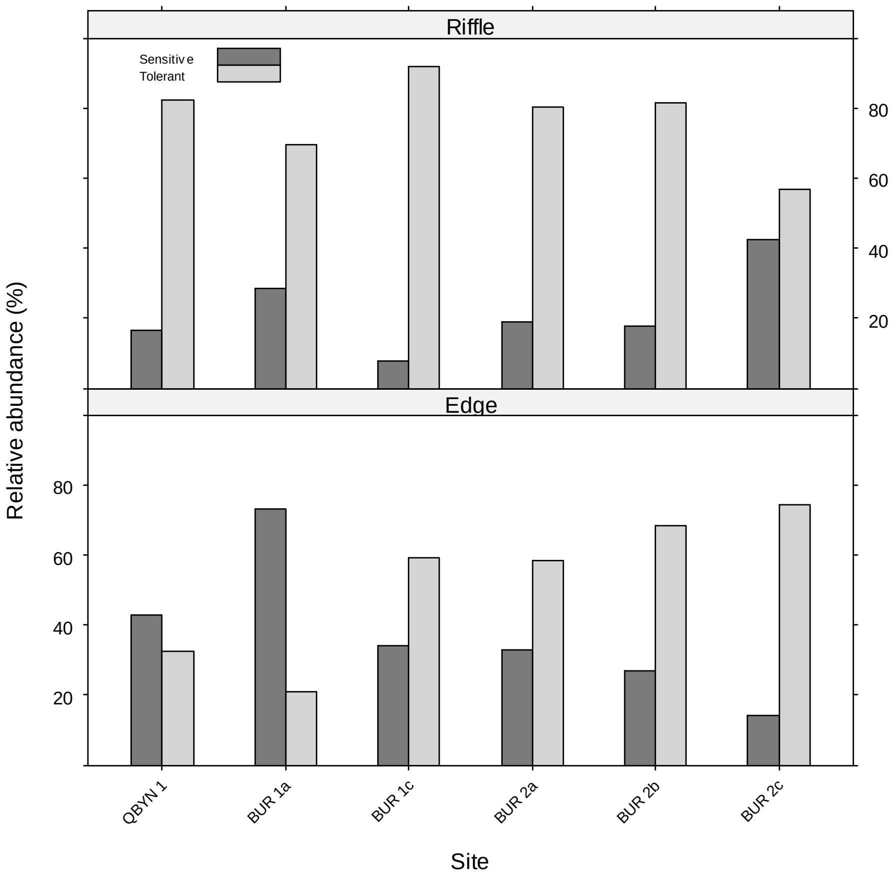


Figure 10. Relative abundance of sensitive taxa (EPT) and tolerant taxa (OCD) in the riffle and edge habitat

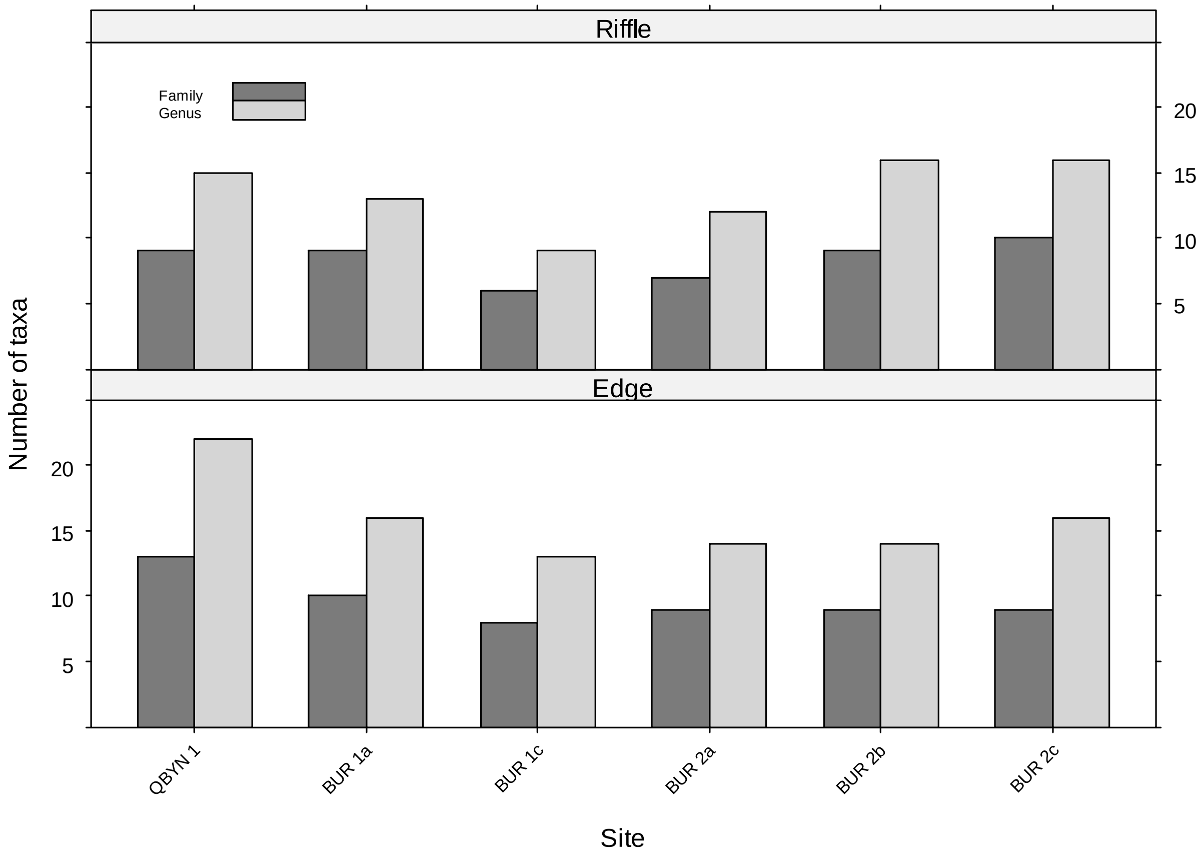


Figure 11. Number of unique taxa collected from the riffle and edge habitats

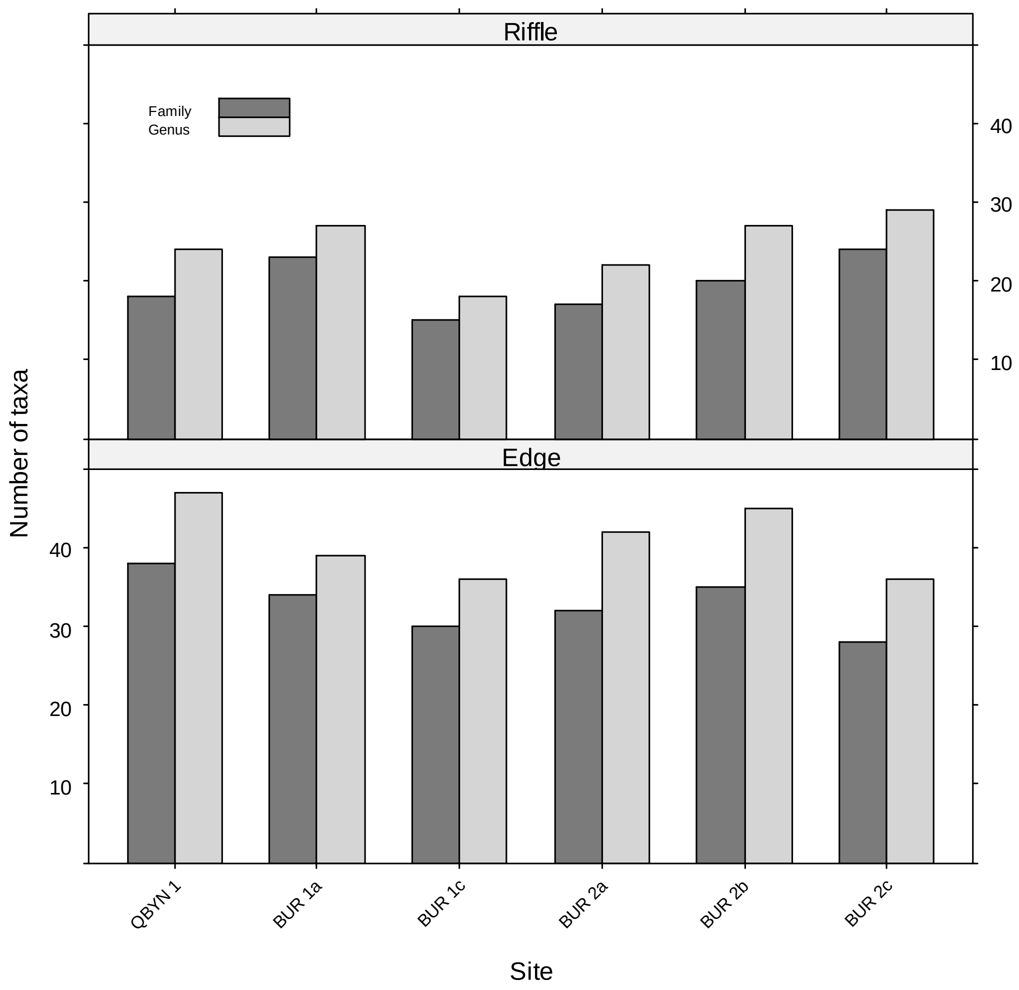


Figure 12. Number EPT taxa at the family and genus level amongst riffle and edge samples for autumn 2012

3.5.2 Edges

Macroinvertebrate assemblages show similar grouping structures as the riffle samples (Figure 13). ANOSIM results, as with the riffle samples, indicate no significant difference between the communities between locations (R=0.36; *P*=0.16). However, as with the riffle sample results it appears this result is driven largely by the positions of BUR 1a and BUR 1c in relation to one another.

