ACTEW Water

Murrumbidgee Ecological Monitoring Program

Autumn 2014

December 2014

Executive summary

The Murrumbidgee Ecological Monitoring Program (MEMP) commenced in 2008. The project is being undertaken by the GHD Water Sciences Group for ACTEW Water to establish information and data regarding relevant biological and water quality information prior to and then following on from the commissioning and initial operation of the Murrumbidgee to Googong (M2G) water transfer project and Murrumbidgee Pump Station. Up until autumn 2013 there were four components to the MEMP; however following the autumn 2013 sampling run, ACTEW Water reviewed the MEMP which resulted in the discontinuation of part 3 (the Murrumbidgee Pump Station component) and part 4 (the Tantangara to Burrinjuck component). This report presents the findings from part 1 (Angle Crossing) and part 2 (Burra Creek), which both relate to the Murrumbidgee to Googong project.

Part 1 – Angle Crossing Overview

ACTEW Water has constructed an intake structure and pipeline to abstract water from the Murrumbidgee River at Angle Crossing (southern border of the ACT). The system is designed to pump up to a nominal 100 ML/d and was completed in August 2012. There are operating rules in place that limit when and how much water can be extracted to ensure that environmental harm is minimised. The Burra Creek component of the MEMP has focused on the assessment of potential impacts associated with flow reductions in the Murrumbidgee River downstream of Angle Crossing as a result of water abstraction.

Part 1 – Angle Crossing Autumn 2014

Flow in the Murrumbidgee River was characterised by a period of reduced summer and early autumn flows. Rainfall events in late March / early April produced three flow pulses ranging between 1,500 ML/d to over 5,000 ML/d. From around mid-April to the end of May, flows receded to autumn baseflow levels.

Water quality was generally good, except for nutrients such as TN and TP, which regularly exceed guideline levels and represented higher concentrations than the previous autumn. Higher flows associated with pulse events in April meant that turbidity levels were elevated above guideline levels for short periods. There was no pattern to suggest any notable difference between the reaches upstream and downstream of Angle Crossing.

Periphyton production (growth on submerged rocks) can be a useful indicator of flow alteration. Periphyton biomass was estimated from chlorophyll-a and ash free dry mass (AFDM) and both parameters were higher in autumn 2013 compared to autumn 2014; although the spatial patterns amongst all sampling locations remained similar to those seen in previous sampling runs. Both chlorophyll-a and AFDM were highest on average upstream of Angle Crossing.

Waterbugs (macroinvertebrates) within the stream habitat (riffle zone), irrespective of location, were mainly those that could survive in environments with poorer water quality and higher sediment deposition such as aquatic worms, flies and some tolerant species of mayflies. The number of species in the riffle habitat was less than the previous autumn sampling run; however there was an increase in the number of macroinvertebrates with distance downstream. Apart from the spatial trend observed for instream species (riffle taxa richness), there were no other patterns to suggest differences in composition or the proportion of pollution sensitive versus pollution tolerant taxa between locations upstream and downstream of Angle Crossing.

The pool edge-associated macroinvertebrate communities were also largely characterised by taxa with moderate to low sensitivity scores. Unlike riffle-habitat assemblages, the number of macroinvertebrate families decreased with distance downstream resulting in a decrease in the AUSRIVAS O/E ratio which is used to calculate the river health bands.

Despite the reduction in taxa richness compared to autumn 2013, all riffle habitat samples returned an AUSRIVAS Band B (significantly impaired) rating. This was mainly the case for edge habitat as well, except for site MUR 28 (upstream of Cotter River confluence), which returned a Band C (severely impaired rating). These results represent little change in condition relative to previous autumn sampling rounds (most sites have predominantly recorded at B rating), except for the decline in condition at site MUR 28. The latter was due to poor quality edge habitat at this site at the time of sampling.

Part 1 – Angle Crossing Recommendations

Considering the MEMP data to date and the recognition that there is likely to be an extended shut-down period of M2G (GHD, 2013_b). It is recommended that:

1) **A review of the periphyton sampling methods is undertaken.** Given that it is likely that there will only be <u>maintenance monitoring</u> requirements in the foreseeable future, there may be less need for the intensity of sampling that has occurred over the baseline collection period. With that in mind, comparisons between the current sampling program and qualitative methods should be addressed so that a scaling back approach can be taken during the maintenance period. This will save monitoring costs and provide a more rapid turn-around of results. However**,** when M2G becomes operational once again, quantitative methods should be re-employed so that there are comparable data sets for statistical analysis.
2) **Installation of rising stage samplers at a location representative of the intake at Angle Crossing.** Currently there is no regular event-based water quality sampling program. Therefore, it is recommended that a rising stage sampler in installed upstream of Angle Crossing to capture event-based water quality parameters in accordance with the M2G operational plan (e.g. TN and TP). This will also maintain the integrity of current event-based data sets for this section of the Murrumbidgee River.
3) **Check comparability of Lobb's Hole and upstream Angle Crossing gauging stations.** Although outside of the direct scope of the MEMP, we recommend this because Lobb's Hole is written into the M2G operations plan as a key monitoring station, therefore the integrity of data collection from this station is paramount; and given the issues of lightning strikes and equipment failure over the past few years, it is important to have a secondary station that can act as a surrogate for that site when unforeseen problems arise. We recommend that a validation review be undertaken between data collected at Lobb's Hole and the upstream Angle Crossing site to determine the degree of concordance between the two stations. This should be conducted using data from normal flow periods, so that there can be confidence in the upstream station being used to assess trigger level compliance for operational purposes.
4) **Review the water quality parameters at the upstream Angle Crossing site (41001702).** This relates to item 3, but because this station is in the process of being moved, it is recommended that the parameters be reviewed and compared to those in place before the move. This may have implications on trigger levels for M2G operations.
5) ***An overall review of the current sampling protocols.*** Again, this follows on from our upstanding that the MEMP is likely going to be scaled back to only monitor maintenance runs in the foreseeable future. This would include an options report which would examine what alternative data collection methods could be applied during the <u>maintenance monitoring</u> period that could meet EPA requirements and allow for meaningful temporal data comparisons.

Part 2 –Burra Creek overview

The operational phase of the M2G will involve the transfer of water from Angle Crossing to Burra Creek, where it will be released as a run of river flow into Googong reservoir for storage. Up to 100 ML/d will be pumped to Burra Creek, which is characterised by low baseflows and peak flow events that only exceed 100 ML/d for short periods of time. Consequently, this will result in changes to the hydrological regime of this system and subsequent changes to its ecology (both detrimental and beneficial). The Burra Creek component of the MEMP has focused on assessing the potential impacts of changes in hydrology on aquatic biota,

Monitoring for the Angle Crossing and Burra Creek components of the MEMP has been carried out in autumn and spring for five years. This includes a baseline monitoring phase between 2009 and 2012 and, nominally, an operation phase from August 2012 to present. However, since the completion of the M2G in August 2012, the system has only been operating in a standby mode. Only limited trial and maintenance abstractions and releases have occurred. Hence the monitoring to date, including the last two years, largely represents an extended baseline survey. However, it has encompassed a range of flow conditions and, consequently, has been useful in terms of collecting data that allow a better understanding of the relationships between biota and flow with better predictive capacity in respect to the likely nature of changes that will occur once the M2G goes into full operation.

Monitoring to date has covered ACT AUSRIVAS macroinvertebrate sampling, periphyton sampling, water quality monitoring (via in situ testing, laboratory analysis and continuous data loggers) and an assessment of hydrology at locations upstream and downstream of Angle Crossing and the nominated release point in Burra Creek.

Part 2 –Burra Creek autumn 2014

Flow in Burra Creek was characterised by several small pulse events during early March of around 100 ML/d, followed by several larger events during late March-early April, one of which was 750 ML/d From around mid-April to the end of May, flows receded to autumn baseflow levels.

Water quality was mainly within the ANZECC & ARMCANZ guidelines, except for electrical conductivity (EC) and nutrients such as total nitrogen (TN) and oxidised nitrogen (NOx), which exceeded guideline levels at most Burra Creek sites in autumn 2014. The former is not unusual for Burra Creek, which is influenced by groundwater inputs. Nutrient levels were higher in concentration than the previous autumn and exceedances for TN more common this autumn than autumn 2013. Also, this was the first time since 2010 that elevated TP concentrations were recorded at the most upstream site, BUR1a. The low flow levels during early March resulted in an increased diurnal range for dissolved oxygen (DO); higher water temperatures (although also related to seasonal trends) and electrical conductivity slightly elevated. The high flow events during late March and early April brought about turbidity spikes and reductions in both pH and EC levels. Following the events, as flow levels receded to base flow conditions, pH, EC and DO levels all returned to their normal ranges, while turbidity remained stable.

Riffle-associated macroinvertebrate assemblages varied between locations, predominantly due to reduced number of taxa at the upstream site, BUR 1a, but indicating a trend of increasing taxa richness and the number of sensitive macroinvertebrates with distance downstream. Despite this trend there was no evidence to suggest that the AUSRIVAS observed to expected (O/E) ratio or the SIGNAL 2 scores differed statistically between locations.

Edge-associated macroinvertebrate communities in Burra Creek were characterised by tolerant taxa Taxa richness and the number of sensitive macroinvertebrates also increased with distance downstream, but this did not translate to increasing O/E scores or SIGNAL 2 scores and statistically there were no significant differences detected between locations with respect to either the O/E or SIGNAL scores.

All riffle habitat samples except those collected at site BUR 1a were given an AUSRIVAS Band B (significantly impaired) rating. This was mainly the case for edge habitat as well, except for site

BUR 1a, which also returned a Band C rating and site BUR 2a, where the edge samples returned a Band A (similar to reference condition) rating. For most sites, AUSRIVAS results remained similar to autumn sampling events in previous years (in terms of overall band ratings), but results for BUR 1a and BUR 2c represent a decline from the condition rating in autumn 2013.

The overall characteristics of each of the indicators used in this study show a high degree of similarity between upstream and downstream locations not only from this study, but over the course of the MEMP as a whole. This reflects the fact that there have only been a minimal number of maintenance runs since completion of the M2G project and generally, the trial and maintenance releases have not been at a magnitude high enough to cause any long lasting effects to the system.

Part 2 –Burra Creek recommendations

1) **Spring sampling should continue with the same protocols and methods used in this study** as this will meet EIS requirements of a full two years following the beginning of the commissioning period, which will therefore complete the commitments under the M2G EIS.
2) **Review periphyton sampling protocols.** This is the same as the first recommendation for Angle Crossing where qualitative assessment can be carried out during the standby period, but ramped up again during the operational phase.
3) **Review overall sampling protocols as we move into maintenance monitoring.** As well as the points noted in the listed item (section 4.7) this review will include a re-evaluation of how the data are analysed and the appropriateness of grouping BUR 1a and BUR 1c. These sites are starkly different in terms of water chemistry, substrate and other physical aspects. Considering these sites separately and assessing relative changes (in terms of similarity coefficients and univariate metrics) may be a more robust approach moving forward.
4) **Installation of rising stage samplers at a location representative of the discharge into Burra Creek.** Currently there is no regular water quality grab sampling program. Therefore, it is recommended that a rising stage sampler be installed downstream at the Burra Road weir (near BUR 2b) to capture event-based water quality parameters in accordance with the M2G operational plan (e.g. TN and TP);
5) **Collect water samples at the discharge site.** Water quality monitoring should be conducted at the discharge weir in addition to other sites which will help estimate and improve understanding of the dilution process in Burra Creek (only during maintenance runs).

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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

APPLE – Angle Crossing Planned Pumped Lubrication Exercise (ACTEW acronym)

ARMCANZ – Agriculture and Resource management Council of Australia and New Zealand

AUSRIVAS – Australian River Assessment System

BACI – Before After Control Impact

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

M2G – Murrumbidgee to Googong

MEMP – Murrumbidgee Ecological Monitoring Programme

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

1. Introduction

During the 2000-2010 drought in the Australian Capital Territory (ACT) and surrounding regions of New South Wales (NSW), the ACT's dam storage volumes declined to unprecedented levels. ACTEW Corporation, the major water utility company in the ACT, developed a water security programme that involved building additional; and upgrading existing infrastructure to improve the future water supply security for the residents of Canberra and Queanbeyan (see Appendix A for a schematic representation of these projects).

The water security projects include:

1. Murrumbidgee to Googong transfer pipeline (M2G): from Angle Crossing just within the ACT's southern border to Burra Creek in the Googong Dam catchment, at a nominal 100 ML/d;
2. Murrumbidgee Pump Station (MPS): adjacent to the existing Cotter Pump station to increase pump capacity from ~50 ML/d to 150 ML/d (nominally 100 ML/d);
3. Tantangara Reservoir release for run of river flow to the M2G abstraction point at Angle Crossing, and;
4. A new 78 GL Cotter Dam called the Enlarged Cotter Dam (ECD) just downstream of the existing 4 GL Cotter Dam.

The Murrumbidgee Ecological Monitoring Programme (MEMP) was set up by ACTEW Water to evaluate the potential impacts of water abstraction from the Murrumbidgee River. It was designed to address concerns raised by both Government and non-Government stakeholders; and to provide ACTEW Water with relevant information regarding any beneficial and/or detrimental ecological effects of the project. The MEMP was implemented prior to the commencement of the M2G project, allowing ACTEW Water to collect pre-abstraction baseline data to compare against the post-abstraction data once the M2G project is in operation. Sampling has been conducted in spring and autumn each year since 2008.

Between spring 2008 and autumn 2013 there were four component areas being considered as part of the MEMP[1]:

- Part 1: Angle Crossing (M2G);
- Part 2: Burra Creek (M2G);
- Part 3: Murrumbidgee Pump Station (MPS) and;
- Part 4: Tantangara to Burrinjuck (Tantangara Transfer).

However, following the autumn 2013 sampling run, ACTEW Water reviewed the MEMP, which resulted in the discontinuation of part 3 (the Murrumbidgee Pump Station component) and part 4 (the Tantangara to Burrinjuck component).

The M2G ecological monitoring component is consistent with the Operation Environmental Management Plan (ACTEW Corporation, 2012) and associated Ecological Monitoring Sub Plan (ACTEW Corporation, 2010), which responds to commitments made during the EIS and subsequent environmental approvals process.

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[1] Note that the MEMP does not include monitoring related to the Enlarged Cotter Dam (point 4 in section 1)

1.1 Background to major projects

1.1.1 Parts 1 & 2 – Murrumbidgee to Googong transfer pipeline (M2G)

The pumping system at Angle Crossing transfers water from the Murrumbidgee River through a 12 km underground pipeline into Burra Creek. The water is then be transported a further 13 km by run of river flows into the Googong Reservoir. Water abstraction from the Angle Crossing pump station will be dictated by the Googong Reservoir's capacity and by the availability of water in the Murrumbidgee River. 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 directed by the Operational Environment Management Plan (OEMP).

During periods of low flow (whether climate related or artificially induced), impacts upon aquatic environments can be measured using surrogate indices based on changes to macroinvertebrate communities, such as changes in taxa richness, abundances and community structure. Such changes can result either directly through invertebrate drift, or indirectly through reductions in habitat diversity or flow conditions which do not suit certain taxa. Dewson*, et al.* (2007) reported that certain macroinvertebrate taxa are especially sensitive to reductions in flow and can be useful indicators in flow restoration assessments and can assist in longer term management of flows in regulated river systems. It is possible that there will be changes to the aquatic ecosystem within the Murrumbidgee River as a result of M2G. Some of these effects include, but are not limited to changes to water chemistry and changes to channel morphology, velocity and depth. All of these changes have potential knock-on effects to the biota within the river's ecosystem (see Appendix B for examples). This current monitoring program will form the basis of an Ecological Monitoring Program to satisfy EIS commitments for the M2G Project.

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. Some beneficial 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 1-1.

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

Property	Possible impact	Source	Comments based on data collected to date
Water Quality	Increased turbidity from Murrumbidgee water which could decrease light penetration, resulting in lower macrophyte and algal growth.	Martin and Rutlidge (2009)	Turbidity increases with the first initial pulse following flow release. These are short term changes only and there is no evidence to date to support the possible impacts in column one.
	The inter-basin transfers (IBT) of soft Murrumbidgee water into the harder water of Burra Creek may change the natural biodiversity within Burra Creek.	Davis *et. al.* (1992) Martin and Rutlidge (2009)	Based on the data collected following the short term maintenance runs, there have been changes to several physico-chemical water quality parameters. The changes to these parameters are short lived and there has been no evidence of alterations to the macroinvertebrate community composition as a result. It is still unknown if this will be the case for prolonged periods of M2G operation or if there are likely to be cumulative impacts to these periodic changes in water quality.
	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)	The changes in the water temperature, turbidity and dissolved oxygen are only short term during the pumping schedule. Compromising fish habitat is not a concern in Burra Creek as the fish community is wholly introduced species.
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)	The current M2G pumping regime has not continued for durations long enough to, nor at volumes large enough to result in significant macrophyte scouring, sediment movement or alter the community composition over and above what occurs naturally within the system.
	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.	Martin and Rutlidge (2009)Davies *et al.* (1992)	No evidence of any new introduced species since the commencement M2G operations.
	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)	The transport of fine sediment within the creek by the operation of M2G is minor compared to the sediment transport capabilities of the natural high flow events that occur in Burra Creek.
	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)	Water transfer has increased the longitudinal connectivity between the pools in Burra Creek. However, the short duration of the releases would be unlikely to facilitate breeding opportunities or range expansion by native fish species.
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. Increased sedimentation may also reduce benthic habitat complexity, which may result in a loss of benthic macroinvertebrate diversity and a potential loss of sensitive taxa.		Natural events have a much larger impact potential upon the geomorphology than the pump maintenance releases from M2G. However, if the pumps are run for a prolonged period (greater than 1 week), this may have additional impact due to saturation of the creek embankment from continued elevated water levels. (GHD, 2013_a)
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)	There has been no evidence of scouring directly related to commissioning flows over and above the scouring which has been recorded following natural high flow events (GHD, 2013_a). Ongoing vegetation monitoring is coinciding with seasonal biological sampling.

1.2 Environmental flows and the 80:90 percentile rule

The environmental flow rules for the Murrumbidgee to Googong project (M2G) have been adopted from the framework outlined in the Environmental Flow Guidelines (ACT Government, 2011).

Under the current licence agreement (ACTEW's Licence to take water, 2012), flows in the Murrumbidgee River at the Cotter Pump Station must be maintained at 20 ML/d during any stage of water restrictions (http://www.actew.com.au). When these restrictions do not apply, flows must be maintained at the 80th or 90th percentile flow, depending on the time of year. The 80:90 rule has been applied to hydrological modelling of the Murrumbidgee River at Angle Crossing for the M2G operational plan; and was based on data collected from the Lobb's Hole gauging station. Specifically the 80th percentile flow applies from November to May and the 90th percentile from June through to October (Figure 1-1).

As can be seen from the Figure 1-1, the lowest flows in the Murrumbidgee River occur in summer and autumn. The 80th percentile flows from November to May are less than the 90th percentile flows except for November. It is during these low flow months that abstraction from the Murrumbidgee River is likely to have the most significant impact, as the proportion of the abstraction rate to the base flow is the greatest.

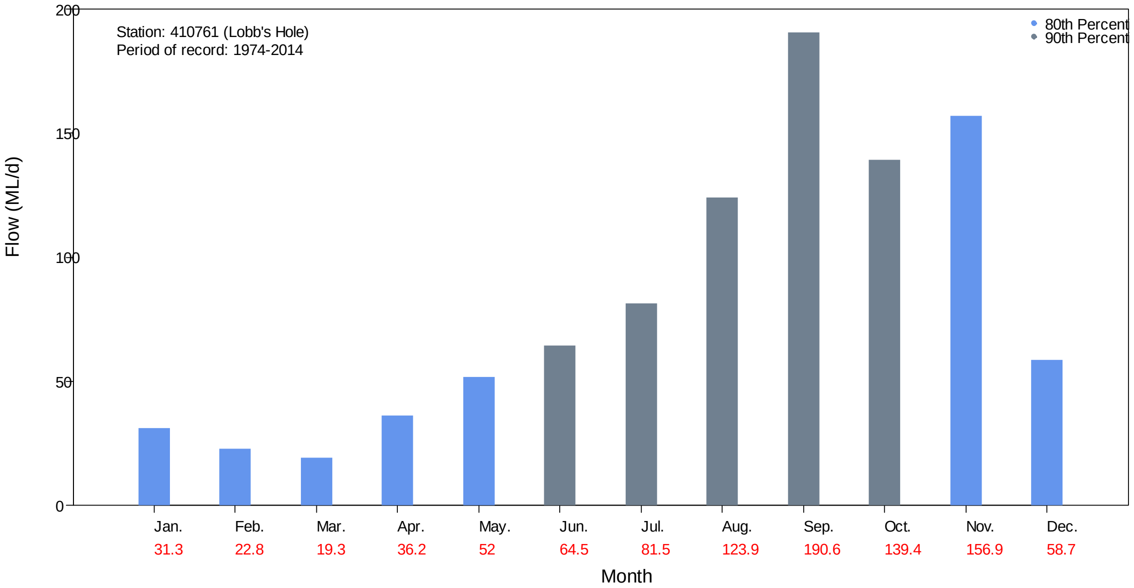


Figure 1-1. Environmental flow values for the operation of M2G

Note: Flow data values for data to 31/05/2014. Mean monthly values in red are megalitres per day (ML/d) and are based on continuous daily flow data from the Lobb's Hole gauging station (410761) since its commencement of operation in 1974.

1.3 The upper Murrumbidgee River

The Murrumbidgee River flows for 1600 km from its headwaters in the Snowy Mountains to its junction with the Murray River. The catchment area to Angle Crossing is 5,096 km^2. As part of the Snowy Mountains Scheme, the headwaters of the Murrumbidgee River are constrained by the 252 GL Tantangara Dam, which was completed in 1961. The reservoir collects water and diverts it outside the Murrumbidgee catchment to Lake Eucumbene. This has reduced base flows and the frequency and duration of floods in the Murrumbidgee River downstream. The Murrumbidgee River is impounded again at Burrinjuck Dam, after the river passes through the ACT. This region above Burrinjuck Dam is generally known as the Upper Murrumbidgee.

Land use varies from National Park in the high country to agriculture and farming in the valley regions. Land use is dominated by urbanisation between Point Hut Crossing and the North Western suburbs of Canberra near the confluence with the Molonglo River. The major contributing urbanised tributary flowing into the Murrumbidgee River is Tuggeranong Creek, which enters the Murrumbidgee River downstream of Point Hut crossing. Annual rainfall in the Upper Murrumbidgee River catchment ranges from greater than 1400 mm in the mountains, to 620 mm at Canberra airport (B.O.M, 2013).

Prior to spring 2010, drought was the most significant impact on catchment quality within the upper Murrumbidgee catchments in recent times. During this period, more than 80% of catchments had been drought-affected since late 2002. Some of the effects of this were drought-induced land degradation, increased stress on surface and groundwater resources, increased soil erosion and a shift from mixed farming and cropping, to grazing and reduced stock numbers. Since the spring of 2010, the drought broke in the ACT and surrounding NSW regions, with more frequent high flow events occurring throughout that year and an upward trend in the monthly average base flows, which peaked in March 2012 (Figure 1-2). More recently, during the period between March 2012 and May 2014, there has been a declining trend to levels that existed in 2010 (Figure 1-2).

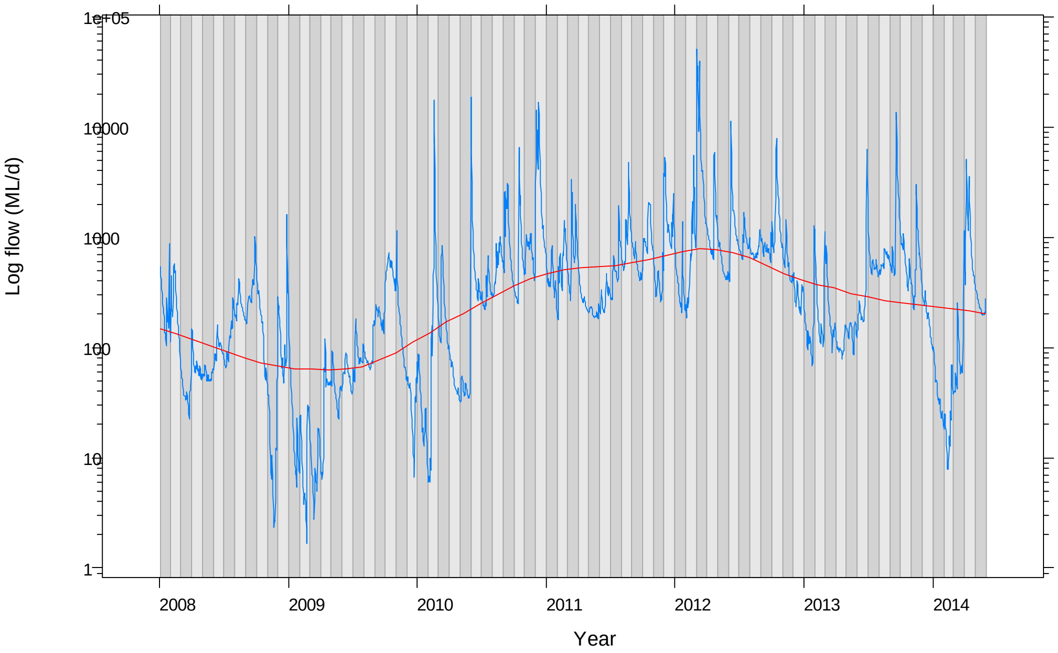


Figure 1-2. Hydrograph of the Murrumbidgee River at Lobb's Hole (410761) from 2008 to the 31st of May 2014

**The red line is a locally weighted smoother (LOESS) trend line with a smoothing coefficient of 0.5.*

1.4 Burra Creek

Burra Creek is a small intermittent stream which flows north to north-east along the western edge of the Tinderry Range into Googong Reservoir. The majority of its catchment is pastoral and small rural holdings with the Tinderry Range being natural dry sclerophyll forest. Burra Creek is characterised by emergent and submergent macrophyte beds with limestone bedrock and frequent pool-riffle sequences throughout its length. During low periods the main channel is commonly choked with *Typha sp.* (also known as cumbungi or bull rush). The creek is within a wider eroded channel in the lower section upstream and downstream of the London Bridge (natural limestone arch). When Googong Reservoir is >80% the lower sections of Burra Creek become inundated by the reservoir.

The mean daily flow in Burra Creek (from January 1st 2008 to the 31st May 2013) was 11.8 ML/d - slightly higher from the previous sampling period due to the operation of the M2G pipeline in August and September 2012 and March and May 2013.

Since flow records began in 1985 a mean monthly flow of 100 ML/d has been exceeded 8 times, while flows in excess of 100 ML/d have occurred less than 2 % (1.68%) of the time on a daily basis.

Flow conditions have varied considerably since the inception of the MEMP in late 2008 (Figure 1-3). In 2008 mean daily flow was 0.15 ML/d and this was followed by an equally dry year in 2009 when the mean daily flow was 0.18 ML/d. In early 2010 there were a few rainfall events and this pattern continued throughout most of the year resulting in an upward trend of daily mean flows, which reached 23.4 ML/d. 2011 was a moderately dry year and mean flows fell back to less than 5 ML/d until March 2012 which saw another period of large rainfall events. These rainfall events resulted in another upward trend in average flows until early spring 2012 (Figure 1-3). However, since November 2012, there has been a downward trend in base flows, which has since levelled, off reflecting the low seasonally reduced rainfall over the past two years.

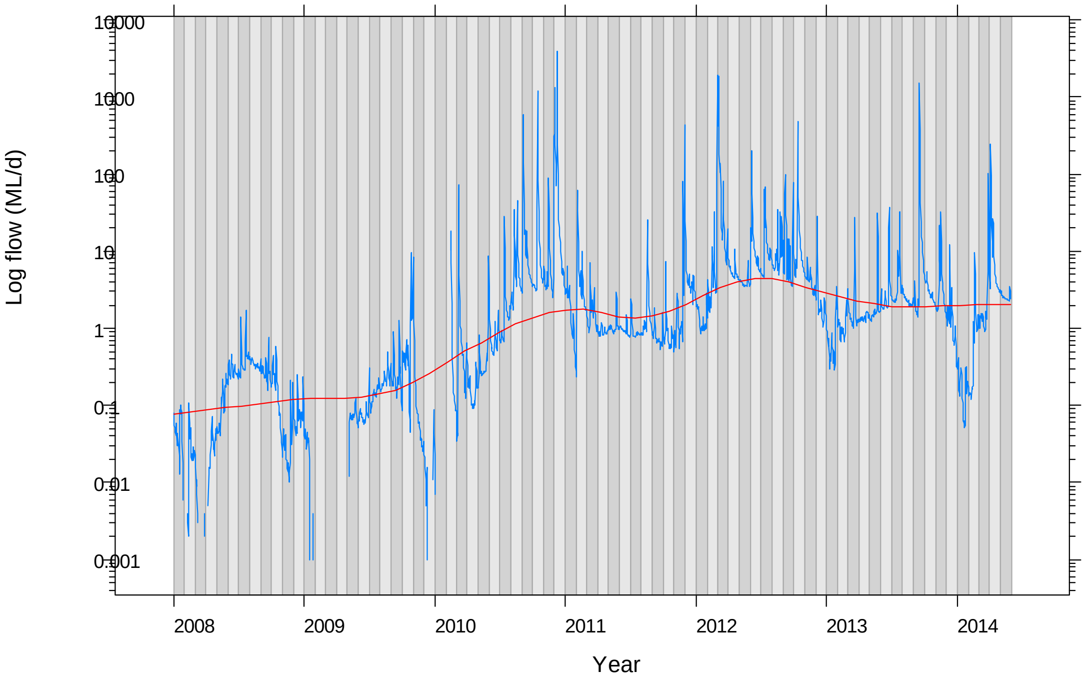


Figure 1-3. Hydrograph of Burra Creek at the Burra Road weir (410774) from 2008 to May 2014

The red line is locally weighted smoother (LOESS) trend line with a smoothing function coefficient of 0.5.

1.5 Project Objectives

The Murrumbidgee Ecological Monitoring Programme (MEMP) was set up by ACTEW Water to evaluate the potential impacts of water abstraction from the Murrumbidgee River and the subsequent changes that might occur in Burra Creek as a result of the M2G project (Parts 1 and 2).

Increasing water abstractions from the Murrumbidgee River could have several impacts on water quality, riparian vegetation, riverine geomorphology and the aquatic ecology of the system. Some beneficial ecological effects could be expected in the reaches downstream of the discharge point in Burra Creek under the proposed flow release regime, including increased habitat availability for native fish species. The increased flow in those locations is also likely to favour flow-dependent macroinvertebrates and improve surface water quality.

The key aims of the MEMP are:

- to determine whether or not, and to what extent, abstraction from Murrumbidgee River is affecting the maintenance of healthy aquatic ecosystems within the river or impacting Burra Creek, in terms of biological communities;
- to determine whether or not, and to what extent, abstraction of water at Angle Crossing is impacting riverine habitat through changes in sediment movement;
- to determine whether or not, and to what extent, abstraction of water at Angle Crossing is impacting riverine habitat through changes in flow;
- to establish baseline and operational information on water quality and stream flow, macroinvertebrate communities, fish, riverine vegetation and geomorphology, relating to aquatic systems impacted by the water abstraction and discharge (M2G), in accordance with the Ecological Monitoring Sub Plan (ACTEW, 2010) of the OEMP (ACTEW, 2012);
- to monitor water quality within Burra Creek, to establish normal annual and seasonal variation so that any changes resulting from the operations of abstraction and release are identified.

