ACTEW Water

Murrumbidgee Ecological Monitoring Program

Autumn 2013

November 2013

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 background aquatic ecology data prior to the construction of, and following commissioning of, the Murrumbidgee to Googong (M2G) transfer project and the Murrumbidgee Pump Station.

The M2G ecological monitoring component is consistent with the Operation Environmental Management Plan (OEMP,2012) and associated Ecological Monitoring Sub Plan which respond to operational requirements as well as commitments made during the EIS and the subsequent environmental approvals process.

Collectively, there are four component areas being considered under the MEMP:

Part 1 - Angle Crossing (M2G)

ACTEW Water has constructed an additional pumping intake structure and pipeline to abstract water from the Murrumbidgee River near Angle Crossing (southern border of the ACT). The system is designed to pump a nominal 100 ML/d, and was completed in August 2012;

Part 2 - Burra Creek (M2G)

This component of the ecological monitoring programme aims to establish the baseline river condition prior to water transfer discharges into Burra Creek and then to continue monitoring after the commencement of the operation phase of the M2G project to determine what changes, if any, are attributable to water discharges from the Murrumbidgee River into Burra Creek;

Part 3 - Murrumbidgee Pump Station

The Murrumbidgee Pump Station (MPS) is located just downstream of the Cotter River confluence with the Murrumbidgee River. The Murrumbidgee Pump Station has undergone a significant upgrade which increased its pumping capacity to Stromlo Water Treatment plant from 50ML/d to approximately 150ML/d. The framework for this programme responds primarily to the ACTEW water abstraction licence reporting requirements. Water abstraction at the MPS, requires an assessment of the response of the river through monitoring methods that can quantify subtle impacts;

Part 4 - Tantangara to Burrinjuck

One of the project options put forward in the ACT Water Futures Strategy was the "Tantangara transfer" which involves transferring water from the Tantangara Reservoir on the upper Murrumbidgee River to the ACT via run of river flow, and then abstracting the water and transferring it to the Googong Reservoir via M2G. This provides a source of water that is less dependent on rainfall within the ACT.

The key results from the autumn 2013 sampling run are summarised below:

Part 1 – Angle Crossing

Low flows characterised the autumn sampling run with base flows over this period were the second lowest since the beginning of the MEMP. Two scheduled M2G maintenance runs occurred in autumn 2013; the first in late March and the second in late May. Each pump run occurred over a period of three days with a total volume of 65 ML transferred in March, and 60 ML in May. Nutrient concentrations were generally inside the ANZECC and ARMCANZ (2000) guideline range. Several water quality parameters exceeded guideline trigger values, generally due to rainfall events; however pH values were inside the historical range of natural variation recorded at these sites.

Continuously gauged water quality data showed no sign of significant changes relating to water abstraction at Angle Crossing. This is attributed to the low proportion of the abstraction relative to base flows during the M2G maintenance runs, and the short duration of the abstraction period overall.

Periphyton data indicated no differences between upstream and downstream sites based on ash free dry mass (AFDM) and chlorophyll-a concentration measurements. There appeared to be a gradual increase in AFDM among the upstream (of Angle Crossing) sites with distance downstream compared to more even distributions downstream. The cause of this pattern is unclear at this point, but is likely due to differences in substrate composition between sites.

AUSRIVAS results showed that all sites were assessed as BAND B ("significantly impaired") which is the same outcome as the autumn 2012 study, when base flows were 80% higher than in autumn 2013. There was some evidence of strong within-site variability in the relative abundances of certain taxa (e.g. at MUR 18 and 19). Increased within-site variability at these sites could be a sign of stress under low flow conditions. Alternatively, small scale changes in near bed hydraulics within these sites or differences in habitat composition in different parts of the riffle habitat could explain this result, though increased habitat heterogeneity can also be associated with periods of low flow due to reductions in wetted area and associated changes to the location, extent, inundation depth and velocities in riffle zones within a given reach.. The fact that similar AUSRIVAS results occurred under low and high flow disturbances indicates a high resistance to change in this system and also reflects the fact that although there are changes in relative abundances, the overall composition of the macroinvertebrates stays relatively stable. Alternatively, it could mean that the ACT AUSRIVAS model is not sensitive enough to detect the impacts of changes to the macroinvertebrate community due to changes in flow.

Part 1 Recommendations

It is recommended that long-term data analysis should be carried out to assess the long term trends in the biological and water quality variables in response to hydrological variables. It is suggested that this be done as a separate report so that the seasonal reporting is left in the current format. As part of the long-term data analysis, taxa missing from the AUSRIVAS models should be looked at to determine any potential points of change that may exist along hydrological gradients. This could assist in the prediction of macroinvertebrate community responses based on certain abstraction regimes, and may assist in the development of more refined biological "health" targets for the Murrumbidgee River during the operation and standby phases of the M2G pipeline.

Spring 2013 and subsequent sampling could be undertaken to target abstraction periods during further maintenance runs. In this way, the influence of naturally occurring hydrological disturbances may be separated resulting in more robust estimates of water quality and biological responses to water abstractions. The recommended approach would be to collect samples prior to a given scheduled maintenance run and then again after the abstraction period, assuming flows in the Murrumbidgee are relatively low to reflect a period where full scale pumping may be undertaken in future. Comparisons of post abstraction to pre abstraction data and previous seasonal data may provide increased information of subtle differences.

Part 2 – Burra Creek

Autumn sampling occurred during a prolonged period of low flows in Burra Creek and the Queanbeyan River following a particularly dry summer and autumn, and during this sampling run the native Burra Creek site was completely dry. Two maintenance runs of M2G occurred within the autumn sampling period (the first occurred in March and the second in late May) which elevated the seasonal averages in Burra Creek.

Water quality responses to the M2G maintenance releases were short-lived and returned to pre-release levels, usually within 24 hours of the M2G pumps shutting down, indicating no lasting effects from the releases. As reported in spring 2012, the water quality responses generally reflected parameter variation seen during and following natural events.

Chlorophyll-a derived from periphyton samples indicated significantly higher concentrations upstream of the discharge weir compared to the Queanbeyan River control site but despite the higher percentile values at upstream sites, there was no difference between locations in Burra Creek. Ash Free Dry Mass was consistent amongst all sampling sites. The high chlorophyll-a concentrations at BUR1c are related to higher coverage of filamentous algae relative to the other sites. The higher coverage of filamentous algae and detrital material at BUR1c may be a reflection of how the conditions without the M2G maintenance flows in the downstream reaches could transpire without periodic natural high flow events.

BUR2c was assigned a BAND A (close to reference) by the AUSRIVAS model; while the remaining sites, including the Queanbeyan Control site, were assessed as BAND B. These results indicate an overall decline at QBYN 1 and BUR 2a since autumn 2012; however, there was no change at the remaining sites. The overall composition of the macroinvertebrate communities is indicative of low flows, showing a high amount of within site variability and communities tended to be dominated by tolerant taxa such as chironomids and caenid mayflies and fewer taxa that require fast flowing water. Riffle habitat samples also contained several taxa that are usually associated with pools and edge habitat. This was particularly evident at BUR1c and BUR2a where the riffle samples showed high similarity from the multivariate analysis with their associated edge samples. This is consistent with the gradual isolation of fringing vegetation and edge habitat that was noted at these sites. The results from autumn 2013 are not unique to this particular sampling run. Low flow effects have been seen previously including the drying of riffle habitat at BUR1a, channel encroachment and fine sediment deposition in riffles and pools. These patterns are usually seasonal and the data obtained over the course of this project suggest that re-colonisation and re-establishment of sensitive taxa is usually relatively fast following spring rainfall and the establishment of surface flows.

Part 2 Recommendations

In a similar vein to the recommendations made in Part 1, long term analysis should be carried out on the data collected for the Burra Creek component of the MEMP. These analyses will assess the long term trends in biological and water quality variables in response to hydrological variables. As part of the long term analysis, targeted analyses of taxa missing from the AUSRIVAS models should be looked at to determine points of change along hydrological variables. This may have particular value to the Burra Creek component as it may facilitate the development of biological "health" targets for Burra Creek during the extended standby phases of the M2G project. Maintenance flows may then be planned to assist in meeting these targets during periods of low flows or related issues such as proliferations of filamentous algae growth or stream channel encroachment by vegetation.

It is also recommended that the trigger levels for EC and pH as suggested in the Burra Creek Ecological Management Plan (BEMP) be used in addition to the ANZECC guidelines in the next round of reporting to provide a more realistic assessment of the naturally high values of these parameters in Burra Creek. These would be included in the current format as a compliment to the ANZECC guidelines as season-specific upper limits in recognition that these parameters exhibit strong seasonal fluctuations.

Part 3 – Murrumbidgee Pump Station

The flow in the Murrumbidgee River at the MPS sites was significantly lower during autumn 2013 compared to autumn 2012, with mean flow levels dropping 80% compared to flows recorded during autumn 2012. Most water quality parameters recorded during autumn showed compliance with the ANZECC & ARMCANZ water quality guidelines. The only parameter which was outside guideline values was pH. Elevated pH readings were recorded at all sites. This finding however is consistent with the trend present during previous seasons for elevated pH values at these sites. Nutrient concentrations have improved since autumn 2012 with no guideline exceedances for total phosphorus, and total nitrogen only exceeding guidelines at three sites.

Analysis of periphyton biomass and organic estimates derived from chlorophyll-a and AFDM concentrations respectively indicate no statistical difference between sampling locations. The main source of variation as indicated by the ANOVA model was within site variability as opposed to differences due to location, implying that there is no influence by the Murrumbidgee Pump Station and the M2C project on periphyton.

The AUSRIVAS results showed that all sites received an overall assessment of Band-B, or "significantly impaired." This is consistent with results for the previous two years in which a majority of assessments have been Band-B. No significant difference was detected between the upstream and downstream sites when the AUSRIVAS O/E 50 scores were analysed. However, there was a difference between locations in regards to relative abundances of macroinvertebrates with much larger numbers collected at the downstream sites.

The results from the water quality, periphyton and macroinvertebrate data collected in autumn 2013 show no detectable impact upon the Murrumbidgee River from the upgraded MPS or subsequent operation of M2C. However, since autumn 2011 the results from the genus level data have indicated a more prominent separation between the upstream and downstream sites, which were not detected at the family level. This separation could be related to the Enlarged Cotter Dam, Bendora Scour Valve or a shift in the hydrological regime following the breaking of the pre-2010 drought conditions.

Part 3 Recommendations

It is advised that the current program be continued using the existing protocols to maintain a constant dataset to enable robust long term analysis in future reports. In light of this, it is suggested that if the MPS pumping schedule, Cotter Dam release schedule and the Bendora Scour Valve operation schedule are made available to GHD prior to the sampling period, it would aid sample scheduling to improve interpretation of the data to more accurately assess potential impacts.

Part 4 – Tantangara to Burrinjuck

The autumn 2013 sampling period of the Upper Murrumbidgee River catchment occurred during the second driest summer-autumn period since 2008. This had implications for all sites. For example, the extent of the edge habitat was notably reduced compared to the same period in 2012 due to a receding wetted area, resulting in the loss of connectivity with fringing vegetation and the persisting habitat being significantly shallower than during previous autumns. Some sites increased the riffle area with shallow runs turning into riffle habitat, while other sites simply showed riffles characterised by increased area of exposed boulders and bedrock. The lower flows were associated with lower velocities and backwaters which appeared ideal conditions for proliferations of filamentous green algae, particularly downstream of the Cotter River confluence.

Overall, Zone 1 (Tantangara Dam to Cooma) was seen to be different in terms of water quality and macroinvertebrate community compared to Zone 2 (Cooma to Angle Crossing) and Zone 3 (Angle Crossing to Molonglo River confluence). Water quality was generally of a higher quality among Zone 1 sites and tended to have high compliance with the ANZECC and ARMCANZ water quality guidelines, due to mainly native land use and position in the catchment. Although some differences were found between Zone 2 and Zone 3, they appeared to be largely similar in terms of site condition, determined by AUSRIVAS modelling. This is probably a reflection of the shared influences of grazing and urbanisation within the catchments. Zone 4 (Molonglo River confluence to Burrinjuck Reservoir) sites were more degraded than sites upstream showing poorer ANZECC & ARMCANZ water quality compliance than other Zones, with highly enriched nutrient levels most likely from the Molonglo River inflow.

The AUSRIVAS assessments showed that although flow conditions leading into the autumn 2013 sampling period were characterised by low flows, the results are consistent with previous years that actually had higher flows, with overall site assessments being either Band-A ("close to reference") or Band-B ("significantly impaired"). Compared to autumn 2012 there were improvements in the AUSRIVAS bands for some of the riffle samples in Zone 3 (below the M2G abstraction point). This provides support to the conclusion that water abstraction from Murrumbidgee River during commissioning and from maintenance flows does not appear to have influenced the results of the Tantangara to Burrinjuck component of the MEMP. The responses are likely to vary depending on the timing, duration and magnitude of the environmental flow releases from Tantangara Reservoir as well as the abstraction at Angle Crossing.

Part 4 Recommendations

As mentioned in previous component summaries; a formal statistical review of historical data is recommended to determine long term trends in ecological health within the Upper Murrumbidgee River under different flow conditions.

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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 (statistics)
ANOVA	Analysis of Variance (statistics)
ANZECC	Australian and New Zealand Environment and Conservation Council
APHA	American Public Health Association
ARMCANZ	Agriculture and Resource management Council of Australia and New Zealand
AUSRIVAS	Australian River Assessment System
BACI	Before After Control Impact
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
OCD	Oligochaeta, Chironomidae and other Diptera
SIMPER	Similarity Percentages
TN	Total Nitrogen
TP	Total Phosphorus

1. Introduction

During the recent drought period 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 100ML/d;
2. Murrumbidgee Pump Station (MPS): adjacent to the existing Cotter Pump station to increase pump capacity from ~50ML/d to 150ML/d (nominally 100ML/d);
3. Tantangara Reservoir release for run of river flow to the M2G abstraction point at Angle Crossing, and;
4. A new 78GL 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.

There are 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).

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

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

1.1 Background of major projects

1.1.1 Parts 1 and 2 - Murrumbidgee to Googong transfer pipeline (M2G)

The Murrumbidgee to Googong transfer incorporates **Part 1** (Angle Crossing) and **Part 2** (Burra Creek).

The pumping system at Angle Crossing transfers water from the Murrumbidgee River through a 12km underground pipeline into Burra Creek. The water is then be transported a further 13km 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 dictated 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 species 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.

1.1.2 Part 3 - Murrumbidgee Pump Station (MPS)

The Murrumbidgee Pump Station (MPS) is located just downstream of the Cotter River confluence with the Murrumbidgee River. It is adjacent to the Cotter Pump Station which can abstract up to 100 ML/d, contributing to the water supply for the ACT. New infrastructure has increased the abstraction amount from the Murrumbidgee River to approximately 150 ML/d via the MPS. The upgraded infrastructure also provides a recirculating flow from the Murrumbidgee to the base of the Enlarged Cotter Dam (ECD), providing environmental flows to the lower Cotter Reach below the dam especially during the construction of the ECD. This project is referred to as Murrumbidgee to Cotter (M2C) transfer. The MEMP project does not aim to monitor the effects of the M2C transfer, but rather provides a characterisation of the Murrumbidgee River condition upstream and downstream of the MPS.

The upgraded pump station was commissioned in 2010. Pumping is dependent on demand, licence requirements, and water quality. The framework for this programme responds primarily to requirements of ACTEW's water abstraction licence.

The increase in abstraction at the Murrumbidgee Pump Station (MPS) may place additional stress on the downstream river ecosystem. This monitoring programme has been established to monitor the condition of the Murrumbidgee River in terms of water quality and ecological condition at key sites both upstream and downstream of the abstraction point (MPS).

The information derived from this program will support ACTEW's and the ACT Environmental Protection Authority's (EPA) adaptive management approach to water abstraction and environmental flow provision in the ACT.

1.1.3 Part 4 -Tantangara Reservoir release for run of river flow to the M2G abstraction point at Angle Crossing

One of the new water security projects put forward was the "Tantangara transfer" which will involve transferring water from the Tantangara Reservoir in the upper Murrumbidgee River to the ACT via run of river flow, with the aim of providing a source of water that is less dependent on rainfall within the ACT. As previously mentioned, abstraction will be dictated by the storage level in Googong reservoir, the level of demand for the water, the availability of water in the Murrumbidgee River allowing for environmental flow requirements, and by the water quality trigger values.

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

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

1.2 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 (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 above, 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.

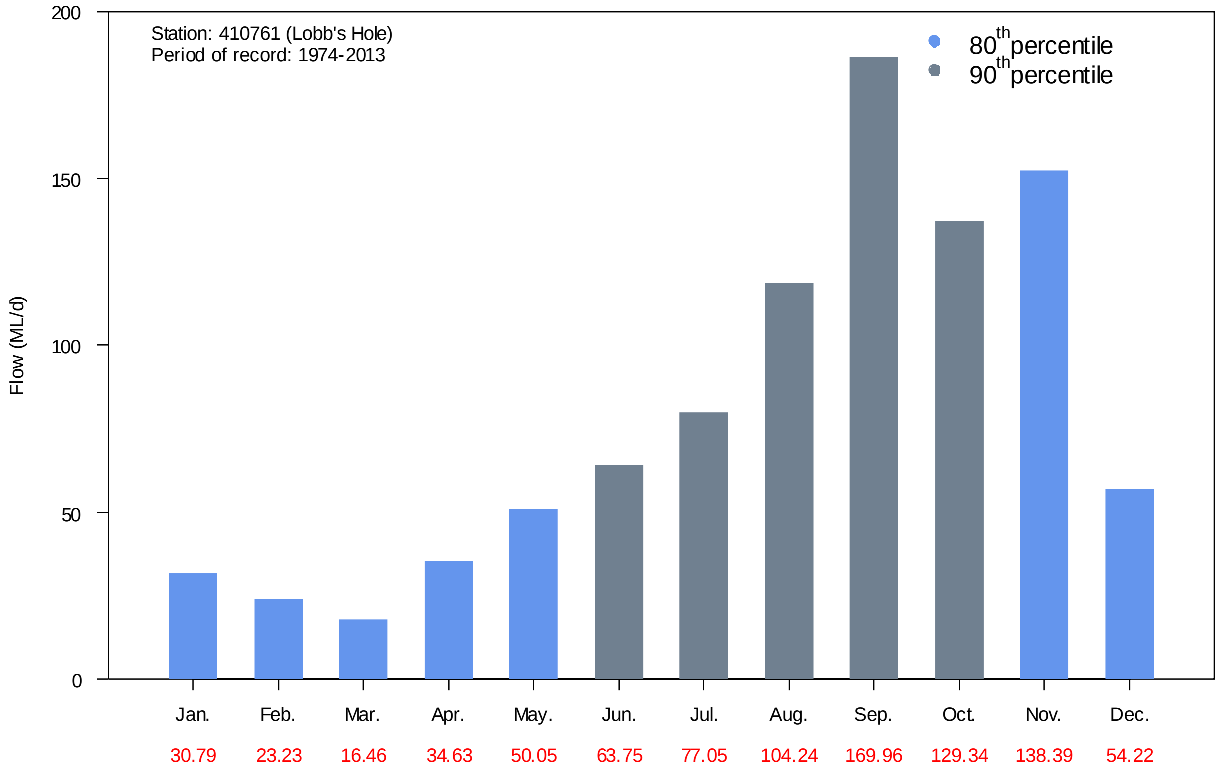

Figure 1-1. Environmental flow values for the operation of the M2G project

Note: Flow data values for data to 31/05/2013. 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 5096 km^2. As part of the Snowy Mountains Scheme, the headwaters of the Murrumbidgee River were 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 (Figure 1-2). More recently, during the period between November 2012 and May 2013, there has been a decline in base flows in the Murrumbidgee River following particularly dry summer and autumn. As of 31st May, base flows in the Murrumbidgee River are currently flowing at similar volumes to those seen in early 2010 and mid-2009 (Figure 1-2).

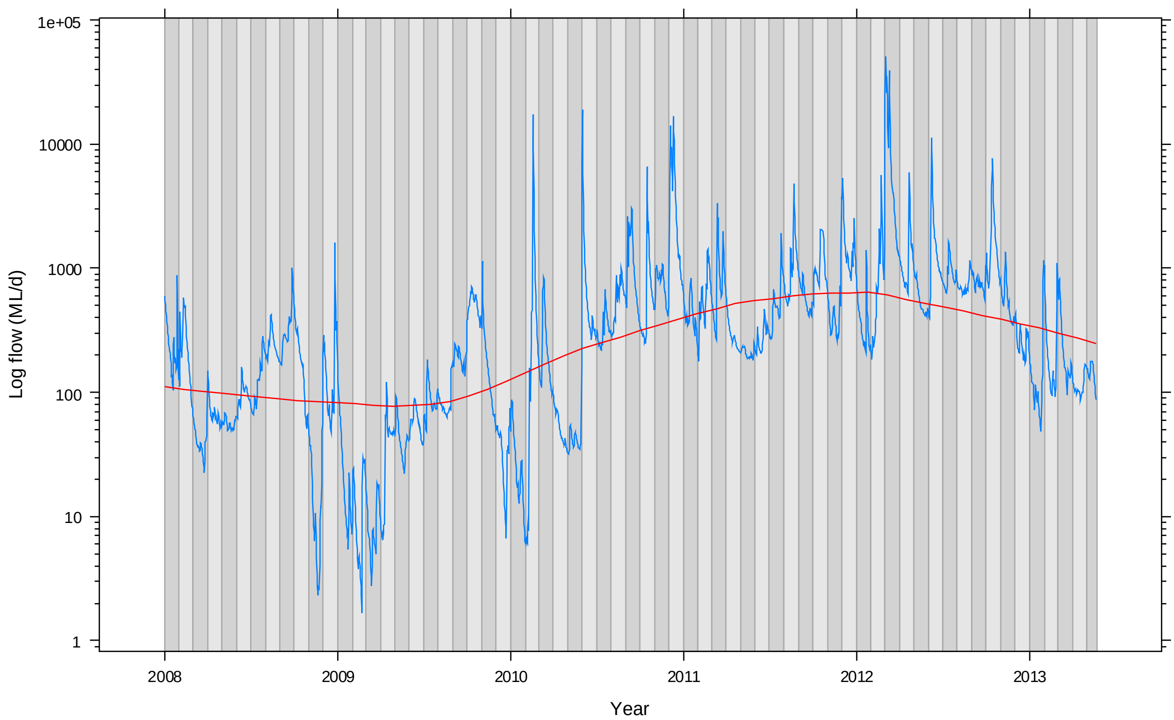

Figure 1-2. Hydrograph of the Murrumbidgee River at Lobb's Hole (410761) from 2008 to May 2013*

**The red line is a locally weighted smoother (LOWESS) 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.* 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 0.15ML/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, reflecting the low seasonal rainfall.

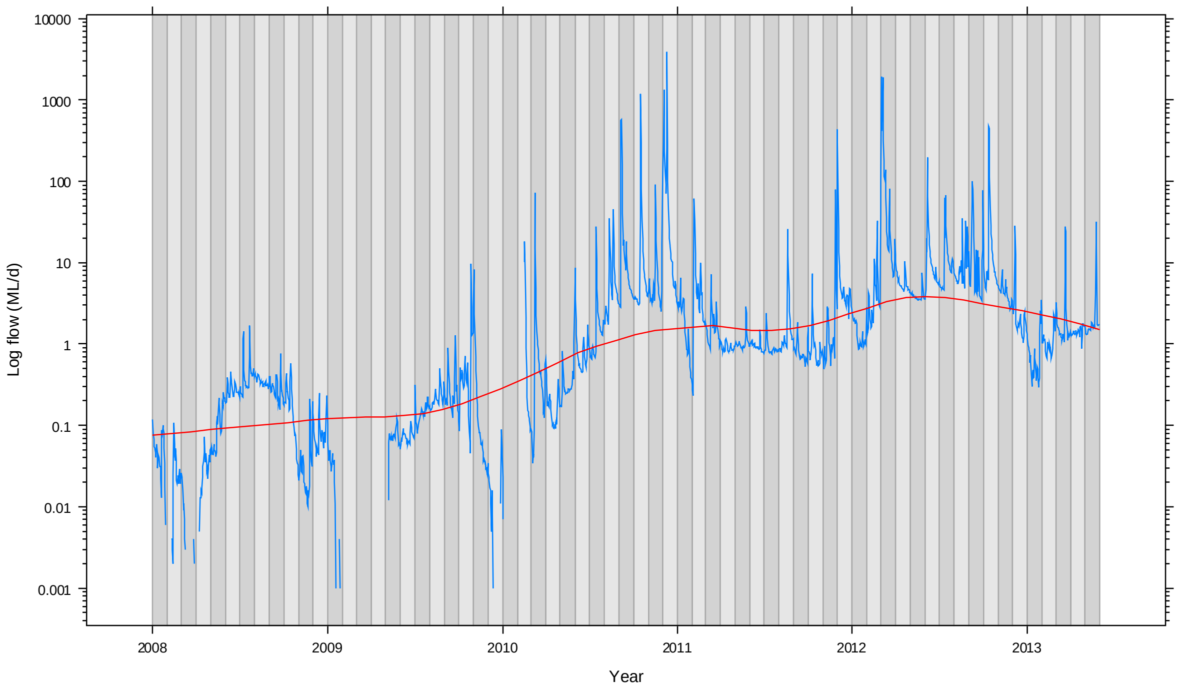

Figure 1-3. Hydrograph of Burra Creek at the Burra Road weir (410774) from 2008 to May 2013*

**The red line is locally weighted smoother (LOWESS) 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). Part 3 of the project assesses the condition of the Murrumbidgee River in terms of water quality and ecological condition at key sites both upstream and downstream of Murrumbidgee Pump Station (MPS) to assess potential impacts related to the increase in abstraction from the upgraded infrastructure; and Part 4 of the MEMP (Tantangara to Burrinjuck) assesses the physical, biological and water quality indicators along the length of the upper Murrumbidgee River from Tantangara to Burrinjuck reservoirs.

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 Tantangara Reservoir and in Burra Creek (downstream of the discharge point) 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 information regarding water quality, the structure of macroinvertebrate communities, and ecosystem health throughout the Upper Murrumbidgee catchment;
- to establish baseline and operational information on water quality and stream flow, macroinvertebrate communities, fish[2], 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 between Tantangara and Burrinjuck Reservoirs, and also 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.

The frequency, monitoring locations and resolution of the monitoring on the Murrumbidgee River and Burra Creek will differ between the components as changes occur at different spatial and temporal scales. 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.

[2] Currently being undertaken by TAMS

1.6 Scope of work

1.6.1 Parts 1-3: Angle Crossing; Burra Creek and MPS

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 autumn 2013 sampling. Specifically, as outlined in the MEMP proposal to ACTEW Corporation (GHD, 2012) this work includes:

- Sampling conducted in autumn 2013;
- 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.

1.6.2 Part 4: Tantangara to Burrinjuck

Several sites within this component of the MEMP are also key components of Parts 1-3 of this monitoring programme. The sampling regime for this component of the MEMP differs slightly to those reported in section 1.6.1. These differences are:

- Macroinvertebrate samples were not collected with replication (i.e. 1 per site and per habitat);
- Macroinvertebrate samples are counted and identified to the taxonomic level of family;
- Periphyton samples are not collected as part of this component of the project.

In order to compare data from the Tantangara to Burrinjuck study to those collected as part of other study components, the first sub-sample from the first replicate macroinvertebrate sample taken at each site from those other studies was selected for inclusion in the data analysis. As a result of this process, it should be recognised that there are small discrepancies between the taxonomic inventories, taxonomic richness measurements and presence / absence of taxa reported here and those reported in relation to other sub-sections of the MEMP.

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 they represent a continuous record of preceding environmental, chemical and physical conditions at a given site. Macroinvertebrates are also very useful indicators in determining specific stressors on freshwater ecosystems because many taxa have known tolerances to heavy metal contamination, sedimentation, and other physical or chemical changes Chessman (2003). Macroinvertebrate community assemblage, and two indices of community condition: the AUSRIVAS index and the proportions of three common taxa (the Ephemeroptera, Plecoptera, and Trichoptera, or EPT index), were used 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 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 (eg. Keen, 2001) took precedence over new sites – allowing 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 MEMP consists of 29 sites which meet these criteria. Details of these sites are given in Table 2-1 and are shown in Figure 2-1.

As the MEMP is separated by various components due to the large geographic and ecological scale of the project, some of the sites used in one component, overlap with sites used in a different component. Sampling sites were divided into four zones for Part 4 (Tantangara to Burrinjuck), which represent geographic or hydrological changes throughout the system (Allan and Castillo, 2008); and obvious changes in land use, erosional processes and/or other potential anthropogenic impacts. These classifications are to some extent subjective, but are based on previous frameworks which have suggested methods for such classifications (e.g. Frissell *et al*., 1986; Hynes, 1970; Allan and Castillo, 2008). Details of the four zones are provided in Table 2-2.

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) for Parts 1-3, and family level for part 4, to characterise each site. Periphyton was sampled in the riffle habitat at each site (Part 4 excluded) 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

Site Code	Location	Alt. (m)	Landuse	Component of the MEMP	Latitude	Longitude
MUR1	D/S Tantangara Reservoir	1200	Native	TB	-35.799448	148.676497
MUR2	Yaouk Bridge	1070	Grazing	TB	-35.826235	148.803273
MUR3	Bobeyan Road Bridge	968	Grazing	TB	-35.980250	148.840200
MUR4	Camp ground off Bobyon Road	968	Recreation / Grazing	TB	-35.980217	148.892800
MUR6	D/S STP Pilot Creek Road	743	Native / Residential	TB	-36.163200	149.095317
MUR9	Murrells Crossing	723	Grazing	TB	-36.109433	149.124983
MUR12	Through Bredbo township	698	Grazing / Residential / Recreation /Sand mining	TB	-35.956233	149.129217
MUR15	Near Colinton - Bumbalong Road	658	Grazing / Recreation	AC / TB	-35.866300	149.135017
MUR16	The Willows - Near Michelago	646	Grazing / Recreation	AC / TB	-35.688033	149.136867
MUR18	U/S Angle Crossing	608	Grazing	AC / TB	-35.587542	149.109902
MUR19	D/S Angle Crossing	608	Grazing / Recreation	AC / TB	-35.583027	149.109486
MUR22	Tharwa Bridge	572	Recreation / Grazing / Residential	TB	-35.508217	149.070700
MUR23	Point Hut Crossing	561	Recreation / Residential	AC /TB	-35.451317	149.074400
MUR27	Kambah Pool	519	Recreation / Residential	TB	-35.393317	149.009767
MUR931	"Fairvale" ~4km U/S of the Cotter Confluence	480	Grazing	MPS / TB	-35.372883	148.991050
MUR28	U/S Cotter River confluence	468	Grazing	AC / MPS / TB	-35.324382	148.950381
MUR935	Casuarina sands	471	Grazing	MPS / TB	-35.319483	148.951667
MUR937	Mt. MacDonald ~5km D/S of the Cotter Confluence	460	Grazing / ex-forestry/ Recreation	MPS / TB	-35.291817	148.9569
MUR29	Uriarra Crossing	445	Grazing	MPS / TB	-35.242983	148.952133
MUR30	U/S Molonglo Confluence	445	Grazing	TB	-35.239784	148.962613
MUR31	D/S Molonglo Confluence	443	Grazing	TB	-35.237050	148.974792
MUR34	Halls Crossing	393	Grazing	TB	-35.131550	148.944083
MUR37	Boambolo	372	Grazing / Sand mining	TB	-35.034217	148.896317
BUR1a	Upper Burra Creek	815	Native	Burra Creek	-35.598461	149.228868
BUR1c	Upstream Williamsdale Road	762	Grazing / residential	Burra Creek	-35.556511	149.221238
BUR2a	Downstream Williamsdale Road	760	Grazing	Burra Creek	-35.554345	149.224477
BUR2b	Downstream Burra Road Bridge	751	Woodland / Grazing	Burra Creek	-35.541985	149.230407
BUR2c	Approximately 1km u/s London Bridge	730	Recreational / Grazing	Burra Creek	-35.517894	149.261452
QBYN1	Flynn's Crossing	685	Recreational / Native	Burra Creek	-35.524317	149.303300

***Notes:** AC = Angle Crossing; BC = Burra Creek; MPS = Murrumbidgee Pump Station; TB = Tantangara to Burrinjuck*

Table 2-2. Zone structure of sites along the Murrumbidgee River

Macro-reach	Zone	Sites included	Land use
Tantangara – Cooma	1	MUR 1 – 4	Native. Reservoir within National Park. Agricultural land downstream of Yaouk.
Cooma – Angle Crossing	2	MUR 6-18	Land use is mainly for agriculture. Some urbanisation. STP upstream of MUR 6.
Angle Crossing – LMWQCC	3	MUR 19 - 30	Residential and urban development increases.
LMWQCC – Taemas Bridge	4	MUR 31 - 37	Intensive agricultural land use downstream of the LMWQCC. Distinct changes in water quality profile downstream of the Molonglo River confluence.

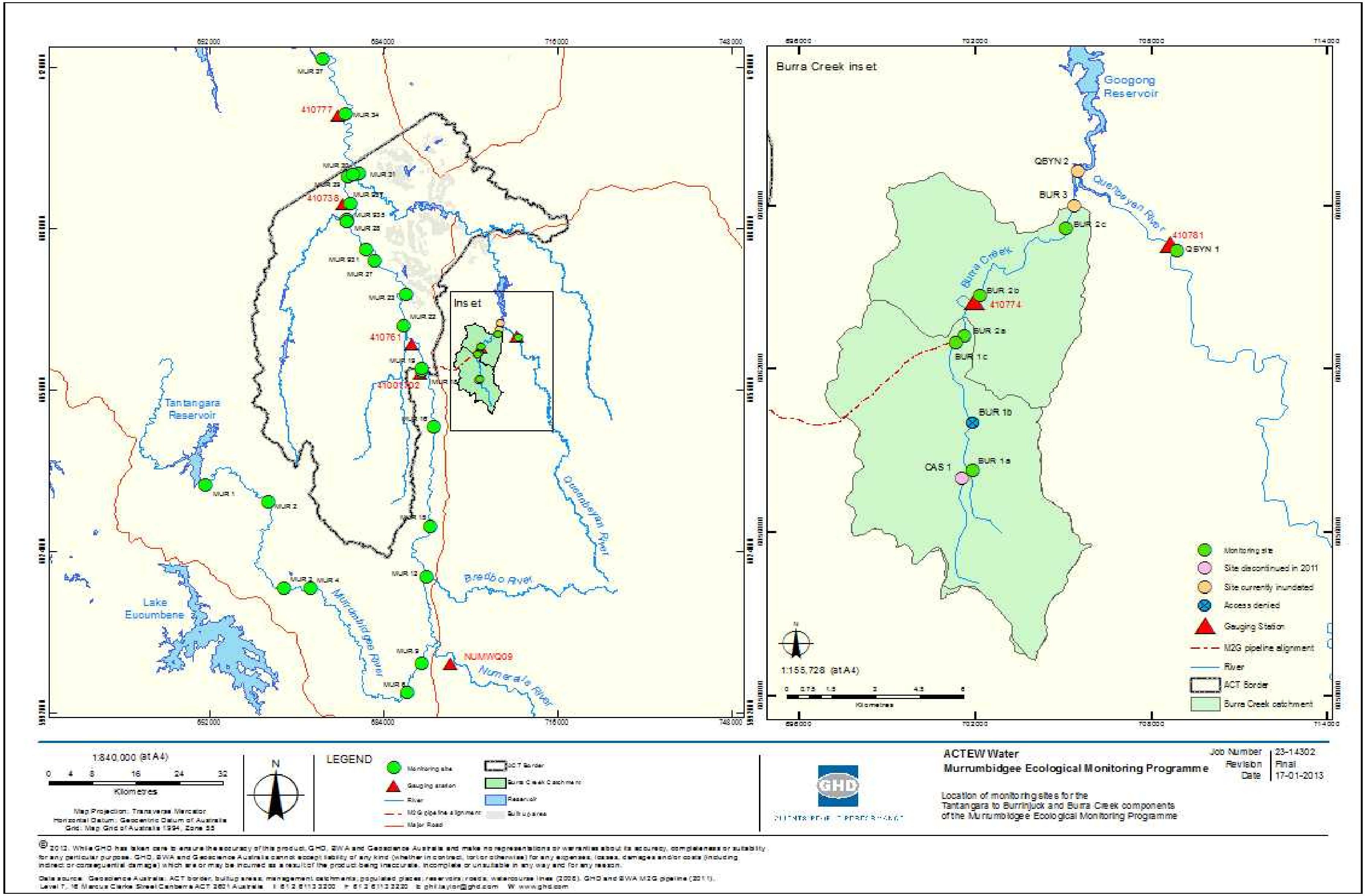

Figure 2-1. Map of site locations on the Murrumbidgee River, Burra Creek and the Queanbeyan River for the MEMP

2.1 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); at Mount MacDonald (downstream of the Cotter River confluence: 410738), Halls Crossing (at MUR 34: 410777), 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 2-3. 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 was 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 2-3. 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	AC, TB
410761	Murrumbidgee River @ Lobb's Hole (D/S of Angle Crossing)	WL, Q, pH, EC, DO, Temp, Turb, Rainfall	-35.5398	149.1001	AC, MPS, TB
410738	Murrumbidgee River @ Mt. MacDonald	WL, Q	-35.2916	148.9552	MPS, TB
410777	Murrumbidgee River @ Hall's Crossing	WL, Q, pH, EC, DO, Temp, Turb, Rainfall	-35.1327	148.9425	TB
410774	Burra Creek D/S road bridge	WL, Q, pH, EC, DO, Temp, Turb, Rainfall	-35.5425	149.2279	BC
410781	Queanbeyan River U/S of Googong Reservoir	WL, Q, pH, EC, DO, Temp, Turb, Rainfall	-35.5222	149.3005	BC

** 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.

2.2 Water quality

Baseline physico-chemical parameters including temperature, pH, electrical conductivity, turbidity and dissolved oxygen were recorded using a multiprobe Hydrolab® minisonde 5a at sites indicated in Table 2-1. The Hydrolab® 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 Hydrolab 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). 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.

2.3 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[3] 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[4] to total up to 6 samples per habitat per site (2 field replicates x 3 laboratory processed replicates). Macroinvertebrates were identified to genus level (where possible) using taxonomic keys outlined in Hawking (2000) and later publications. Specimens that could not be identified to the specified taxonomic level (i.e. immature or damaged taxa) were removed from the data set prior to analysis.

[3] Note that only one sample per habitat type was collected for Part 4 of the MEMP
[4] No replication of sub samples was carried out for Part 4 of the MEMP

2.4 Periphyton

Estimates of algal biomass were made using complementary data from both chlorophyll-a (which measures autotrophic biomass) and ash free dry mass (AFDM, which estimates the total organic matter in periphyton samples and includes the biomass of bacteria, fungi, small fauna and detritus in samples) measurements. 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)[5]. 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.

2.5 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 will be 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.

2.6 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.

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[5] Periphyton is not collected for Part 4 of the MEMP

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, 2012). 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 2013 sampling.

Principal Components Analysis (PCA) was conducted to determine the combination of physical/chemical variables that most strongly contributes to differences between Zones. From the available environmental variables, DO (mg/L) and TSS were omitted as these variables were strongly correlated with DO (% saturation) and turbidity, respectively. The variables TKN and Nitrite were also omitted as Nitrogen levels were better represented by Total Nitrogen. Draftsman plots were used in PRIMER to determine which data transformation, if any, should be applied to the environmental variables. Draftsman plots were examined for raw data (i.e. no transformation) and data which had square root, fourth root and log (x+1) transformations applied. Based on these plots, all data were left in their raw form except for Ammonia, Total Nitrogen and NOx which were subjected to fourth root transformation. Measurements of Ammonia that were at the limits of reporting (LOR) were divided by two (2) before inclusion in the PCA. However, interpretation of the PCA in relation to ammonia must be made with caution since there is no differentiation between the LOR values which falsely indicates a similarity between these sites.

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 Autumn 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 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.

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 (up- and downstream) was considered a fixed, constant effect. Data transformations were not necessary because the model assumptions were met on all accounts. Models were constructed 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.

All multivariate analyses were performed using PRIMER version 6 (Clarke and Gorley, 2006) Univariate statistics were performed using R version 3.0.1 (R Development Core Team, 2012).

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

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

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 “LMERConvenieceFucntions” (Trembley and Ransijn, 2013)

Part 1 - Angle Crossing

4. Angle Crossing

4.1 Summary of sampling and river condition

Autumn sampling was undertaken between 6th of May and 8th of May 2013. During this sample collection period, weather conditions were mostly fine with daily maximum temperatures ranging from 17 - 21°C. Flows were low (<200 ML/d) and stable during this sampling period owing to the absence of rainfall.

Overall there were noticeable reductions in habitat area at all sampling sites; however MUR 16 and MUR 28 were the only sites in which all macroinvertebrate samples were not collected. At these sites one edge habitat was missed due to a lack of adequate edge habitat for sampling.

Photographs of the sampling sites during autumn 2013 are shown in Plate 4-1.

4.2 Hydrology and rainfall

The flow and rainfall summaries for the upstream Angle Crossing and Lobb's Hole gauging stations are shown in Table 4-1. Total rainfall collected at Lobb's Hole in autumn 2013 was 50.2 mm which is approximately 80% less than the 251.2 mm that fell in autumn 2012 (Figure 4-1; Table 4-1). This resulted in low seasonal base flows (< 200 ML/d) across the sampling sites (Plate 4-1; Figure 4-2). Within the autumn period of 2013, there was one natural high flow event, which occurred at the end of February and extended into early March This event had two peaks – the first at 1118 ML/d in late February and the second at 899 ML/d in early March. Both peaks were less than 1:1 ARI events.

Since spring, there were two scheduled maintenance runs of M2G. The first occurred between the 19th of March and 21st and resulted in a total of abstraction of 68.55 ML from Angle Crossing. The second maintenance run occurred between the 22nd and the 24th of May with a total volume of 60.22 ML being abstracted from Angle Crossing (Table 4-2).

