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MURRUMBIDGEE ECOLOGICAL MONITORING PROGRAM

PART 2: BURRA CREEK

SPRING 2011

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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 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 being developed to enable pumping of up to 100 ML/d, and is expected to be operational by mid-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 hydrological change 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 were to:

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

This report presents the findings from biological sampling of Burra Creek and the Queanbeyan River conducted in spring 2011. Sampling was conducted on the 4th and 5th October 2011 and was based on ACT AUSRIVAS sampling protocols; but was extended to include multiple replicates from each site where specimens were identified to genus level, instead of family level.

The purpose of this protocol was to:

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

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

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

Key results from the spring 2011 sampling run show that:

1) *Flows in both catchments (Burra and Queanbeyan) preceding the sampling period were stable with no significant rainfall or high flow events occurring prior to sampling;*

2) *Compared to spring 2010, the AUSRIVAS assessment for the riffle habitat showed an improvement in condition at BUR 1a; BUR 2a and QBYN 1. The overall site assessments showed that QBYN 1 was close to reference while the remaining sites were considered to be significantly impaired (BAND B). Due to inconsistent assessments from the subsampling procedure, there were no reliable assessments available for the edge habitat at BUR 1c and BUR 2a;*

3) *Edge habitats for the most part, were in better condition than the riffle habitats, with higher taxa richness and fewer taxa missing than predicted by AUSRIVAS. This is likely due to the more permanent nature of the edge habitat compared to the riffles in Burra Creek, which were shallow and slow flowing. There is some evidence to suggest that the permanent pools in the middle sections of Burra Creek are important refuges for riffle taxa during dry periods;*

4) *The upper (native) site – BUR 1a had the highest overall diversity of taxa and also had a high diversity of EPT genera. Proportionally the Queanbeyan River supported very high numbers of the highly sensitive stonefly (Gripopterygidae) suggesting the physical and chemical conditions at this site were of a high standard;*

5) *Periphyton results show no obvious pattern in the median values amongst sites, although, variation in the distribution of AFDM and chlorophyll-a was higher at the Queanbeyan River site and native site on Burra Creek, which could reflect higher substrate diversity at these sites. Ash free dry mass was higher at BUR 1c than the other sites. There were some relatively high values at this site and these are likely due to the large amount of detrital material seen in the riffle zone from decaying macrophytes as the water level dropped. A significant amount of new macrophyte growth along the bank margins was noted during this field run, as were some patchy tufts of new algal growth which would have contributed to the chlorophyll-a content in the periphyton*;

6) *The water quality results indicate that the majority of the parameters analysed in spring 2011 were within the ANZECC guidelines for healthy ecosystems (ANZECC & ARMCANZ, 2000); however, as has been the case ever since the inception of this project, electrical conductivity (EC) in Burra Creek (downstream of the Cassidy Creek confluence) is consistently exceeding the upper limit of 350 $\mu s/cm^{-2}$. Due to the nature of Burra Creek, this trigger value is unlikely to ever be consistently met during routine monitoring because of the high level of carbonates surfacing from the groundwater;*

7) *Naturally high EC readings in Burra Creek are unlikely to be detrimental to the current state of the aquatic fauna because communities and individuals residing in and around Burra Creek are likely to have become either locally adapted to the water characteristics of the creek or are taxa that out compete and therefore have a preference for these conditions. With this in mind, basing the currently employed trigger values, which were developed for perennial systems with moderately soft water, on a system with naturally hard water is currently meaningless in terms of ecosystem protection. The most likely impact on the system will be the introduction of Murrumbidgee River water, which has lower pH and EC;*

8) *Previously ALS has recommended a re-evaluating of these trigger values (ALS, 2011b). To this end we are currently working on documentation to support increasing the upper threshold for the EC levels from the current value of 350 $\mu s/cm^{-2}$. At this stage of the data review, it is a reasonable estimate that the proposed new upper limit for EC in Burra Creek will fall in the range of 400-450 $\mu s/cm^{-2}$ based on the 80th percentile values for the period of record from the Burra Creek gauging station.*

Surface flow appears to be the governing factor in the determination of macroinvertebrate assemblages within Burra Creek. Burra Creek, especially in the upper reaches, is reliant on rainfall for surface flows. During dry periods, as was experienced leading up to the spring sampling run, the majority of the surface flows is from groundwater and seepage can be rather low as the season progresses. These natural periods of wetting and drying in Burra Creek lead to a high degree of variation, both within and between sites.

The Queanbeyan River experiences similar seasonal variations, but because of the perennial nature of that river, the community assemblages show less variation and to some degree are more predictable. During the operation of M2G we are likely to see longer periods of higher volume (relative to the natural flow regime) flow within the downstream sites in Burra Creek. This is likely to create a more stable environment for flow sensitive taxa and encourage localised recruitment. This in-turn may facilitate fish and platypus populations to return to Burra Creek as many of these sensitive taxa feature in their diets.

If as suggested, the pool/edges do provide an important refuge for taxa during dry periods, one of the management goals should be to ensure that they are maintained during these periods. This factor is likely to become increasingly important if fish begin to recruit and utilise Burra Creek more readily once M2G is operational, because during the ramp down, fish will require stable habitat for survival once flows cease again.

Upstream of Williamsdale bridge (BUR 1a and BUR 1c), there are unlikely to be any change in the system over and above what we are seeing currently. These sections will remain intermittent and highly dependent on rainfall and surface runoff for surface flows.

All of the recommendations made to date concerning Burra Creek have been synthesised in a recommendations summary document which has been provided to the M2G Environmental Reference Group. Outside of this document, there are no new recommendations to be made following the spring sampling run.

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 is to undertake 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.

ActewAGL is constructing an additional pumping structure and pipeline to abstract water from the Murrumbidgee River from a location near Angle Crossing (southern border of the ACT). The pumping system will transfer water from the Murrumbidgee River, through an underground pipeline into Burra Creek, and then transfer the water by 'run of river' flows into the Googong Reservoir. The system is being designed to enable pumping of up to 100 ML/d, and is expected to be operational in 2012. Abstraction from the Murrumbidgee River and the subsequent discharges to Burra Creek will be dictated by the level of demand for the water, availability of water in the Murrumbidgee River, and compliance with EPA trigger levels. This development is referred to as the Murrumbidgee to Googong project (M2G).

Burra Creek stream flow data from 1985 through to 2011 (as of 31st December) shows the mean daily flow as 9.75 ML/d (median =5.8 ML/d). However, over the last five years flows have reduced substantially to 5.5 ML/d (median =1.59 ML/d). 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 light of the current low flow conditions in Burra Creek, it is expected that the increased flow through the discharge from the Murrumbidgee River will 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 (downstream 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 connectability 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). Further, 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 program, on which this program is based.

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

Property	**Possible impact**	**Source**
Water Quality	Increased turbidity from Murrumbidgee water which could decrease light penetration, resulting in lower macrophyte and algal growth.	Biosis, (2009)
	The inter-basin 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.	Biosis, (2009)
Ecology	Changes in macroinvertebrate communities and diversity through habitat loss from sedimentation, riparian vegetation and scouring of macrophytes. Changes in macroinvertebrates are also expected with an increase of flow (e.g. increased abundances of flow dependant taxa).	Bunn and Arthington (2002)
	Potential risk of exotic species recruitment from IBT, this could displace native species in the catchment and pose a risk of the spread of disease.	Biosis, 2009; Davies et al. (1992)
	Infilling from fine sediment transport could threaten the quality of the hyporheic zone, which provides important habitat for macroinvertebrates in temporary streams.	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.	Biosis, (2009)
Bank Geomorphology	Bank failure from the initial construction phase and first releases. This could result in increased sedimentation, loss of riparian vegetation and 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 Program (MEMP) are to provide ActewAGL 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 ActewAGL water abstraction licence requirements;

2) Collect baseline macroinvertebrate, water quality and periphyton data in order to ascertain whether the future discharges into Burra Creek from the Murrumbidgee River are likely to impact the ecology and ecological “health" of Burra Creek;

3) Collect baseline periphyton data that will be used as a guide to monitor seasonal and temporal changes, 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 Program (MEMP) program has been estimated using ACT AUSRIVAS protocols for macroinvertebrate community data, combined with a suite of commonly used biological metrics and descriptors of community composition. As outlined in the MEMP proposal to ACTEW Corporation (ALS, 2011a) 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.

Six months prior to the commencement of this program, ALS sought advice from independent industry experts on the sampling regime and study design required for a robust interpretation of the biological data collected. The 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 (the Ephemeroptera, Plecoptera, and Trichoptera, or EPT index), were used during this study to assess river health.

Periphyton is the matted floral and microbial community that resides on the river bed. The composition of these communities is dominated by algae but the term “periphyton” also includes fungal and bacterial matter (Biggs and Kilroy, 2000). Periphyton is important to maintaining healthy freshwater ecosystems as it absorbs nutrients from the water, adds oxygen to the ecosystem via photosynthesis, and provides a food 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 BUR2a 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 BUR2a is now included as an impact site on Burra Creek (Figure 1; Table 2). Site photographs can be seen in APPENDIX A.

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, has been dry or inundated 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. Further, 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 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

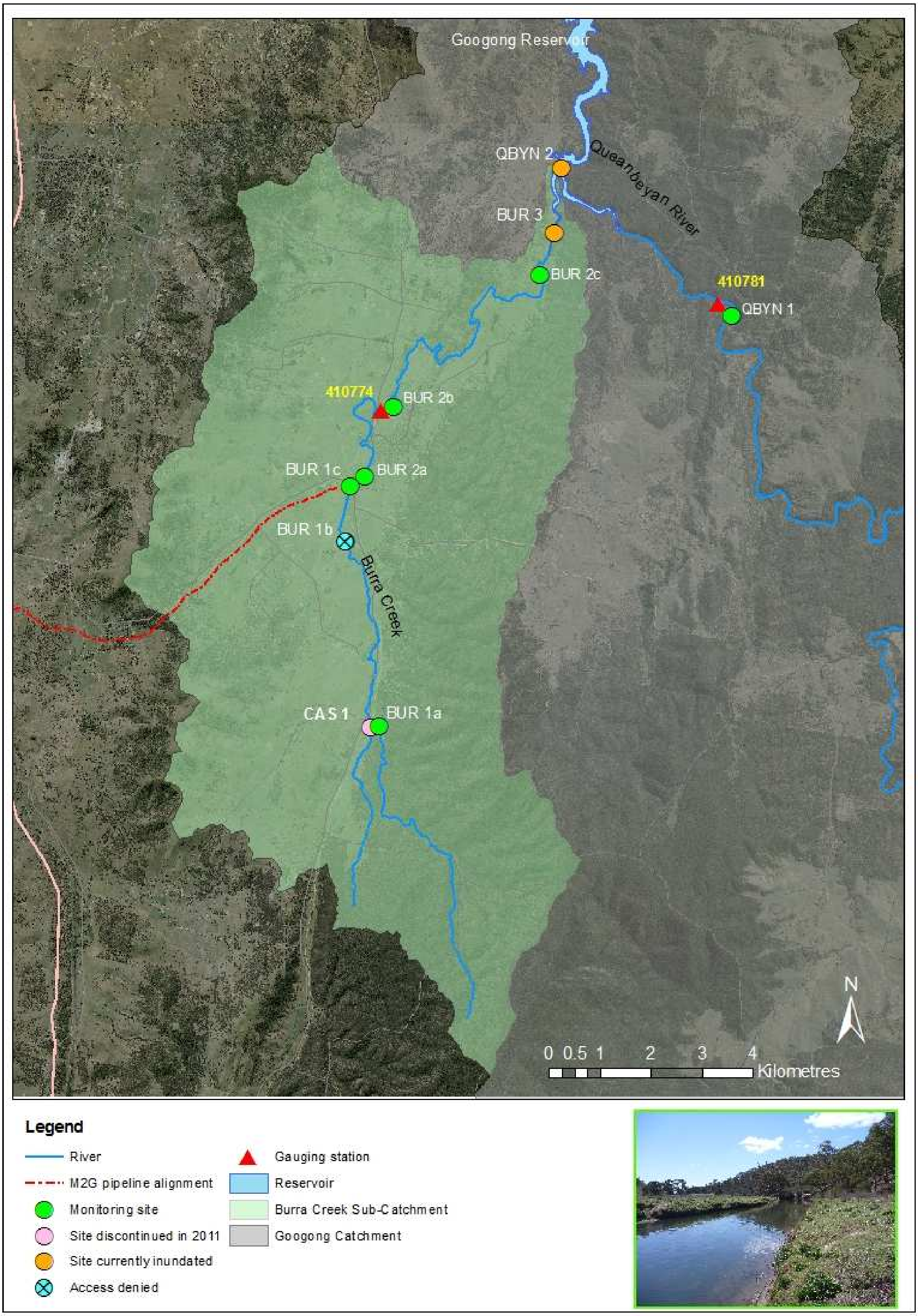

Figure 1. Location of the monitoring sites and gauging stations for the Burra Creek monitoring program

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 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 ALS QA procedures and the manufacturer's requirements prior to sampling.