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.

This monitoring programme is designed to be adaptive. Through the reporting of data and results, liaison with the client and technical advisory groups, it may be decided that certain monitoring methodologies need to be changed or adapted to enhance the outcomes of the program. However, with these procedures in place, GHD will be able to provide ACTEW Water with appropriate information to further develop knowledge and understanding of environmental flows and ecosystem thresholds. The information derived from this programme will also support ACTEW Waters' adaptive management approach to water abstraction and environmental flow provision in the ACT. Frequent review of the MEMP will ensure that the monitoring has the capacity to adapt to changing environmental, social and economic conditions with regard to ACTEW Water's operational requirements.

1.6 Scope of work

Parts 1 and 2: Angle Crossing & Burra Creek

The current ecological health of the sites monitored as part of the MEMP was estimated using AUSRIVAS protocols for macroinvertebrate community data, combined with a suite of commonly used biological metrics and descriptors of community composition. The scope of this report is to convey the results from the spring 2013 sampling. Specifically, as outlined in the MEMP proposal to ACTEW Corporation (GHD, 2012) this work includes:

- Sampling conducted autumn 2014;
- Macroinvertebrate communities collected from riffle and edge habitats using AUSRIVAS protocols;
- Macroinvertebrate samples counted and identified to the taxonomic level of genus;
- Riffle and edge samples assessed through the appropriate AUSRIVAS model;
- Periphyton samples collected at each site;
- *In-situ* water quality measurements collected and samples analysed for nutrients in the Australian Laboratory Services (ALS) Canberra NATA accredited laboratory.

1.7 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 the community structure at any one times represents a cumulative response to 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 composition, and two indices of community condition: the AUSRIVAS index and the proportions of three insect orders (the Ephemeroptera, Plecoptera, and Trichoptera, or EPT index), were used as part of this study to assess river health.

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

Changes in total periphyton biomass and/or the live component of the periphyton (as determined by chlorophyll *a*) can vary with changes in flow volume, so these variables are often used as indicators of river condition in relation to monitoring the effects of flow regulation, environmental flow releases or water abstraction impacts.

Water abstractions from Angle Crossing will not affect the timing or magnitude of higher flows, but could affect conditions during the seasonal low flow period, such as increasing the nutrient availability through increased residence time, reducing scouring impacts on benthic organisms (such as periphytic algae) and reducing surface flows over riffle habitats and thus decreasing habitat quality and availability. As changes in flow volume are expected with the proposed changes in the Murrumbidgee River water abstraction regime, periphyton biomass and chlorophyll *a* are included as biological indices.

2. Materials and methods

2.1 Study sites

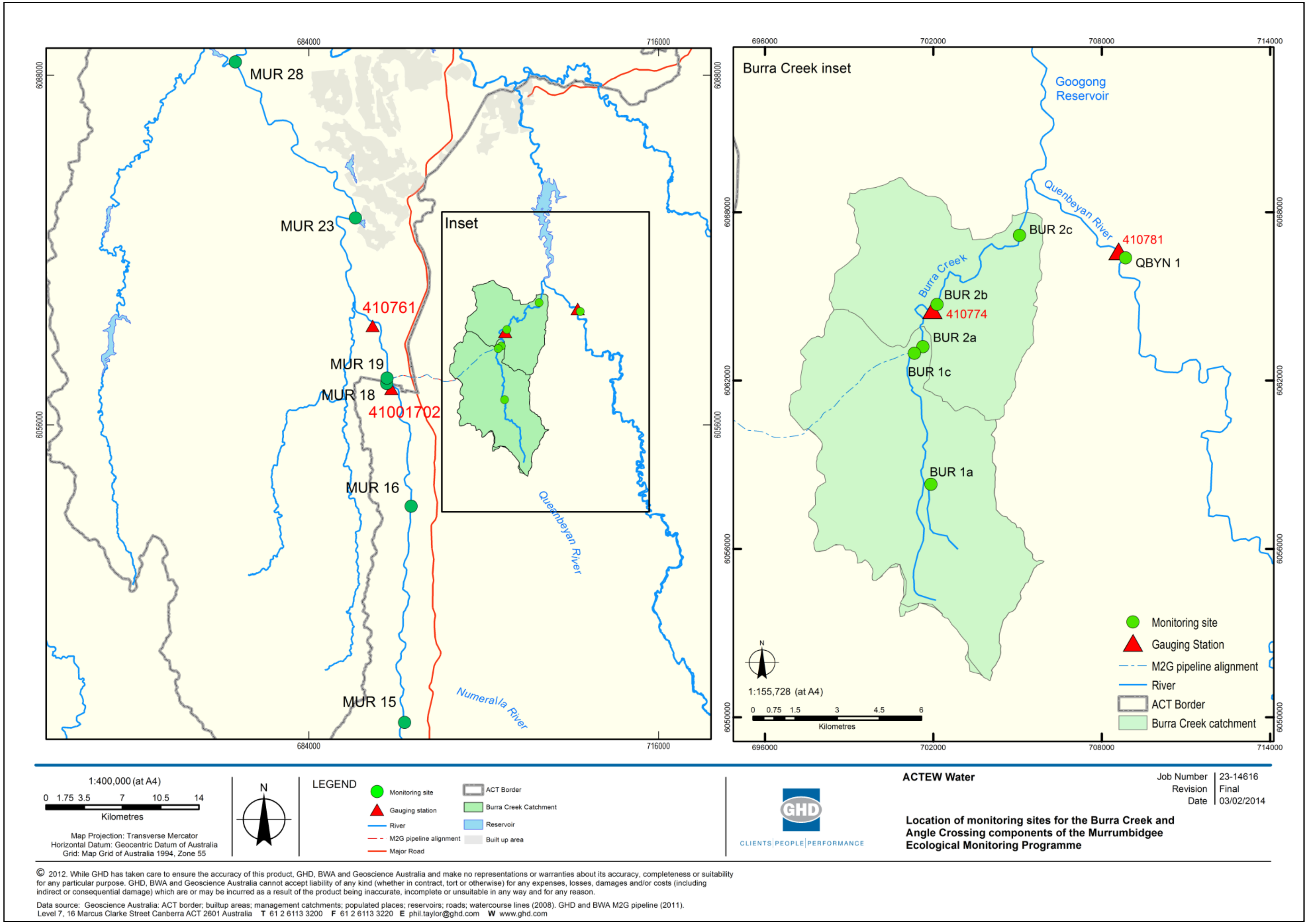
Prior to sampling, comprehensive site assessments were carried out, including assessments of safety, suitability and access permission from landowners. There are no suitable reference sites in the proximity for the MEMP, so a Before – After / Control – Impact (BACI) design (Downes *et al*., 2002) was 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. Sites were chosen based on several criteria, which included:

- Safe access and approval from land owners;
- Sites have representative habitats (i.e. riffle / pool sequences). If both habitats were not present then sites with riffle zones took priority as they are the most likely to be affected by abstractions;
- Sites which have historical ecological data sets (e.g. Keen, 2001) took precedence over new sites –allowing for comparisons through time to help assess natural variability through the system. This is especially important in this programme, because there is less emphasis on the reference condition, and more on comparisons between and among sites of similar characteristics in the ACT and surrounds over time.

Potential sites were identified initially from topographic maps, they were visited prior to sampling and their suitability was subsequently considered. The number and location of sites to be included in this study were then reviewed by an independent biometrician (Robinson, 2008), which resulted in the final site selection. Robinson (2008) also provided recommendations towards the number replicates and sub-samples that should be included in this program. The MEMP consists of 12 sites which meet these criteria. Details of these sites are given in Table 2-1 and are shown in Figure 2-1. Macroinvertebrate community composition, periphyton assemblages and water quality were monitored from sites on the Murrumbidgee River, Burra Creek and the Queanbeyan River with the aim of building a knowledge base on the ecological condition based upon the AUSRIVAS river health framework and following the ANZECC guidelines for ecological monitoring (ANZECC & ARMCANZ, 2000). 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 habitat 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).

Table 2-1. Sampling site locations and details

Component of the MEMP		Site Code	Location	Altitude (mAHD)	Landuse	Latitude	Longitude
PART 1	Angle Crossing	MUR15	Near Colinton - Bumbalong Road	658	Grazing / Recreation	-35.8663	149.1350
		MUR16	The Willows - Near Michelago	646	Grazing / Recreation	-35.6880	149.1369
		MUR18	U/S Angle Crossing	608	Grazing	-35.5875	149.1099
		MUR19	D/S Angle Crossing	608	Grazing / Recreation	-35.5830	149.1095
		MUR23	Point Hut Crossing	561	Recreation / Residential	-35.4513	149.0744
		MUR28	U/S Cotter River confluence	468	Grazing	-35.3244	148.9504
PART 2	Burra Creek	BUR1a	Upper Burra Creek	815	Native	-35.5985	149.2289
		BUR1c	Upstream Williamsdale Road	762	Grazing / residential	-35.5565	149.2212
		BUR2a	Downstream Williamsdale Road	760	Grazing	-35.5543	149.2245
		BUR2b	Downstream Burra Road Bridge	751	Woodland / Grazing	-35.5420	149.2304
		BUR2c	Approximately 1km u/s London Bridge	730	Recreational / Grazing	-35.5179	149.2615
		QBYN1	Flynn’s Crossing	685	Recreational / Native	-35.5243	149.3033



Data source: Geoscience Australia: ACT border; builtup areas; management catchments; populated places; reservoirs; roads; watercourse lines (2008). GHD and BWA M2G pipeline (2011).
Level 7, 16 Marcus Clarke Street Canberra ACT 2601 Australia T 61 2 6113 3200 F 61 2 6113 3220 E phil.taylor@ghd.com W www.ghd.com

Figure 2-1. Map of site locations on the Murrumbidgee River, Burra Creek and the Queanbeyan River for the MEMP

2.2 Hydrology and rainfall

River flows and rainfall for the sampling period were recorded at ALS operated gauging stations located: upstream of Angle Crossing (41000270); at Lobb's Hole (downstream of Angle Crossing: 410761); Burra Creek (upstream of BUR 2b: 410774) and the Queanbeyan River (upstream of Googong Reservoir: 410781). A list of parameters measured at each station is given in Table 2-2. Stations were calibrated according to ALS protocols and data were downloaded and verified before quality coding and storage in the ALS database. Water level data were manually verified by comparing the logger value to the physical staff gauge value and adjusted if required. Rain gauges were also calibrated and adjusted as required. Records were stored using the HYDSTRA$^{©}$ database management system.

Table 2-2. River flow monitoring locations and parameters

Site Code	Location/Notes	Parameters*	Latitude∞	Longitude	Component of the MEMP
41001702	Murrumbidgee River, U/S of Angle Crossing	WL, Q, pH, EC, DO, Temp, Turb, Rainfall	-35.5914	149.1204	Angle Crossing
410761	Murrumbidgee River @ Lobb's Hole (D/S of Angle Crossing)	WL, Q, pH, EC, DO, Temp, Turb, Rainfall	-35.5398	149.1001	Angle Crossing
410774	Burra Creek D/S road bridge	WL, Q, pH, EC, DO, Temp, Turb, Rainfall	-35.5425	149.2279	Burra Creek
410781	Queanbeyan River U/S of Googong Reservoir	WL, Q, pH, EC, DO, Temp, Turb, Rainfall	-35.5222	149.3005	Burra Creek

** WL = Water Level; Q = Rated Discharge; EC = Electrical Conductivity; DO = Dissolved Oxygen; Temp = Temperature; Turb = Turbidity; Rainfall = Rainfall (mm) D/S = downstream; U/S = upstream.*

∞ Negative value indicates south of equator.

2.3 Water quality

Baseline physico-chemical parameters including temperature, pH, electrical conductivity, turbidity and dissolved oxygen were recorded using a YSI multiprobe unit at sites indicated in **Error! Reference source not found.**. The multiprobe was calibrated following QA procedures and the manufactures requirements prior to sampling. Additionally, grab samples were taken from each site in accordance with the AUSRIVAS protocols (Coysh *et al*., 2000) for multiprobe verification and nutrient analysis. All samples were placed on ice, returned to the ALS Canberra laboratory, and analysed for nitrogen oxides (total NOx), total nitrogen and phosphorus in accordance with the protocols outlined in APHA (2005), with NATA certified results. Collectively, this information on the water quality parameters was used to assist in the interpretation of biological data and provide a basis on which to gauge ecosystem changes potentially linked to flow reductions at these key sites following water abstractions.

2.4 Macroinvertebrate sampling and processing

At each site, macroinvertebrates were sampled in the riffle and edge habitats where available. Both habitats were sampled to provide a more comprehensive assessment of each site (Coysh *et al*., 2000) and potentially allow the programme to isolate flow-related impacts from other disturbances. The reasoning behind this is that each habitat is likely to be affected in different ways by changes in flow conditions. Riffle zones, for example, are likely to be one of the first habitats affected by low flows and water abstractions as water abstraction will result in an immediate reduction in flow velocities and inundation level over riffle zones downstream of the abstraction point. Impacts on edge habitat macroinvertebrate assemblages might be less immediate as it may take some time for the reduced flow conditions to cause loss of macrophyte beds and access to trailing bank vegetation habitat. Therefore, monitoring both habitats will allow the assessment of the short-term and longer-term impacts associated with water abstraction.

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 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 n*et al*ong 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. Genus identification was recommended by Chessman (2008) from his review of the MEMP project design. 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.

2.5 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. 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). Qualitative assessments of the estimated substrate coverage by periphyton and filamentous green algae were also conducted at each site in accordance with the AUSRIVAS habitat assessment protocols (Nichols *et al.*, 2000) to compliment the quantitative samples.

2.6 Macroinvertebrate quality control

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

- Organisms that were heavily damaged were not selected during sorting. To overcome losses associated with damage to intact organisms during vial transfer; attempts were made to obtain significantly more than 200 organisms;
- Identification was performed by qualified and experienced aquatic biologists with more than 100 hours of identification experience;
- When required, taxonomic experts confirmed identification. Reference collections were also used when possible;
- ACT AUSRIVAS QA/QC protocols were followed;
- An additional 10% of samples were re-identified by another senior taxonomist and these QA/QC results are found in Appendix C;
- 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.

2.7 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 aquatic ecology field staff hold current AUSRIVAS accreditation.

3. Data analysis

Data were analysed using both univariate and multivariate techniques. Analyses were performed in PRIMER V6 (Clarke and Gorley, 2006) and R version 3.0.1 (R Development Core Team, 2013). Descriptive statistics performed on rainfall, hydrology and continuous water quality parameters were organised in the time series data management software - HYDSTRA©.

3.1 Water quality

Water quality parameters were examined for compliance with ANZECC water guidelines for healthy ecosystems in upland streams (ANZECC and ARMCANZ, 2000). This report presents results based on autumn 2014 sampling. Summary statistics were determined for the parameters collected at the gauging stations and time series plots were created to assist with the interpretation.

3.2 Macroinvertebrate communities

3.2.1 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, and:
- ACT AUSRIVAS O/E scores and bandings.

3.2.1.1 Taxa richness

The number of taxa (taxa richness) was counted for each site and other descriptive metrics such as the relative abundances of pollution-sensitive taxa (Ephemeroptera, Plecoptera and Trichoptera - EPT) and, pollution-tolerant taxa, (i.e. Oligochaeta, Chironomids and other Diptera) were examined at family and genus levels. Taxa richness was monitored as a means of assessing macroinvertebrate diversity. In assessing the taxonomic richness of a site, it is important to keep in mind that high taxa richness scores may, though does not always, indicate better ecological condition at a given location. In certain instances high taxa richness may indicate a response to the provision of new habitat or food resources that might not naturally occur as a result of anthropogenic activities.

3.2.1.2 SIGNAL-2

Stream Invertebrate Grade Number – Average Level (SIGNAL) is a biotic index based on pollution sensitivity values (grade numbers) assigned to aquatic macroinvertebrate families that have been derived from published and unpublished information on their tolerance to pollutants, such as sewage and nitrification (Chessman, 2003). Each family in a sample is assigned a grade between 1 (most tolerant) and 10 (most sensitive).to these assigned bandwidths to aid the interpretation of each site assessment. 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. 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.

3.2.1.3 AUSRIVAS

In addition to assessing the composition and calculating biometrics from the macroinvertebrate data, riffle and edge samples, river health assessments based on the ACT AUSRIVAS spring riffle and edge models were conducted. AUSRIVAS is a prediction system that uses macroinvertebrate communities 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 which cannot be influenced due to human activities, e.g. altitude) are then compared to the observed fauna (O) and the ratio derived is used to indicate the extent of any impact (O/E). The ratio derived from this analysis is compiled into bandwidths (i.e. X, A-D; Table 3-1) which are used to gauge the overall health of 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 3-1).

The 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 an A assessment in the edge and a B Band in the riffle would be given an overall site assessment of B (Coysh *et al*., 2000). In cases where the bands deviate significant between habitat (e.g. D – A) then an overall site-level assessment was 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 be noted that the presence or absence of rare taxa does vary naturally 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 or the effects of a recent hydrological disturbance rather than truly reflecting ecological change.

Table 3-1. AUSRIVAS band widths and interpretations for the ACT autumn edge and riffle models

BAND	RIFFLE	EDGE	Explanation
	O/E Band width	O/E band width	
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 – 0.88	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.

3.2.1.4 Univariate analysis techniques

Linear mixed effects ANOVA models were conducted separately for the riffle and edge samples to test for location differences in the univariate metrics: SIGNAL-2 scores and AUSRIVAS O/E 50 ratios. The factor, “site” (nested within location) was considered a random effect representing the river condition upstream and downstream of the proposed abstraction point; while location (upstream and downstream) was considered a fixed, constant effect. Data transformations were not necessary, because the model assumptions were met on all accounts. Models were made using lme4 (Bates *et* *al*., 2013) a statistical package applied in the R environment (R Development Core Team, 2013). For all analyses, the level of significance (alpha) was set to 5%.

3.2.2 Multivariate analysis

The initial step in this process was to calculate a similarity matrix for all pairs of samples based on the Bray-Curtis similarity coefficient (Clarke and Warwick, 2001). For the macroinvertebrate data collected during this survey, the final number of dimensions was reduced to two.

Non-metric multidimensional scaling (NMDS) ordination was performed to reduce dimensionality of the macroinvertebrate data in order to provide a visual representation of the macroinvertebrate relationships between sites and locations. Within the NMDS plot, sites closer together indicate that the macroinvertebrate communities are more similar to one another than sites further apart in the ordination space. In other words, NMDS reduces the dimensionality of the data by describing trends in the joint occurrence of taxa. This procedure was performed on the macroinvertebrate community data following the initial cluster-analysis.

Stress values for each NMDS plot were examined before results were interpreted. 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 and can be considered a measure of “goodness of fit” to the original data matrix (Kruskal, 1964). Stress values near zero suggest that NMDS patterns are very representative of the multidimensional data, while stress values greater than 0.2 indicate a poor representation and, therefore, the need to interpret NMDS plots with these sorts of stress values with caution (Clarke and Warwick, 2001).

An Analysis Of Similarities test (ANOSIM) was performed on the macroinvertebrate similarity matrix to test whether macroinvertebrate communities were statistically different between upstream and downstream locations. Sites were nested within location for the analysis (Parts 1-3 only). The Similarity percentages (SIMPER) routine was carried out on the datasets only if the initial ANOSIM test was significant (i.e. P<0.05), to examine which taxa were responsible for, and explained the most variation among statistically significant groupings (Clarke and Warwick, 2001). This process was also used to determine which taxa characterised particular groups of sites.

3.3 Periphyton

To test whether estimated biomass (AFDM) and live content (chlorophyll-a) were different between sites upstream and downstream of Angle Crossing, a mixed effects, analysis of variance model was fitted to the Log-transformed AFDM and Chlorophyll-a data. The factor “site”, was nested within location (upstream or downstream of the abstraction point). Consequently, site and location were treated as random and fixed effects, respectively in the ANOVA model. Log-transformations were necessary to meet the assumptions of equal variances in the response variable residuals.

Post-hoc tests performed on the periphyton data collected for the Burra Creek component were carried out using the p-values function available in the R package “LMERConvenienceFunctions” (Trembley and Ransijn, 2013).

4. Angle Crossing

4.1 Summary of sampling and river conditions

Sampling of Angle Crossing sites was conducted on the 6th & 7th of May 2014. Local weather conditions during this period were fine and sunny with maximum daily temperatures 16°C and 15°C on the 6th & 7th respectively (Bureau of Meteorology, 2014). Flow in the Murrumbidgee River was receding during this period following a high flow event during mid-April (Figure 4-2).

Site photographs are shown in Plate 4-1 and full site summaries can be found in Appendix D. One edge sample was missed from MUR 28 (Table 4-1) as a result of insufficient habitat.

There were no obvious changes in the physical condition of any of the monitoring sites. Macrophyte cover on the substrate was minimal at all sites (however, substrate coverage was highest at MUR 23). The two dominant genera were *Myriophyllum* and *Callitriche* although in the upper section of the MUR15 reach, ribbon weed (*Vallisneria gigantea*) was highly abundant. The sediments in the littoral zone at MUR 15 had a strong anaerobic odour when disturbed.

Table 4-1. Samples collected during autumn 2014 at Angle Crossing sites

Site	Riffle	Edge	Comment
MUR 15	2	2	All samples collected
MUR 16	2	2	All samples collected
MUR 18	2	2	All samples collected
MUR 19	2	2	All samples collected
MUR 23	2	2	All samples collected
MUR 28	2	1	Insufficient edge habitat for a second sample

MUR 15 – 240 ML/d

MUR 16 – 240 ML/d

MUR 18 – 310 ML/d

MUR 19 – 430 ML/d

MUR 23 – 290 ML/d

MUR 28 – 290 ML/d

Plate 4-1. Photographs of the Angle Crossing sites during autumn 2014 sampling

Note: Flow values from the relevant gauging sites (410050: MUR 15 & 16; 41001702: MUR 18 & 19; 410761: MUR 23 & 28)

4.2 Hydrology and rainfall

Over the past five years, rainfall has typically been greater in March than in April and May and 2014 was no exception (Figure 4-1). Flow and rainfall summaries for upstream Angle Crossing and Lobb's Hole in autumn 2014 are provided in Table 4-2. Rainfall recorded during the autumn period was 181.2 mm at the upstream Angle Crossing (41001702) gauging station, compared to 214.8 mm at Lobb's Holes (410761).

Flow levels at both the upstream and downstream stations started the season at very low base-flow levels with approximately 30 ML/d (Figure 4-2), which is less than the reported releases from Tantangara Dam during that time of 50 ML/d (Snowy Hydro Limited, 2014). A small spike was recorded at the Lobb's Hole station in response to the small localised event which occurred during early March, which peaked and receded rapidly with a peak of more than 400 ML/d on the 6th of March. Rainfall events during late March to mid-April created three separate high flow events (Figure 4-2).

The first of these events during late March was the smallest of the three, peaking at the Lobb's Hole Gauging station at over 1,300 ML/d on the 30th. The event during early April was the largest event of the season, which was recorded at over 5,600 ML/d at Lobb's Hole on the 6th. This was followed by the final event of the season, again recorded at Lobb's Hole, which peaked at over 4,000 ML/d on the 13th of April. Following this series of high flow events, flow continued to recede for the remainder of the season before a small rainfall event at the end of May increased flow into June. Monthly comparisons of flow conditions to those in autumn 2013 show that March 2013 was ~50% higher than the current sampling period (410761), however in April and May 2014, flows were considerably higher compared to the same period in 2013 (Figure 4-3).

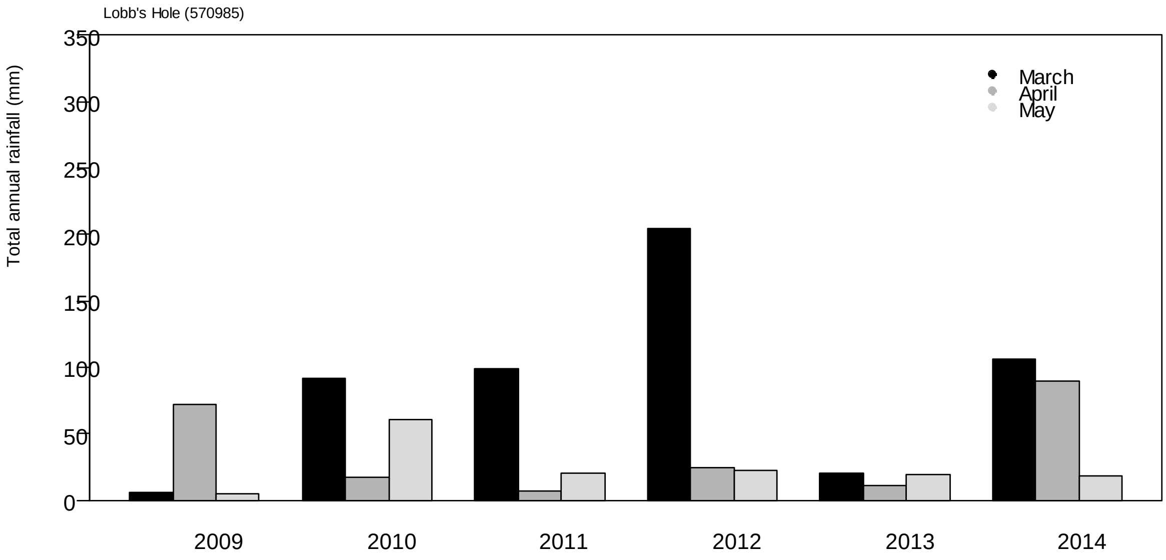


Figure 4-1. Annual comparison of spring rainfall (mm) recorded at Lobb's Hole (570985)

Table 4-2. Autumn rainfall and flow summaries upstream and downstream of Angle Crossing

	Upstream Angle Crossing (41001702)		Lobb's Hole (410761)	
	Rainfall Total (mm)	Mean Flow (ML/d)	Rainfall Total (mm)	Mean Flow (ML/d)
March	82.8	140	106.4	150
April	83.6	1,200	89.8	1,400
May	14.8	230	18.6	250
Autumn (mean)	181.2 (60.4)	530	214.8 (71.6)	600

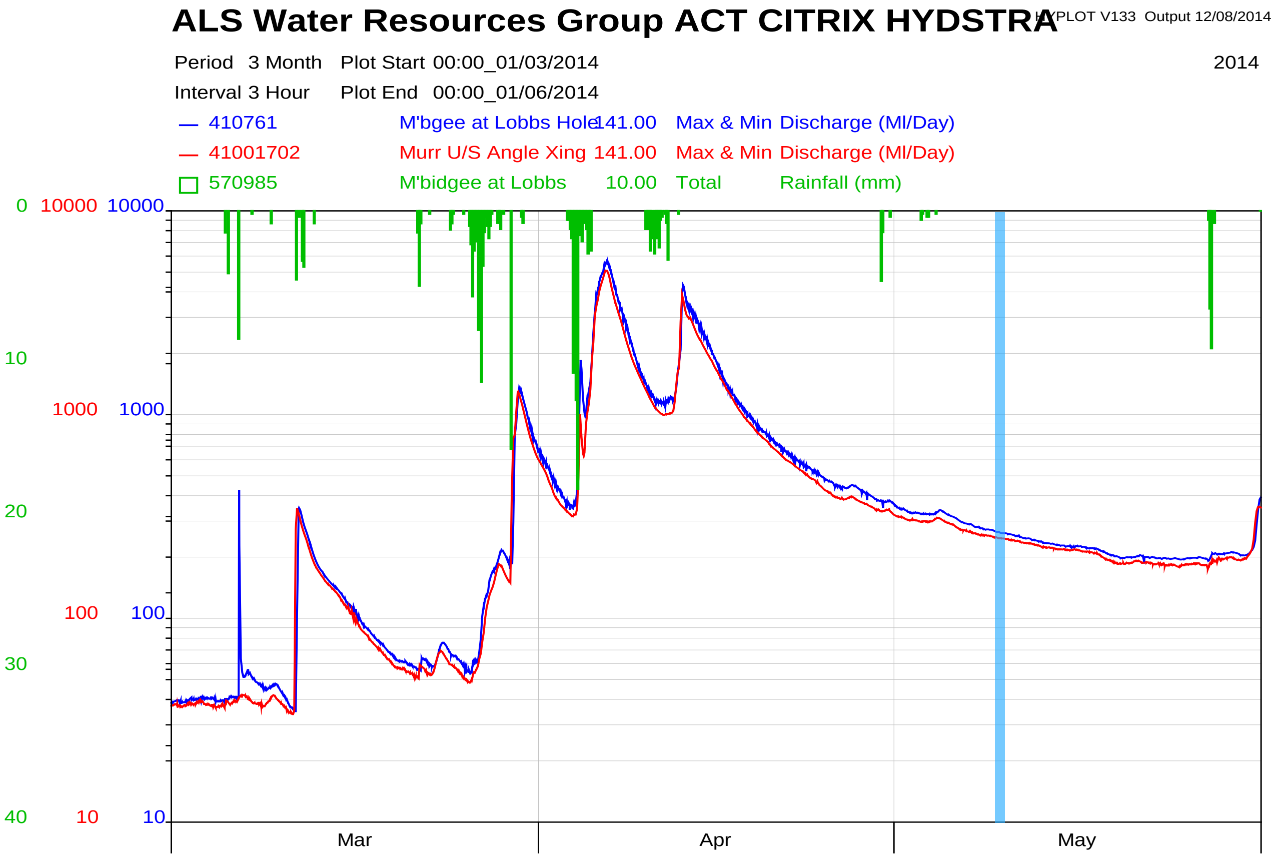


Figure 4-2. Autumn hydrograph of the Murrumbidgee River upstream of Angle Crossing (41001702) and downstream of Angle Crossing at Lobb's Hole (410761)

Note: Green shaded area indicates sampling period

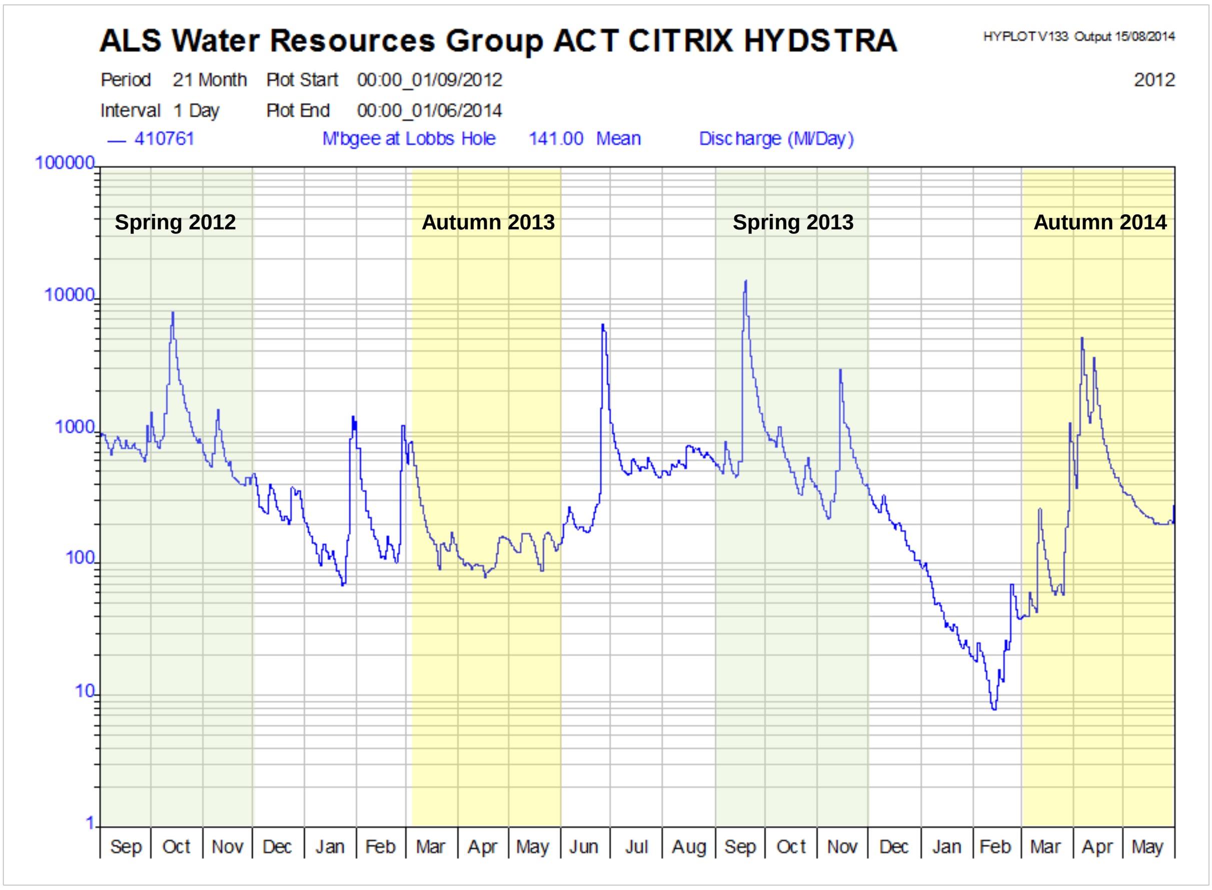


Figure 4-3 Hydrograph from Lobb's Hole highlighting the past four sampling periods between September 2012 and May 2014

4.3 Water quality

4.3.1 Grab samples and *in-situ* parameters

Results from the grab samples and in-situ recorded parameters are presented in Table 4-3, highlighting exceedances in the ANZECC & ARMCANZ (2000) guidelines. *In-situ* parameters showed two exceedances on the recommended ranges at MUR 23 and MUR 28. The dissolved oxygen (DO) recommended maximum value was exceeded at MUR 23 with a value 3.6% over the upper limit of 110%. The exceedance of the pH recommended upper limit at MUR 28 is not uncommon and is within the expected range for pH for this reach of the Murrumbidgee River. Further, results for 2014 represent an overall reduction in the pH at Angle Crossing sites compared to autumn 2013, when three sites exceeded the recommended upper limit and two sites were on the cusp of the upper limit. All results recorded for electrical conductivity (EC) and turbidity were within the recommended ranges set by the ANZECC & ARMCANZ (2000) guidelines.