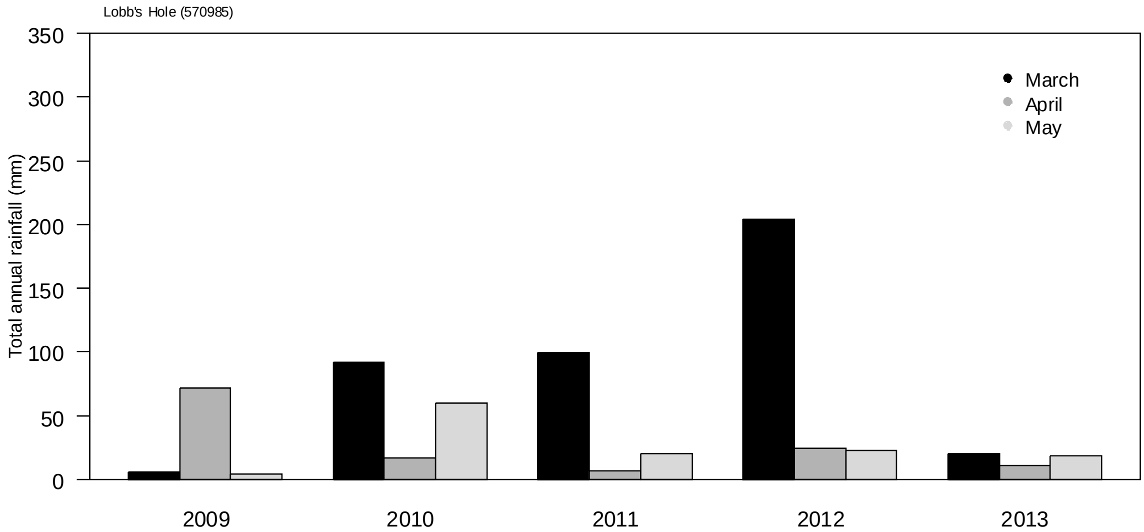


Figure 4-1. Annual comparisons of spring rainfall (mm) recorded at Lobb's Hole (570985)

Table 4-1. Autumn rainfall and flow summaries upstream and downstream of Angle Crossing

	Upstream Angle Crossing (41000270)		Lobb's Hole (410761)	
	Rainfall Total (mm)	Mean Flow (ML/d)	Rainfall Total (mm)	Mean Flow (ML/d)
March	14.6	253.2	20.2	279.4
April	13.6	101.7	11.0	108.2
May	14.2	133.3	19.0	135.8
Autumn (mean)	**42.4**	**162.7**	**50.2**	**174.4**

Table 4-2. Murrumbidgee to Googong maintenance runs and daily abstraction volumes during autumn 2013*

Date	Water volume abstracted (Megalitres)	Mean flow on the day of abstraction (ML/d) – upstream Angle Crossing (41001702)	Proportion of base flow abstracted
19/03/2013	10.07	119.1	0.09
20/03/2013	36.46	120.0	0.30
21/03/2013	22.02	123.0	0.18
22/05/2013	6.81	161.9	0.04
23/05/2013	43.02	168.9	0.25
24/05/2013	10.39	168.7	0.06

* Data supplied by ACTEW Water

MUR 15 Looking upstream

MUR 16 Looking upstream from the head of the riffle

MUR 18 Facing upstream

MUR 19 Looking upstream with the road crossing in the background

MUR 23 Looking downstream from the bridge

MUR 28 Looking upstream

Plate 4-1. Photographs of the sampling sites for the Angle Crossing component of the MEMP

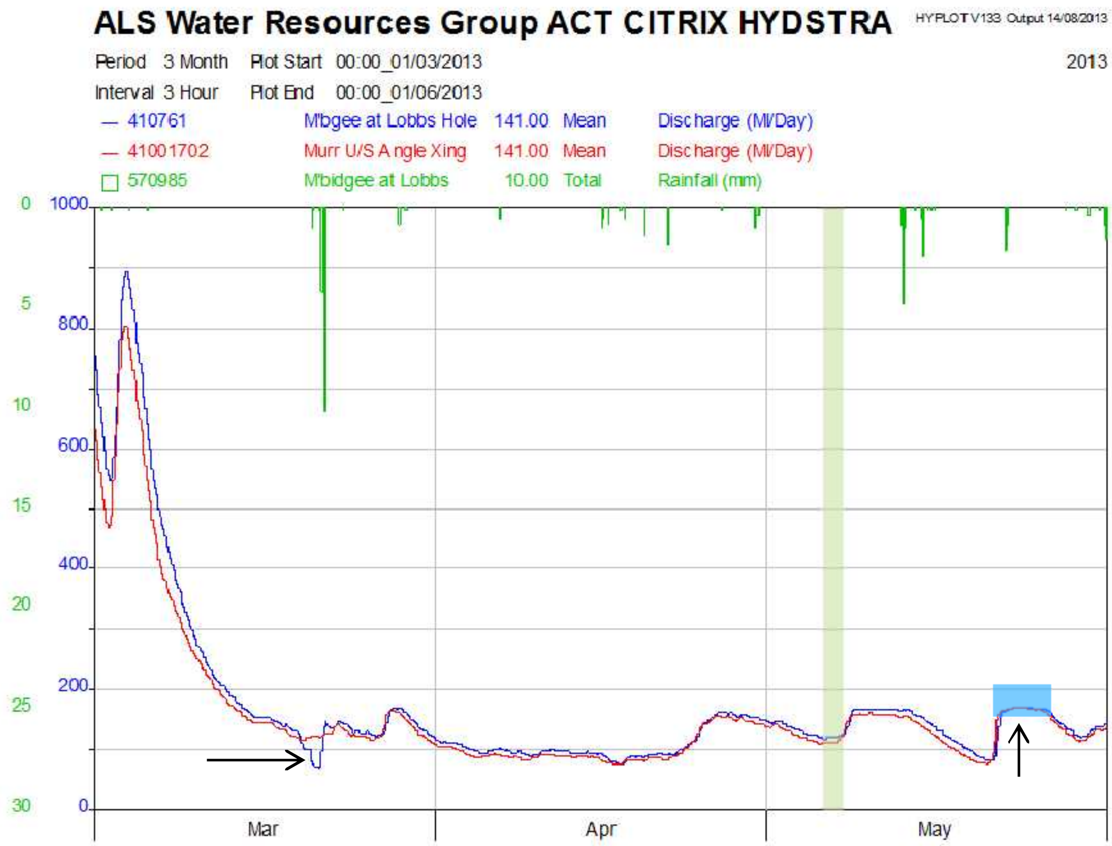


Figure 4-2. Autumn hydrograph of the Murrumbidgee River upstream of Angle Crossing (41001702) and downstream of Angle Crossing at Lobb's Hole (410761)*

Notes: Green shaded area indicates sampling period; arrows indicate Murrumbidgee River water abstraction time for M2G runs; blue shaded area indicates data gap in the flow record at Lobb's Hole.

4.3 Water quality

4.3.1 Grab samples and *in-situ* parameters

The results from the lab analysed grab samples and the *in-situ* measured parameters are presented in Table 4-3

Surface water temperature ranged between 10.9°C at MUR 15 to 13.8°C at MUR 28. Electrical conductivity and turbidity readings were within ANZECC and ARMCANZ (2000) guidelines at all sites. Electrical conductivity ranged from 141 (µs/cm) at MUR 15 to 178 (µs/cm) at MUR 28.

pH was on the cusp of the upper limit set by the ANZECC and ARMCANZ (2000) guidelines at MUR 15 and MUR 28; while pH values at MUR 16, 18 and 19 exceeded the upper limits by up to 0.2 of a pH unit. The recorded pH value at MUR 23 was within the guidelines.

Dissolved oxygen (% saturation) ranged between 91.1% and 101.4 % at MUR 18 and MUR 16 respectively and all recorded values were within the ANZECC and ARMCANZ guideline range at the time of sampling.

Turbidity was low across all sites and ranged between 3.1 at MUR 16 and 4.4 at MUR 15 (Table 4.3)

The results from the nutrient analysis showed the most noticeable change compared to autumn 2012. In autumn 2012, 100% of the total phosphorus (TP) and total nitrogen (TN) data exceeded the recommended upper limits of 0.02 (mg/L) and 0.25 (mg/L) respectively. During this sampling run, TP was on the cusp of the upper limit at MUR 15 and was below the upper limit at the remaining sites. TN concentrations were exceeded at MUR 15 and MUR 23, although the concentrations recorded in this sampling run were almost half of those recorded in the same period in 2012.

4.3.2 Continuous water quality monitoring

Continuously logged water data from the stations upstream of Angle Crossing (41001702) and downstream of Angle Crossing (Lobb's Hole (410761)) are presented in Figures 4.3 & 4.4 and Table 4-4.

During the abstraction periods, water quality data at Lobb's Hole (downstream of Angle crossing) showed minor fluctuations (Figure 4-4) relative to the upstream site (Figure 4-3). These changes in parameters were insignificant relative to natural flow variation due to the short duration of the M2G maintenance run and the relatively low proportion of water that was actually abstracted relative to the base flows at the time of the maintenance run (Table 4-2).

There still appears to be issues with the sensors at 41001702 (upstream of Angle Crossing), which can be seen in the turbidity time series data (particularly in May: Figure 4-3). The elevated readings during this period are not related to any significant changes in the hydrology during that period (Figure 4-2) nor are the readings consistent with the in-situ readings (Table 4-3) or the data collected at Lobbs Hole over the same period, indicating interference with the turbidity sensor.

Apart from the turbidity readings, the monthly summaries from the upstream and downstream (of angle Crossing) gauging stations do not indicate location differences that could be attributed to the operation of M2G. All parameters are highly congruent aside from the natural downstream differences that are normally apparent. There was generally low compliance to the guidelines with respect to pH (Table 4-5); however for the most part, exceedances of the upper ANZECC and ARMCANZ guideline values were less than 0.1 of a pH unit. There are only two weeks of data available for Lobbs Hole (the last two weeks of May) and during this time daily averages were again, less than .1 of a pH unit over the recommended upper limit. Electrical conductivity was within the guidelines for the entire autumn period at both gauging stations and despite the elevated turbidity readings in May, the upstream Angle Crossing station recorded 71% and 80% compliance values in March and April respectively. Turbidity at Lobb's Hole was within the guidelines for the entire autumn period (Table 4-5).

Table 4-3. In-situ water quality results from Angle Crossing during autumn 2013

ANZECC and ARMCANZ (2000) guidelines are in red bold parentheses, yellow 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	06/05/2013	10.30	10.9	141	4.4	5	8.00	100.4	11.00	57	<0.002	<0.002	<0.002	0.004	0.02	0.26
	MUR 16	06/05/2013	14.00	11.5	166	3.1	5	8.2	101.4	11.04	65	<0.002	<0.002	<0.002	0.003	0.015	0.24
	MUR 18	07/05/2013	10.05	11.3	168	3.3	4	8.1	91.1	9.79	66	<0.002	<0.002	<0.002	0.003	0.013	0.24
Downstream	MUR 19	07/05/2013	11.50	11.5	168	3.0	3	8.1	96.9	10.56	66	0.002	0.002	<0.002	<0.002	0.013	0.23
	MUR 23	08/05/2013	09.45	12.1	162	3.8	4	7.95	100.0	10.75	73	0.002	<0.002	0.002	<0.002	0.014	0.28
	MUR 28	08/05/2013	14.05	13.8	178	4.3	5	8.0	101.1	10.48	66	<0.002	<0.002	<0.002	<0.002	0.015	0.24

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

Analyte	Temp. °C		EC (uS/cm) (30-350)		pH (6.5-8.0)		Turbidity (NTU) (2-25)		D.O. (% sat.) (90-110)	
Location	U/S[1]	D/S	U/S	D/S	U/S	D/S	U/S[2]	D/S[2]	U/S	D/S
March	20.6	20.7	158.8	154.8	8.06	No data	33.7 (109)	6.5 (10.7)	82.8 – 103.6	87.5 – 95.6
April	16.1	15.5	181.2	182.5	8.20	No data	20.8 (48)	3.2 (6.1)	81.5 – 97.4	86.8 – 96.1
May	10.7	9.7	159.8	167.4	8.18	8..08	95.4 (261)	2.1 (4.3)	83.8 – 96.5	91.7 – 97.5
Autumn	**15.8**	**15.3**	**166.4**	**168.1**	**8.15**	**8.08***	**50.3 (261)**	**3.9 (10.7)**	**82.7 - 99.2**	**88.7 – 96.4**

NOTES:

1) All values means, except dissolved oxygen (% saturation) which is expressed as mean monthly minimums and maximums. Maximum values for turbidity are the maximum daily mean value- in parentheses. ANZECC & ARMCANZ (2000) guidelines are inside red parentheses.

* Based on data from 15/05/2013 – 31/05/2013 only

2) Turbidity values are from the archived data. The upstream sites appear to be too high and may be affected by silt movement near the probe, whereas the downstream data appears to be too low as rainfall events appear to have had very little impact on the maximum values. Instrumentation and data is being reviewed by ALS as the service provider.

Table 4-5. Compliance (%) to ANZECC & ARMCANZ (2000) guideline values from the continuous gauging stations upstream (41001702) and downstream (410761) of Angle Crossing

Analyte[1]	EC (us/cm) (30-350)		pH (6.5-8.0)		Turbidity (NTU) (2-25)		D.O. (% sat.) (90-110)	
Location	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S
March	100	100	42	No data	71	100	90	87
April	100	100	0	No data	73	87	33	80
May	100	100	0	0*	10	55	52	100
Autumn	**100**	**100**	**14**	**0***	**51**	**80**	**59**	**89**

NOTES:

1) There are currently no guidelines for water temperature.

2) Compliance values are expressed as the percentage of days throughout the autumn period (based on daily means) that values met the guidelines.

* Based on data between 15/05/2013 and 31/05/2013.

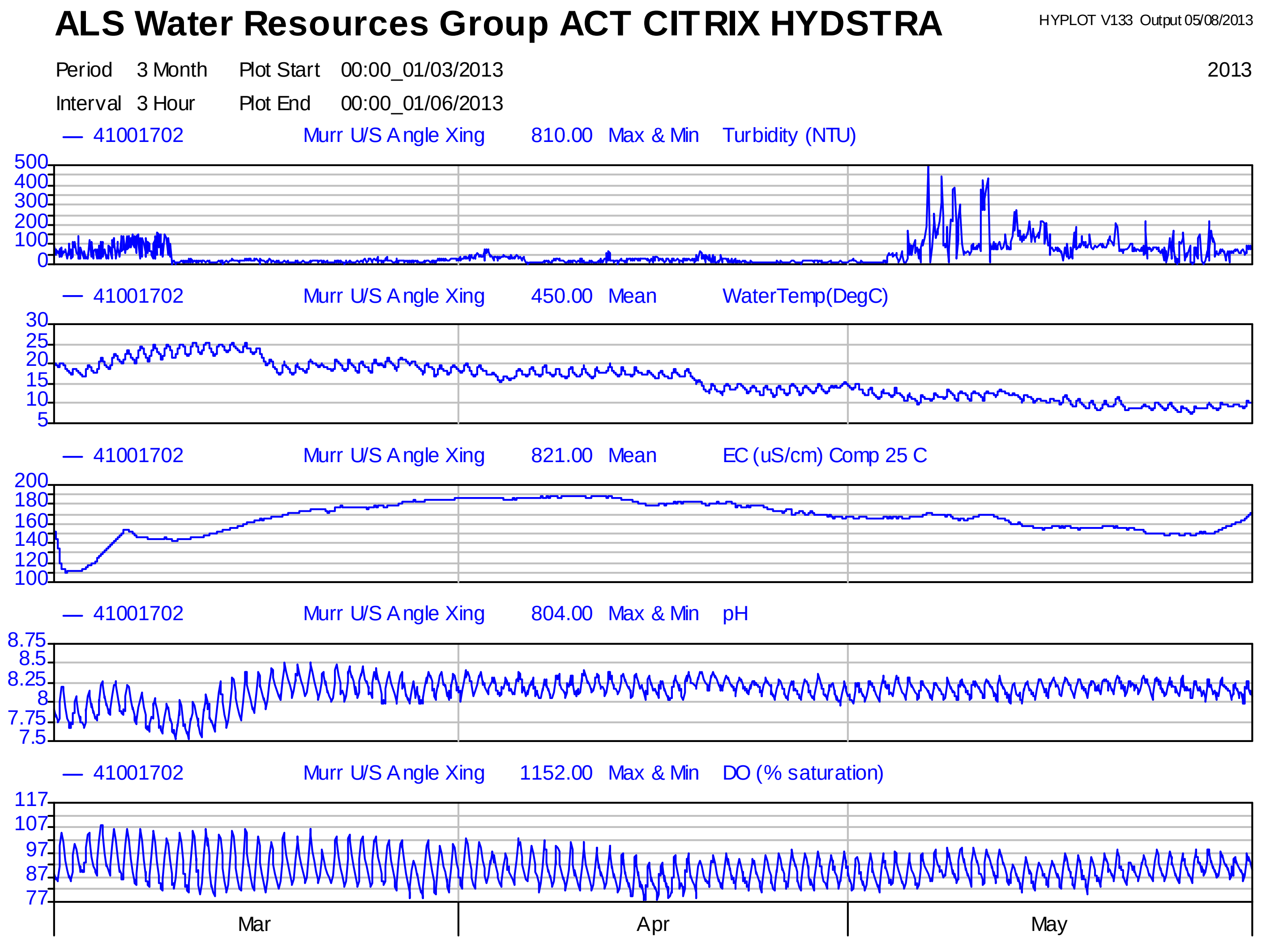


Figure 4-3. Continuous water quality records from upstream of Angle Crossing (41001702) for autumn 2013

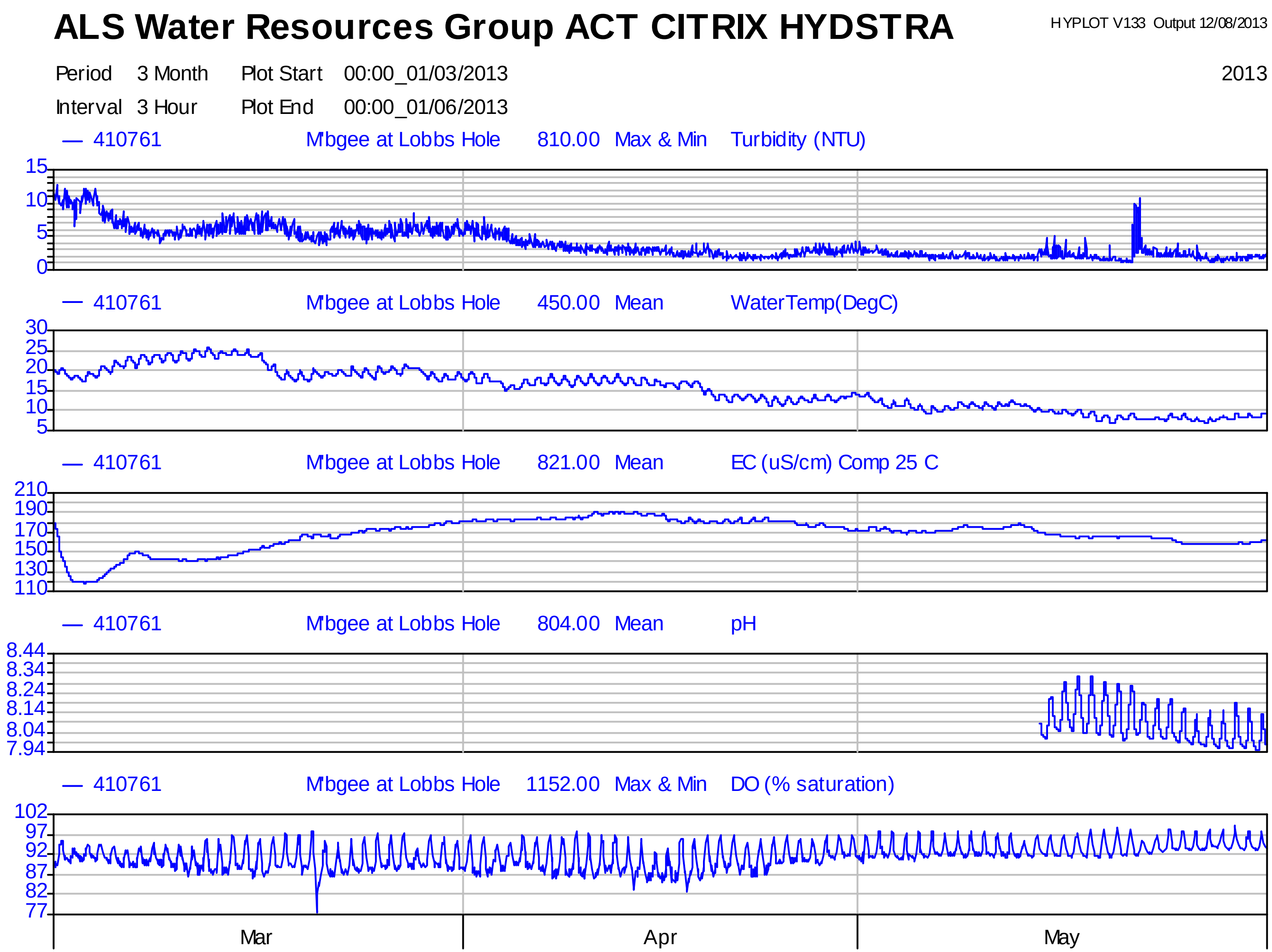


Figure 4-4. Continuous water quality records from Lobb's Hole (410761) for autumn 2013

4.4 Periphyton

During autumn 2013 the most obvious feature of the Murrumbidgee River was the low base flows during sampling. Chlorophyll-a concentrations over this period ranged from 2583 (ug/m^2) at MUR 19 (downstream of Angle Crossing) to 43,059 (ug/m^2) at MUR 16 (Figure 4-5). These values were approximately 60% higher on average compared to autumn 2012; and despite the wide range of values between sites, the overall distribution of values amongst sites were similar regardless of location ($F_{1,35}$= 0.03; *P*=0.87) (Figure 4-5). Most of the variation in the chlorophyll-a data was explained by within site variability (88%) while a small component of the total variance was due to site to site variation specific to a given location (12%).

Ash Free Dry Mass (AFDM) concentrations, were higher downstream of Angle Crossing (mean = 4,939 mg/m^2) compared to sites upstream (mean = 3,360 mg/m^2). There were some violations of the assumption of equal variances in the AFDM dataset and these were dealt with by using $log_{(10)}$ transformed data. The results suggest that there was no difference in average AFDM concentrations between locations ($F_{1,35}$= 1.35; *P*=0.31) despite some obvious location differences in the distributions (Figure 4-6). Variance partitioning shows that a moderate proportion of the total variance was explained by site to site variation (35%) regardless of location; while sites nested with location account for 55% of the total and location effects only accounted for 10% of the total.

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

Response	Source	DF	F	P-value
Chlorophyll-*a*	Location	1	0.03	0.87
	Site [Location]	4	1.67	0.18
	Residual	35		
AFDM	Location	1	1.35	0.31
	Site [Location]	4	16.27	<0.001
	Residual	35		

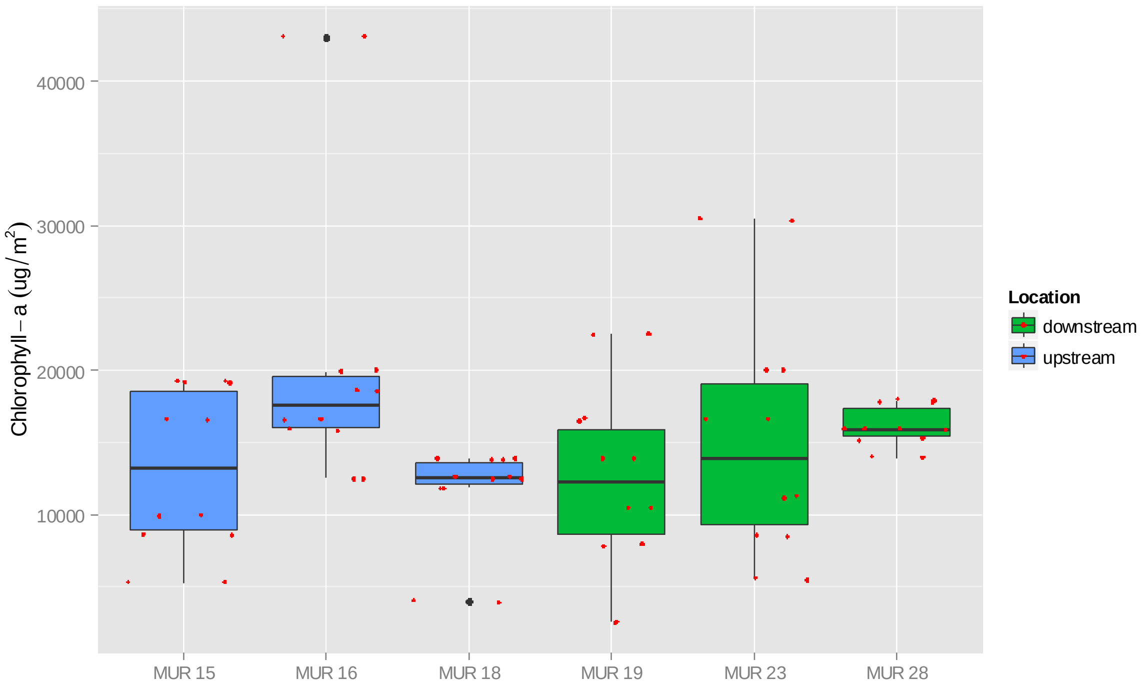


Figure 4-5. Chlorophyll-a concentrations up and downstream of Angle Crossing

Red points represent the raw values for each site

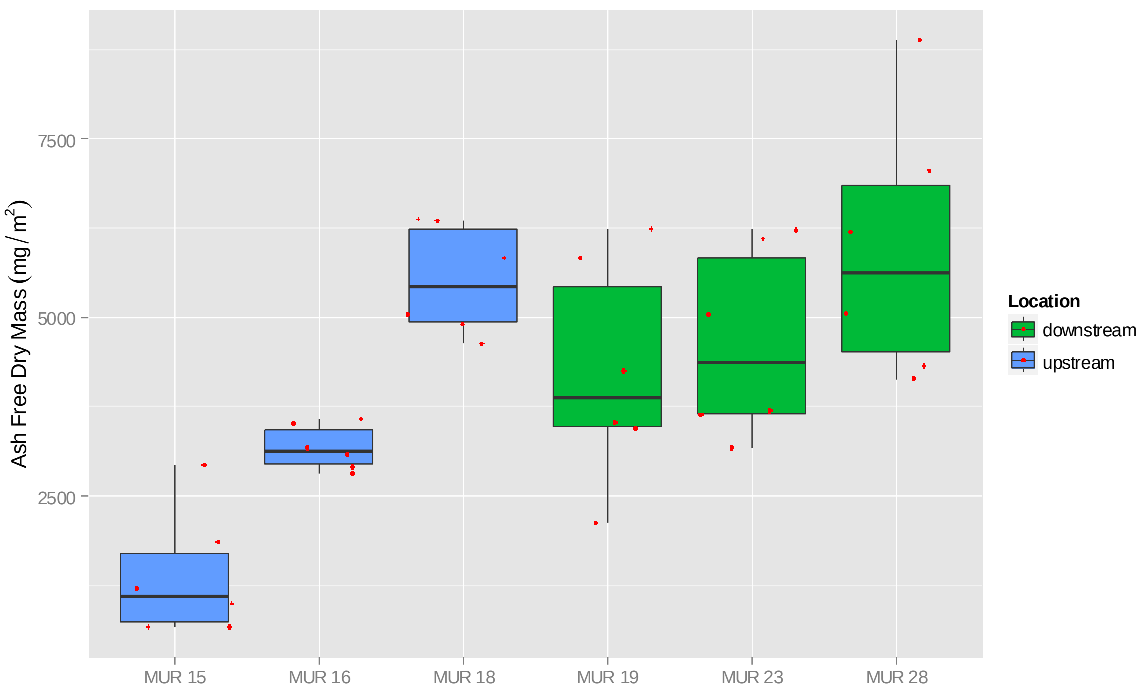


Figure 4-6. Ash free dry mass at Angle Crossing sites

Red points represent the raw values for each site

4.5 Macroinvertebrates

4.5.1 Community assemblages

4.5.1.1. Riffle habitat

There was no significant difference between upstream sites and downstream sites based on community assemblages (analysis of similarities; Global R =-0.185; P=1.00). Negative Global R values arise when samples from one group of interest are more similar to samples from comparative groups than they are to samples within their own group. In this study the negative R-value is a result of the sub-group to the right of Figure 4-7, which contains replicate 2 from MUR 18 (upstream of Angle Crossing and MUR 19 (downstream of Angle Crossing).

Further examination of these samples showed that both sites contained lower estimated abundances of, *Austrosimulium,sp*. [Simulium; Diptera]; *Jappa sp.* [Leptophlebiidae; Ephemeroptera], *Tasmanocoenis sp.*[Caenidae; Ephemeroptera] and *Cheumatopsyche sp.*[Hydropsycidae; Trichoptera] (Figure 4-8).

The overall relationship of the samples indicated that all sites grouped together at approximately 40% similarity and the sub-groups occurred with 60% similarity (Figure 4-7). As indicated by the bubble plots in Figure 4-9, the position and relationship of these sites is primarily driven by differences (particularly the smaller of the sub-groups) in the rank abundances of the same suite of taxa. This can be seen when the same data set is converted to presences and absences, which analyses composition only (Figure 4-9) in that the overall similarity increases from 40-60% once the influence of abundances are removed from the data set.

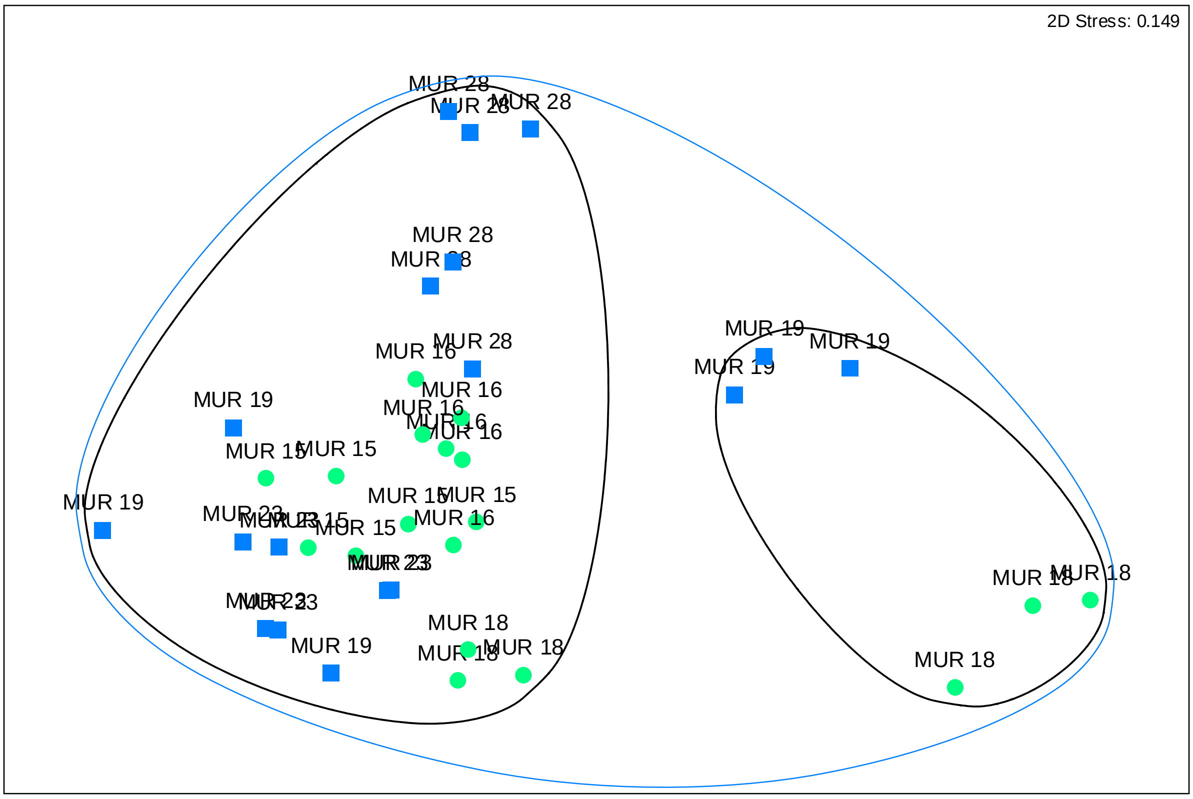


Figure 4-7. Non metric multidimensional scaling of macroinvertebrate (genus level) data collected from the riffle habitat

The blue ellipse represents 40% similarity and the black ellipse represents 60% similarity groups. Green circles are upstream sites and blue squares are downstream sites.

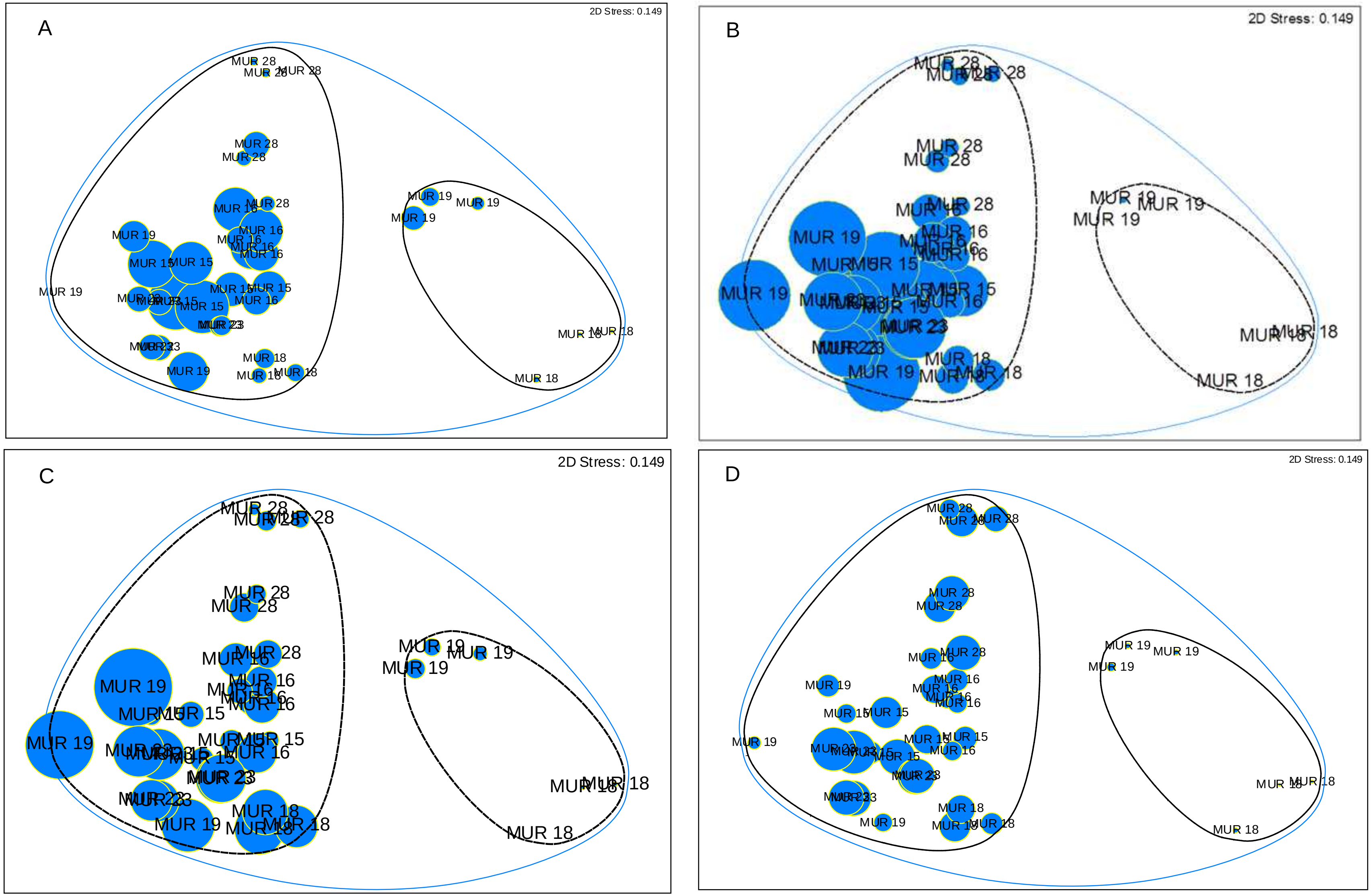


Figure 4-8. (A-D) NMDS bubble plots showing relative abundances of A) *Austrosimulium sp.*, B) *Jappa sp.*, C) *Tasmanocoenis sp.* and D) *Cheumatopsyche sp.*

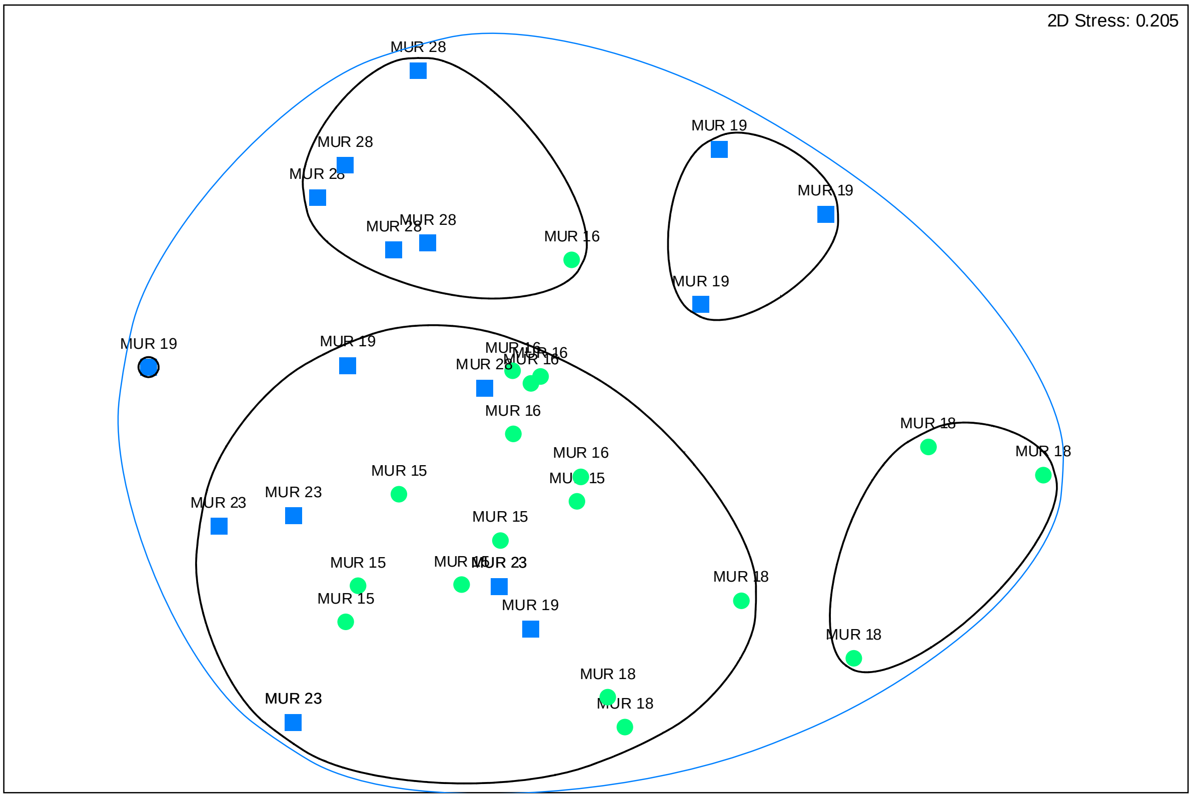


Figure 4-9. Non metric multidimensional scaling of macroinvertebrate (genus level) data collected from the riffle habitat based on presence absence information only

Notes:

1) Data are represented as composition only (presence/absence) and are based on Sorenson's simple-matching coefficient.

2) The blue ellipse represents 60% similarity and the black ellipse represents 70% similarity groups. Green circles are upstream sites and blue squares are downstream sites.

Aside from the differences in abundance amongst sites, there were no obvious differences in composition between sites. Sites from both locations were characterised by Black fly (Simuliidae; SIGNAL=5) larvae; moderately tolerant mayflies (Caenidae: SIGNAL =4) and caddis flies (Hydroptilidae; SIGNAL =4, Hydropsychidae: SIGNAL =6), although the sensitive mayfly family, Leptophlebiidae (SIGNAL =8) was also widely distributed across all sites.

The number of families collected in this sampling run ranged from 17 at MUR 15, MUR 16 and MUR 23 to 23 at MUR 18 and MUR 19 (Figure 4-10). Compared to autumn 2012 this represents an increase in family level richness at each site except MUR 23, which lost five families compared to the same time last year. At the genus level, there were ten less taxa at MUR 23, one less at MUR 18 and gains of between 1 and 8 at MUR 16 and MUR 19 respectively.

The number of EPT taxa was more consistent amongst sites than total richness, ranging from 7 to 9 families at MUR 23 and MUR 19 respectively (Figure 4-11) and 11 to 17 genera at MUR 15 and MUR 16.

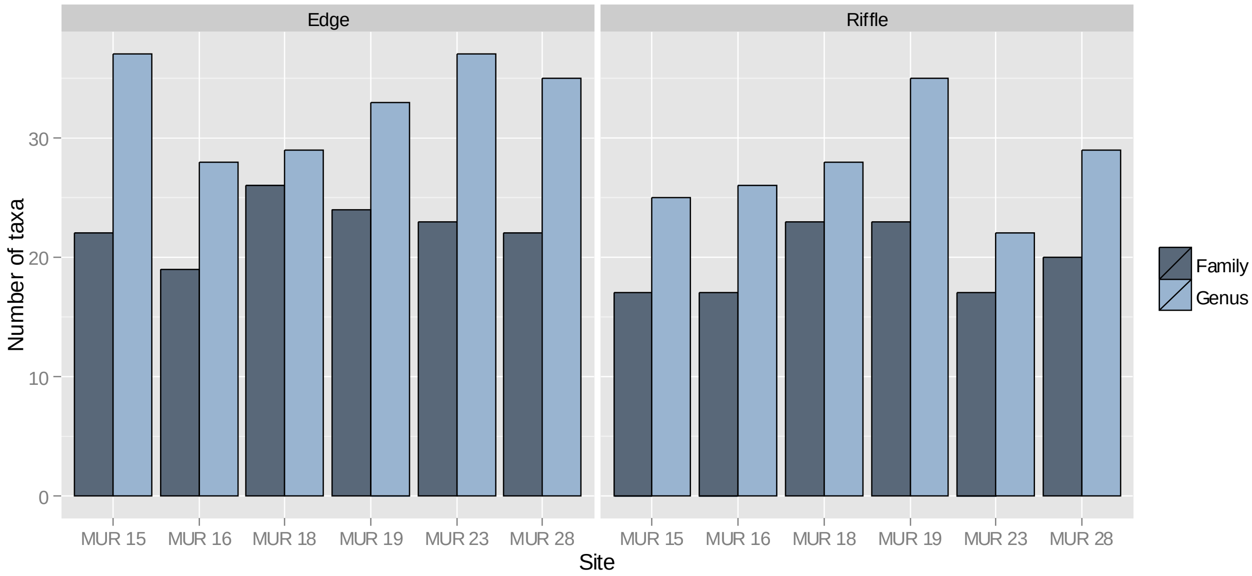


Figure 4-10. Total number of taxa at genus and family level from riffle and edge habitats

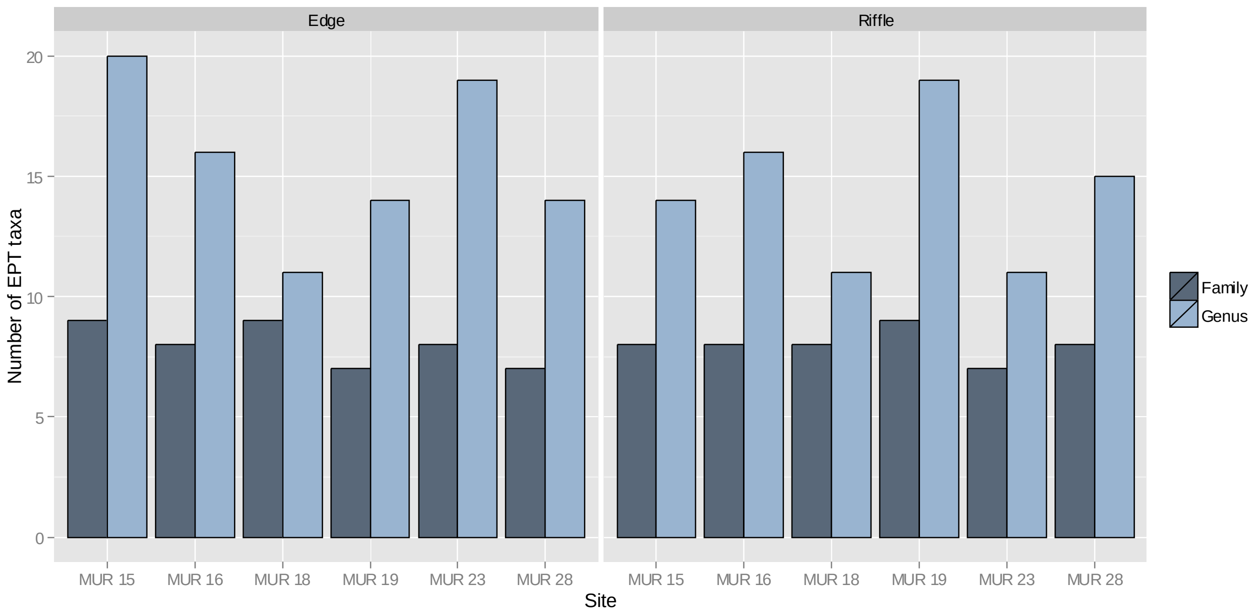


Figure 4-11. Total number of EPT taxa at genus and family level from riffle and edge habitats

4.5.1.2. Edge habitat

ANOSIM results show that macroinvertebrate community assemblages were not statistically different between upstream and downstream locations (Global R = 0.185; P=0.40). The low Global R value supports this result and suggests that on average, the similarities between and within locations are the same, on average.

The ordination plot (Figure 4-12) indicates an overall grouping of approximately 40% similarity, while four sub-groups exist within this at 60% similarity.

Macroinvertebrate communities from edge habitat were characterised by relatively high mayfly (Ephemeroptera) and caddisfly (Trichoptera) diversity, which accounts for up to 35% and 50% of the EPT richness values respectively (Figure 4-11). There were also high abundances of Orthocladiinae (SIGNAL=4); Simuliidae (SIGNAL=5) and Tanypodinae (SIGNAL=4). Taxa that are usually collected in high relative abundances such as Corixidae, Notonectidae and other edge-associated taxa (e.g. Dytiscidae and Gyrinidae) were less common and in considerably lower relative abundances than in the previous sampling run.