Additionally, grab samples were taken from each site in accordance with ACT AUSRIVAS protocols for Hydrolab® verification 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 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 (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 two habitats (edge and riffle - where available) at most sites in spring. 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 2.13.2 (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 and 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.

2.6.3.1 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 (Chessman, 2003)
- ACT AUSRIVAS O/E scores and bandings

Taxa Richness refers to the number of different taxa contained in a sample. EPT Taxa Index refers to the proportional representation of key macroinvertebrate taxa belonging to the Ephemeroptera, Plecoptera and Trichoptera groups. Stream Invertebrate Grade Number – Average Level (SIGNAL) is a biotic index based on pollution sensitivity values (grade numbers) assigned to aquatic macroinvertebrate families that have been derived from published and unpublished information on their tolerance to pollutants, such as sewage and nitrification. Each family in a sample is assigned a grade between 1 (most tolerant) and 10 (most sensitive). The SIGNAL index is then calculated as the average grade number for all families present in the sample. The resulting index score can then be interpreted by comparison with reference and/or control sites. Recently these grades have been improved and standard errors applied under the SIGNAL2 model approach developed by Chessman (2003). These changes were introduced to improve the reliability of the SIGNAL index. The 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.

2.6.3.2 Multivariate analysis

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

Non-metric multidimensional Scaling (NMDS) was performed on the macroinvertebrate community data following the initial cluster analysis. NMDS is a multivariate procedure that reduces the dimensionality of multivariate data by describing trends in the joint occurrence of taxa. The initial step in this process was to transform the data (4^{th} 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 habitat (e.g. D – A) an overall assessment is avoided due to the unreliability of the results.

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

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

2.7 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 these QA/QC results will be made available as part of the final report; 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 spring riffle and edge models

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

2.8 Licenses 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)).

ALS field staff maintains current AUSRIVAS accreditation.

3 Results

3.1 Summary of sampling conditions

The spring sampling run for Burra Creek was completed on the 4th and 5th of October. Six sites were sampled in this sampling run; one site was missed because access permission from one of the land owners has been revoked (BUR 1b: Table2). QBYN 2 and BUR 3 are still currently inundated by Googong dam water (Figure 1) and for this reason were not sampled. BUR 2c was added to the programme as an alternative to BUR 3. There is no suitable alternative for QBYN 2 within this section of the Queanbeyan River. In total 21 samples were collected (of a possible 24). Three were missed (Table 5) due to low flows above Williamsdale bridge (i.e. at the upstream control sites).

Table 5. Macroinvertebrate samples collected during the autumn sampling run

Site	Edge	Riffle	Notes
QBYN1	2	2	
BUR1a	1	1	Limited riffle and edge habitat due to low surface flow
BUR1c	1	2	Edge not deep enough in sections. Only one sample was possible
BUR2a	2	2	
BUR2b	2	2	
BUR2c	2	2	Replacement for BUR 3 while it is inundated

Flows in Burra Creek averaged 0.53 ML/d over the two day period; while flows in the Queanbeyan River averaged 86 ML/d. Weather conditions were mild, with maximum temperatures ranging from 16-18°C over the two day period.

Immediately upstream of the Williamsdale road bridge, construction work has intensified (Plate 1), which involves the excavation for the pipe installation and the M2G discharge structure. This work also involves the diversion of upstream flow around the trench to below Williamsdale Road to enable work to proceed.

Plate 1. Looking downstream Williamsdale Bridge (left) and creek water being diverted downstream of Williamsdale Bridge during construction

3.2 Hydrology and rainfall

Prior to the spring sampling run in early October (4th and 5th) Burra Creek was flowing less than 1ML/d for the month of September (Figure 2; Table 6). In contrast, flows in September 2010 averaged 38 ML/ d which correspond to a considerably wetter September and October in previous years compared to the current (Figure 3). Rainfall in November was the highest on record for that month and was 60% greater that the long term average. Flows increased to a maximum of 747 ML/d on the 30th following 5 days of constant rainfall.

Rainfall and the Hydrograph for the Queanbeyan River followed a similar pattern to Burra Creek (Figure 4) in that the majority of spring rainfall fell in the later part of November and rainfall in September and October was below the period of record average for each month.

Flows on the days that sampling took place were 84 Ml/d on the Queanbeyan River in the 4th of October and 0.63 an d 0.76 ML/d in Burra Creek on the 4th and 5th respectively. Burra Creek had 32 wet days in total over the spring period.

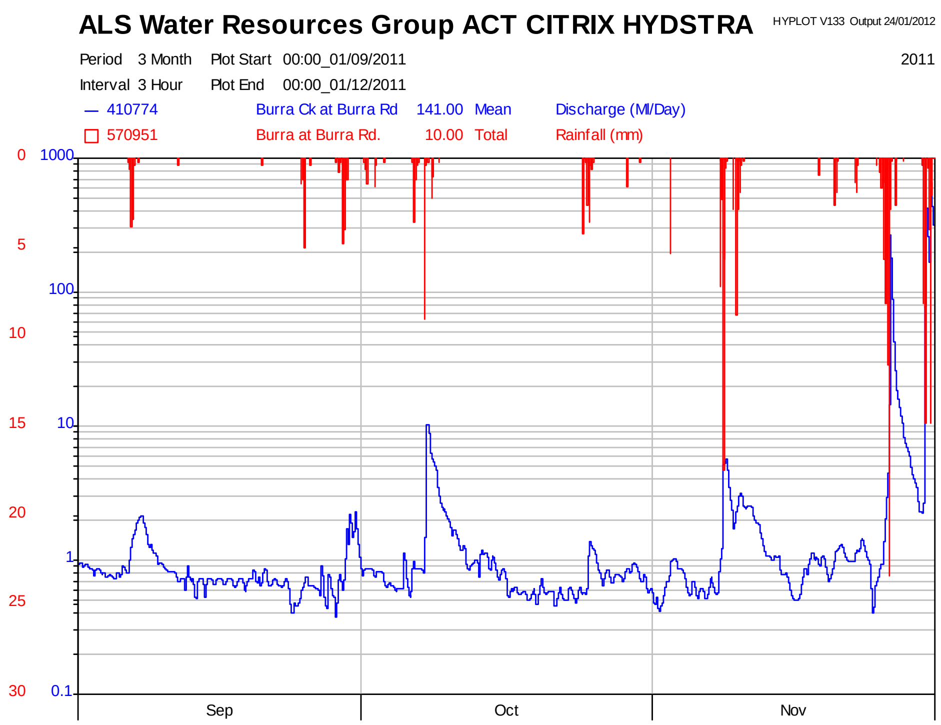

Figure 2. Spring hydrograph and rainfall for Burra Creek

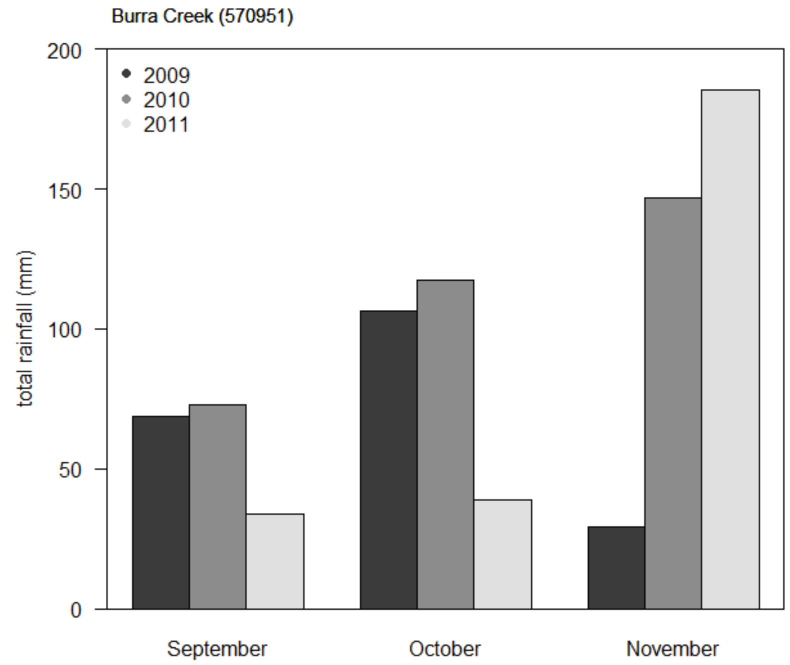

Figure 3. Rainfall comparisons on a monthly basis for spring (2009-2011) recorded at Burra Creek (570951)

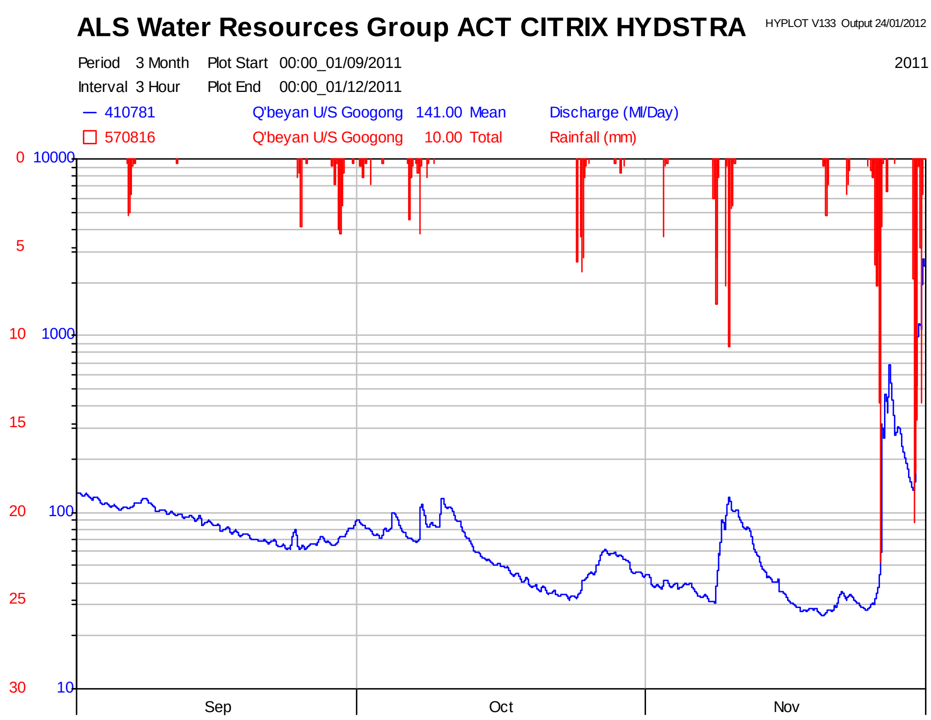

Figure 4. Spring hydrograph and rainfall for the Queanbeyan River (upstream of Googong reservoir)

3.3 Water quality

The continuous water quality parameters in Burra Creek remained stable throughout September and October (Figure 5). Turbidity increased in response to rainfall-induced runoff. There were four days in early October where instant maximums went over the upper ANZECC limits, however based on the daily means, turbidity was within the limits 100% of the time in September and October, but because of heavy rainfall in late November, the upper guideline limits were exceeded for 8 days (26%) in November.