Compared to the riffle habitats, edges contained greater biodiversity. The number of families ranged between 28-38 at BUR 2c and QBYN 1 respectively (Figure 11). The number of genera ranged from 36-47 also at BUR 2c and QBYN 1 respectively. Of these taxa, between 9-13 families belonged to the EPT group and 13-22 genera belonged to the EPT group. Sites QBYN 1 and BUR 1a had higher proportions of sensitive taxa to tolerant taxa, while the remaining sites were largely dominated by the more tolerant groups (Figure 10). The most abundant and diverse of the sensitive taxa were Leptoceridae (SIGNAL = 4) at QBYN 1 and BUR 1a and Leptophlebiidae. From BUR 1c to BUR 2c, Orthocladiinae tended to become more dominant in the samples, resulting in a slight shift from the dominance of EPT taxa to more tolerant taxa (Figure 10).

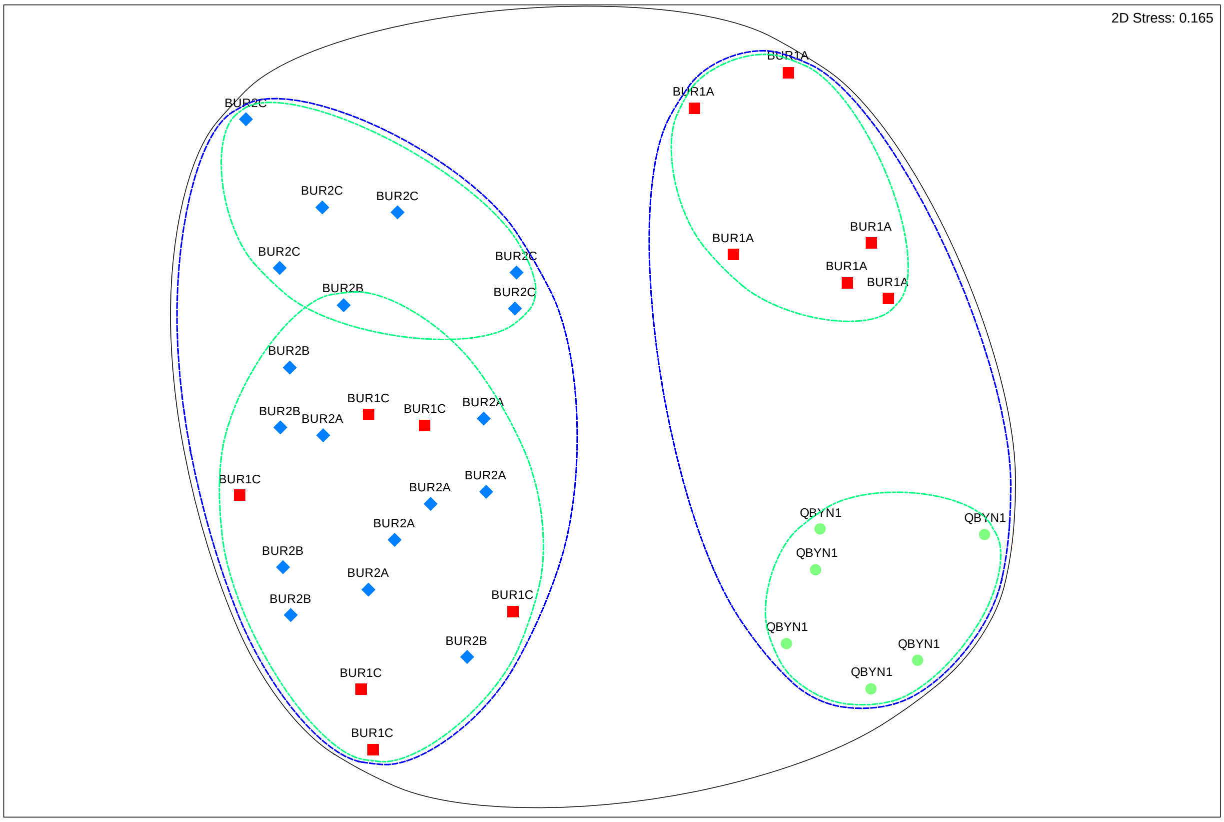


Figure 13. Non-metric multidimensional scaling ordination plot of genus level macroinvertebrates from the autumn edge samples

Ellipses represent 40% (black), 50 % (blue) and 60% (green) similarity groupings. Red squares show sites on Burra Creek upstream of the discharge point, blue diamond's indicate sites downstream of the discharge point. Green circles show samples from the perennial control sites on the Queanbeyan River

3.6 AUSRIVAS Assessment

All of the sampling sites were assessed as having fewer taxa than predicted by the AUSRIVAS model resulting in overall site assessments of BAND B (Table 9). These assessments were not statistically different between locations for the riffle based assessment ($F_{2,29}$ = 0.43; *P*=0.68; Table 10; Figure 14) nor the edge based assessments ($F_{2,35}$ = 0.11; *P*=0.89; Table 11; Figure 15). These results are comparable to the previous two sampling runs (Table 12); where the Burra Creek sites, when sampled have all been assessed as BAND B. The edge habitat at the Queanbeyan River site (QBYN 1) and BUR 2a (downstream of Williamsdale Road) were both assessed as BAND A (close to reference condition).

BUR 1c and BUR 2b both were assessed as having several taxa (7 and 15 respectively) missing that were predicted by the AUSRIVAS model, resulting in BAND C assessments at those sites (Appendix D). For a complete list of taxa collected refer to Appendix E. Taxa missing from the riffle samples included a variety of taxonomic groups ranging in their SIGNAL scores from tolerant (SIGNAL = 2) to highly sensitive (SIGNAL = 9) but on average were higher in riffles at the Queanbeyan River site compared to the Burra Creek sites ($F_{2,29}$=12.42; *P*=0.03: Table 10: Figure 14). The SIGNAL scores derived from the edge samples showed no statistical difference between locations ($F_{2,35}$=1.92; *P*=0.29; Table 11; Figure 15) but did tend to be higher at QBYN 1 and BUR 1a compared to the remaining sites in Burra Creek.

Table 9. AUSRIVAS and SIGNAL-2 scores for autumn 2012

SITE	Rep.	SIGNAL-2		AUSRIVAS O/E score		AUSRIVAS band		Overall habitat assessment		Overall site assessment
		Riffle	Edge	Riffle	Edge	Riffle	Edge	Riffle	Edge	
QBYN 1	1	5.54	4.55	0.77	0.85	B	A	B	A	B
QBYN 1	2	5.54	4.42	0.77	0.93	B	A			
QBYN 1	3	5.54	4.45	0.77	0.85	B	A			
QBYN 1	4	5.54	4.45	0.77	0.85	B	A			
QBYN 1	5	5.57	4.45	0.83	0.85	B	A			
QBYN 1	6	5.67	4.50	0.71	0.93	B	A			
BUR 1a	1	5.62	4.18	0.8	0.85	B	A	C	B	B
BUR 1a	2	5.1	4.73	0.61	0.85	C	A			
BUR 1a	3	4.7	4.45	0.61	0.85	C	A			
BUR 1a	4	5.00	4.42	0.68	0.93	B	A			
BUR 1a	5	4.78	4.22	0.55	0.70	C	B			
BUR 1a	6	4.92	4.22	0.74	0.70	B	B			
BUR 1c	1	4.63	4.29	0.64	0.67	B	B	B	B	B
BUR 1c	2	4.90	4.00	0.80	0.77	B	B			
BUR 1c	3	4.56	4.22	0.72	0.86	B	A			
BUR 1c	4	NS	4.00	NS	0.77	NS	B			
BUR 1c	5	NS	4.00	NS	0.77	NS	B			
BUR 1c	6	NS	4.22	NS	0.86	NS	A			
BUR 2a	1	4.90	4.20	0.75	0.97	B	A	B	A	B
BUR 2a	2	4.90	4.00	0.75	1.07	B	A			
BUR 2a	3	4.90	4.22	0.75	0.97	B	A			
BUR 2a	4	NS	4.22	NS	0.97	NS	A			
BUR 2a	5	NS	4.22	NS	0.97	NS	A			
BUR 2a	6	NS	4.22	NS	0.97	NS	A			
BUR 2b	1	5.08	4.00	0.71	0.78	B	B	C	B	B
BUR 2b	2	5.3	4.36	0.59	0.85	C	A			
BUR 2b	3	5.08	4.00	0.71	0.78	B	B			
BUR 2b	4	4.71	4.00	0.42	0.78	C	B			
BUR 2b	5	4.90	4.42	0.59	0.93	C	A			
BUR 2b	6	4.90	4.00	0.59	0.70	C	B			
BUR 2c	1	5.08	4.10	0.83	0.69	B	B	B	B	B
BUR 2c	2	4.92	4.20	0.83	0.69	B	B			
BUR 2c	3	4.85	4.50	0.90	0.55	A	B			
BUR 2c	4	4.90	4.44	0.69	0.62	B	B			
BUR 2c	5	4.90	4.22	0.69	0.62	B	B			
BUR 2c	6	4.90	4.27	0.69	0.76	B	B			

NS: Not sampled as limited riffle habitat available.