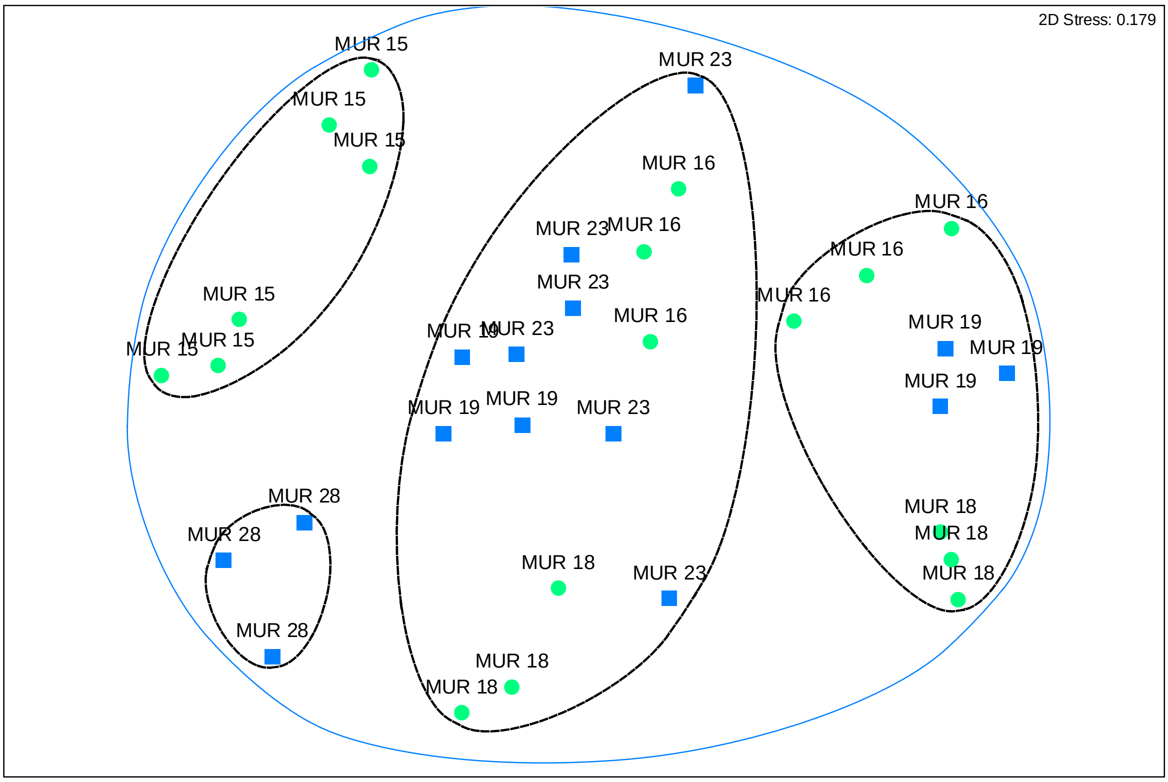


Figure 4-12. Non metric multidimensional scaling of macroinvertebrate (genus level) data collected from the edge habitat

The blue ellipse represents 60% similarity and the black ellipse represents 60% similarity groups. Green circles are upstream sites and blue squares are downstream sites.

4.5.2 AUSRIVAS

Despite some notable changes in relative abundances and diversity measures amongst sites, AUSRIVAS results from the autumn 2013 sampling period show all sites were assessed as BAND B ("*Significantly impaired*") based on the overall site appraisals (Table 4-7). Each site contained a mixture of BAND A results and BAND B results, however, because this assessment uses replication, the lowest of the two BANDS must be taken as the final assessment according to AUSRIVAS assessment protocols (Barmuta *et al.*, 2003).

There was no location difference found based on the O/E50 scores from the riffle habitat ($F_{1,4} = 0.18$; P=0.69; Table 4-7) (mean upstream =0.82; mean downstream =0.84) or the edge habitat ($F_{1,4} = 0.18$; P=0.14; Table 4-8) (mean upstream = 0.81; mean downstream =0.72).

SIGNAL scores from the riffle habitat communities were higher downstream of Angle Crossing (mean = 5.05) compared to the upstream sites (mean = 4.96). SIGNAL scores derived from the edge habitat were higher downstream compared to upstream (downstream mean = 4.86; upstream mean =4.86). For both habitat types, the differences were not statistically significant (Table 4-8 and Table 4-9).

Compared to spring 2012, MUR 15 and MUR 23 moved from BAND A to BAND B, while the other sites remained the same (Table 4-10), however, all site assessments were unchanged compared to autumn 2012.

The distribution of missing taxa, predicted by the AUSRIVAS riffle habitat model (APPENDIX D) was not consistent for each group of taxa. For example, some groups such as the family, Elmidae (SIGNAL=7) were missing from each site that it was predicted, although this group was found more frequently downstream of Angle Crossing. Other missing taxa, such as Caenidae (SIGNAL =4) and Baetidae (SIGNAL =5) were only missing from two sites and from only a single replicate within each of those sites.

Compared to the autumn 2012 sampling run, the range of missing taxa in the current study was much the same with the addition of Caenidae (SIGNAL =4), Baetidae (SIGNAL =5) and Oligiochaeta (SIGNAL=2). Oligiochaeta are usually ubiquitous throughout these sampling sites, but in this sampling run, were not collected at MUR 23 and were less common than usual amongst remaining sites.

There was a considerable list of missing taxa from the edge habitats in this sampling run. Between 4 and 12 taxa were missing from edge habitats in the present study. Sites with the least number of missing taxa were: MUR 15, MUR 16 and MUR 18, while MUR 19 recorded the highest. Twelve families were missing but predicted at MUR 19 (APPENDIX D). Tolerance values of those missing taxa also ranged considerably (SIGNAL = 2-8), although considering the distribution of these taxa across sites, there does not appear to be any obvious pattern in these absences. However, Elmidae (SIGNAL=7) were recorded downstream of Angle Crossing despite being missing at all of the upstream sites. Conoesucidae (SIGNAL=7) were absent at all of the sites that they were predicted, albeit with relatively low probabilities (APPENDIX D). However, it should also be recognised that this family of caddis fly are rarely collected in these sections of the Murrumbidgee River (ALS, 2010, 2011_a; GHD, 2012_a).

Table 4-7. AUSRIVAS and SIGNAL-2 scores for autumn 2013

= 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	5.06	4.15	0.89	0.87	A	A	**B**	**B**	**B**
MUR 15	2	5.18	4.60	0.89	0.87	A	A			
MUR 15	3	4.89	4.77	0.89	0.95	A	A			
MUR 15	4	4.63	4.33	0.78	0.79	B	B			
MUR 15	5	5.19	4.44	0.89	0.95	A	A			
MUR 15	6	4.93	4.10	0.67	0.63	B	B			
MUR 16	1	4.89	4.74	0.89	0.85	A	A	**B**	**B**	**B**
MUR 16	2	5.39	4.92	0.89	0.93	A	A			
MUR 16	3	4.94	4.68	0.78	0.76	B	B			
MUR 16	4	5.10	4.93	0.78	0.76	B	B			
MUR 16	5	4.88	5.28	0.89	0.68	A	B			
MUR 16	6	5.17	5.00	0.89	0.68	A	B			
MUR 18	1	5.29	4.26	0.67	0.88	B	A	**B**	**B**	**B**
MUR 18	2	5.51	4.42	0.78	0.96	B	A			
MUR 18	3	5.07	4.47	0.78	0.88	B	A			
MUR 18	4	4.63	5.10	0.78	0.8	B	B			
MUR 18	5	4.29	5.08	0.89	0.64	A	B			
MUR 18	6	4.19	5.07	0.78	0.64	B	B			
MUR 19	1	5.43	4.85	1	0.77	A	B	**B**	**B**	**B**
MUR 19	2	5.29	4.88	0.78	0.77	B	B			
MUR 19	3	5.13	4.80	0.78	0.7	B	B			
MUR 19	4	4.87	5.17	0.89	0.57	A	B			
MUR 19	5	4.95	5.47	0.78	0.57	B	B			
MUR 19	6	4.88	5.26	0.78	0.57	B	B			
MUR 23	1	5.28	4.72	0.89	0.69	A	B	**B**	**B**	**B**
MUR 23	2	5.35	4.88	0.78	0.75	B	B			
MUR 23	3	5.08	4.64	0.67	0.69	B	B			
MUR 23	4	5.26	4.59	0.89	0.82	A	A			
MUR 23	5	5.31	4.82	0.78	0.69	B	B			
MUR 23	6	5.05	4.92	0.67	0.69	B	B			
MUR 28	1	4.88	4.64	1	0.86	A	A	**B**	**B**	**B**
MUR 28	2	4.88	4.62	1	0.78	A	B			
MUR 28	3	4.92	4.69	0.89	0.86	A	A			
MUR 28	4	4.69	NS	0.89	NS	A	NS			
MUR 28	5	4.86	NS	0.78	NS	B	NS			
MUR 28	6	4.77	NS	0.89	NS	A	NS			

Table 4-8. Nested analysis of variance results for riffle samples

Response	Source	DF	F	P-value
OE 50	Location	1	0.18	0.69
	Site [Location]	4	2.43	0.07
	Residual	35		
SIGNAL-2	Location	1	0.49	0.52
	Site [Location]	4	2.10	0.10
	Residual	35		

Table 4-9. Nested analysis of variance results for edge samples

Response	Source	DF	F	P-value
OE 50	Location	1	3.38	0.14
	Site [Location]	4	1.82	0.15
	Residual	32		
SIGNAL-2	Location	1	0.77	0.43
	Site [Location]	4	4.98	0.00
	Residual	32		

Table 4-10. Overall site assessments for the current and previous four sampling runs for Angle Crossing

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

4.6 Discussion

4.6.1 Water quality and periphyton

The Murrumbidgee River was characterised by low base flows during the autumn 2013 sampling period, resulting in some notable changes in the *in situ* water quality results compared to autumn 2012. For example, total nitrogen and total phosphorus concentrations were considerably lower than autumn 2012 which is a result of low rainfall and subsequently, little runoff over the later part of summer and autumn period. This effectively resulted in high compliance of nutrient concentrations with the ANZECC and ARMCANZ (2000) guidelines. The only two exceedances were at MUR 15 and MUR 23 for total nitrogen only. All of the total phosphorus and total NOx concentrations were on or under the upper trigger value for these parameters (Table 4-3).

The only water quality parameter to exceed the guidelines from the in-situ water quality monitoring was pH. Point Hut crossing was within the recommended range of 6.5-8.0 on this sampling occasion. Despite the values exceeding the upper limits of the guideline values, pH was still within the range of values recorded throughout the MEMP, but tend to be higher during periods of low flow, although in autumn 2012, despite higher base flows, pH exceeded guideline limits downstream of Angle Crossing.

Continuous pH data were missing downstream of Angle Crossing for the majority of the autumn period at Lobb's Hole due to sensor repairs, ongoing maintenance and issues with the installation itself. During the period that pH data were collected compliance with the ANZECC and ARMCANZ (2000) guidelines was zero and levels tended to fluctuate during its daily cycle between 7.9 and 8.3 (Figure 4-2), which is not unusual during low flow conditions In the Murrumbidgee River.

Turbidity readings were consistently low downstream of Angle Crossing which reflects the absence of natural rainfall events and subsequent runoff during autumn. However, upstream of Angle Crossing turbidity readings were considerably higher than those recorded at Lobb's Hole. The time series plot (Figure 4-3) indicates that these values were an order of magnitude higher than downstream despite the grab samples taken at MUR 18 indicating turbidity values <5 NTU at the time of sampling, suggesting fouling of the turbidity sensor.

During the two maintenance runs there was no evidence of significant or lasting changes to the water quality parameters outside of seasonal influences or changes relative to natural flow variations. This is because the magnitude of water abstraction was relatively low (Table 4-2) and the duration of the abstraction period was very short-term.

Ash free dry mass (AFDM) and chlorophyll-a concentrations derived from the periphyton samples showed no location effect (Table 4-6). AFDM, showed a distinct longitudinal increase with distance downstream among sites upstream of Angle Crossing (Figure 4-6). No similar pattern was found for sites MUR 19-28 (downstream of Angle Crossing), possibly due to the greater level of within-site variability at these sites. The reason for the longitudinal gradient in AFDM for upstream sites is unclear, though differences in substrate composition may have contributed to this observation.

There were no environmental or water quality variables correlated with the periphyton samples in this sampling run, which suggests key driver of the periphyton patterns was either not measured, or more likely, as previously suggested, there is a lag effect that is not being detected because the nutrient data are collected concurrently with the biological samples. Gradients in the nutrient concentrations may help explain the similar distribution in Chlorophyll-a concentrations amongst sampling sites. In previous sampling periods, we have sometimes found large variations in chlorophyll-a concentrations between sites (both upstream and downstream of Angle Crossing) when nutrient concentrations vary between sites.

4.6.2 AUSRIVAS and macroinvertebrate assemblages

Flow conditions in the Murrumbidgee River in autumn 2013 were approximately 80% lower that base flows during the autumn 2012 period. Flows were relatively stable throughout autumn 2013; with the only natural high flow event occurring in late February and that being less than a 1:1 ARI event. Compared to all previous autumn sampling runs, autumns 2013 was ranked as having the second lowest mean daily flow (averaged over March, April and May) of 176 ML/d. Autumn 2012, on the other hand was ranked highest, with a seasonal average flow of 4,239 ML/d.

In autumn 2012, macroinvertebrate communities showed a high degree of similarity within and among sites and this was argued to be a result of the preceding high flow events which in essence “reset” the macroinvertebrate community assemblages at each site (GHD, 2012). The resulting communities were represented by macroinvertebrates that are common and can be highly abundant in the post – succession process. In fact, the key differences between sites were found not to be based on composition, but rather differences in relative abundances of certain taxa. In this study, a similar pattern was observed, in that when considering macroinvertebrate communities among sites based on relative abundances, similarities among sites was low (all sites approximately 40% similar; Figure 4-7). However based on composition (presence-absence) alone (Figure 4-9) the overall similarity amongst sites increased by approximately 30%. For analyses based on relative abundance and presence-absence data, there were no statistical differences recorded in macroinvertebrate community composition between locations. During periods of low flows, within-site variability can increase as a function of habitat fragmentation through the process of diminishing habitat, changes in depth and if low flows persist, changes in water quality and other knock on effects. This might explain some of the observed within-site variability observed for the autumn 2013 relative abundance data.

The cause of the differences in relative abundances of certain taxa (Figure 4-8) at MUR 18 and MUR 19 might be explained by differences in the substrate at these locations. At MUR 18, it was noted that this sample was collected in very loose gravels and pebbles packed with sand. This type of substrate composition does not generally support high diversity or high secondary production due to its relative instability and low heterogeneity (Minshall, 1984; Allan and Castillo, 2008).

There were no obvious differences in substrate composition at MUR 19. However, MUR 19 did exhibit considerable variability in the velocity readings compared to other sites, which may help explain such high within-site variability in relative abundance estimates. Brooks *et al.* (2005) showed that macroinvertebrate abundance and number of taxa were negatively related to a suite of near-bed hydraulic indices and concluded that small-scale differences in hydraulics plays an important role in the spatial distribution of macroinvertebrates in riffle habitats.

Given the relatively high similarity amongst sites (based on composition data), it is unsurprising that there are no statistical differences in SIGNAL-2 scores or the O/E 50 ratios between locations collected from riffle (Table 4-8) or edge (Table 4-9) habitats. Despite the differences in the hydrological characteristics between autumn 2012 and autumn 2013 the AUSRIVAS bands remained unchanged between sampling occasions (Table 4-10). Taxa that were missing but expected to occur from the riffle habitats included Elmidae (SIGNAL=7) and Tipulidae (SIGNAL=5) and Gripopterygidae (SIGNAL=8), all of which were missing from the autumn 2012 samples.

Identifying the principal cause of the absence of these taxa is complicated by the fact that the same set of taxa are missing during both high and low flow periods. Low flows are known to have detrimental impacts of Elmid beetles (Elliot, 2008) and Gripopterygidae prefer cool, fast flowing water, but are also susceptible to changes in water quality, which would explain their absence in the low flow periods. During periods of higher base flows, as was the case in autumn 2012, taxa can be displaced by bed scouring, and high shear velocities followed by slow colonisation rates, may have been the reason for their absence then.

Missing taxa from the edge habitat ranged from 4 to 12 at MUR 15 and MUR 19 (downstream of Angle Crossing) respectively (APPENDIX D). MUR 19 had the highest number of missing taxa compared to the previous sampling run. There were up to 7 additional families missing from MUR 19 compared to autumn 2012 ,despite this site having the equivalent AUSRIVAS assessment as last year.

The most likely explanation for the number of missing taxa from MUR 19 specifically is the reduction in inundation depth compared to the previous two sampling periods and relative to the other sites in this component. Compared to autumn 2012, the average depth at MUR 19 decreased by 57%.

The macroinvertebrate communities and taxa richness seen in this study are similar to those seen in the previous two sampling periods, despite being collected under different hydrological characteristics. This shows a certain degree of resistance (Lake, 2011) to hydrological disturbance in the upper Murrumbidgee River, in that although there have been changes in the estimated relative abundances and small changes in the number of taxa over these periods; the AUSRIVAS bands have remained the same. However, this could also reflect a lack of sensitivity of the autumn ACT AUSRIVAS model, particularly with regards to changes in the abundance / presence of taxa with lower probabilities of occurrence in the Murrumbidgee River system that have been recorded in the MEMP study from time to time. The other consideration is that the hydrological disturbances that have occurred in the upper Murrumbidgee River since the inception of the MEMP, have not occurred over prolonged periods, which prevents the onset of changes to water quality or periphyton production, and thus does not translate to changes at the secondary producer level (i.e. macroinvertebrate community composition).

4.7 Angle Crossing Conclusions and Recommendations

During autumn 2013 the characterising feature of the Murrumbidgee River was the low base flows. Only autumn 2009 recorded a lower autumn mean flow (< 40 ML/d) since the beginning of this project. There was little evidence to suggest that any of the indicators used in this study were affected by the earlier of the two maintenance runs (the second occurred approximately two weeks after the completion of the autumn sampling run) of M2G in the autumn 2013 period. Water quality over the autumn period was characteristic of low flow periods, with low nutrient concentrations and EC concentrations slightly elevated but comparable to autumn 2009, when base flows were also low.

Macroinvertebrate richness was similar to previous reporting periods, although there were some changes to the relative abundances at MUR 18 and MUR 19, which affected the overall similarity between sites. Within these sites, there was high variability in the distribution of certain taxa, which may be due to small-scale differences in hydraulics and/or differences in substrate composition at those sites. Both of these factors are attributed to low flows, which can cause habitat fragmentation, increase within-site velocities as riffle and pool depths decline and increase the settlement of fine sediments.

The absence of a response to the M2G abstraction is no surprise given the short duration of the abstraction period, and the low proportion of the Murrumbidgee River base flows abstracted. Kennen *et al*. (2010) found that duration and magnitude of low flows to be important hydrological variables in determining changes in macroinvertebrate communities. While Finn *et al.* (2009) showed that loss of sensitive taxa and increases in the number of tolerant taxa were most strongly associated with the number of low flow events over a 1 year period. The upshot of these findings is that changes may be expected as a cumulative function of low flow periods, such as the period of low flows leading up to and including the autumn 2013 sampling period, rather than short-term responses to short-lived fluctuations in flow linked to abstraction.

The M2G pipeline will be used to supplement the raw water supply when the Googong reservoir volume falls below a set trigger level. The pipeline might be operated during the summer months and this will result in potentially larger proportions of the Murrumbidgee River’s flow being abstracted than there were during the M2G maintenance runs seen in autumn 2013 and in the early commissioning phase in August and September 2012. If flows during these vulnerable periods (i.e. summer and autumn) are artificially maintained through ongoing water abstractions, we could expect to see deterioration in water quality and changes to periphyton communities that would then begin to influence the more sensitive macroinvertebrate taxa. Due to the resistance and resilience of macroinvertebrate communities in the Upper Murrumbidgee River, it is likely that following periods of abstraction, recovery will probably occur by the following season. However, as Marsh *et al.* (2012) point out, community composition may diminish as resilience and resistance to stressors declines if these patterns continue over subsequent years (i.e. due to the cumulative effects of water abstraction). And this will have repercussions to fish populations which rely on healthy macroinvertebrate populations as a food resource, but are also sensitive to changes in water quality outside their natural thresholds (Ingram and De Silva, 2007; King, 2005; Tonkin *et al.*, 2006).

It is recommended that long-term data analysis be carried out to assess the long term trends in the biological and water quality variables in response to hydrological variables. It is suggested that this be done as a separate report so that the seasonal reporting is left in the current format. As part of the long-term data analysis, taxa missing from the AUSRIVAS models should be looked at to determine any potential points of change that may exist along hydrological gradients. This could assist in the prediction of macroinvertebrate community responses based on certain abstraction regimes, and may assist in the development of more refined biological “health” targets for the Murrumbidgee River during the operation and shut down phases of the M2G project.

Part 2 – Burra Creek

5. Burra Creek

5.1 Summary of sampling and river condition

The Burra Creek component of the MEMP was sampled on the 20th and 21st of May 2013; with the exception of BUR 1a, which was dry (Plate5-1). The completion of sampling was delayed to accommodate the possibility that surface flow may have re-commenced following rainfall which was forecasted in late May. After returning to BUR 1a on the 31st May 2013 the site remained dry; and this included all of the pools in the sampling reach which usually hold at least small amount of surface water. The low surface flow was evident through Burra Creek where some large stands of in stream macrophytes were noted. This was especially obvious upstream of the M2G discharge point, at BUR 1c, where the main channel was heavily encroached by Spike rush (*Eleocharis sp*.) and Cumbungi (*Typha sp*.) (Plate 5-1).

5.2 Hydrology and rainfall

M2G maintenance runs occurred over two, three day periods in autumn. The first run took place between the 19th and 21st of March (inclusive) with a total release volume of 68.5 ML and the second maintenance run occurred on 23rd and 24th of May with a total release volume of 60.2 ML (Figure 5-1 and Figure 5-3). Outside of these two maintenance releases, there were no significant natural events over the autumn period in Burra Creek (Figure 5-1), although there were two small events that occurred in Queanbeyan River at the beginning of autumn (early March) and a smaller one still in the third week of April (Figure 5-3).

At the time of sampling, base flows in Burra Creek and the Queanbeyan River were lower than the previous autumn sampling run (Figure 5-4). Mean daily flow in Burra Creek during autumn 2012 was 53.1 ML/d compared to the current study where mean flow for the autumn period was 2.5 ML/d (Table 5-1). Similarly, in the Queanbeyan River mean flow over the autumn 2012 period was 734 ML/d compared to 61.2 ML/d in 2013. Rainfall for the autumn period was consistent across months (range: 17.0 – 23 mm; Table 5-1) and the early autumn spikes (in March) that were evident in the previous two years, were not seen in 2013 (Figure 5-5); resulting in autumn 2013 receiving the lowest seasonal rainfall since the commencement of the MEMP.

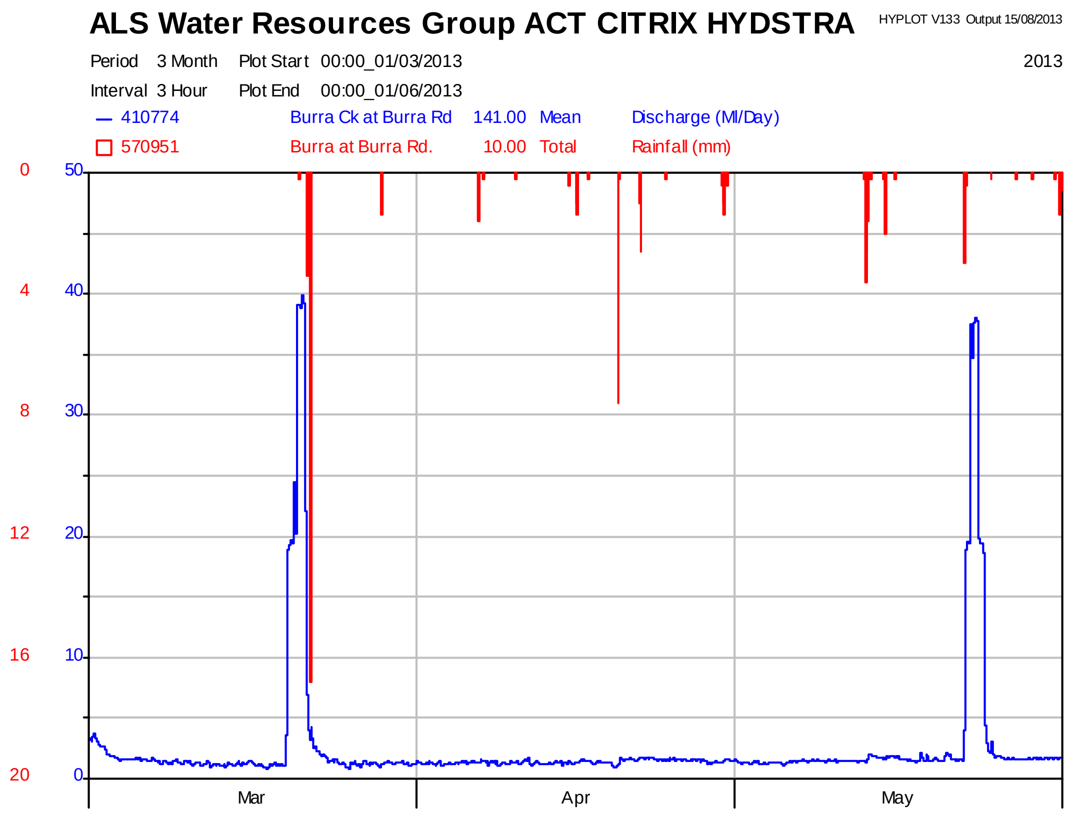


Figure 5-1 Hydrograph and rainfall from Burra Creek over the autumn period, 2013

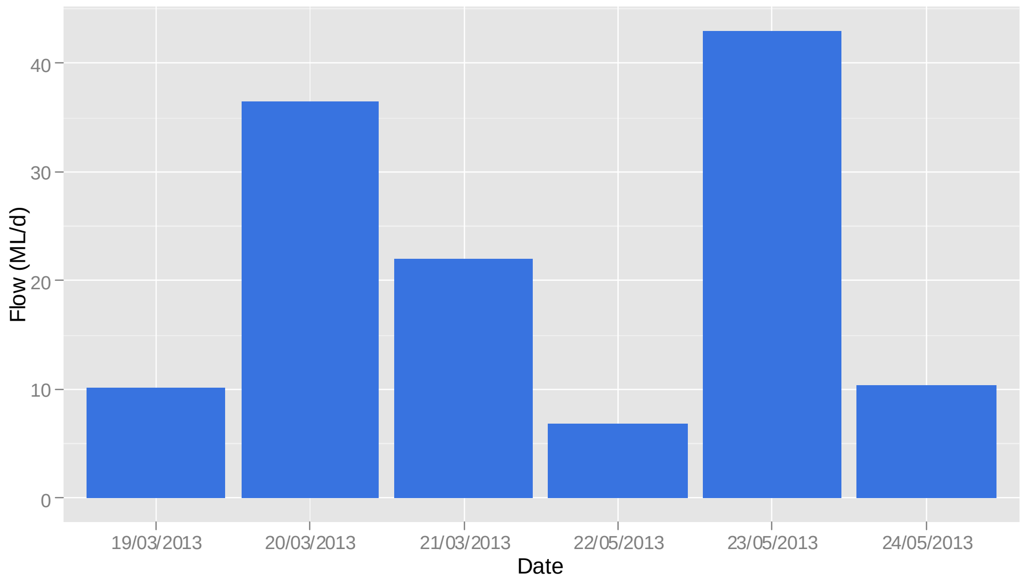


Figure 5-2 Daily discharge volumes from the M2G maintenance runs between spring 2012 and the end of autumn 2013

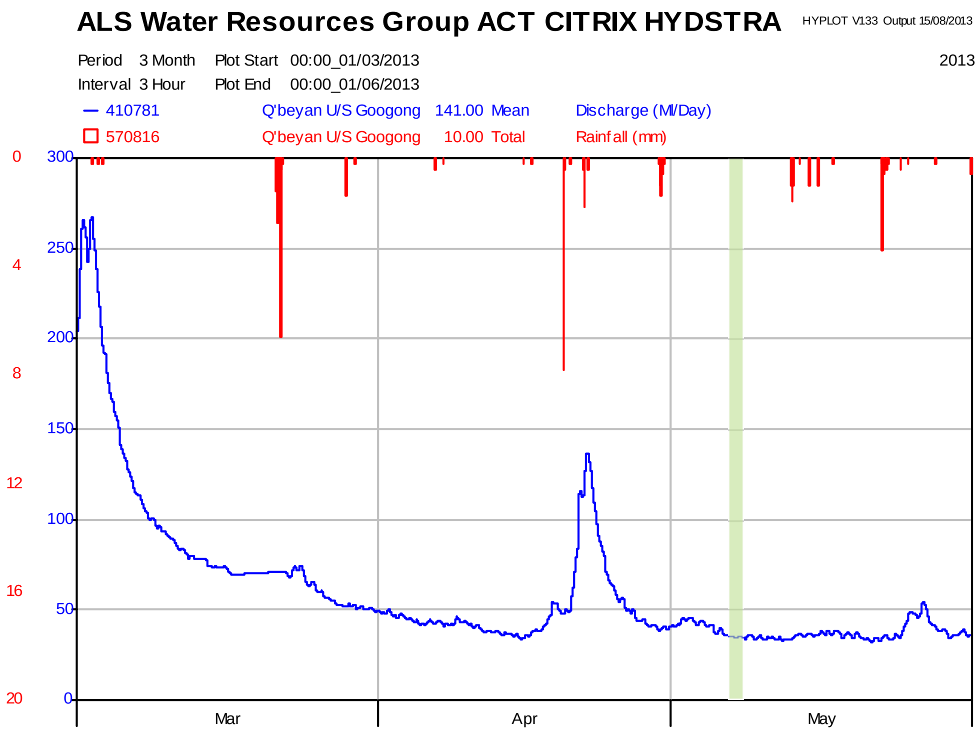


Figure 5-3. Hydrograph and rainfall from the Queanbeyan River (410781) during the spring 2012 period

Note: Green shaded area indicates sampling period

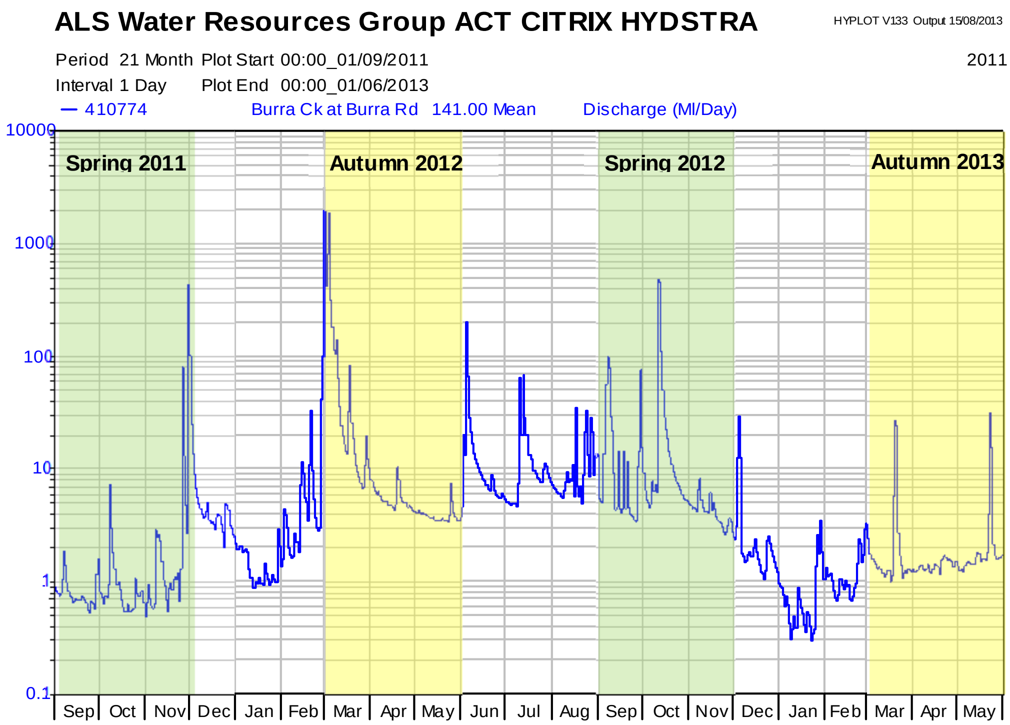


Figure 5-4. Burra Creek hydrograph highlighting the past four sampling periods between September 2011 and May 2013

Table 5-1. Autumn rainfall and flow summaries for Burra Creek and the Queanbeyan River

	Burra Creek (410774)		Queanbeyan River (410781)	
	Total Rainfall (mm)	Mean Flow (ML/d)	Total Rainfall (mm)	Mean Flow (ML/d)
March	23.0	3.1	13.6	95.2
April	20.2	1.4	15.4	50.7
May	17.0	3.0	12.2	37.8
Autumn	**60.2**	**2.5**	**41.2**	**61.2**

Note: Flow values are monthly means with the autumn value being the three month seasonal mean; rainfall is monthly total (mm) or seasonal total (mm).

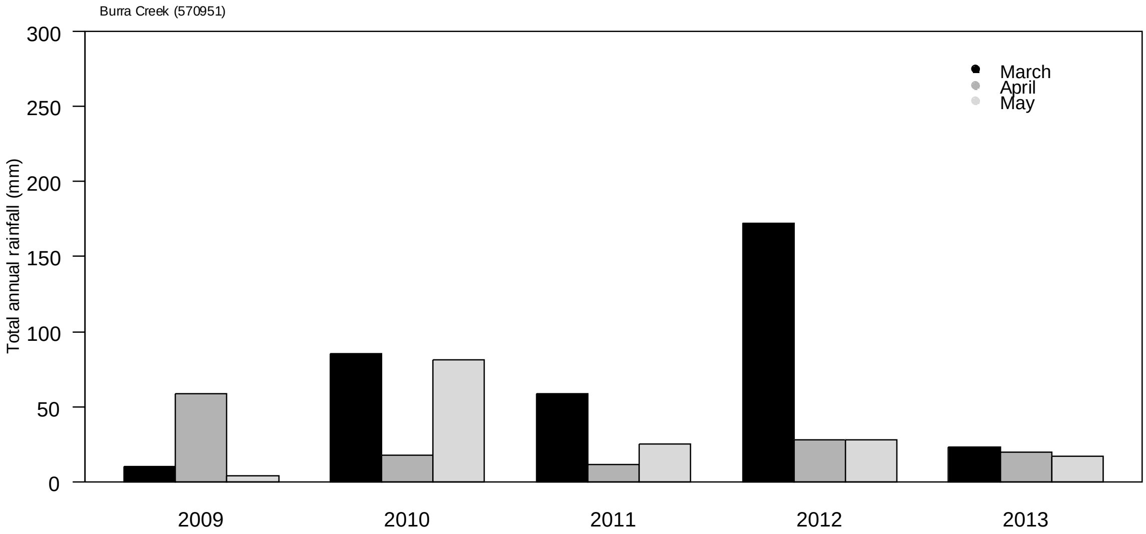


Figure 5-5. Annual comparisons of autumn rainfall (mm) recorded at Burra Creek (570951)

BUR 1 Dry riffle, facing upstream

BUR 1c Encroachment through the riffle habitat

BUR 2a Edge/pool habitat – facing downstream

BUR 2b Facing upstream

BUR2c Looking downstream from the head of the riffle habitat

QBYN 1 Dry riffle – looking upstream

Plate 5-1. Photographs of sampling sites for the Burra Creek component of the MEMP

5.3 Water quality

5.3.1 Grab samples and *in-situ* parameters

Results from the autumn 2013 grab samples and the *in-situ* measured parameters are presented in Table 5-3. Compliance with nutrient values was high among all sites, which reflects the low rainfall for the autumn period (Table 5-3). Total NOx reached or exceeded the recommended upper limit of 0.15 mg/L at all the sites in Burra Creek situated downstream of the discharge point (i.e. BUR2a, BUR2b and BUR2c). The highest reading came from BUR 2a (the closest site to the M2G discharge point) and then decreased reasonably quickly downstream to BUR 2b and BUR 2c.

Electrical conductivity exceeded guidelines at all of the Burra Creek sites and ranged from 552.1(µs/cm) at BUR 1c to 582.3 (µs/cm) these values ranged from being 12-25% higher than those recorded in autumn 2012, reflecting the low base flow in Burra Creek in autumn 2013. These values, despite being marginally higher than the previous autumn sampling run, remain within the historical data range seen during similar hydrological conditions. pH exceeded the upper limits of the guidelines at all of the Burra Creek sites; the highest being 8.3 at BUR 2b. Dissolved oxygen was exceeded at BUR 2a with a reading of 124.7%.

5.3.2 Continuous water quality monitoring

Water quality time series data collected from Burra creek (410744) and the Queanbeyan River are shown in Figure 5-6 and Figure 5-7.

During the M2G maintenance runs most of the continuously gauged water quality parameters showed temporary responses to additional water volumes entering Burra Creek (Figure 5-6). Turbidity spiked to 120 NTU in response to the first release but was not influenced by the second release in May, indicated by the 50% compliance (with ANZECC and ARMCANZ guidelines) assessment during the release period (Figure 5-6). Changes in water temperature were less conspicuous due to diurnal and weekly changes. However, following the March release, there was a 2.6°C increase in mean daily temperature and a 2.3°C increase following the May release. Electrical conductivity exhibited the most obvious change, with decreases of 386 and 375 µs/cm recorded for the March and May releases respectively, which are also reflected in the 100% compliance assessment for the release period (Table 5-2).

Table 5-2. Compliance of Burra Creek water quality parameters before M2G maintenance releases and following

Period	Turbidity	pH	EC	D.O.%
During trial releases (19-21 Mar 2013 and 23-24 May 2013)	50%	66%	100%	50%
Autumn (inclusive of trial releases)	96%	30%*	7%	13%

Note: Values are expressed as percentage of days throughout each period that values (daily means) are within the ANZECC and ARMCANZ water quality guidelines. * Does not include nine days of missing data in the latter part of April.

Table 5-3. In-situ water quality results from Burra Creek during autumn 2013

ANZECC and ARMCANZ (2000) guidelines are in red bold parentheses, yellow 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)**	TSS mg/L	pH **(6.5-8)**	D.O.(% Sat.) **(90-110)**	D.O. (mg/L)	Alkalinity (mg/L)	NOx (mg/L) **(0.015)**	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L) **(0.02)**	TN (mg/L) **(0.25)**
Upstream	BUR 1a	21/05/2013	09.30	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
	BUR 1c	21/05/2013	14.20	10.1	552.1	6.5	3	8.1	93.5	10.5	203	<0.002	<0.002	<0.002	<0.002	0.005	0.20
Downstream	BUR 2a	20/05/2013	10.30	5.8	562.5	5.8	<2	8.1	124.7	15.5	238	0.36	0.35	0.003	0.002	0.006	0.51
	BUR 2b	20/05/2013	11.40	6.4	582.3	3.6	4	8.1	96.2	11.8	252	0.016	0.016	<0.002	<0.002	0.008	0.19
	BUR 2c	20/05/2013	14.35	9.1	552.4	3.1	<2	8.2	101.6	11.7	242	0.015	0.015	<0.002	<0.002	0.005	0.16
Control	QBYN 1	21/05/2013	11.55	8.1	87.2	2.6	<2	7.7	99.6	11.7	38	<0.002	<0.002	<0.002	0.002	0.010	0.18

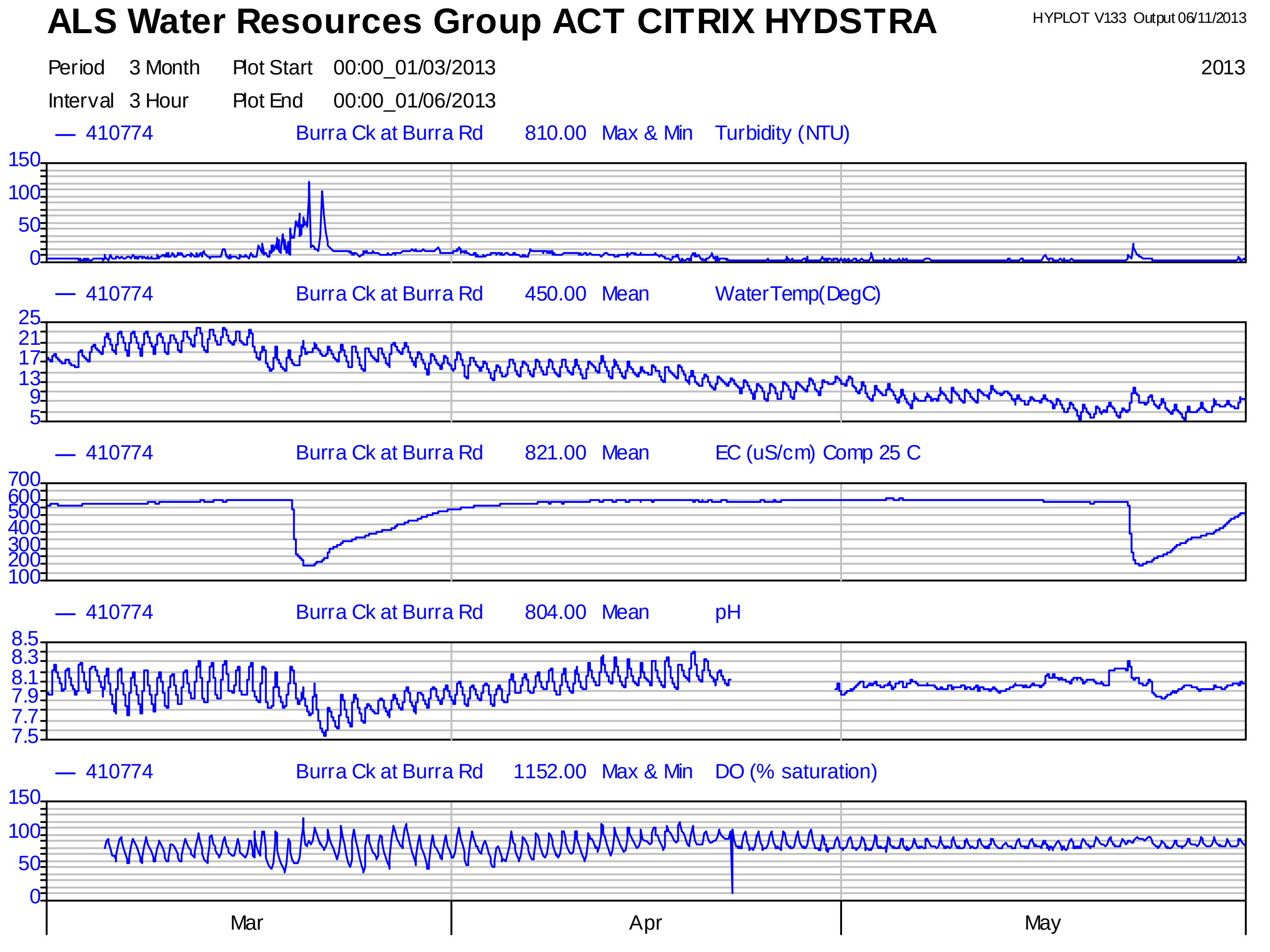


Figure 5-6. Continuous water quality records from Burra Creek (410774) for autumn 2013

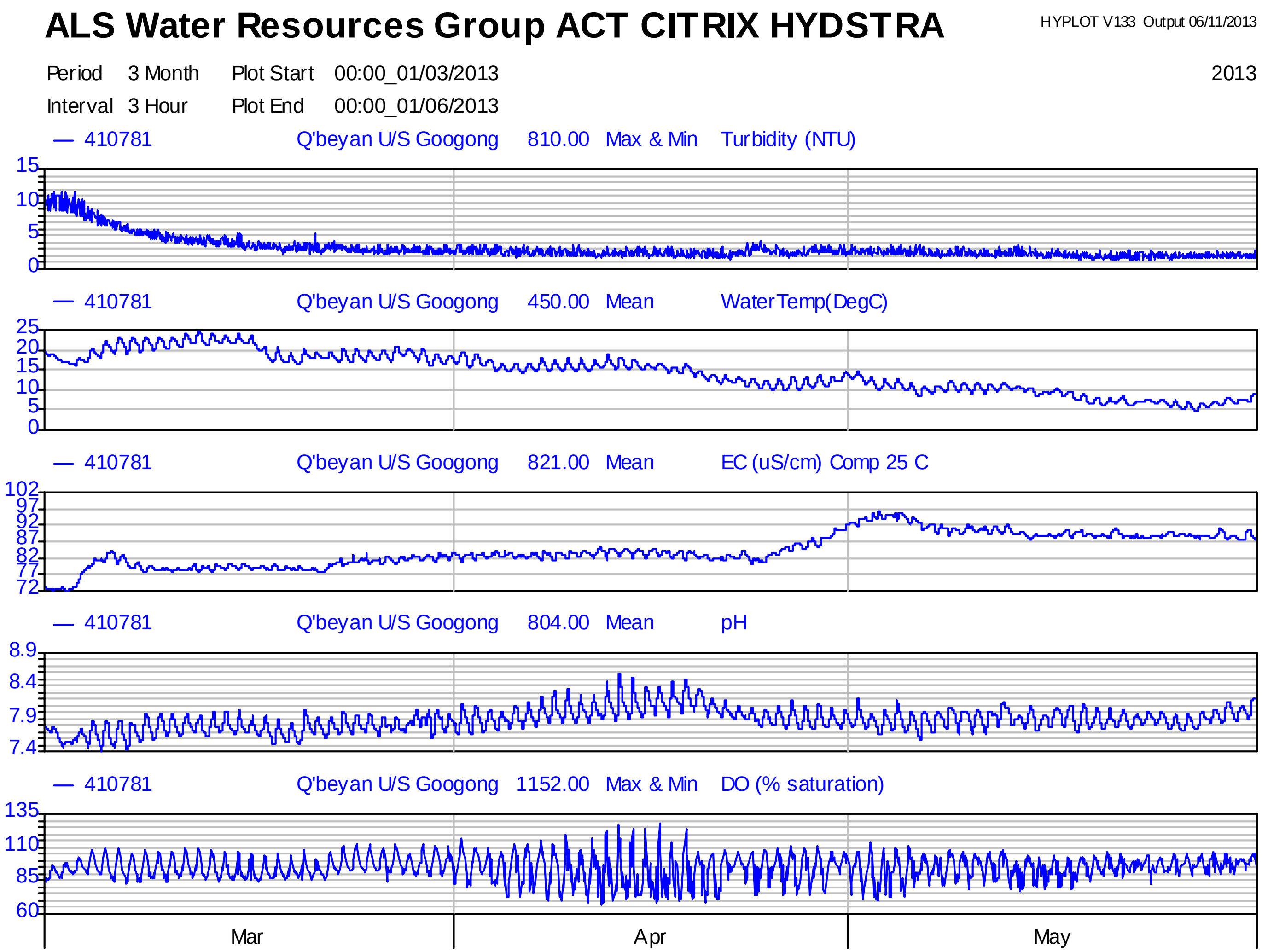


Figure 5-7. Continuous water quality records from the Queanbeyan River (410781) for autumn 2013

5.4 Periphyton

Periphyton samples were not collected at BUR1a in autumn 2013 because the site was dry (Plate 5-1).