Nutrient concentrations were elevated to levels above the ANZECC & ARMCANZ (2000) guideline trigger values at all sites for total nitrogen (TN) and four of the sites for total phosphorus (TP). The furthest downstream site (MUR 28) recoded TP within the guidelines level, while TP at MUR 23 was on the cusp of exceeding that level. These results represent a substantial increase in nutrients compared to autumn 2013, when only two sites exceeded the TN guideline (MUR 15 & 23), while there were no exceedances of the TP guideline. There were no exceedances of the NO_x guideline level during either autumn 2014 or autumn 2013.

There was very little difference in water quality between upstream and downstream reaches in autumn 2014 (Table 4-3), indicating that the operation of the pump station at Angle Crossing had no impact on water quality at the time of sampling.

4.3.2 Continuous water quality monitoring

Time series plots of water quality data from Lobb's Hole (410761) and Upstream Angle Crossing (41001702) are presented in Figures 4-4 and Figure 4-5 respectively. Monthly summary statistics for these parameters are provided in Table 4-5.

The record of continuous water quality data at Lobb's Hole (410761) is incomplete for the autumn 2014 sampling period due to sensor damage experienced in the early March (Figure 4-4). At the time of writing this report, this issue is being addressed by the manufactures (Andy Cumming (ALS), *pers. comm*). The main impact of this was to the pH sensor resulting in a loss of data for the entire autumn period from early March onward. There was also a loss of turbidity, electrical conductivity and dissolved oxygen information for various periods; however, temperature was the only parameter to be unaffected by the event which impacted the multi-probe sensor.

During autumn 2014, compliance to ANZECC & ARMCANZ (2000) guidelines was higher overall compared to the autumn 2013 period. EC at both locations had 100% compliance, as did turbidity in May at both stations and for dissolved oxygen in April (Lobb's Hole only) and in March (upstream Angle Crossing only) (Figure 4-4 & Figure 4-5 respectively). Results for pH at Angle Crossing were largely within the recommended range in autumn 2014, but were elevated in March to a point where no values were within guideline levels that month. Although dissolved oxygen showed the highest number of instances of non-compliance, the values falling below the lower limit of 90% were only 1-5 dissolved oxygen percentage units outside of this limit, which should be taken into account when interpreting these statistics. It should also be noted that, apart from March, compliance rates with respect to dissolved oxygen levels were higher in the downstream reach than the upstream reach (Figure 4-4 & Figure 4-5). Compliance rates for the downstream reach in March are affected by the lack of dissolved oxygen data for much of that month due to probe failure.

Monthly continuous monitoring water quality result summaries are provided in Table 4-5 and those results support the conclusions reached above based on instantaneous *in situ* water quality sampling in that water quality was broadly consistent between upstream and downstream reaches.

Table 4-3. *In-situ* water quality results from Angle Crossing during autumn 2014

ANZECC and ARMCANZ (2000) guidelines are in yellow parentheses in the column heading, yellow shaded cells indicate values outside of the guidelines and orange values are on the cusp of the guideline values.

	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)	NO_x (mg/L) (0.015)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L) (0.02)	TN (mg/L) (0.25)
Upstream	MUR 15	6/5/2014	9:30	10.3	132.1	5.64	5	7.89	100.8	11.04	48	0.003	< 0.002	0.002	< 0.002	0.028	0.33
	MUR 16	6/5/2014	12:45	11.5	142.6	5.26	4	7.77	100.4	11.03	52	< 0.002	< 0.002	< 0.002	< 0.002	0.026	0.34
	MUR 18	7/5/2014	13:50	11.1	145.9	4.30	3	7.50	104.6	11.17	53	< 0.002	< 0.002	< 0.002	0.003	0.021	0.33
Downstream	MUR 19	6/5/2014	14:35	11.6	146.3	4.61	3	7.32	98.5	10.99	52	< 0.002	< 0.002	0.002	< 0.002	0.022	0.34
	MUR 23	7/5/2014	11:10	11.3	142.6	4.96	4	7.11	113.6	12.44	50	< 0.002	< 0.002	< 0.002	0.002	0.02	0.34
	MUR 28	7/5/2014	9:30	11.1	144.5	4.15	2	8.01	109.6	11.06	51	< 0.002	< 0.002	< 0.002	0.002	0.018	0.36

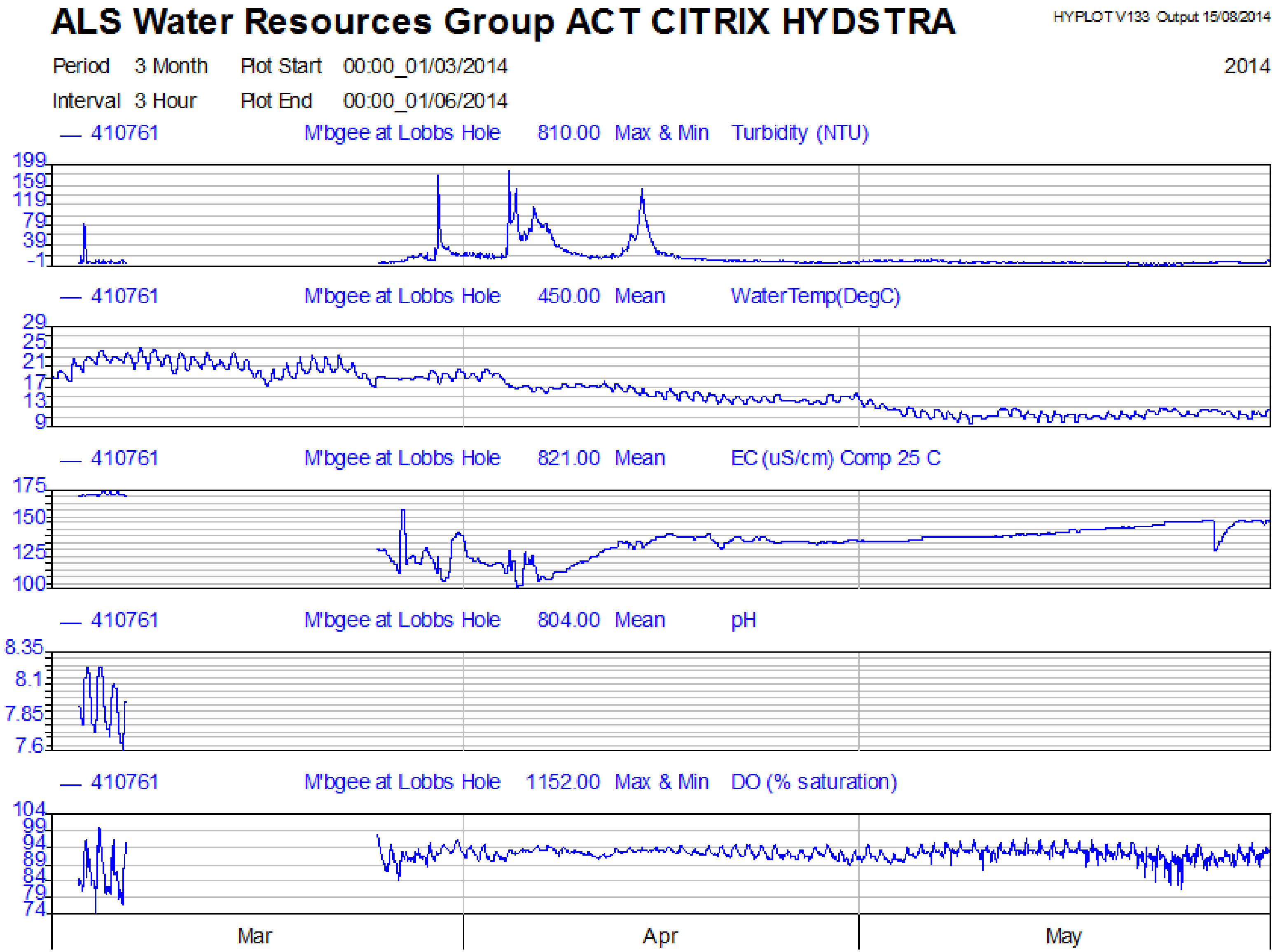


Figure 4-4. Continuous water quality records from Lobb's Hole (410761) for autumn 2014

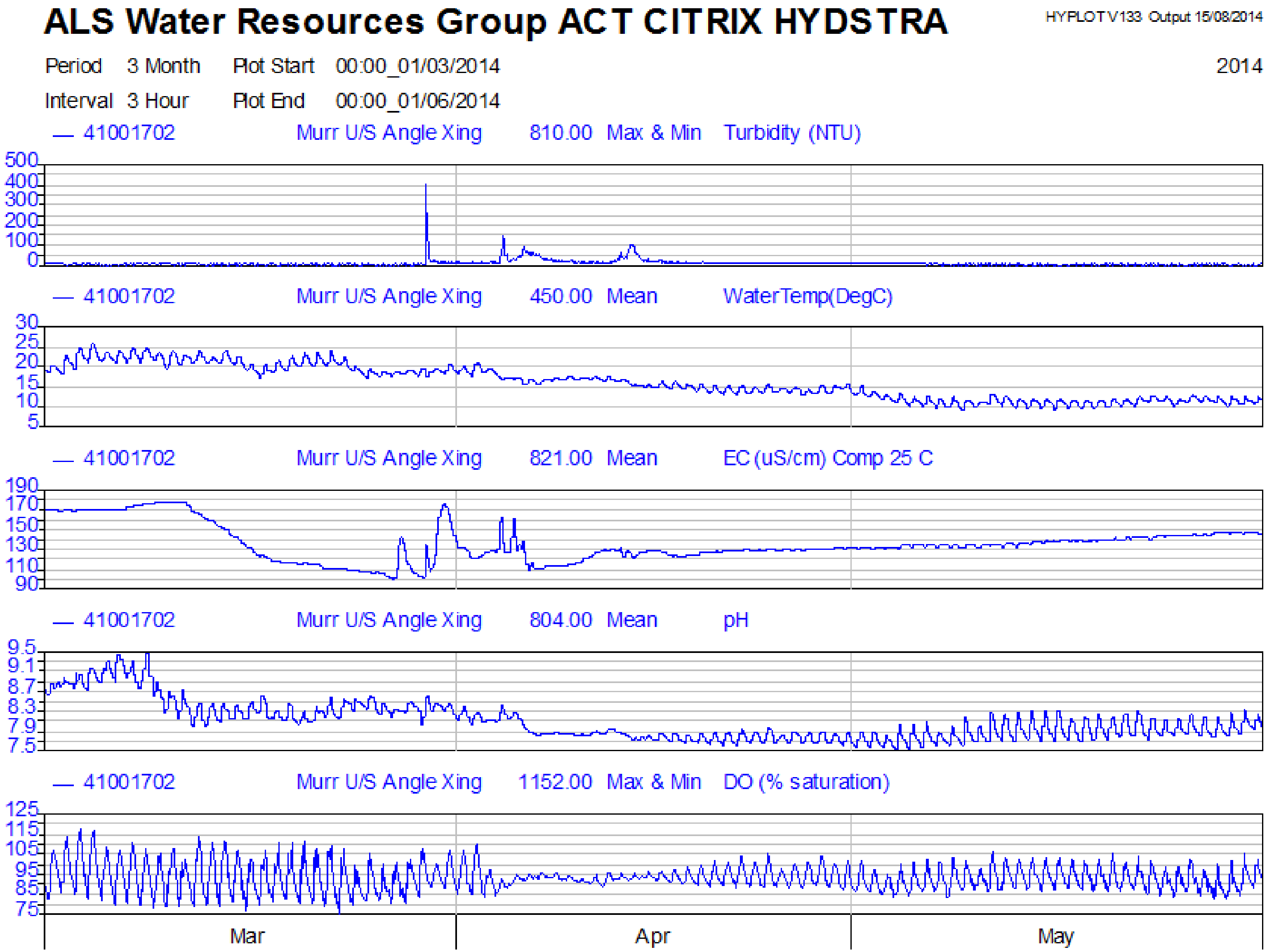


Figure 4-5. Continuous water quality records from upstream Angle Crossing (41001702) for autumn 2014

Table 4-4. Compliance (%) to ANZECC & ARMCANZ (2000) guideline values from the continuous gauging stations upstream (41001702) and downstream (410761) of Angle Crossing

Analyte	Electrical Conductivity (µS/cm) (30-350)		pH (6.5-8)		Turbidity (NTU) (2-25)		Dissolved Oxygen (% Saturation) (90-110)	
Location	**U/S**	**D/S**	**U/S**	**D/S**	**U/S**	**D/S**	**U/S**	**D/S**
March	100%	100%	0%	100%*	97%	89%†	100%	55%†
April	100%	100%	84%	No data	80%	74%	94%	100%
May	100%	100%	90.4%	No data	100%	100%	91%	97%
Autumn	**100%**	**100%**	**58.1%**	**/**	**92.3%**	**87.6%**	**95%**	**84%**

Notes:

- Compliance values are expressed as the percentage of days throughout the spring period (based on daily means) that values were within the guidelines (in yellow in the column heading);
- ANZECC & ARMCANZ (2000) guidelines are inside yellow parentheses;
- * Only three days available for March 2014;
- † Nine days available for March 2014.

Table 4-5. Monthly water quality statistics from upstream (41001702) and downstream (410761) of Angle Crossing

Analyte	Temperature (°C)		Electrical Conductivity (µS/cm) (30-350)		pH (6.5-8)		Turbidity (NTU) (2-25)		Dissolved Oxygen (% Saturation) (90-110)	
Location	**U/S**	**D/S**	**U/S**	**D/S**	**U/S**	**D/S**	**U/S**	**D/S**	**U/S**	**D/S**
March	20.8	17.5	142.7	140.6	8.5	7.9	6.9 (410.2)	15.2 (180.6)	87.7-99.4	74-100
April	15.8	15.7	126.4	129.8	7.8	No data	18.7 (149.8)	24.9 (187.6)	88.7-95.7	88.9-95.2
May	11.5	9.8	138.4	143.2	7.9	No data	4.5 (9.10)	4.5 (12.8)	89.6-94.4	81.4-96.6
Autumn	**16**	**14.3**	**135.8**	**137.8**	**8.06**	**7.9**	**10** **(410.2)**	**14.8** **(187.6)**	**88.6-96.5**	**81.4-97.2**

Note: All values are means, except dissolved oxygen (% saturation) which is expressed as mean monthly minimums and maximums. ANZECC & ARMCANZ (2000) guidelines are in yellow in the column heading. Turbidity readings are monthly means with monthly instantaneous maximums in parentheses.

4.4 Periphyton

Periphyton production peaked at MUR 18 (~ 500 upstream of Angle Crossing), where areal concentrations exceeded 75,000 ug/m^2 (Figure 4-6). The remaining sites all had concentrations ranging between 17,000 and 19,000 ug/m^2. At both locations, these concentrations are considerably higher than they were compared to autumn 2013, equating to a 45% increase in chlorophyll-a upstream of Angle Crossing; and a 19% increase downstream of Angle Crossing in this study compared to autumn 2013

In terms of location, mean concentrations were notably different upstream of Angle Crossing (27,646 ± 9907) compared to downstream sites (17999 ± 4977); however, there was no statistical significance ($F_{1,4,}$= 1.24; *P*=0.33) between the two locations. Furthermore, variation due to location only accounted for 3.2% of the total whereas 28.6% was due to site to site variation.

Compared to autumn 2013, biomass in this study was 67% higher at the upstream sites and 50.5% higher at the downstream sites. Biomass (as ash free dry mass) tended to increase downstream from MUR 15 to MUR 18 and, after an abrupt change at MUR 19, displayed a similar pattern between that site and MUR 28 as the upstream sites (Figure 4-7). Location differences in ash free dry mass were negligible as mean biomass estimates upstream of Angle Crossing were (10,452 ± 2839 mg/m^2) compared to the downstream sites (10,010 ± 3480 mg/m^2) ($F_{1,4}$ = 0.01; *P*=0.91) (Table 4-6), which is supported by the zero variance explained by location effects as opposed to the 37.3% explained by site to site variation.

Table 4-6. Nested analysis of variance results for chlorophyll-a and AFDM concentrations Angle Crossing

Response	Source	DF	F	P-value	Variance component
Chlorophyll-*a*	Location	1	1.24	0.33	3.2
	Site [Location]	4	3.53	0.02	28.6
	Total	35			
AFDM	Location	1	0.01	0.91	0.0
	Site [Location]	4	4.58	0.01	37.3
	Total	35			

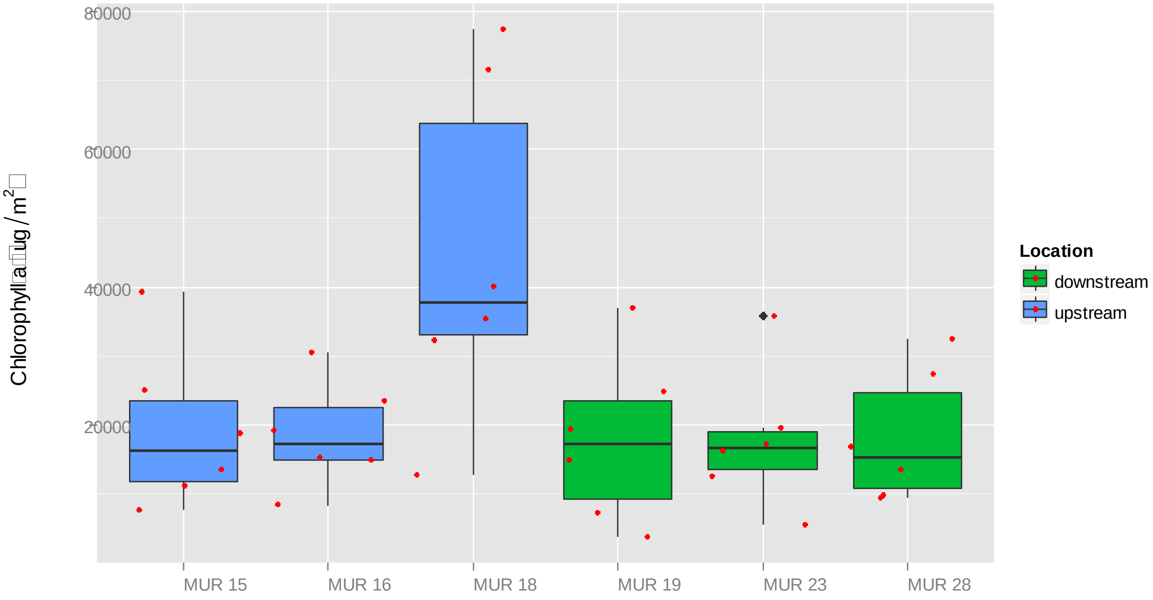


Figure 4-6. Chlorophyll-a concentrations at Angle Crossing sites

Note: Red points represent the raw values for each site.

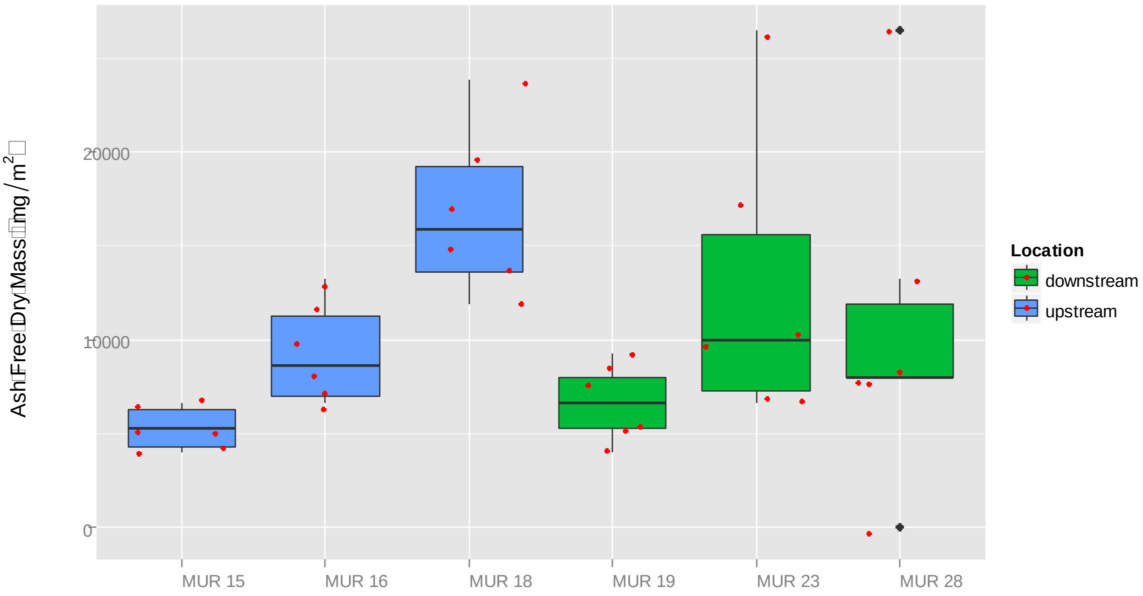


Figure 4-7. Ash free dry mass at Angle Crossing sites

Note: Red points represent the raw values for each site.

4.5 Macroinvertebrates

4.5.1 Community assemblages

Riffle habitat

In autumn 2014, macroinvertebrate fauna in the riffle habitat in both locations was characterised by moderately tolerant to tolerant taxa. Dominant groups amongst all sampling sites included families and sub-families in the order Diptera (true flies), Oligochaeta (22) (aquatic worms), the moderately tolerant Caenidae (4) from the order of Mayflies (Ephemeroptera) and moderately sensitive: Hydropsycidae (6) from the order Trichoptera (Caddis-flies). The dominance of these key groups amongst all sampling locations resulted in a non-metric multidimensional ordination plot that shows little differentiation in community composition between sampling locations (Figure 4-8; ANOSIM: R=-0.11; *P*=0.70).

In riffle habitat, the number of unique taxa tended to increase with distance downstream from MUR 15 (14 families, 17 genera) to MUR 28 (18 families, 24 genera) (Figure 4-9). Interestingly, however, the reverse trend was observed for edge habitat (Figure 4-9). There has been an overall decline in the number of families and genera collected in this study period compared to autumn 2013. For example, we found up to eight families in 2014 compared to 2013. The maximum number was found at MUR 18 while there were only two less families at MUR 28 and we found no change at MUR 23. At the genus level, all of our sampling sites produced fewer genera compared to 2013; which ranged from six fewer at MUR 23 to 20 at MUR 19.

The number of unique EPT families was, for the most part, the same at all sites (Figure 4-10). The number of EPT genera ranged from 9 at MUR 15 to 13 at MUR 28. EPT taxa were dominated by three families, all of which were Mayflies: Baetidae (5), Caenidae (4) and Leptophlebiidae (8). Other groups such as Trichoptera, which have shown considerable diversity at the genus level in previous sampling runs, were generally represented by a single genus. When the ratio of the number of genera to the

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[2] Denotes SIGNAL-2 tolerance score

number of families is taken into account, we found that in 2013 there were on average 1.7 genera per family, compared to 1.2 in autumn 2014.

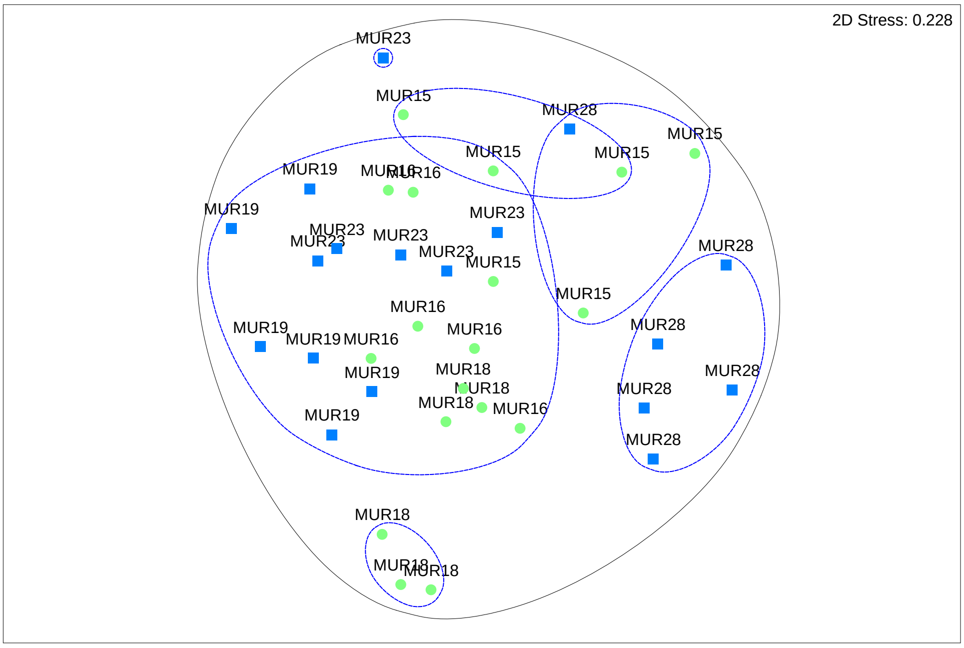

Figure 4-8. Non-metric multidimensional scaling of macroinvertebrate data (genus level) collected from the riffle habitat

Note: Blue ellipses represent 60% similarity and the black ellipses indicate 75% similarity groups. Green circles are upstream sites and blue squares and downstream sites.