Surface water temperatures gradually increased over spring at both water quality stations in response to increasing air temperature. In Burra Creek, the average temperature at the beginning of spring was 11.6 °C which increased to 19.2 °C by the end of November. Temperature in the Queanbeyan River ranged from 11.4 – 20.3 for the same period (Figure 6).

Electrical conductivity in Burra Creek ranged considerably from 131.7 – 592 µs/m^{-2} over the spring period. Daily averages stayed above 500 µs/m^{-2} until the end of November when the dilution effect from the increased flows dropped EC to 131 µs/m^{-2}. EC in the Queanbeyan River followed the same temporal trend over the spring period except that the range was considerably lower (65 – 115 µs/m^{-2}).

There were similar changes in the diurnal ranges of dissolved oxygen recorded at both stations (Figure 5 & 6). Both stations indicate a widening of the difference in daily maximums and minimums as mean surface flows and temperature increase. Dissolved oxygen was within the recommended guideline limits of 90-110 % for 68% of spring (based on daily means). During November, D.O was below 90% for 29 out of the 30 days. pH was within the recommended upper limit of 8.0 for 4 days of the three month spring period (4.3%).

The results from both the field measurements and the lab analysed grab samples are presented in Table 7, with relevant ANZECC and ARMCANZ (2000) guideline limits.

Total Nitrogen levels have dropped since spring 2010 when all sites exceeded guidelines. All sites are now below the guidelines with the exception BUR1c. Total Phosphorus results also represent a decrease since spring 2010. Again, during the previous spring period, all sites were in breach of the ANZECC guideline upper limits, but are now within or on the cusp of the upper limit of 0.02 mg/L. There is an obvious increase in EC and pH below BUR1a, with all values for pH and EC exceeding the guideline values downstream of this site.

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

	Burra Creek (410774)		Queanbeyan River (410781)	
	Rainfall	Mean Flow (ML/d)	Rainfall	Mean Flow (ML/d)
September	33.8	0.84	28.8	88.38
October	39.0	1.10	40.8	61.29
November	185.6	14.9	202.0	122.7
Spring Total	258.4	5.61	271.6	90.79

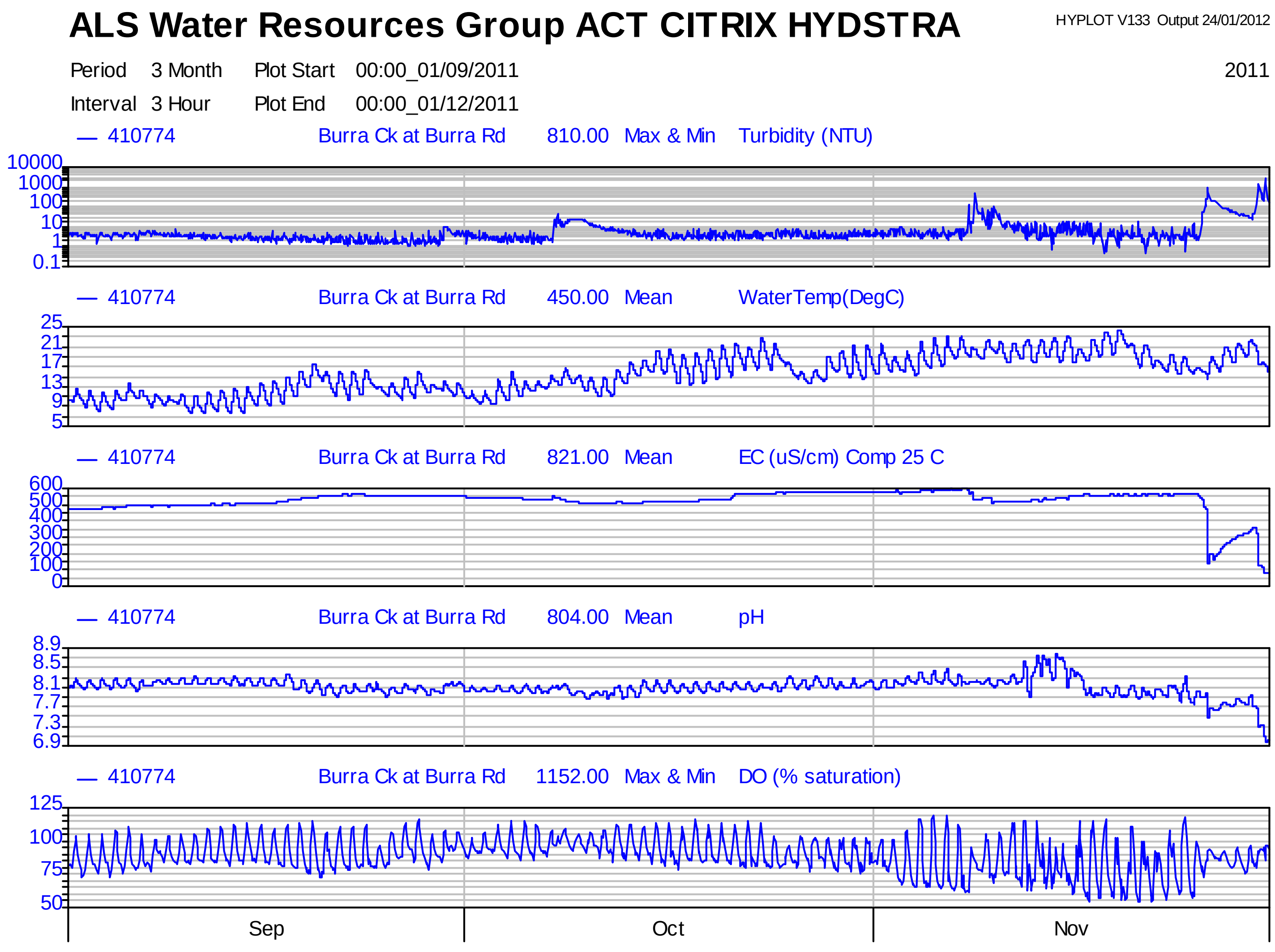

Figure 5. Continuous water quality records from Burra Creek (410774) for spring 2011

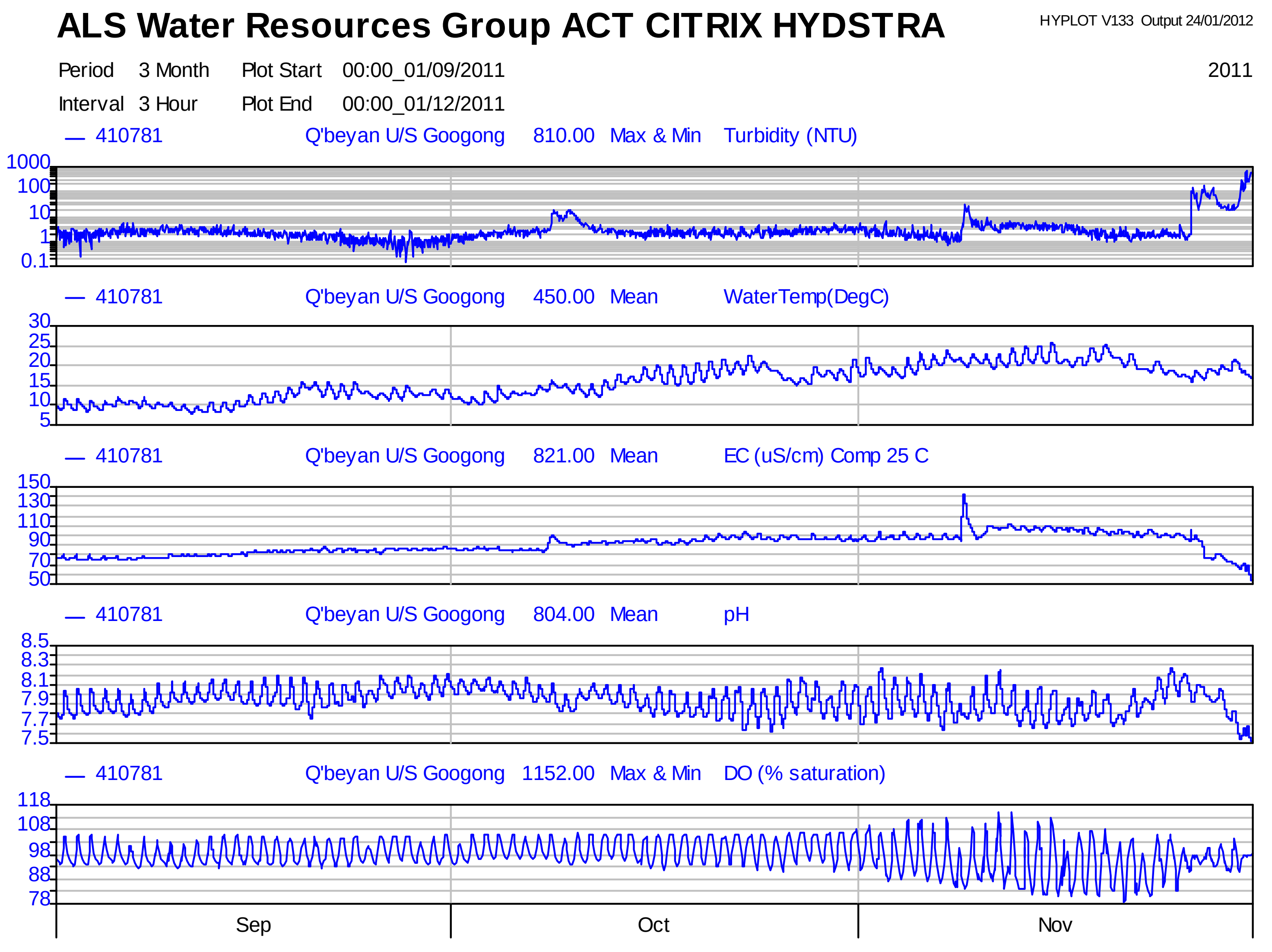

Figure 6. Continuous water quality records from the Queanbeyan river (upstream of Googong Reservoir: 410781) for spring 2011

Table 7. In-situ water quality results from spring 2011 (ANZECC guidelines are in bold parentheses). Yellow cells indicate values outside of ANZECC and ARMCANZ (2000) guidelines. Orange cells indicate value is on the cusp of the guideline.