Chlorophyll-a concentrations at BUR 1c (28,816 ug/m^2) where found to be ten-fold higher than the Queanbeyan control site (2859 ug/m^2). Chlorophyll-a concentrations averaged over the three downstream sites (BUR 2a, 2b and 2c) was 17,334 ug/m^2 (Figure 5-8). There was a statistically significant effect of location based on the chlorophyll-a data ($F_{2,2}$ = 30.65; P=0.03; Table 5-4). Monte Carlo methods were used to derive post – hoc comparisons to identify where these differences were (Table 5-5). The results of this analysis corroborate Figure 5-5, which suggests differences between the Queanbeyan Control site and both Burra Creek locations. No difference was found between the upstream and downstream locations in Burra Creek (*P*=0.23; Table 5-5).

Ash free dry mass (AFDM) was relatively consistent amongst sampling locations (Figure 5-9) and this is supported by the absence of statistical difference between these locations ($F_{2,2}$ = 7.40; P=0.12; Table 5-4).

The majority of the variation in the AFDM model arises from within a given site (85%), while variation based only on location accounts for 15 % of the total (compared to 78% in the chlorophyll-a model).

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

Response	Source	DF	F	P-value
Chlorophyll-*a*	Location	2	30.65	0.03
	Site [Location]	2	1.01	0.38
	Residual	29		
AFDM	Location	2	7.40	0.12
	Site [Location]	2	0.23	0.79
	Residual	29		

Table 5-5. Post-hoc comparisons of chlorophyll-a concentrations between each sampling location

	Control	Upstream	Downstream
Control			
Upstream	< 0.0001*		
Downstream	< 0.0001*	0.23*	

**P*-values derived from the Markov Chain Monte Carlo (MCMC) procedure from 9999 starts

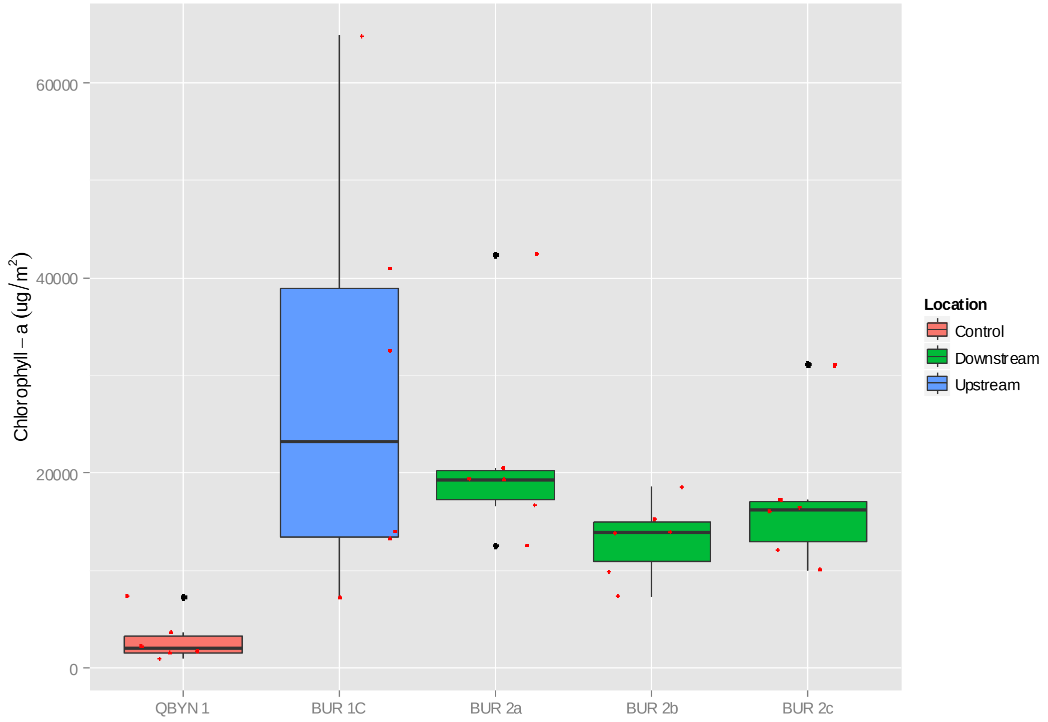


Figure 5-8. Chlorophyll-a concentrations in Burra Creek and the Queanbeyan River

Red points represent the raw values for each site

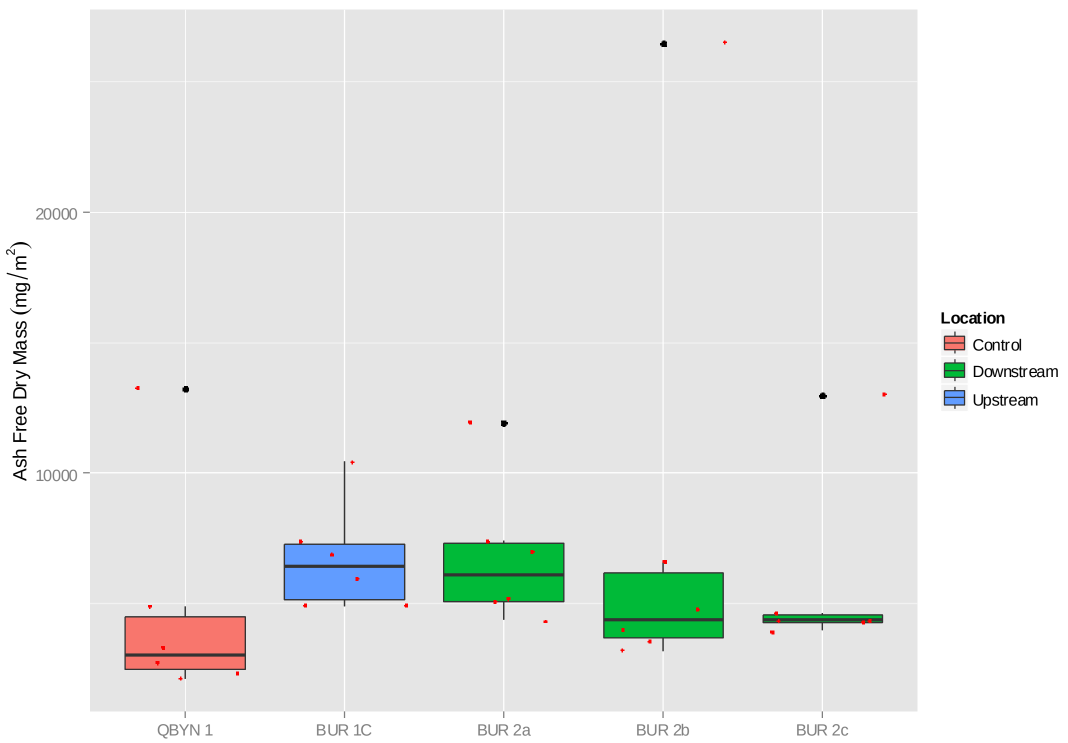


Figure 5-9. Ash free dry mass in Burra Creek and the Queanbeyan River

Red points represent the raw values for each site

5.5 Macroinvertebrates

5.5.1 Community assemblages

5.5.1.1 Riffle habitat

Based on the whole community assemblages, the riffle samples formed two distinct groups (Figure 5-10). Group 1 (on the left hand side of Figure 5-9) comprises downstream sites (BUR 2b and BUR 2c) and also the Queanbeyan control site and group 2 (on the right hand side of Figure 5-10). ANOSIM indicated that macroinvertebrate communities amongst sampling locations were not statistically different (Global- R=0.14; *P*=0.4), which supports these grouping structures. As has been seen in previous reports, the low Global-R value (i.e. approaching 0) represents sites within a given location sharing higher similarity coefficients with sites from a different location (BUR 1c and BUR 2a for example). Furthermore, one of the replicates from the Queanbeyan River appears as an outlier in Figure 5-10, and also shares higher similarity scores with BUR 2b and BUR 2c than other Queanbeyan samples.

The macroinvertebrate community composition upstream of the discharge weir (BUR 1c) was characterised by taxa with low to moderate SIGNAL scores and a tolerance to silted and slow flowing waters. Caenidae (SIGNAL= 4; Ephemeroptera) for example, are often found in slow moving, silt laden habitats (Gooderham and Tsyrlin, 2002). Chironomids (Diptera) such as Chironominae (SIGNAL =3) and Orthocladiinae (SIGNAL =4) were also highly abundant and their high relative abundance at this site is indicative of sites with soft sediments and relatively high detritus content due to their feeding ecology. Dytiscidae (SIGNAL=2), *Micronecta sp.* (Corixidae; SIGNAL = 2); Gyrinidae (SIGNAL=4) and Notonectidae (SIGNAL=1), Dytiscidae (SIGNAL=2) and *Micronecta sp.* (Corixidae; SIGNAL = 2), which are usually associated with edge habitats were also collected at BUR 1a, BUR2a and to a lesser extent BUR2b. The addition of these taxa in the riffle community composition is reflected in Figure 5-11, which shows high similarities amongst the riffle and edge samples at BUR1c and BUR2a.

Sites downstream of the discharge point in Burra Creek (i.e. BUR 2a, BUR 2b and BUR 2c) were compositionally similar to BUR 1c, with the exception of the largely edge-obligate taxa (i.e. *Necterosoma sp.* and *Micronecta sp.*) that were collected upstream. The most dominant taxa downstream of the discharge weir included several sub-families belonging to family Chironomidae, including those mentioned for BUR 1c (Chironominae and Orthocladiinae). Characteristic taxa also included Baetidae (SIGNAL=5), Caenidae (SIGNAL=4) and Hydropsychidae (SIGNAL=6). Simuliidae (SIGNAL=5) and Leptophlebiidae (SIGNAL=8) became increasingly abundant at BUR 2c, which relates to the cleaner habitat and higher velocity readings recorded at that site.

Compared to the Burra Creek sites, the Queanbeyan River control site was characterised by taxa associated with faster flowing water and heterogeneous substrates that are not armoured or dominated by fine silts and detritus. For example, Simuliidae and the net-building caddis, *Cheumatopsyche sp*. were both highly abundant at this site and both require fast flowing water due to their feeding ecology. Other taxa such as *Chimarra sp*. (Philopotamidae: SIGNAL =8) and *Illiesoperla sp.* (Gripopterygidae: SIGNAL =8) prefer coarse substrates and fast flowing water and were highly abundant at QBYN 1.

The number of families was highly comparable amongst sites, ranging from 24 at BUR 2c to 29 at QBYN 1 (Figure 5-12). At the genus level, the range was slightly wider with 29 genera collected at BUR 1c and 40 collected at QBYN 1. There were clear differences in the number of EPT genera between sites BUR 1c and BUR 2a (10 and 11 respectively) compared to sites further downstream in Burra Creek (BUR 2b and BUR 2c) and QBYN 1 (18, 16 and 21 respectively) (Figure 5-13).

Small changes in the number of EPT families were found at every site except BUR 2a, which did not change compared to autumn 2012(Figure 5-14). At the genus level small declines (ranging from 1 to 3) were seen at all of the downstream sites on Burra Creek, while the number of EPT genera at QBYN 1 and BUR 1c increased since autumn 2012.

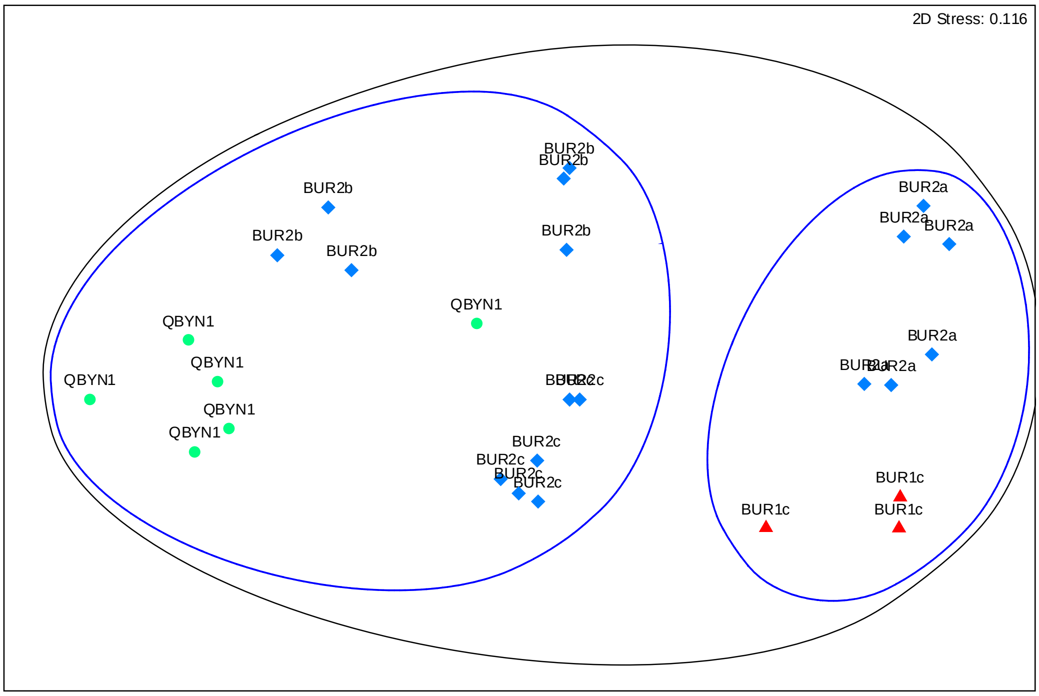


Figure 5-10. Non-metric multidimensional scaling ordination plot of genus level macroinvertebrate data from the autumn riffle samples

Note: The blue ellipse represents 50% similarity and the black ellipse represents 40% 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 show the Queanbeyan River control site.

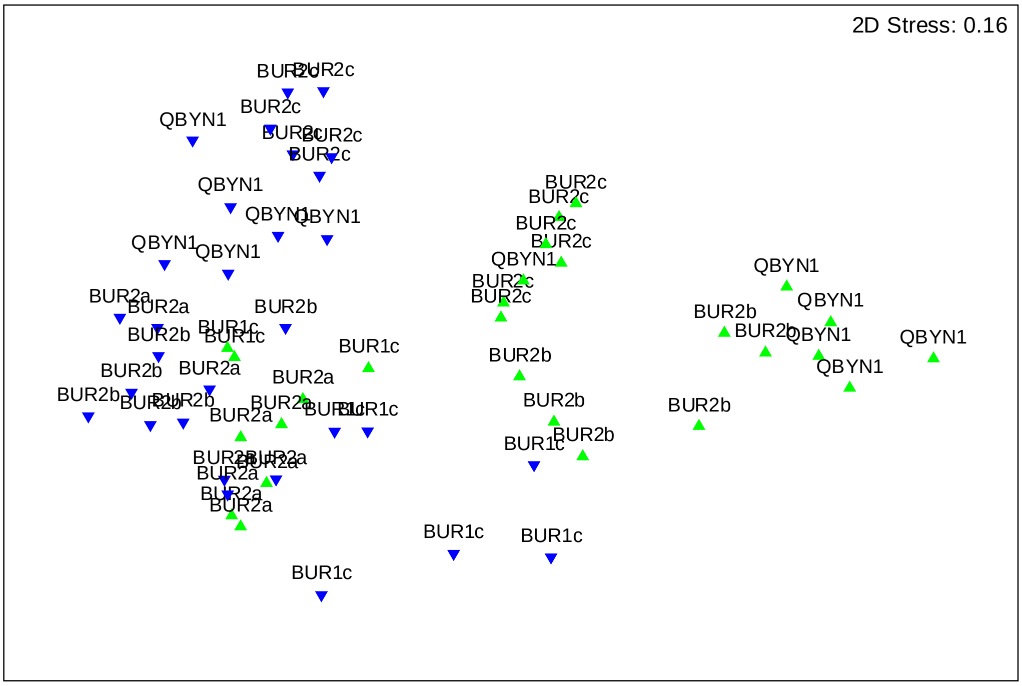


Figure 5-11. Non-metric multidimensional scaling ordination plot of genus level macroinvertebrate data from the autumn riffle and edge samples

Note: The blue triangles represent edge samples and green triangles show riffle samples

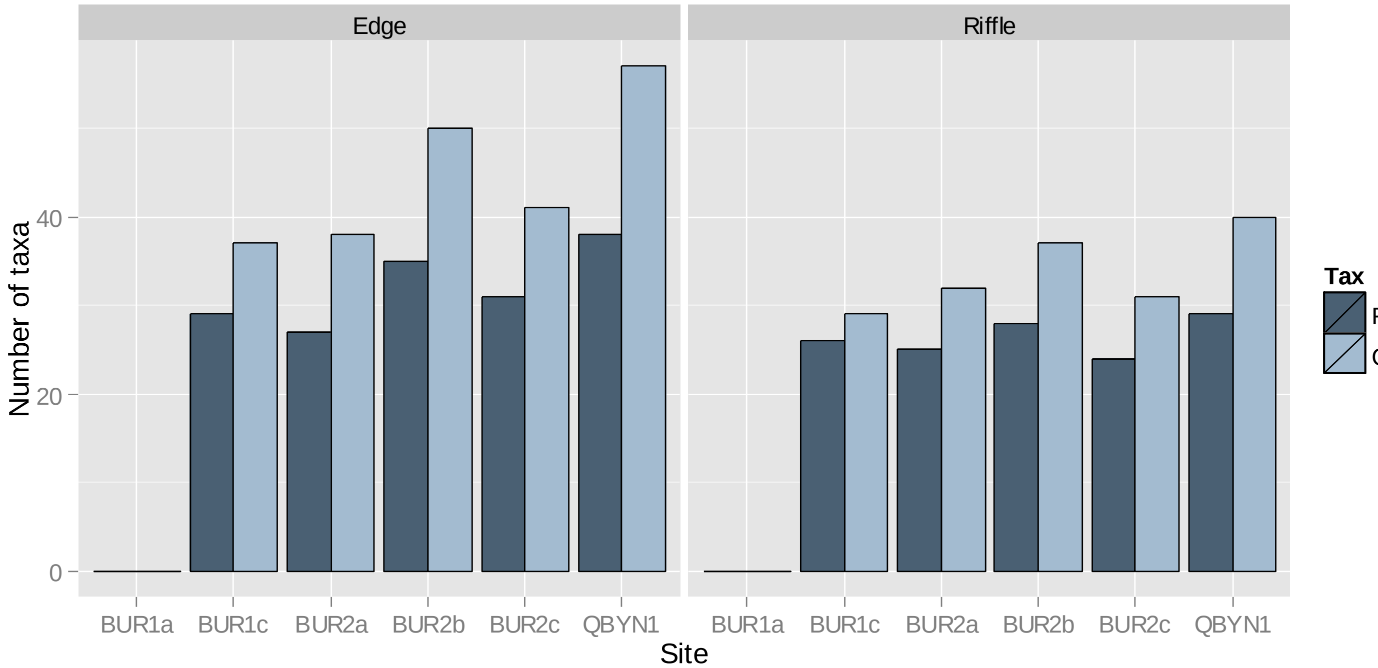


Figure 5-12. Number of taxa collected from the riffle and edge habitats

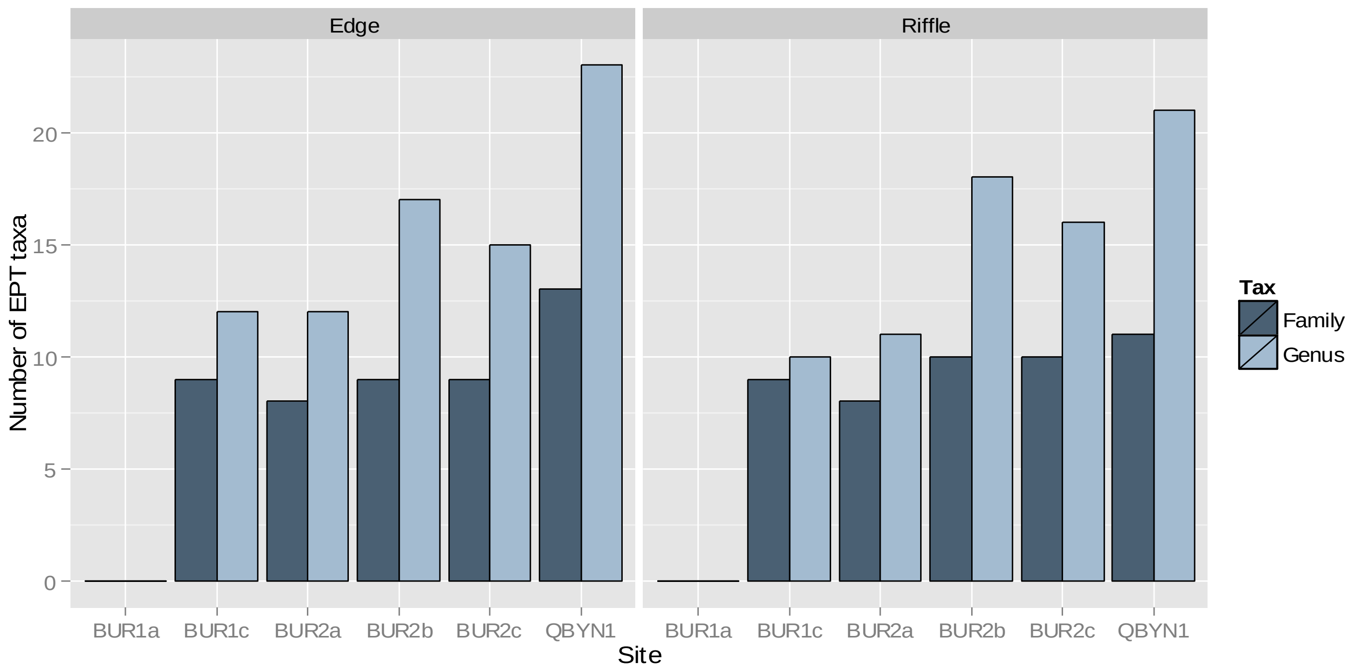


Figure 5-13. Number of EPT taxa collected from the riffle and edge habitats

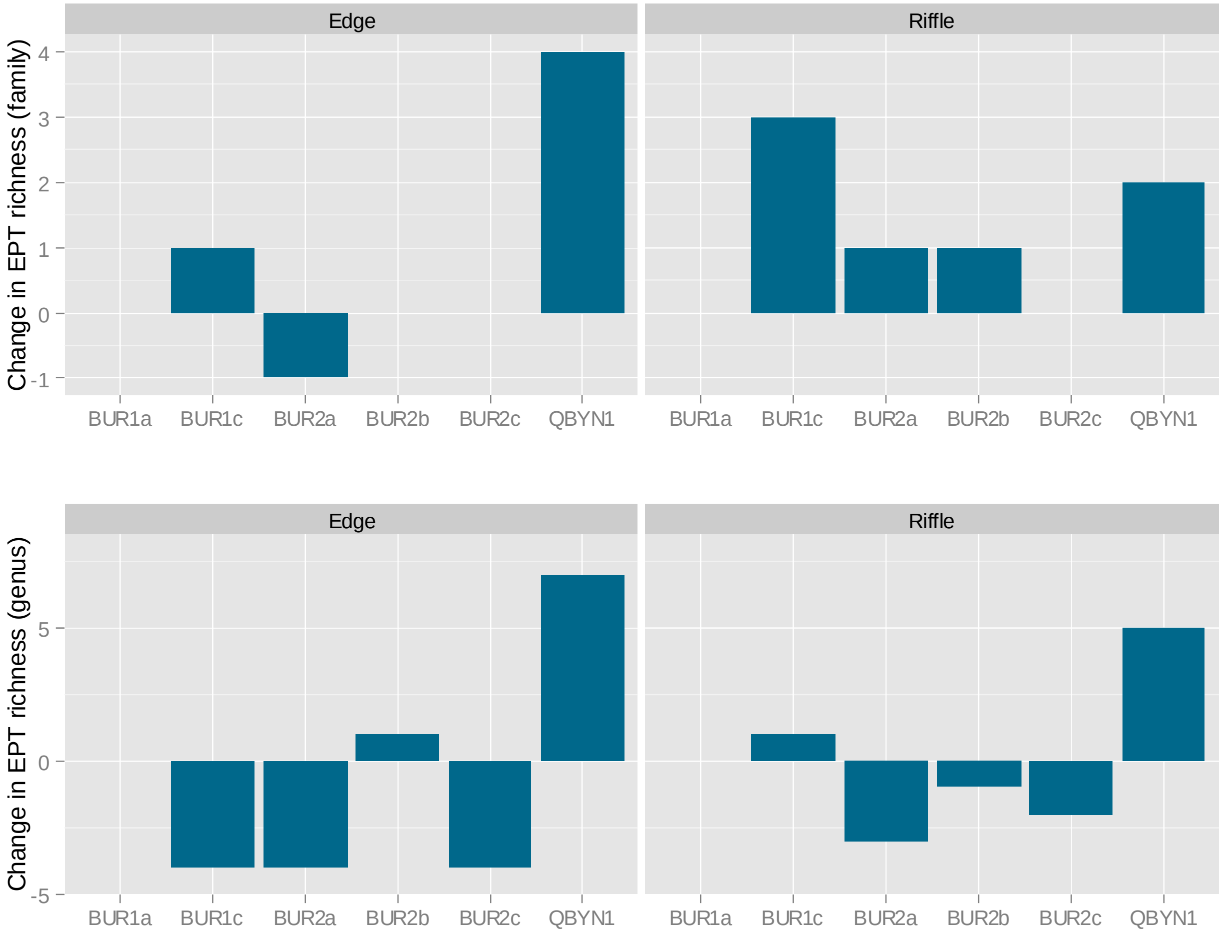


Figure 5-14. Change in the number of EPT taxa at the family level (top) and genus level (bottom) compared to autumn 2012

5.5.1.2 Edge habitat

Edge community assemblages formed two groups with 50 % Bray – Curtis similarity (Figure 5-15). BUR1c formed one of these groups, while the remainder of sites formed the other group. Sub-groups formed from 65% similarity co-efficents in the largest groups contained all samples from a given site, while there were differences between the two replicates at BUR1c. ANOSIM supports the relationships presented in the NMDS ordination plot, which indicates no significant differences in macroinvertebrate community composition according to location (Global-R = 0.048; *P*=0.50).

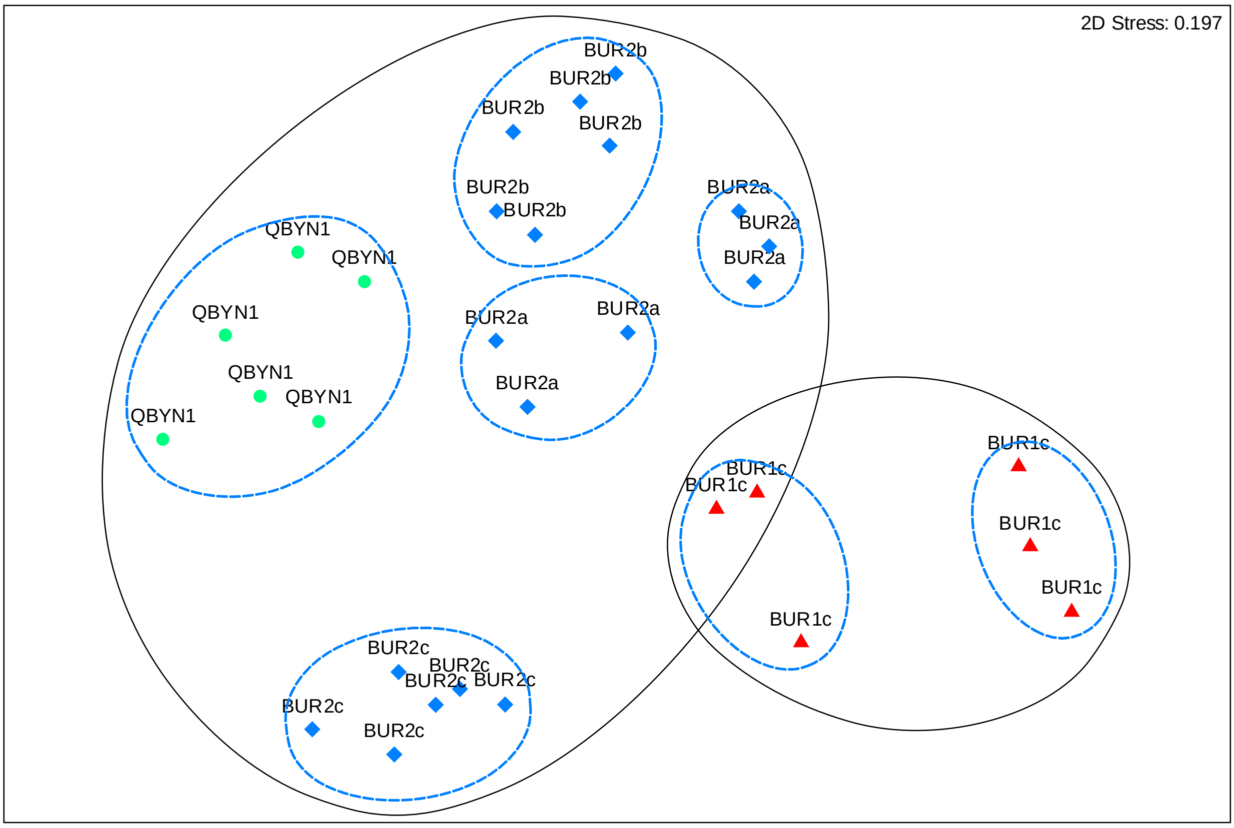


Figure 5-15.Non-metric multidimensional scaling ordination plot of genus level macroinvertebrate data from the spring edge samples

Note: Ellipses represent 65% (Blue) and 50% (Black) 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 show the Queanbeyan River control site.

The key difference between BUR1c and the larger group was the absence, or lower abundance of several highly sensitive taxa in families such as Gripopterygidae and Leptophlebiidae and a higher relative abundance of tolerant taxa such as Chironominae (SIGNAL = 3) and Orthocladiinae (SIGNAL= 4). Another key difference was the absence or lower relative abundances of Dytiscidae and Corixidae (APPENDIX D) from BUR1c, which are usually very common and can be highly abundant at this site. As noted in the previous section, these taxa were collected from the riffle samples.

Overall taxa richness was highest at the Queanbeyan River control site (Figure 5-12) as was the total number of families and genera in the EPT group Figure 5-13. In Burra Creek, taxa richness ranged from 27 at BUR1c to 35 at BUR 2b and the number of sensitive EPT taxa did not vary much between sites at the family level (range: 8-9) but ranged between 10 (at BUR1c) and 18 (BUR2b) at the genus level. Compared to autumn 2012 there was no change in the number of EPT families at BUR2b and BUR2c, while there were increases at BUR1c (1 family) and QBYN 1 (4 families) (Figure 5-14).

5.5.2 AUSRIVAS

There was no assessment for BUR 1a for the autumn 2013 sampling run. Compared to the previous autumn sampling run four of the sampling sites remained as BAND B and one (BUR 2c) had an improved health rating and was assessed as BAND A (Table 5-6).

The average O/E 50 ratio from the riffle samples for sites downstream of the discharge point was (0.83) compared to 0.80 at BUR 1c and 0.79 at QBYN 1 (Figure 5-16). As indicated from Figure 5-15 there was a high degree of variation at BUR 1c which possibly obscured statistical differences in the O/E50 ratio between locations ($F_{2,2}$ = 0.02; P=0.98; Table 5-7). SIGNAL scores derived from the riffle data were highest at QBYN1 (5.61 ± 0.34 $_{[95\%\ CI]}$) and despite the notable differences between sampling locations shown in Figure 5-16, the nested analysis of variance indicated no statistical difference ($F_{2,2}$ = 0.02; P=0.98; Table 5-7). An explanation for this contradiction is given on page 64 as a footnote.

SIGNAL-2 scores from the edge samples were generally low compared to the riffle scores, but this is somewhat expected given that the edge habitat tends to contain fewer EPT taxa. The lowest observed was at BUR 2a (3.85) and the highest observed was at BUR 1c (4.44). There was no statistically significant location effect detected with respect to SIGNAL-2 scores from edge habitat in Burra Creek ($F_{2,2}$ =1.6; P=0.38; Table 5-8). Similarly, the O/E50 ratios were not statistically different between locations ($F_{2,2}$=12.48; P=0.07; Table 5-8), albeit that the p-value was on the cusp of the rejection threshold.

Details of the individual site and replicate assessments are shown in Table 5-9. From the edge habitat, 57% of samples were BAND A and 43%, BAND B. The riffle samples had 37% BAND A assessments and 63% BAND B. The number of taxa missing from the riffle samples ranged from 3 to11 families, and these covered a wide range of SIGNAL-2 sensitivity scores (2 to 9) (APPENDIX D). Examples of sensitive taxa not recorded from some riffle habitat samples include: Glossosomatidae (SIGNAL=9), Conoesucidae (SIGNAL=7) and Elmidae (SIGNAL =7). Taxa missing from the edge habitat also had a broad range of sensitivity scores (2 to 8). Among these, the more sensitive taxa included: Elmidae (SIGNAL=7), Conoesucidae (SIGNAL=7) and Gripopterygidae (SIGNAL=8).

Table 5-6. Overall site assessments for the current and previous three sampling runs for Burra Creek

	Autumn 2011	Spring 2011	Autumn 2012	Spring 2012	Autumn 2013	Change since previous sampling run
QBYN1	B	A	B	A	B	↓
BUR1a	B	B	B	B	NS	NS
BUR1c	NS	NRA	B	B	B	_
BUR2a	NRA	NRA	B	A	B	↓
BUR2b	B	B	B	B	B	_
BUR2c	B	B	B	A	A	_

Note: NS = Not Sampled; NRA = No Reliable Assessment; NC = No Change

Table 5-7. Nested analysis of variance results from the riffle samples based on O/E50 and Signal-2 scores

Response	Source	DF	F	P-value
OE 50	Location	2	0.02	0.98
	Site [Location]	2	22.87	0.00
	Residual	26		
SIGNAL-2	Location	2	0.95[6]	0.51[6]
	Site [Location]	2	30.18	<0.001
	Residual	26		

Table 5-8. Nested analysis of variance results from the edge samples based on O/E50 and Signal-2 scores

Response	Source	DF	F	P-value
OE 50	Location	2	12.48	0.07
	Site [Location]	2	1.38	0.27
	Residual	29		
SIGNAL-2	Location	2	1.60	0.38
	Site [Location]	2	2.46	0.11
	Residual	29		

[6] It is evident from Figure 5-16 that there is a difference between Signal scores collected between locations (specifically, QBYN1 and the Burra Creek sites, despite the P-value indicating that there is not. The contradiction between the graphical summary of the means and errors in Figure 5-15 and the nested analysis of variance in table 5-7 arises from the unbalanced design. When a design is unequal, the estimates derived from the model are not as robust as balanced models. To adjust for this we applied a Satterthwaite approximation which uses modified mean squares to account for the imbalance. This correction was less accurate than the uncorrected model so the uncorrected P-value is presented, which is overly conservative and indicates no difference in SIGNAL scores, whereas the confidence intervals around these estimates suggests that this is incorrect.

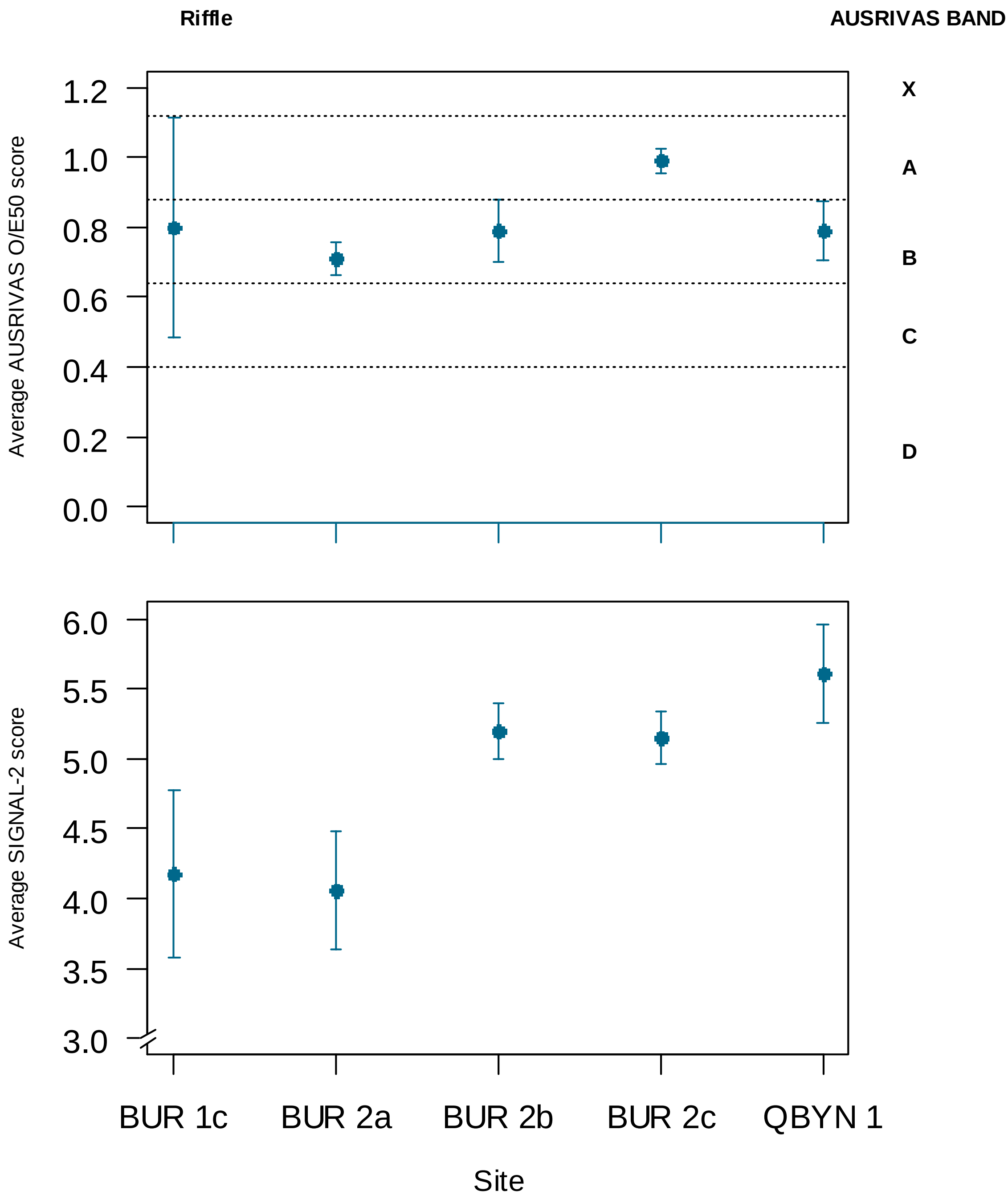


Figure 5-16. Average O/E50 scores derived from the AUSRIVAS model (top) and Average (weighted) SIGNAL scores (bottom) from riffle samples

Note: Error bars are 95% confidence intervals

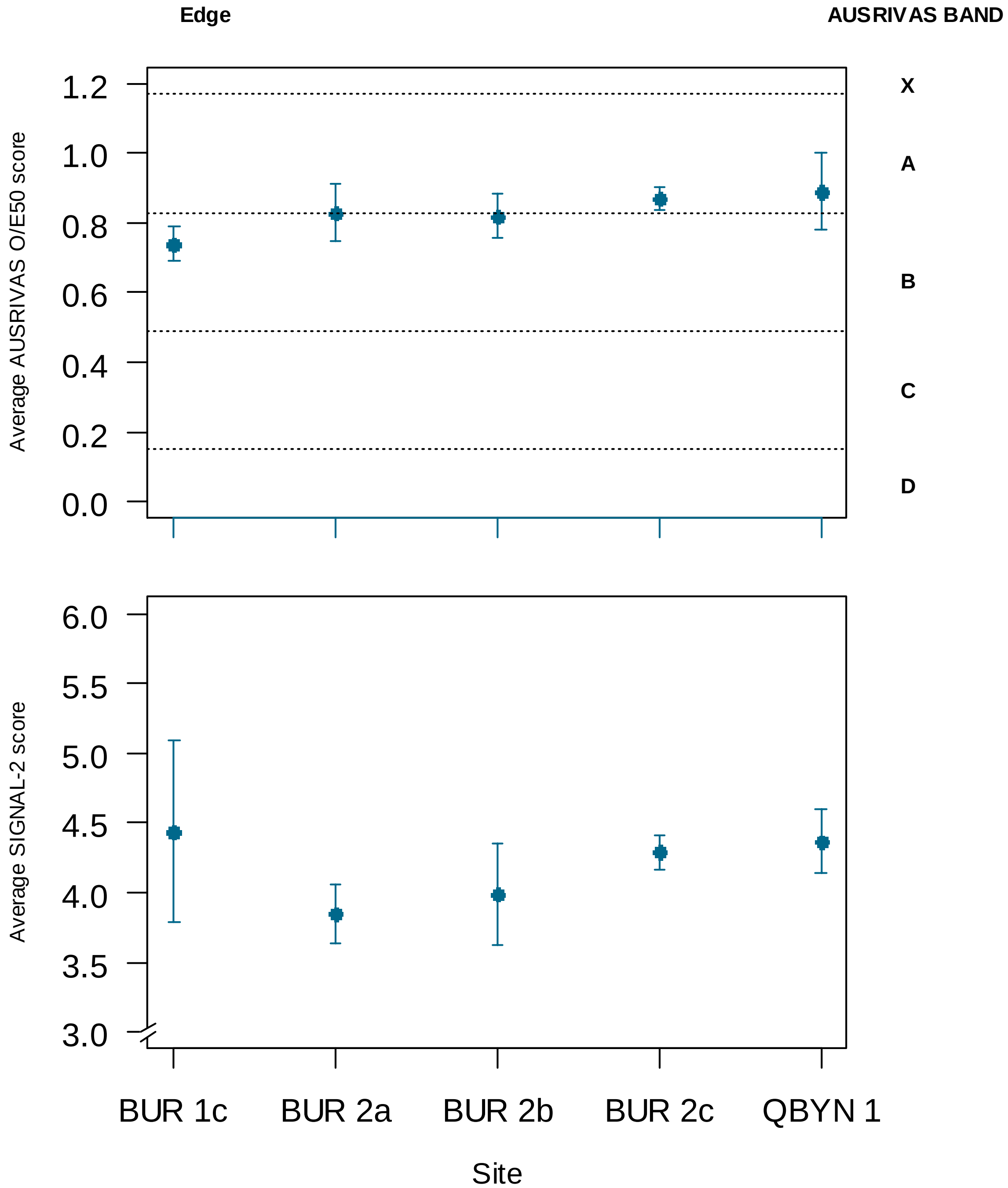


Figure 5-17. Average O/E50 scores derived from the AUSRIVAS model (top) and average (weighted) SIGNAL scores (bottom) from edge samples

Note: Error bars are 95% confidence intervals

Table 5-9. AUSRIVAS and Signal -2 scores for autumn 2013

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	5.74	4.28	0.83	0.93	B	A	B	B	B
QBYN 1	2	5.13	4.02	0.83	0.85	B	A			
QBYN 1	3	5.57	4.61	0.89	0.7	A	B			
QBYN 1	4	5.33	4.53	0.77	0.93	B	A			
QBYN 1	5	5.94	4.29	0.77	0.93	B	A			
QBYN 1	6	5.94	4.52	0.65	1.01	B	A			
BUR 1a	1	NS	NS	NS	NS	NS	NS	NS	NS	NS
BUR 1a	2	NS	NS	NS	NS	NS	NS			
BUR 1a	3	NS	NS	NS	NS	NS	NS			
BUR 1a	4	NS	NS	NS	NS	NS	NS			
BUR 1a	5	NS	NS	NS	NS	NS	NS			
BUR 1a	6	NS	NS	NS	NS	NS	NS			
BUR 1c	1	4.09	4.13	0.73	0.77	B	B	B	B	B
BUR 1c	2	4.46	3.57	0.95	0.77	A	B			
BUR 1c	3	4.00	4.05	0.73	0.77	B	B			
BUR 1c	4	NS	5.03	NS	0.68	NS	B			
BUR 1c	5	NS	4.75	NS	0.68	NS	B			
BUR 1c	6	NS	5.15	NS	0.77	NS	B			
BUR 2a	1	4.09	3.65	0.75	0.86	B	A	B	B	B
BUR 2a	2	4.46	3.83	0.67	0.86	B	A			
BUR 2a	3	4.00	3.71	0.67	0.78	B	B			
BUR 2a	4	5.13	4.24	0.75	0.86	B	B			
BUR 2a	5	5.04	3.82	0.75	0.93	B	A			
BUR 2a	6	5.12	3.85	0.67	0.7	B	B			
BUR 2b	1	5.15	4.06	0.77	0.78	B	B	B	B	B
BUR 2b	2	5.57	4.53	0.77	0.93	B	A			
BUR 2b	3	5.20	4.19	0.65	0.85	B	A			
BUR 2b	4	4.89	3.52	0.77	0.78	B	B			
BUR 2b	5	5.21	3.89	0.89	0.85	A	A			
BUR 2b	6	5.03	3.79	0.89	0.78	A	B			
BUR 2c	1	5.11	4.30	0.97	0.89	A	A	A	A	A
BUR 2c	2	5.36	4.15	0.97	0.89	A	A			
BUR 2c	3	5.32	4.23	0.97	0.89	A	A			
BUR 2c	4	4.09	4.44	1.04	0.89	A	A			
BUR 2c	5	4.46	4.42	1.04	0.89	A	A			
BUR 2c	6	4.00	4.21	0.97	0.89	A	A			

5.6 Discussion

5.6.1 Water quality and periphyton

Water quality parameters in the autumn 2013 period were characteristic of periods of low flow. This was particularly evident from the low nutrient concentrations relative to previous years (ALS, 2010_a; GHD, 2012), and the higher electrical conductivity values. Compliance to ANZECC guidelines was 100% for turbidity and total phosphorus. pH, and EC exceeded the upper limit of the guideline values at all the Burra Creek sites, but this is representative of the naturally high values for these parameters in the catchment. Since the beginning of the MEMP, mean daily EC levels have been below the ANZECC recommended upper limit a total of 237 times. As expected the majority (~60%) of these occurrences transpired in winter and spring, while only 15% occurred in autumn indicating that the recommendations in the Burra Creek Environmental Management Plan "*Water quality guidelines and standards*" section 2.2.1 (ACTEW, 2011) should be trialled as an alternative compliance and "management action" protocol for this component of the MEMP. The values presented in that management plan agree with data presented in GHD (2012a), which show strong seasonal trends in EC and pH values and imply the need to adopt season-specific trigger values.