Table 10. Nested analysis of variance from the riffle samples, based on OE50 and SIGNAL scores

Response	Source	DF	F-value	P-value
OE 50	Location	2	0.43	0.68
	Site [Location]	3	5.01	0.007
	Residual	29		
SIGNAL -2	Location	2	12.42	0.03
	Site [Location]	3	2.18	0.11
	Residual	29		

Table 11. Nested analysis of variance from the edge samples, based on OE50 and SIGNAL scores

Response	Source	DF	F-value	P-value
OE 50	Location	2	0.11	0.89
	Site [Location]	3	23.38	<0.001
	Residual	35		
SIGNAL-2	Location	2	1.92	0.29
	Site [Location]	3	3.95	0.01
	Residual	35		

TableTable 12. Overall site assessments for the current and two previous sampling periods

	Autumn 2011	Spring 2011	Autumn 2012
QBYN 1	B	A	B
BUR 1a	B	B	B
BUR 1c	NS	NRA	B
BUR 2a	NRA	NRA	B
BUR 2b	B	B	B
BUR 2c	B	B	B

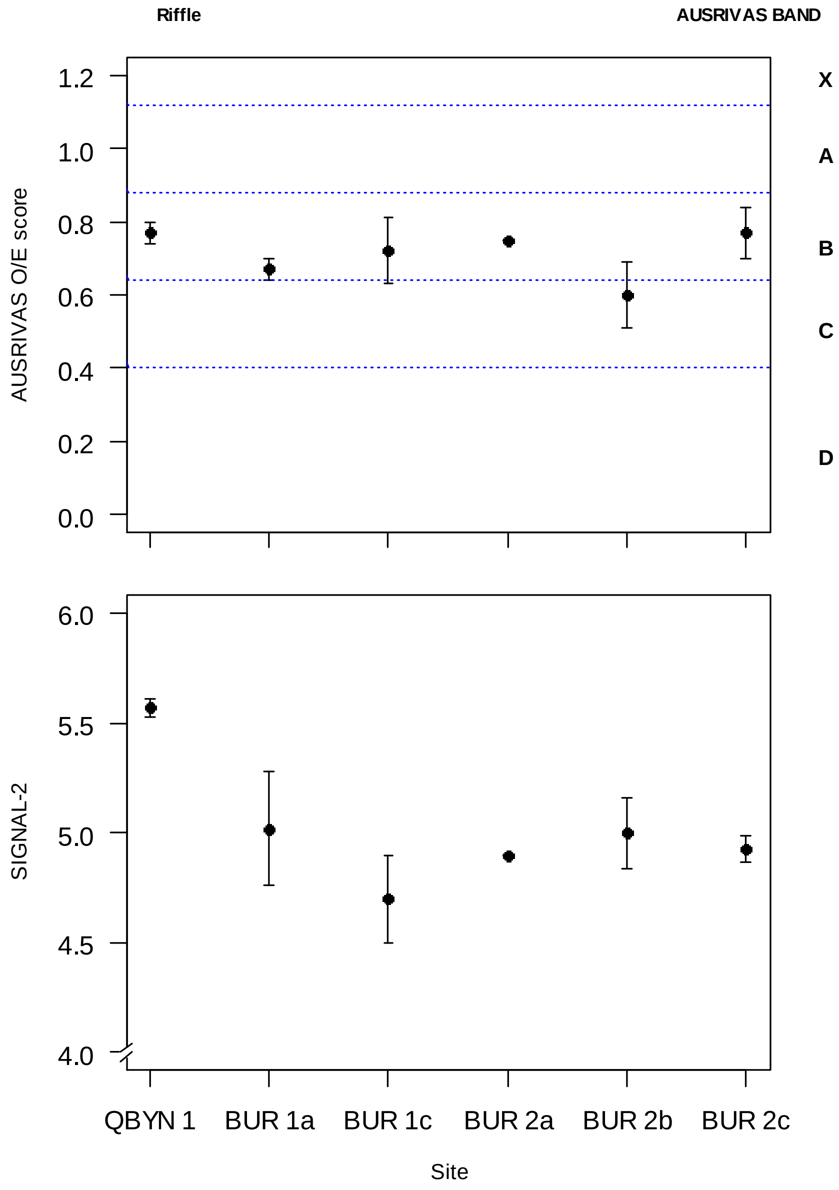


Figure 14. Average OE/50 scores derived from the AUSRIVAS modelling (top) and average SIGNAL scores (bottom) for riffle samples

Error bars are 95% confidence intervals

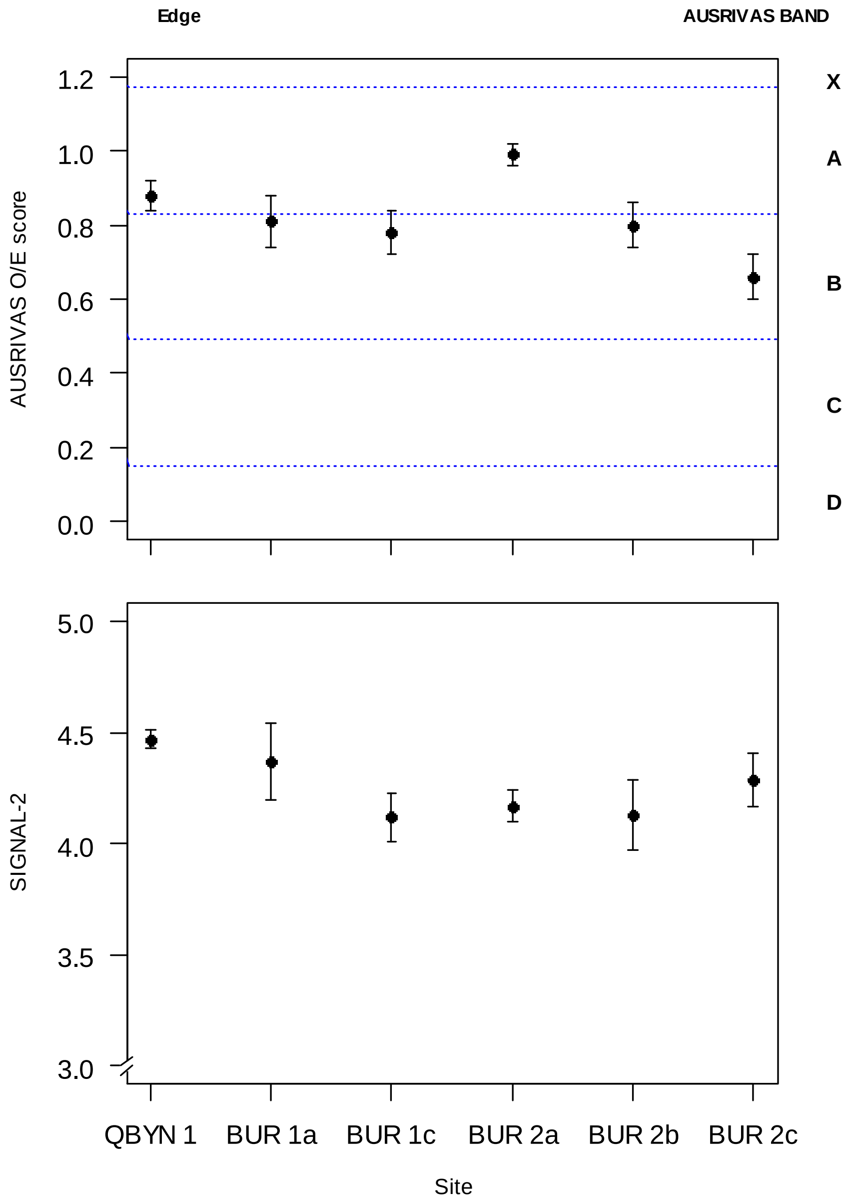


Figure 15. Average OE/50 scores derived from the AUSRIVAS modelling (top) and average SIGNAL scores (bottom) for edge samples

Error bars are 95% confidence intervals

4. Discussion

4.1 Water quality and periphyton

Electrical conductivity and pH continue to exceed the current ANZECC & ARMCANZ (2000) guideline limits for aquatic ecosystem health (Table 7) and because of the geology and higher groundwater contribution to surface water within the Burra Creek Catchment (specifically downstream of the Cassidy Creek confluence - Figure 1), it is unlikely that sites downstream of this point will fully comply with the ANZECC & ARMCANZ (2000) guidelines. Previous recommendations have included the support to have the water quality guideline values for Burra Creek revised, particularly pH and EC, although a complete revision would be preferable. Box and whisker plots of pH and EC data are presented in Appendix F, which illustrate the period of record data for Burra Creek broken down into seasonal and annual components. Plots in Appendix F show that the median pH value has been naturally increasing since the drought broke. Based on these descriptive statistics there is justification to re-evaluate trigger levels indicated in the M2G stream flow and water quality sub-plan to better reflect the natural condition of Burra Creek (Hart, 2001).

Most parameters analysed through grab samples and *in situ* water quality monitoring indicate that the construction zone at the outlet for M2G upstream of the Williamsdale Road bridge is not impacting on the water quality within Burra Creek, and this result is consistent with the previous sampling run (ALS, 2011).

Total nitrogen exceeded the guidelines at all of the sampling sites (Table 7) and oxidised forms exceeded the limits at all of the downstream sites in Burra Creek. The levels of NO_X at BUR 2a are thirty times higher than they are at BUR 1c and twelve times higher than the ANZECC & ARMCANZ (2000) guideline trigger value. This increase was confirmed to be coming from Holdens Creek which flows into Burra Creek downstream of BUR 1c (but just upstream of the M2G discharge structure) and runs parallel to the M2G pipeline alignment near the mini-hydro. Whether this is linked to M2G related works or runoff from adjacent farm land is unclear at this point.

It is suggested that if these levels continue to exceed the guidelines downstream of BUR 1c, additional samples are to be collected upstream and away from the M2G construction area which will allow the source of increased concentrations to be properly assessed. Our preliminary findings suggest that the significantly higher chlorophyll-a downstream of the discharge point is strongly correlated to TN (R^2 = 0.93) and to a lesser extent NOx (R^2 = 0.68).