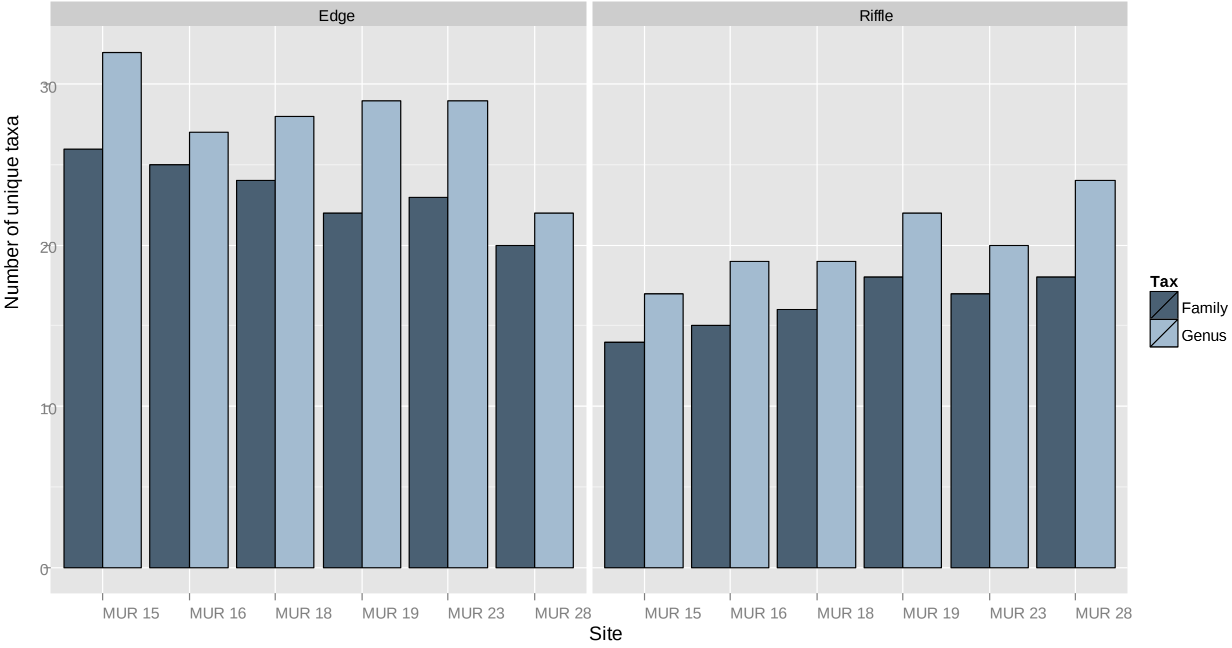

Figure 4-9. Total number of taxa at genus and family level from riffle and edge habitats

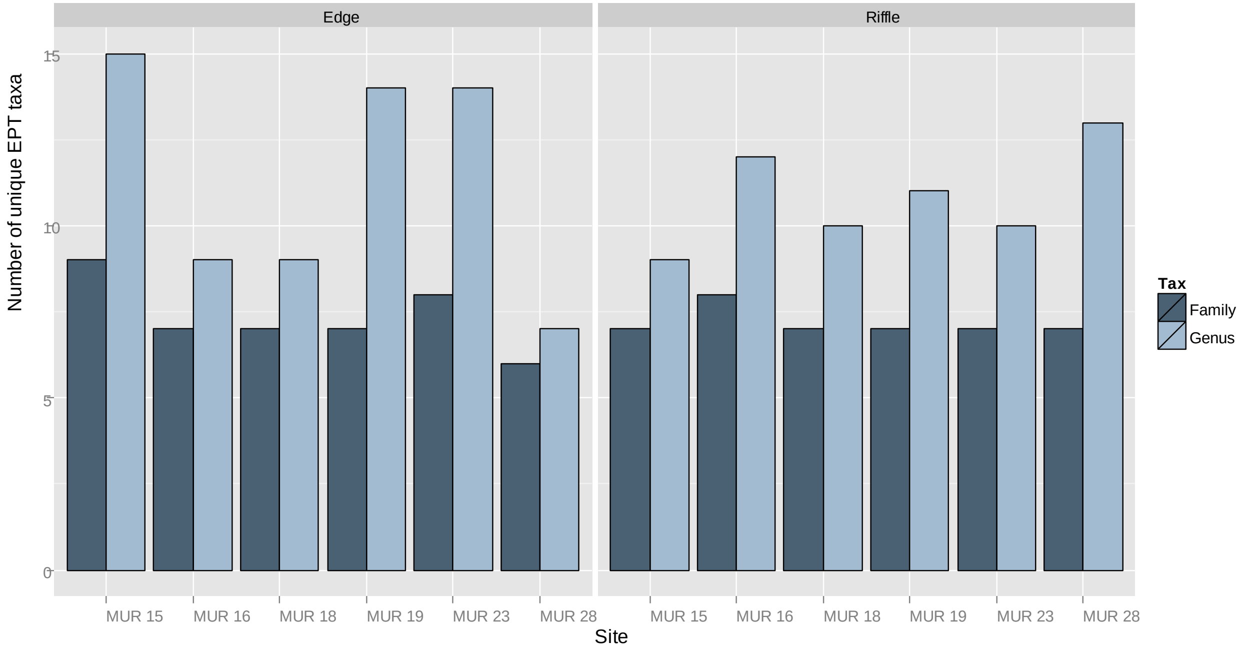

Figure 4-10. Total number of EPT taxa at genus and family level from riffle and edge habitats

Edge habitat

As we found with the macroinvertebrate communities collected from the riffle samples, the edge communities were largely characterised by taxa with moderate to low sensitivity scores. These taxa included sub-families of the Chironomidae (non-biting midges): Chironominae (3) and Orthocladiinae (4); Caenidae (4) from the Mayfly order and Simuliidae (5) (Black fly larvae). ANOSIM results suggest that while there is some evidence of separation between the communities collected upstream of Angle Crossing compared to the downstream sites, the evidence is weak to conclude this is ecologically significant (R=0.37; *P*=0.10)[3]. In practical terms it would appear that although upstream and downstream sites do appear to diverge (Figure 4-11), sites MUR 16 and MUR 18 and MUR 19 were more similar to each other in terms of community composition than they were to other sites in their respective locations, resulting in a moderate R-value and a statistically non-significant outcome.

The subtle differences in the communities between upstream and downstream locations, based on the raw data, are due to differences in estimated abundances rather than compositional changes. For example, Simuliidae, Hydropsycidae and Baetidae all increased in abundance downstream of Angle Crossing, while Micronecta (2) and Leptophlebiidae (8) were both more common and abundant in the samples collected upstream of Angle Crossing. Macroinvertebrate diversity ranged from 20 families and 22 genera at MUR 28 to 26 families and 32 genera at MUR 15. EPT taxa diversity was also highest at MUR 15 (15 genera) and lowest at MUR 28 (7 genera), however MUR 19 and MUR 23 has a similar number of EPT taxa (14) (Figure 4-10).

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[3] Monte Carlo permutations were performed using PERMANOVA to verify this result, given the low number of unique permutations from the ANOSIM test. The results from this procedure agree with the ANOSIM procedure, which were based on 9999 permutations. (60 unique permutations: Pseudo-$F_{1,4}$ =1.82; P=0.11).

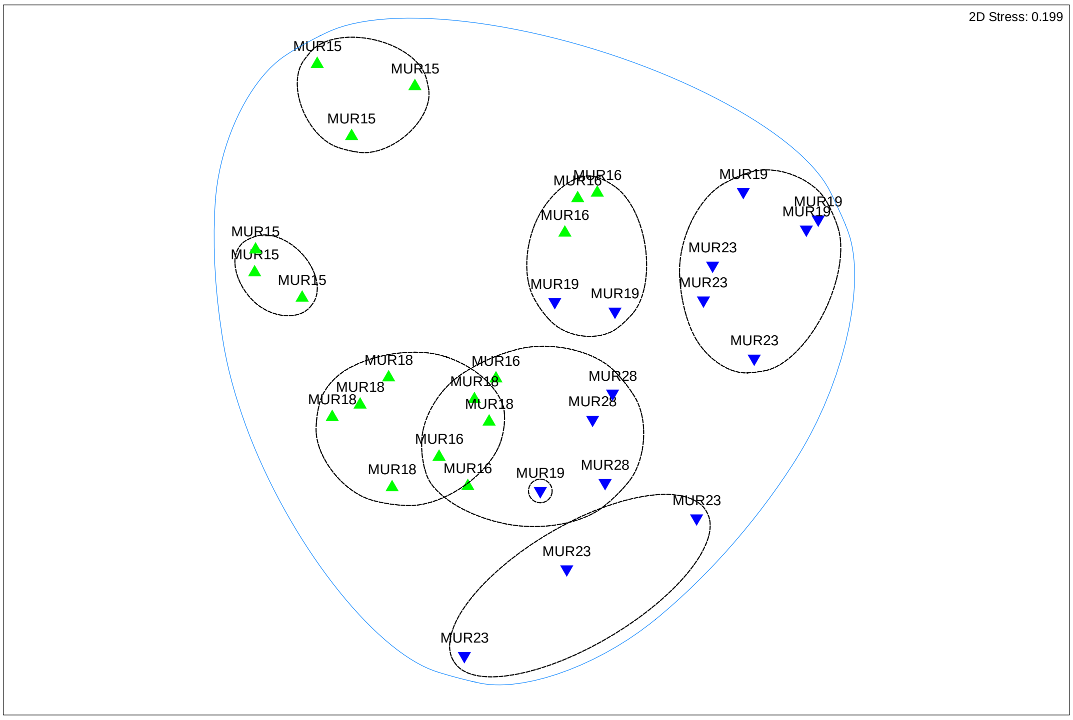

Figure 4-11. Non-metric multidimensional scaling of macroinvertebrate data (genus level) collected from the edge habitat

Note: Blue ellipses represent 60% similarity and the black ellipses indicate 75% similarity groups. Green circles are upstream sites and blue squares and downstream sites.

4.5.2 AUSRIVAS and SIGNAL 2

There was little differentiation in the AUSRIVAS results from the riffle habitat between sampling locations in the 0/E50 scores ($F_{1,4}$=2.33: *P*=0.20; Table 4-7). Site to site variation was also negligible (Table 4-7) and only accounted for 10% of the total variation in O/E50 scores. Edge habitat assessments varied more so than the riffle habitat and the mean O/E50 scores showed a tendency to decline with distance downstream (Table 4-8). Despite the longitudinal decline in O/E50 scores, there was no difference in these scores due to location ($F_{1,4}$=2.37: *P*=0.20; Table 4-8). All riffles were assessed as BAND B by AUSRIVAS (i.e. "*significantly impaired*" compared to reference condition) (Table 4-10); while edge habitats were assessed as BAND B at sites MUR 15-MUR 23, but MUR 28 was assessed a BAND C (i.e. *"severely impaired" compared to reference condition*) (Table 4-10). The latter resulted in a decline in overall site condition for site MUR 28 since the previous autumn assessment (Table 4-9).

The dominance of moderately tolerant macroinvertebrates is reflected in the similar SIGNAL 2 scores for amongst sites in the edge and riffle habitats (Figure 4-12). Variability in riffle SIGNAL 2 scores was due mainly to within site variation (96%) meaning there was no statistically significant effect of location on SIGNAL 2 scores ($F_{1,4}$=0.01; *P*=0.93; Table 4-7), while location explained 5% of the variation in edge SIGNAL 2 scores it was within-site variation that was the dominant component (69%).

Of the predicted taxa to occur in the riffle habitat, Gripopterygidae (8) and Hydropsycidae (6) were the only two families that were not collected in this sampling run compared to autumn 2013 (Appendix E1). Other taxa that were missing included: Oligochaeta (2), Elmidae (7) Tipulidae (5) and Baetidae (5). Tipulidae and Elmidae were absent from the majority of samples, and Baetidae the least. The number of missing taxa from the edge habitat ranged widely from four at MUR 15 to as many as 10 at MUR 28 (Appendix E2) and included taxa with SIGNAL 2 scores from ranging from 2-8; including Planorbidae (2), Corixidae (2) and Leptophlebiidae (8).

The most obvious difference compared to previous autumn assessment is the decline in condition at MUR 28, which is likely due to poor habitat quality.

Table 4-7. Nested analysis of variance results for the O/E 50 ratios and SIGNAL-2 scores from the riffle habitats

Response	Source	DF	F	P-value
O/E 50	Location	1	2.33	0.20
	Site [Location]	4	1.92	0.13
	Total	35		
SIGNAL-2	Location	1	0.01	0.93
	Site [Location]	4	1.24	0.31
	Total	35		

Table 4-8. Nested analysis of variance results for the O/E 50 ratios and SIGNAL-2 scores from the edge habitat

Response	Source	DF	F	P-value
O/E 50	Location	1	2.37	0.20
	Site [Location]	4	5.86	<0.001
	Total	32		
SIGNAL-2	Location	1	1.47	0.29
	Site [Location]	4	2.99	0.04
	Total	32		

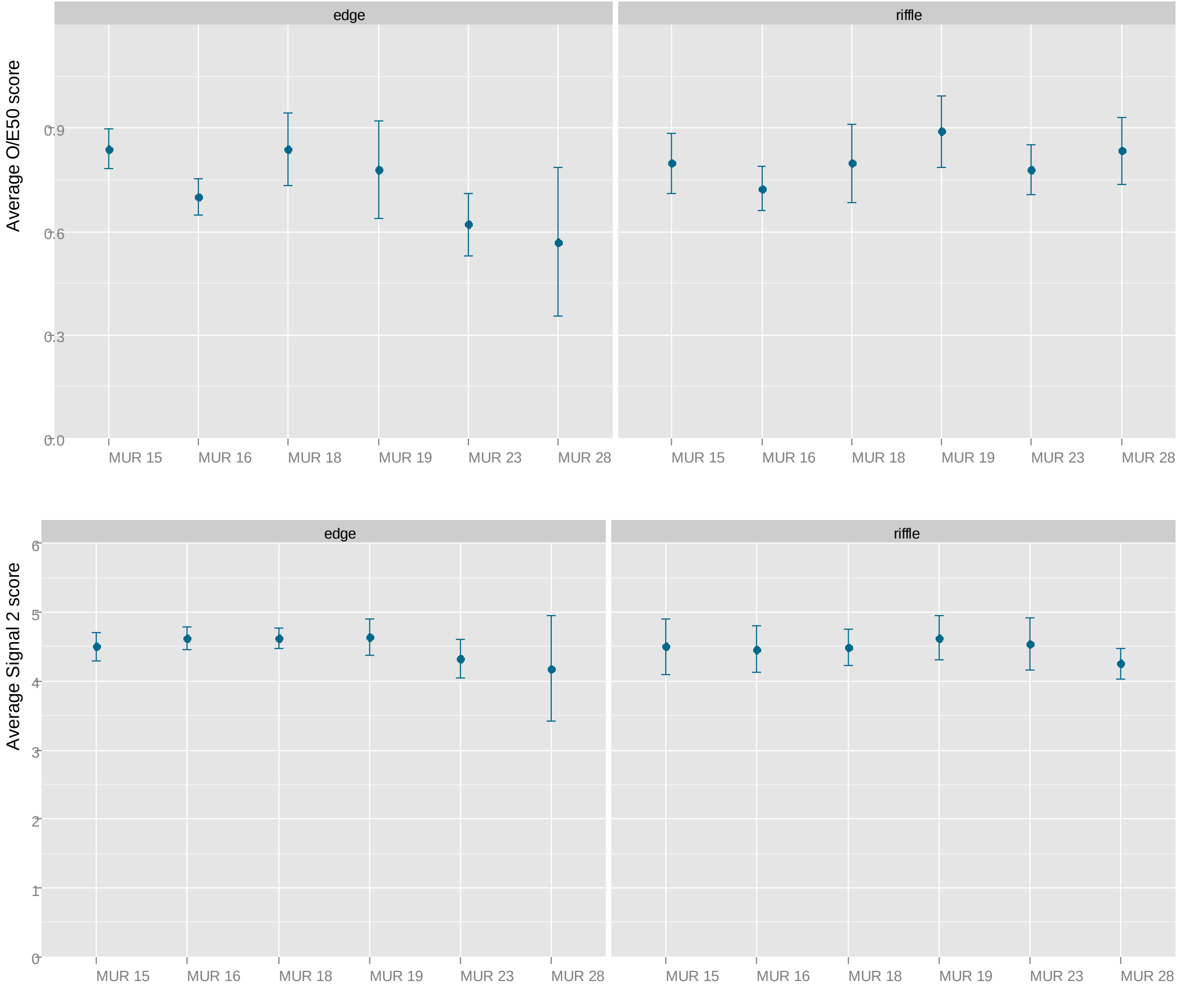

Figure 4-12. Means plots of SIGNAL-2 scores and O/E 50 ratios for edge and riffle habitats

Note: Error bars are 95% confidence intervals

Table 4-9. Overall site assessments for autumn and spring since 2011

	Autumn 2011	Spring 2011	Autumn 2012	Spring 2012	Autumn 2013	Spring 2013	Autumn 2014	Change since previous autumn sampling run
MUR 15	B	A	B	A	B	B	B	↔
MUR 16	B	A	B	B	B	B	B	↔
MUR 18	B	B	B	B	B	B	B	↔
MUR 19	A	A	B	B	B	B	B	↔
MUR 23	B	A	B	B	B	A	B	↔
MUR 28	B	B	B	B	B	B	C	↓

Notes: NRA= no reliable assessment; NS = no sample

Table 4-10. AUSRIVAS and SIGNAL-2 scores for autumn 2014

Note: All riffle samples are “nearly outside the experience of the model.” NS = No Sample

Site	Rep.	SIGNAL-2		AUSRIVAS O/E score		AUSRIVAS band		Overall habitat assessment		Overall site assessment
		Riffle	Edge	Riffle	Edge	Riffle	Edge	Riffle	Edge	
MUR 15	1	4.63	4.55	0.89	0.85	A	A	**B**	**B**	**B**
MUR 15	2	4.43	4.82	0.78	0.85	B	A			
MUR 15	3	4.14	4.20	0.78	0.78	B	B			
MUR 15	4	4.14	4.50	0.78	0.93	B	A			
MUR 15	5	4.50	4.50	0.89	0.78	A	B			
MUR 15	6	5.17	4.45	0.67	0.85	B	A			
MUR 16	1	4.50	4.67	0.67	0.70	B	B	**B**	**B**	**B**
MUR 16	2	4.50	4.67	0.67	0.70	B	B			
MUR 16	3	5.00	4.67	0.78	0.70	B	B			
MUR 16	4	4.14	4.67	0.78	0.70	B	B			
MUR 16	5	4.50	4.30	0.67	0.78	B	B			
MUR 16	6	4.14	4.75	0.78	0.62	B	B			
MUR 18	1	4.63	4.60	0.89	0.85	A	A	**B**	**B**	**B**
MUR 18	2	4.63	4.55	0.89	0.94	A	A			
MUR 18	3	4.63	4.63	0.89	0.68	A	B			
MUR 18	4	4.50	4.56	0.67	0.77	B	B			
MUR 18	5	4.00	4.91	0.67	0.94	B	A			
MUR 18	6	4.57	4.50	0.78	0.85	B	A			
MUR 19	1	4.89	4.88	1.00	0.72	A	B	**B**	**B**	**B**
MUR 19	2	4.5	5.00	0.89	0.63	A	B			
MUR 19	3	4.89	4.50	1.00	0.72	A	B			
MUR 19	4	4.5	4.36	0.89	0.99	A	A			
MUR 19	5	4.86	4.6	0.78	0.90	B	A			
MUR 19	6	4.14	4.5	0.78	0.72	B	B			
MUR 23	1	4.14	4.25	0.78	0.62	B	B	**B**	**B**	**B**
MUR 23	2	4.63	4.38	0.89	0.62	A	B			
MUR 23	3	5.00	4.25	0.78	0.62	B	B			
MUR 23	4	4.86	4.29	0.78	0.54	B	B			
MUR 23	5	4.14	4.00	0.78	0.54	B	B			
MUR 23	6	4.50	4.80	0.67	0.78	B	B			
MUR 28	1	4.63	3.88	0.89	0.62	A	B	**B**	**C**	**C**
MUR 28	2	4.25	4.17	0.89	0.47	A	C			
MUR 28	3	4.25	4.50	0.89	0.62	A	B			
MUR 28	4	4.14	NS	0.78	NS	B	NS			
MUR 28	5	4.25	NS	0.89	NS	A	NS			
MUR 28	6	4.00	NS	0.67	NS	B	NS			

4.6 Discussion

4.6.1 Water quality

In the current sampling period, flows in the Murrumbidgee River flows ranged from monthly averages of 150 ML/d (March) to 1,400 ML/d (April) and the water quality characteristics during this period reflect this. The majority of the grab sample parameters were within ANZECC and ARMCANZ (2000) guidelines with the exception of a marginal exceedance of pH at MUR 28 and dissolved oxygen at MUR 23. Nutrients were for the most, outside of the guideline values. Compared to autumn 2013, total nitrogen concentrations were between 17% and 33% higher and between 16% and 42% higher for total phosphorus. The increase in nutrient concentrations did not differentiate upstream or downstream sites, but reflected the increased background levels due to surface runoff following a high flow in mid-April (Figure 4-2). Results from the remaining water quality parameters during autumn 2014 were all within the ranges analysed throughout this program.

In early March, a localised rainfall event (Figure 4-2) caused instrument failure at Lobb's Hole (410761) resulting in a loss of water quality data (except water temperature) for approximately 2 weeks. While all the water quality sensors were restored after this period, pH was not and at the time of writing, the pH sensor was currently being repaired and should be in operation within the next month. Therefore, the compliance values for March (Table 4-4. Compliance (%) to ANZECC & ARMCANZ (2000) guideline values from the continuous gauging stations upstream (41001702) and downstream (410761) of Angle Crossing) should be considered with an element of caution given that 100% value reported is not based on a full calendar month.

Base flows in autumn 2013 were generally much lower (i.e. <140 ML/d for most of the autumn period), which not only resulted in higher electrical conductivity and pH readings for that sampling period; but also the longitudinal gradient of those parameters was more pronounced. During periods of low flow, and during extraction periods, the gradients in electrical conductivity and potentially other parameters become steeper, which may result in changes to aspects of the river ecology depending on the duration and volume of the abstractions (Hynes, 1970; Marsh *et al*., 2012). However, tolerance thresholds related to electrical conductivity have been shown to be very high (relative to what EC levels are in the Murrumbidgee River) (see Kefford, 1998), which would suggest that direct changes to river ecology via these parameters is very unlikely. Based on our understanding, increasing temperatures caused by decreased depth in the water column and lower velocities and reductions in dissolved oxygen are more likely to result in changes to macroinvertebrate communities during M2G operating at its full capacity.

4.6.1 Periphyton

Results from this study indicate that location explained a negligible amount of the variation in the periphyton data set (Table 4-6) and that site to site variation explained 28% (chlorophyll a) and 37% (AFDM), suggesting site to site differences were more important than whether a sample was collected upstream or downstream of Angle Crossing. Watts *et al.*, (2001) suggested that although biofilms can be very good indicators of flow alteration, the responses can be highly dependent on localised flow conditions, which may help explain why (over and above differences in substrate composition) site to site variation has been a major contributing factor in the periphyton results to date.

The results here are consistent with the findings from previous sampling runs, although on a season by season basis, mean biomass and productivity estimates have varied considerably over time. For example, despite the mean flow being up to three times the mean autumn flow in autumn 2013, biomass and productivity (i.e. AFDM and chlorophyll-a) were also considerably higher in at that time. This may seem counter-intuitive given that flow plays an important role as a scouring force upon periphyton communities. In other words, during periods of high flow we would expect to see lower estimates of periphyton biomass than during periods of low flows. However, periphyton dynamics (scouring and accrual) depend on a complex interaction of opposing factors including flow, nutrient availability and uptake, temperature, light and grazing pressure so isolating the exact cause in an observation – type study can be difficult.

In autumn 2011 (ALS, 2011), we found a similar trend, where periphyton increased with increasing flow. This trend is consistent the findings of Biggs and Stokseth (1996) who demonstrated that under medium to high velocities, the uptake of nutrients was higher than it was during low flows as long as shear stress was not high enough that scour exceeded accrual rates. Additionally, in this study, flows prior to sampling were lower (summer flows were the lowest encountered in the Murrumbidgee River since summer 2009) than the previous autumn sampling run, suggesting that accrual rates during the summer months may have led to high standing crops that may have been relatively undisturbed by the autumn high flow events, leading to higher biomass and production in the current study.

4.6.2 AUSRIVAS and macroinvertebrate community assemblages

The only change in ecological condition since autumn 2013 was found at MUR 28 (Table 4-9), which shifted from BAND B ("*significantly impaired"*) to BAND C ("*severely impaired"*) because of poor edge habitat quality. It should be noted that the riffle habitat, on its own merits, was assessed as BAND B, which is consistent with all of the other sampling sites (Table 4-10), so the Band C site rating for MUR 28 in autumn 2014 represents a conservative rating.

Taxa missing from the edge at MUR 28 included families that are normally highly abundant in this habitat including: Corixidae (2), Baetidae (5) and Hydroptilidae (4). The absence of Corixidae would suggest that high velocities at the time of sampling may have been a limiting factor given their preference for deep, slow moving habitat conditions. Furthermore, it has been found that hydrology is of major importance to mayfly species richness, abundance and diversity (Brittain, 1982). Watts *et al.*, (2001) suggest that mayfly responses to changes in flow regime are most apparent in short temporal scales (10-30 days), which coincides with the most recent high flow event in this study. While response's to the most recent high flow event may help explain local responses (i.e. at MUR 28), the presence of the taxa missing from site MUR 28 further upstream probably relates to catchment area and perhaps better quality and diverse edge habitat at the upstream sites.

Although there was a change in the AUSRIVAS BAND scheme at MUR 28, the overall effect on the study objectives was negligible as we found no location effect for either SIGNAL-2 scores or O/E50 scores for each of the habitats sampled (Table 4-7; Table 4-8); which indicates that these small changes in composition, in relative terms, has had a minimal impact upon our overall conclusions from each location. Based on previous experience and the historical data, it is likely that recovery at MUR 28 will occur in the next round of sampling.

This study found that there was a high degree of similarity in macroinvertebrate assemblages as determined from the ordination analyses (Figure 4-8; Figure 4-11). One of the best explanations for this high level of similarity between monitoring sites is the standardising effect that high flow events tend to have on aquatic habitats. Thomaz*, et al.* (2007) found that high flow events increase biotic similarities between sites because they (high flows) increase connectivity and tend to dilute water quality parameters resulting in comparable habitat conditions and hence comparable macroinvertebrate communities between sampling sites. The dominant taxa amongst all sites were not only considered to be tolerant or moderately tolerant taxa, they are also considered to be early colonising taxa (Niemi *et al.,* (1990)).

Following high flow events, re-colonisation follows a series of reasonably well understood successional stages which begins with Dipterans (e.g. Simuliids and Chironomids) followed by Ephemeroptera, Trichoptera and Plecoptera, which for the most helps explain the communities outlined in this report. Additionally, in this study, taxa richness and EPT richness were lower, as was the ratio of the number of genera to families than the previous autumn. Death (2008) explains that recovery trajectories to pre-flood conditions generally occurs in 2-4 months but recovery may not be complete if there are further high flow events within this time period. Both of these points are relevant this study because a second, smaller event (~3,000 ML/d) occurred, meaning recolonisation and radiation (i.e. increasing numbers of genera within family groups) may have been slowed by a) the relatively short time elapsing between the return to base-flow and sampling time and also the occurrence of the second flow pulse during the initial recovery phase.

The fact that flows were as low as 10 ML/d in the Murrumbidgee River during the preceding summer months should not be ignored, because the stress upon the macroinvertebrate communities during that period may have also resulted in communities dominated by taxa that can tolerate low flows, increasing water temperatures and low oxygen concentrations, which may have further restricted recolonisation rates once flows began to increase again. Historical flow conditions whether it is a low flow disturbance (e.g. Finn *et al.*, 2009; Chessman *et al.*, 2012) or high flow disturbance (e.g. Greenwood and Booker, 2014) can be more important than recent hydrological conditions in determining macroinvertebrate community structure, and should demand equal consideration in water management frameworks.

4.7 Conclusions and recommendations

Several studies have considered the impact of water abstraction on various aspects of river health including water quality, river morphology, hydrology and biology. An important review of these indicators was published by Dewson *et al*., (2007). In that review it was found that there were several interconnecting factors that were likely to affect the ecological condition of water ways depending on the duration, timing and magnitude aspects of the proposed regulation.

From that conceptual framework (Appendix B), there were several aspects of the Murrumbidgee River system that we hypothesised would change with the onset of water abstractions of up to 100 ML/d; including changes to habitat area and quality, changes in water quality characteristics downstream of the abstraction point and several indirect and direct impacts upon primary production, periphyton standing crops and macroinvertebrate assemblages.

The overall characteristics of each of the indicators used in this study show a high degree of similarity between upstream and downstream locations not only from this study, but over the course of the MEMP as a whole. This reflects the fact that there have only been a minimal number of maintenance runs during the operational phase of the M2G project and generally, these abstractions have not been at a magnitude high enough to cause any long lasting effects to the system. And secondly, while we have conducted sampling that has corresponded to several natural disturbances, such as low flow periods (particularly in 2009) and high flow events, these have not been over prolonged periods and so there has been little evidence of long lasting or cumulative impacts to the system. Furthermore, as was noted in the spring 2013 (GHD, 2013), the absence of M2G maintenance runs during the autumn period, means that the results presented in this report are entirely reflective of the natural flow regime.

In summary, it appears that because of the size of the Murrumbidgee River, and the resilience to disturbance combined with the resistance to change that has been found in previous reports, that abstracting 100 ML/d will have a negligible impact on the downstream reaches as a whole, but may impact localised sections of the river during these abstraction periods – this will depend of course on the timing and duration of these abstractions. The key question will be how far downstream that these impacts can be traced and at what level these changes begin to occur.

Considering the MEMP data to date and the recognition that there is likely going to be an extended shut-down period of M2G (GHD, 2013_b).

It is recommended that:

1) **A review of the periphyton sampling methods is undertaken.** Given that it is likely that there will only be maintenance monitoring requirements in the foreseeable future, there may be less need for the intensity of sampling that has occurred over the baseline collection period. With that in mind, comparisons between the current sampling program and qualitative methods should be addressed so that a scaling back approach can be taken during the maintenance period. This will save monitoring costs and provide a more rapid turn-around of results. However**,** when M2G becomes operational once again, quantitative methods should be re-employed so that there are comparable data sets for statistical analysis.

2) **Installation of rising stage samplers at a location representative of the intake at Angle Crossing.** Currently there is no regular event-based water quality sampling program. Therefore, it is recommended that a rising stage sampler is installed upstream of Angle Crossing to capture event-based water quality parameters in accordance with the M2G operational plan (eg. TN and TP). This will also maintain the integrity of current event-based data sets for the section of the Murrumbidgee River.

3) **Check comparability of Lobb's Hole and upstream Angle Crossing gauging stations.** Although this is outside of the direct scope of the MEMP, we recommend that because Lobb's Hole is written into the M2G operations plan as a key monitoring station, the integrity of data collection from this station is paramount; and given the issues of lightning strikes and equipment failure over the past few years, it is important to have a secondary station that can act as a surrogate for that site when unforeseen problems arise. Therefore, we recommend that a validation review be undertaken between data collected at Lobb's Hole and the upstream Angle Crossing site to determine the degree of concordance between the two stations. This should be conducted using data from normal flow periods, so that there can be confidence in USAC station being used to assess trigger level compliance for operational purposes.

4) **Review the water quality parameters at the upstream Angle Crossing site (41001702).** This relates to item 3, but because this station is in the process of being moved, it is recommended that the parameters be reviewed and compared to those in place before the move. This will have implications on trigger levels for M2G operations.

5) **An overall review of the current sampling protocols.** Again, this follows on from our upstanding that the MEMP is likely going to be scaled back in to only monitor maintenance runs in the foreseeable future. This would include an options report which would address the current sampling regime and determine ways in which useful information can still collected and which meet EPA requirements through the maintenance monitoring period, while at the same time maintaining the integrity of the program so that once M2G is actively transferring flow into Burra Creek, there is comparable base line and operation data.

5. Burra Creek

5.1 Summary of sampling and river conditions

The autumn 2014 sampling of the Burra Creek sites was conducted on the 8th and 9th of May 2014. The weather during this period was fine and sunny with morning cloud clearing, with maximum temperatures in Canberra on the 8th & 9th being 16.1°C and 17.4°C respectively (Bureau of Meteorology, 2014). Flows in Burra Creek and the Queanbeyan River during the sampling event were low and stable as flows had receded to base flow levels following peaks in April (Figure 5-1 and Figure 5-3). Site photographs are shown from the autumn sampling in Plate 5-1 on the next page.

Samples collected during the autumn 2013 sampling run for Burra Creek are resented in Table 5-1. Only single riffle samples at both BUR 1a & 2a were possible due to the limited habitat availability resulting from low flows. Sampling was also restricted to single samples for both habitats at BUR 1c and from the riffle habitat at BUR 2b. These samples were not collected due to large stands of emergent macrophytes restricting the amount of habitat which was available to be sampled. The level of organics collected in the riffle samples along Burra Creek was high during autumn 2014, particularly at BUR 1c & 2a, which is likely to be related to the large scale macrophyte die-back during this time of year.

Table 5-1. Samples collected during autumn 2014 at Burra Creek sites

Site	Riffle	Edge	Comments
BUR 1a	1	2	Insufficient riffle habitat for a second sample
BUR 1c	1	1	Riffle & edge habitat largely covered by macrophytes limiting the habitat available appropriate for sampling
BUR 2a	1	2	Insufficient riffle habitat for a second sample
BUR 2b	1	2	Riffle habitat largely covered by macrophytes limiting the habitat available appropriate for sampling
BUR 2c	2	2	All samples collected
QBYN 1	2	2	All samples collected

BUR 1a – 2.5 ML/d

BUR 1c – 2.5 ML/d

BUR 2a – 2.5 ML/d

BUR 2b – 2.5 ML/d

BUR 2c – 2.5 ML/d

QBYN 1 – 48 ML/d

Plate 5-1. Photographs of the Burra Creek and Queanbeyan River sites during autumn 2014 sampling

Note: Flow values from the relevant gauging sites (410774 (Burra Creek) and 410781 (Queanbeyan River)).