Location	Site	Time Date	Temp (℃)	EC (µs/cm) **(30-350)**	Turb. (NTU) **(2-25)**	TSS(mg/L)	pH **(6.5-8)**	D.O. (% Sat.) **(90-110)**	Dissolved Oxygen (mg/L)	Alk.	NOX (mg/L) **(0.015)**	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L) **(0.02)**	TN (mg/L) **(0.25)**
Control sites	QBYN1	11:30 4/10/11	13.4	88.0	3	3	8.0	102.7	9.78	37	0.004	0.002	<0.002	0.007	0.02	0.16
	BUR1	13:50 5/10/11	16.4	124	4	6	7.3	104.8	9.22	28	0.004	0.002	<0.002	<0.002	0.011	0.23
	BUR1c	15:10 5/10/11	17.0	476	11	16	8.0	104.8	9.15	170	0.004	0.002	<0.002	<0.002	0.019	0.29
Downstream sites	BUR2a	11:15 5/10/11	14.8	546	7	10	8.1	103.5	9.49	210	0.045	0.043	<0.002	<0.002	0.014	0.24
	BUR2b	09:20 5/10/11	13.7	553	5	6	8.3	102.8	9.66	214	0.003	0.001	<0.002	<0.002	0.012	0.21
	BUR2c	14:10 4/10/11	14.0	538	2	3	8.2	93.9	8.83	209	0.005	0.003	<0.002	0.003	0.01	0.23

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

3.4 Periphyton

Chlorophyll-a concentrations varied considerably amongst sites (Figure 7). The highest concentrations were at QBYN 1 (19873 µg/ m^{-2}) and the lowest were recorded at BUR 2b (410 µg/m^{-2}). Mean values were highest at the upstream control site (9241 ± 7346) and the upstream Burra Creek Sites (mean=7905 ± 4718) compared to the downstream sites in Burra Creek (5454 ± 2856) owing to the large variance around these mean values however, the nested ANOVA results show no statistical difference between locations ($F_{2,35}$=3.47; P=0.16; Table 8).

The highest biomass estimates from the ash free dry mass (AFDM) analysis were found at BUR 1c (Figure 8) where the maximum was 72000 mg/m^{-2}. BUR 1c showed considerable variation in its distribution of values (15103 - 72000 mg/m^{-2}) compared to the range of values across all remaining sites (3047 - 22000 mg/m^{-2}). Despite the apparent spike in the biomass estimates at BUR 1c, there was no other obvious spatial pattern in the distribution of the AFDM values. AFDM showed no statistically significant difference between locations ($F_{2,35}$=3.47; P=0.27; Table 8).

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

Response	Source	DF	F-value	P-value
Chlorophyll-a	Location	2	3.47	0.16
	Site [Location]	3	0.30	0.82
	Residual	35		
AFDM	Location	2	2.06	0.27
	Site [Location]	3	4.52	0.009
	Residual	35		

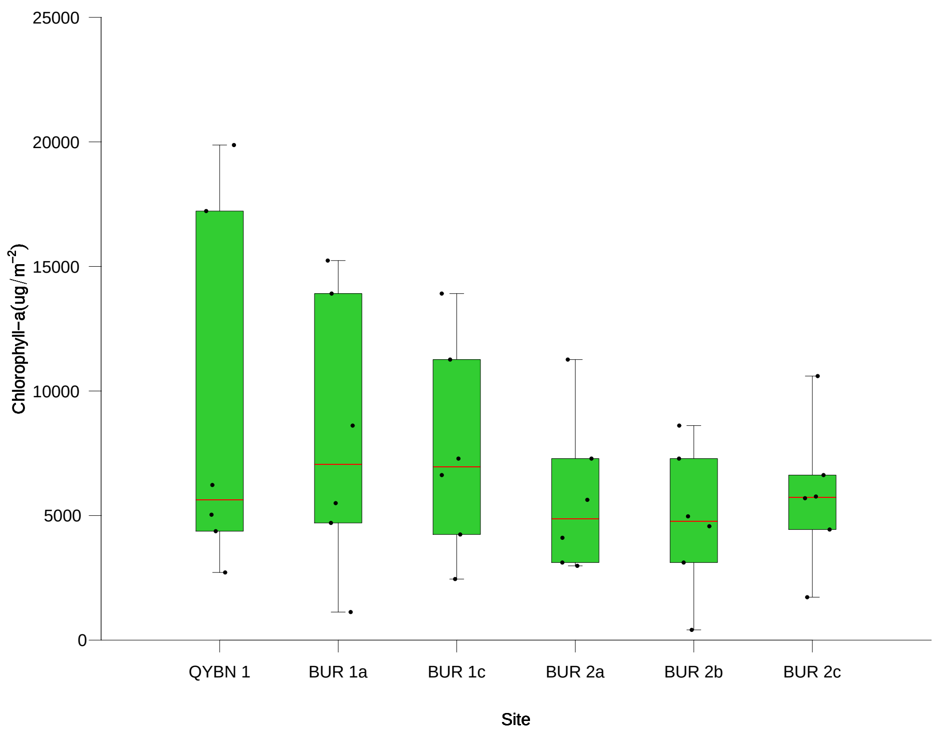

Figure 7. The distribution of Chlorophyll-a at sites along the Queanbeyan River and Burra Creek. Strip chart values (in black) represent the raw data values for each site

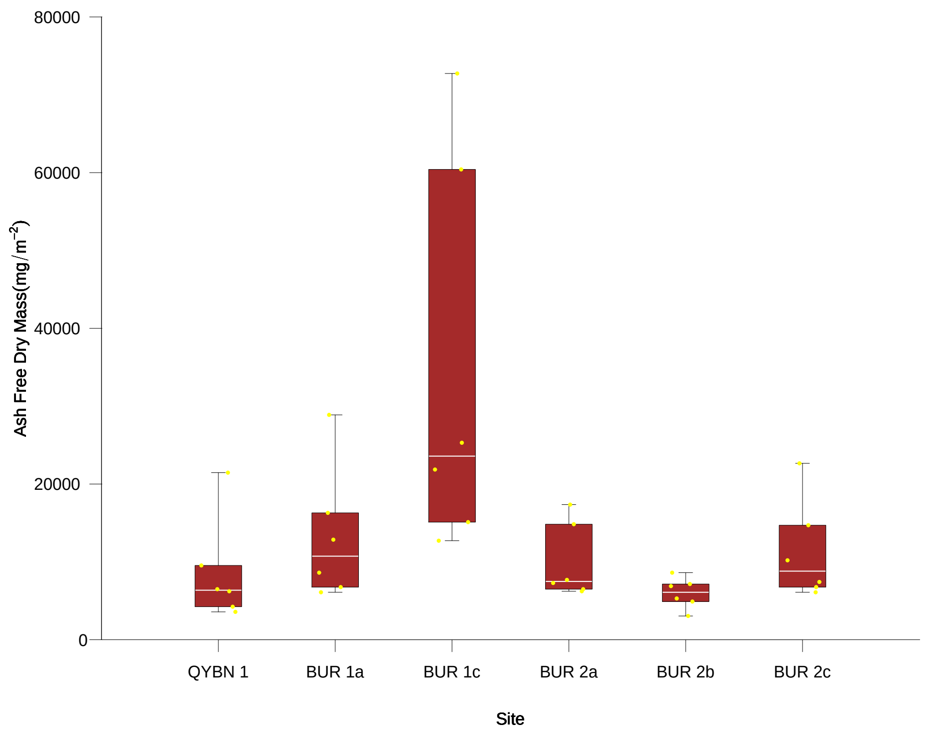

Figure 8. The distribution of Ash Free Dry Mass at sites along the Queanbeyan River and Burra Creek. Strip chart values (in yellow) represent the raw data values for each site

See APPENDIX C for an explanation of how to interpret box and whisker plots.

3.5 Macroinvertebrate communities

3.5.1 Riffles

Results from the analysis of similarities (ANOSIM) indicate no significant location difference in the macroinvertebrate community structure (R=0.5; P=0.067). Sites forming the main group in Figure 9 (which have a Bray-Curtis similarity coefficient of 60%) are located downstream of the Williamsdale Road bridge, with the exception of BUR 1c which is located approximately 400m upstream of BUR 2a.

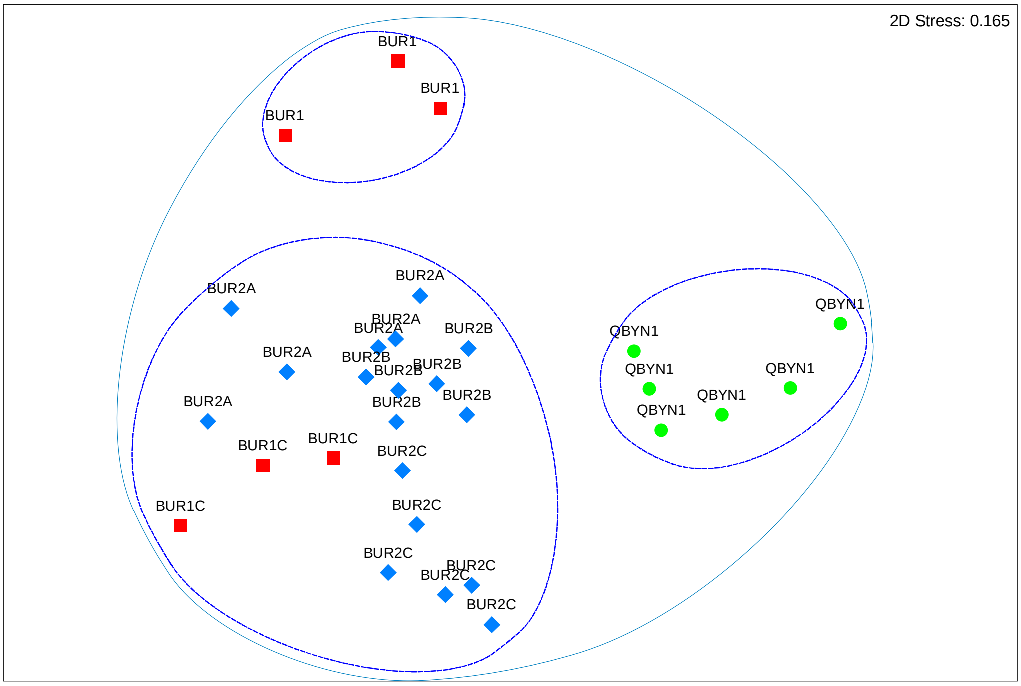

Figure 9. Non-metric multidimensional scaling of genus level data from spring riffle samples

Outer ellipse represent s 50% similarity; the inner ellipses represent 60% similarity groupings. Red squares show sites upstream of the Williamsdale Road bridge, Blue diamond's represent sites downstream of the bridge and green circles represent the Queanbeyan River

Since there was no overall location effect and as such, SIMPER analysis was not applied to the taxa that best discriminate between groups, but was used to determine which taxa characterised each location group. This analysis shows that the macroinvertebrate communities within the upstream and downstream locations in Burra Creek were dominated by high to moderately tolerant taxa such as: Orthocladiinae (SIGNAL=4); Chironominae (SIGNAL=3); Ceratopogonidae (SIGNAL=4) and Caenidae (SIGNAL=4). The majority of these sites form the main group in the NMDS plot (Figure 9) – the exception being BUR 1 which, like QBYN1 appears to be distinctly different from the main group.

BUR 1 and QBYN 1 differ from the main group. For QBYN 1, this is primarily due to an increase in the proportion of more sensitive taxa (i.e. SIGNAL >7). The location of BUR 1 (positioned away from the main group and QBYN 1) is largely due to the presence of certain shared taxa with QBYN 1 and is not necessarily related to the absolute number of these taxa. For example, Elmidae (Coleoptera: SIGNAL=7) and Leptophlebiidae (Ephemeroptera: SIGNAL=8) were only found at QBYN 1 and BUR 1. Other examples include Hydrobiosidae (Trichoptera: SIGNAL=8), which were only found at QBYN 1 and the genus *Chimarra* (family Philopotamidae: SIGNAL=8) which was found in its highest numbers at QBYN1 but also at BUR 1 albeit in lower numbers. In other words, it appears that the separation of BUR 1 and QBYN 1 is more to do with changes in relative numbers of specific taxa than the presence or absence of these taxa between sites.

The high number of sensitive genera and overall richness at BUR 1 is highlighted in Figures 10, 11 & 12. QBYN 1 had 19 genera in the EPT group, while 14 were collected at BUR 1. The lowest number of EPT genera was recorded at BUR 1c. Taxonomic richness ranged from 36 genera in 28 families at BUR 1 to 33 genera in 27 families at BUR 2a.