However, is should be pointed out that at the Queanbeyan River control site, where chlorophyll-a concentrations were also higher than the upstream Burra Creek sites (Figure 7), TN concentrations were approximately the same as the upstream Burra Creek sites and NOx was within the guidelines levels. This indicates that the increases downstream of discharge point are not necessarily related to increased nutrient levels. Of course algal biomass accrual rates are likely to be influenced differently between catchments and one of the factors influencing this is habitat quality. Filamentous algae stands in the Queanbeyan River can become high in spring and summer (*P. Taylor, pers. obs*., 2008-2009) compared to Burra Creek which may be attributed to larger fractions of the substrate providing a more stable environment, regardless of nutrient concentrations. Currently the higher chlorophyll-a concentrations downstream of Williamsdale Bridge do not appear to be correlated with increased dissolved oxygen concentrations, either from the continuous records (Figures 5 and 6) or the grab samples (Table 7) as would be expected with increased algal growth.

4.2 AUSRIVAS assessment and macroinvertebrate assemblages

Although there was no statistical difference between the riffle or edge macroinvertebrate assemblages (Figures 9 & 13; Appendix C) these results should be considered carefully given the evidence from the raw data and that the positioning of the sites in the ordination plot indicate a certain degree of separation between the native Burra Creek site (BUR 1a) and the perennial control on the Queanbeyan River. Both of these upstream sites (i.e. BUR 1a and QBYN 1) had higher numbers of the stonefly family: Gripopterygidae (SIGNAL = 8), which thrive in fast flowing and highly oxygenated water. QBYN 1 was also characterised by riffle beetles which, apart from having only a few individuals being collected from BUR 1a, were absent from Burra Creek. This is likely a consequence of the different flow regimes between the catchments. Bond and Cottingham (2008) explain that in intermittent streams the connectivity between the headwaters and downstream reaches can be poorly connected because of extended periods of low or no flow between reaches. Consequently, this may limit dispersal leading to higher dissimilarities between sites.

The other key factor that goes some way in explaining the difference between BUR 1a and the downstream sites is the physical properties of the site compared to the downstream reaches. BUR 1a lies within a highly shaded section of the Creek with riparian vegetation. In some sections BUR 1a has a fairly dense canopy that provides both shade and organic carbon in the form of leaf litter and woody debris into the system. This organic matter provides habitat and a food source that is not provided in the downstream sections and thus has probably resulted in the differences seen in the ordination analyses (Figures 9 & 13).

Burra Creek sites downstream of BUR 1a were, for the most part, dominated by moderately to highly tolerant taxa such as Oligochaetes (segmented worms) and Dipterans (true flies) which is reflected in the relative abundance plots (Figure 10) and also when comparing SIGNAL scores between the Queanbeyan River site and the Burra Creek sites (Figure 14). The dominance of the moderately tolerant taxa in Burra Creek have been discussed previously (ALS, 2011) but may be due to either lower flows in Burra Creek, the quality and quantity of the habitat, or a combination of both. Plate 4 shows the highly silted substrate at BUR 1c which also contains fine organic material from decaying macrophytes that have not been flushed through. Taxa such as Chironomidae and Oligochaetes can thrive by burrowing into the sediment and have a higher tolerance for poorer water quality which may prevail in such environments (Gooderham and Tsyrlin, 2005).

Plate 4. Substrate in the riffle habitat at BUR 1c

The influence of water quality on the community assemblages cannot be ruled out as there is evidence that some of the taxa that characterise QBYN 1 are also found at BUR 1a which has similar water characteristics. If water quality rather than habitat quality is the leading factor in the determination of the macroinvertebrate community structure, then changes to the macroinvertebrate assemblages downstream of the release point relative to those seen upstream at BUR 1a and BUR 1c can be expected once M2G is operational.

The overall AUSRIVAS assessments indicate no change from the previous two sampling runs at the Burra Creek sites, and a decline from Band A to Band B at QBYN 1. Macroinvertebrate families that were predicted to occur, but were absent from the autumn models, are shown in Appendix D. These results show a range of taxa missing with various SIGNAL scores. The most frequently missing taxa included: Elmidae (riffle beetles: SIGNAL = 7); Psephenidae (SIGNAL = 6); Gripopterygidae (SIGNAL = 8); Glossosomatidae (SIGNAL = 9) and Ecnomidae (SIGNAL = 4) which for the most part show no definitive pattern in terms of location differences within Burra Creek. The only obvious pattern, which has already been discussed, is the difference in the Elmidae (riffle beetles) between QBYN 1 and the Burra Creek sites. Overall, the edge habitat tended to be in better condition than the riffle (Table 9) which reflects the relative stability of the edge habitat compared to the riffle habitat during periods of fluctuating and extreme flow events.

The high flow event at the beginning of March (Figure 3) is likely to have influenced these habitats in different ways with the riffle habitat communities most immediately affected through substrate movement. This may have resulted in an immediate loss of diversity and reduction of abundances, particularly those taxa prone to high flow disturbances (e.g. mayflies and stoneflies) (Lake, 2000). Edge communities on the other hand can act as a buffer and a refuge during high flow events resulting in faster recruitment to pre-flood conditions depending on the magnitude and duration of the high flow event.

The macroinvertebrate communities collected during the autumn sampling are consistent with patterns seen in previous sampling runs following high flow events and are indicative of communities in later stages of succession. Taxa such as Chironomids can be highly prolific during these periods through a combination of their resilience to high flow events and being able to out-compete other taxa in early stages following high flow events. Other taxa, such as free living mayflies, may be more prone to dislodgement and as such, were poorly represented in the samples collected in autumn. Recolonisation following disturbances can be dependent upon the species pool further upstream because downstream drift is an important facet of this process. In intermittent streams, and indeed Burra Creek, this process may be limited and take longer than perennial streams because permanent linkages between riffle zones can become disconnected during low flow periods, as has been a feature of the autumn sampling period in previous years.

Lake (2000) suggests that another factor slowing the recolonisation of macroinvertebrate communities can be the quality of the substrate and therefore the availability of interstitial spaces as refuge during high flow events. Sites with loosely structure sand beds or sites that are highly silted, such as those in Burra Creek, may therefore experience a relatively slow colonisation period. Furthermore, because of the impoverished riparian zone along the downstream sections of Burra Creek, aerial recolonisation may be relied upon over much greater distances (Bunn and Hughes, 1997) compared to the upstream site (BUR 1a) and the Queanbeyan River and would therefore slow the process further.

5. Conclusions and Recommendations

Following the high flow event at the beginning of March, there was a reduction in the number of sensitive macroinvertebrate genera and families meaning the communities were dominated by moderately to high tolerant taxa compared to previous sampling runs. The resulting AUSRIVAS bands for the sites under assessment were all determined to be Band B indicating that fewer families were collected than would be expected compared to reference condition. None of the taxa missing from the AUSRIVAS model point to a specific impact and this is primarily because for the most part, the missing taxa were not missing from one specific site or location. Rather they were missing across most of the sampling sites indicating a large scale impact as opposed to a specific cause.

Indeed, based on the data collected for autumn 2012, there is no conclusive evidence to suggest that differences in macroinvertebrate assemblages are a direct result of the M2G construction. However, there is an indication from the water quality results that a significant proportion of nitrogen immediately downstream of the release site at Williamsdale Road is in oxidised forms (NOx) and that a potential source could be from Holdens Creek, adjacent to the construction site. These elevated NO_x levels have been correlated to chlorophyll-a levels which for the first time show a significant increase downstream of Williamsdale Road. This circumstantial evidence suggests a possible impact from increased nitrogen concentrations and if they persist, further investigations are warranted. Initially this would be to identify the source.

Several recommendations from previous reports have been actioned, including winter and summer macroinvertebrate monitoring, and determination of the approximate depth of oxygen exchange in the subsurface of Burra Creek. Other recommendations have been compiled into a summary document (ALS, 2012). Included in this document is the need to review the water quality guideline trigger levels within Burra Creek, which are discussed in section 4.1 of this report.

6. Literature Cited

ALS (2011). Murrumbidgee Ecological Monitoring Program: Part II – Burra Creek. May 2011. Report for Actew Corporation.

ALS (2012) Murrumbidgee Ecological Monitoring Program: Summary 2008 – 2011. Report for ActewAGL Distribution. Report Number: CN211063-WR-0112-002.

ANZECC & ARMCANZ (2000) Australian Guidelines for Monitoring and Reporting, National Water Quality Management Strategy Paper no. 7. Australia and New Zealand Environment and Conservation Council /Agriculture and Resource Management Council of Australia and New Zealand.

APHA (2005) *Standard methods for the examination of water and waste water. 21st Edition. American Public Health Association*, Washington.

ARMCANZ, A. (2000) *Australian Guidelines for Monitoring and Reporting, National Water Quality Management Strategy Paper no. 7. Australia and New Zealand Environment and Conservation Council /Agriculture and Resource Management Council of Australia and New Zealand*.

Biggs, B. J. F. (2000) *New Zealand periphyton guideline: detecting, monitoring and managing enrichment of streams*, Ministry for the Environment, Wellington.

Biggs, B. J. F. and Kilroy, C. (2000) *Stream Periphyton Monitoring Manual. NIWA, Christchurch.*, NIWA.

Bond, N. and Cottingham, P. (2008) *Ecology and hydrology of temporary streams: implications for sustainable water management*, eWater Technical Report. eWater Cooperative Research Centre, Canberra. http://ewatercrc.com.au/reports/Bond_Cottingham-2008-Temporary_Streams.pdf.

Brunke, M. and Gonser, T. (1997) The ecological significance of exchange processes between rivers and groundwater. *Freshwater Biology*, **37** (1), 1-33.

Bunn, S. E. and Arthington, A. H. (2002) Basic principles and ecological consequences of altered flow regimes for aquatic biodiversity. *Environmental Management*, **30** (4), 492-507.

Bunn, S. E. and Hughes, J. H. (1997) Dispersal and Recruitment in Streams: Evidence from Genetic Studies. *Journal of the North American Benthological Society*, **16** (2), 338-346.