During the M2G maintenance runs (March and May) there was no evidence of significant or lasting changes to the water quality parameters outside of seasonal influences or changes relative to natural flow variations. This is because the magnitude of the discharge was low and the duration of the abstraction period was very short-term. During these release periods, compliance occurrences increased (Table 5-2) as the surface water flows were dominated by Murrumbidgee River water, which has lower electrical conductivity and generally lower pH than Burra Creek. The exception to this rule was a spike in turbidity during the initial March run which was probably a result of the remobilisation of fine sediments either from the discharge pipe or the pool immediately downstream of the discharge weir. Aside from this initial spike in turbidity, water clarity in Burra Creek during autumn was of a high standard.

The low total phosphorus values recorded in autumn 2013 were comparable to those recorded in autumn 2012 and were within the guidelines values at all sampling sites. Total nitrogen was highest at BUR2a and was almost twice the recommended upper limit of the ANZECC guidelines (Table 5-3). The source of the spike in total nitrogen downstream of Williamsdale Road was previously confirmed to be Holden's Creek (GHD, 2012). Despite the increased nitrogen concentrations at BUR2a, there is no evidence of a biological response from the periphyton data as there was no spike in biomass (either as AFDM or inferred from the chlorophyll-a concentrations) that would be expected downstream of this discharge weir. The low phosphorus values relative to nitrogen levels may indicate that periphyton growth is partially phosphorus limited (Withers and Jarvie, 2008). However, given the time of year it is just as likely that surface water temperature limited accrual rates (Biggs, 1996).

It should be noted that the higher chlorophyll-a concentrations at BUR1c is consistent with the high filamentous algae coverage noted in our field records. BUR1c was given a category 3 assessment (35-65%) compared to category 1's (<10%) given to the remaining Burra Creek sites, suggesting that the additional flows provided by the M2G release may have been enough to remove filamentous algae from the riffle substrate at the downstream sites.

5.6.2 AUSRIVAS and macroinvertebrate assemblages

Compared to autumn 2012, BUR2c improved from BAND B to BAND A indicating that the macroinvertebrates at this site are currently close to reference condition. AUSRIVAS bands at the remaining sites did not change since autumn 2012 (Table 5-6). These results do not indicate any obvious impact –negative or beneficial – as a consequence of the M2G maintenance runs as there was no location effect detected for O/E50 ratios for either the riffle or edge habitat (Table 5-7; Table 5-8). This result is not surprising given the length of time between releases and the short duration and low magnitude of the releases since spring 2012.

Despite the non-significant ANOSIM result, it should be recognised that there are distinct site to site differences present within Burra Creek and the macroinvertebrate community structure within each site is strongly dependant on flow regime and localised environmental influences such as geology and channel morphology. The combination of these factors often results in sites within a given location (i.e. upstream, downstream or control) being more similar to sites in other locations; resulting in non-significant statistics even though there may be clear differences between key site pairs such as BUR1a and BUR2a.

The higher SIGNAL-2 scores found at BUR2b, BUR2c and QBYN1 compared to BUR1a and BUR2a (Figure 5-16) were due to the presence of Gripopterygidae (SIGNAL=8), Philopotamidae (SIGNAL=8) and a more diverse Trichopteran fauna in general at these sites. This is probably linked to habitat quality rather than water quality given that the sensitive mayfly grazer, *Jappa sp.* (Leptophlebiidae: SIGNAL=8) was relatively common at BUR1c and BUR 2b and there were no significant differences in water quality between these sites.

The improvement in SIGNAL-2 scores seen at BUR 2c since the autumn 2012 sampling run was due to three families being collected in the most recent sampling run: Elmidae (SIGNAL=7); Gomphidae (SIGNAL=5) and Leptoceridae (SIGNAL=6). The presence of Elmidae, coupled with the high relative abundance of Hydropsychidae and Gripopterygidae may be an indication of improved hydraulic conditions at this site; however the reason for the absence of Elmidae in autumn 2012 is unclear considering base flows were higher in that sampling run compared to the present and Elmidae have preferences for flowing water (Gooderham and Tsyrlin, 2005).

AUSRIVAS Bands at the remaining Burra Creek sites (with the exception of BUR1a) did not change since autumn 2012. All sites were dominated by high numbers of Chironomid sub-families including: Tanypodinae; Orthocladiinae and Chironominae. Elmidae, Psphenidae (SIGNAL =6) and Simuliidae were predicted to occur at BUR 2a and BUR2b but were missing from the majority of samples at these sites (APPENDIX D). As these taxa depend on steady flowing water due to feeding and life history requirements (Minshall, 1984; Gooderham and Tsyrlin, 2005; Lake, 2008) their absence further implies a response to the low flow conditions at the time of sampling.

An indirect effect of these low flow conditions was the varying degrees of encroachment by macrophytes during autumn. BUR1c was the site most affected by macrophyte encroachment, which in turn facilitates the settlement of fine sediments and can lead to changes in bed composition (Jones *et al.*, 2012) and biochemical processes (Dahm, 2003). The resulting high silt content and detrital matter particularly at BUR1c but also at BUR2a and BUR2b explains the high relative abundances of sediment dwelling taxa such as the aforementioned chironomids and the absence of some of the more sensitive taxa that were predicted to occur (APPENDIX D). This is reflected in the contrasting SIGNAL-2 scores, especially between QBYN1, which is dominated by cobbles, boulders and pebble, and BUR1c.

Another consequence of the onset of seasonal low flows in Burra Creek is that the fringing vegetation becomes isolated as wetted width decreases and exposes and removes an important habitat for macroinvertebrates. Fringing vegetation may provide attachment points for filter feeders (Boulton, 2003) or a buffer to high velocity flows in the main channel. Under low flow conditions or during the drying phase, taxa can be displaced resulting in overlap in obligate edge and riffle faunas. In this study, for example we found relatively high numbers of Dytiscidae (SIGNAL=2), *Micronecta sp.* (Corixidae; SIGNAL = 2); Gyrinidae (SIGNAL=4) and Notonectidae (SIGNAL=1) and in the riffle habitat at BUR1a, BUR2a and to a lesser extent, BUR2b (Figure 5-11). These taxa are usually characteristic of slow flowing water and are generally ubiquitous in pool/edge samples. Boulton and Lake (1992) found overlap of edge and riffle taxa at temporary sites, while the more permanent sites had distinct segregation of taxa between habitats. The results of this study agree with Boulton and Lake’s in that the occurrence of these taxa in riffle habitats was confined to Burra Creek.

The results from autumn 2013 are not unique to this particular sampling run. Low flow effects have been seen previously including the drying of riffle habitat at BUR1a, channel encroachment and sediment deposition in riffles and pools. These patterns are usually seasonal, and the data obtained over the course of this project suggest that re-colonisation and re-establishment of sensitive taxa is usually relatively fast following spring rainfall and the establishment of surface flows.

As a result of above average flows into the Googong Reservoir in recent times, the requirement to utilise the M2G pipeline for water transfer in the near future has significantly diminished. Therefore the M2G pumps are currently in “Standby” mode where they remain ready to run but are only switched on once every two months for maintenance runs. In this mode the maximum flow rate during the maintenance runs is likely to be approximately 49ML/d. This flow volume also has the potential to be used as a riffle maintenance flow within Burra Creek. The benefit of the flow is to remove algae, remobilise and transport fine sediment, and perhaps reduce some encroachment of vegetation into the central stream channel.

5.7 Burra Creek Conclusions and Recommendations

Autumn was characterised by low flows in both Burra Creek and the Queanbeyan River. Comparisons to drier years indicate very similar macroinvertebrate community structures and comparable taxa richness values to those seen in this study. AUSRIVAS Bands have remained remarkably consistent throughout this study, which either implies that the Burra Creek system has high resistance to change or the banding scheme is insensitive to changes associated with the intermittent nature of the Burra Creek flow characteristics.

In fact, some caution needs to be placed on these bandings based on the fact that the AUSRIVAS model does not take into account the permanency of flow conditions in Burra Creek. Chessman *et al.* (2010) argued that because several of the AUSRIVAS models do not include hydrological variables in the model, as is the case with the ACT autumn riffle model, the AUSRIVAS model has no means to vary predictions depending on existing or previous hydrological conditions, which can have a strong influence on the current structure of macroinvertebrate communities (Finn *et al.*, 2009).

The data collected during the autumn sampling period shows no conclusive evidence that the macroinvertebrate community composition, water quality or periphyton patterns are directly related to the ongoing M2G maintenance runs. Instead, the water characteristics and patterns in the biological indicators are indicative with the direct and indirect effects of low flows that are a natural component of the seasonal dynamics of Burra Creek.

It is recommended that long term analysis be carried out to assess trends in the biological and water quality variables in response to hydrological parameters. It is suggested that this be done as a separate report so that the seasonal reporting is left in the current format. As part of the long term analysis, targeted analyses of taxa missing from the AUSRIVAS models should be looked at to determine points of change along hydrological gradients. This may assist in both the prediction of health assessments based on certain abstraction regimes, and may assist in the development of biological “health” targets for Burra Creek during the operation and shut down phases of the M2G project.

It is also proposed that the trigger levels for EC and pH as suggested in the Burra Creek management plan also be used in the next round of reporting to provide a more realistic assessment of the naturally high values in Burra Creek. These would be included in the current format as a compliment to the ANZECC guidelines as season-specific upper limits in recognition that these parameters exhibit strong seasonal fluctuations.

Part 3 - Murrumbidgee Pump Station

6. Murrumbidgee Pump Station

6.1 Summary of sampling and river condition

The Murrumbidgee Pump Station sites were sampled on the 8th, 9th and 13th of May 2013. During this time daily maximum temperatures ranged from 14 to 22°C (BOM, 2013). The weather was fine for the initial two days of sampling; however moderate rainfall fell consistently during sampling on the 13th of May. The flow in the Murrumbidgee River during this time was steadily increasing with an increase in flows from the 9th to the 13th of approximately 30%.

Overall flow levels were lower when compared to autumn 2012, with the lowest average monthly flows for the season since autumn 2010. The difference between autumn 2012 and autumn 2013 was over 600 ML/d measured at the Lobb's Hole gauging station for the duration of sampling.

During the autumn 2013 sampling run two edge samples were missed, one from MUR 28 and one from MUR 937. These missed samples are a result of the limited habitat availability due to the low flows during the sampling period. Photos of the sampling sites are shown in Plate 6-1, while full site summaries are shown in APPENDIX E.

MUR 931. Looking upstream towards the riffle
166 ML/d

MUR 28. Looking upstream across the riffle
145 ML/d

MUR 935. Looking across the riffle habitat
195 ML/d

MUR 937. Riffle habitat looking upstream
145 ML/d

MUR 29. Looking across the channel with multiple riffles
195 ML/d

Plate 6-1. Photographs of sampling sites for the MPS component of the MEMP

6.2 Hydrology and rainfall

Base flow during the autumn period was relatively stable with the hydrograph in recession during the early weeks of March from a small event which peaked on the last day of February at just over 1,800 ML/d at the Mt. MacDonald gauging station (410738). Flows dropped until a small rainfall event in late March created a small rise in the hydrograph before receding to base levels (Figure 6-1). Flows remained between approximately 100 ML/d and 200 ML/d for the rest of the period. Consistent rain on the 13th of May occurred during sampling, however this only created a very small rise on the hydrograph and did not affect sampling in any way. Flows were more responsive to releases from Tantangara Dam during May, which were fluctuating during this period, than to the local rainfall. Table 6-1 shows the monthly flow and rainfall statistics for the autumn period.

Plate 6-2 and Plate 6-3 illustrate the reduction in flow in the Murrumbidgee River when compared to autumn 2012. The wetted width and river margins have clearly reduced with flow comparisons from Lobb's Hole gauging station (410761) showing that only approximately 20% of the water flowing through this section of river during autumn sampling in 2012 was flowing through during autumn sampling in 2013. Flow in the Cotter River downstream of the Cotter Dam was quite variable during the March, but settled out into a more consistent flow level for the remainder of the autumn period (Figure 6-2), with flows during the sampling period consistently 40-45 ML/d.

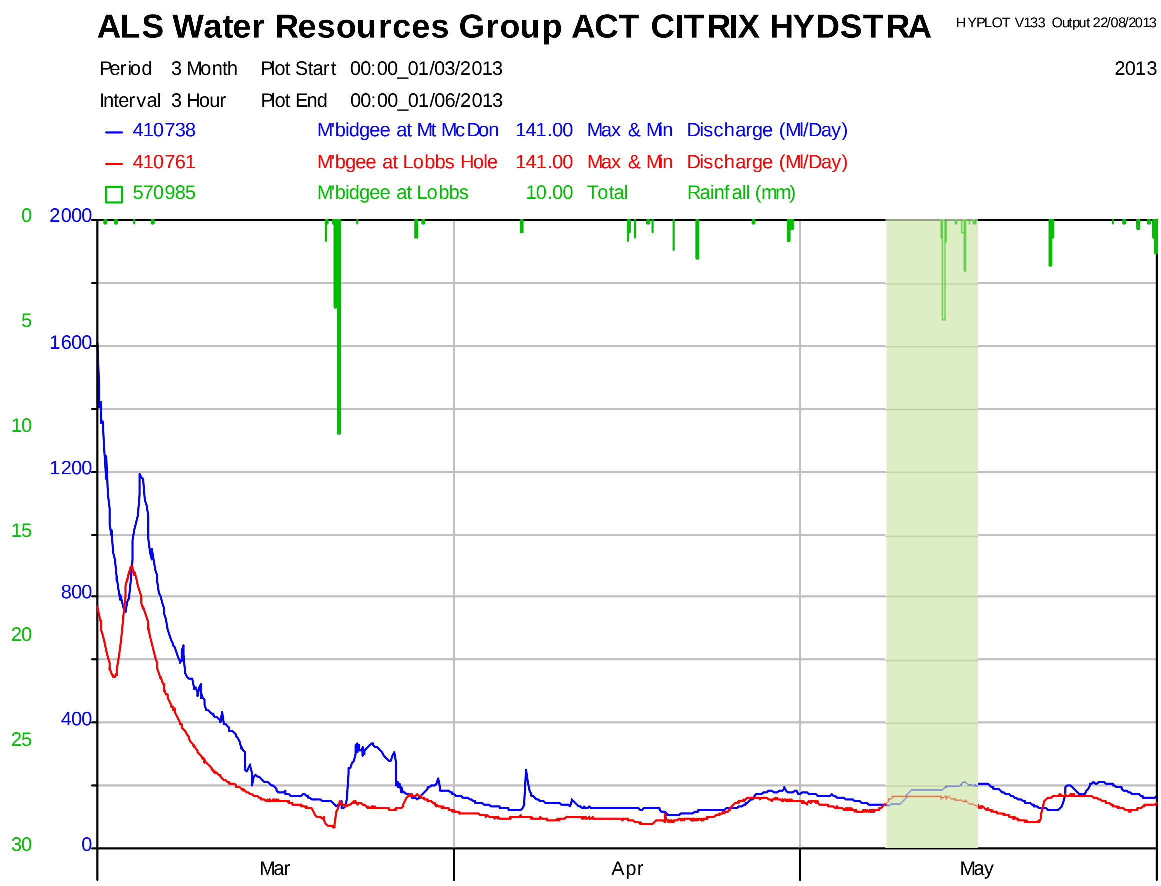


Figure 6-1. Spring hydrograph of the Murrumbidgee River at Lobb's Hole (410761) and Mt. MacDonald (410738), including total rainfall for the Lobb's Hole gauge (570985)

Note: Green shading indicates sampling period.

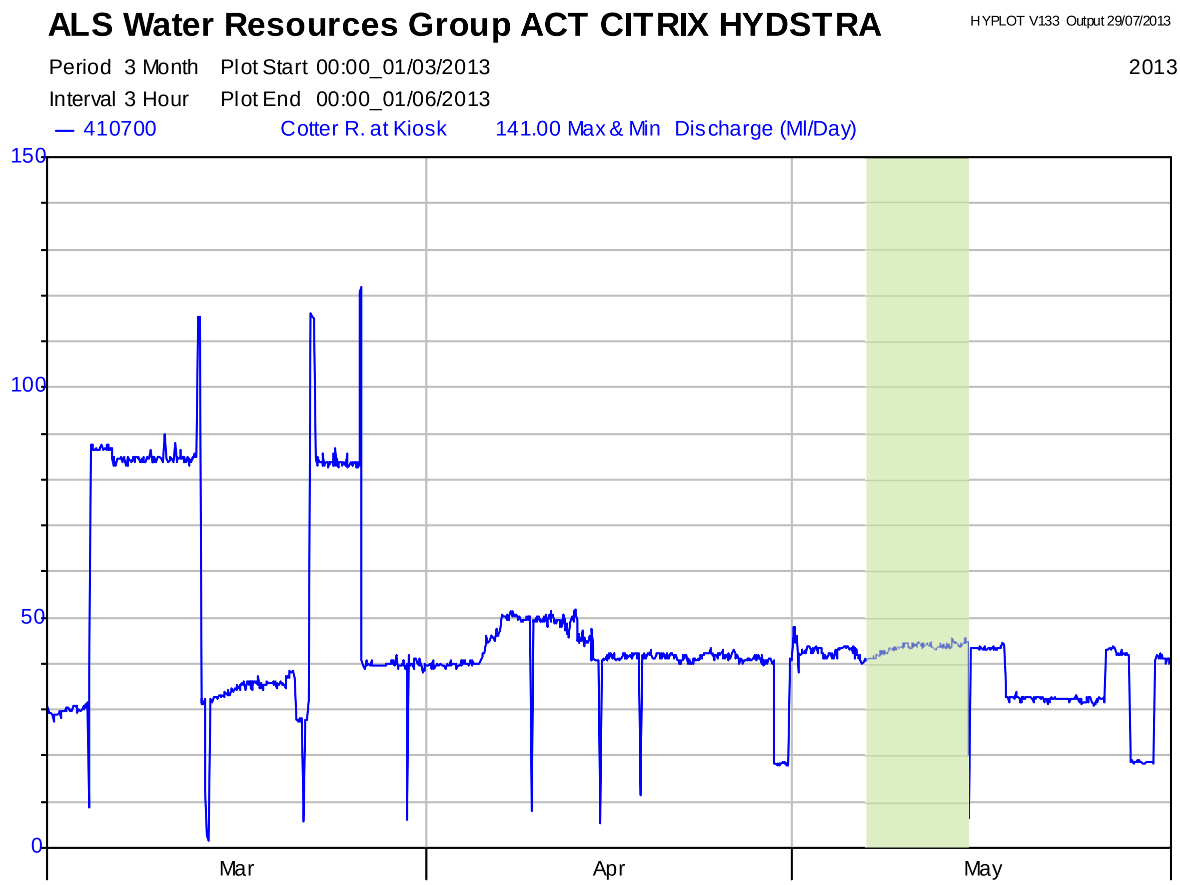


Figure 6-2. Hydrograph for the Cotter River downstream of the Cotter Dam (410700) for autumn 2013

Note: Green shading indicates the sampling period.

Table 6-1. Monthly flow and rainfall statistics for autumn 2013 at Lobb's Hole (410761) and Mt. MacDonald (410738)

	Lobb's Hole (410761)		Mt. MacDonald (410738)
	Total Rainfall (mm)	Mean Flow (ML/d)	Mean Flow (ML/d)
March	**20.2**	**279.4**	**418.7**
April	**11.0**	**108.2**	**139.9**
May	**19.0**	**140.2**	**172.6**
Autumn (mean)	**16.7**	**175.9**	**243.7**

2012 – 1,600 ML/d (3/5/2012)

2013 – 140 ML/d (8/5/2013)

Plate 6-2. The Murrumbidgee River upstream of the Cotter Rd bridge and the MPS, in autumn 2012 (top) and autumn 2013 (bottom)

2012 – 1,600 ML/d (3/5/2012)

2013 – 140 ML/d (8/5/2013)

Plate 6-3. The Murrumbidgee River downstream of the Cotter Rd bridge, with the MPS on the right bank, in autumn 2012 (top) and autumn 2013 (bottom)

6.3 Water quality

6.3.1 Grab samples and *in-situ* parameters

The water quality from the grab samples collected at each site showed that most parameters were within the ANZECC & ARMCANZ (2000) guidelines (Table 6-2). All electrical conductivity (EC), turbidity and dissolved oxygen (DO) readings were within the guidelines. MUR 931, the farthest upstream site had the lowest DO reading of 90.8 % saturation, however this is still above the minimum recommended level. All sites were recorded outside the recommended range for pH. These readings were slightly higher compared to autumn 2012 where only three sites exceeded the recommended range, while the remaining two sites, MUR 931 and MUR 29, were on the cusp of the upper limit.

Nutrient levels within the Murrumbidgee River were lower compared to the levels recorded in autumn 2012. All of the total phosphorus (TP) concentration readings were below the recommended ANZECC & ARMCANZ (2000) guideline trigger level. The autumn 2012 TP results showed exceedances at the three furthest upstream sites (MUR 931, 28 & 935). Indeed, prior to autumn 2013, there had not been an occasion where all sites recorded TP results below the guideline trigger level during the one season since autumn 2010. Three sites recorded total nitrogen (TN) concentrations exceeding the recommended guideline range (MUR 931, 937 & 29), with MUR 935 recording TN concentrations on the cusp of the guideline trigger value. These values are an improvement on those recorded in autumn 2012, when all five MPS sites exceeded the ANZECC & ARMCANZ (2000) guideline trigger value for TN.

6.3.2 Continuous water quality monitoring

The continuous water quality monitoring data collected from Lobb's Hole (410761) are presented in Figure 6-3. The temperature data collected at the gauging site shows a reduction throughout the period which corresponds to the cooler ambient temperatures throughout autumn leading into winter. The EC readings remained within the recommended range set out in the ANZECC & ARMCANZ (2000) guidelines for the entire autumn period. EC initially dropped with the higher flows in late February, but climbed to more indicative levels as base flow became more stable.

The turbidity readings were low due to the limited rainfall during autumn, with no exceedances of the upper limit for the recommended range of the ANZECC & ARMCANZ (2000) guidelines for daily mean. However, 18 daily means were below the lower limit for the guidelines. The pH sensor was not operational for most of the autumn period with only the last two weeks of May recorded. This is due to a lightning strike which damaged the probe in January 2013, resulting in ongoing issues since. The pH during late May showed a diurnal trend which was slightly elevated above the guideline range. However, this is normal for this part of the Murrumbidgee River based in historic data. The dissolved oxygen (DO) levels recorded were similar to previous autumn seasons with readings close to the lower limit of the ANZECC & ARMCANZ (2000) recommended range, showing 10 daily means were below the range for this season.

Table 6-2. *In-situ* water quality results from Murrumbidgee Pump Station during autumn 2013

ANZECC and ARMCANZ (2000) guidelines are in red bold parentheses, yellow cells indicate values outside of the guideline values, 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	MUR 931	13/05/2013	9:55	12.7	168.5	4.38	6	8.12	90.8	9.63	68	0.002	0.002	< 0.002	0.002	0.017	0.26
	MUR 28	8/05/2013	14:05	13.8	178.5	4.32	5	8.26	101.1	10.48	66	< 0.002	< 0.002	< 0.002	< 0.002	0.015	0.24
Downstream	MUR 935	13/05/2013	13:20	12.8	167.9	6.93	7	8.1	95.3	10.08	69	0.003	0.003	< 0.002	< 0.002	0.016	0.25
	MUR 937	9/05/2013	10:20	12.1	171.7	3.49	6	8.12	101.7	10.92	70	< 0.002	< 0.002	< 0.002	< 0.002	0.015	0.28
	MUR 29	13/05/2013	15:00	13.2	168.7	9.71	7	8.17	94.9	9.95	69	< 0.002	< 0.002	< 0.002	< 0.002	0.017	0.27

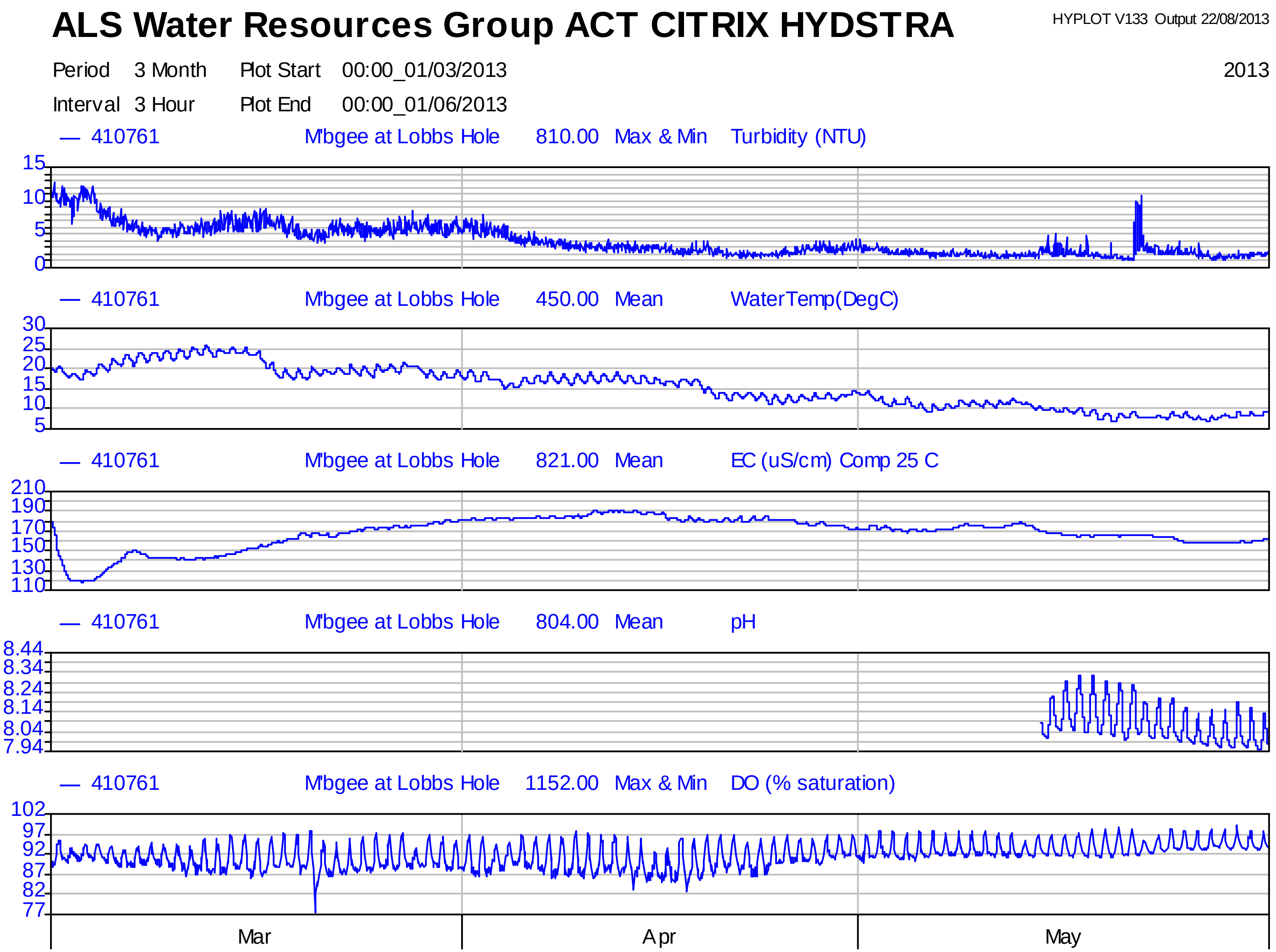


Figure 6-3. Continuous water quality records from Lobb's Hole (410761) for autumn 2013

6.4 Periphyton

In autumn 2013 there was no statistical difference in chlorophyll-a concentrations between upstream (mean = 25,062.9 ± 8799.4 ug/m^2) and downstream (mean = 15,151.8 ± 2946.1 ug/m^2) locations ($F_{1,3}$ = 2.33; P=0.22; Table 6-3) despite the noticeably higher percentile values at MUR 931 (Figure 6-4). The variance portioning method used in the nested mixed model approach revealed that most of the total model variance was within individual sites (46%), sites nested within location accounted for 36% of the total and location differences accounted for 17%.

Ash free dry mass (AFDM) was reasonably consistent amongst sampling locations (Figure 6-5), which is supported by the absence of statistical difference between these locations ($F_{1,3}$ = 0.21; P=0.68; Table 6-3). There was an obvious outlier at MUR 931, which was considered not to be highly influential on the model fit after log10 transformations had been conducted. The majority of the variation in the AFDM model arises from within a given site (95%), while variation based only on location accounted for <5%.

Table 6-3. Nested analysis of variance results for chlorophyll-a and AFDM concentrations for MPS

Response	Source	DF	F	P-value
Chlorophyll-*a*	Location	1	2.33	0.22
	Site [Location]	3	5.12	0.01
	Residual	29		
AFDM	Location	1	0.21	0.68
	Site [Location]	3	0.52	0.68
	Residual	29		

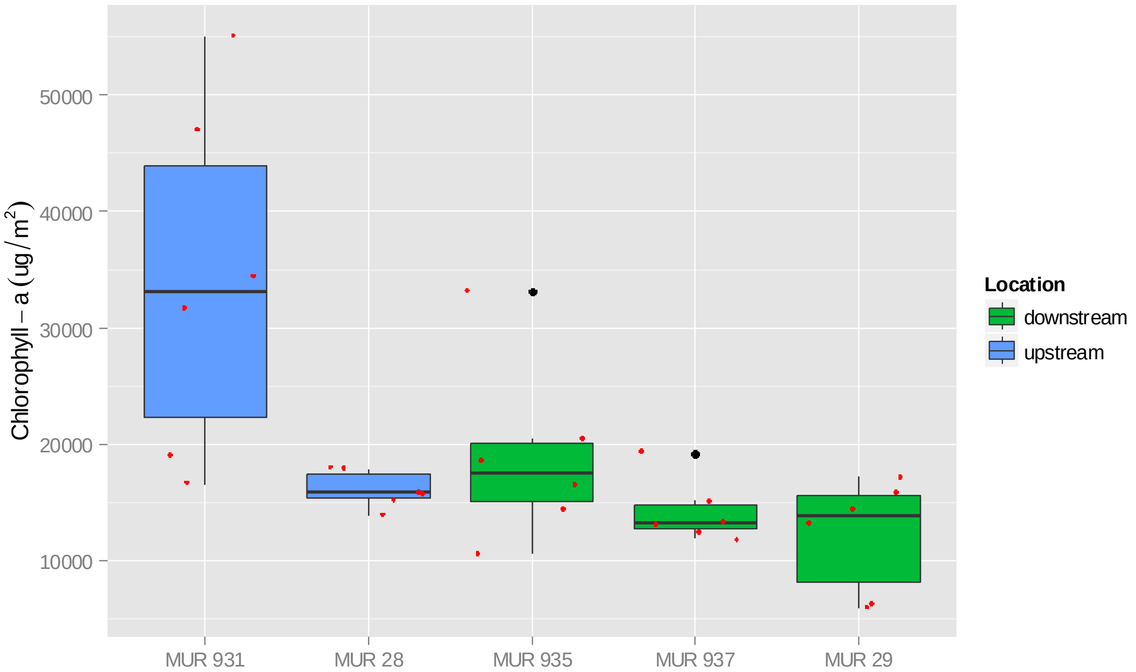


Figure 6-4. Chlorophyll-a concentrations upstream and downstream of the Murrumbidgee Pump Station

Red points represent the raw values for each site

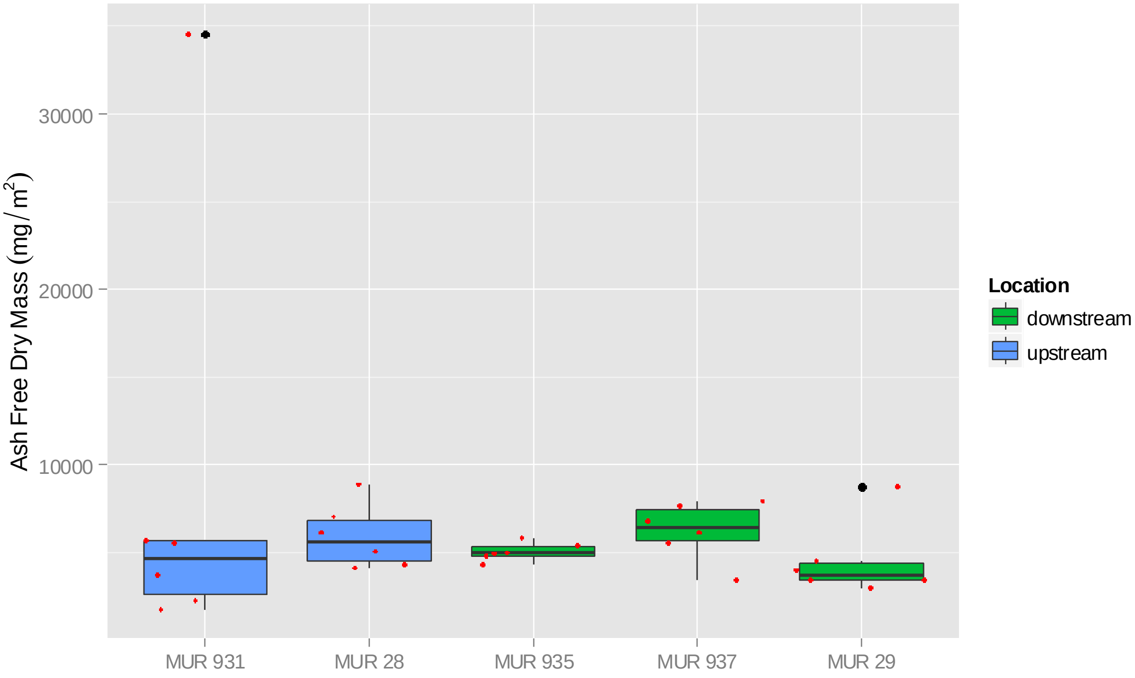


Figure 6-5. Ash free dry mass (AFDM) collected upstream and downstream of the Murrumbidgee Pump Station

Red points represent the raw values for each site

6.5 Macroinvertebrates

6.5.1 Community assemblages

The number of unique taxa and the number of Ephemeroptera, Plecoptera and Trichoptera (EPT) taxa which were collected in both the edge and riffle habitats are shown in Figure 6-6 and Figure 6-7 respectively. Data in these tables are separated to show both family and genus taxonomic level results. While there is some between-site variation within the upstream and downstream locations, differences at both taxonomic levels for EPT taxa in both habitats are negligible. No difference was found between upstream and downstream sites for unique taxa in the riffle habitat. However a slight difference in the number of unique genera collected between the upstream and downstream sites was recorded for the edge habitat, showing more genera were present at the upstream sites when compared to downstream sites on average.

The NMDS ordination plot for the riffle habitat shows some separation between the upstream and downstream sites, with MUR 937 and three of the replicates (one sample) from MUR 29 separated from the rest of the samples (Figure 6-8). However it is important to note that these differences only equate to approximately 5% Bray-Curtis similarity coefficient (i.e. only 5% difference in the number of shared taxa, so only a small difference). Results of the ANOSIM confirm this as no statistical difference was found between the upstream and downstream sites (R=0.50; *P*=0.20). The ANOSIM relies on permutations to generate the *P*-value based on rank similarities, however due to the number of sites in this component of the sampling program the smallest possible *P*-value is 0.10. For this reason a PERMANOVA model was used to allow for Monte Carlo permutations which also resulted in a non-significant result (Monte Carlo *P*=0.08; 9999 permutations) (Table 6-4). Combined, these results provide confidence that there were no changes in macroinvertebrate community composition attributable to the MPS.

The dominant taxa within the riffle habitat were Hydropsychidae (SIGNAL=6), Simuliidae (SIGNAL=5), Caenidae (SIGNAL=4) and Chironominae (SIGNAL=3). Relative abundances of taxa were different between locations with relative abundances of downstream sites much higher than those of upstream sites. This difference in relative abundance was driven by higher abundances of three of the dominant taxa: Hydropsychidae, Simuliidae and Caenidae at the downstream sites. The differences in relative abundances of these taxa between sites and locations is likely to explain some of the differences between groups in the NMDS plot (Figure 6-8) and this is likely the reason that only subtle differences in community composition were observed between upstream and downstream reaches overall.

The NMDS ordination plot in Figure 6-9 shows the relationship between autumn 2013 edge habitat samples in terms of their taxonomic composition. In this plot all sites are separated from each other at the 60% similarity level, with the exception of MUR 935 and 29. The separation of samples from MUR 931 is more pronounced with samples from this site forming two separate clusters at the 60% similarity level, highlighting the greater level of within-site variability at this site. This is reflected in the results of the ANOSIM where there was no significant difference detected between the upstream and downstream sites (R=0.50; *p*=0.10). Similar to the riffle habitat data analysis procedure a PERMANOVA model was used to allow for Monte Carlo permutations which also showed a non-significant result (Monte Carlo *p*=0.12; 9999 permutations) (Table 6-5).

The dominant taxa in the edge habitat were Chironominae, Caenidae and Corixidae (SIGNAL=2). These taxa are usually associated with this habitat due to their affinity for slow flowing water and soft sediment (Gooderham & Tsyrlin, 2005), however some overlap with the riffle habitat was observed. Differences in the relative abundances from upstream sites to downstream sites were present to a smaller degree than in the riffle habitat. The three dominant taxa, Chironominae, Caenidae and Corixidae were responsible for this difference with larger abundances of these taxa at the downstream sites compared to the upstream sites.