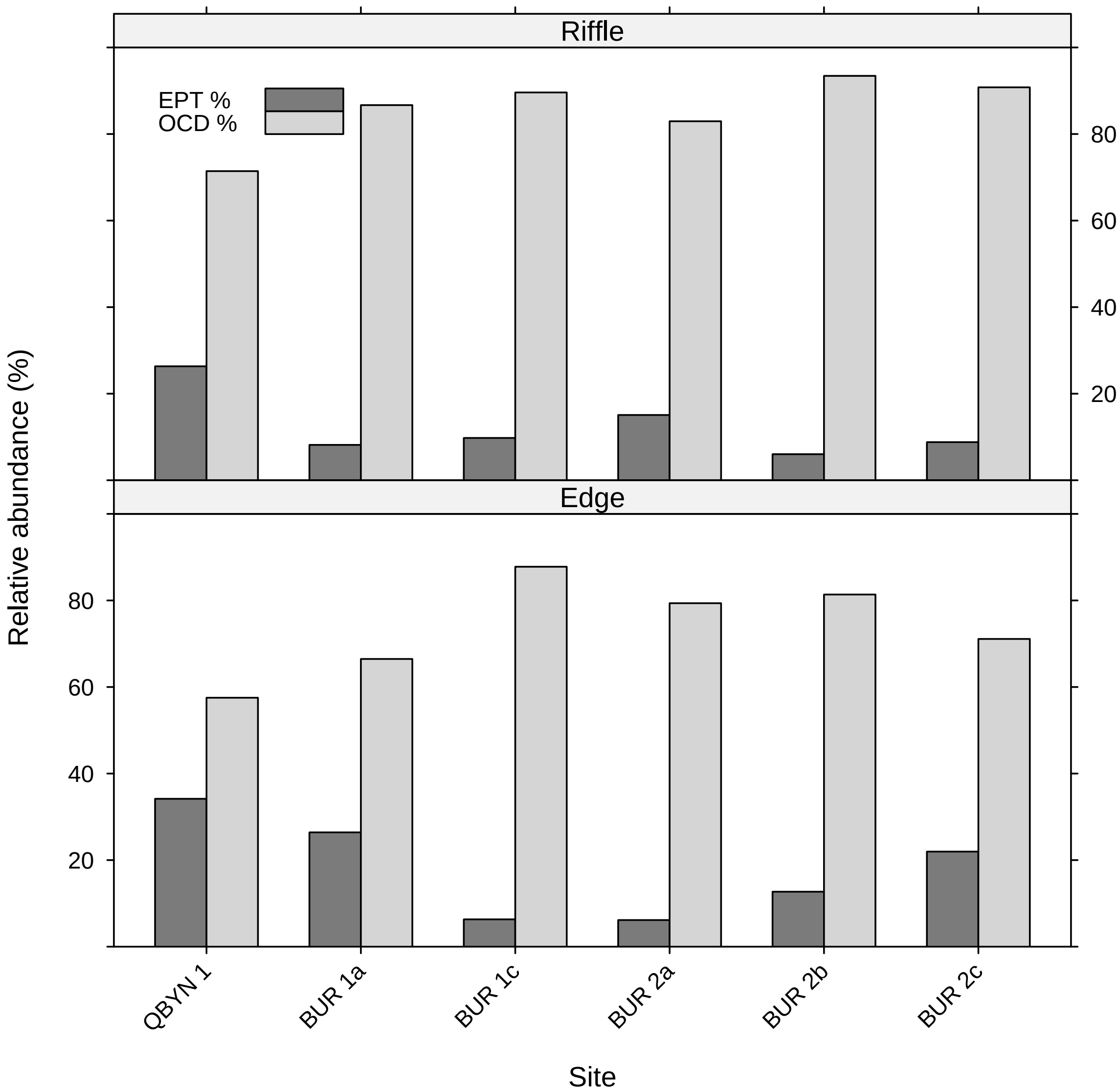

Figure 10. Average relative abundances of sensitive and tolerant taxa

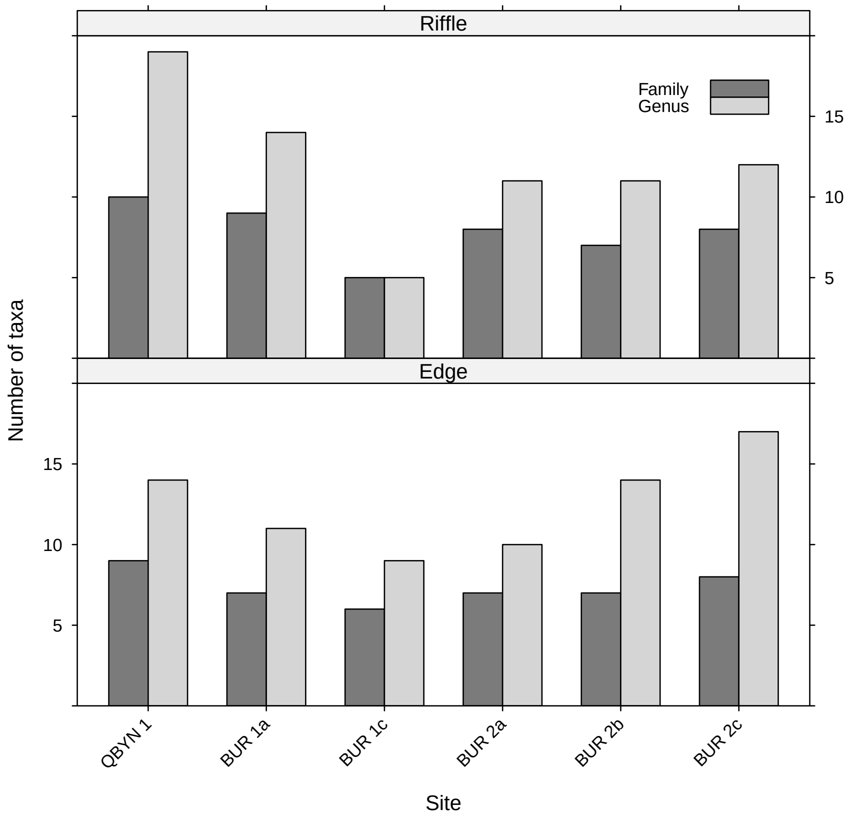

Figure 11. EPT richness in the riffle and edge habitats

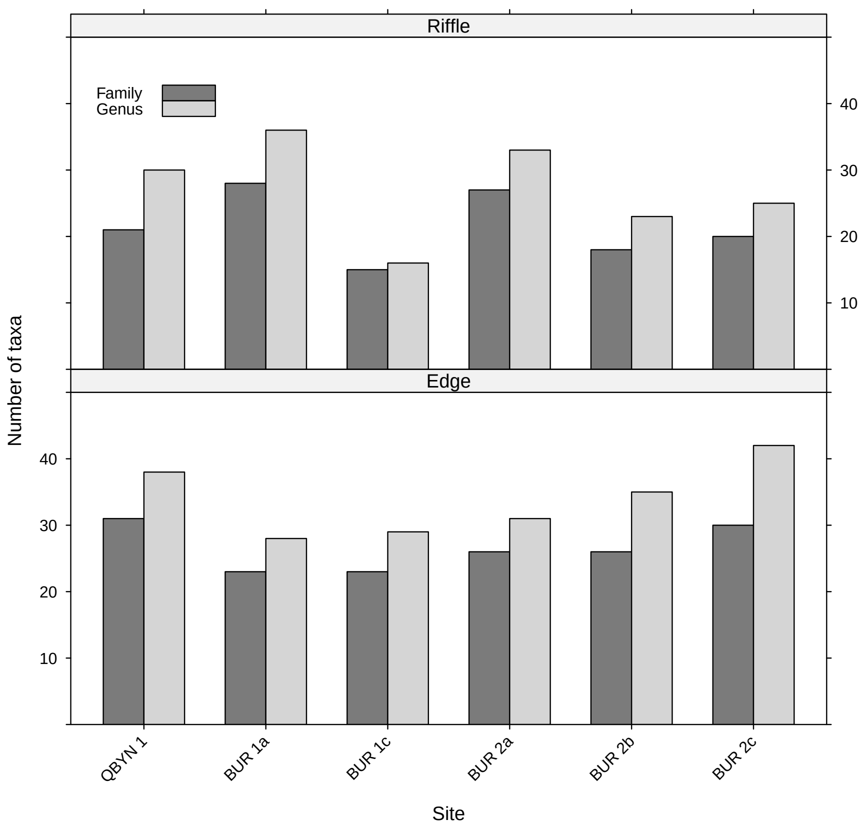

Figure 12. Total taxonomic richness in the riffle and edge habitat

3.5.2 Edges

The edge communities were not significantly different by location (R=0.18; P=0.31). The low R-value indicates a low association between samples within the same location group. This can be seen in Figure 13 where site BUR 1c and BUR 2a and 2b are more similar in their macroinvertebrate composition than other sites in the sample location.

As with the riffle data, BUR 1 is distinctly different from the main groups. The community assemblage at BUR 1 was dominated by Chironomids (SIGNAL=3); Leptoceridae (SIGNAL=4); Caenidae (SIGNAL=4) and Corixidae (SIGNAL=2).

BUR 1 and QBYN 1 had a higher proportion of sensitive EPT taxa than all of the other sites (26% and 35% respectively) (Figure 10). EPT richness at the family level was highest at QBYN 1 with 9 families being collected; however the genus level, BUR 2c (upstream of London Bridge) registered the richest fauna with 19 genera collected (Figure 11). Overall richness was also highest at QBYN 1 (31 families); however at the genus level, 42 genera were collected from BUR 2c (Figure 12).

The sites forming the main cluster in Figure 13 (namely BUR 2a, 2b and BUR 1c) were all dominated by Oligochaetes (SIGNAL=2) Caenidae (SIGNAL=4) and Chironomids (SIGNAL=3). Dysticidae (SIGNAL=2) and Corixidae (SIGNAL=2) all characterised these sites. There was also a notable absence of Gripopterygidae (SIGNAL=8), which featured at QBYN 1 and BUR 1a. Other sensitive taxa, such as Leptophlebiidae and Baetidae were collected, but were rare in the samples compared to previous sampling events and the other sites in this assessment.