5.2 Hydrology and rainfall

Summaries of the flow and rainfall data collected for the autumn 2014 period are presented in Table 5-2. This highlights that flow was highest during April in both Burra Creek and the Queanbeyan River. Mean flow in Burra Creek for the autumn 2014 period was 9.35 ML/d, which is only just below the long term average for this season based on data collected between 2008 and May 2013 as part of the MEMP. This result was achieved largely through rainfall events in late March and early April.

Table 5-2. Rainfall and flow summaries for Burra Creek and the Queanbeyan River for autumn 2014

	Burra Creek (410774)		Queanbeyan River (410781)	
	Total Rainfall (mm)	Mean Flow (ML/d)	Total Rainfall (mm)	Mean Flow (ML/d)
March	113.4	6.07	108.7	60.5
April	75.0	19.4	69.5	138
May	17.6	2.58	21.7	46.4
Autumn (mean)	206.0 (68.7)	9.35	199.9 (66.6)	81.7

Flow through Burra Creek during the autumn period was very low at the start of March, with flows dropping below 1 ML/d at times (Figure 5-1). After some small patches of rain during this early March period, some larger rainfall events occurred during late March-early April. This increased rainfall resulted in multiple flow peaks. The event during late March peaked at the Burra Weir gauging station (410774) on the 29th at over 1,100 ML/d, which was the largest event of the season. This was then followed by an event in early April which peaked at over 900 ML/d on the 4th, while a second smaller peak followed a week later reaching over 35 ML/d on the 11th. Following this flow receded to base flow levels and remained stable for the rest of the period, with a small increase in flow on the 28th of May from a small rainfall event.

Flow in the Queanbeyan River followed a similar pattern to that of Burra Creek; however the rainfall events during early March had more impact on the flow, creating three small pulse events (Figure 5-3). These small pulse events during early March peaked at over 110 ML/d, 90 ML/d & 100 ML/d on the 6th, 11th & 13th of March respectively, as recorded at the upstream Googong Reservoir gauging station (410781). The larger events during late March-early April, corresponding to similarly timed events in Burra Creek, peaked at over 500 ML/d, over 750 ML/d & 200 ML/d on the 29th of March, 5th & 12th of April respectively. Flow continued to recede for the remainder of the period with a similar increase at the end of autumn on the 30th of May from a small rainfall event.

Annual comparisons of rainfall across the previous autumn seasons recorded at Burra Creek are shown in Figure 5-2. Historical flow in Burra Creek for the previous four sampling seasons is also shown in Figure 5-4. Results presented in Figure 5-2 indicate that April has traditionally been the wettest autumn month and 2014 was no exception. Results presented in Figure 5-4 show that flows in autumn 2014 in Burra Creek were, on average, higher than they were in autumn 2013. However, autumn 2014 was preceded by very low summer period flows and this may have had impact on resident aquatic fauna – a point worth noting when interpreting autumn 2014 biological monitoring results.

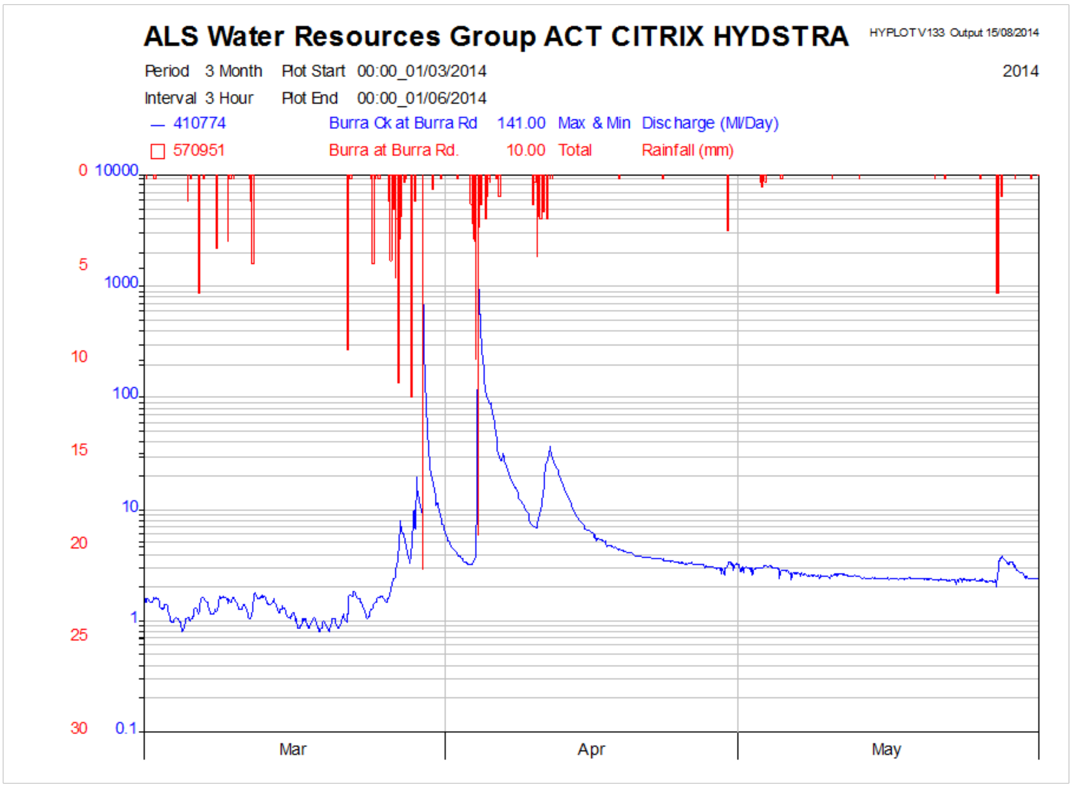

Figure 5-1. Hydrograph and rainfall from Burra Creek (410774) during autumn 2014

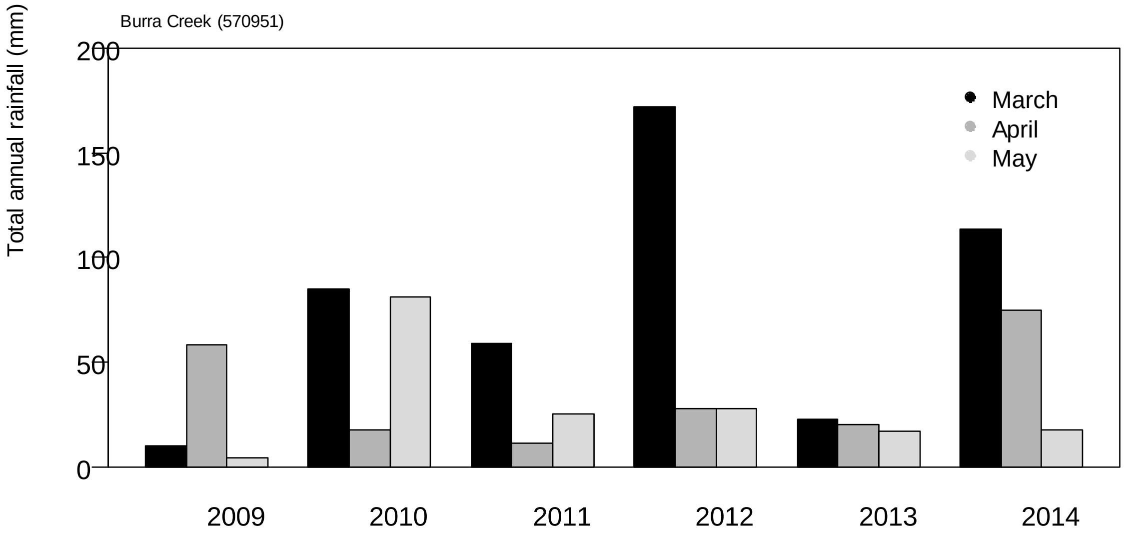

Figure 5-2. Annual comparisons of autumn rainfall (mm) recorded at Burra Creek (570951)

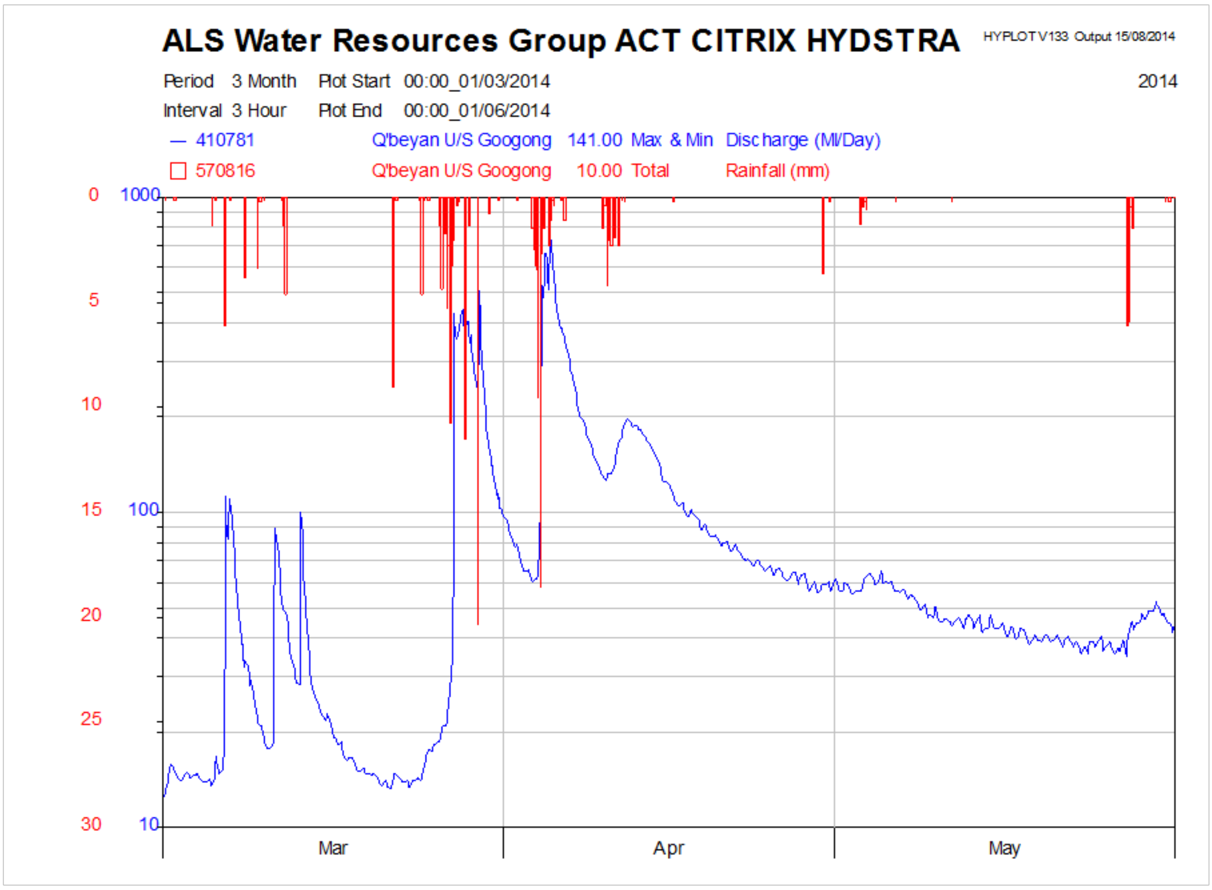

Figure 5-3. Hydrograph and rainfall from the Queanbeyan River (410781) during autumn 2014

Note: the green vertical bar represents the sampling period.

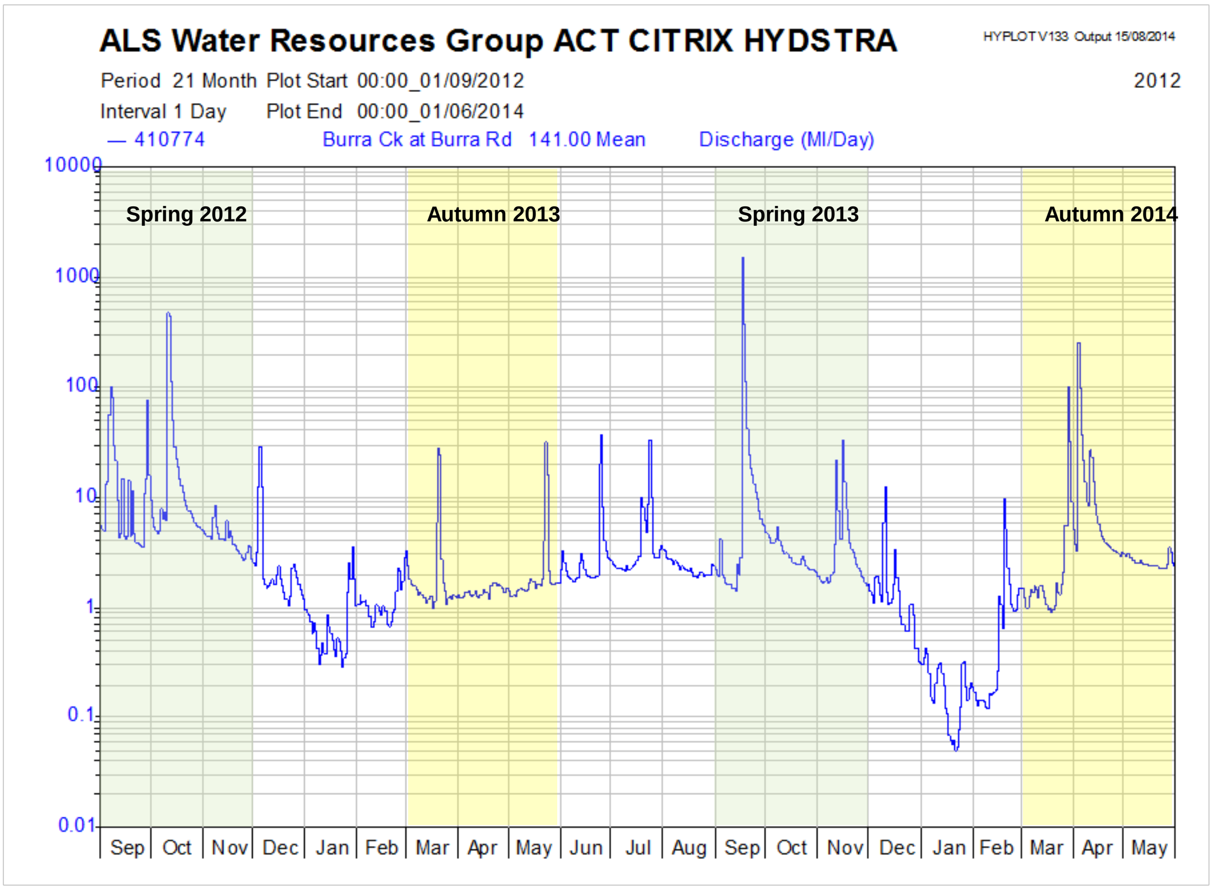

Figure 5-4. Burra Creek hydrograph highlighting the past four sampling periods between September 2012 and May 2014

5.3 Water quality

5.3.1 Grab samples and *in-situ* parameters

The grab samples and *in-situ* recorded parameters from all autumn 2014 Burra Creek and Queanbeyan River sampling sites are presented in Table 5-3. QBYN 1 was found to be within the ANZECC & ARMCANZ (2000) guidelines for all parameters for autumn 2014, which was also the case during autumn 2013. In Burra Creek, turbidity was found to be within the recommended range at all sites, as was pH. This shows a reduction in pH compared to autumn 2013 when all sites containing water exceeded the recommended pH upper limit. All Burra Creek sites downstream of BUR 1a, were found to be in exceedance of the electrical conductivity (EC) upper limit. This is normal for Burra Creek and is consistent with previous results. Dissolved oxygen (DO) was recorded below the lower limit at BUR 1a during autumn 2014, while the rest of the Burra Creek sites were within the ANZECC & ARMCANZ (2000) recommended range.

Nutrient levels at the Burra Creek sites during 2014 have increased when compared to those recorded during autumn 2013. Autumn 2014 results show that all Burra Creek sites downstream of the discharge (BUR 2a, 2b & 2c) exceeded the ANZECC & ARMCANZ (2000) guidelines for NO_x. This was similar to autumn 2013 when both BUR 2a & 2b exceeded the recommended guideline, while BUR 2c was on the cusp. Exceedance of the total nitrogen (TN) guideline was only recorded at BUR 2a in autumn 2013, while TN was exceeded at BUR 1a during autumn 2012. This has increased in autumn 2014 with BUR 1a, 2a & 2b all recording TN levels in exceedance of the guidelines while BUR 2c was on the cusp. Only a single site (BUR 1a) was recorded exceeding the total phosphorus (TP)

ANZECC & ARMCANZ (2000) guideline. BUR 1a has not been recorded exceeding the TP guideline during autumn since 2010.

5.3.2 Continuous water quality monitoring

The results of the continuous water quality monitoring from the Burra Creek and Queanbeyan River gauging stations (410761 & 410781 respectively) are presented in Figure 5-5 and Figure 5-6 respectively. These figures show the responses of the water quality in these systems to a variety of flow conditions during the autumn period. The flow levels during early March were very low and, accordingly, the diurnal trend found in the dissolved oxygen (DO) readings corresponded to this with an increased range, water temperatures were also higher (although also related to seasonal trends) and electrical conductivity was slightly elevated. The large events of the season during late March and early April brought about turbidity spikes and reductions in both pH and EC levels. As flow levels receded to base flow conditions pH, EC and DO levels all returned to their normal ranges, while turbidity remained stable.

ANZECC & ARMCANZ (2000) guideline exceedances recorded during the autumn period were generally related to the two largest rainfall events (Figure 5-5 and Figure 5-6). DO at both stations was at times below the recommended range during early March, as a result of the low flows. pH was also recorded exceeding the upper limit of the ANZECC & ARMCANZ (2000) guidelines during mid-April following the high flow event at the Queanbeyan River site (410781).

Table 5-3. *In-situ* water quality results from Burra Creek and Queanbeyan River during autumn 2014

ANZECC and ARMCANZ (2000) guidelines are in yellow parenthesis in the column heading, yellow shaded cells indicate values outside of the 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)	SS 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	8/5/2014	9:45	8.1	96.8	42.9	67	7.11	83.5	9.82	22	0.006	0.003	0.003	0.011	0.027	0.40
	BUR 1c	8/5/2014	11:30	10.5	415.1	6.84	8	7.61	106.9	11.30	148	0.004	0.003	< 0.002	< 0.002	0.006	0.22
Downstream	BUR 2a	8/5/2014	13:55	11.0	510.4	4.62	< 2	7.72	104.8	11.56	194	0.230	0.229	< 0.002	< 0.002	0.007	0.40
	BUR 2b	9/5/2014	14:40	10.4	515.8	5.80	4	7.92	105.6	11.34	209	0.038	0.038	< 0.002	< 0.002	0.012	0.26
	BUR 2c	9/5/2014	11:50	10.1	510.3	2.91	< 2	7.93	103.3	11.43	206	0.062	0.062	< 0.002	< 0.002	0.007	0.25
Control	QBYN 1	9/5/2014	10:00	9	91.3	4.82	3	7.99	103.6	11.71	37	< 0.002	< 0.002	< 0.002	< 0.002	0.013	0.19

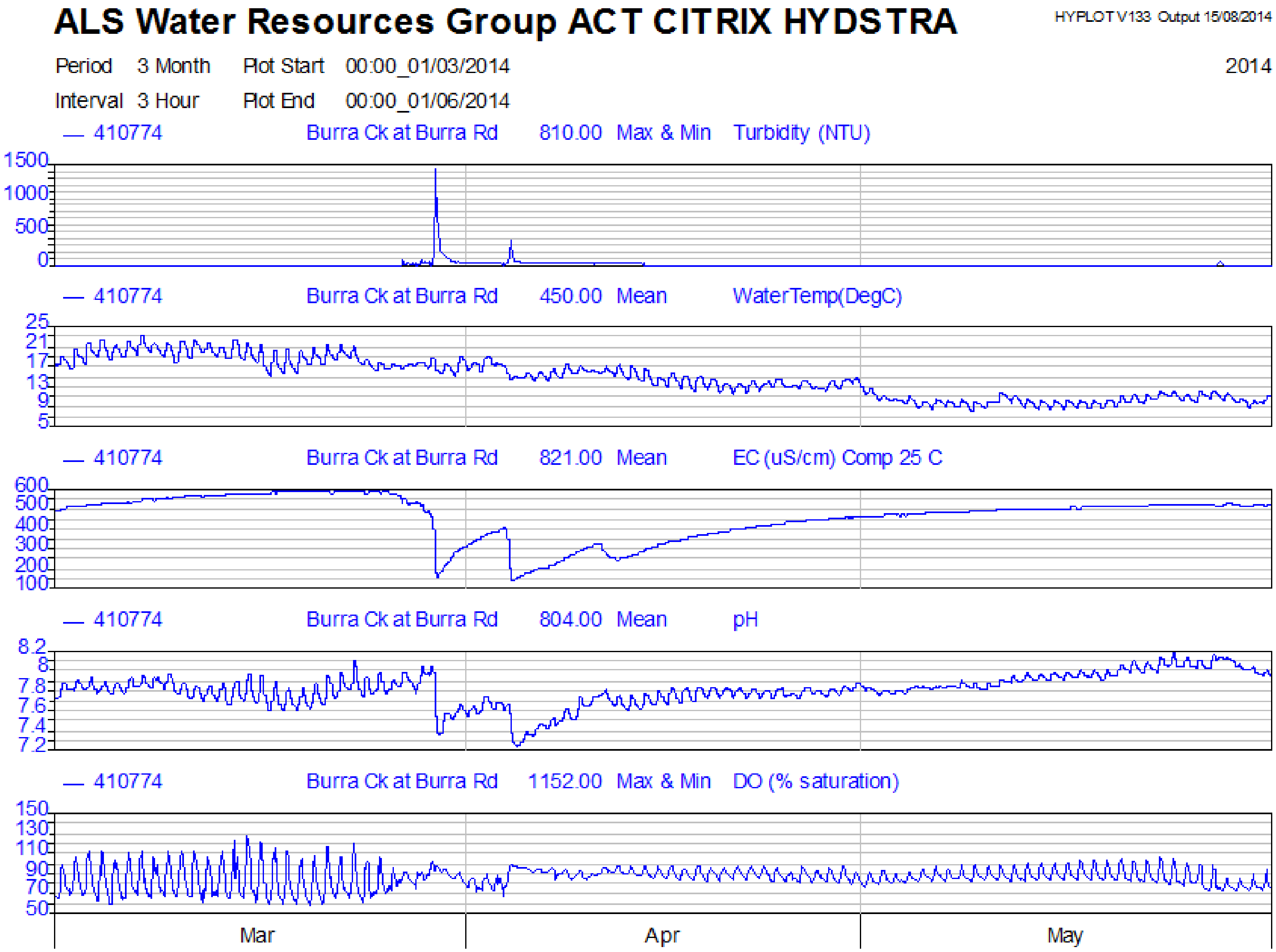

Figure 5-5. Continuous water quality records from Burra Creek (410774) for autumn 2014

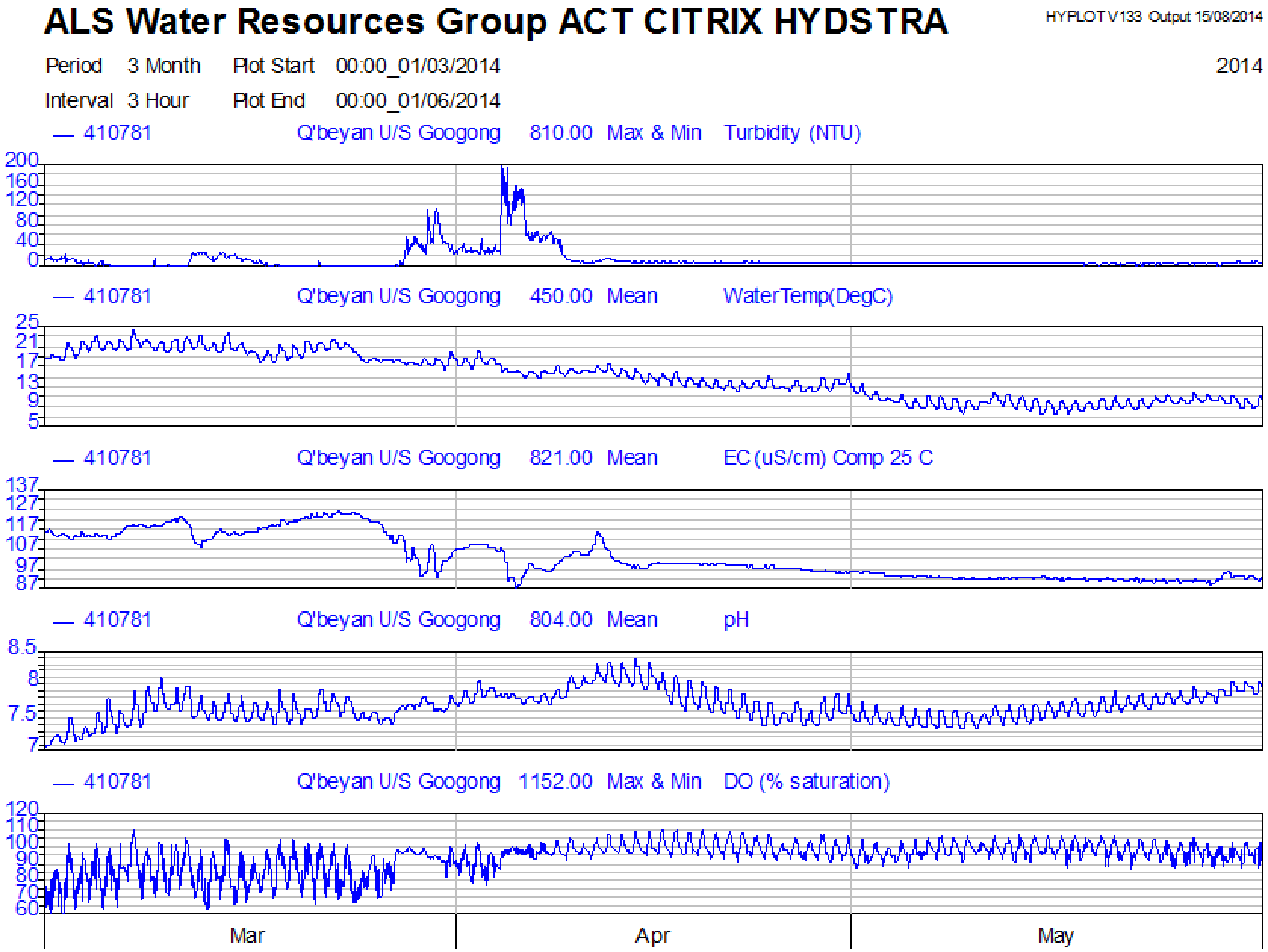

Figure 5-6. Continuous water quality records from the Queanbeyan River (410781) for autumn 2014

5.4 Periphyton

The highest chlorophyll a concentrations were found at BUR 1c (Figure 5-7), although median values were highest at BUR 2b (downstream of the Burra Road weir). In this study, location effects explained approximately 30% of the variation in the chlorophyll a data (Table 5-4) although there were no statistically significant differences found between locations ($F_{2,3}$=5.21; *P*=0.11). Furthermore, there was an insignificant amount of variation in the data was explained by site to site variation (<2%), with the majority being accounted for by high within-site variation (~68%). Compared to autumn 2013, the spatial patterns in the data are similar in this study in that the lowest values occurred at QBYN 1, and the highest at BUR 1c. The key difference in this study is that the data ranges at QBYN 1 and at the downstream sites was broader than in autumn 2013, and this is reflected by the high within-site variance contribution.

As with the chlorophyll a estimates, ash free dry mass (AFDM) showed very similar spatial patterns amongst sampling locations in the current study when compared to autumn 2013. For example, biomass was lowest at QBYN1 (5741 mg/m^2) and in Burra Creek the highest mean values were found at BUR 1c (37,406 mg/m^2) and BUR 2b (35,695 mg/m^2) (Figure 5-8). Compared to autumn 2013, biomass estimates in autumn 2014 were considerably higher. For example, at the upstream sites average AFDM was 15,678 mg/m^2 compared to 6757 mg/m^2 in autumn 2013. Similarly, mean AFDM downstream of the discharge point was 14,647 mg/m^2 in the current study compared to 6896 mg/m^2 in 2013. Statistical differences in mean areal concentrations were found between locations ($F_{2,3}$=35.7; *P*=0.01). Post hoc analysis found that these differences lay between the Queanbeyan control site and both locations within Burra Creek, but no statistically significant difference was found between the upstream and downstream locations in Burra Creek, albeit results were on the cusp of being significant (Table 5-5).

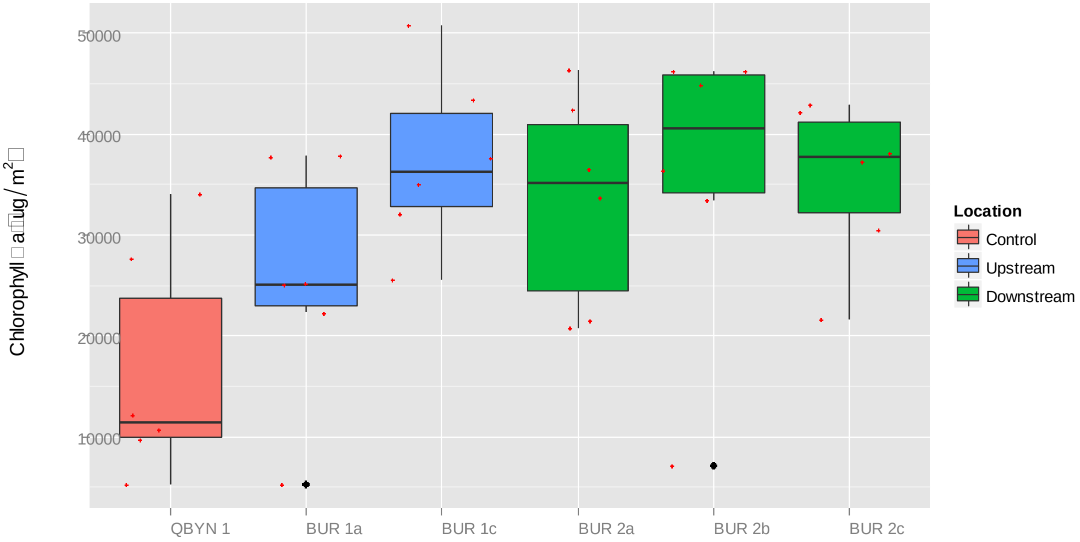

Figure 5-7. Chlorophyll-a concentrations in Burra Creek and the Queanbeyan River

Note: Red points represent the raw values for each site.