Cao, T., Larsen, D. P. and ST-J. Thorne, R. (2001) Rare species in multivariate analysis for bioassessment: some considerations. *Journal of the North American Benthological Society*, **20** (1), 144-153.

Chessman, B. C. (2003) New sensitivity grades for Australian river macroinvertebrates. *Marine and Freshwater Research*, **54** (2), 95-103.

Clarke, K. R. and Gorley, R. N. (2006) *PRIMER v6: User Manual/Tutorial*, PRIMER-E: Plymouth.

Clarke, K. R. and Warwick, R. M. (2001) *Change in marine communities: an approach to statistical analysis and interpretation, 2nd edition*, PRIMER-E: Plymouth.

Coysh, J. L., Nichols, S. J., Simpson, J. C., Norris, R. H., Barmuta, L. A., Chessman, B. C. and Blackman, P. (2000) Australian River Assessment System (AUSRIVAS) National River Health Program Predictive Model Manual.

Davies, B. R., Thoms, M. and Meador, M. (1992) An assessment of the ecological impacts of inter-basin water transfers, and their threats to river basin integrity and conservation. *Aquatic Conservation: Marine and Freshwater Ecosystems*, **2** (4), 325-349.

Harrod, J. J. (1964) The distribution of invertebrates on submerged aquatic plants in a chalk stream. *Journal of Animal Ecology*, **33** (2), 335-348.

Kruskal, J. B. (1964) Multidimensional scaling by optimizing goodness of fit to a non-parametric hypothesis. *Psychometrika*, **20** 1-27.

Lake, P. S. (2000) Disturbance, patchiness, and diversity in streams. *Journal of the North American Benthological Society*, **19** (4), 573-592.

Loeb, S. L. (1981) An in situ method for measuring the primary productivity and standing crop of the epilithic periphyton community in lentic systems. *Limnology and Oceanography*, **26** (2), 394-399.

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

Martin, T. and Rutlidge, A. (2009) *Murrumbidgee to Googong Water Transfer Project: Aquatic Impact Assessment*, Biosis Research Pty. Ltd.

R Development Core Team (2012). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org/.

Wallace, J. B. (1990) Recovery of lotic macroinvertebrate communities from disturbance. *Environmental Management*, **14** (5), 605-620.

Appendix A
Site Condition Summaries

BUR1a

Burra Native
4/5/2012 10:25am

Temp. (°C)	EC (µs/cm)	Turb. (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
7.2	98	7.7	< 2	7.2	91.4	9.6

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
25	0.003	0.001	< 0.002	0.004	0.010	0.26

Daily Flow: 4.4 ML/day

Recorded at the closest station (410774), located on Burra Creek at Burra Road.

Compared to current flow:

Spring 2011:

Autumn 2011:

AUSRIVAS Results

	Autumn 2011	Spring 2011	Autumn 2012
Riffle Habitat	B	A	C
Edge Habitat	B	B	B
Overall Site Assessment	B	B	C

Riffle Habitat

- Substrate is bare through the centre of the channel, with periphyton along the margins
- Dominant substrate was cobble

Dominant Taxa

- Leptoceriidae
- Baetidae

Sensitive Taxa (SIGNAL-2 ≥ 8)

- Leptophlebiidae
- Gripopterygidae
- Hydrobiosidae

Edge Habitat

- Dominant trailing bank vegetation was *Kunzea sp.*
- Mountain Galaxias (*Galaxias olidus*) caught in the sample, subsequently released

Dominant Taxa

- Leptophlebiidae

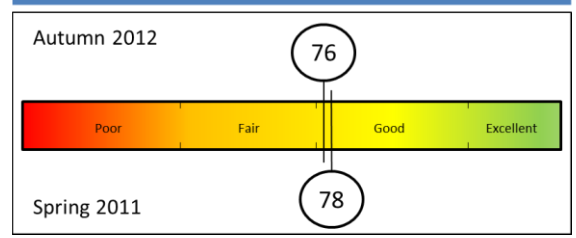
Sensitive Taxa (SIGNAL-2 ≥ 7)

- Dixidae
- Leptophlebiidae

Additional Comments

- High level of erosion on the right hand bank
- Some deposition of sand on the inside of the bend on the right hand bank
- Large levels od sand have been scoured from the pools leaving a much rockier substrate than previously

Site Quality Assessment



BUR1c

Upstream Williamsdale Road
4/5/2012 12:00pm

Temp. (°C)	EC (µs/cm)	Turb. (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
11.2	410	5.4	9	8.1	102.1	9.9

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
165	0.006	0.004	< 0.002	0.002	0.008	0.27

Daily Flow: 4.4 ML/day

Recorded at the closest station (410774), located on Burra Creek at Burra Road.

Compared to current flow:

Spring 2011: ↓ Autumn 2011: **NS**

AUSRIVAS Results

	Autumn 2011	Spring 2011	Autumn 2012
Riffle Habitat	NS	C	B
Edge Habitat	NS	A	B
Overall Site Assessment	NS	NRA	B

Riffle Habitat

- Limited rifle habitat resulting in only a single sample
- Riffle habitat has shifted slightly due to substrate movement following high flow event in March
- Dominant substrate was cobble

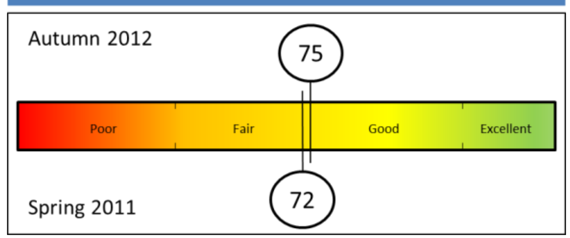
Dominant Taxa

- Simuliidae

Sensitive Taxa (SIGNAL-2 ≥ 8)

- Hydrobiosidae

Site Quality Assessment



Edge Habitat

- Dominant trailing bank vegetation was macrophytes

Dominant Taxa

- Chironomidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Dixidae

Additional Comments

- Large sections of dead macrophytes due to inundation during high flows
- High deposition of silt through channel
- Some areas of sand deposition

BUR2a

Downstream Williamsdale Road
4/5/2012 1:30pm

Temp. (°C)	EC (µs/cm)	Turb. (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
11.1	480	6.6	3	8.1	103.7	10.2

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
198	0.18	0.178	< 0.002	0.003	0.008	0.40

Daily Flow: 4.4 ML/day

Recorded at the closest station (410774), located on Burra Creek at Burra Road.

Compared to current flow:

Spring 2011: ↓ Autumn 2011: ↓

AUSRIVAS Results

	Autumn 2011	Spring 2011	Autumn 2012
Riffle Habitat	C	A	B
Edge Habitat	B	NRA	A
Overall Site Assessment	C	NRA	B

Riffle Habitat

- Riffle zone is highly silted
- Dominant substrate was cobble

Dominant Taxa

- Simuliidae
- Baetidae

Sensitive Taxa (SIGNAL-2 ≥ 8)

- Leptophlebiidae

Edge Habitat

- Dominant trailing bank vegetation was macrophytes

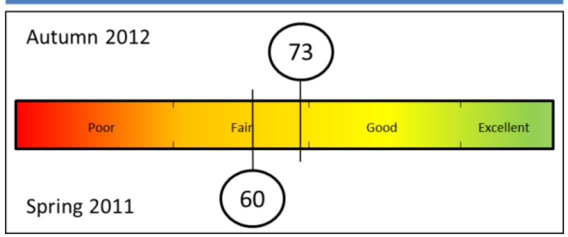
Dominant Taxa

- Chironomidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

Site Quality Assessment



Additional Comments

- Large sections of dead grasses and macrophytes due to inundation during high flows
- New moss growth
- Some sand deposition on the left hand bank

BUR2b

Downstream Burra Road
4/5/2012 3:00pm

Temp. (°C)	EC (µs/cm)	Turb. (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
12.4	480	5.9	2	8.3	107.5	10.3

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
202	0.037	0.035	< 0.002	0.003	0.009	0.27

Daily Flow: 4.4 ML/day

Recorded at the closest station (410774), located on Burra Creek at Burra Road.

Compared to current flow:

Spring 2011: ↓ Autumn 2011: ↓

AUSRIVAS Results

	Autumn 2011	Spring 2011	Autumn 2012
Riffle Habitat	B	B	C
Edge Habitat	B	A	B
Overall Site Assessment	B	B	C

Riffle Habitat

- Filamentous algae, periphyton and silt were dominant within the riffle zone
- Riffle habitat only present in small sections connected by pool and run habitat
- Dominant substrate was cobble and pebble

Dominant Taxa

- Chironomidae
- Simuliidae
- Hydrobiosidae

Sensitive Taxa (SIGNAL-2 ≥ 8)

- Hydrobiosidae

Additional Comments

- Deposition of sand on the right hand bank
- High abundance of filamentous algae throughout the site where stable habitat was present

Edge Habitat

- Dominant trailing bank vegetation was macrophytes (mainly *Phragmites australis*)

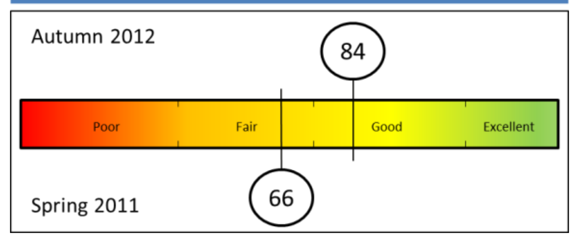
Dominant Taxa

- None

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Hydrobiosidae

Site Quality Assessment



BUR2c

Upstream London Bridge
3/5/2012 1:55pm

Temp. (°C)	EC (µs/cm)	Turb. (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
14.6	490	2.75	< 2	8.2	109.4	11.2

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
210	0.041	0.039	< 0.001	0.002	0.006	0.28

Daily Flow: 4.7 ML/day

Recorded at the closest station (410774), located on Burra Creek at Burra Road.