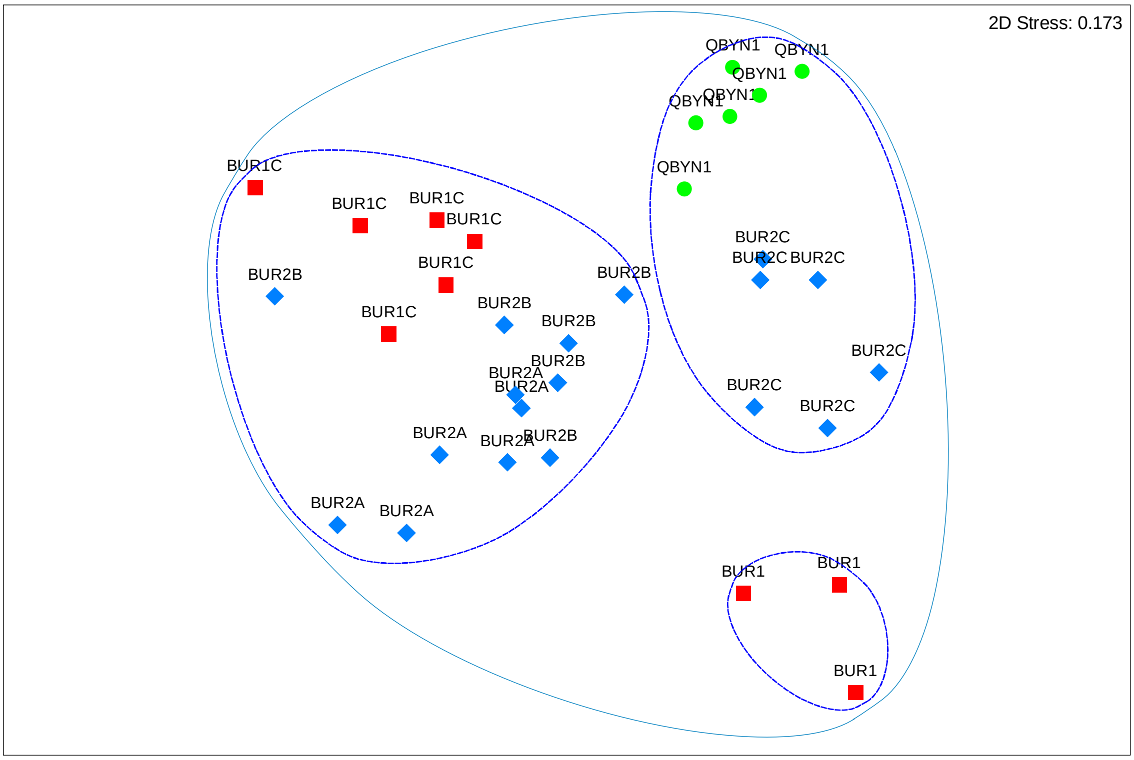

Figure 13. Non-metric multidimensional scaling of genus level data from spring edge samples. Ellipses represent the 40 % and 55% similarity groups

Red squares show sites upstream of the Williamsdale Road Bridge, Blue diamond's represent sites downstream of the bridge and green circles represent the Queanbeyan River

3.7 AUSRIVAS Assessment

Compared to spring 2010, the AUSRIVAS assessment for the riffle habitat showed an improvement in condition at BUR 1a; BUR 2a and QBYN 1. The overall site assessments showed that QBYN 1 was close to reference while the remaining sites were considered to be significantly impaired (BAND B; Table 9). Due to inconsistent assessments from the subsampling procedure, there were no reliable assessments available for BUR 1c and BUR 2a.

Statistically, there were no differences found between locations based on the OE/50 scores from the riffle samples ($F_{2,3}$=1.31; P=0.38; Table 10); nor were there any significant differences detected for the SIGNAL-2 scores amongst locations ($F_{2,3}$=2.63; P=0.21; Table 10). The OE/50 scores from the edge samples at the Queanbeyan control site were significantly higher than the Burra Creek sites (both up and downstream of the discharge point) ($F_{2,3}$=108.35; P=0.001; Table 11). However there was no location difference detected in for the SIGNAL-2 scores amongst locations ($F_{2,3}$=8.29; P=0.06; Table 11).

The number of missing taxa from the riffle samples ranged from 2-7. The Queanbeyan River control site had the least number of missing taxa on average (APPENDIX D). These taxa included pea shells (Sphaeriidae: SIGNAL=5); freshwater mites (Acarina: SIGNAL=6) and sand-flies (Ceratopogonidae: SIGNAL=4). These taxa were missing from most of the other sampling sites, but also included were riffle beetles (Elmidae: SIGNAL=7); Leptophlebiidae (SIGNAL=8) and another less sensitive mayfly family – Baetidae (SIGNAL=5). Only two taxa were missing from the Queanbeyan edge samples. These were Acarina and Leptophlebiidae (APPENDIX D), though it should be noted that Leptophlebiidae was only absent from one of the six subsamples. The usually ubiquitous Corixidae (SIGNAL=2) was absent only from BUR 2c, while other (usually) common taxa such as Baetidae and stick caddis (Leptoceridae: SIGNAL=6) were also absent at several sites (mainly at sites in Burra Creek downstream of the discharge point).

The highly sensitive stonefly family, Gripopterygidae (SIGNAL=8) was highly abundant at QBYN 1. This family was completely absent from the edge samples at all Burra Creek sites, but was collected in the riffle samples. Gripopterygidae was absent from at least one sample from every other site, but not entirely absent. A full taxonomic inventory is shown in APPENDIX E.

Table 9. AUSRIVAS and SIGNAL-2 scores for spring 2011

SITE	Rep.	SIGNAL-2		AUSRIVAS O/E score		AUSRIVAS band		Overall habitat assessment		Overall site assessment
		Riffle	Edge	Riffle	Edge	Riffle	Edge	Riffle	Edge	
QBYN1	1	5.17	4.44	1.11	0.97	A	A	A	A	A
QBYN1	2	5.20	4.80	0.92	1.07	A	A			
QBYN1	3	5.27	4.80	1.01	1.07	A	A			
QBYN1	4	5.00	4.80	1.11	1.09	A	A			
QBYN1	5	4.90	4.80	0.92	1.09	A	A			
QBYN1	6	5.17	4.80	1.11	1.09	A	A			
BUR1	1	4.80	4.44	0.97	0.97	A	A	A	B	B
BUR1	2	4.67	4.44	0.87	0.97	A	A			
BUR1	3	4.80	4.17	0.97	0.65	A	B			
BUR1C	1	4.25	4.25	0.73	0.88	B	A	C	A	NRA
BUR1C	2	4.25	4.25	0.73	0.88	B	A			
BUR1C	3	4.17	4.25	0.55	0.88	C	A			
BUR1C	4		4.67		0.98		A			
BUR1C	5		4.25		0.88		A			
BUR1C	6		4.67		0.98		A			
BUR2A	1	4.73	4.14	1.01	0.82	A	B	A	NRA	NRA
BUR2A	2	4.50	4.44	0.92	1.05	A	A			
BUR2A	3	4.73	4.67	1.01	1.05	A	A			
BUR2A	4	4.80	4.80	0.92	1.17	A	X			
BUR2A	5	4.82	4.25	1.01	0.93	A	A			
BUR2A	6	4.82	4.44	1.01	1.05	A	A			
BUR2B	1	4.33	4.75	0.83	0.94	B	A	B	A	B
BUR2B	2	4.25	4.38	0.74	0.94	B	A			
BUR2B	3	4.33	4.67	0.83	1.05	B	A			
BUR2B	4	4.33	4.80	0.83	1.17	B	X			
BUR2B	5	4.33	4.67	0.83	1.05	B	A			
BUR2B	6	4.70	4.67	0.92	1.05	A	A			
BUR2C	1	4.78	4.78	0.83	1.00	B	A	B	A	B
BUR2C	2	4.33	4.38	0.83	0.89	B	A			
BUR2C	3	4.56	4.44	0.83	1.00	B	A			
BUR2C	4	5.00	4.55	0.92	1.22	A	X			
BUR2C	5	5.09	4.78	1.01	1.00	A	A			
BUR2C	6	4.25	4.80	0.74	1.11	B	A			

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

Response	Source	DF	F-value	P-value
OE 50	Location	2	1.31	0.38
	Site [Location]	3	10.24	<0.01
	Residual	29		
SIGNAL -2	Location	2	2.63	0.21
	Site [Location]	3	7.46	<0.01
	Residual	29		

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

Response	Source	DF	F-value	P-value
OE 50	Location	2	108.35	0.001
	Site [Location]	3	0.065	0.97
	Residual	32		
SIGNAL-2	Location	2	8.29	0.06
	Site [Location]	3	0.72	0.54
	Residual	32		

4 Discussion

4.1 Water Quality and periphyton

The water quality results indicate that the majority of the parameters analysed in spring 2011 were within the ANZECC & ARMCANZ (2000) guidelines for healthy ecosystems; however, as has been the case ever since the inception of this project, electrical conductivity (EC) in Burra Creek (downstream of the Cassidy Creek confluence) is consistently exceeding the upper limit of 350 µs/cm^{-2}. Due to the nature of Burra Creek, this trigger value is unlikely to ever be consistently met during routine monitoring because of the high level of carbonates surfacing from the groundwater.

These naturally high readings in Burra Creek are unlikely to be detrimental to the current state of the aquatic fauna because communities and individuals residing in and around Burra Creek are likely to have become either locally adapted to the water characteristics of the creek or are taxa that out compete and therefore have a preference for these conditions. With this in mind, basing the currently employed trigger values, which were developed for perennial systems with moderately soft water, on a system with naturally hard water is currently meaningless in terms of ecosystem protection. The most likely impact on the system (downstream of the discharge point – Figure 1) will be the introduction of Murrumbidgee River water, which has lower pH and EC.

Previously ALS has recommended a re-evaluation of these trigger values (ALS, 2011b). To this end we are currently working on documentation to support increasing the upper threshold for the EC levels from the current value of 350 µs/cm^{-2}. At this stage of the data review, it is a reasonable estimate that the proposed new upper limit for EC in Burra Creek will fall in the range of 400-450 µs/cm^{-2} based on the 80th percentile values for the period of record from the Burra Creek gauging station.

Total nitrogen concentrations were lower in this round of sampling compared to spring 2010. This is likely due to fewer rainfall events prior to the sampling event, which would have reduced the amount of surface runoff. However, it should be noted that the natural levels of TN within Burra Creek can be high (i.e. in spring 2009, TN was three times higher than the ANZECC trigger value at BUR 1a) given that the historical data is now showing levels exceeding the upper ANZECC limits in the nature reserve (BUR 1a) indicating that the source is not necessarily always pastoral runoff; but moderate levels are also present in the rainfall itself (Hynes, 1970). Although BUR 1c still exceeds the ANZECC guidelines for this parameter, this reading is below the lowest value from spring 2010 (0.35 mg/L). The riffle depth was lowest at BUR 1c and for that reason it might be reasonable to assume that there was a greater groundwater contribution at this site, which may have led to higher (than the other sites) TN values (Table 7). Further evidence of this comes from our field observations where frequent patches of iron bacteria were noted (APPENDIX A). The high TN value at BUR 1c can also be attributed to the high ash free dry mass content (AFDM; Figure 8), where this high organic content would account for a considerable amount of TN as CPOM (coarse particulate organic material), since the dissolved inorganic content (i.e. nitrates, nitrites and ammonia) is low.

The continuous pH and dissolved oxygen (D.O %) analytes (Figure 5) show consistent diurnal patterns over the spring period. D.O. (% sat.) increased its diurnal range in November as the surface temperature rose. This is consistent with previous spring data. The consistent pattern over much of spring is due to the lack of rainfall (compared to previous years – Figure 3). Overall, these patterns indicate good water quality and no notable change outside of what can be considered natural variation.

Periphyton results as Chlorophyll-a and ADFM (Figures 7 and 8) showed no obvious pattern in the median values amongst sites, although, variation in the distribution was higher at the Queanbeyan River site and native site on Burra Creek, which could reflect higher substrate diversity at these sites. Ash free dry mass as already indicated was higher at BUR 1c than the other sites. There were some relatively high values at that site and these are likely due to the large amount of detrital material seen in the riffle zone from decaying macrophytes as the water level dropped. A significant amount of new macrophyte growth along the bank margins was noted during this field run, as were some patchy tufts of new algal growth (e.g. *Stigeoclonium spp.*) which would have contributed to the chlorophyll-a content in the periphyton.

4.2 AUSRIVAS assessment and macroinvertebrate assemblages

Although there were improvements at the (riffle) habitat level at BUR 1a, BUR 2a and QBYN 1 since the previous spring sampling run, only QBYN 1 displayed an overall site improvement (based on both habitat AUSRIVAS bands) – moving from BAND B to BAND A. The remaining sites (all in Burra Creek) were assessed as BAND B, which is consistent with the results from spring 2010.

High loads of organic matter, combined with very low flows and a high silt load at BUR 1c are likely the key contributing factors to its current condition. Other sites under assessments are consistent with previous spring results suggesting that the current assessments are reflective of natural variation within the system. At this point it is fair to suggest that the construction work under taken at Williamsdale Road bridge has not had a negative impact upon any of the key indicators addressed as part of this monitoring program. The caveat to this is that this monitoring was undertaken during a sustained period without rainfall and hence surface runoff. Assessing responses following rainfall events would require additional monitoring.