Table 6-4. Riffle habitat PERMANOVA refit for Monte Caro permutations

Source	DF	MS	Pseudo-F	*P*-value (Perm)	Unique Permutations	*P*-value (MC)
Location	1	3800.8	2.17	0.19	10	0.08
Site [Location]	3	1749.9	4.46	0.00	9900	0.00
Residual	25	392.39				

Table 6-5. Edge habitat PERMANOVA refit for Monte Carlo permutations

Source	DF	MS	Pseudo-F	*P*-value (Perm)	Unique Permutations	*P*-value (MC)
Location	1	3979	1.92	0.03	30	0.12
Site [Location]	3	2239.6	4.07	0.00	9898	0.00
Residual	18	550.54				

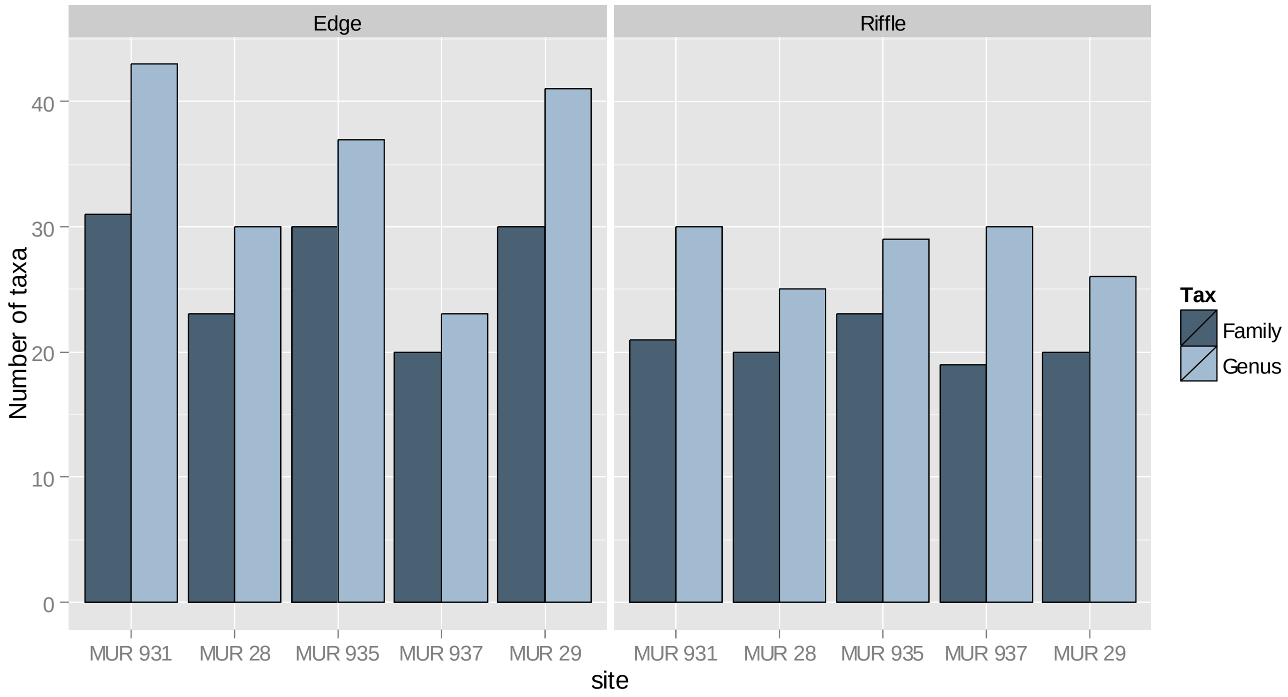


Figure 6-6 . Number of unique taxa in the edge and riffle habitats

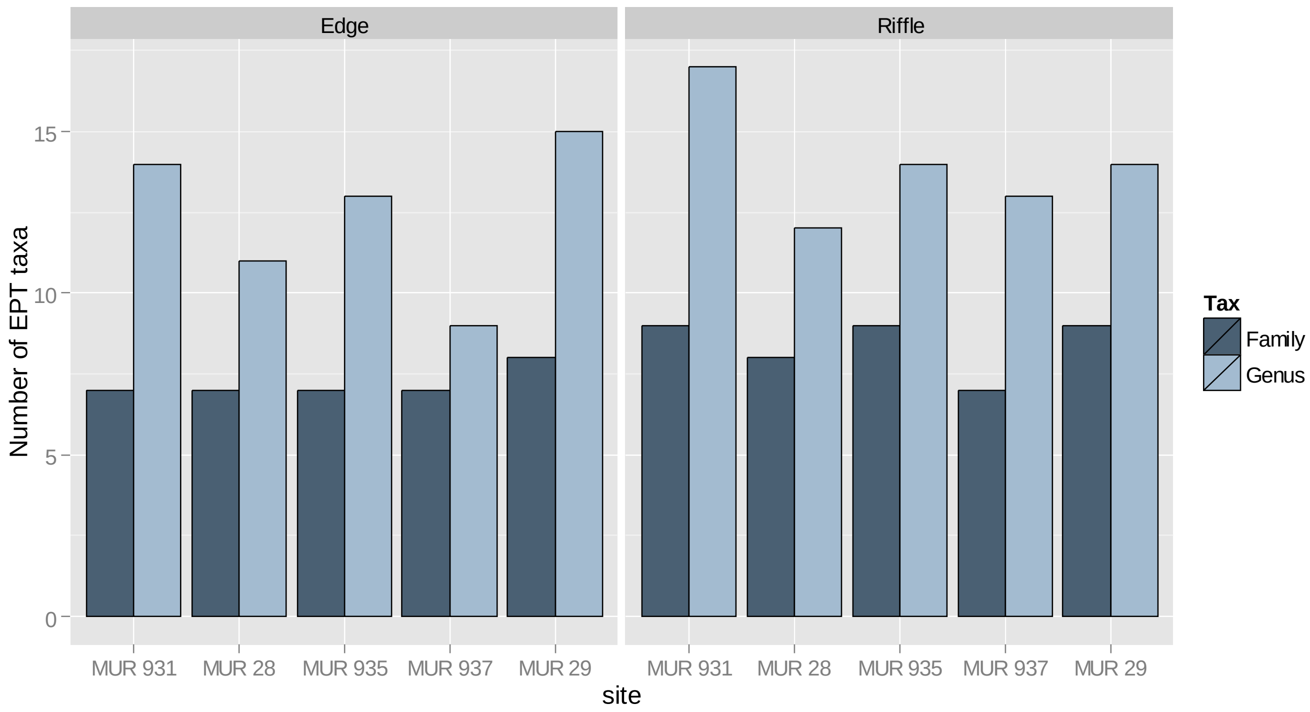


Figure 6-7 . Number of EPT taxa in the edge and riffle habitats

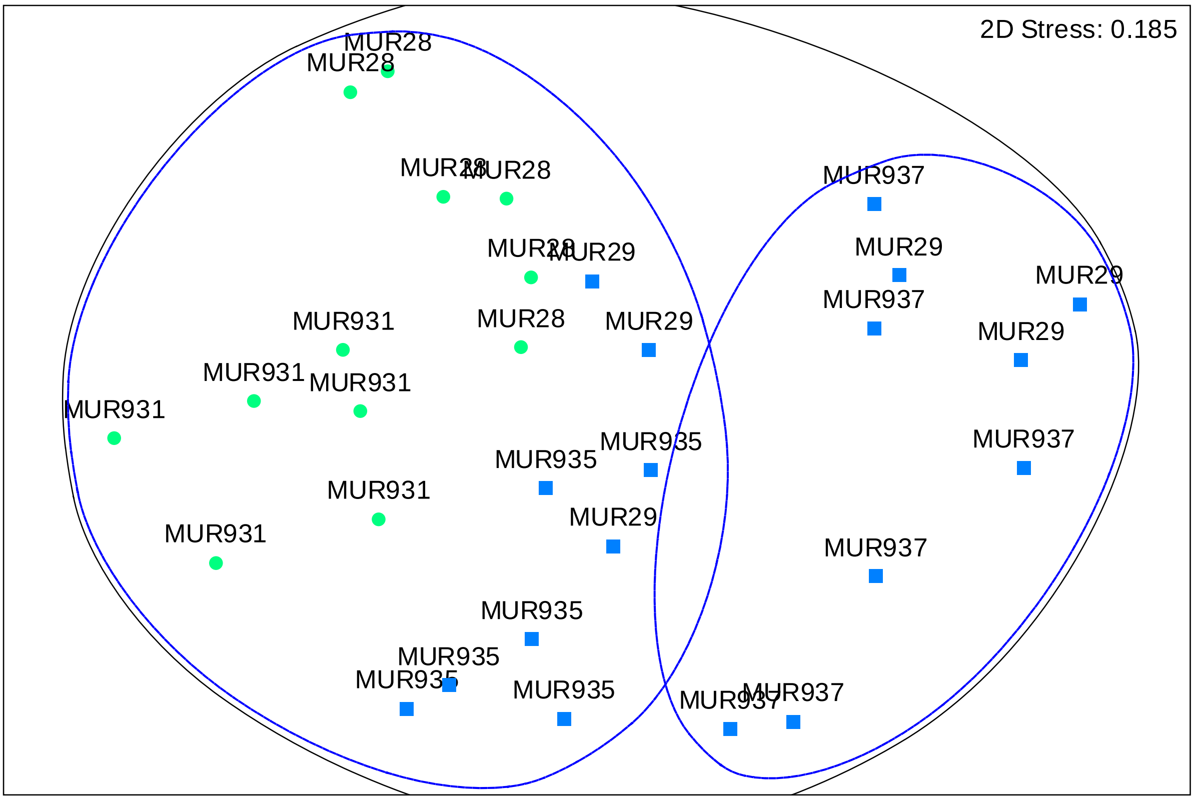


Figure 6-8 . NMDS ordination plot displaying autumn 2013 riffle macroinvertebrate data

Note: Black ellipse represents 55% similarity grouping and blue ellipses represent 60% similarity groups based on cluster analysis output; green circles represent sites upstream blue squares represent sites downstream of the MPS.

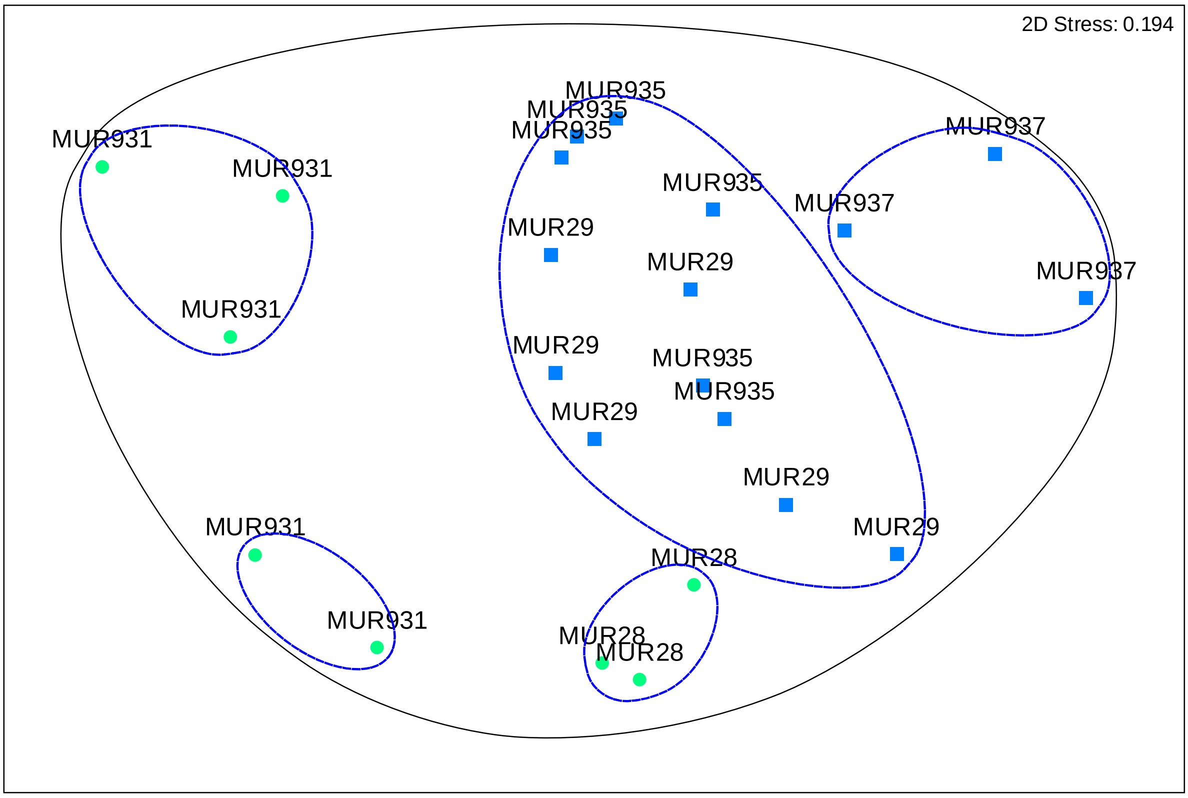


Figure 6-9 . NMDS ordination plot displaying autumn 2013 edge macroinvertebrate data

Note: Black ellipse represents 55% similarity grouping and blue ellipses represent 60% similarity groups based on cluster analysis output; green circles represent sites upstream blue squares represents sites downstream of the MPS.

6.5.2 AUSRIVAS and SIGNAL-2

The analysis of variance (ANOVA) performed on the O/E 50 scores from the riffle habitat showed no significant difference between the upstream and downstream sites (*P*=0.33) (Table 6-6). The overall habitat assessments for the riffle samples at all sites were defined as "*significantly impaired*," or Band-B (Table 6-10). However, the banding variation within sites is not apparent from the overall assessments. At three of the sites (MUR 28, 935 and 29) only one replicate was assessed as Band-B, while only two and three replicates were assessed as Band-B for the remaining sites MUR 931 and 937 respectively. All replicates assessed as Band-B were missing only a single taxa compared to the remaining replicates from the same site, which were assessed as Band-A, or "*similar to reference*". This highlights that, on the whole, the taxa expected to be present at these site were actually recorded in autumn 2013. The overall site rating as Band B for these sites comes as a by-product of the precautionary approach under AUSRIVAS which bases condition on the poorest rated result for a given site.

The ANOVA performed on the O/E 50 scores from the edge habitat also showed no significant difference between the upstream and downstream sites ($F_{1,3}$ =7.82; *P*=0.07) (Table 6-7). The overall habitat assessments produced Band-B ratings for all edge habitats with the exception of MUR 937, which was assessed as Band-A. Similar to the riffle habitats at Site MUR 28 and 29 only a single replicate was assessed as Band-B and this replicate had only one additional taxa missing when compared to the replicates from the same site which were assessed as Band-A. A list of macroinvertebrates which were predicted but not collected and a full taxonomic inventory list can be found in APPENDIX D & APPENDIX F respectively.

The ANOVA's performed on the SIGNAL-2 values from the riffle and edge habitats showed that there is no statistical difference between upstream and downstream SIGNAL-2 scores for the riffle habitat ($F_{1,3}$ =4.52; *P*=0.12), while a statistical difference was found between the upstream and downstream SIGNAL-2 scores for the edge habitat ($F_{1,3}$ =13.6; *P*=0.03) (Table 6-6 and Table 6-7). The mean weighted SIGNAL-2 scores for the edge habitat are 4.73 for the upstream sites and 4.54 for the downstream sites. This indicates that more sensitive taxa were collected at the upstream sites than the downstream sites. This result is misleading because of the larger abundances of dominant taxa at the downstream sites. The large increases in abundances of some of the macroinvertebrates with lower SIGNAL scores are skewing the weighted results. Although the differences between locations for the riffle habitat was found to be not significant, the mean weighted SIGNAL-2 scores were 5.00 for upstream and 5.18 for downstream. This suggests, opposite to the edge habitat, that more sensitive taxa were collected at the downstream sites than the upstream sites.

Table 6-6. One way analysis of variance results for O/E 50 and SIGNAL-2 scores from the riffle habitat

Response	Source	DF	F	P-value
OE 50	Location	1	1.37	0.33
	Site [Location]	3	0.36	0.78
	Residual	29		
SIGNAL-2	Location	1	4.52	0.12
	Site [Location]	3	1.55	0.23
	Residual	29		

Table 6-7. One way analysis of variance results for O/E 50 and SIGNAL-2 scores from the edge habitat

Response	Source	DF	F	P-value
OE 50	Location	1	7.82	0.07
	Site [Location]	3	0.84	0.49
	Residual	22		
SIGNAL-2	Location	1	13.6	0.03
	Site [Location]	3	0.54	0.66
	Residual	22		

Results for the AUSRIVAS component of the MPS, when considering the previous two years of data, has been very consistent as shown in Table 6-8. With the exception of MUR 931 in spring 2011 and MUR 935 in autumn 2012, all sites have received overall site assessments of Band-B. Although overall site assessments have been Band-B, Table 6-9 shows the variability of the replicates within the locations from the previous two autumns, with a large proportion of replicates actually being assessed as Band-A. Table 6-9 shows that the percentage of replicates which have been assessed as Band-A has slightly reduced at the upstream sites since autumn 2012. While the percentage of replicates which have been assessed as Band-A at the downstream sites has increased considerably since autumn 2012.

There are some subtle changes from autumn 2012 with MUR 937 improving the overall edge habitat assessment from Band-B to Band-A. Also the riffle habitat at MUR 935 was given an NRA (no reliable assessment) rating in autumn 2012 due to a variety of AUSRIVAS bands across the replicates. Assessments resulted in a single replicate as Band-C, "*severely impaired*," a single replicate as Band-A and the remaining replicates as Band-B. This has improved with 5/6 replicates now assessed as Band-A with a single replicate remaining at Band-B.

Table 6-8. Overall site assessments for the current and previous three sampling runs for MPS

	Autumn 2011	Spring 2011	Autumn 2012	Spring 2012	Autumn 2013	Change since previous sampling run
MUR 931	B	C	B	B	B	-
MUR 28	B	B	B	B	B	-
MUR 935	B	B	NRA	B	B	-
MUR 937	B	B	B	B	B	-
MUR 29	B	B	B	B	B	-

Table 6-9. Comparison of replicate banding percentage for autumn 2012 and autumn 2013

Season	AUSRIVAS Band	Riffle		Edge	
		Upstream (%)	Downstream (%)	Upstream (%)	Downstream (%)
Autumn 2012	Band-A	83	20	56	11
	Band-B	17	70	44	89
	Band-C	0	10	0	0
Autumn 2013	Band-A	75	72	22	80
	Band-B	25	28	78	20
	Band-C	0	0	0	0

Table 6-10. AUSRIVAS and SIGNAL-2 scores for autumn 2013

= nearly outside the experience of the model

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 931	1	4.91	4.48	0.78	0.78	B	B	**B**	**B**	**B**
MUR 931	2	4.95	4.78	1.11	0.78	A	B			
MUR 931	3	5.05	4.77	1.00	0.70	A	B			
MUR 931	4	5.41	4.96	0.89	0.70	A	B			
MUR 931	5	4.95	4.75	0.89	0.62	A	B			
MUR 931	6	5.16	NS	0.78	NS	B	NS			
MUR 28	1	4.99	4.68	1.00	0.86	A	A	**B**	**B**	**B**
MUR 28	2	4.96	4.66	1.00	0.78	A	B			
MUR 28	3	4.94	4.79	0.89	0.86	A	A			
MUR 28	4	4.83	NS	0.89	NS	A	NS			
MUR 28	5	4.96	NS	0.78	NS	B	NS			
MUR 28	6	4.87	NS	0.89	NS	A	NS			
MUR 935	1	5.31	4.44	0.89	0.97	A	A	**B**	**B**	**B**
MUR 935	2	5.38	4.85	1.00	0.87	A	A			
MUR 935	3	5.24	4.63	0.78	0.87	B	A			
MUR 935	4	5.42	4.71	0.89	0.77	A	B			
MUR 935	5	5.24	4.34	0.89	0.68	A	B			
MUR 935	6	5.13	4.58	1.00	1.16	A	A			
MUR 937	1	5.57	4.38	0.78	0.85	B	A	**B**	**A**	**B**
MUR 937	2	5.06	4.36	0.78	0.85	B	A			
MUR 937	3	5.14	4.62	0.89	0.85	A	A			
MUR 937	4	5.25	NS	1.00	NS	A	NS			
MUR 937	5	4.95	NS	0.78	NS	B	NS			
MUR 937	6	4.89	NS	0.89	NS	A	NS			
MUR 29	1	5.16	4.30	0.89	0.85	A	A	**B**	**B**	**B**
MUR 29	2	5.32	4.56	0.89	0.77	A	B			
MUR 29	3	5.32	4.59	0.89	1.02	A	A			
MUR 29	4	5.17	4.71	1.00	1.02	A	A			
MUR 29	5	5.09	4.37	0.78	0.85	B	A			
MUR 29	6	4.65	4.69	0.89	0.85	A	A			

NS - No sample

6.6 Discussion

Baseflow in the Murrumbidgee River was considerably lower than the previous autumn 2012 season. This resulted in patches of filamentous green algae in the margins, reduced edge habitat and increased exposure of boulders and bedrock within the riffle habitat across all sites. Large sand deposits have been exposed at MUR 937 and MUR 29, likely deposited during the high flows of March 2012 but only being exposed now due to reduced river levels. The invasive Mosquitofish (*Gambusia holbrooki*) was common within the riffle habitats, which is usually found in the slower moving waters and around vegetation (Lintermans, 2007).

6.6.1 Water quality

All water quality results indicate that there has been no detectable impact on the water quality of the Murrumbidgee River by the Murrumbidgee Pump Station. The water quality data showed a high level of compliance with the ANZECC & ARMCANZ (2000) guidelines.

The *in-situ* pH readings exceeded guidelines at every site and were consistent with the continuous monitoring station data which showed elevated readings above ANZECC & ARMCANZ (2000) guidelines. These elevated readings are not uncommon within this region of the Murrumbidgee River, with pH elevation at similar levels during most sampling runs. The data from the *in-situ* readings indicates a dilution effect downstream of the Cotter River confluence which appears to have reduced pH at MUR 935 directly downstream of the MPS relative to sites upstream. Increased groundwater contributions during late summer and during autumn leading up to sampling are the likely cause of these increased pH readings, with higher contribution than normal with the dryer conditions and lower river levels than have been seen during the recent wetter years.

The dissolved oxygen (DO) (% saturation) levels were within the guidelines at all sites for the *in-situ* readings, but remained very close to the lower limit of the guidelines range for the duration of the period at the continuous monitoring station. The recorded periods that the DO dropped below the lower threshold of the ANZECC & ARMCANZ (2000) guidelines were very brief and occurred during the diurnal trend for short periods during non-photosynthetic periods (during the night). The limited duration and very small decrease in concentrations reduces the likelihood of these reductions impacting upon the ecological communities.

Elevated TN concentrations were not present at all sites as has been the case during previous autumn periods. In fact the autumn 2013 TN concentrations were the lowest autumn readings recorded since the inception of the MEMP. Previous sample runs have shown a pattern of the highest concentrations at the upstream site with TN dissipating downstream as it is assimilated by biological processes. Results from this sampling run, however, show that the major nutrient input is upstream of MUR 937, with the highest concentrations recorded at this site. The lower TN concentrations recorded in autumn 2013 are likely due to the reduced rainfall during summer and autumn which has limited the level of nutrients entering the Murrumbidgee River upstream via runoff.

6.6.2 Periphyton

The periphyton results indicate that there is no detectable impact from the Murrumbidgee Pump Station on the periphyton production and biomass. While a statistical difference was detected between locations for chlorophyll-a, further investigation identified within site and within location differences accounted for most of the recorded variability. The non-significant result for AFDM is not surprising considering the relative uniformity across the results, with the exception of the outlier at MUR 931.

The high chlorophyll-a and AFDM concentrations which were present within some replicates at MUR 931 far exceeded those which were collected at any other site. However, large concentrations have been consistently recorded at this site. The site location, directly downstream of a series of large pools with some large stands of macrophytes, compared to other sites suggest local habitat conditions could be responsible for this result. Although the higher AFDM result was only a single replicate outlier for the site it does highlight the patchy periphyton coverage of the site. It was noted during sampling there was an algal crust on the substrate with denser patches towards the top end of the riffle.

Compared to autumn 2012, concentrations of both chlorophyll-a and AFDM were similar at MUR 28, 935 and 937. MUR 931 chlorophyll-a concentrations were elevated over other samples in 2012 but to much higher levels than during autumn 2013. Chlorophyll-a concentrations at MUR 29 were lower in autumn 2013 compared to autumn 2012. This is surprising as the low concentrations last year were attributed to the high flow event prior to sampling scouring the periphyton communities. It is possible that the lower nutrient levels recorded this year within the river may have been a limiting factor for periphyton growth at some sites.

6.6.3 AUSRIVAS and macroinvertebrate assemblages

The macroinvertebrate results from autumn 2013 do not indicate a significant difference between the sites upstream and downstream of the MPS as demonstrated through the non-significant results of the O/E 50 ANOVA's for each habitat (Table 6-6 & Table 6-7). However, differences were identified between the upstream and downstream locations in regards to the relative abundances. This difference was also found in relation the riffle habitats during autumn 2012, but during autumn 2013 was evident for both riffle and edge habitats.

The dominant taxa within each habitat were the main contributors to the differences in relative abundance. The dominant taxa in the riffle habitat include; Hydropsychidae (SIGNAL=6), Simuliidae (SIGNAL=5), Caenidae (SIGNAL=4) and Chironominae (SIGNAL=3), with the exception of Chironominae, are found in much larger abundances at the downstream sites. While the dominant taxa in the edge habitat, Chironominae, Caenidae and Corixidae (SIGNAL=2), were also found in larger abundances at the downstream sites.

Although Simuliidae and Hydropsychidae show a preference for flowing waters (Gooderham & Tsyrlin, 2005), changes in the riffle habitat do not appear to be driven by increased flows downstream of the Cotter River Confluence. Recorded velocities show that the site with the lowest velocity (MUR 937) had the highest abundances of these dominant taxa, with MUR 29 also having a lower velocity than the upstream sites. The reduction in flows appears to have impacted the upstream and downstream sites differently due to the differences between the morphology of the sites. The upstream sites have more restricted riffle zones which are generally deeper, while downstream sites are generally shallower, but the riffle zone covers a much larger area. This meant that the overall riffle area has not changed at the upstream sites, with only the riffle depth reducing, while at the downstream sites the riffles were slightly shallower but riffle area was noticeably reduced. Therefore the increased macroinvertebrate numbers may be due to populations condensing into available wetted habitat at the downstream sites.

The dominant taxa in the edge habitat all show a preference for the slow moving waters found in this habitat, with some Chironominae also showing a preference for soft sediment substrate (Gooderham & Tsyrlin, 2005). The abundance difference in the edge habitat is mainly being driven by the poor abundances of macroinvertebrates at the upstream site of MUR 28 and the extremely high abundances of dominant taxa at the downstream site MUR 937. Both of these sites were limited to only single samples due to limited habitat availability from low flows, which may be impacting the results. The intra-site variability may be more pronounced due to the limited edge habitat with varying habitat quality particularly when low flows are impacting these edge habitats. This emphasises the need for replication to account for natural variability within the samples to get a more accurate representation of the habitat and of the site as a whole.

The overall habitat assessments from the AUSRIVAS model showed that all sites were Band-B or "*significantly impaired*" in the riffle habitat, while the same was found for the edge habitat with the exception of MUR 937 which was assessed as Band-A or "*similar to reference*." This shows consistency across seasons with previous results also dominated by Band-B assessments. It is important to note however that a large number of replicates produced Band-A results however in line with AUSRIVAS procedures the lower band was allocated as the overall result, when only one or two replicates were assessed as Band-B. These Band-B replicates were often only missing a single family when compared to the replicates which received Band-A assessments.

Some of the taxa collected in the riffle habitat at all sites during autumn 2013 were taxa which are generally associated with the edge habitat. Some of these taxa included Caenidae, Corixidae, Chironomidae and Palaemonidae (SIGNAL=4) and are generally associated with slow flows and vegetation (Gooderham & Tsyrlin (2005). Growns & Davis (1994) classified macroinvertebrates into flow exposure groups identifying Caenidae and Chironomidae as avoiders (spend most of their life cycle out of contact with direct stream flows). While Corixidae and Palaemonidae were identified as facultatives (can inhabit areas of low flow and higher flows), although Growns & Davis (1994) note that facultative organisms were difficult to determine and therefore assignments can only be regarded as preliminary.

The receding flows prior to and during sampling may have impacted the distribution of the macroinvertebrates with edge habitats at all sites reducing, while remaining habitats such as the riffle habitat may have provided a refuge for displaced taxa. For example Chester & Robson (2011) found that perennially flowing water was one of the drought refuge habitats which harboured the most diverse macroinvertebrate taxa. Furthermore Fritz & Dodds (2004) also found that perennially flowing water was the main refuge for Kansas prairie streams.

The observance of *Gambusia holbrooki* within the riffle habitats may be linked to the occurrence of these 'edge taxa' in the riffle habitat. *G. holbrooki* is generally associated with edge habitats due to its affinity for slow-flowing water and vegetation (Lintermans, 2007). This movement into the riffle habitat could be linked to following prey with the previously mentioned 'edge taxa' being collected in the riffle samples, likely as a refuge from shrinking margins and reduced edge habitat resulting from low flows. The four taxa highlighted above: Caenidae, Corixidae, Chironomidae and Palaemonidae, have been found to be among the predominant taxa in the diet of *G. holbrooki* (Pen & Potter, 1991). Both intra- and inter-species competition may also be occurring with edge habitat area reducing resulting in some species of fish hunting in different habitats.

6.7 MPS Conclusions and Recommendations

This component of the MEMP aims to assess the impact, if any, of the abstractions by the Murrumbidgee Pump Station on the Murrumbidgee River, through the collection of macroinvertebrate, periphyton and water quality data.

The results from the water quality, periphyton and macroinvertebrate sampling during autumn 2013 do not indicate a significant difference between the sites located upstream of the MPS compared to the sites located downstream of the MPS. It is recommended that a closer assessment of data associated with the MPS pumping schedule, Cotter Dam release schedule and the Bendora Scour Valve operation schedule would aid interpretation of the results and more accurately assess potential impacts.

Since autumn 2011 the results from the genus level data have indicated a separation between the upstream and downstream sites, which were not detected at the family level. This separation could be related to the Enlarged Cotter Dam, Bendora Scour Valve or a shift in the hydrological regime. It is advised that the current program be continued using the existing protocols to maintain a constant dataset to enable robust long term analysis in future reports. In light of this, it is recommended that the MPS pumping schedule, Cotter Dam release schedule and the Bendora Scour Valve operation schedule be made available to GHD prior to the start of the spring and autumn season to aid optimising the benefit of the sampling run.

Part 4 - Tantangara to Burrinjuck

7. Tantangara to Burrinjuck

7.1 Summary of sampling and river condition

Sampling was conducted between the 6th and the 16th of May 2013. The maximum daily temperature during this period ranged from 13.8°C on the 13th and 24.1°C on the 10th, with rainfall occurring on the 13th, 14th and 15th. Flows during sampling were relatively consistent with a small increase in flow on the 8th of May and flows beginning to recede on the 14th of May with flows continuing to recede for the duration of sampling, despite the additional rainfall. Release targets set for the Murrumbidgee River downstream of Tantangara Dam indicated that flows were alternating between releases of 0 ML/d and 100 ML/d during the sampling period (Snowy Hydro Limited, 2013).

All samples were collected at each site with no missed samples, including at MUR 28, the only site in spring 2012 to be missing an edge sample. However, the lower flows during autumn made access to limited edge habitat possible during this season.

The low flows resulted in changes to both edge and riffle habitats with reduced edge habitat across most sites. The persisting edge habitat was considerably shallower than during previous sampling events. Riffle habitats were characterised by larger areas of exposed boulders and bedrock. Lower flows also resulted in much lower velocities in the river margins which provided ideal conditions for the patchy growth of filamentous green algae. Filamentous green algae was found across multiple sites, but was more prevalent further downstream. These conditions also resulted in increased macrophyte growth compared to autumn 2012.

Construction on the bridge directly upstream of MUR 3, where structural beams were being replaced, is unlikely to have impacted upon conditions at this site due to completion of sampling before construction began. Immediately upstream of the riffle at MUR 2 is a section of river that provides direct access for stock. During sampling there were numerous cows drinking from the river, and also wading into the main channel. MUR 37 (the furthest downstream site) was characterised by large sand deposits and wood debris, while the sediment in the edge habitat was anaerobic. Individual site summaries can be found in APPENDIX E.

7.2 Hydrology and rainfall

Figure 7-2 shows the flow levels during the autumn period at the four monitoring stations on the Murrumbidgee River. The rainfall recorded at Lobb's Hole (570985) is also shown and is considered to be representative of the region; although a plot showing rainfall at all rain gauges can be found in APPENDIX G. Table 7-1 shows the monthly flow and rainfall statistics at all Murrumbidgee River sites, however, there is no rain gauge located at the Mt. MacDonald station.

A rainfall event at the end of February put the hydrograph into recession during early March. As flows receded a rainfall event towards the end of March created a small peak in the hydrograph before flows returned to base flow conditions. Flows remained stable for the remainder of the period. Flow levels during autumn 2013 were much lower when compared to autumn flows during the recent years. In comparison to autumn 2012, the flow during sampling was 500-600 ML/d less during autumn 2013. This reduction in flows can be attributed to the dry conditions during late summer into autumn with the driest summer-autumn rainfall since 2008 when the MEMP program begun (235.7 mm).

The variation in the hydrograph in May was attributable primarily to releases from Tantangara Dam. During this period flow releases of 100 ML/d were activated for approximately one week, alternating with blocks of approximately one week where no water was released (Snowy Hydro Limited, 2013). The hydrograph from the NSW Office of Water gauging station on the Murrumbidgee River at Yaouk (41000260) clearly defines the periods during May that water was being released from Tantangara

Dam (Figure 7-1). This shows that during sampling at MUR 1 (downstream of Tantangara Dam wall) on the 14th there was no water being released from the reservoir.

Table 7-1. Average monthly flow and rainfall statistics for autumn 2013

Site Location	March Average Flow (ML/d)	April Average Flow (ML/d)	May Average Flow (ML/d)	Total Rainfall (mm)
Upstream Angle Crossing (41000270)	253.2	101.7	133.3	42.4
Lobb's Hole (410761)	279.4	108.2	140.2	50.2
Mt. MacDonald (410738)	418.7	139.9	172.6	-
Hall's Crossing (410777)	757.8	314.9	352.9	72.6

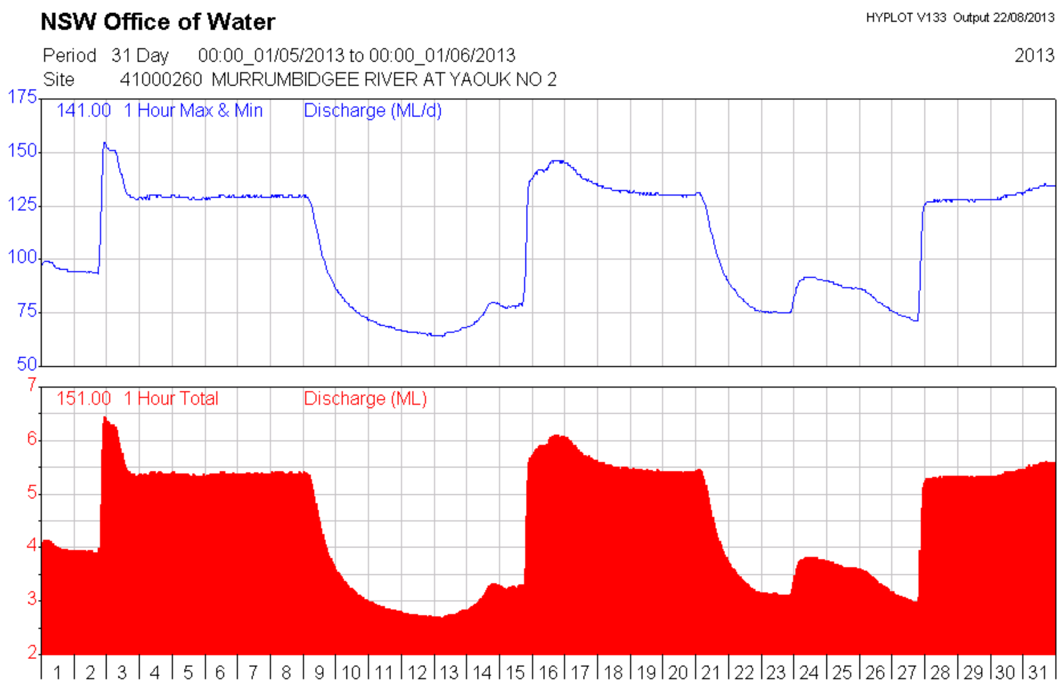


Figure 7-1 . Hydrograph for May 2013 at the Yaouk gauging station (41000260)

Source: NSW Office of Water (www.water.nsw.gov.au)

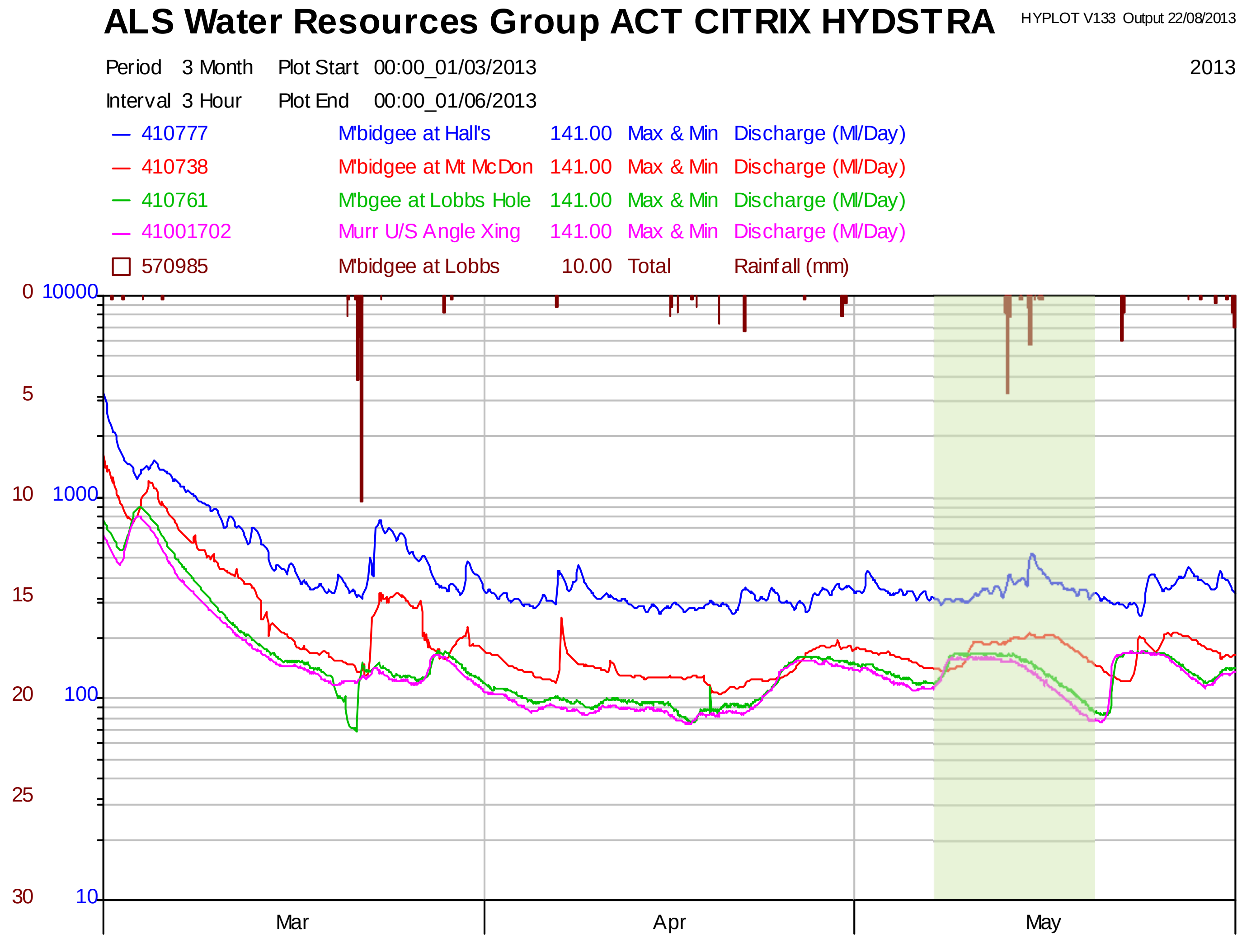


Figure 7-2. Autumn hydrograph of the Murrumbidgee River flows (log scale) and rainfall

Note: Green shading indicates sampling period

7.3 Water quality

7.3.1 Grab samples and in-situ parameters

The grab samples and water quality parameters measured *in-situ* at each site are presented in Table 7-2. The water temperature from the *in-situ* readings during the autumn 2013 sampling period ranged from 8.0°C to 15.8°C at MUR 4 and MUR 31 respectively. The electrical conductivity (EC) readings recorded were within the ANZECC & ARMCANZ (2000) guidelines at most sites with the exception of two sites in Zone 1, which recorded EC levels below the recommended range and all sites within Zone 4, which recorded EC levels above the recommended range. While sites within Zone 1 have often recorded EC levels below the recommended range, autumn EC readings have not exceeded the recommended range since autumn 2009, when all Zone 4 sites also recorded elevated EC levels.

The pH readings in autumn 2013 were above the ANZECC & ARMCANZ (2000) guideline upper range from site MUR 15 (Zone 2) to the remaining sites downstream in Zones 3 and 4, with the exception of MUR 23. This trend is consistent with previous sampling runs, though the pH values recorded in autumn 2013 were slightly higher on average than those recorded during autumn 2012. All but one site (MUR 31) recorded dissolved oxygen (% saturation; DO) levels were within the recommended range and at site MUR 31, the DO reading was only 0.7% higher than the recommended upper limit. In autumn 2012, four sites exceeded the recommended range's upper limit with one additional site on the cusp.

Nutrient concentrations were reduced when compared to the autumn 2012 results. Most sites were within the ANZECC & ARMCANZ (2000) guideline level for NO_x concentrations, however, MUR 1 and all sites in Zone 4 exceeded the guideline level for this parameter. This is an improvement on the exceedance of NO_x guidelines levels at 11 sites during autumn 2012, which included sites within all four Zones. The NO_x readings in Zone 4 in autumn 2013 were very high with readings at MUR 31 over 400 times the guideline level concentrations. Total nitrogen (TN) concentrations ranged mainly between 0.18 mg/L and 0.28 mg/L, except in Zone 4, where like NO_x, TN concentrations were much greater (up to more than 25 times greater than the guideline concentration). Also of note was the fact that elevated TN levels were recorded at MUR 1 in autumn 2013. TN levels have previously only been recorded above the guideline at this site during spring 2011.

Total phosphorus (TP) levels were above guideline levels at MUR 3, MUR 15 and all sites within Zone 4. Once again, the highest TP concentrations were recorded in Zone 4. While results still show lower TP concentrations in Zone 1 compared to Zone 4, in previous autumn sampling rounds, there has been a stronger pattern of increasing TP from Zone 1 to Zone 4. This year, TP concentrations in Zones 1 to 3 were relatively similar on average.

Principal components analysis performed on 10 water quality parameters explained 45.9% of the total variation on axis 1 and 19.1% along axis 2 (Figure 7-3). Axis 1 was negatively related to physico-chemical parameters in general; however the parameters with the highest eigenvector coefficients were: water temperature (-0.417), EC (-0.454) and pH (-0.402). These parameters separated sites within zone 1 and MUR 6 and MUR 9 from zones 3 and 4. Principal components axis 2 was positively related to nutrient parameters, namely: ammonia (0.347), TP (0.425) and TN (0.307), which accounted for the separation of the sites within zone 4 from the other sites (full PCA output can be found in APPENDIX H).

7.3.2 Continuous water quality monitoring

The continuous water quality monitoring data from upstream Angle Crossing (41001702), Lobb's Hole (410761) and Hall's Crossing (410777) are presented in Figure 7-4, Figure 7-5 and Figure 7-6, with most parameters showing typical autumn seasonal trends. Decreasing water temperature at all three sites corresponded with ambient temperatures decreasing for the duration of the season towards the start of winter. Electrical conductivity (EC) was also very similar across the sites with lower levels during early March corresponding to the recession from the event in late February, returning to normal levels as base flow returned, remaining stable for the remainder of the period. DO showed a distinct diurnal pattern across all gauging stations with concentrations also similar at all gauging stations. However, diel variation in DO at Lobb's Hole was reduced, particularly in May, compared to the other two gauging stations.

The pH sensor at Lobb's Hole was not operational for most of the autumn period with only the last two weeks of May recorded. This was due to a lightning strike which damaged the probe in January 2013 resulting in ongoing issues since. The pH values recorded during late May at this site featured diurnal peaks that were slightly elevated above the guideline range, which is normal for this part of the Murrumbidgee River at this time of year. This pattern was also observed at upstream Angle Crossing for much of autumn 2013, with slightly reduced pH values recorded during March associated with higher flows. The pH readings at Hall's Crossing were generally lower than upstream gauging stations during April and May, which is likely to be a reflection of the increased volumes of water in the downstream reaches of the Murrumbidgee River.

The turbidity sensor at upstream Angle Crossing had some issues, particularly during May, which were a result of probe interference. Outside of this, turbidity was higher during March at all sites and was within the ANZECC & ARMCANZ (2000) guidelines at most times during the assessment period at all three gauging stations.