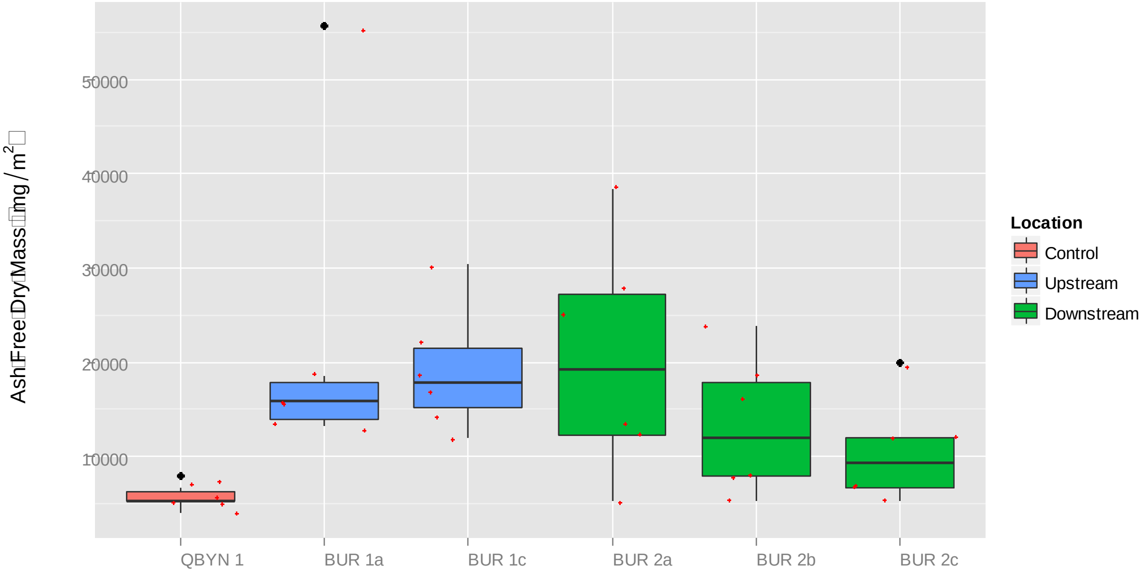

Figure 5-8. Ash free dry mass in Burra Creek and the Queanbeyan River

Note: Red points represent the raw values for each site.

Table 5-4. Nested analysis of variance results for chlorophyll-a and AFDM concentrations for Burra Creek

Response	Source	DF	F	P-value	Variance component
Chlorophyll-*a*	Location	2	5.21	0.11	30.1
	Site [Location]	3	1.16	0.34	1.76
	Total	35			
AFDM	Location	2	35.7	0.01	36.2
	Site [Location]	3	0.18	0.91	0.0
	Residual	35			

Table 5-5. Post-hoc comparisons of ash free dry mass between sampling locations

	Control	Upstream	Downstream
Control			
Upstream	0.003*		
Downstream	0.015*	0.066*	

**P*-values are estimates based on Markov Chain Monte Carlo (MCMC) procedure with 9999 restarts

5.5 Macroinvertebrates

5.5.1 Community assemblages

Riffle habitat

Riffle habitat communities in Burra Creek formed similar groups to those in autumn 2013. Overall similarity amongst sites was moderate (~40%; Figure 5-9), while sites downstream of the discharge weir in Burra Creek were grouped together with 65% similarity and the Queanbeyan Control and BUR 1c sites were also grouped independently at 65% similarity. These groups are then grouped together within a 60% similarity band, suggesting only marginal differences in composition between the three locations (Figure 5-9).

As we have found in previous sampling periods, BUR 1a sits well away from the other sites in ordination space, which in this study, represents an approximate 20% difference between that site and the remaining sites. This is reflected by the moderately high R-values indicating a degree of separation between locations (R=0.64; *P*=0.05).

The key difference between BUR 1a and the other sites was the absence of any mayfly taxa and an overall depauperate EPT fauna, which was represented by three caddis fly families (Hydrobiosidae (8)[4], Hydropsycidae (6) and Ecnomidae (4) and one stonefly family (Gripopterygidae (8)). Aside from this key difference, all the upstream sites in autumn 2014 were characterised by Dipteran (true flies) families including Simuliidae (5) and several sub-families of the non-biting midges (Chironomidae) including: Orthocladiinae (4), Chironominae (3) and Ceratopogonidae (4). Dominant taxa collected from the downstream sites included most of the previously mentioned taxa, except that there were higher abundances of Hydropsycids (6), Leptophlebiidae (8) and Caenidae (4) and Baetidae (5) compared to the upstream sites. In contrast the Queanbeyan Control was characterised by Caenid mayflies and Simuliidae (black flies), Hydropsycidae (caddis fly) and high numbers of another sensitive caddis fly: Philopotamidae (8).

The number of macroinvertebrate families displayed a linear increase with distance downstream in Burra Creek; ranging from 16 at BUR 1a to 28 at BUR 2c (Figure 5-10). The number of EPT taxa was highest at QBYN 1 (11), while the lowest was at BUR 1a with four EPT families. The lack of EPT diversity at the genus level was evident at BUR 1a and BUR 1c where each family was represented by a single genus (Figure 5-10), whereas at BUR 2c and QBYN 1 had high numbers of EPT genera (17 and 18 respectively) relative to the number of families (10 and 11 respectively) at those sites.

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[4] Denotes SIGNAL 2 score

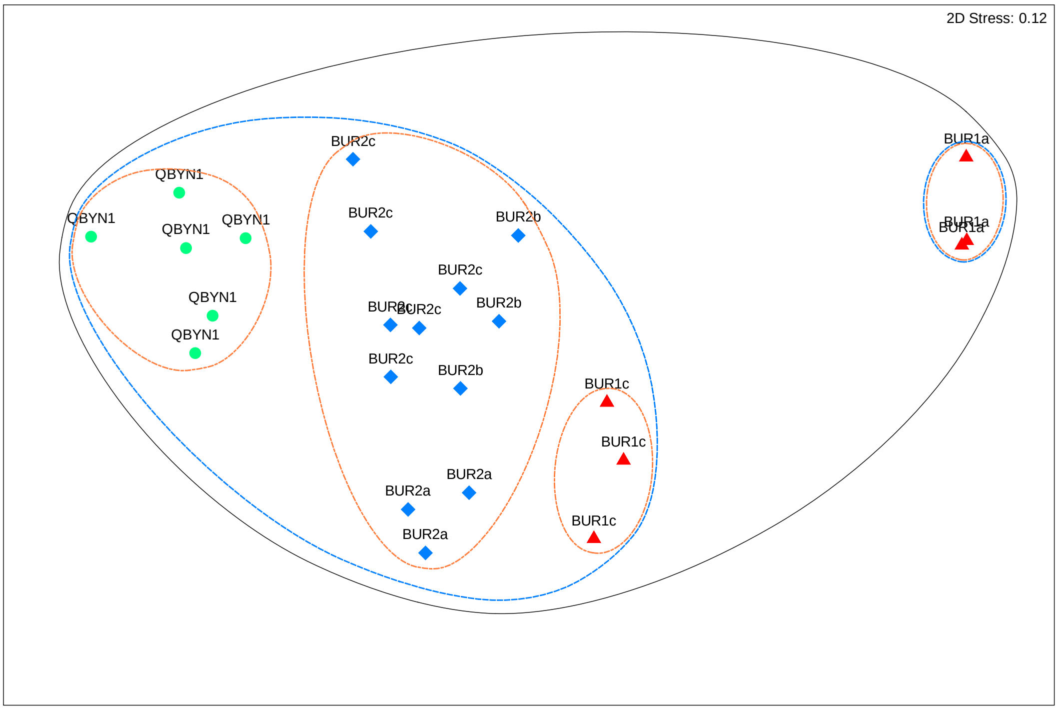

Figure 5-9. Non-metric multidimensional scaling of macroinvertebrate data (genus level) from the autumn riffle samples

Note: Ellipses represent 40% (black) and 60% (blue) and 65% (red) similarity groupings derived from cluster analysis. Red triangles represent sites upstream of the discharge point, blue diamonds are sites downstream of the discharge point and green circles represent the control site.

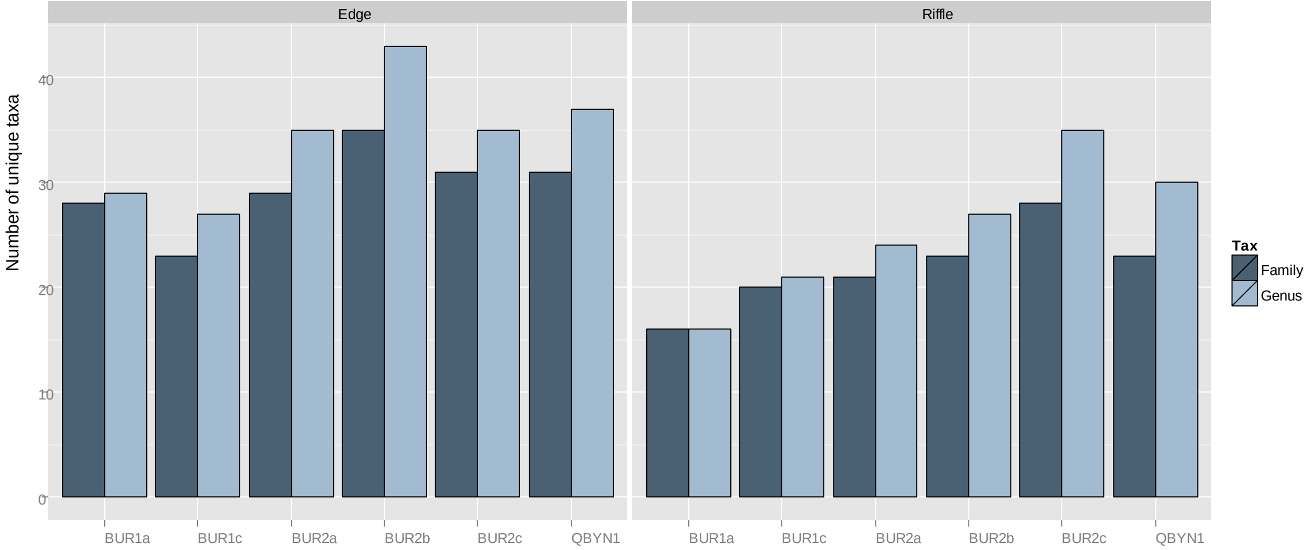

Figure 5-10. Number of taxa collected from the riffle and edge habitats

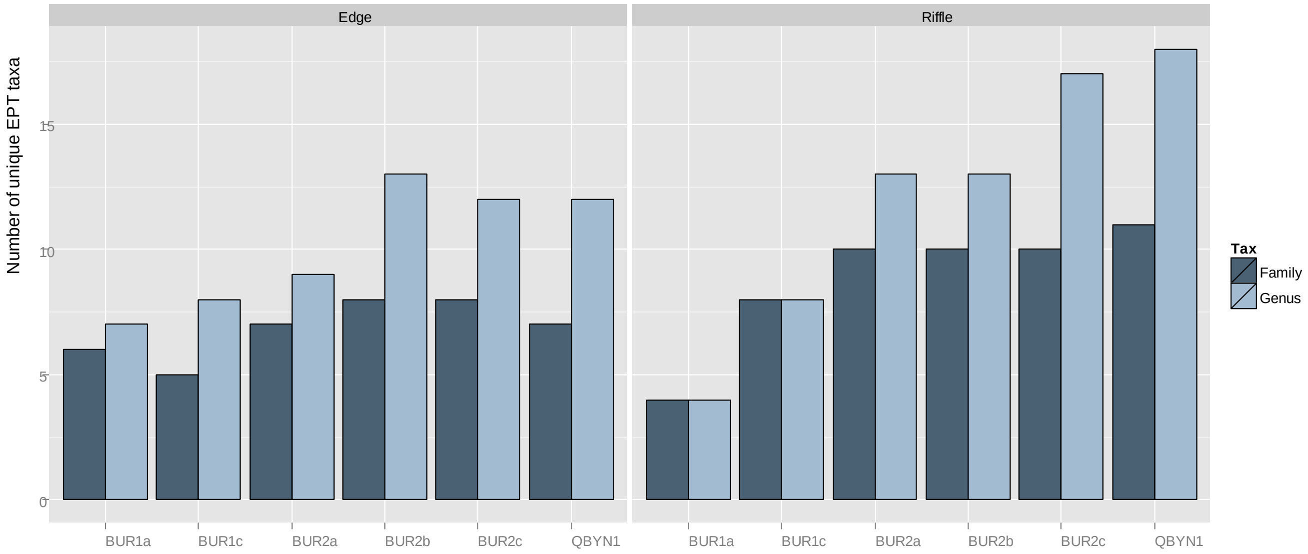

Figure 5-11. Number of EPT taxa collected from the riffle and edge habitats

Edge habitat

Tolerant taxa including: Orthocladiinae (4) and Chironominae (3); and the tolerant mayfly families: Baetidae (5) and Caenidae (4) were the dominant taxa in both the downstream and upstream locations in Burra Creek. The dominant macroinvertebrate families at QBYN 1 included the previously mentioned taxa, but also included: Leptoceridae (4) and Hydroptilidae (4) from the caddis fly order. The ordination analyses of the edge habitat macroinvertebrate assemblages indicate moderately low similarity amongst all sites (~40%; Figure 5-12) and while BUR 1a shows some degree of separation from the main group (to the left of the plotting area in Figure 5-12), the difference is just 10%. Furthermore, the community composition in samples collected from BUR 1c was more similar to that for samples collected from sites in other locations than to samples collected in the same location (i.e. BUR 1a samples). This resulted in a negative R-value and a non-significant ANOSIM result (R=-0.27; *P*=0.80), which suggests that there was no significant difference in edge habitat macroinvertebrate composition between locations.

There was some indication that there was a longitudinal increase in taxa richness, similar to that seen for the riffle habitat; however the pattern was not as distinctive as that seen in the riffle habitat samples (Figure 5-10). Taxa richness ranged from 23 families and 27 genera at BUR 1c to 35 families and 43 genera at BUR 2b. BUR 2b also had the highest genus EPT diversity, while the lowest was found at BUR 1a (Figure 5-11).

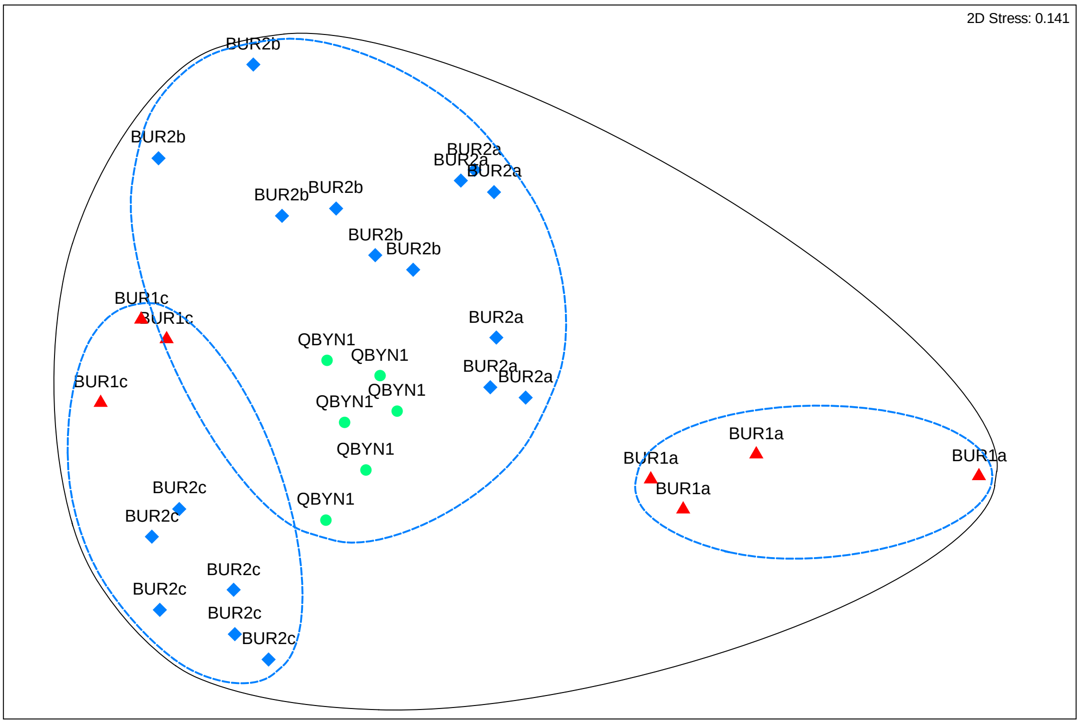

Figure 5-12. Non-metric multidimensional scaling of macroinvertebrate data (genus level) from the autumn 2014 edge samples

Note: Ellipses represent 40% (black) and 50% (blue) similarity groupings derived from cluster analysis. Red triangles represent sites upstream of the discharge point, blue diamonds are sites downstream of the discharge point and green circles represent the control site.

5.5.2 AUSRIVAS

Overall health ratings for autumn included five BAND B assessments and a BAND C assessment for BUR 1a (Table 5-6). Compared to autumn 2013, these assessments represent a decline in ecological health at BUR 2c (moving from BAND A in autumn 2013). BUR 1a was not sampled in autumn 2013 because the site was dry, however we found no change since autumn 2013 at the remaining sites (QBYN 1, BUR 2a, BUR 2b and BUR 1c). On an individual habitat level, BUR 2a (the first site downstream of the discharge weir) had the healthiest edge (BAND A) while all remaining sites had equivalent riffle and edge assessments (Table 5-7).

Riffle O/E50 scores and the SIGNAL 2 scores had a tendency, as they did for the taxa richness values, to increase with distance downstream (Figure 5-13) and the highest SIGNAL 2 scores occurring at QBYN 1. Despite this trend we found no evidence that the AUSRIVAS O/E50 ratio or the SIGNAL 2 scores differed statistically between locations for riffle data (Table 5-8) or edge data (Table 5-9). However, it should be pointed out that for the SIGNAL 2 scores in the riffle habitat, location effects explained approximately 68% of the variation and results were on the cusp of showing a significant location effect.

Missing taxa from the riffle habitat macroinvertebrate assemblages included up to twelve taxa at BUR 1a, which was essentially devoid of any EPT taxa despite having probabilities (of occurrence) greater than 90% (Appendix E3). In terms of location differences, there is no evidence from Appendix E3 to suggest there are clear upstream/downstream patterns. Of the 19 taxa presented in Appendix E3, 12 of those (~64%) had SIGNAL 2 scores of 6 or higher. The number of missing taxa from the edge assemblages ranged from 2 at BUR 2a to 10 at BUR 1a (Appendix E4). The SIGNAL 2 scores represented by these taxa also ranged considerably (2-8). It is difficult to generalise any clear patterns in the missing taxa list, mainly because sites are placed in different group categories, and as such, have different suites of predicted macroinvertebrate families.

Table 5-6. Overall site assessments from Burra Creek for autumn and spring since 2011

	Autumn 2011	Spring 2011	Autumn 2012	Spring 2012	Autumn 2013	Spring 2013	Autumn 2014	Change since previous autumn sampling run
QBYN 1	B	A	B	A	B	A	B	↔
BUR 1a	B	B	B	B	NS	A	C	/
BUR 1c	NS	NRA	B	B	B	B	B	↔
BUR 2a	NRA	NRA	B	A	B	A	B	↔
BUR 2b	B	B	B	B	B	A	B	↔
BUR 2c	B	B	B	A	A	A	B	↓

Notes: NRA= no reliable assessment; NS = no sample

Table 5-7. AUSRIVAS and SIGNAL-2 scores for autumn 2014

Note: NS = no sample.

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	5.62	4.20	0.84	0.78	B	B	**B**	**B**	**B**
QBYN 1	2	5.33	4.20	0.78	0.78	B	B			
QBYN 1	3	5.8	3.78	0.97	0.70	A	B			
QBYN 1	4	5.36	4.45	0.91	0.86	A	A			
QBYN 1	5	5.33	4.75	0.78	0.94	B	A			
QBYN 1	6	5.54	4.75	0.84	0.94	B	A			
BUR 1a	1	4.86	3.75	0.45	0.63	C	B	**C**	**C**	**C**
BUR 1a	2	4.75	3.67	0.52	0.47	C	C			
BUR 1a	3	4.75	NS	0.52	NS	C	NS			
BUR 1a	4	NS	4.60	NS	0.78	NS	B			
BUR 1a	5	NS	4.89	NS	0.71	NS	B			
BUR 1c	1	4.67	4.30	0.84	0.74	B	B	**B**	**B**	**B**
BUR 1c	2	4.50	4.50	0.70	0.74	B	B			
BUR 1c	3	4.50	4.33	0.70	0.67	B	B			
BUR 2a	1	4.50	4.31	0.73	1.11	B	A	**B**	**A**	**B**
BUR 2a	2	4.64	4.18	0.81	0.94	B	A			
BUR 2a	3	4.92	4.18	0.88	0.94	A	A			
BUR 2a	4	NS	4.18	NS	0.94	NS	A			
BUR 2a	5	NS	4.40	NS	0.85	NS	A			
BUR 2a	6	NS	4.18	NS	0.94	NS	A			
BUR 2b	1	4.64	4.11	0.81	0.73	B	B	**B**	**B**	**B**
BUR 2b	2	4.70	4.42	0.73	0.97	B	A			
BUR 2b	3	5.00	4.30	0.81	0.81	B	B			
BUR 2b	4	NS	4.20	NS	0.81	NS	B			
BUR 2b	5	NS	4.18	NS	0.89	NS	A			
BUR 2b	6	NS	4.42	NS	0.97	NS	A			
BUR 2c	1	4.92	4.20	0.83	0.68	B	B	**B**	**B**	**B**
BUR 2c	2	5.14	4.64	0.97	0.75	A	B			
BUR 2c	3	5.00	4.50	0.76	0.82	B	A			
BUR 2c	4	5.23	4.36	0.90	0.75	A	B			
BUR 2c	5	5.21	4.64	0.97	0.75	A	B			
BUR 2c	6	5.23	4.36	0.90	0.75	A	B			

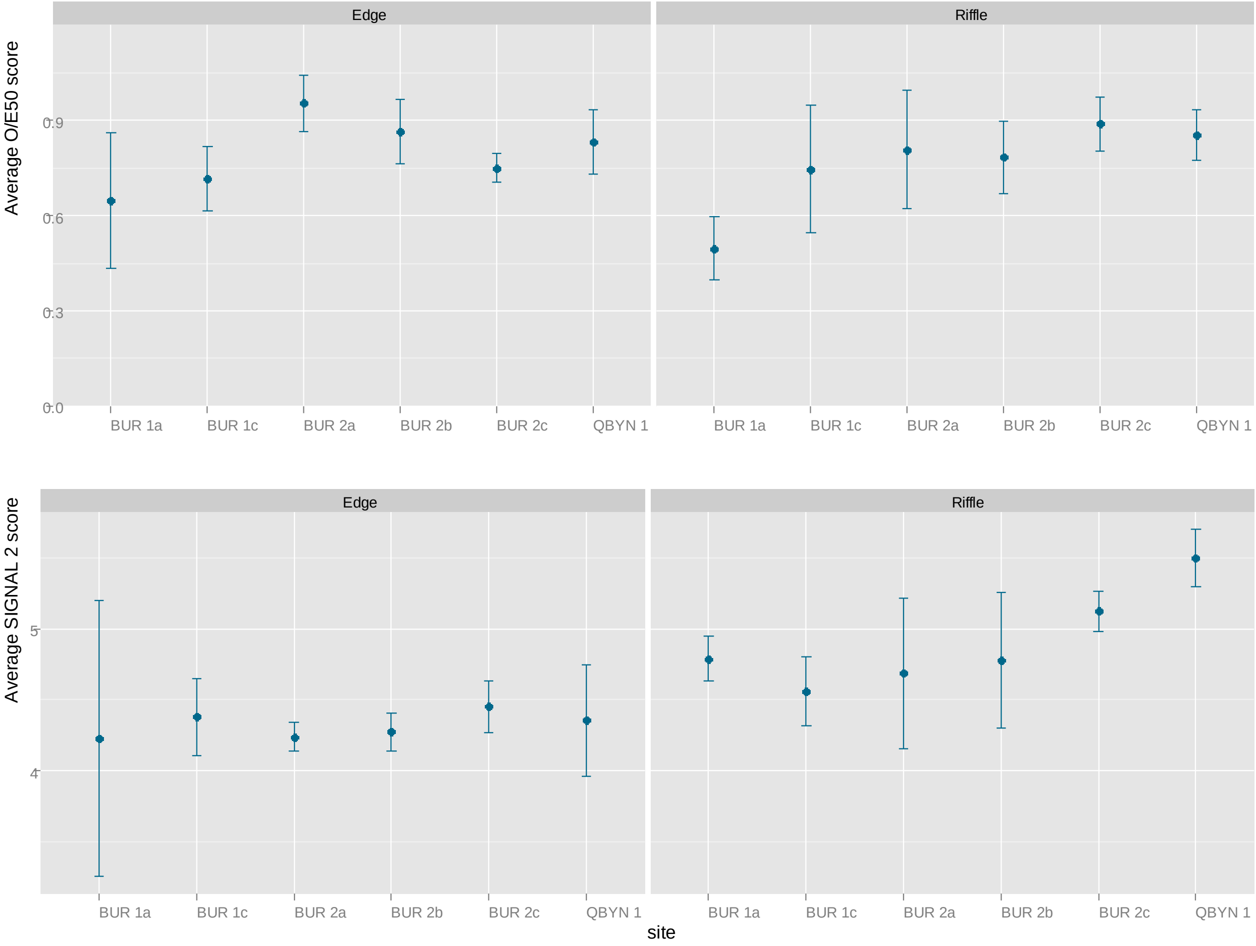

Figure 5-13. Means plots of SIGNAL-2 and O/E 50 scores for edge and riffle habitats

Note: Error bars are 95% confidence intervals.

Table 5-8. Nested analysis of variance results for O/E 50 and SIGNAL-2 scores for Burra Creek from the riffle habitat

Response	Source	DF	F	P-value
O/E 50	Location	2	2.81	0.21
	Site [Location]	3	7.76	<0.001
	Total	23		
SIGNAL-2	Location	2	7.74	0.07
	Site [Location]	3	6.22	<0.001
	Residual	23		

Table 5-9. Nested analysis of variance results for O/E 50 and SIGNAL-2 scores for Burra Creek from the edge habitat

Response	Source	DF	F	P-value
O/E 50	Location	2	1.88	0.30
	Site [Location]	3	5.64	<0.001
	Total	30		
SIGNAL-2	Location	2	0.10	0.91
	Site [Location]	3	0.76	0.53
	Residual	30		

5.6 Discussion

The inter-basin transfer of water from the Murrumbidgee River to Burra Creek (M2G) is a project which will bring about alteration to hydrological regimes and this has potential ecological risks associated with it, including the transfer of flora and fauna between basins, water quality degradation and changes to geomorphological processes (Table 1-1). These issues have been discussed in some length in the literature using existing case studies (mainly internationally: see Davies *et al.*, 1992; Ghassemi and White, 2007; Gupta and van der Zaag, 2008). This project was established to detect any potential impacts on aquatic ecosystem integrity (positive and negative) arising from the transfer of Murrumbidgee River water into Burra Creek via the M2G pipeline. During this reporting time frame however, there have been no releases, meaning that autumn 2014 sampling results presented here are considered to be additional baseline data. Hence, results presented in this report should not be interpreted as being indicative of potential impacts associated with the M2G operational phase.

5.6.1 Water quality

Water quality results from both the continuous water quality monitoring stations, collected grab samples and *in-situ* readings are indicative of the responses to natural variability in the flow regime. During the autumn period there were a number of exceedances of the ANZECC & ARMCANZ (2000) guidelines recorded. Some of these guideline breaches were a result of the high flow events recorded during late March and early April, such as changes in turbidity and pH (Queanbeyan River only) readings during this time. Others, such as the elevated EC readings at most sites in late autumn 2014, are typical for Burra Creek under lower flow conditions.

Dissolved oxygen (DO) levels recorded at the continuous gauging stations on both Burra Creek and Queanbeyan River showed increased range in the diurnal trend showing saturation levels of down to 60% during March. These low readings breach the ANZECC & ARMCANZ (2000) guidelines lower limit of 90% saturation. These reduced saturation levels were caused by the low flows during the period prior to the high flow events, which were a legacy of the very low flows which prevailed in Burra Creek during the preceding summer.

Flows during the summer months leading into spring have not reached such low levels since the summer of 2009-2010 at the end of the millennium drought. Following the rainfall events during autumn, flow reduced to very low levels, particularly at the farthest upstream Burra Creek site (BUR 1a) which resulted in the breach of the lower limit of the DO guideline at BUR 1a recorded from the *in-situ* reading.

Electrical conductivity (EC) in Burra Creek is naturally elevated above the ANZECC & ARMCANZ (2000) guidelines downstream of the confluence of Cassidy's Creek, immediately downstream of BUR 1a. It is not unexpected that during the autumn period the only time that EC was recorded within the guideline range was during the high flow events. It has previously been recommended that a more appropriate local guideline range be used for the monitoring of the EC levels within the creek (GHD, 2013). pH within Burra Creek is also historically elevated within the range of approximately 7.8 – 8.2. While *in-situ* readings during autumn 2014 did not exceed the guideline upper limit of 8.0 at any site, continuous monitoring station data showed that pH values were increased in the Queanbeyan River following the high flow events and reached levels of almost 8.5.

Elevated nutrient levels at BUR 1a above the ANZECC & ARMCANZ (2000) guidelines (total phosphorus & total nitrogen) suggests that groundwater inputs in this section of the creek were higher than normal during autumn 2014, but could also be due to high organic content and a lack of flushing flows leading up to the sampling period.

5.6.2 Periphyton

Periphyton results showed considerable within-site variation wiht respect to both chlorophyll-a and AFDM. Site to site variation could not be linked to nutrient levels, suggesting either a lag effect between nutrient delivery and uptake, or more complex relationships between flow and physico-chemical properties (for example, temperature) are involved; or a combination of the two.

The significant increase in the chlorophyll-a and AFDM biomass between autumn 2013 and the current season, is likely linked with the flows during the period and preceding summer months. During autumn 2013 the flows for the period were low, similar to those of autumn 2014; however there was no high flow event in autumn 2013 of a similar magnitude to that which occurred in late March 2014. This flow event may have acted as a flushing mechanism for the system, producing new growth with nutrient delivery in the weeks prior to sampling taking place, while also potentially increasing the organic loads within the sites through increased detrital matter. It is also possible that the increased flows may have facilitated in nutrient uptake by existing periphyton mats, resulting in higher biomass and production compared to autumn 2013.

The implications for the operation of the M2G pipeline during periods of low flow within Burra Creek are that the transfer may mimic small natural events and act either as growth promoter (i.e. through increased nutrient uptake) or as a scouring agent. However, based on our current understanding of the system, the maximum pumping volume may not be of a high enough magnitude to cause changes over and above what we have reported on following natural high flow events. However, because the increased flow volumes will only occur downstream of the discharge weir, there may be changes in the spatial patterns of AFDM and chlorophyll-a, which in turn, may effect macroinvertebrate communities by changing their functional properties and diversity.