Missing taxa from the riffle habitat in Burra Creek included taxa with a range of sensitivity scores (range: 4-8) (APPENDIX E). For example, Hydropsychidae (SIGNAL=6); Baetidae (SIGNAL=5); Leptophlebiidae (SIGNAL=8); Elmidae (SIGNAL=7) and Sphaeriidae (SIGNAL=5) were amongst the most frequently missing taxa. The Queanbeyan River site had the least number of highly sensitive taxa (i.e. SIGNAL >7) missing compared to the Burra Creek sites (APPENDIX E). For example, both Leptophlebiidae and Gripopterygidae (SIGNAL=8) were present at QBYN 1 but missing from four of the Burra Creek sites, while Elmidae (riffle beetles) were present in the majority of QBYN 1 samples and missing in Burra Creek.

The absence of the riffle beetles in Burra Creek points towards flow as the key factor influencing their distribution. Velocity readings indicated considerably slower flows than recorded in the Queanbeyan River. Grubbs (2010) found higher densities and relative abundances in a perennial stream compared to a nearby intermittent stream and related this to flow permanence and differences in velocity. Riffle beetles (as their names suggest) have an affinity to regular flow so this result is unsurprising.

Baetid mayflies (SIGNAL=5) were missing only from the riffles at the upstream Burra Creek sites (BUR 1a and BUR 1c). The distribution of this family of mayfly can also be related to flow to a certain extent given that they prefer cooler faster flowing water (Brittain, 1982; Brittain and Saltveit, 1989). Velocity readings at the upstream sites were lower on average than the downstream sites (upstream = 0.1 m/s; downstream = 0.3m/s) and the average depth upstream of Williamsdale Road bridge was considerably shallower than the downstream riffles (upstream = 7.5 cm; downstream = 13.4cm).

Under these low flow conditions the mean upstream temperature was higher by 2.6 °C compared to the downstream sites, which may have also been a contributing factor to their absence (Brittain, 1982). Stanley et al. (1997) explain that during drying periods, surface water can become depleted in oxygen, favouring taxa such as some species of Chironomids that use alternative forms (other than the dissolved form) for respiration. Further, they found that taxa with high dissolved oxygen requirements were either absence or notably depleted in drying riffle habitats, similar to those experienced at BUR 1a and BUR 1c. This agrees with the current data, which shows lower relative abundances of sensitive taxa at the upstream Burra Creek sites (Figure 10) and lower EPT richness in this location (Figure 11). This group of taxa contains many of the mayflies requiring surface flow for respiration.

During low flow conditions, the edge habitat may have provided refuge for these mayflies (Boulton, 1989; Karr, 1999) given that at both sites where they were absent from the riffle, they were present in the edge samples (APPENDIX E). Edge habitats had fewer taxa missing than the riffle habitats, suggesting that during dry periods of low base-flow there is some resistance to these otherwise unfavourable conditions. Consequently, the AUSRIVAS results indicate generally healthy edge communities (Table 9) with high taxonomic richness (Figure 12). Also of note is that taxonomic richness was higher in the edge habitat compared to the riffle habitat at sites with long standing pools (i.e. BUR 1c, BUR 2a, BUR 2b and BUR 2c). This either suggests that these semi-permanent pools are indeed acting as a refuge for riffle taxa during low flow or dry periods or, the less frequent disturbance regime within these pools is allowing diversity within the communities to be retained during periods of stress. The data collected during this monitoring run supports both ideas to a certain level. There was a low degree of overlap between riffle and edge faunas (approximately 15%) among these sites (based on Jaccard's similarity[1]) showing that some taxa common to the riffle were also found in the edge habitat. Further examination of these data revealed that most of the taxa shared among habitats were not specialist riffle dwellers and therefore whether or not these particular groups were seeking refuge remains uncertain.

It should be noted that while there was no reliable assessment (NRA) available for BUR 2a (Table 9), the majority of the edge samples were either assessed as BAND A (close to reference) or BAND X (more taxa than expected). The problem with the overall assessment at this site was that there was more than a bandwidth difference between the highest and lowest assessment (i.e. X and B). This is the conservative approach to site assessment under the AUSRIVAS protocols (Barmuta et al., 2003) and it should be noted that the BAND B's only occurred as a result of a single family (Baetidae: SIGNAL =5) being missing – this family was present in all other samples collected at this site.

Although there was no statistically significant differences in the community assemblages amongst locations, there appeared to be distinct faunas in the BUR 1a (native) site compared to QBYN 1 (perennial control) and the main group, which contained the remaining Burra Creek sites (Figures 9 and 13). The absence of any significant difference is largely driven by the relationship of BUR 1c with the downstream sites in Burra Creek, compared to BUR 1a, which is also upstream of Williamsdale Bridge, but is certainly distinct from the main group. BUR 1a is within the headwater section of Burra Creek and has a considerable riparian zone, providing both shade and organic carbon in the form of leaf litter to the system. These key differences are likely to be the main factors contributing to the community differences between BUR 1a and BUR 1c given that the riparian strip adjacent to BUR 1c has been cleared and is essentially restricted to a mixture of pastoral and native grasses.

The apparent separation of QBYN 1 from all of the Burra Creek sites is most likely a function of the degree of flow permanence between streams (Smith and Wood, 2002). The Queanbeyan River, being a perennial stream naturally supports a wider diversity and higher number of taxa that require or have a preference for fast flowing water. Gripopterygidae, for example, were found in very high numbers at QBYN 1 compared to all other Burra Creek sites, while Elmidae and *Chimarra sp.* (Philopotamidae), were only found at QBYN 1, where the riffles were generally cooler with higher surface velocities. In a comparison of intermittent and perennial streams, Miller and Golladay (1996) reported collecting *Chimarra sp.* from the perennial stream but never from the nearby intermittent stream and suggested that the periodic drying in-between the periods of constant surface flow prevent these taxa from completing their lifecycle.

[1] Data not shown, but available on request

5 Conclusions and Recommendations

Surface flow appears to be the governing factor in the determination of macroinvertebrate assemblages within Burra Creek. Burra Creek, especially in the upper reaches, is reliant on rainfall runoff for in-stream flow. During dry periods, as was experienced leading up to the spring sampling run, the majority of the surface flow from groundwater and seepage can be rather low as the season progresses. These natural periods of wetting and drying in Burra Creek lead to a high degree of variation, both within and between sites.

The Queanbeyan River experiences similar seasonal variations, but because of the perennial nature of this river, the community assemblages show less variation and to some degree are more predictable. During the operation of M2G we are likely to see longer periods of higher volume (relative to the natural flow regime) flow within the downstream sites in Burra Creek. This is likely to create a more stable environment for flow sensitive taxa such as those mentioned previously and encourage localised recruitment. This in turn may facilitate fish and platypus populations to return to Burra Creek as many of these sensitive taxa feature in their diets (McLachlan-Troup et al., 2010). If as suggested, the pool and edges do provide an important refuge for taxa during dry periods, one of the management goals could be to ensure that they are maintained between operational pumping times with top up discharges. This factor is likely to become increasingly important if fish begin to recruit and utilise Burra Creek more readily once M2G is operational, because during the ramp down phase of the operation, fish will require stable habitat for survival once flows return to their current low flow levels.

Upstream of Williamsdale bridge (BUR 1a and BUR 1c), there are unlikely to be any changes in the system over and above what we are seeing currently. These sections will remain intermittent and highly dependent on rainfall and surface runoff for maintain the flow.

All of the recommendations made to date concerning Burra Creek have been synthesised in a recommendations summary document (ALS, 2012). Outside of this document, there are no new recommendations to be made following the spring sampling run.

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Appendix A –
Site Photographs

BUR 1a – upstream of Cassidy's Creek confluence

Looking downstream towards Cassidy Creek

Looking upstream

BUR 1c – upstream of Williamsdale Bridge

Highlighting the limited riffle habitat

Iron bacteria along the margins

BUR 2a – downstream of Williamsdale Bridge

Sorting macroinvertebrates

Silt boom downstream of Williamsdale Bridge

BUR 2b – downstream of Burra Road Bridge

Pool downstream of Burra Road Bridge

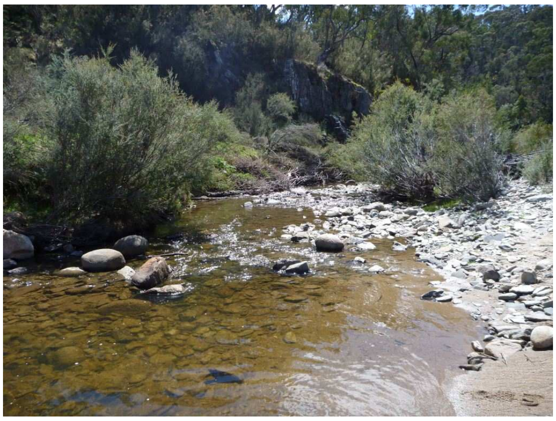
Riffle habitat (mid-ground)

BUR 2c – upstream of London Bridge

Riffle habitat

QBYN 1 – Flynn's Crossing

Riffle habitat facing upstream

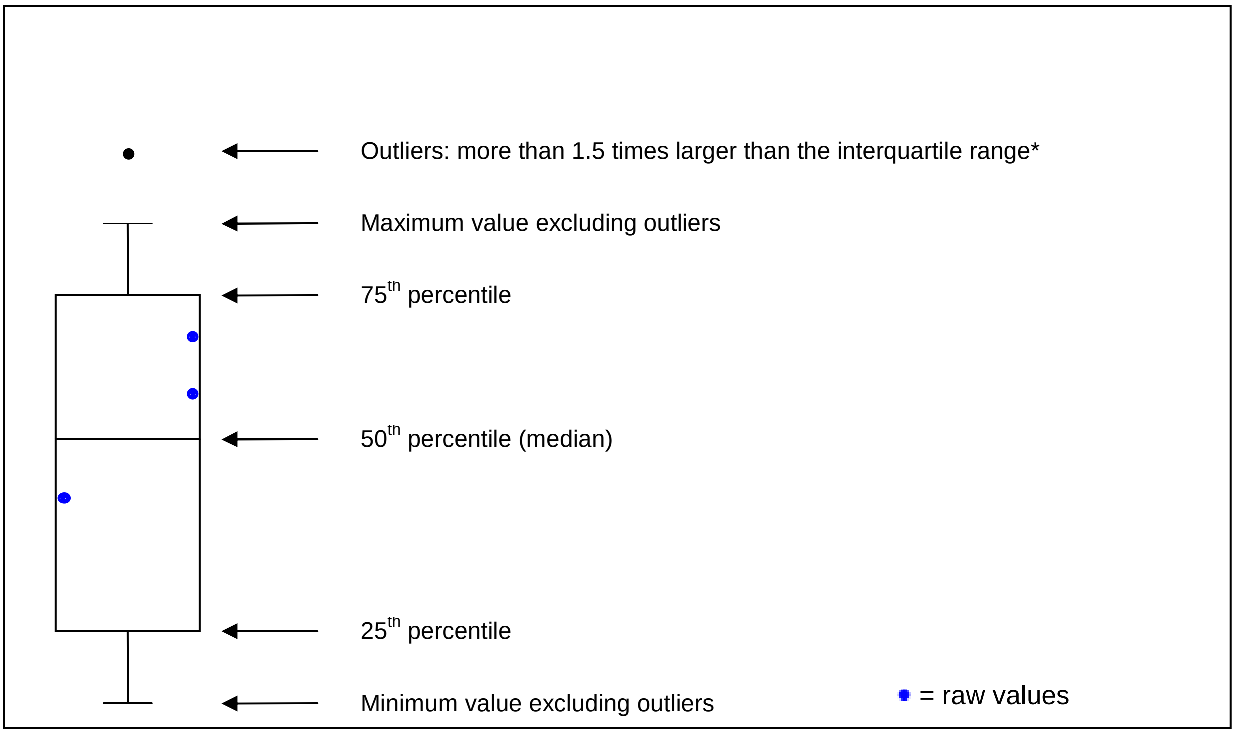


Riffle habitat facing downstream

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

Two-Way Nested Analysis

TESTS FOR DIFFERENCES BETWEEN Site Code GROUPS
(across all Location groups)
Global Test
Sample statistic (Global R): 0.731
Significance level of sample statistic: 0.1%
Number of permutations: 999 (Random sample from 28588560)
Number of permuted statistics greater than or equal to Global R: 0