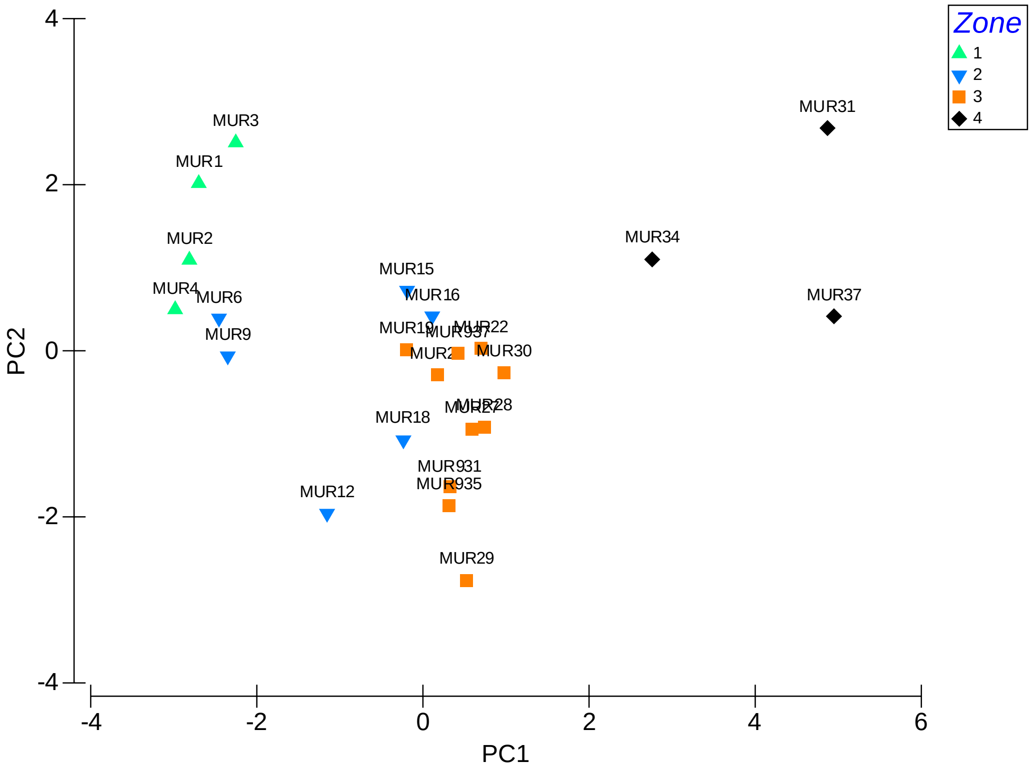


Figure 7-3. Principal component analysis ordination plot indicating site relationships based on water quality parameters among Murrumbidgee River sites

Table 7-2. In-situ water quality results from Tantangara to Burrinjuck during autumn 2013

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

	Site	Date	Time	Temp. (°C)	EC (µs/cm) (30-350)	Turbidity (NTU) (2-25)	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)
Zone 1	MUR 1	14/05/2013	12:10	10.5	24.3	2.25	4	7.64	92.1	10.28	14	0.028	0.028	< 0.002	0.012	0.016	0.27
	MUR 2	14/05/2013	15:30	9.6	31.3	2.82	3	7.55	94.7	10.81	18	0.009	0.009	< 0.002	0.004	0.013	0.18
	MUR 3	15/05/2013	11:50	8.9	28.7	2.34	< 2	7.46	98.2	11.38	16	0.004	0.004	< 0.002	0.002	0.029	0.25
	MUR 4	15/05/2013	13:15	8	43.3	5.42	5	7.34	90.2	10.67	22	0.003	0.003	< 0.002	0.003	0.017	0.23
Zone 2	MUR 6	16/05/2013	11:10	9.7	53.1	6.10	5	7.45	95.7	10.88	26	0.003	0.003	< 0.002	0.003	0.018	0.19
	MUR 9	16/05/2013	12:30	9.9	52.7	5.45	5	7.47	92.4	10.44	26	< 0.002	< 0.002	< 0.002	0.002	0.019	0.19
	MUR 12	16/05/2013	14:30	11.4	133.5	8.89	9	7.65	94.0	10.26	54	< 0.002	< 0.002	< 0.002	< 0.002	0.012	0.22
	MUR 15	6/05/2013	10:30	10.9	141.5	4.39	5	8.08	100.4	11.00	57	< 0.002	< 0.002	< 0.002	0.004	0.022	0.26
	MUR 16	6/05/2013	14:00	11.5	166.4	3.11	5	8.19	101.4	11.04	65	< 0.002	< 0.002	< 0.002	0.003	0.015	0.24
	MUR 18	7/05/2013	10:05	11.3	168.7	3.29	4	8.07	91.1	9.79	66	< 0.002	< 0.002	< 0.002	0.003	0.013	0.24
Zone 3	MUR 19	7/05/2013	11:50	11.5	168.3	3.02	3	8.06	96.9	10.56	66	0.002	0.002	< 0.002	0.004	0.013	0.23
	MUR 22	7/05/2013	14:50	13.9	157.4	2.87	4	8.31	104.9	10.85	64	0.002	0.002	< 0.002	0.003	0.015	0.24
	MUR 23	8/05/2013	9:45	12.1	162.0	3.81	6	7.95	100.0	10.75	73	< 0.002	< 0.002	< 0.002	< 0.002	0.014	0.28
	MUR 27	8/05/2013	11:25	13.0	168.8	5.11	5	8.18	99.9	10.52	69	< 0.002	< 0.002	< 0.002	< 0.002	0.016	0.27
	MUR 931	13/05/2013	9:55	12.7	168.5	4.38	6	8.12	90.8	9.63	68	0.002	0.002	< 0.002	0.002	0.017	0.26
	MUR 28	8/05/2013	14:05	13.8	178.5	4.32	5	8.26	101.1	10.48	66	< 0.002	< 0.002	< 0.002	< 0.002	0.015	0.24
	MUR 935	13/05/2013	13:20	12.8	167.9	6.93	7	8.10	95.3	10.08	69	0.003	0.003	< 0.002	< 0.002	0.016	0.25
	MUR 937	9/05/2013	10:20	12.1	171.7	3.49	6	8.12	101.7	10.92	70	< 0.002	< 0.002	< 0.002	< 0.002	0.015	0.28
	MUR 29	13/05/2013	15:00	13.2	168.7	9.71	7	8.17	94.9	9.95	69	< 0.002	< 0.002	< 0.002	< 0.002	0.017	0.27
	MUR 30	9/05/2013	15:00	13.8	174.3	3.59	5	8.32	106.8	11.04	71	< 0.002	< 0.002	< 0.002	< 0.002	0.013	0.27
Zone 4	MUR 31	9/05/2013	13:20	15.8	363.2	2.71	4	8.20	110.7	10.98	96	6.1	6.1	0.004	0.003	0.049	6.4
	MUR 34	10/05/2013	10:00	13.1	356.5	2.93	4	8.34	100.9	10.59	97	5.8	5.8	0.011	0.005	0.021	5.9
	MUR 37	10/05/2013	12:45	14.3	355.2	5.25	9	8.55	107.3	10.97	104	4.3	4.3	0.011	0.003	0.027	4.9

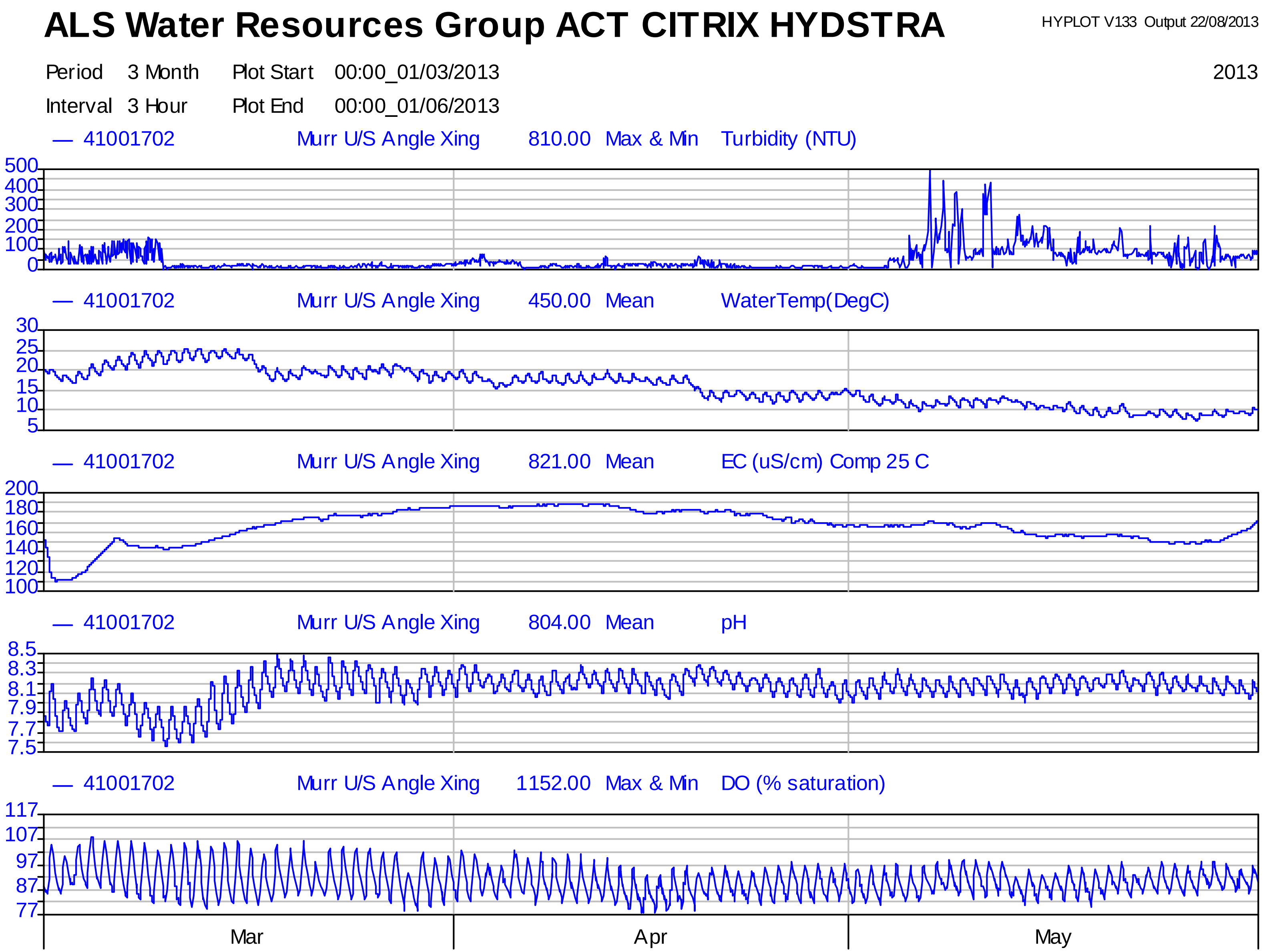


Figure 7-4. Continuous water quality results recorded upstream of Angle Crossing (41000270) duirng autumn 2013

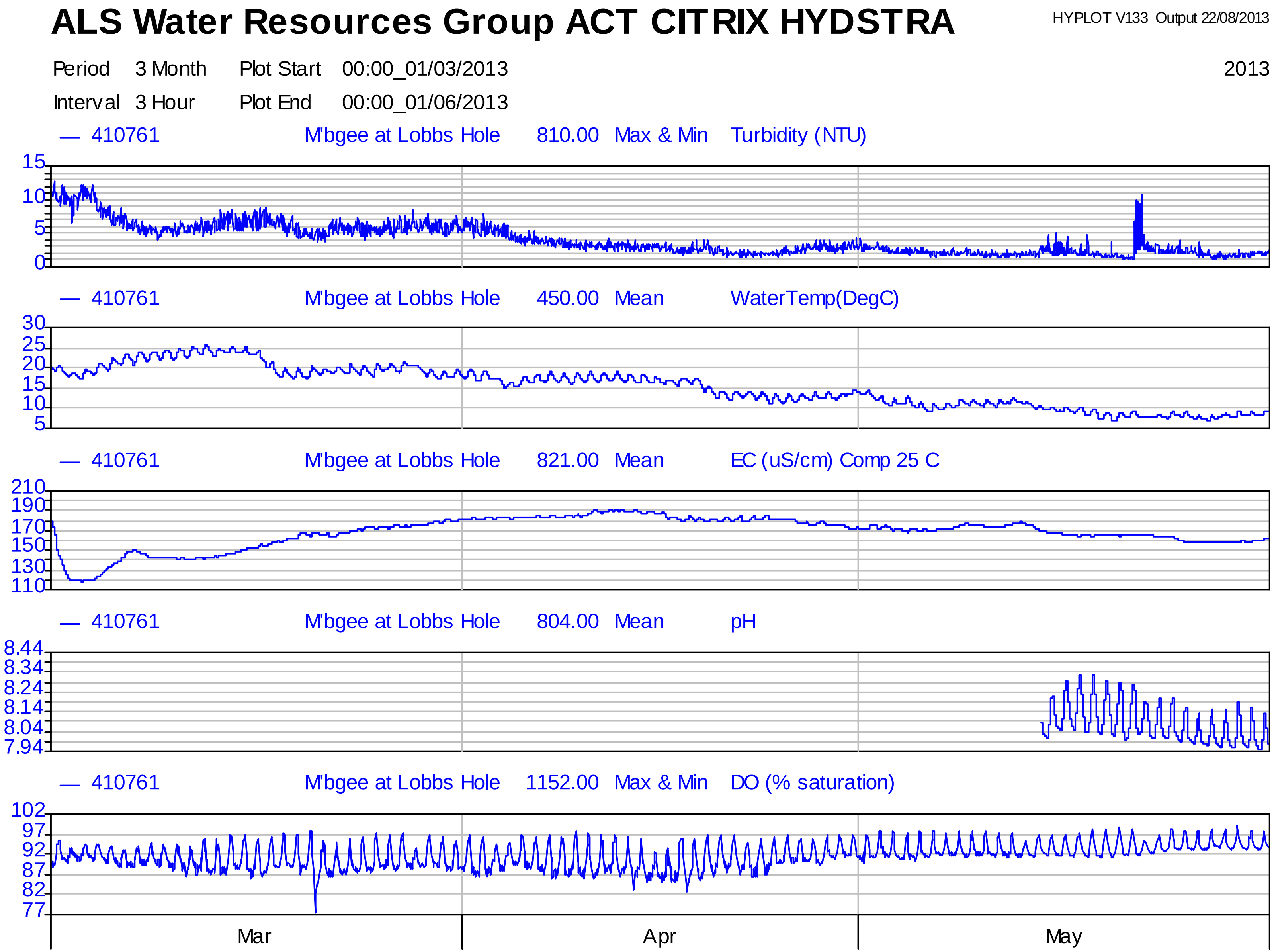


Figure 7-5. Continuous water quality results for Lobb's Hole (410761) during autumn 2013

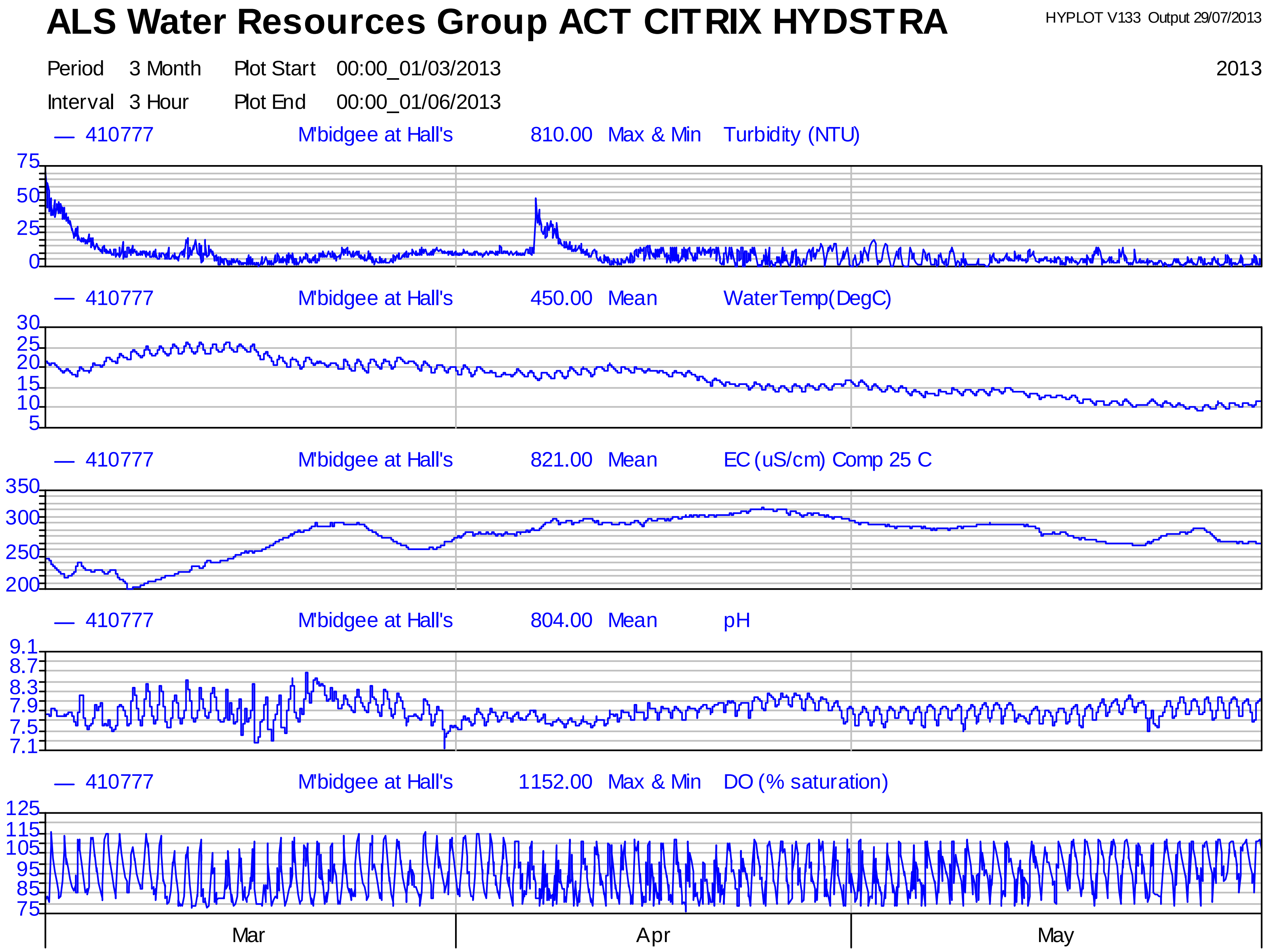


Figure 7-6. Continuous water quality results for Hall's Crossing (410777) during autumn 2013

7.4 Macroinvertebrates

7.4.1 Community assemblages

7.4.1.1 Riffle habitat

The NMDS ordination plot in Figure 7-7 indicates an overall similarity coefficient of approximately 40% in macroinvertebrate community composition between riffle samples. The ordination plot shows that there is relatively low dissimilarity between Zone 2 and Zone 3 sites with the exception of MUR 6 and MUR 9, which were just as similar to both Zone 1 and Zone 2 sites. Within-zone variability was highest within Zone 1 and sites from within this Zone were strongly separated from Zone 3 and Zone 4 sites.

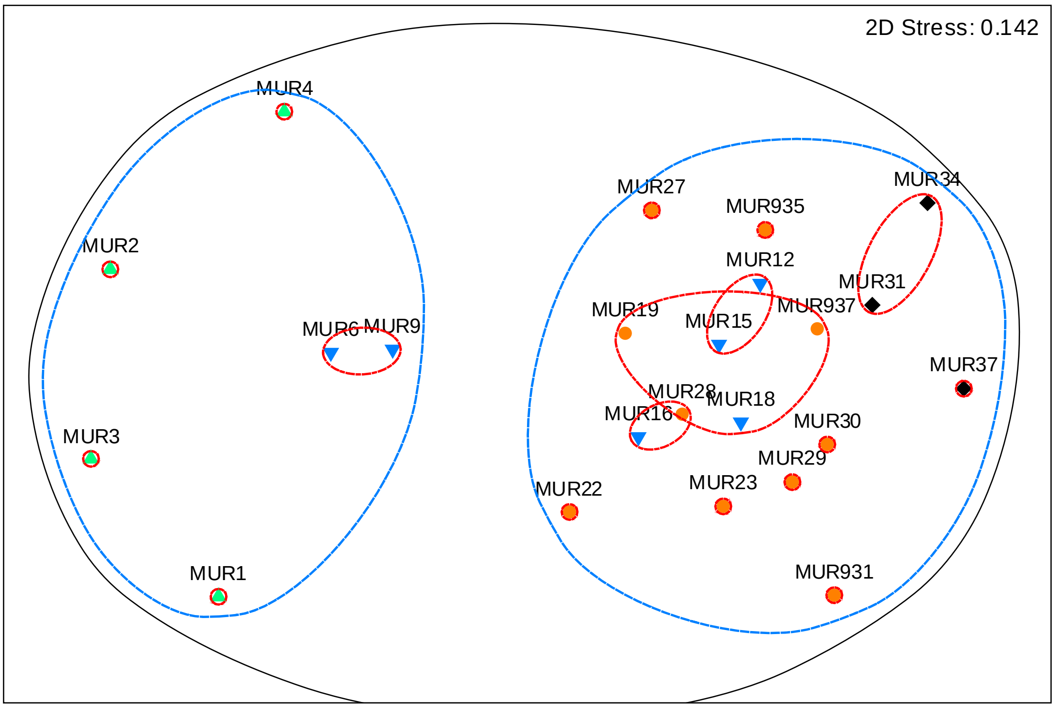


Figure 7-7. Non-metric multidimensional scaling of family level data for the autumn 2013 riffle samples

The black ellipse represents 40% similarity groups; blue, 60% and red ellipses are 80% groups. Green circles are site in zone 1, blue triangles are sites in zone 2; orange circles represent sites in zone 3 and black diamonds are sites in zone 4.

PERMANOVA detected significant differences in macroinvertebrate community assemblages between sampling zones ($P<0.05$). The multiple comparisons test found significant ($p<0.05$) differences in the riffle community between all combinations of Zones except for Zones 2 and 3 (Table 7-4). This result supports the pattern in the NMDS ordination plot. Table 7-3 summarises the average similarity within and between Zones. The lowest similarity was observed in the riffle community between Zones 1 and 4. Based on the NMDS plot, the greatest differences may have been expected between Zone 1 and Zone 4.

Following the significant main effects test, similarity percentages analysis (SIMPER) was performed to determine which taxa contributed to the differences detected between zones. The five taxa that contribute most strongly to differences in the riffle samples between zones are provided in Table 7-5 to Table 7-9. Taxa contributing most strongly to differences in the riffle community between Zone 3 and 4 (Table 7-9) were Acarina, Baetidae (SIGNAL=5; Figure 7-8), Empididae (SIGNAL=5), Hydropsychidae and Simuliidae (Figure 7-9).

Acarina and Empididae were generally found in slightly higher abundances as Zone 3 sites while Hydropsychidae, Simuliidae and Baetidae were found in higher abundances at Zone 4 sites. A table was not provided for the Zone 2 and 3 as these Zones were not found to be significantly (p<0.05) different. Bubble plots were also provided showing the change in abundance between sites (Figure 7-8 to Figure 7-12).

Unsurprisingly, due to the average similarity of riffle samples collected from Zones 2 and 3, the list of distinguishing taxa between Zones are similar (Table 7-5; Table 7-6). The main differences between Zone 1 compared to Zones 2 and 3 are higher abundances of Gripopterygidae (SIGNAL=8; Figure 7-11), Coloburiscidae (SIGNAL=8; Figure 7-10) and Conoesucidae (SIGNAL=7) and reduced abundances of Simuliidae (SIGNAL=5; Figure 7-9) and Caenidae (SIGNAL=4) in Zone 1 riffle samples.

Differences between Zones 1 and 4 (Table 7-7) include higher abundances of Simuliidae and Hydropsychidae (SIGNAL=6; Table 7-16) at Zone 4 compared to Zone 1 riffles and an absence of Gripopterygidae, Oligochaeta and Coloburiscidae in Zone 4 samples.

The riffle community between Zones 2 and 4 (Table 7-7) includes increased abundances of Leptophlebiidae (SIGNAL=8; Figure 7-12) at Zone 2 sites, the increased abundances of Hydropsychidae at Zone 4 sites and the absence of Oligochaeta, Acarina (SIGNAL=6) and Gripopterygidae at Zone 4 sites.

Table 7-3. Average similarity in riffle macroinvertebrate samples between and within zone groups

Zone	1	2	3	4
1	66.2%			
2	61.7%	72.9%		
3	55.9%	72.4%	72.8%	
4	48.7%	67.3%	70.6%	80.0%

Table 7-4. *P*-values for multiple comparison tests between Zones – riffle samples.

Note: Significant *P*-values are highlighted in red (P<0.05).

Zone	1	2	3
1			
2	0.016		
3	0.001	0.212	
4	0.028	0.031	0.003

Table 7-5. Major differentiating taxa between Zone 1 and Zone 2 riffle samples

Family	Av abundance		Contribution to group differences (%)
	Zone 1	Zone 2	
Gripopterygidae	5.85	2.05	8.13
Simuliidae	4.26	6.83	5.79
Caenidae	1.88	4.51	5.72
Coloburiscidae	3.15	1.04	5.49
Conoesucidae	2.36	0.00	4.71

Table 7-6. Major differentiating taxa between Zone 1 and Zone 3 riffle samples

Family	Av abundance		Contribution to group differences (%)
	Zone 1	Zone 3	
Gripopterygidae	5.85	0.97	8.63
Caenidae	1.88	5.76	6.92
Coloburiscidae	3.15	0.00	5.63
Oligochaeta sp.	4.35	1.57	4.97
Simuliidae	4.26	6.24	4.72

Table 7-7. Major differentiating taxa between Zone 1 and Zone 4 riffle sample

Family	Av abundance		Contribution to group differences (%)
	Zone 1	Zone 4	
Gripopterygidae	5.85	0.00	9.65
Oligochaeta sp.	4.35	0.00	7.20
Simuliidae	4.26	8.61	7.16
Hydropsychidae	4.25	8.28	6.41
Coloburiscidae	3.15	0.00	5.27

Table 7-8. Major differentiating taxa between Zone 2 and Zone 4 riffle samples

Family	Av abundance		Contribution to group differences (%)
	Zone 2	Zone 4	
Oligochaeta sp.	3.23	0.00	9.52
Acarina sp.	3.16	0.00	9.41
Hydropsychidae	5.51	8.28	8.88
Leptophlebiidae	5.1	3.09	6.10
Gripopterygidae	2.05	0.00	5.55

Taxa contributing most strongly to differences in the riffle community between Zones 3 and 4 (Table 7-9) were Acarina, Hydropsychidae, Simuliidae, Baetidae (SIGNAL=5; Figure 7-8) and Empididae (SIGNAL=5). Acarina and Empididae were generally found in slightly higher abundances at Zone 3 sites while Hydropsychidae, Simuliidae and Baetidae were found in higher abundances at Zone 4 sites.

Table 7-9. Major differentiating taxa between Zone 3 and Zone 4 riffle samples

Family	Av abundance		Contribution to group differences (%)
	Zone 3	Zone 4	
Acarina sp.	3.06	0.00	10.54
Hydropsychidae	6.22	8.28	9.14
Simuliidae	6.24	8.61	8.98
Baetidae	4.74	6.27	5.86
Empididae	1.52	1.05	5.40

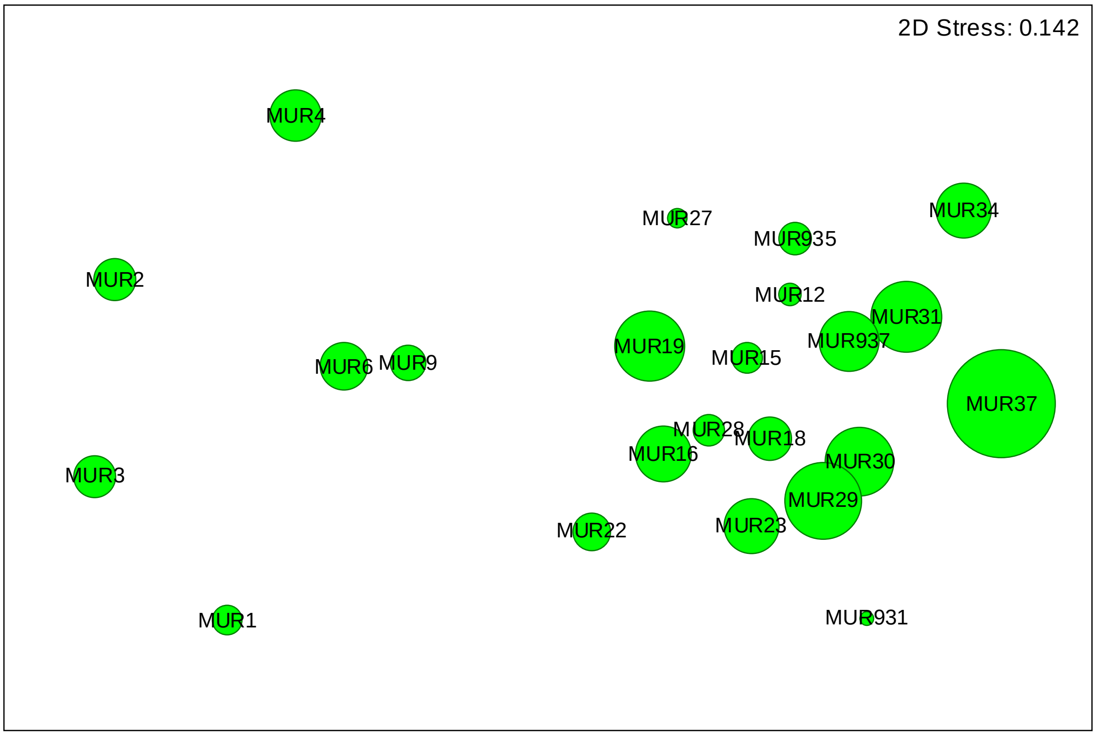


Figure 7-8 . Bubble plot indicating relative abundance of Baetidae among riffle samples

Note: The size of the bubble is proportional to the relative number of individuals at each site

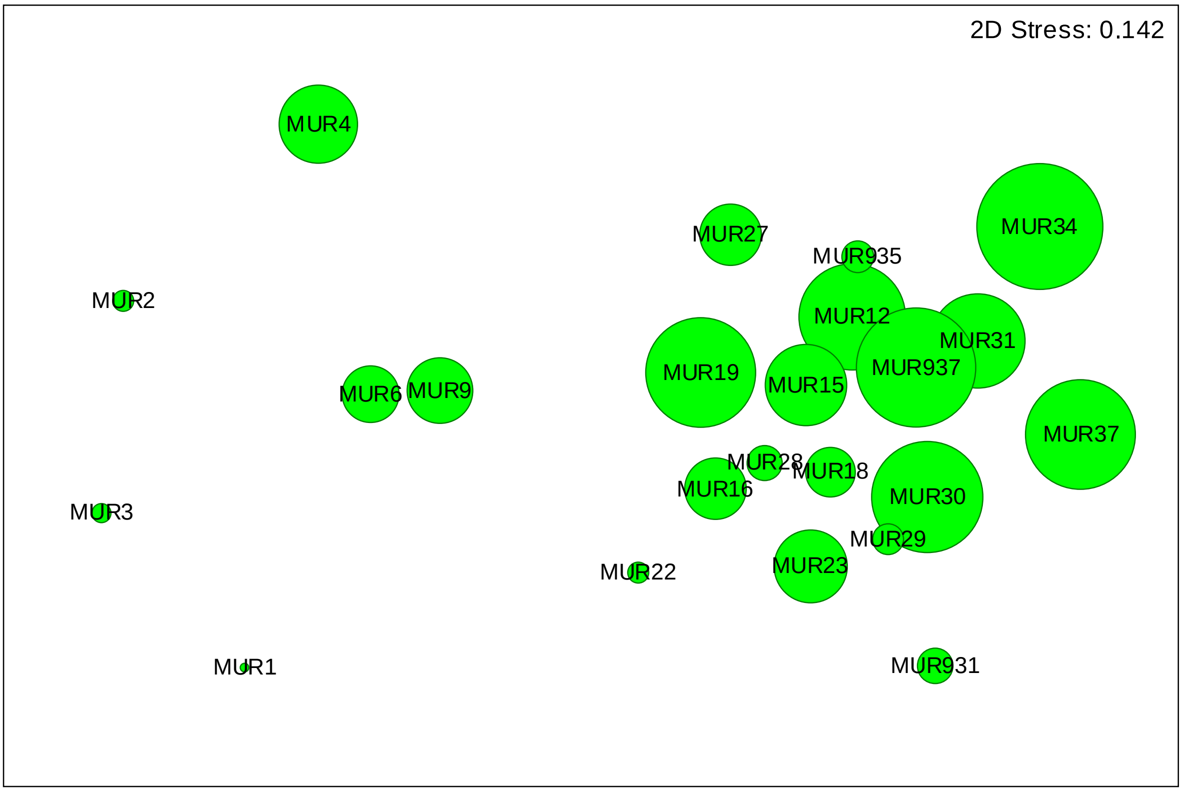


Figure 7-9 . Bubble plot indicating relative abundance of Simuliidae among riffle samples

Note: The size of the bubble is proportional to the relative number of individuals at each site

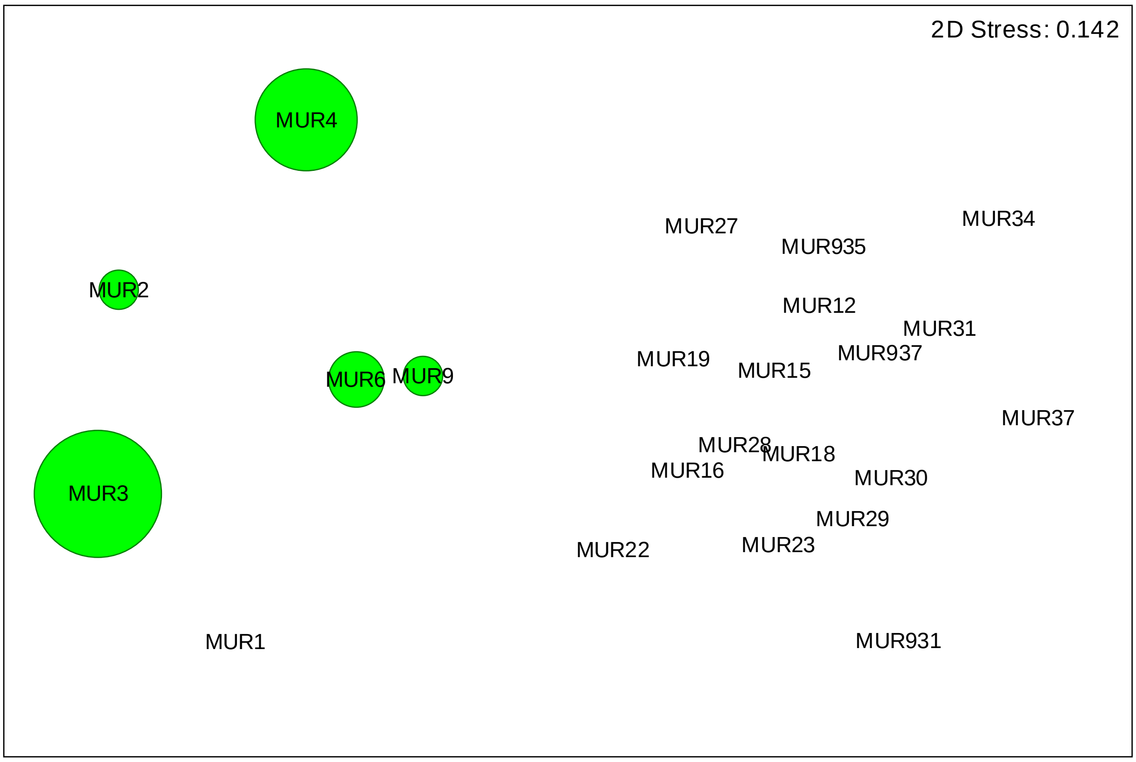


Figure 7-10. Bubble plot indicating relative abundance of Coloburiscidae among riffle samples

Note: The size of the bubble is proportional to the relative number of individuals at each site

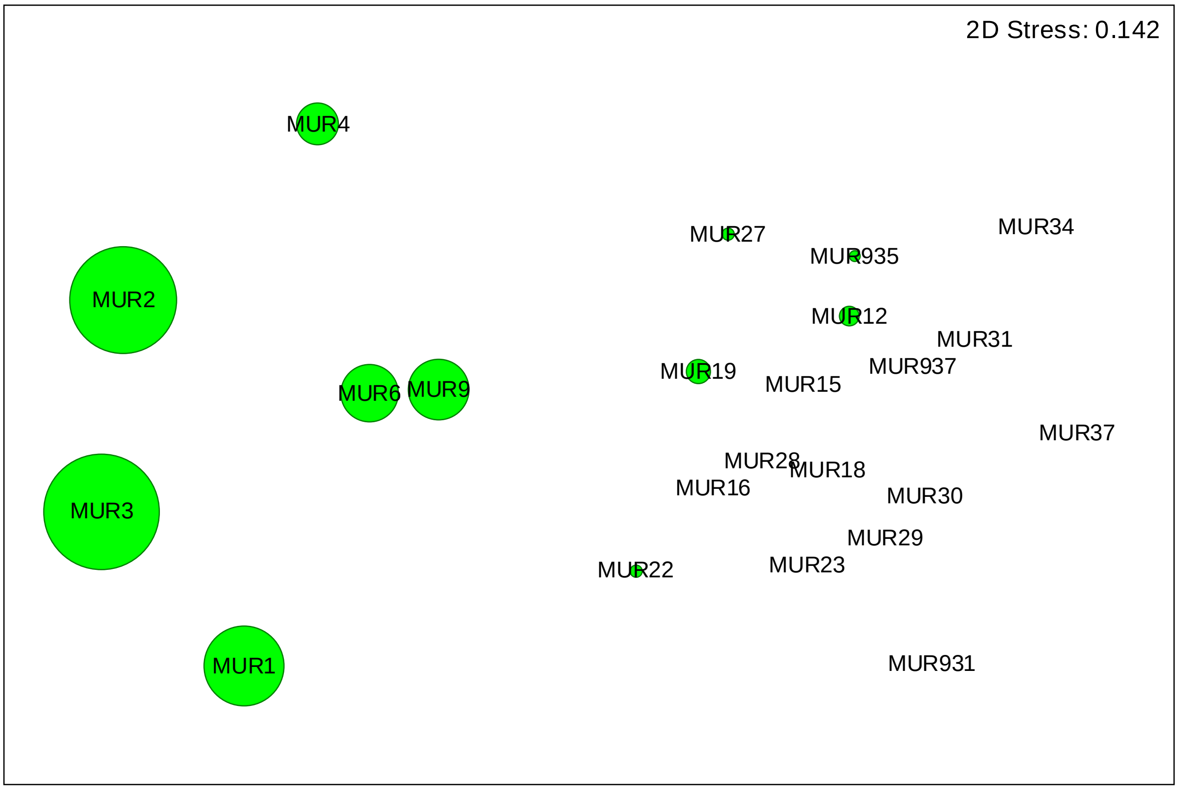


Figure 7-11. Bubble plot indicating relative abundance of Gripopterygidae among riffle samples

Note: The size of the bubble is proportional to the relative number of individuals at each site

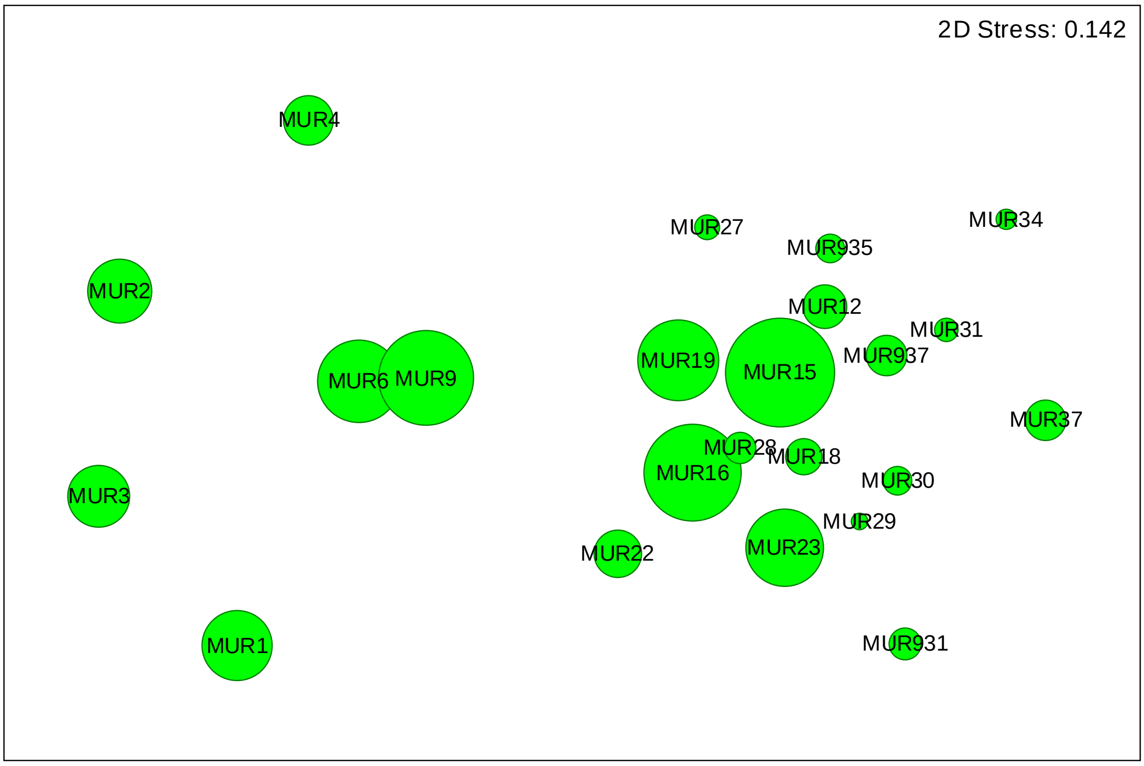


Figure 7-12. Bubble plot indicating relative abundance of Leptophlebiidae among riffle samples

Note: The size of the bubble is proportional to the relative number of individuals at each site

7.4.1.1 Edge habitat

The multivariate patterns present in the edge habitat macroinvertebrate community were similar to those for riffle habitats in that more intra-zone variation was observed in Zone 1, there was higher inter-zone similarity between Zones 2 and 3 and stronger separation of Zones 1 and 4 (Figure 7-13). SIMPER indicated that average within-Zone similarity was generally higher than between-Zone similarity (Table 7-10).

PERMANOVA confirmed significant (p<0.05) differences in the edge community between all pairs of Zones except between Zones 2 and 3 (Table 7-11); which is suggested by the relationships among sampling sites and zones in Figure 7-13.

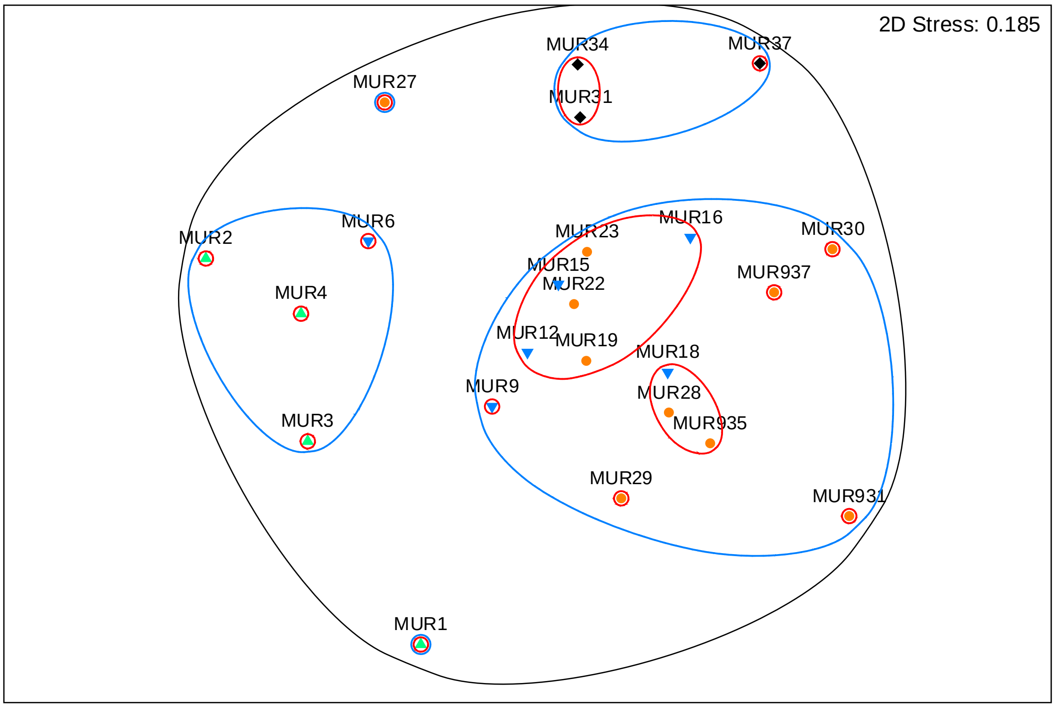


Figure 7-13. Non-metric multidimensional scaling of family level data for the autumn 2013 edge samples

The black ellipse represents 40% similarity groups; blue, 60% and red ellipses are 70% groups. Green circles are sites in zone 1, blue triangles are sites in zone 2; orange circles represent sites in zone 3 and black diamonds are sites in zone 4.

Table 7-10. Average similarity in edge macroinvertebrate samples between and within zone groups

Zone	1	2	3	4
1	60.45%			
2	59.18%	70.11%		
3	54.26%	67.25%	65.22%	
4	51.60%	61.57%	59.29%	70.47%

Table 7-11. *P*-values for multiple comparison tests between Zones – edge samples

Note: Significant *P*-values are highlighted in red (P<0.05).

Zone	1	2	3
1			
2	0.009		
3	<0.001	0.340	
4	0.028	0.012	0.003

The five edge taxa contributing most strongly to differences between each pair of Zones are summarised in Table 7-12 to Table 7-16. Higher abundances of Baetidae (SIGNAL=5), Talitridae (SIGNAL=3), Gripopterygidae (SIGNAL=8) and Tanypodinae (SIGNAL=4; Figure 7-16) were observed in Zone 1 compared to Zone 2 (Table 7-12). Reduced abundances of Caenidae (SIGNAL=4; Table 7-20) were observed on average in edge samples collected from Zone 1.