Compared to current flow:

Spring 2011: ↓ Autumn 2011: **NS**

AUSRIVAS Results

	Autumn 2011	Spring 2011	Autumn 2012
Riffle Habitat	NS	B	B
Edge Habitat	NS	A	B
Overall Site Assessment	NS	B	B

Riffle Habitat

- Dominant substrate was cobble

Dominant Taxa

- Chironomidae
- Baetidae

Sensitive Taxa (SIGNAL-2 ≥ 8)

- Leptophlebiidae
- Hydrobiosidae

Edge Habitat

- Dominant trailing bank vegetation was macrophytes (mainly *Typha sp.* and *Eleocharis sp.*)

Dominant Taxa

- Chironomidae
- Corixidae
- Leptoceridae

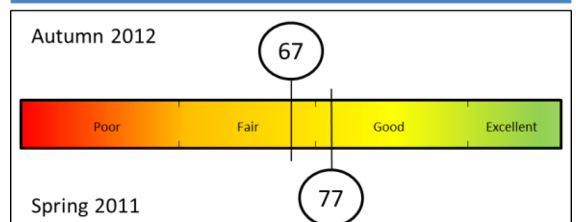
Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

Additional Comments

- Periphyton is mainly organic matter
- The *Myriophyllum sp.* was covered in silt
- Large pool directly upstream of the riffle zone partially filled with sand and silt, due to sediment movement during the March event
- Wooden stakes indicated that the anoxic zone is much closer to the surface on the left hand side of the channel
- Both banks show evidence of erosion
- Site area was overrun by weeds

Site Quality Assessment



QBYN1

Flynn's Crossing
3/5/2012 12:20pm

Temp. (°C)	EC (µs/cm)	Turb. (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
11.7	85	4.2	5	7.8	109.4	12.0

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
37	< 0.002	< 0.001	< 0.002	0.003	0.018	0.28

Daily Flow: 156 ML/day

Recorded at the closest station (410781), located on the Queanbeyan River, upstream of Googong Dam.

Compared to current flow:

Spring 2011:  Autumn 2011: 

AUSRIVAS Results

	Autumn 2011	Spring 2011	Autumn 2012
Riffle Habitat	B	A	B
Edge Habitat	B	A	A
Overall Site Assessment	B	A	B

Riffle Habitat

- Possible blue-green algae proliferation in the riffle zone
- Dominant substrate was boulder, cobble and pebble

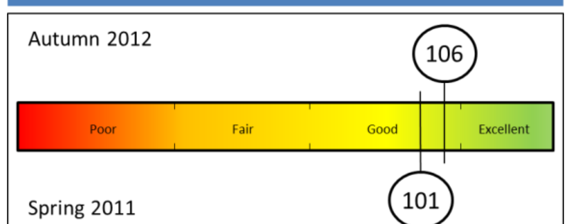
Dominant Taxa

- Simuliidae
- Baetidae
- Leptophlebiidae
- Hydrobiosidae

Sensitive Taxa (SIGNAL-2 ≥ 8)

- Leptophlebiidae
- Gripopterygidae
- Hydrobiosidae
- Philopotamidae

Site Quality Assessment



Edge Habitat

- Dominant trailing bank vegetation was wood and native shrubs

Dominant Taxa

- Corixidae
- Leptoceridae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Gripopterygidae

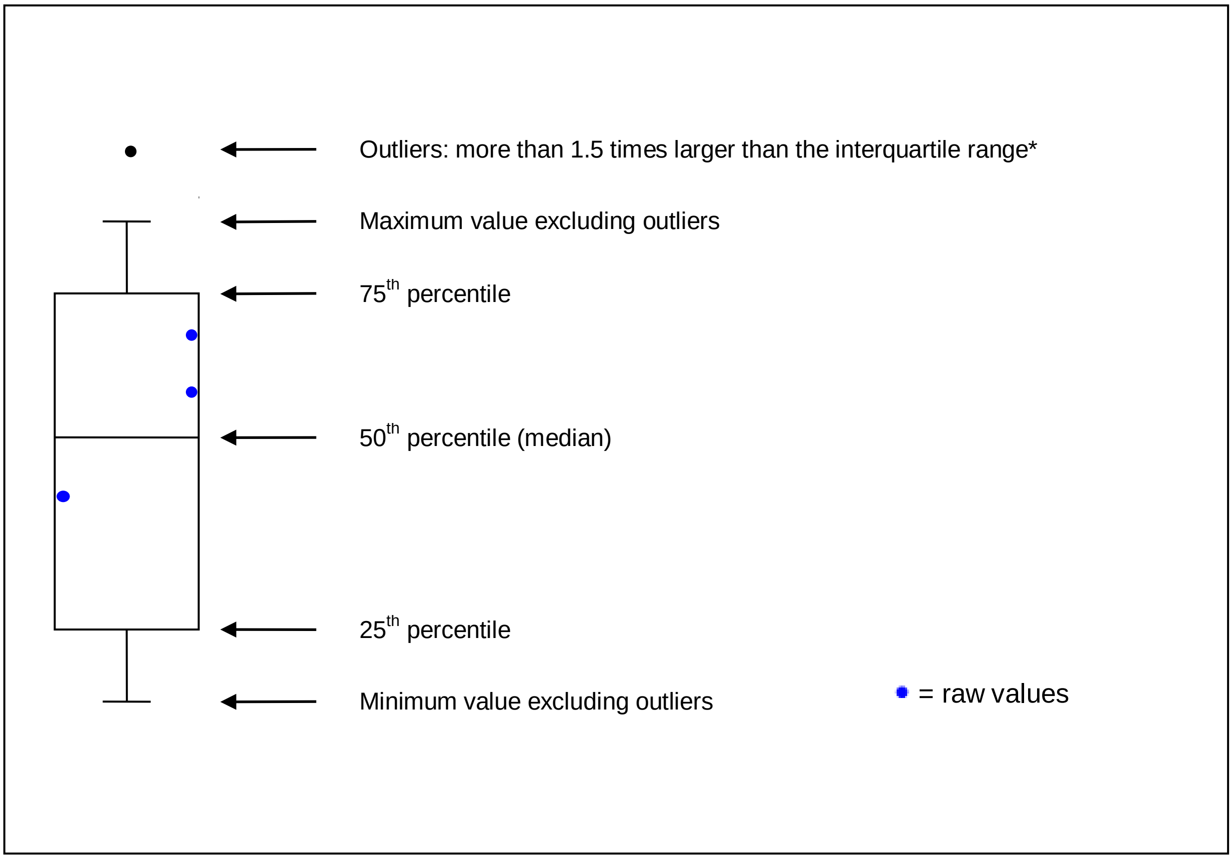
Additional Comments

- Crossing has been graded, flattening the last metre of the upstream riffle
- Grading has increased the loose sediment and chances of sediment entering the waterway through runoff
- Some isolated erosion on the right hand bank
- Large levels of sand deposited on the bar during the March event
- New riffle created in the 2nd braid, in alright condition after the flows have receded (not sampled)

Appendix B

Interpreting box and whisker plots

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



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

Appendix C

ANOSIM output for riffle and edge samples

RIFFLE

TESTS FOR DIFFERENCES BETWEEN Site Code GROUPS
(across all Location 1 groups)
Global Test
Sample statistic (Global R): 0.759
Significance level of sample statistic: 0.1%
Number of permutations: 999 (Random sample from 17657640)
Number of permuted statistics greater than or equal to Global R: 0

TESTS FOR DIFFERENCES BETWEEN Location 1 GROUPS
(using Site Code groups as samples)
Global Test
Sample statistic (Global R): 0.182
Significance level of sample statistic: 30%
Number of permutations: 60 (All possible permutations)

Number of permuted statistics greater than or equal to Global R: 18

EDGE

TESTS FOR DIFFERENCES BETWEEN Site Code GROUPS
(across all Location 1 groups)
Global Test
Sample statistic (Global R): 0.759
Significance level of sample statistic: 0.1%
Number of permutations: 999 (Random sample from a large number)
Number of permuted statistics greater than or equal to Global R: 0

TESTS FOR DIFFERENCES BETWEEN Location 1 GROUPS
(using Site Code groups as samples)
Global Test
Sample statistic (Global R): 0.364
Significance level of sample statistic: 16.7%
Number of permutations: 60 (All possible permutations)

Number of permuted statistics greater than or equal to Global R: 10

Appendix D

Taxa predicted to occur with >50% probability but not collected in the autumn samples

APPENDIX D. Taxa expected, but not collected in the riffle habitat. The number in each cell is the probability of collection (np = not predicted to occur)