TESTS FOR DIFFERENCES BETWEEN Location GROUPS
(using Site Code groups as samples)
Global Test
Sample statistic (Global R): 0.5
Significance level of sample statistic: 6.7%
Number of permutations: 60 (All possible permutations)
Number of permuted statistics greater than or equal to Global R: 4

EDGE

Two-Way Nested Analysis

TESTS FOR DIFFERENCES BETWEEN Site Code GROUPS
(across all Location groups)
Global Test
Sample statistic (Global R): 0.757
Significance level of sample statistic: 0.01%
Number of permutations: 9999 (Random sample from 240143904)
Number of permuted statistics greater than or equal to Global R: 0

TESTS FOR DIFFERENCES BETWEEN Location GROUPS
(using Site Code groups as samples)
Global Test
Sample statistic (Global R): 0.182
Significance level of sample statistic: 31.7%
Number of permutations: 60 (All possible permutations)
Number of permuted statistics greater than or equal to Global R: 19

Appendix D –

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

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

Site	Taxa	Oligochaeta	Acarina	Ceratopogonidae	Baetidae	Leptophlebiidae	Gripopterygidae	Leptoceridae	Corixidae	Total number of missing taxa
	SIGNAL	2	6	4	5	8	8	6	2	
QBYN1			*0.62*			*0.88*				*2*
QBYN1			*0.62*							*1*
QBYN1	Edge		*0.62*							*1*
QBYN1			*0.55*							*1*
QBYN1			*0.55*							*1*
QBYN1			*0.55*							*1*
BUR1			*0.59*				*0.78*			*2*
BUR1	Edge		*0.59*				*0.78*			*2*
BUR1		*1.00*	*0.59*		*0.64*	*0.88*	*0.78*			*5*
BUR1C			*0.51*				*0.72*	*0.89*		*3*
BUR1C			*0.51*				*0.72*	*0.89*		*3*
BUR1C	Edge		*0.51*				*0.72*	*0.89*		*3*
BUR1C			*0.52*					*0.89*		*2*
BUR1C			*0.52*				*0.73*	*0.89*		*3*
BUR1C			*0.52*				*0.73*	*0.89*		*3*
BUR2A			*np*		*0.62*	*0.84*		*0.89*		*3*
BUR2A			*np*				*0.68*			*1*
BUR2A	Edge		*np*					*0.89*		*1*
BUR2A			*np*							*0*
BUR2A			*np*				*0.68*	*0.89*		*2*
BUR2A			*np*				*0.68*			*1*
BUR2B			*np*					*0.89*		*1*
BUR2B			*np*				*0.68*			*1*
BUR2B	Edge		*np*		*0.62*			*0.89*		*2*
BUR2B			*np*							*0*
BUR2B			*np*					*0.89*		*1*
BUR2B			*np*	*0.64*				*0.89*		*2*
BUR2C					*0.62*		*0.63*		*0.52*	*3*
BUR2C					*0.62*		*0.63*		*0.52*	*3*
BUR2C	Edge								*0.52*	*1*
BUR2C										*0*
BUR2C					*0.62*				*0.52*	*2*
BUR2C									*0.52*	*1*

APPENDIX D (cntd.) Taxa expected, but not collected in the riffle habitat spring 2011

Site	Taxa	Sphaeriidae	Acarina	Elmidae	Ceratopogonidae	Simuliidae	Tanypodinae	Leptophlebiidae	Baetidae	Gripopterygidae	Hydropsychidae	Total number of missing taxa
	SIGNAL	5	6	7	4	5	4	8	5	8	6	
QBYN1	Riffle	*0.52*			*0.51*							2
QBYN1		*0.52*	*0.73*		*0.51*		*0.76*					4
QBYN1		*0.52*					*0.76*					2
QBYN1		*0.52*	*0.73*		*0.51*							3
QBYN1		*0.52*		*0.91*	*0.51*						*0.52*	4
QBYN1		*0.52*			*0.51*							2
BUR1	Riffle	*np*	*0.73*	*0.92*					*0.67*		*0.52*	4
BUR1		*np*	*0.73*	*0.92*					*0.67*		*0.52*	4
BUR1		*np*		*0.92*					*0.67*		*0.52*	3
BUR1C	Riffle	*0.59*	*0.70*	*0.91*				*0.75*	*0.68*	*0.81*	*0.52*	7
BUR1C		*0.59*	*0.70*	*0.91*				*0.75*	*0.68*		*0.52*	6
BUR1C		*0.59*	*0.70*	*0.91*		*0.81*			*0.68*		*0.52*	6
BUR2A	Riffle	*0.51*					*0.80*	*0.79*			*0.52*	4
BUR2A		*0.51*		*0.92*				*0.79*			*0.52*	4
BUR2A		*0.51*	*0.73*					*0.79*				3
BUR2A		*0.51*		*0.92*		*0.81*					*0.52*	4
BUR2A		*0.51*		*0.92*							*0.52*	3
BUR2A		*0.51*	*0.73*	*0.92*								3
BUR2B	Riffle	*0.52*	*0.73*	*0.91*				*0.78*			*0.52*	5
BUR2B		*0.52*	*0.73*	*0.91*				*0.78*	*0.62*		*0.52*	6
BUR2B		*0.52*	*0.73*	*0.91*				*0.78*		*0.84*	*0.52*	6
BUR2B		*0.52*	*0.73*	*0.91*							*0.52*	4
BUR2B		*0.52*	*0.73*	*0.91*				*0.78*			*0.52*	5
BUR2B		*0.52*	*0.73*	*0.91*							*0.52*	4
BUR2C	Riffle	*0.56*	*0.73*	*0.91*	*0.51*						*0.51*	5
BUR2C		*0.56*	*0.73*	*0.91*				*0.77*			*0.51*	5
BUR2C		*0.56*		*0.91*	*0.51*					*0.82*	*0.51*	5
BUR2C		*0.56*	*0.72*		*0.51*						*0.51*	4
BUR2C		*0.56*	*0.72*		*0.51*							3
BUR2C		*0.56*	*0.72*		*0.51*			*0.77*		*0.82*	*0.51*	6

APPENDIX E- Taxonomic inventory

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

CLASS Order	Family *Sub Family*	QBYN1	BUR1	BUR1C	BUR2A	BUR2B	BUR2C
ACARINA		●	●		●		●
BIVALVIA	Sphaeriidae						
CLADOCERA					●		
Coleoptera	Dytiscidae		●		●		●
Coleoptera	Elmidae	●			●		●
Coleoptera	Gyrinidae			●	●	●	
Coleoptera	Hydraenidae		●				
Coleoptera	Hydrochidae						
Coleoptera	Hydrophilidae						
Coleoptera	Psephenidae						
Coleoptera	Scirtidae		●	●	●	●	
COLLEMBOLA			●		●		
COPEPODA			●		●		
Decapoda	Atyidae						
Decapoda	Parastacidae				●		●
Diptera	Ceratopogonidae	●	●	●	●	●	●
Diptera	*Chironominae*	●	●	●	●	●	●
Diptera	Dixidae		●				
Diptera	Empididae	●	●		●	●	●
Diptera	*Orthocladiinae*	●	●	●	●	●	●
Diptera	Simuliidae	●	●	●	●	●	●
Diptera	Stratiomyidae				●	●	
Diptera	*Tanypodinae*	●	●	●	●	●	●
Diptera	Tipulidae	●	●	●	●	●	●
Ephemeroptera	Baetidae	●			●	●	●
Ephemeroptera	Caenidae	●	●	●	●	●	●
Ephemeroptera	Leptophlebiidae	●	●	●	●	●	●
GASTROPODA	Ancylidae	●					
GASTROPODA	Lymnaeidae						
GASTROPODA	Physidae		●	●			
Hemiptera	Corixidae						
Hemiptera	Notonectidae						
Hemiptera	Veliidae						
HIRUDINEA	Richardsonianidae				●		
Odonata	Aeschnidae						
Odonata	Coenagrionidae						
Odonata	Gomphidae		●				●
Odonata	Zygoptera						
OLIGOCHAETA		●	●	●	●	●	●
OSTRACODA	Ostracoda		●				
Plecoptera	Gripopterygidae	●	●	●	●	●	●
Trichoptera	Calamatoceridae						
Trichoptera	Ecnomidae	●	●	●	●	●	●
Trichoptera	Hydrobiosidae	●	●	●	●	●	●
Trichoptera	Hydropsychidae	●	●		●		●
Trichoptera	Hydroptilidae	●	●		●		●
Trichoptera	Leptoceridae	●	●				
Trichoptera	Philopotamidae	●	●			●	
Turbellaria	Dugesiidae		●				

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

CLASS Order	Family *Sub Family*	QBYN1	BUR1	BUR1C	BUR2A	BUR2B	BUR2C
ACARINA					●	●	
BIVALVIA	Sphaeriidae	●			●		
CLADOCERA				●		●	
Coleoptera	Dytiscidae	●	●	●	●	●	●
Coleoptera	Elmidae	●					●
Coleoptera	Gyrinidae		●	●			
Coleoptera	Hydraenidae	●	●	●	●	●	●
Coleoptera	Hydrochidae						●
Coleoptera	Hydrophilidae			●	●		●
Coleoptera	Psephenidae						●
Coleoptera	Scirtidae	●	●	●	●		●
COLLEMBOLA		●		●			
COPEPODA		●		●		●	
Decapoda	Atyidae	●			●		
Decapoda	Parastacidae		●				●
Diptera	Ceratopogonidae	●	●	●	●	●	●
Diptera	*Chironominae*	●	●	●	●	●	●
Diptera	Dixidae						
Diptera	Empididae						●
Diptera	*Orthocladiinae*	●	●	●	●	●	●
Diptera	Simuliidae	●				●	●
Diptera	Stratiomyidae				●	●	●
Diptera	*Tanypodinae*	●	●	●	●	●	●
Diptera	Tipulidae	●				●	●
Ephemeroptera	Baetidae	●	●	●	●	●	●
Ephemeroptera	Caenidae	●	●	●	●	●	●
Ephemeroptera	Leptophlebiidae	●	●	●	●	●	●
GASTROPODA	Ancylidae		●				
GASTROPODA	Lymnaeidae		●		●	●	●
GASTROPODA	Physidae	●		●		●	●
Hemiptera	Corixidae	●	●	●	●	●	●
Hemiptera	Notonectidae			●	●		
Hemiptera	Veliidae		●		●	●	●
HIRUDINEA	Richardsonianidae						
Odonata	Aeschnidae				●		
Odonata	Coenagrionidae	●					
Odonata	Gomphidae	●	●				●
Odonata	Zygoptera	●			●		●
OLIGOCHAETA		●	●	●	●	●	●
OSTRACODA	Ostracoda	●	●	●		●	
Plecoptera	Gripopterygidae	●		●	●	●	●
Trichoptera	Calamatoceridae	●	●				●
Trichoptera	Ecnomidae	●	●	●	●	●	●
Trichoptera	Hydrobiosidae	●					
Trichoptera	Hydropsychidae						
Trichoptera	Hydroptilidae	●	●	●	●	●	●
Trichoptera	Leptoceridae	●	●		●	●	●
Trichoptera	Philopotamidae						
Turbellaria	Dugesiidae					●	