5.6.3 AUSRIVAS and macroinvertebrate assemblages

During autumn 2014, the macroinvertebrate communities at BUR1a was distinctly different from the other sampling sites (Table 5-5), which was caused by a complete absence of mayflies (Ephemeroptera) at that site and an overall poor representation of taxa from the EPT group and moderately sensitive taxa. The absence of these taxa are the primary reason for the poor riffle AUSRIVAS band (BAND C) at this site as five of the missing twelve taxa were from the EPT group (Appendix E3). Further, four of the ten missing, but expected, taxa were from the EPT group in the edge habitat. Mayflies and some of the more tolerant caddis flies prefer fast flowing water with high oxygen content. (Table 5-3), it is reasonable to assume that the absence of these taxa were in part (if not due to additional factors) due to these conditions.

Compared to autumn 2013, the majority of sites retained the same AUSRIVAS band (Band B). The exception to this was site BUR 2c, which has been given an overall BAND A (reference condition) assessment for the past three sampling runs (Table 5-6); but was assessed as BAND B in the current study. It should be noted that the majority of scores for the riffle habitat were BAND A. However, because we have adopted a conservative approach in line with the recommendations by Barmuta *et* *al.*, (2003) of assigning the lowest BAND to a site when more than one habitat is sampled, this is not accounted for in the overall site assessment score sheet.

The difference between 2013 and the current study in terms of missing taxa was minimal with the key difference being the absence of Elmidae (riffle beetle) and the dragonfly family Gomphidae in autumn 2014. Both taxa prefer different scales of the flow continuum. Elmidae (aptly named riffle beetles) prefer faster flowing water and are associated with woody debris whereas Gomphidae prefer slower moving water and are often associated with substrates covered in detritus (Gooderham and Tsyrlin, 2005).

The high flow event in April removed a lot of the detritus and other organic material that was event over summer, however the periphyton data indicates that concentrations of AFDM and chlorophyll-a were still high relative to last year. Base flows were comparable to the previous autumn sampling period, so it is not clear whether the flows leading up to the sampling run or some other factors are responsible for the absence of these taxa. The most likely explanation is that a combination of factors, for example, flow and food availability were contributing factors to their absence in this sampling period.

Edge assessments were generally in agreement with the riffle assessments, expect for BUR 2a where the edge habitat was assessed as BAND A (similar to reference), which represents an improvement since 2013. BUR 2a had perhaps the deepest pool / edge habitat of all of the sampling sites, which might provide a more stable habitat for taxa in times of low flow stress or as a refuge to riffle taxa during these periods (Boulton and Lake, 1992). Comparisons between edge and riffle habitats would be a useful addition to the analysis suite during these low flow periods, because the proportion of shared taxa in times of high flows versus low flows may help understand if and how macroinvertebrates are utilising the edge habitat for refuge (thereby providing an understanding of strategies that provide resilience to changing flow conditions).

As was found with the Angle Crossing component of this report, there was an overall decline in the number of taxa since autumn 2013, and the number of genera per family had also declined over the two seasons (i.e. since spring 2013). It is likely that, the high flow event prior to sampling resulted in a loss of taxa through drift and scouring, while the prolonged dry period over summer could have resulted in communities dominated by taxa that favour low flow conditions; which are more vulnerable to scour removal. Another explanation is that the very low flow conditions during summer may have increased ecosystem stress and delayed the recruitment and recolonisation process, resulting in fewer taxa being present in autumn.

Despite the lower number of taxa, the overall site assessments compared to previous sampling periods were for the most part, not impacted. For example, SIGNAL 2 scores were approximately the same as those seen in autumn 2013, as were the AUSRIVAS assessments (apart from the small changes that are discussed above) and spatial patterns in taxonomic richness again showed a similar upstream / downstream gradient, with the highest EPT and taxa richness occurring at QBYN 1.

The multivariate ordination analysis was also consistent with the previous autumn sampling period (aside from BUR1a not being sampled in autumn 2013). In the current study, BUR 1a (upstream control site) is distinct from all other sampling sites, including BUR 1c, which is also acting as an upstream control site in this program. Sites further downstream in Burra Creek (BUR 2b and BUR 2c) tended to show a higher degree of similarity to QBYN 1 than they did s to upstream sites suggesting, perhaps, that the degree of flow permanence is more important in shaping the macroinvertebrate communities rather than differences in water quality.

5.7 Conclusions and recommendations

The results presented here are the responses and characteristics of water quality, periphyton and macroinvertebrates to naturally occurring events and environmental variation since spring 2013. Although M2G is technically in the operation phase of its history, there have been no maintenance flows or releases in-between the two sampling periods. Hence, results are indicative of natural spatio-temporal variability under the scenario of very low flow summer period followed by a moderate flow autumn punctuated by a relatively large pulse flow event.

Ultimately we have found no lasting change to any of the indicators considered in this study to date, despite previous sampling runs being in response to several high flow events. Analysis of the long term trends show that in 2009, towards the end of the Millennium drought, there were some changes to water quality and a loss of a broad range of taxa in the Murrumbidgee River, which suggests that drought stress is perhaps more of a concern than high flow stress in the Murrumbidgee River. Evidence from Burra Creek during this period is difficult to interpret owing to the fact that Burra Creek dries out much sooner and is more prone to boom and bust cycles. Regardless, a preliminary look at the long term trends has identified this period as distinctly different in terms of macroinvertebrate communities from all other sampling years and so if M2G is to operate during these periods of water stress, there should be some benefit to the reaches downstream of the discharge weir of the 100 ML/d.

The option for an extended shut-down of M2G means that, for the foreseeable future, there will only be requirements for maintenance monitoring. In light of this, the following recommendations are made with the recognition that sometime in the future there will likely be a need to operate M2G at full capacity. This will call for comparable data to the extensive baseline collection that now exists for this project.

Therefore, we recommend:

1) **Spring sampling should continue with the same protocols and methods used in this study** as this will meet EIS requirements of a full two years following the beginning of the commissioning period, which will therefore complete the commitments under the M2G EIS.

2) **Review periphyton sampling protocols** – refer to same recommendation for Angle Crossing, section 4.7.

3) **Review overall sampling protocols as we move into maintenance monitoring –** refer to same recommendation for Angle Crossing, section 4.7. As well as the points noted for Angel Crossing, this review will include a re-evaluation of how the data are analysed and the appropriateness of grouping BUR 1a and BUR 1c. These sites are starkly different in terms of water chemistry, substrate and other physical aspects. Considering these sites separately and assessing relative changes (in terms of similarity coefficients and univariate metrics) may be a more robust approach moving forward.

4) **Installation of rising stage samplers at a location representative of the discharge into Burra Creek.** Currently there is no regular water quality grab sampling program. Therefore, it is recommended that a rising stage sampler is installed downstream at the Burra Road weir (near BUR 2b) to capture event-based water quality parameters in accordance with the M2G operational plan (e.g. TN and TP).

5) **Collect water samples at the discharge site.** Water quality monitoring should be conducted at the discharge weir in addition to other sites which will help estimate and better understand dilution process in Burra Creek (only during maintenance runs).

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Appendices

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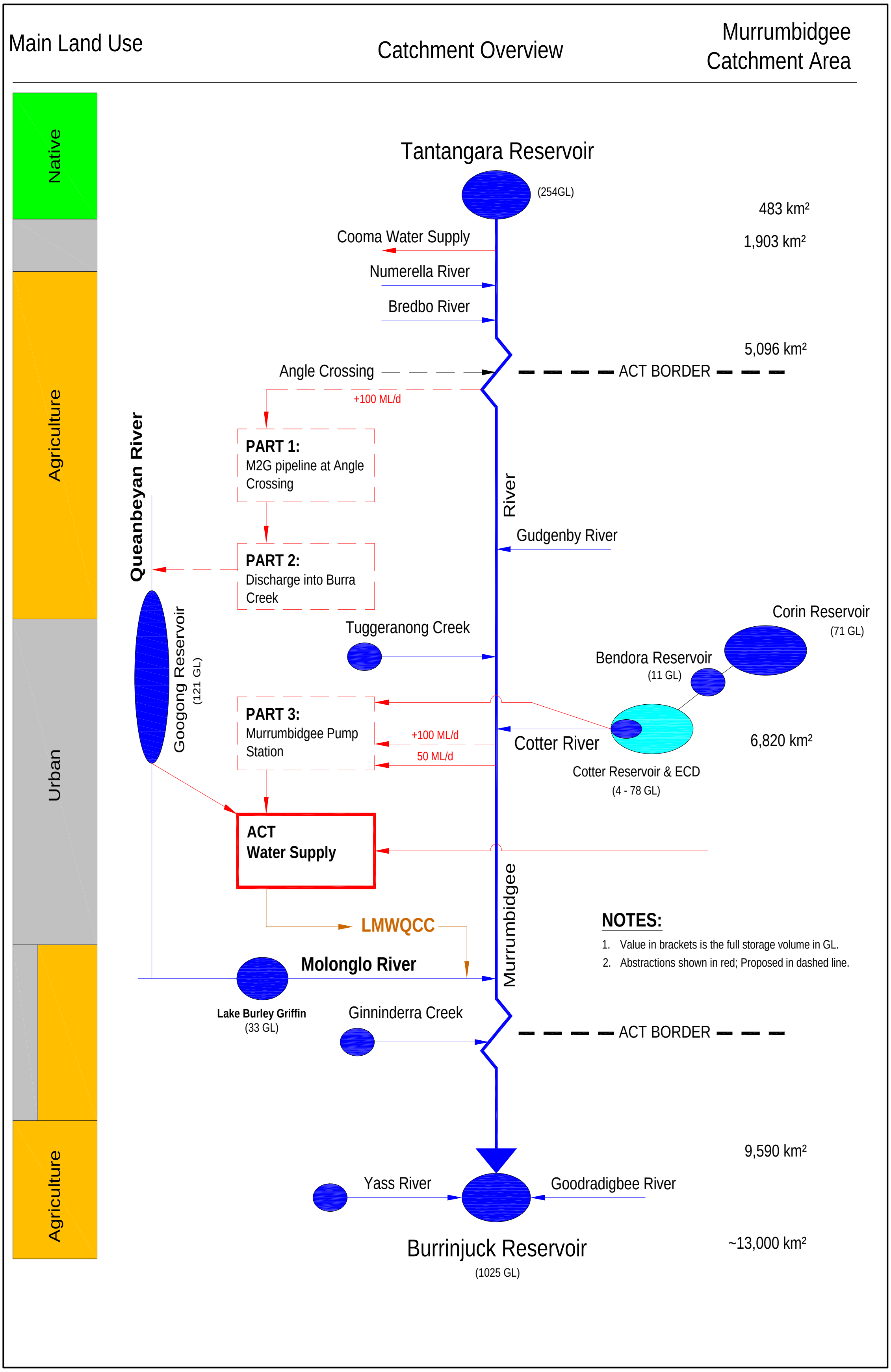
Appendix A - Schematic representation of the Murrumbidgee Catchment and ACTEW Water's major projects

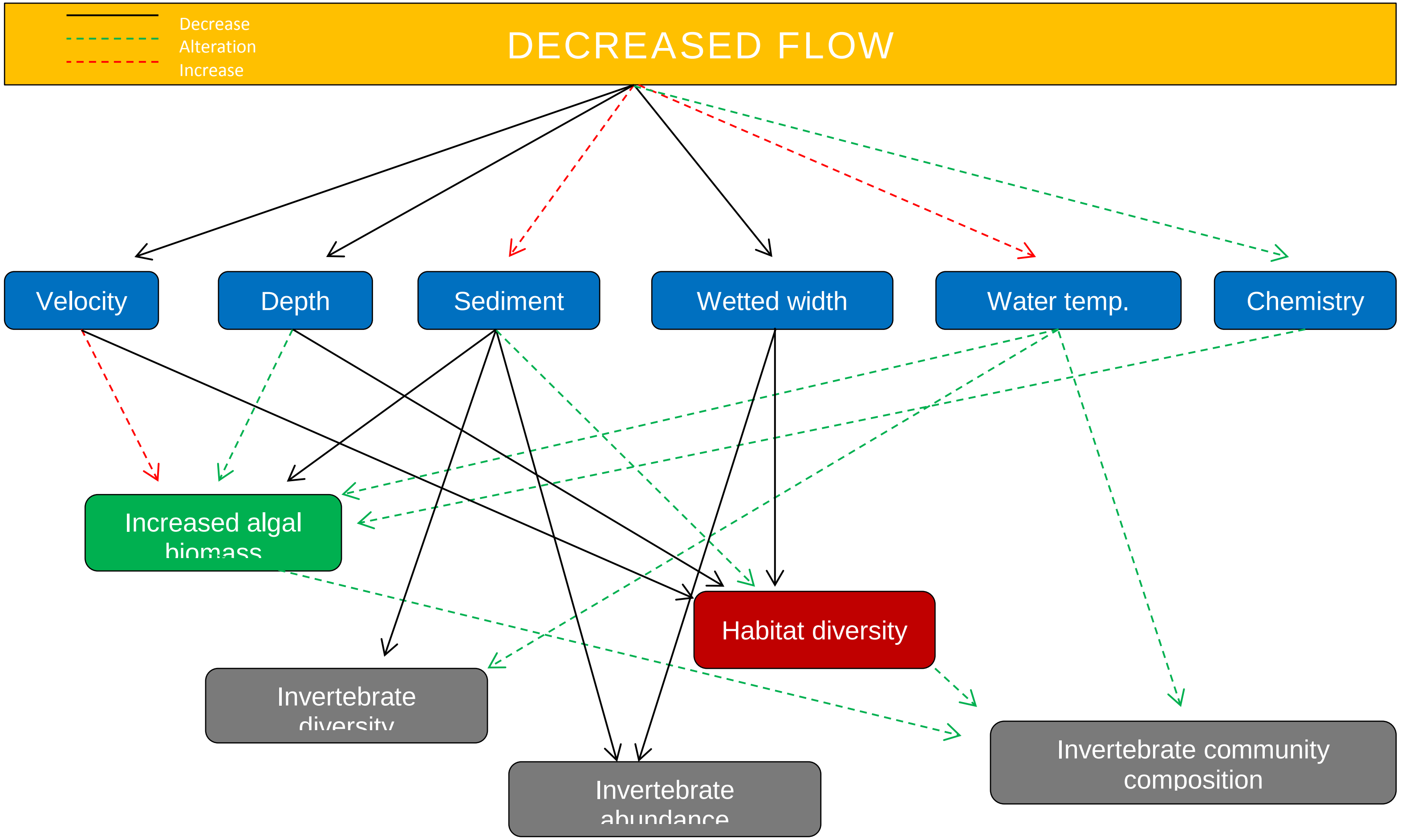
Appendix A1. Overview of ACTEW Water's major projects



Appendix B - Conceptual framework of the effects of reduced flow

Appendix B1. Summary of the effects of reduced flows on various habitat conditions and macroinvertebrate communities (Dewson, 2007)

Note: Reproduced with permission from the authors.



Appendix C - QA/QC Results

Appendix C1. QA/QC results for Burra Creek and Angle Crossing from autumn 2014. (Any differences highlighted in yellow.)

		Site Code	MUR15		MUR18		MUR18		MUR23		BUR2A		QBYN1	
		Habitat	Riffle		Riffle		Edge		Edge		Edge		Riffle	
		Sample	1		1		2		1		2		2	
		Replicate	2	QA	1	QA	3	QA	2	QA	3	QA	2	QA
CLASS / Order	**Family / Sub-Family**	**Genus**												
ACARINA					1	1	6	6					25	23
Amphipoda	Ceinidae										3	3		
Coleoptera	Dytiscidae	Megaporus									1	1		
	Elmidae	Austrolimnius											15	15
	Scirtidae										5	5		
Decapoda	Atyidae	Paratya					4	4	12	12	1	1		
	Palaemonidae	Macrobrachium			1	1	3	3						
Diptera	Ceratopogonidae	Ceratopoginae					4	4					3	3
	Chironominae		18	18	60	59	26	26	28	28	8	8	2	2
	Dixidae										1	1		
	Empididae								2	2				
	Orthocladiinae		5	5	11	11	17	17	9	9	13	13	5	5
	Simuliidae	Austrosimulium	37	37	2	2			1	1			15	15
		Simulium	6	6										
		sp.	102	100	6	6	1	1	1	1			5	5
	Stratiomyidae	Odontomyia									2	2		
	Tanypodinae	sp.			1	1					1	1		
Ephemeroptera	Baetidae	Baetidae Genus 1									2	2	1	0
		Cloeon									4	4		
		sp.	1	1	6	6					82	83	9	9
	Caenidae	Irapacaenis					4	4					6	6
		Tasmanocoenis	13	13	48	47	8	8	3	3	1	1	28	28
		sp.			20	20	6	6	1	1	1	1	21	21
	Leptophlebiidae	Atalophlebia			2	2	5	5			6	6		
		Jappa			2	2							1	1
		sp.	2	2	9	9	5	5	2	2	14	14	4	4
GASTROPODA	Planorbidae	Ferrissia									1	1		
	Ancylidae								2	2				
	Lymnaeidae	Pseudosuccinea							1	1	1	1		

		Site Code	MUR15		MUR18		MUR18		MUR23		BUR2A		QBYN1	
		Habitat	Riffle		Riffle		Edge		Edge		Edge		Riffle	
		Sample	1		1		2		1		2		2	
		Replicate	2	QA	1	QA	3	QA	2	QA	3	QA	2	QA
CLASS / Order	**Family / Sub-Family**	**Genus**												
	Physidae	Physa							1	1	1	1		
Hemiptera	Micronectidae	micronecta					2	2			1	1		
	Notonectidae	Paranisops					2	2			3	3		
Hydrozoa	Hydridae	Hydra					1	1						
Odonata	Telephlebiidae	Spinaeschna											1	1
Odonata	Zygoptera										2	2		
OLIGOCHAETA			2	2	7	7	111	108	131	128	14	14	7	7
Plecoptera	Gripopterygidae	Dinotoperla			1	1	1	1						
		Illiesoperla	1	1										
		sp.			2	2							4	4
Trichoptera											2	2		
	Ecnomidae	Ecnomina									1	1		
		Ecnomus			1	1			1	1			1	1
		sp.					2	2			1	1		
	Hydropsychidae	Cheumatopsyche			4	4							29	29
		sp.			2	2							3	3
	Hydroptilidae	Hellyethira							1	1	19	19	1	1
		Hydroptila			1	1								
		Orthotrichia	1	1			1	1	1	1				
		sp.	1	1									4	4
	Leptoceridae	Oecetis											2	2
		Triaenodes							5	5			2	2
		Triplectides					3	3			9	9		
		sp.					1	1			2	2		
	Philopotamidae	Chimarra											5	5
		sp.											5	5
		Error	1.07%		1.08%		1.43%		1.51%		0.49%		1.49%	
		Pass Rate	< 5%		< 5%		< 5%		< 5%		< 5%		< 5%	
		Pass / Fail	Pass		Pass		Pass		Pass		Pass		Pass	

Appendix D - Site summaries

Part 1: Angle Crossing

MUR15

Bumbalong Road
6/5/2014 9:55 am

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
10.3	132.1	5.64	5	7.89	100.8	11.04

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
48	0.003	< 0.002	0.002	< 0.002	0.028	0.33

Daily Flow: 240 ML/day

Recorded at the closest station (410050) - located on the Murrumbidgee River at Billilingra. (Source: www.water.nsw.gov.au)

Compared to current flow:

Spring 2013: ⇧ Autumn 2013: ⇩

Riffle Habitat

- Dominant substrate was cobble

Dominant Taxa

- Simuliidae
- Baetidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

Edge Habitat

- Sediment was anaerobic
- Dominant trailing bank vegetation was from overhanging shrubs and trees

Dominant Taxa

- Corixidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

AUSRIVAS Results

	Autumn 2013	Spring 2013	Autumn 2014
Riffle Habitat	B	NRA	B
Edge Habitat	B	A	B
Overall Site Assessment	B	NRA	B

Site Quality Assessment

Additional Comments

- None

MUR16

The Willows – Near Michelago
6/5/2014 12:30 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
11.5	142.6	5.26	4	7.77	100.4	11.03

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
52	< 0.002	< 0.002	< 0.002	< 0.002	0.026	0.34

Daily Flow: 240 ML/day

Recorded at the closest station (410050), located on the Murrumbidgee River at Billilingra. (Source: www.water.nsw.gov.au)

Compared to current flow:

Spring 2013: ⇧ Autumn 2013: ⇩

AUSRIVAS Results

	Autumn 2013	Spring 2013	Autumn 2014
Riffle Habitat	B	B	B
Edge Habitat	B	B	B
Overall Site Assessment	B	B	B

Riffle Habitat

- Dominant substrate was cobble

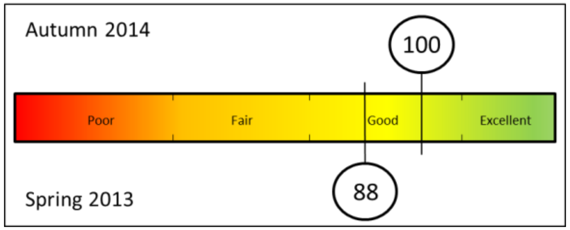
Dominant Taxa

- Simuliidae
- Baetidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Gripopterygidae

Site Quality Assessment



Edge Habitat

- Second edge sample collected further upstream than previous due to lower flow level as during previous sample run (spring 2013)
- Dominant trailing bank vegetation was overhanging native shrubs

Dominant Taxa

- Atyidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- None

Additional Comments

- Some large stands of *Myriophyllum sp.*
- Water level slightly below ‘normal’

MUR18

Upstream Angle Crossing
7/5/2014 2:00 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
11.1	145.9	4.30	3	7.50	104.6	11.17

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
53	< 0.002	< 0.002	< 0.002	0.003	0.021	0.33

Daily Flow: 270 ML/day

Recorded at the closest station (41001702), located on the Murrumbidgee River at upstream Angle Crossing.

Compared to current flow:

Spring 2013: ⇧ Autumn 2013: ⇩

AUSRIVAS Results

	Autumn 2013	Spring 2013	Autumn 2014
Riffle Habitat	B	B	B
Edge Habitat	B	A	B
Overall Site Assessment	B	B	B

Riffle Habitat

- Reduced velocity through the riffle zone
- High levels of organic material within the riffle habitat
- Dominant substrate was pebble

Dominant Taxa

- None

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

Edge Habitat

- Dominant trailing bank vegetation was wood debris and overhanging native shrubs

Dominant Taxa

- Atyidae

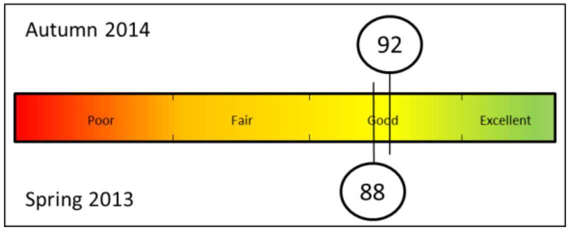
Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

Additional Comments

- High levels of periphyton coverage across the site

Site Quality Assessment



MUR19

Downstream Angle Crossing
5/5/2014 2:30 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
11.6	146.3	4.61	3	7.32	98.5	10.99

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
52	< 0.002	< 0.002	0.002	< 0.002	0.022	0.34

Daily Flow: 330 ML/day

Recorded at the closest station (410761), located on the Murrumbidgee River at Lobb's Hole.

Compared to current flow:

Spring 2013: ⇧ Autumn 2013: ⇩

AUSRIVAS Results

	Autumn 2013	Spring 2013	Autumn 2014
Riffle Habitat	B	B	B
Edge Habitat	B	A	B
Overall Site Assessment	B	B	B

Riffle Habitat

- Abundance of *Myriophyllum sp.* throughout the habitat
- Dominant substrate was pebble

Dominant Taxa

- Baetidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Telephlebiidae
- Leptophlebiidae

Edge Habitat

- Dominant trailing bank vegetation was overhanging willow & other shrubs

Dominant Taxa

- None

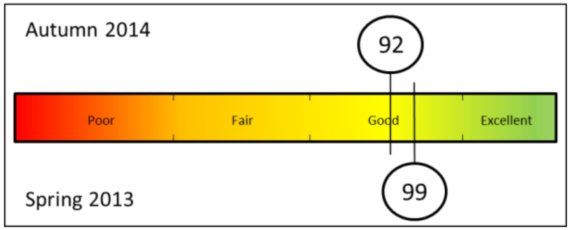
Sensitive Taxa (SIGNAL-2 ≥ 7)

- None

Additional Comments

- None

Site Quality Assessment



MUR23

Point Hut Crossing
7/5/2014 11:10 am

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
11.3	142.6	4.96	4	7.11	113.6	12.44

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
50	< 0.002	< 0.002	< 0.002	0.002	0.02	0.34

Daily Flow: 290 ML/day

Recorded at the closest station (410761), located on the Murrumbidgee River at Lobb's Hole.

Compared to current flow:

Spring 2013: ↑ Autumn 2013: ↓

Riffle Habitat

- Dominant substrate was sand

Dominant Taxa

- Baetidae
- Simuliidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Gripopterygidae

Edge Habitat

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

Dominant Taxa

- Atyidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- None

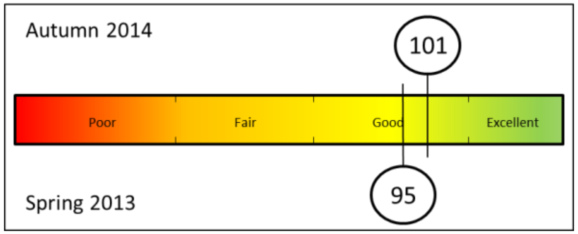
AUSRIVAS Results

	Autumn 2013	Spring 2013	Autumn 2014
Riffle Habitat	B	A	B
Edge Habitat	B	A	B
Overall Site Assessment	B	A	B

Additional Comments

- None

Site Quality Assessment



MUR28

Upstream Cotter River Confluence
7/5/2014 9:15 am

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
11.1	144.5	4.15	2	8.01	109.6	11.06

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
51	< 0.002	< 0.002	< 0.002	0.002	0.018	0.36

Daily Flow:

290 ML/day
Recorded at station 410761, located on the Murrumbidgee River at Lobb's Hole.

400 ML/day
Recorded at station 410738, located on the Murrumbidgee River at Mt. MacDonald.

38 ML/day
Recorded at station 410700, located on the Cotter River at Cotter Kiosk (below the Enlarged Cotter Dam).

The variation in flows down the Cotter River limit the comparability of this site's flow between seasons, which is further complicated by the operation of the Bendora Scour Valve.

AUSRIVAS Results

	Autumn 2013	Spring 2013	Autumn 2014
Riffle Habitat	B	B	B
Edge Habitat	B	NRA	C
Overall Site Assessment	B	NRA	C

Riffle Habitat

- Little organic matter in the samples, likely due to higher velocities at this site
- Dominant substrate was boulder and sand

Dominant Taxa

- None

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

Edge Habitat

- Poor quality habitat
- Only 1 samples collected due to limited habitat availability
- Dominant trailing bank vegetation was overhanging *Casuarina sp.* and wood debris

Dominant Taxa

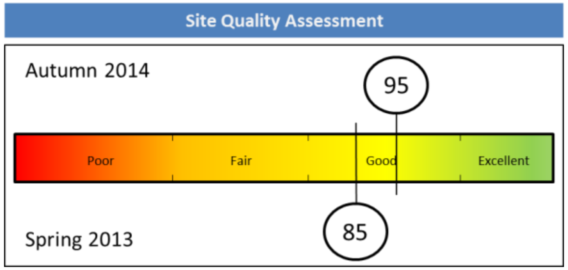
- Atyidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- None

Additional Comments

- Few macrophytes across the site



Part 2: Burra Creek

BUR1a

Burra Native
8/5/2014 9:30 am

Temp. (°C)	EC (µs/cm)	Turb. (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
8.1	96.8	42.9	67	7.11	83.5	9.82

Alkalinity	NO$_x$ (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
22	0.006	0.003	0.003	0.011	0.027	0.40

Daily Flow: 2.5 ML/day

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

Compared to current flow:

Spring 2013: ⇧ Autumn 2013: ⇩

AUSRIVAS Results

	Autumn 2013	Spring 2013	Autumn 2014
Riffle Habitat	NS	A	C
Edge Habitat	NS	A	C
Overall Site Assessment	NS	A	C

Riffle Habitat

- Only a single sample was collected due to limited habitat availability
- Dominant substrate was pebble and gravel

Dominant Taxa

- Chironomidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- None

Edge Habitat

- Dominant trailing bank vegetation was overhanging shrubs (mainly *Kunzea sp.*)

Dominant Taxa

- Acarina

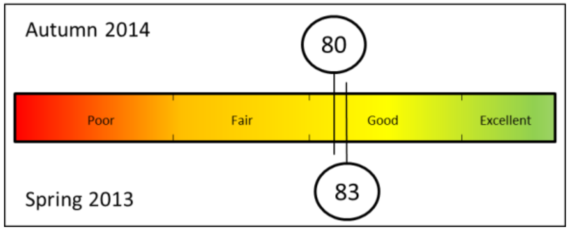
Sensitive Taxa (SIGNAL-2 ≥ 7)

- None

Additional Comments

- Flows were very low
- Some disconnection between pools

Site Quality Assessment



BUR1c

Upstream Williamsdale Road
8/5/2014 11:30 am

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
10.5	415.1	6.84	8	7.61	106.9	11.3

Alkalinity	NO$_x$ (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
148	0.004	0.003	< 0.002	< 0.002	0.006	0.22

Daily Flow: 2.5 ML/day

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

Compared to current flow:

Spring 2013: ↑ Autumn 2013: ↓

AUSRIVAS Results

	Autumn 2013	Spring 2013	Autumn 2014
Riffle Habitat	B	B	B
Edge Habitat	B	X	B
Overall Site Assessment	B	B	B

Riffle Habitat

- Poor quality, highly silted habitat
- Only a single sample was collected due to limited habitat availability
- Dominant substrate was silt

Dominant Taxa

- None

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Hydrobiosidae

Edge Habitat

- Only a single sample was collected due to limited habitat availability
- Dominant trailing bank vegetation was macrophytes (mainly *Schoenoplectus sp.*)

Dominant Taxa

- None

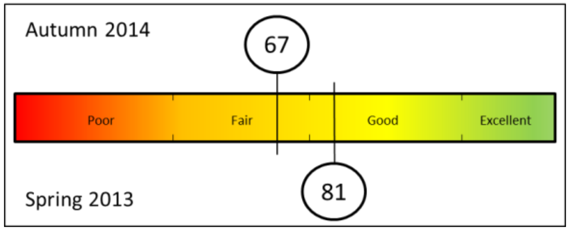
Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

Additional Comments

- Very little flow

Site Quality Assessment



BUR2a

Downstream Williamsdale Road
8/5/201 1:55 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
11.0	510.4	4.62	< 2	7.72	104.8	11.56

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
194	0.230	0.229	< 0.002	< 0.002	0.007	0.40

Daily Flow: 2.5 ML/day

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

Compared to current flow:

Spring 2013: ⇧ Autumn 2013: ⇩

AUSRIVAS Results

	Autumn 2013	Spring 2013	Autumn 2014
Riffle Habitat	B	A	B
Edge Habitat	B	A	A
Overall Site Assessment	B	A	B

Riffle Habitat

- Only a single sample was collected due to limited habitat availability
- Dominant substrate is silt

Dominant Taxa

- Baetidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Hydrobiosidae

Edge Habitat

- Dominant trailing bank vegetation was macrophytes (mainly *Phragmites australis* and *Schoenoplectus sp.*)