Site		Hydrobiidae	Ancylidae	Acarina	Hydrophilidae	Elmidae	Psephenidae	Podonominae	Tanypodinae	Leptophlebiidae	Caenidae	Corydalidae	Gomphidae	Gripopterygidae	Glossosomatidae	Hydroptilidae	Philopotamidae	Hydropsychidae	Ecnomidae	Conoesucidae	Leptoceridae	Number of missing taxa
	Signal 2	4	4	6	2	7	6	6	4	8	4	7	5	8	9	4	8	6	4	7	6	
QBYN 1 R1	riffle	*np*	*np*		0.5		0.86	0.59	0.5			0.59	0.64		0.64				0.5	0.86	*np*	9
QBYN 1 R2	riffle	*np*	*np*		0.5		0.86	0.59	0.5			0.59	0.64		0.64				0.5	0.86	*np*	9
QBYN 1 R3	riffle	*np*	*np*		0.5		0.86	0.59	0.5			0.59	0.64		0.64				0.5	0.86	*np*	9
QBYN 1 R4	riffle	*np*	*np*		0.5		0.86	0.59	0.5			0.59	0.64		0.64				0.5	0.86	*np*	9
QBYN 1 R5	riffle	*np*	*np*		0.5			0.59	0.5			0.59	0.64		0.64				0.5	0.86	*np*	8
QBYN 1 R6	riffle	*np*	*np*		0.5		0.86	0.59	0.5			0.59	0.64		0.64	0.59			0.5	0.86	*np*	10
BUR 1a R1	riffle	*np*	*np*		*np*		0.86	0.59			0.82	0.59			0.63	0.59			0.5	0.86	*np*	8
BUR 1a R2	riffle	*np*	*np*		*np*	0.95	0.86	0.59				0.59	0.63		0.63	0.59	0.68	0.95	0.5	0.86	*np*	11
BUR 1a R3	riffle	*np*	*np*		*np*	0.95	0.86	0.59			0.82	0.59	0.63	0.86	0.63		0.68	0.95		0.86	*np*	11
BUR 1a R4	riffle	*np*	*np*		*np*	0.95	0.86	0.59			0.82	0.59	0.63	0.86	0.63			0.95		0.86	*np*	10
BUR 1a R5	riffle	*np*	*np*		*np*	0.95	0.86	0.59				0.59	0.63	0.86	0.63	0.59	0.68	0.95	0.5	0.86	*np*	12
BUR 1a R6	riffle	*np*	*np*		*np*	0.95	0.86	0.59				0.59	0.63		0.63		0.68	0.95		0.86	*np*	9
BUR 1c R1	riffle	*np*	*np*	0.59	*np*	0.99	*np*	0.57	0.67	0.87		*np*	0.52	*np*	*np*	0.68	*np*		*np*	*np*	*np*	7
BUR 1c R2	riffle	*np*	*np*	0.59	*np*	0.99	*np*	0.57	0.67			*np*	0.52	*np*	*np*		*np*		*np*	*np*	*np*	5
BUR 1c R3	riffle	*np*	*np*	0.59	*np*	0.99	*np*	0.57		0.87		*np*	0.52	*np*	*np*	0.68	*np*		*np*	*np*	*np*	6
BUR 2a R1	riffle	*np*	*np*	0.55	*np*	0.99	0.51	0.57	0.65			*np*	0.53	*np*	*np*		*np*		*np*	*np*	*np*	6
BUR 2a R2	riffle	*np*	*np*	0.55	*np*	0.99	0.51	0.57				*np*	0.53	*np*	*np*	0.67	*np*		*np*	*np*	*np*	6
BUR 2a R3	riffle	*np*	*np*	0.55	*np*	0.99	0.51	0.57	0.65			*np*	0.53	*np*	*np*		*np*		*np*	*np*	*np*	6
BUR 2b R1	riffle	*np*	*np*	0.09	0.5	0.95	0.86	0.59	0.5			0.59	0.64	0.86	0.64					0.86	*np*	11
BUR 2b R2	riffle	*np*	*np*	0.09	0.5	0.95	0.86	0.59	0.5		0.82	0.59	0.64	0.86	0.64				0.5	0.86	*np*	12
BUR 2b R3	riffle	*np*	*np*	0.09	0.5	0.95	0.86	0.59			0.82	0.59	0.64	0.86	0.64					0.86	*np*	11
BUR 2b R4	riffle	*np*	*np*	0.09	0.5	0.95	0.86	0.59	0.5	0.91	0.82	0.59	0.64	0.86	0.64	0.59	0.68		0.5	0.86	*np*	15
BUR 2b R5	riffle	*np*	*np*		0.5	0.95	0.86	0.59	0.5		0.82	0.59	0.64	0.86	0.64		0.68			0.86	*np*	12
BUR 2b R6	riffle	*np*	*np*		0.5	0.95	0.86	0.59	0.5			0.59	0.64	0.86	0.64	0.59	0.68			0.86	*np*	12
BUR 2c R1	riffle	0.59	0.59		*np*	1	*np*	0.57	0.7			*np*	0.5	*np*	*np*		0.04		*np*	*np*		7
BUR 2c R2	riffle	0.59	0.59		*np*	1	*np*	0.57				*np*	0.5	*np*	*np*		0.04		*np*	*np*	0.53	7
BUR 2c R3	riffle	0.59		0.69	*np*	1	*np*	0.57				*np*	0.5	*np*	*np*		*np*		*np*	*np*		5
BUR 2c R4	riffle	0.59	0.59	0.69	*np*	1	*np*	0.57	0.7			*np*	0.5	*np*	*np*		*np*		*np*	*np*	0.53	7
BUR 2c R5	riffle	0.59	0.59	0.69	*np*	1	*np*	0.57				*np*	0.5	*np*	*np*	0.7	*np*		*np*	*np*	0.53	8
BUR 2c R6	riffle	0.59	0.59	0.69	*np*	1	*np*	0.57				*np*	0.5	*np*	*np*	0.7	*np*		*np*	*np*	0.53	8

APPENDIX D (cont.). Taxa expected, but not collected in the edge habitat. The number in each cell is the probability of collection (np = not predicted to occur)

		Ancylidae	Planorbidae	Acarina	Hydrophilidae	Elmidae	Ceratopogonidae	Simuliidae	Podonominae	Leptophlebiidae	Corixidae	Coenagrionidae	Synlestidae	Gomphidae	Gripopterygidae	Hydroptilidae	Ecnomidae	Conoesucidae	Calamoceratidae	Leptoceridae	Number of missing taxa
Signal Score		4	2	6	2	7	4	5	6	8	2	2	7	5	8	4	4	7	7	6	
QBYN 1 R1	Edge	np	0.55	np	np	0.62	np		np			np	0.65	np		0.92		0.58	np		5
QBYN 1 R2		np	0.55	np	np		np		np			np	0.65	np	0.68			0.58	np		4
QBYN 1 R3		np	0.55	np	np		np		np			np	0.65	np	0.68		0.58	0.58	np		5
QBYN 1 R4		np	0.55	np	np		np		np			np	0.65	np	0.68		0.58	0.58	np		5
QBYN 1 R5		np	0.55	np	np		np		np			np	0.65	np	0.68	0.92		0.58	np		5
QBYN 1 R6		np	0.55	np	np	0.62	np		np			np	0.65	np				0.58	np		4
BUR 1a R1	Edge	np	0.55	np	np	0.62	np		np			np	0.65	np	0.69			0.59	np		5
BUR 1a R2		np	0.55	np	np	0.62	np		np		0.62	np	0.65	np				0.59	np		5
BUR 1a R3		np	0.55	np	np		np		np			np	0.65	np	0.69		0.58	0.59	np		5
BUR 1a R4		np	0.55	np	np		np		np			np	0.65	np	0.69			0.59	np		4
BUR 1a R5		np	0.55	np	np	0.62	np		np			np	0.65	np	0.69	0.93	0.58	0.59	np		7
BUR 1a R6		np	0.55	np	np	0.62	np		np			np	0.65	np	0.69	0.93	0.58	0.59	np		7
BUR 1c R1	Edge	np	np	np	0.74	0.73	np		np		0.66	np	np	np	0.56	np	np	np	np	0.97	5
BUR 1c R2		np	np	np	0.74	0.73	np		np			np	np	np	0.56	np	np	np	np	0.97	4
BUR 1c R3		np	np	np	0.74	0.73	np		np			np	np	np	0.56	np	np	np	np		3
BUR 1c R4		np	np	np	0.74	0.73	np		np			np	np	np	0.56	np	np	np	np	0.97	4
BUR 1c R5		np	np	np	0.74	0.73	np		np			np	np	np	0.56	np	np	np	np	0.97	4
BUR 1c R6		np	np	np	0.74	0.73	np		np			np	np	np	0.56	np	np	np	np		3
BUR 2a R1	Edge	np	np	np	0.66	0.7	np		np			np	np	np	0.56		np	np	np		3
BUR 2a R2		np	np	np		0.7	np		np			np	np	np	0.56		np	np	np		2
BUR 2a R3		np	np	np	0.66	0.7	np		np			np	np	np	0.56		np	np	np		3
BUR 2a R4		np	np	np	0.66	0.7	np		np			np	np	np	0.56		np	np	np		3
BUR 2a R5		np	np	np	0.66	0.7	np		np			np	np	np	0.56		np	np	np		3
BUR 2a R6		np	np	np	0.66	0.7	np		np			np	np	np	0.56		np	np	np		3
BUR 2b R1	Edge	np	0.55	np	np	0.62	np		np			np	np	np	0.69			0.59	np	0.97	5
BUR 2b R2		np	0.55	np	np	0.62	np		np			np	np	np				0.59	np	0.97	4
BUR 2b R3		np	0.55	np	np	0.62	np		np			np	np	np	0.69			0.59	np	0.97	5
BUR 2b R4		np	0.55	np	np	0.62	np		np			np	np	np	0.69			0.59	np	0.97	5
BUR 2b R5		np	0.55	np	np		np		np			np	np	np	0.69			0.59	np		3
BUR 2b R6		np	0.55	np	np	0.62	np		np			np	np	np	0.69	0.93		0.59	np	0.97	6
BUR 2c R1	Edge	0.56	np	0.73	0.88			0.52	0.51	0.94	0.67		np	0.5	np	np	np	np	0.5		9
BUR 2c R2		0.56	np	0.73	0.88	0.76		0.52	0.51			0.5	np	0.5	np	np	np	np	0.5		9
BUR 2c R3		0.56	np	0.73	0.88	0.76	0.59	0.52	0.51		0.67	0.5	np	0.5	np	np	np	np	0.5		10
BUR 2c R4		0.56	np	0.73	0.88	0.76		0.52	0.51		0.67	0.5	np	0.5	np	np	np	np	0.5		10
BUR 2c R5		0.56	np	0.73	0.88	0.76	0.59	0.52	0.51			0.5	np	0.5	np	np	np	np	0.5		10
BUR 2c R6		0.56	np	0.73	0.88	0.76		0.52	0.51			0.5	np		np	np	np	np	0.5		8

Appendix E

Taxonomic inventory

Appendix E. Taxonomic inventory of the macroinvertebrate taxa collected for the riffle habitat

CLASS / Order	Family / subfamily	Genus	QBYN1	BUR1a	BUR1c	BUR2a	BUR2b	BUR2c
ACARINA			■	■			■	■
BIVALVIA	Sphaeriidae							■
	Corbiculidae							■
Coleoptera	Dytiscidae	*Rhantus*	■	■	■			
	Elmidae		■	■				
	Gyrinidae	*Macrogyrus*			■			■
	Psephenidae	*Sclerocyphon*	■					
	Scirtidae			■	■	■	■	■
Decapoda	Atyidae	*Paratya*	■			■		
	Parastacidae	*Cherax*					■	
Diptera	Ceratopogonidae	*Ceratopoginae*		■	■		■	■
	Chironominae		■	■	■	■	■	■
	Empididae		■	■			■	■
	Ephydridae							
	Chironomidae / Orthocladiinae		■	■	■	■	■	■
	Psychodidae			■				■
	Simiuliidae	*Austrosimulium*	■	■	■	■	■	■
		Simulium	■	■	■	■	■	■
	Chironomidae / Tanypodinae			■	■	■		■
	Tipulidae			■		■		
Ephemeroptera	Baetidae	*Genus 2*	■	■	■	■	■	■
		Baetis	■	■	■	■	■	■
	Caenidae	*Genus C*						
		sp.	■	■			■	■
		Tasmanocoenis	■	■	■	■	■	■
	Leptophlebiidae	*Jappa*	■	■	■	■	■	■
		sp.	■	■	■	■	■	■
GASTROPODA	Ancylidae	*Ferrissia*						■
Hemiptera	Corixidae	*Micronecta*					■	
Odonata	Gomphidae		■	■				
OLIGOCHAETA			■	■	■	■	■	■
Plecoptera	Gripopterygidae		■	■			■	■
Trichoptera	Ecnomidae	*Ecnomus*		■		■	■	■
		sp.				■	■	■
	Hydrobiosidae		■	■	■	■	■	■
		Taschorema	■	■	■		■	■
	Hydropsychidae	*Asmicridea*					■	■
		Cheumatopsyche	■		■	■	■	■
		sp.	■		■	■	■	■
	Hydroptilidae	*Hellyethira*				■	■	
		Hydroptila	■			■	■	
		Oxyethira			■		■	■
		sp.	■	■		■	■	■
	Leptoceridae	*Notalina*						
		Oecetis	■	■				■
	Philopotamidae	*Chimarra*	■				■	■

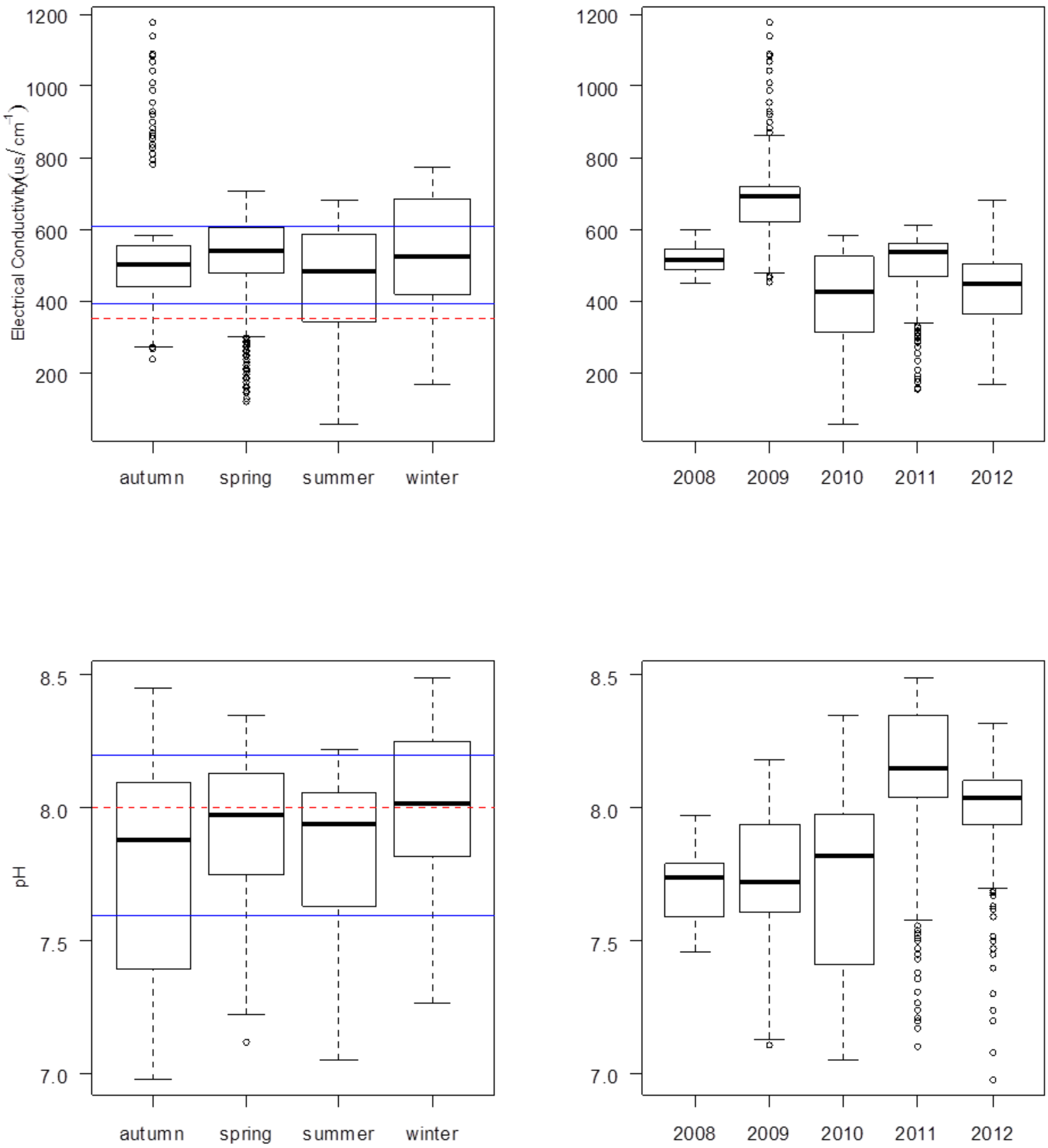
Appendix E (cntd.). Taxonomic inventory of the macroinvertebrate taxa collected for the edge habitat

CLASS / Order	Family / Sub-family	Genus	QBYN1	BUR1a	BUR1c	BUR2a	BUR2b	BUR2c
ACARINA								
BIVALVIA	Corbiculidae	*Corbicula*						
		Corbiculina						
		sp.						
	Sphaeriidae							
Coleoptera	Dytiscidae	*Necterosoma*						
		sp.						
		Sternopriscus						
	Elmidae	*Austrolimnius*						
	Hydraenidae	*Hydraena*						
	Hydrochidae	*Hydrochus*						
	Hydrophilidae	*Berosus*						
		sp.						
	Scirtidae							
Decapoda	Atyidae	*Paratya*						
	Parastacidae	*Cherax*						
Diptera	Ceratopogonidae	*Ceratopoginae*						
		Forcipomyiinae						
	Chironominae							
	Culicidae							
	Dixidae							
	Empididae							
	Orthocladiinae							
	Psychodidae							
	Simuliidae	*Austrosimulium*						
		Simulium						
	Stratiomyidae	*Odontomyia*						
	Chironomidae / Tanypodinae							
	Tipulidae							
Ephemeroptera	Baetidae	*Genus 1*						
		Genus 2						
		Centroptilum sp						
		Cloeon						
		sp.						
	Caenidae	*Genus C*						
		Tasmanocoenis						
		Atalophlebia						
		Jappa						
		sp.						
GASTROPODA	Ancylidae							
	Physidae	*Physa*						
Hemiptera	Corixidae	*Micronecta*						
	Notonectidae	*Notonecta*						
		sp.						
	Pleidae	*Plea*						
	Hemiptera	*sp.*						
	Veliidae	*Microvelia*						
Megaloptera	Sialidae	*Stenosialis*						
Odonata	Aeshnidae	*Brevyistyla*						
	Coenagrionidae	*Ischnura*						
	Gomphidae							
	Libellulidae							
	Zygoptera							
OLIGOCHAETA								
Plecoptera	Gripopterygidae	*Dinotoperla*						
		sp.						
Temnocephalida	Temnocephalidae	*Temnocephala*						
Trichoptera	Atriplectidae	*Atriplectides*						
	Calamoceratidae	*Anisocentropus*						
	Ecnomidae	*Ecnomus*						
		sp.						
	Helicopsychidae	*helicopshyce*						
	Hydrobiosidae	*sp.*						
		Taschorema						
	Hydropsychidae	*Cheumatopsyche*						
		sp.						
	Hydroptilidae	*Hellyethira*						
		sp.						
	Leptoceridae	*Notalina*						
		Oecetis						
		sp.						
		Triaenodes						
		Triplectides						

Appendix F

Burra Creek (410774) EC and pH compared to ANZECC & ARMCANZ (2000) guidelines

APPENDIX F. Box and whisker plots showing continuous EC and pH data collected from 410774 and the Burra Road Weir. Data are broken down by season (left hand side) and year. Solid blue lines indicate the 80th (top) and 20th percentile values for each distribution. Dashed red line indicates current upper limit ANZECC guidelines.



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