Dominant Taxa

- Microcrustaceans

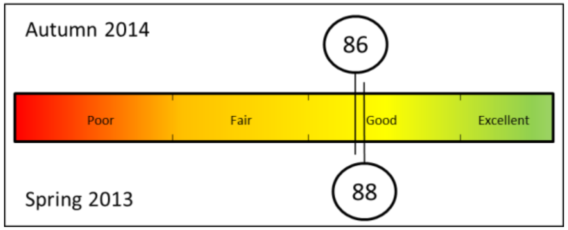
Sensitive Taxa (SIGNAL-2 ≥ 7)

- None

Additional Comments

- *Gambusia holbrooki* dominant at the site

Site Quality Assessment



BUR2b

Downstream Burra Road
9/5/2014 2:15 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
10.4	515.8	5.80	4	7.92	105.6	11.34

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
209	0.038	0.038	< 0.002	< 0.002	0.012	0.26

Daily Flow: 2.5 ML/day

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

Compared to current flow:

Spring 2013: ↑ Autumn 2013: ↓

AUSRIVAS Results

	Autumn 2013	Spring 2013	Autumn 2014
Riffle Habitat	B	A	B
Edge Habitat	B	A	B
Overall Site Assessment	B	A	B

Riffle Habitat

- Only a single sample was collected due to limited habitat availability
- Dominant substrate is gravel

Dominant Taxa

- Baetidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Hydrobiosidae
- Leptophlebiidae

Edge Habitat

- *Gambusia holbrooki* present in the edge habitat
- Dominant trailing bank vegetation is macrophytes (mainly *Phragmites australis*)

Dominant Taxa

- None

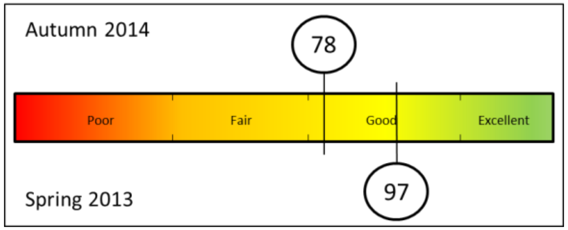
Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

Additional Comments

- None

Site Quality Assessment



BUR2c

Upstream London Bridge
9/5/2014 11:30 am

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
10.1	510.3	2.91	< 2	7.93	103.3	11.43

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
206	0.062	0.062	< 0.002	< 0.002	0.007	0.25

Daily Flow: 2.5 ML/day

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

Compared to current flow:

Spring 2013: ↑ Autumn 2013: ↓

AUSRIVAS Results

	Autumn 2013	Spring 2013	Autumn 2014
Riffle Habitat	A	A	B
Edge Habitat	A	A	B
Overall Site Assessment	A	A	B

Riffle Habitat

- Dominant substrate was cobble

Dominant Taxa

- None

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Hydrobiosidae

Edge Habitat

- Sediment in the edge habitat was anaerobic
- Dominant trailing bank vegetation was macrophytes (mainly *Phragmites australis* and *Schoenoplectus sp.*)

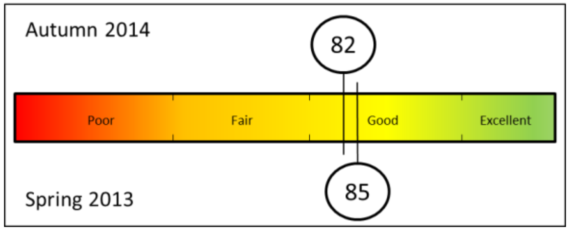
Dominant Taxa

- Chironomidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

Site Quality Assessment



Additional Comments

- None

QBYN1

Flynn's Crossing
9/5/2014 9:45 am

Temp. (°C)	EC (μs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
9.0	91.3	4.82	3	7.99	103.6	11.71

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
37	< 0.002	< 0.002	< 0.002	< 0.002	0.013	0.19

Daily Flow: 48 ML/day

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

Compared to current flow:

Spring 2013: ↑ Autumn 2013: ↓

AUSRIVAS Results

	Autumn 2013	Spring 2013	Autumn 2014
Riffle Habitat	B	A	B
Edge Habitat	B	A	B
Overall Site Assessment	B	A	B

Riffle Habitat

- Clean substrate with limited periphyton
- Dominant substrate was cobble

Dominant Taxa

- Leptophlebiidae
- Baetidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Hydrobiosidae
- Leptophlebiidae

Edge Habitat

- High macroinvertebrate richness found in edge habitat scan
- Dominant trailing bank vegetation overhanging shrubs (mainly *Kunzea sp.*)

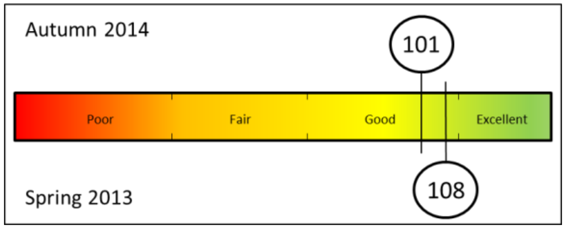
Dominant Taxa

- Atyidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

Site Quality Assessment



Additional Comments

- Site is likely to remain at the current channel, change in channel morphology is limiting flow in the usual channel
- High level of organic matter across the site

Appendix E – Taxa predicted to occur with >50% probability, but were not collected

Appendix E1 – Taxa predicted to occur with >50% probability but not collected at Angle Crossing sites from the riffle habitat

Site	Taxa	Oligochaeta	Elmidae	Tipulidae	Baetidae	Gripopterygidae	Hydropsychidae	Total number of missing taxa
	SIGNAL-2	2	7	5	5	8	6	
MUR15	Riffle		*1.00*	*0.80*				2
MUR15			*1.00*	*0.80*			*1.00*	3
MUR15			*1.00*	*0.80*		*0.60*		3
MUR15			*1.00*	*0.80*		*0.60*		3
MUR15				*0.80*		*0.60*		2
MUR15		*0.80*		*0.80*	*0.80*		*1.00*	4
MUR16	Riffle	*0.80*	*1.00*	*0.80*		*0.60*		4
MUR16		*0.80*	*1.00*	*0.80*		*0.60*		4
MUR16		*0.80*	*1.00*	*0.80*				3
MUR16			*1.00*	*0.80*		*0.60*		3
MUR16		*0.80*	*1.00*	*0.80*		*0.60*		4
MUR16			*1.00*	*0.80*		*0.60*		3
MUR18	Riffle		*1.00*	*0.80*				2
MUR18			*1.00*	*0.80*				2
MUR18			*1.00*	*0.80*				2
MUR18		*0.80*	*1.00*	*0.80*		*0.60*		4
MUR18			*1.00*	*0.80*	*0.80*	*0.60*		4
MUR18			*1.00*	*0.80*	*0.80*			3
MUR19	Riffle			*0.80*				1
MUR19				*0.80*		*0.60*		2
MUR19				*0.80*				1
MUR19				*0.80*		*0.60*		2
MUR19		*0.80*		*0.80*		*0.60*		3
MUR19			*1.00*	*0.80*		*0.60*		3
MUR23	Riffle		*1.00*	*0.80*		*0.60*		3
MUR23			*1.00*	*0.80*				2
MUR23		*0.80*	*1.00*	*0.80*				3
MUR23		*0.80*		*0.80*		*0.60*		3
MUR23			*1.00*	*0.80*		*0.60*		3
MUR23		*0.80*	*1.00*	*0.80*		*0.60*		4
MUR28	Riffle		*1.00*	*0.80*				2
MUR28			*1.00*			*0.60*		2
MUR28			*1.00*			*0.60*		2
MUR28			*1.00*	*0.80*		*0.60*		3
MUR28			*1.00*			*0.60*		2
MUR28			*1.00*	*0.80*	*0.80*	*0.60*		4

Appendix E2 – Taxa predicted to occur with >50% probability but not collected from Angle Crossing sites in the edge habitat

Site	Taxa	Planorbidae	Oligochaeta	Acarina	Hydrophilidae	Elmidae	Ceratopogonidae	Tanypodinae	Baetidae	Leptophlebiidae	Corixidae	Synlestidae	Gripopterygidae	Hydroptilidae	Ecnomidae	Conoesucidae	Leptoceridae	Total number of missing taxa
	SIGNAL-2	2	2	6	2	7	4	4	5	8	2	7	8	4	4	7	6	
MUR15	Edge	0.55				0.62		0.90				0.65				0.59		5
MUR15		0.55						0.90				0.65		0.93		0.59		5
MUR15		0.55				0.62		0.90				0.65	0.69			0.59		6
MUR15		0.55				0.62						0.65				0.59		4
MUR15		0.55				0.62			0.90			0.65			0.59	0.59		6
MUR15		0.55				0.62			0.90			0.65				0.59		5
MUR16	Edge	0.55				0.62		0.90			0.62	0.66				0.59	0.97	7
MUR16		0.55				0.62		0.90			0.62	0.66				0.59	0.97	7
MUR16		0.55				0.62		0.90			0.62	0.66				0.59	0.97	7
MUR16		0.55				0.62					0.62	0.66			0.59	0.59	0.97	7
MUR16		0.55				0.62			0.90			0.66				0.59	0.97	6
MUR16		0.55				0.62					0.62	0.66		0.93	0.59	0.59	0.97	8
MUR18	Edge	0.51			0.56	0.68		0.92							0.51			5
MUR18		0.51			0.56	0.68									0.51			4
MUR18		0.51			0.56	0.68		0.92	0.91					0.64	0.51			7
MUR18		0.51			0.56	0.68		0.92	0.91					0.64				6
MUR18		0.51			0.56				0.91		0.64							4
MUR18		0.51			0.56	0.68		0.92	0.91									5
MUR19	Edge				0.78		0.51	0.93			0.66						0.97	5
MUR19			0.99	0.61	0.78			0.93			0.66						0.97	6
MUR19					0.78	0.73		0.93			0.66						0.97	5
MUR19					0.78	0.73												2
MUR19					0.78	0.73					0.66							4
MUR19					0.78	0.73		0.93			0.66						0.97	5
MUR23	Edge	0.55				0.62				0.96	0.62	0.64			0.58	0.58	0.97	8
MUR23		0.55				0.62		0.90	0.90		0.62	0.64	0.68			0.58		8
MUR23		0.55				0.62				0.96	0.62	0.64			0.58	0.58	0.97	8
MUR23		0.55				0.62		0.90			0.62	0.64	0.68		0.58	0.58	0.97	9
MUR23		0.55				0.62		0.90		0.96	0.62	0.64	0.68		0.58	0.58		9
MUR23		0.55				0.62		0.90			0.62	0.64				0.58		6
MUR28	Edge	0.55				0.62			0.90			0.64	0.68		0.58	0.58	0.97	8
MUR28		0.55				0.62			0.90		0.62	0.64	0.68	0.91	0.58	0.58	0.97	10
MUR28		0.55				0.62					0.62	0.64	0.68	0.91	0.58	0.58		8

Appendix E3 – Taxa predicted to occur with >50% probability but not collected from the Burra Creek sites in the riffle habitat

Site	Taxa	Hydrobiidae	Ancylidae	Acarina	Elmidae	Psephenidae	Podonominae	Tanypodinae	Chironominae	Baetidae	Leptophlebiidae	Caenidae	Corydalidae	Gomphidae	Hydrobiosidae	Glossosomatidae	Philopotamidae	Hydropsychidae	Conoesucidae	Leptoceridae	Total number of missing taxa
	SIGNAL-2	4	4	6	7	6	6	4	3	5	8	4	7	5	8	9	8	6	7	6	
QBYN1	Riffle					*0.79*	*0.59*	*0.53*					*0.50*	*0.61*	*0.60*				*0.77*		7
QBYN1						*0.79*	*0.59*	*0.53*					*0.50*	*0.61*	*0.60*	*0.56*			*0.77*		8
QBYN1							*0.59*	*0.53*					*0.50*	*0.61*					*0.77*		5
QBYN1							*0.59*	*0.53*					*0.50*		*0.60*	*0.56*			*0.77*		6
QBYN1						*0.79*	*0.59*	*0.53*					*0.50*	*0.61*	*0.60*	*0.56*			*0.77*		8
QBYN1							*0.59*	*0.53*	*1.00*				*0.50*		*0.60*	*0.56*			*0.77*		7
BUR1a	Riffle				*0.96*	*0.79*	*0.59*	*0.53*		*0.96*	*0.90*	*0.84*	*0.50*	*0.61*		*0.56*	*0.58*	*0.95*	*0.77*		13
BUR1a					*0.96*	*0.79*	*0.59*			*0.96*	*0.90*	*0.84*	*0.50*	*0.61*		*0.56*	*0.58*	*0.95*	*0.77*		12
BUR1a					*0.96*	*0.79*	*0.59*			*0.96*	*0.90*	*0.84*	*0.50*	*0.61*		*0.56*	*0.58*	*0.95*	*0.77*		12
BUR1C	Riffle	*0.57*	*0.57*				*0.57*				*0.87*			*0.51*	*0.85*						6
BUR1C		*0.57*	*0.57*	*0.67*	*1.00*		*0.57*							*0.51*	*0.85*					*0.51*	8
BUR1C		*0.57*	*0.57*	*0.67*	*1.00*		*0.57*							*0.51*	*0.85*					*0.51*	8
BUR2A	Riffle	*0.54*	*0.54*	*0.64*	*1.00*		*0.57*							*0.51*	*0.84*						7
BUR2A		*0.54*	*0.54*		*1.00*		*0.57*							*0.51*	*0.84*						6
BUR2A		*0.54*	*0.54*		*1.00*		*0.57*							*0.51*							5
BUR2B	Riffle	*0.54*	*0.54*		*1.00*		*0.57*							*0.51*	*0.84*						6
BUR2B		*0.54*	*0.54*		*1.00*		*0.57*	*0.68*						*0.51*	*0.84*						7
BUR2B		*0.54*	*0.54*		*1.00*		*0.57*	*0.68*						*0.51*							6
BUR2C	Riffle	*0.59*	*0.59*		*1.00*		*0.57*							*0.50*						*0.53*	6
BUR2C		*0.59*	*0.59*				*0.57*							*0.50*							4
BUR2C		*0.59*	*0.59*		*1.00*		*0.57*	*0.70*						*0.50*						*0.53*	7
BUR2C		*0.59*	*0.59*				*0.57*	*0.70*						*0.50*							5
BUR2C		*0.59*	*0.59*				*0.57*	*0.70*													4
BUR2C		*0.59*	*0.59*				*0.57*	*0.70*						*0.50*							5

Appendix E4 – Taxa predicted to occur with >50% probability but not collected from the Burra Creek sites in the edge habitat

Site	Taxa	Ancylidae	Planorbidae	Acarina	Hydrophilidae	Elmidae	Ceratopogonidae	Simuliidae	Podonominae	Tanypodinae	Leptophlebiidae	Caenidae	Corixidae	Coenagrionidae	Synlestidae	Gomphidae	Gripopterygidae	Ecnomidae	Conoesucidae	Calamoceratidae	Leptoceridae	Total number of missing taxa
	SIGNAL-2	4	2	6	2	7	4	5	6	4	8	4	2	2	7	5	8	4	7	7	6	
QBYN1	Edge		0.55			0.63									0.63		0.67	0.58	0.58			6
QBYN1			0.55			0.63									0.63		0.67	0.58	0.58			6
QBYN1			0.55			0.63					0.96				0.63		0.67	0.58	0.58			7
QBYN1			0.55			0.63											0.67	0.58	0.58			5
QBYN1			0.55			0.63												0.58	0.58			4
QBYN1			0.55			0.63												0.58	0.58			4
BUR1A	Edge		0.55			0.63					0.96	0.97			0.62		0.68	0.57	0.59			8
BUR1A			0.55			0.63					0.96	0.97	0.60		0.62		0.68	0.57	0.59		0.95	10
BUR1A			0.55			0.63						0.97			0.62			0.57	0.59			6
BUR1A			0.55			0.63						0.97	0.60		0.62			0.57	0.59			7
BUR1C	Edge			0.72	0.88	0.76			0.51				0.67	0.50							0.97	7
BUR1C		0.56			0.88	0.76			0.51				0.67	0.50							0.97	7
BUR1C		0.56		0.72	0.88	0.76			0.51				0.67	0.50							0.97	8
BUR2A	Edge		0.51			0.68																2
BUR2A			0.51		0.55	0.68											0.51					4
BUR2A			0.51		0.55	0.68											0.51					4
BUR2A			0.51			0.68							0.64				0.51					4
BUR2A			0.51		0.55	0.68							0.64				0.51					5
BUR2A			0.51		0.55	0.68											0.51					4
BUR2B	Edge	0.53		0.69	0.85	0.75	0.57														0.97	6
BUR2B					0.85	0.75				0.94												3
BUR2B				0.69	0.85	0.75	0.57			0.94												5
BUR2B				0.69	0.85	0.75	0.57	0.51														5
BUR2B				0.69	0.85	0.75		0.51														4
BUR2B					0.85	0.75				0.94												3
BUR2C	Edge	0.58		0.75	0.90	0.76		0.53	0.52					0.52		0.50				0.50		9
BUR2C		0.58			0.90	0.76			0.52				0.68	0.52		0.50				0.50		8
BUR2C				0.75	0.90	0.76			0.52				0.68	0.52						0.50		7
BUR2C		0.58			0.90	0.76		0.53	0.52					0.52		0.50				0.50		8
BUR2C		0.58			0.90	0.76		0.53	0.52				0.68	0.52						0.50		8
BUR2C		0.58			0.90	0.76		0.53	0.52				0.68			0.50				0.50		8

Appendix F - Taxonomic Inventory

Appendix F1. Taxonomic Inventory of macroinvertebrates collected from the riffle habitat at the Angle Crossing sites

CLASS / Order	Family / Sub-Family	Genus	MUR15	MUR16	MUR18	MUR19	MUR23	MUR28
ACARINA			■	■	■	■	■	■
BIVALVIA						■		
	Corbiculidae	*Corbicula*	■			■	■	■
Coleoptera	Elmidae	*Austrolimnius*	■					
		sp.				■	■	
	Gyrinidae	*Macrogyrus*				■		
	Hydrophilidae				■			
Decapoda	Palaemonidae	*Macrobrachium*			■		■	■
Diptera	Ceratopogonidae	*Ceratopoginae*		■		■		■
	Chironominae		■	■	■	■	■	■
	Empididae			■	■	■		■
	Orthocladiinae		■	■	■	■	■	■
	Simuliidae	*Austrosimulium*	■	■	■	■	■	■
		Simulium	■					
		sp.	■	■	■	■	■	■
	Tanypodinae				■			
	Tipulidae							■
Ephemeroptera	Baetidae	*Baetidae Genus 1*	■	■	■	■	■	
		Baetidae Genus 2	■	■	■	■	■	■
		sp.	■	■	■	■	■	■
	Caenidae	*Irapacaenis*		■		■		■
		Tasmanocoenis	■	■	■	■	■	■
		sp.	■	■	■	■	■	■
	Leptophlebiidae	*Atalophlebia*	■	■	■	■		■
		Jappa	■	■	■	■		■
		Nousia						■
		sp.	■	■	■	■	■	■
GASTROPODA	Physidae	*Physa*					■	
Hemiptera	Micronectidae	*micronecta*						■
Lepidoptera	Crambidae	*sf Nymphulinae sp.*					■	
OLIGOCHAETA			■	■	■	■	■	■
Plecoptera	Gripopterygidae	*Dinotoperla*	■		■	■	■	
		Illiesoperla	■				■	
		sp.	■	■	■	■	■	■
Trichoptera	Ecnomidae	*Ecnomus*	■	■	■	■	■	■
		sp.						■
	Hydrobiosidae	*Ulmerochorema*		■				
	Hydropsychidae	*Asmicridea*					■	■
		Cheumatopsyche	■	■	■	■	■	■
		Diplectrona					■	
		sp.	■	■	■	■	■	■
	Hydroptilidae	*Hydroptila*			■			■
		Orthotrichia	■	■	■	■		■
		Oxyethira		■		■		■
		sp.	■	■			■	■
Turbellaria	Dugesiidae	*Dugesia*				■		

Appendix F2. Taxonomic Inventory of macroinvertebrates collected from the edge habitat at the Angle Crossing sites

CLASS / Order	Faimly / Sub-Family	Genus	MUR15	MUR16	MUR18	MUR19	MUR23	MUR28
ACARINA			▨	▨	▨	▨	▨	▨
BIVALVIA								▨
	Corbiculidae	*Corbicula*			▨	▨		
		sp.				▨	▨	
	Sphaeriidae		▨					
Coleoptera	Elmidae		▨		▨	▨		
	Gyrinidae	*Macrogyrus*		▨				
	Hydrochidae	*Hydrochus*		▨	▨			
	Scirtidae		▨				▨	
Decapoda	Atyidae	*Paratya*	▨	▨	▨	▨	▨	▨
	Palaemonidae	*Macrobrachium*	▨	▨	▨	▨	▨	▨
Diptera	Ceratopogonidae	*Ceratopoginae*	▨	▨	▨	▨	▨	▨
		Forcipomyiinae						▨
	Chironominae		▨	▨	▨	▨	▨	▨
	Empididae		▨		▨		▨	▨
	Orthocladiinae		▨	▨	▨	▨	▨	▨
	Simuliidae	*Austrosimulium*	▨	▨	▨	▨	▨	▨
		sp.	▨	▨	▨	▨	▨	▨
	Stratiomyidae	*Odontomyia*		▨				
	Tanypodinae		▨	▨	▨	▨	▨	▨
	Tipulidae			▨				▨
Ephemeroptera	Baetidae	*Baetidae Genus 1*		▨		▨	▨	
		Baetidae Genus 2	▨			▨	▨	
		sp.	▨	▨	▨	▨	▨	▨
	Caenidae	*Irapacaenis*	▨		▨	▨	▨	▨
		Tasmanocoenis	▨	▨	▨	▨	▨	▨
		sp.	▨	▨	▨	▨	▨	▨
	Leptophlebiidae	*Atalophlebia*	▨	▨	▨	▨		
		Jappa	▨			▨		
		sp.	▨	▨	▨	▨	▨	▨
GASTROPODA	Ancylidae						▨	
	Lymnaeidae	*Pseudosuccinea*					▨	
	Physidae	*Physa*	▨			▨	▨	
Hemiptera	Micronectidae	*micronecta*	▨	▨	▨	▨		▨
	Notonectidae	*Anisops*			▨			
		Enithares			▨			
		Paranisops		▨	▨			▨
		sp.		▨				
	Veliidae	*Microvelia*		▨				
Hydrozoa	Hydridae	*Hydra*			▨			
Lepidoptera	Crambidae	*sf Nymphulinae sp.*	▨					
Odonata	Gomphidae			▨				
OLIGOCHAETA			▨	▨	▨	▨	▨	▨
Plecoptera	Gripopterygidae	*Dinotoperla*	▨	▨	▨			
		Illiesoperla					▨	
		sp.	▨	▨	▨		▨	
Temnocephalida	Temnocephalidae	*Temnocephala*	▨	▨		▨		
Trichoptera	Calamatoceridae	*Anisocentropus*	▨					
	Ecnomidae	*Ecnomus*	▨	▨	▨	▨	▨	
		sp.	▨	▨	▨			
	Hydropsychidae	*Asmicridea*					▨	
		Cheumatopsyche	▨	▨		▨	▨	▨
		sp.		▨		▨	▨	▨
	Hydroptilidae	*Hellyethira*		▨	▨	▨	▨	▨
		Hydroptila				▨		
		Orthotrichia	▨	▨	▨	▨	▨	
		Oxyethira	▨	▨		▨	▨	
		sp.	▨	▨	▨	▨	▨	▨
	Leptoceridae	*Notalina*	▨					

CLASS / Order	Faimly / Sub-Family	Genus	MUR15	MUR16	MUR18	MUR19	MUR23	MUR28
		Oecetis	■			■	■	
		Triaenodes	■			■	■	
		Triplectides	■		■			
		sp.	■		■	■		■
Turbellaria	Dugesiidae	*Dugesia*	■		■	■		

Appendix F3. Taxonomic Inventory of macroinvertebrates collected from the riffle habitat at the Burra Creek sites

CLASS / Order	Family / Sub-Family	Genus	BUR1A	BUR1C	BUR2A	BUR2B	BUR2C	QBYN1
ACARINA			■	■	■	■	■	■
BIVALVIA	Sphaeriidae					■	■	
Coleoptera	Dytiscidae	Platynectes	■					
	Elmidae	Austrolimnius		■			■	■
		sp.					■	■
	Gyrinidae	Macrogyrus					■	
	Hydraenidae	Hydraena	■					
	Psephenidae	Sclerocyphon					■	■
	Scirtidae		■	■	■	■	■	
Diptera	Ceratopogonidae	Ceratopoginae	■	■	■	■	■	■
		Forcipomyiinae		■				
	Chironominae		■	■	■	■	■	■
	Dolichopodidae						■	
	Empididae			■	■	■	■	
	Orthocladiinae		■	■	■	■	■	■
	Simuliidae	Austrosimulium	■	■	■	■	■	■
		Simulium				■		
		sp.	■	■	■	■	■	■
	Stratiomyidae	Odontomyia		■		■		
	Tanypodinae		■	■	■	■	■	
	Tipulidae					■	■	
Ephemeroptera	Baetidae	Baetidae Genus 1			■	■	■	■
		Baetidae Genus 2			■	■	■	■
		sp.		■	■	■	■	■
	Caenidae	Irapacaenis					■	■
		Tasmanocoenis		■	■	■	■	■
		sp.		■	■	■	■	■
	Leptophlebiidae	Atalophlebia		■	■	■		
		Jappa			■	■	■	■
		Nousia					■	■
		sp.		■	■	■	■	■
GASTROPODA	Lymnaeidae	Lymnaea	■					
Hemiptera	Veliidae	Microvelia					■	
Lepidoptera	Crambidae							■
Odonata	Gomphidae	Hemigomphus					■	■
		sp.					■	■
	Telephlebiidae	Spinaeschna						■
OLIGOCHAETA			■	■	■	■	■	■
Plecoptera	Gripopterygidae	Dinotoperla	■	■		■	■	
		Illiesoperla				■	■	■
		sp.	■	■	■	■	■	■
Temnocephalida	Temnocephalidae	Temnocephala		■	■			
Trichoptera	Ecnomidae	Ecnomina	■					
		Ecnomus		■	■	■	■	■
		sp.			■	■	■	■
	Glossosomatidae	Agapetus						■
	Hydrobiosidae	Taschorema			■		■	■
		Ulmerochorema	■					
		sp.	■			■	■	
	Hydropsychidae	Asmicridea					■	■
		Cheumatopsyche		■	■	■	■	■
		sp.			■	■	■	■
	Hydroptilidae	Hellyethira		■	■		■	■
		Hydroptila			■			■
		Oxyethira	■			■	■	■
		sp.			■	■	■	■
	Leptoceridae	Notalina		■			■	
		Oecetis				■	■	■
		Triaenodes						■

CLASS / Order	Family / Sub-Family	Genus	BUR1A	BUR1C	BUR2A	BUR2B	BUR2C	QBYN1
		Triplectides			■			
		sp.					■	
	Philopotamidae	Chimarra			■	■	■	■
		sp.						■
Turbellaria	Dugesiidae	Dugesia	■		■	■	■	■

Appendix F4. Taxonomic Inventory of macroinvertebrates collected from the edge habitat at the Burra Creek sites

CLASS / Order	Family / Sub-Family	Genus	BUR1A	BUR1C	BUR2A	BUR2B	BUR2C	QBYN1
ACARINA			■	■		■	■	■
Amphipoda	Ceinidae				■			
	Talitridae			■				
BIVALVIA	Corbiculidae	Corbicula				■		
		sp.					■	
	Sphaeriidae				■		■	■
Coleoptera	Dytiscidae	Megaporus			■			
		Necterosoma	■	■	■		■	■
		Sternopriscus			■			
		sp.	■	■	■	■	■	■
	Gyrinidae	Macrogyrus				■	■	
	Hydrochidae	Hydrochus	■			■		
	Hydrophilidae	Berosus			■			
		sp.			■			
	Psephenidae	Sclerocyphon					■	
	Scirtidae		■		■	■		■
	Staphylinidae					■		
Decapoda	Atyidae	Paratya		■	■	■	■	■
Diptera	Ceratopogonidae	Ceratopoginae	■	■	■	■	■	■
		Forcipomyiinae		■				■
		sp.					■	
	Chironominae		■	■	■	■	■	■
	Culicidae	Aedes	■					■
	Dixidae		■	■	■			■
	Empididae		■				■	
	Orthocladiinae		■	■	■	■	■	■
	Simuliidae	Austrosimulium	■	■	■	■	■	■
		sp.		■		■		
	Stratiomyidae	Odontomyia			■	■		■
	Tanypodinae		■	■	■	■	■	■
	Tipulidae		■			■		
Ephemeroptera	Baetidae	Baetidae Genus 1		■	■	■		■
		Baetidae Genus 2		■		■		
		Centroptilum		■		■	■	
		Cloeon	■		■	■		■
		sp.	■	■	■	■	■	■
	Caenidae	Irapacaenis						■
		Tasmanocoenis		■	■	■	■	■
		sp.		■	■	■	■	■
	Leptophlebiidae	Atalophlebia		■	■	■	■	■
		Jappa				■	■	
		Nousia				■		
		sp.	■	■	■	■	■	■
GASTROPODA							■	
	Planorbidae	Ferrissia	■	■	■	■	■	■
	Ancylidae					■		
	Lymnaeidae	Lymnaea		■				
		Pseudosuccinea	■		■	■		■
	Physidae	Physa		■	■	■	■	■
Hemiptera	Micronectidae	micronecta	■		■	■	■	■
	Notonectidae	Anisops			■			
		Enithares		■	■	■		■
		Notonecta	■			■		
		Paranisops			■	■		
		sp.						■
	Veliidae	Microvelia			■	■		
Lepidoptera	Crambidae		■					
Odonata	Aeshnidae	Adversaeschna		■				
	Coenagrionidae	Agriocnemis				■		

CLASS / Order	Family / Sub-Family	Genus	BUR1A	BUR1C	BUR2A	BUR2B	BUR2C	QBYN1
		Austrocnemis					■	
		Ischnura				■		
		sp.	■		■	■		
	Epiprocta						■	■
	Gomphidae					■	■	
	Libellulidae							■
	Synlestidae	Synlestes						■
	Zygoptera		■	■	■	■	■	■
OLIGOCHAETA			■	■	■	■	■	■
Plecoptera	Gripopterygidae	Dinotoperla			■			
		Illiesoperla				■		
		sp.	■		■	■	■	■
Temnocephalida	Temnocephalidae	Temnocephala	■	■		■	■	
Trichoptera					■		■	
	Calamatoceridae	Anisocentropus						■
	Ecnomidae	Ecnomina			■			
		Ecnomus		■	■	■	■	
		sp.			■	■	■	
	Hydropsychidae	Cheumatopsyche	■				■	
		sp.				■		
	Hydroptilidae	Hellyethira	■	■	■	■	■	■
		Orthotrichia		■				
		Oxyethira					■	
		sp.	■		■		■	■
	Leptoceridae	Notalina	■				■	■
		Oecetis					■	■
		Triaenodes	■					■
		Triplectides			■	■	■	■
		sp.	■		■		■	■
Turbellaria	Dugesiidae	Dugesia						■

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