Table 7-12. Major differentiating taxa between Zone 1 and Zone 2 edge samples

Family	Av abundance		Contribution to group differences (%)
	Zone 1	Zone 2	
Baetidae	3.10	1.92	4.48
Talitridae	2.11	0.00	4.34
Gripopterygidae	2.98	1.35	4.24
Caenidae	2.22	3.75	3.78
Tanypodinae	4.49	2.78	3.68

Gripopterygidae, Oligochaeta, Baetidae and Tanypodinae were collected in higher abundances from Zone 1 sites compared to Zone 3 sites. Higher numbers of Caenidae were observed at Zone 3 sites compared to Zone 1 sites.

An almost identical list of taxa was found to be most influential on differences between Zone 4 and all other sites (Table 7-14; Table 7-15; Table 7-16). Tanypodinae or Hydroptilidae (SIGNAL=4; Figure 7-15) were both absent from Zone 4 sites, which were observed in samples collected from Zones 1 to 3. There were also higher abundances of Corixidae (SIGNAL=2; Figure 7-14), Hydropsychidae and Oligochaeta in Zone 4 edge samples compared to the other three Zones.

Table 7-13. Major differentiating taxa between Zone 1 and Zone 3 edge samples

Family	Av abundance		Contribution to group differences (%)
	Zone 1	Zone 3	
Gripopterygidae	2.98	0.20	5.29
Oligochaeta sp.	3.90	1.70	4.68
Baetidae	3.10	1.45	4.45
Caenidae	2.22	4.38	4.33
Tanypodinae	4.49	2.37	4.09

Table 7-14. Major differentiating taxa between Zone 1 and Zone 4 edge samples

Family	Av abundance		Contribution to group differences (%)
	Zone 1	Zone 4	
Tanypodinae	4.49	0.00	8.02
Hydroptilidae	3.81	0.00	6.86
Hydropsychidae	1.25	4.40	5.64
Gripopterygidae	2.98	0.00	5.36
Corixidae	3.33	5.89	4.74

Table 7-15. Major differentiating taxa between Zone 2 and Zone 4 edge samples

Family	Av abundance		Contribution to group differences (%)
	Zone 2	Zone 4	
Tanypodinae	2.78	0.00	7.64
Hydropsychidae	1.79	4.40	7.25
Hydroptilidae	2.40	0.00	6.61
Corixidae	3.93	5.89	5.84
Oligochaeta sp.	3.58	3.12	5.65

Table 7-16. Major differentiating taxa between Zone 3 and Zone 4 edge samples

Family	Av abundance		Contribution to group differences (%)
	Zone 3	Zone 4	
Oligochaeta sp.	1.70	3.12	6.8
Hydropsychidae	2.19	4.40	6.28
Corixidae	3.60	5.89	6.25
Tanypodinae	2.37	0.00	6.11
Hydroptilidae	2.22	0.00	5.75

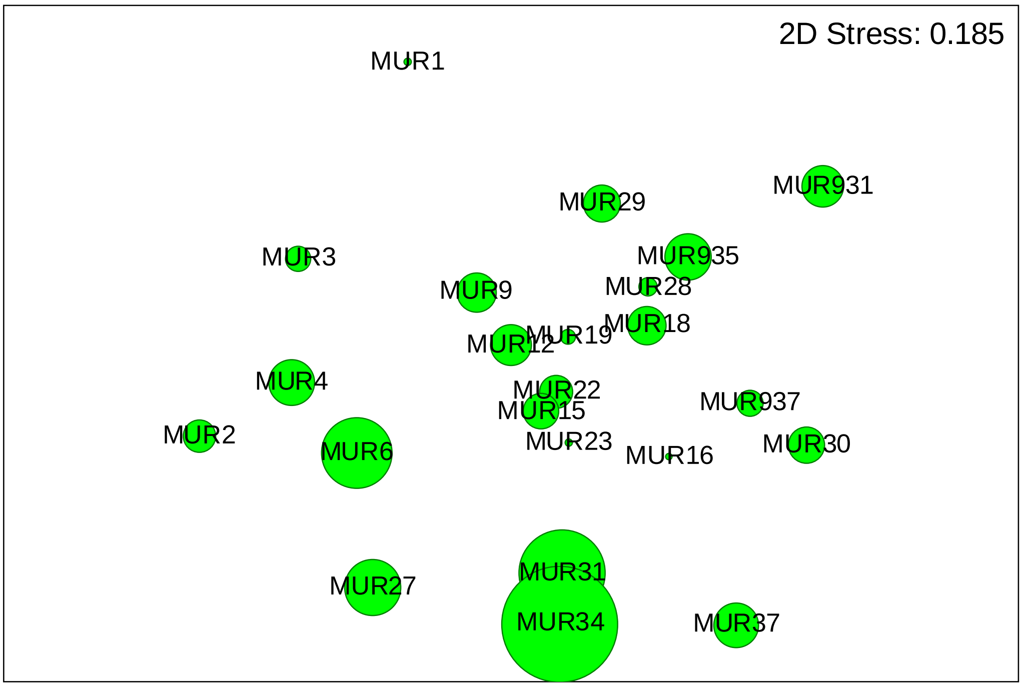


Figure 7-14. Bubble plot indicating relative abundance of Corixidae between edge samples

Note: The size of the bubble is proportional to the relative number of individuals at each site

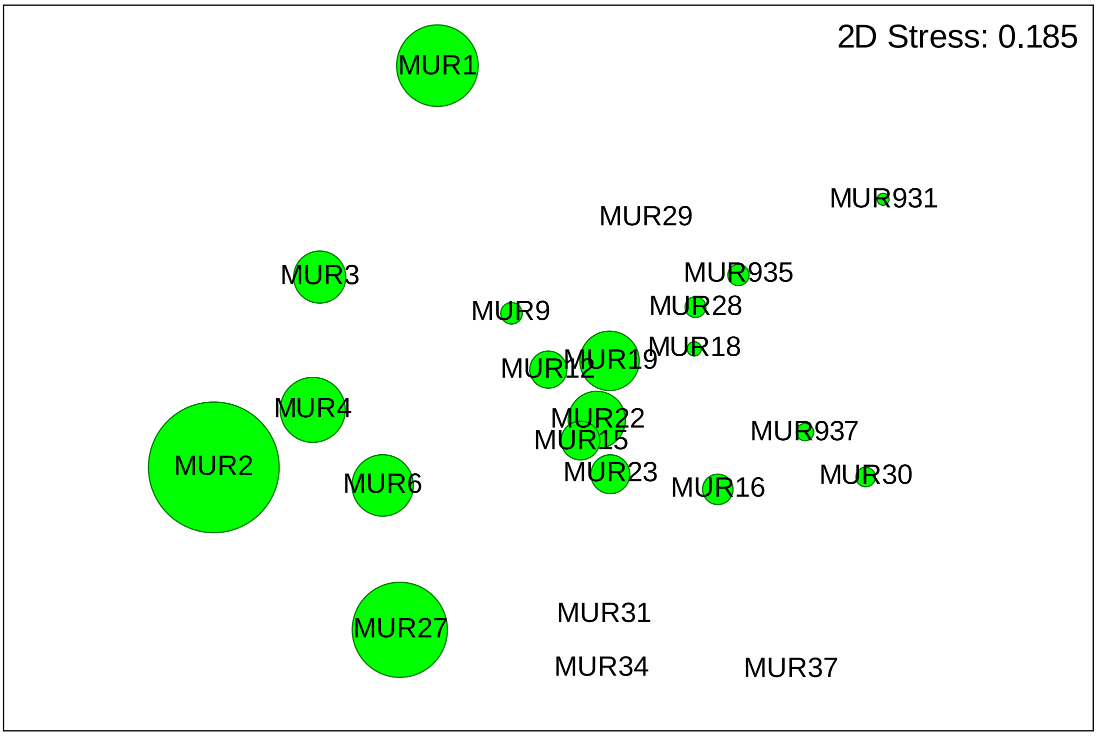


Figure 7-15. Bubble plot indicating relative abundance of Hydroptilidae between edge samples

Note: The size of the bubble is proportional to the relative number of individuals at each site

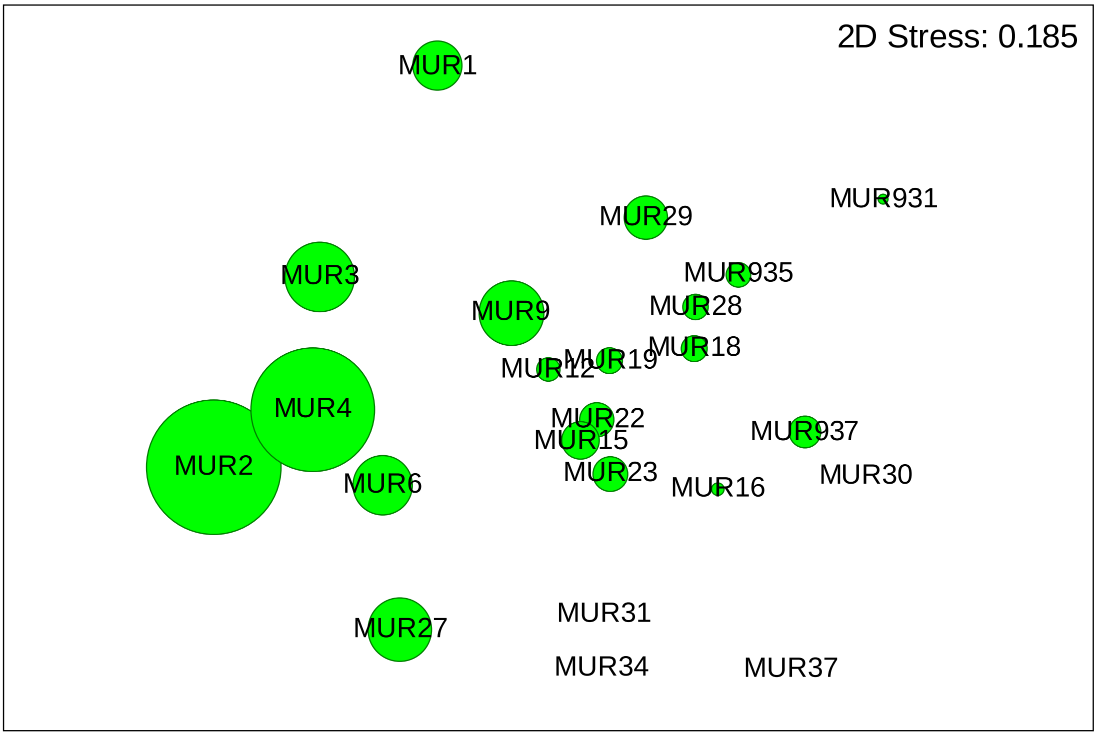


Figure 7-16. Bubble plot indicating relative abundance of Tanypodinae between edge samples

Note: The size of the bubble is proportional to the relative number of individuals at each site

7.4.2 Univariate Indices

Total richness and EPT richness from riffle samples were noticeably higher in Zone 1 compared to the other zones (Figure 7-17). However, the proportion of total richness comprised of EPT taxa was similar if not higher among Zone 4 sites. EPT richness generally made up just under half of the total richness within riffle samples.

Richness in edge samples was less variable, particularly in Zones 2 and 3 but again, richness was among the lowest at sites furthest downstream (i.e. Zone 4). Total richness was generally higher within edge samples but the proportion of EPT taxa was lower (Figure 7-17).

Kruskal-Wallis tests were conducted to test for differences in total richness and EPT richness between Zones. Total richness and EPT richness were found to be significantly ($P<0.05$) lower in Zone 4 compared to Zone 1 for both riffle and edge samples (Table 7-17; Table 7-18; Table 7-19; Table 7-20).

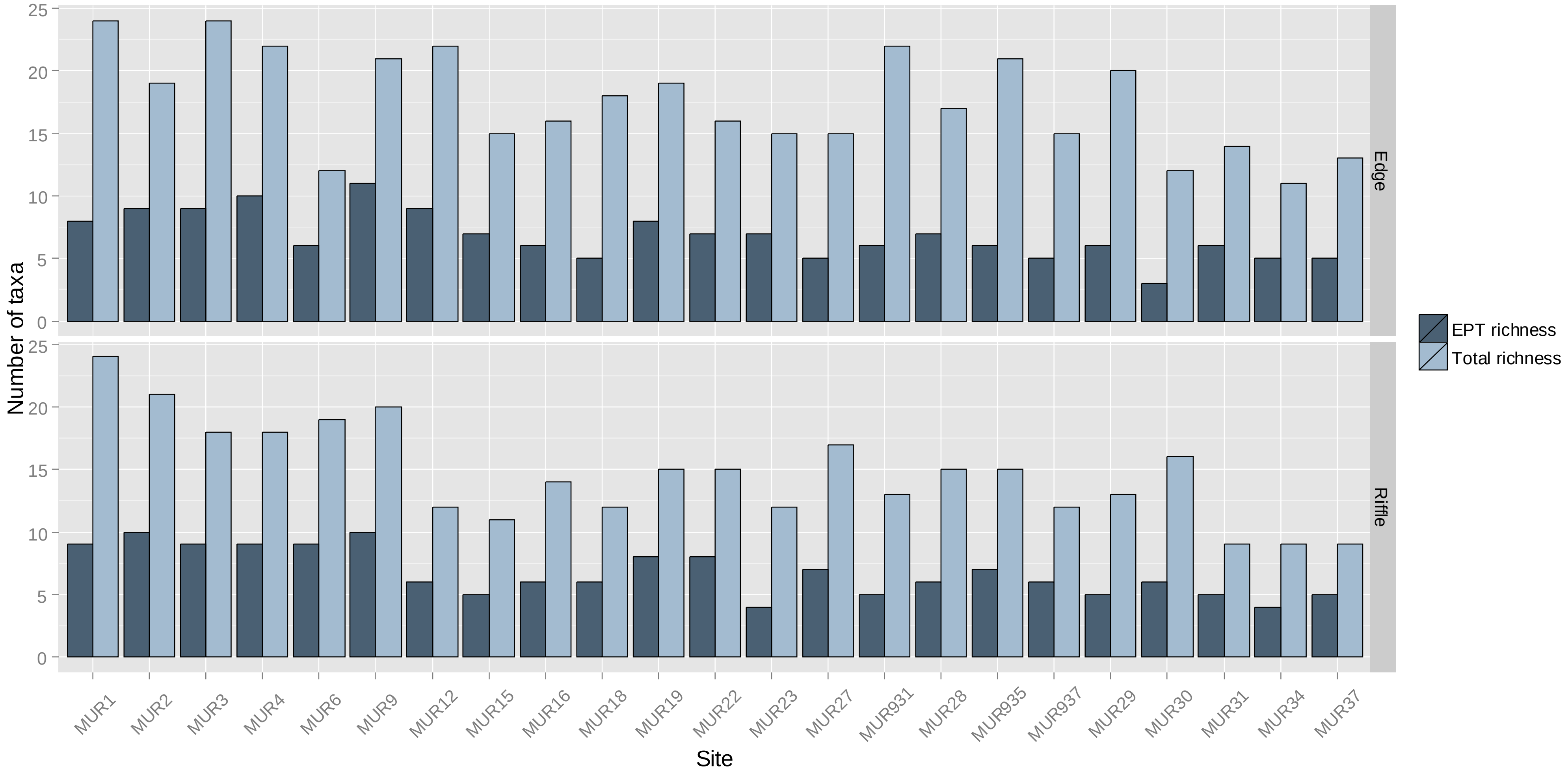


Figure 7-17. Total richness and EPT richness at Murrumbidgee River sites

Table 7-17. Multiple comparisons in Total Richness for riffle samples between Zones

Zone	1	2	3
1			
2	0.238		
3	0.192	1.000	
4	0.002	0.285	0.159

Table 7-18. Multiple comparisons in EPT Richness for riffle samples between Zones

Zone	1	2	3
1			
2	0.609		
3	0.090	1.000	
4	<0.001	0.322	0.812

Table 7-19. Multiple comparisons in Total Richness for edge samples between Zones

Zone	1	2	3
1			
2	0.397		
3	0.228	1.000	
4	0.008	0.457	0.394

Table 7-20. Multiple comparisons in EPT Richness for edge samples between Zones

Zone	1	2	3
1			
2	0.840		
3	0.074	1.000	
4	0.040	0.682	1.000

Estimated relative abundance within edge and riffle samples was highly variable across sites and zones in autumn 2013. Abundance did appear to be consistently lower within Zones 2 and 3 but no significant (P>0.05) difference was detected between zones for riffle samples. In edge samples, abundance was found to be significantly lower in Zone 3 compared to Zone 1 (Table 7-21).

Table 7-21. Multiple comparisons in Abundance for edge samples between Zones

Zone	1	2	3
1			
2	0.541		
3	0.044	1.000	
4	1.000	1.000	0.182

SIGNAL-2 and AUSRIVAS results are provided for each site in Table 7-22. Average SIGNAL-2 was generally higher in riffle samples compared to edge samples (Figure 7-18) although there was no obvious trend between zones. An AUSRIVAS band of A or B was assigned to each of the sites but for most sites, the B rating was only applied to one out of the two habitats sampled. The only sites that received B ratings for both habitats were MUR 931, MUR 34 and MUR 37 (i.e. mainly Zone 4 sites). Overall, the Edge habitat was associated with improved scores at sites upstream of Zone 3 compared to autumn 2012. No significant (P>0.05) difference was detected in SIGNAL or O/E 50 scores for riffle or edge samples between zones, which is supported by the broad confidence intervals around the point estimates in Figure 7-18.

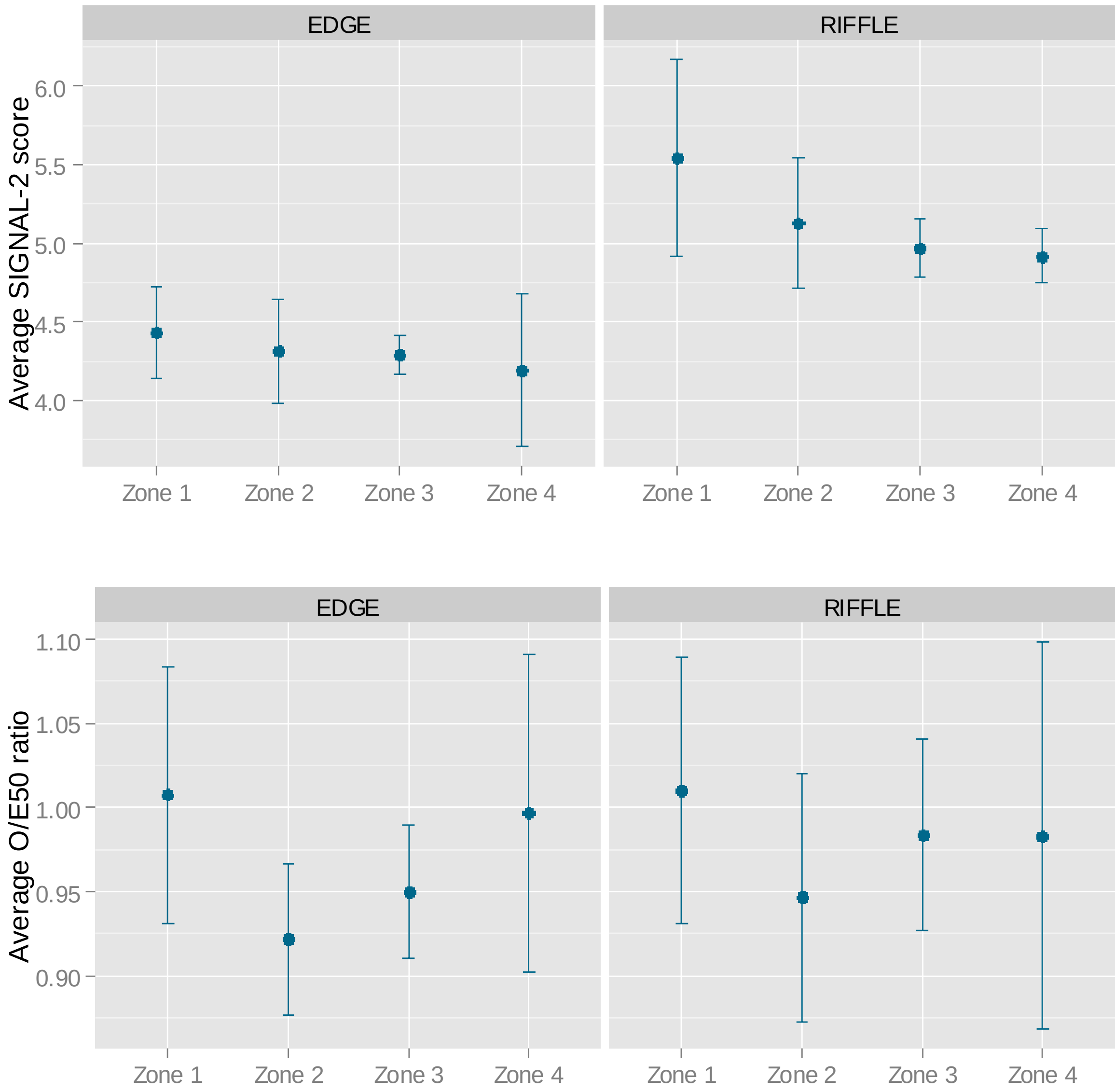


Figure 7-18. Means plot of SIGNAL-2 and O/E 50 scores between Zones

Table 7-22. AUSRIVAS and SIGNAL-2 scores for autumn 2013

= nearly outside the experience of the model

Zone	Site	Location	SIGNAL-2		AUSRIVAS O/E50 score		AUSRIVAS BAND		Overall Site Assessment
			Riffle	Edge	Riffle	Edge	Riffle	Edge	
1	MUR 1	D/S Tantangara Reservoir	5.01	4.37	0.95	1.05	A	A	**A**
	MUR 2	Yaouk Bridge	5.75	4.70	1.04	1.01	A	A	**A**
	MUR 3	Bobeyan Road Bridge	5.49	4.35	0.99	1.03	B	A	**B**
	MUR 4	Camp ground off Bobeyan Road	5.92	4.31	1.06	0.94	B	A	**B**
2	MUR 6	D/S STP Pilot Creek Road	5.56	3.94	1.02	0.91	A	A	**A**
	MUR 9	Murrells Crossing	5.65	4.74	1.03	0.95	B	A	**B**
	MUR 12	Through Bredbo township	4.75	4.54	0.96	0.98	A	A	**A**
	MUR 15*	Near Colinton - Bumbalong Road	5.02	3.98	0.93	0.88	A	A	**A**
	MUR 16*	The Willows - Near Michelago	4.71	4.39	0.88	0.87	A	A	**A**
	MUR 18*	U/S Angle Crossing	5.06	4.30	0.86	0.94	B	A	**B**
3	MUR 19*	D/S Angle Crossing	5.26	4.56	1.01	0.99	A	B	**B**
	MUR 22	Tharwa Bridge	5.19	4.12	1.09	0.92	A	B	**B**
	MUR 23*	Point Hut Crossing	5.14	4.34	1.01	0.96	A	B	**B**
	MUR 27	Kambah Pool	4.80	4.21	1.02	0.86	A	B	**B**
	MUR 931*	"Fairvale" ~4km U/S of the Cotter Confluence	4.65	4.32	0.86	0.99	B	B	**B**
	MUR 28*	U/S Cotter River confluence	4.69	4.57	0.94	0.97	A	A	**A**
	MUR 935*	Casuarina sands	4.96	4.30	1.09	1.04	A	A	**A**
	MUR 937*	Mt. MacDonald ~5km D/S of the Cotter Confluence	5.29	4.23	1.01	0.87	B	A	**B**
	MUR 29*	Uriarra Crossing	5.08	4.04	0.93	0.96	A	A	**A**
	MUR 30	U/S Molonglo Confluence	4.61	4.19	0.88	0.94	A	B	**B**
4	MUR 31	D/S Molonglo Confluence	5.00	4.15	1.01	1.04	B	A	**B**
	MUR 34	Halls Crossing	4.89	4.02	1.01	0.97	B	B	**B**
	MUR 37	Boambolo	4.87	4.40	0.93	0.98	B	B	**B**

7.5 Discussion

The Tantangara transfer component of ACTEW Waters water security initiative will involve transferring water from the Tantangara Reservoir in the upper Murrumbidgee River to the ACT via run of river flow, with the aim of providing a source of water that is less dependent on rainfall within the ACT. This component (Part 4) of the MEMP (Tantangara to Burrinjuck) aims to assess the physical, biological and water quality indicators along the length of the upper Murrumbidgee River from Tantangara to Burrinjuck reservoirs. The information derived from this component will also support ACTEW Waters' adaptive management approach to water abstraction and environmental flow provision in the ACT. The following is a discussion relating to the results obtained from the autumn 2013 sampling run.

7.5.1 Water quality

The entire upper Murrumbidgee Catchment was subject to seasonally low flows following particularly dry summer and autumn periods. During the preceding summer total rainfall was 185.4mm and was the driest since 2008/09 when 158.8mm fell (data sourced from the Lobb's Hole rainfall station: 570985). Total rainfall for autumn 2013 (47.8mm) was slightly lower than 2008 (49.8mm).

Water quality parameters throughout the Upper Catchment reflect this dry period which resulted in some nutrient concentrations being lower than autumn 2012 and sites in zone 4 having elevated electrical conductivity concentrations. During the wetter 2012 period 66% of total phosphorus readings exceeded the ANZECC guidelines compared to the current sampling period where 21% exceeded the guidelines (Table 7-2). Similarly, Total Nitrogen readings exceeded the upper limit of the ANZECC guidelines at 74% of the sampling sites in 2012 compared to 56% in 2013; suggesting that although influenced by surface runoff, the background concentrations in the Murrumbidgee River between Tantangara and Burrinjuck Reservoirs are relatively high. However, concentrations of both TP and TN are intensified in zone 4 by the influence of the Molonglo River water, which can at times have a high proportion of LMWQCC effluent, especially during autumn. This is emphasised by the patterns shown in PCA ordination plot (Figure 7-3) which shows the separation of sites in zone 4 based on increasing nutrient values along the second axis.

There are several sources that may have contributed to increased nutrient levels within the Upper Murrumbidgee River. These include the presence of cattle within the waterway at MUR 2 and MUR 3, the STP located upstream of MUR 6 and the introduction of urban influences from Tuggeranong Creek located between MUR 23 and MUR 27.

The exceedances of pH at all but one of the sites between MUR 15 downstream to MUR 37 are similar to the pattern observed in autumn 2012, indicating naturally high values in this part of the catchment.

EC levels followed a similar pattern across the stations, levels starting low at the beginning of March, peaking in April and gradually decreasing across May. This pattern strongly reflects the trend in flow that was observed at these sites across autumn. And this strong longitudinal gradient is reflected in the results of the principal components analysis which shows a strongly negative relationship between electrical conductivity and indeed water temperature and pH along axis 1; and these parameters are the key physico-chemical parameters that separated sites in zone 1 and the remaining sites.

The fact that there is no clear separation between zones 2 and 3, which contain several arbitrary sites placements (e.g. MUR 18 and MUR 19 are in two separate zones despite being only 500m apart, based on the location of the M2G infrastructure) suggests that there are no obvious changes in water quality outside of natural variation downstream of the M2G infrastructure of the Murrumbidgee Pump station that can be attributed to either releases from Tantangara reservoir, or abstractions from Angle Crossing for M2G maintenance runs.

7.5.2 AUSRIVAS and patterns in the macroinvertebrate communities

Despite reductions in flow and related changes to the edge and riffle habitats, as noted in the field observations, the zonation patterns remain comparable to previous sampling runs. Zonation was implied from the significant differences amongst the macroinvertebrate communities between all pairs of zones except between Zone 2 and Zone 3; and the non-significant difference detected between the zone 2 and 3 pairwise test is consistent with the lack of evidence separating zones 2 and 3 based on the water quality characteristics collected within these zones.

The results of SIMPER indicated a number of taxa contributing to these differences. The clearest and most frequently observed trends were increased numbers of sensitive taxa Gripopterygidae, Coloburiscidae, Leptophlebiidae, Hydroptilidae and Conoesucidae at sites in the upper catchment and generally an absence of these taxa in Zone 4. The higher number of these sensitive taxa in Zone 1 is considered to be a combination of environmental factors such as altitude, climate, habitat and generally higher quality water in this part of the catchment.

Lower numbers of Simuliidae and Hydropsychidae were again observed in riffles within Zone 1 compared to sites further downstream. These taxa require clean substrates and fast flowing water for the delivery of food resources (Gooderham and Tsyrlin, 2005). It is not clear why these taxa were in lower numbers in Zone 1. However, the generally high quality substrate relative to the lower reaches of the river suggests that it is flow related. Gyrinidae were collected in the riffle samples at MUR 1, 2 and 3 (APPENDIX F) which is also evidence of low flow effects given that these taxa are usually associated with fringing vegetation, pools and edge habitats.

AUSRIVAS results indicated some improvement in the overall site assessments with 9 of the 23 sites (39%) being assessed as BAND A in the current sampling run compared to 26% for the same period in 2012. Total richness and EPT richness was significantly higher in both edge and riffle samples in Zone 1 compared to Zone 4 (7-26), which attributed to the slightly higher SIGNAL 2 scores at sites within that Zone.

There appears to be no obvious pattern in the relationship between Zone and AUSRIVAS Bands, which is supported by the non-significant Zone effect from the ANOVA model. At the individual habitat level, however, the edge habitat tended to have more BAND A assessments compared to the riffle zone and these assessments varied considerably, which probably reflects different susceptibilities of a given habitat at any given site to receding water levels. For example, variation in channel dimensions, and slope amongst zones will have a strong influence on wetted width, which in turn will impact available habitat and resources under hydrological stress. Changes in slope will determine the stability and therefore composition of substrates at a given site (Rice *et al.*, 2001). Both of these factors will ultimately play key roles in the resulting macroinvertebrates communities at a given site.

The majority of edge samples in Zones 1 and 2, for example, were BAND A, however low flows and a noticeable reduction in riffle habitat area at MUR 3, 4 and 9 resulted in BAND B assessments (Table 7-22). Missing taxa from MUR 3, 4 and 9 (APPENDIX D) vary in their ecological traits and tolerance ratings rather than being specifically associated with flowing water, suggesting that the lack of habitat resulting from the reduction in flows as opposed to flow *per se* is the likely cause for these assessments.

During abstraction periods, it is expected that the first sign of a flow related impact would be seen in riffle zones. Since spring 2012 there have been a number of M2G maintenance runs and ongoing environmental flow releases from Tantangara Reservoir. At the key sites upstream and downstream of Angle Crossing there is no indication of an impact relating to these flow operations (analysed in detail in Part 1 of this report). Furthermore the contrasting hydrologic conditions between autumn 2012 and autumn 2103 provides some insight into how macroinvertebrate communities and health assessments respond to the conditions. The large flow event that occurred in February / March 2012 was the largest flow event in the Murrumbidgee since 1991.

The resulting water quality, macroinvertebrate community assemblages and AUSRIVAS health Band's following this event mirror the overall zonation patterns seen in both the water quality characteristics and macroinvertebrate assemblages seen in the autumn 2013, which represents the driest period since 2008 when the MEMP began. The upshot to this is that the Murrumbidgee River system displays a high resistance to change and appears to be highly adapted to the natural flow characteristics (Poff *et al.,* 1997), further suggesting that the given operation proposals for the Tantangara Transfer option are unlikely to have lasting impacts upon the Upper Murrumbidgee River Catchment between Tantangara and Burrinjuck Reservoirs. The responses are likely to vary depending on the timing, duration and magnitude of the releases from Tantangara Reservoir and the abstraction at Angle Crossing.

7.6 Tantangara to Burrinjuck Conclusions and Recommendations

The autumn sampling period was characterised by low rainfall and low base flows following a particularly dry summer. The resulting water quality results reflected these conditions by showing improvements in nutrient concentration compliance to the ANZECC and ARMCANZ guidelines for healthy ecosystems. Electrical conductivity exceeded the upper limits of the guideline values due to the higher proportion of Molonglo River relative to the Murrumbidgee River water. These patterns downstream of the Molonglo River confluence have been seen in previous sampling events and the indications from these data is there does not appear to be any impact upon the macroinvertebrate communities.

The overall sites assessments based on AUSRIVAS modelling show that despite being exposed to a period of low flows, and little rainfall, sampling sites in the upper Murrumbidgee River were comparable to previous years with overall site health ratings being either BAND A ("*close to reference*") or BAND B (*"significantly impaired"*). Missing taxa from the AUSRIVAS models tended to have a broad range of SIGNAL tolerance scores and a variety of ecological traits, which may suggest that habitat availability and competition may have resulted in the absence of these taxonomic groups as opposed to being purely flow related. There was also an indication that fringing vegetation and some of the edge habitats may have been impacted by the reduction on water level and wetted area by the presence of several pool/edge taxa being collected in the riffle samples.

Compared to autumn 2012 there were improvements in the AUSRIVAS bands for some of the riffle samples in Zone 3 (below the Angle Crossing abstraction point). This provides some evidence to support the conclusion that water abstraction from Murrumbidgee River does not appear to have influenced the results of the Tantangara to Burrinjuck component of the MEMP, at least in a persistent way. However, as has been previously discussed, a formal statistical review of historical data will be required to determine long term trends in ecological health within the Upper Murrumbidgee River under different flow conditions.

8. Literature cited

ACT Government (2011) Environmental Flow Guidelines.

ACTEW Corporation (2010). Murrumbidgee to Googong Water Transfer: Ecological Monitoring Sub Plan.

ACTEW (2011) Burra Creek Environmental Management Plan.

ACTEW Corporation (2012). *Murrumbidgee to Googong Water Transfer: Operation Environmental Management Plan.*

Allan, J.D. & Castillo, M.M. (2008) *Stream Ecology: Structure and Function of Running Waters.* Springer. The Netherlands.

ALS (2010) Murrumbidgee Ecological Monitoring Program - Part 1: Angle Crossing ~ Autumn 2010. Water Science Group, Canberra AC_A10_R5.

ALS (2010_a) Murrumbidgee Ecological Monitoring Program - Part 2: Burra Creek ~ Autumn 2010. Water Science Group, Canberra.

ALS (2011) Murrumbidgee Ecological Monitoring Program: Recommendation Summary 2008-2011. Water Science Group, Canberra CN211063-WR-0112-002

ALS (2011_a) Murrumbidgee Ecological Monitoring Program - Part 1: Angle Crossing ~ Autumn 2010. Water Science Group, Canberra CN211063-AC-A11-R7-v3.

ALS (2012_a) Murrumbidgee Ecological Monitoring Program – Part 2: Burra Creek: Spring 2011. Water Science Group, Canberra CN211063-P1--S11-R8-V4

ALS (2012_b) Murrumbidgee Ecological Monitoring Program - Part 4: Tantangara to Burrinjuck: Spring 2011. Water Science Group, Canberra. CN211063-P4--S11-R8-V4.

ALS (2012_c) Murrumbidgee Ecological Monitoring Program: Part 1: Angle Crossing: Spring 2011. Water Science Group, Canberra CN211063-P1—S11-R8-4

Anderson, M. J., Gorley, R. N. and Clarke, K. R. (2008) *PERMANOVA+ for PRIMER: Guide to Software and Statistical Methods.* PRIMER-E: Plymouth, UK.

Antoine Tremblay, Dalhousie University, Johannes Ransijn and University of Copenhagen (2013). LMERConvenienceFunctions: A suite of functions to back-fit fixed effects and forward-fit random effects, as well as other miscellaneous functions. R package version 2.0. http://CRAN.R-project.org/package=LMERConvenienceFunctions

ANZECC & ARMCANZ (2000) National water quality management strategy: Paper No. 4. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Volume 1. The Guidelines. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand.

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

Australian Government Bureau of Meteorology (2013) www.bom.gov.au

Barmuta, L.A., Chessman, B.C. & Hart, B. (2003) Australian River Assessment System: Interpretation of the Outputs from AUSRIVAS (Milestone report). Monitoring River Health Initiative Technical Report Number 24. . Land and Water resources Research and Development Corporation.

Bates, D., Maechler, M., and Bolker, B. (2013). lme4: Linear mixed-effects models using S4 classes. R package version 0.999999-2. http://CRAN.R-project.org/package=lme4

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

Biggs, B.J.F. & Close, M.E. (1989) Periphyton biomass dynamics in gravel bed rivers: The relative effects of flows and nutrients. *Freshwater Biology*, **22**, 209-231.

Biggs, B.J.F. (1996) “Patterns in benthic algae in streams”. In: *Algal Ecology. Freshwater Benthic Ecosystems,* Stevenson, R.J., Bothwell, M.L. and Lowe, R.L. (Eds.). Academic Press: San Diego, CA., USA, pp.31-58.

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

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

Brittain, J.E. & Eikeland, T.J. (1988) Invertebrate drift - a review. *Hydrobiologia,* **166,** 77-93.

Brooks, A.J., Haeusler, T., Reinfelds, I. & Williams, S. (2005) Hydraulic microhabitats and the distribution of macroinvertebrate assemblages in riffles. *Freshwater Biology,* **50,** 331-344.

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

Boulton, A.J. (2003) Parallels and contrasts in the effects of drought on stream macroinvertebrate assemblages. *Freshwater Biology,* **48,** 1173-1185.

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

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

Carlisle, D.M., Wolock, D.M. & Meador, M.R. (2011) Alteration of streamflow magnitudes and potential ecological consequences: a multiregional assessment. *Frontiers in Ecology and the Environment,* **9,** 264-270.

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

Chessman, B., Jones, H.A., Searle, N.K., Growns, I.O. & Pearson, M.R. (2010) Assessing the effects of flow alteration on macroinvertebrate assemblages in Australian dryland rivers. *Freshwater Biology,* **55,** 1780-1800.

Chester, E.T. & Robson, B.J. (2011) Drought refuges, spatial scale and recolonisation by invertebrates in non-perennial streams. Freshwater Biology, **56** (10), 2094-2104.

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

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

Coysh, J., Nichols, S., Ransom, G., Simpson, J., Norris, H. R., Barmuta, L. A. and Chessman, B. C. (2000) *AUSRIVAS Macroinvertebrate bioassessment: predictive modelling manual*, CRC for Freshwater Ecology.

Dahm, C.N., Baker, M.A., Moore, D.I. & Thibault, J.R. (2003) Coupled biogeochemical and hydrological responses of streams and rivers to drought. *Freshwater Biology,* **48,** 1219-1231.

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

Dean, J. C., St Clair, R.M. and Cartwright, D. I. 2004. Identification Keys to Australian Families and Genera of Caddis-Fly Larvae (Trichoptera) CRCFE Thurgoona NSW.

Downes, B.J., Barmuta, L.A., Fairweather, P.G., Faith, D.P., Keough, M.J., Lake, P.S., Mapstone, B.D. & Quinn, G.P. (2002) *Monitoring Environmental Impacts - Concepts and Practice in Flowing Waters.*, Cambridge, U.K.

Elliot, J.M. (2008) The ecology of riffle beetles (Coleoptera: Elmidae). *Freshwater Reviews*, **1**, 189-203.

Finn, M.A., Boulton, A.J. & Chessman, B.C. (2009) Ecological responses to artificial drought in two Australian rivers with differing water extraction. *Fundamental and Applied Limnology Archiv fur Hydrobiologie,* **175,** 231-248.

Frissell, C.A., Liss, W.J., Warren, C.E. & Hurley, M.D. (1986) A hierarchical framework for stream habitat classification: viewing streams in a watershed context. *Environmental Management,* **10,** 199-214.

Fritz, K.M. & Dodds, W.K. (2004) Resistance and Resilience of Macroinvertebrate Assemblages to Drying and Flood in a Tallgrass Prairie Stream System. Hydrobiologia, **527** (1), 99-112.

GHD (2012) Murrumbidgee Ecological Monitoring Program - Part 1: Angle Crossing - autumn 2012. Water Science Group, Canberra. 23/14302/67973.

GHD (2012a) Murrumbidgee Ecological Monitoring Program - Part 2: Burra Creek - autumn 2012. Water Science Group, Canberra. 23/14302/67987.

Gooderham, J. and E. Tsyrlin (2005) The Waterbug Book: *A guide to the freshwater macroinvertebrates in temperate Australia*. CSIRO Publishing.

Growns, I.O. & Davis, J.A. (1994) Longitudinal Changes in Near-Bed Flows and Macroinvertebrate Communities in a Western Australian Stream. Journal of the North American Benthological Society, **13** (4), 417-438.

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

Hemphill, N. (1988) Competition between two stream dwelling filter-feeder, *Hydropsyche oslari* and *Simulium virgatum*. *Oceologia,* **77,** 33-80.

Hawking, J.H. (2000) Key to Keys: A guide to keys and zoological information to identify invertebrates from Australian inland waters. Cooperative Research Centre for Freshwater Ecology, Albury.

Ingram, B.A. & De Silva, S.S. (2007) Diet composition and preference of juvenile Murray cod, trout cod and Macquarie perch (Percichthyidae) reared in fertilised earthen ponds. *Aquaculture,* **271,** 260-270.

Jones, J.I., Collins, A.L., Naden, P.S. & Sear, D.A. (2012) The relationship between fine sediment and macrophytes in rivers. *River Research and Applications,* **28,** 1006-1018.

Jowett, I.G. & Biggs, B.J.F. (1997) Flood and velocity effects on periphyton and silt accumulation in two New Zealand rivers. *New Zealand Journal of Marine and Freshwater Research*, **31**, 287-300.

King, A.J. (2005) Ontogenetic dietry shifts of fishes in an Australiand floodplain river. *Marine and Freshwater Research,* **56,** 215-225.

Kruskal, J. (1964) Multidimensional scaling by optimizing goodness of fit to a nonmetric hypothesis.

Lake, P.S. (2008) Drought, the "creeping disaster" effects on aquatic ecosystems. Land & Water Australia.

Lake, P.S. (2011) Drought and Aquatic Ecosystems: Effects and Responses. Wiley-Blackwell. West Sussex, U.K.

Lintermans, M. (2007) Fishes of the Murray-Darling Basin: An Introductory Guide. Murray-Darling Basin Authority, Canberra.

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

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

Marsh, N., Sheldon, F. & Rolls, R. (2012) Synthesis of case studies quantifying ecological repsonses to low flows In: *Low Flows Series.* (Ed^Eds, p. 62. National Water Commission, Canberra.

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

Minshall, W. (1984) Aquatic insect-substratum relationships. In: *Ecology of Aquatic Insects* (pp. 358-389). Praeger Press, N.Y.

Nichols, S., Sloane, P., Coysh, J., Williams, C. & Norris, R.H. (2000) AUStralian RIVer Assessment System - Australian Capital Territory: Sampling and Processing Manual. Cooperative Research Centre for Freshwater Ecology, Canberra.

Niemi, G.J., Devore, P., Detenbeck, N., Taylor, D., Lima, A., Pastor, J., Yount, D.J. & Naiman, R.J. (1990) Overview of case studies on recovery of aquatic systems from disturbance. *Environmental Management,* **14,** 571-587.

Pen, L.J. & Potter, I.C. (1991) Reproduction, growth and diet of Gambusia holbrooki (Girard) in a temperate Australian river. Aquatic Conservation: Marine and Freshwater Ecosystems, **1** (2), 159-172.

R Core Team (2013). R: A language and environment for statistical computing. R Foundation for Statistical Computing,Vienna, Austria. URL http://www.R-project.org/.

Reice, S.R., Wissmar, R.C. & Naiman, R.J. (1990) Disturbance regimes, resilience, and recovery of animal; communities and habitats in lotic ecosystems. *Environmental Management,* **14,** 647-659.

Rice, S.P., Greenwood, M.T. & Joyce, C.B. (2001) Tributries, sediment sources, and the longitudinal organisation of macroinvertebrate fauna along river systems. *Canadian Journal of fisheries and Aquatic Science,* **58,** 824-840.

Schulz, M., Kozerski, H., Pluntke, T. & Rinke, K. (2003) The influence of macrophytes on sedimentation and nutrient retention in the lower River Spree (Germany). *Water Research*, 37, 569-578.

Snowy Hydro Limited (2013) Tantangara Dam Daily Release Targets for 2013-14 Water Year, http://www.snowyhydro.com.au/wp-content/uploads/pdfs/watrel/TN_DT.pdf. Snowy Hydro Limited, 04/06/2013.

Tonkin, Z.D., Humphries, P. & Pridmore, P.A. (2006) Ontogeny of feeding in two native and one alien fish species from the Murray-Darling Basin, Australia. *Environmental Biology of Fishes,* **76,** 303-315.

Vinson, M.R. & Hawkins, C.P. (1996) Effects of sampling area and subsampling procedure on comparisons of taxa richness among streams. *Journal of the North American Benthological Society,* **15,** 392-399.

Walters, A.W. & Post, D.M. (2011) How low can you go? Impacts of a low-flow disturbance on aquatic insect communities. *Ecological Applications,* **21,** 163-174.

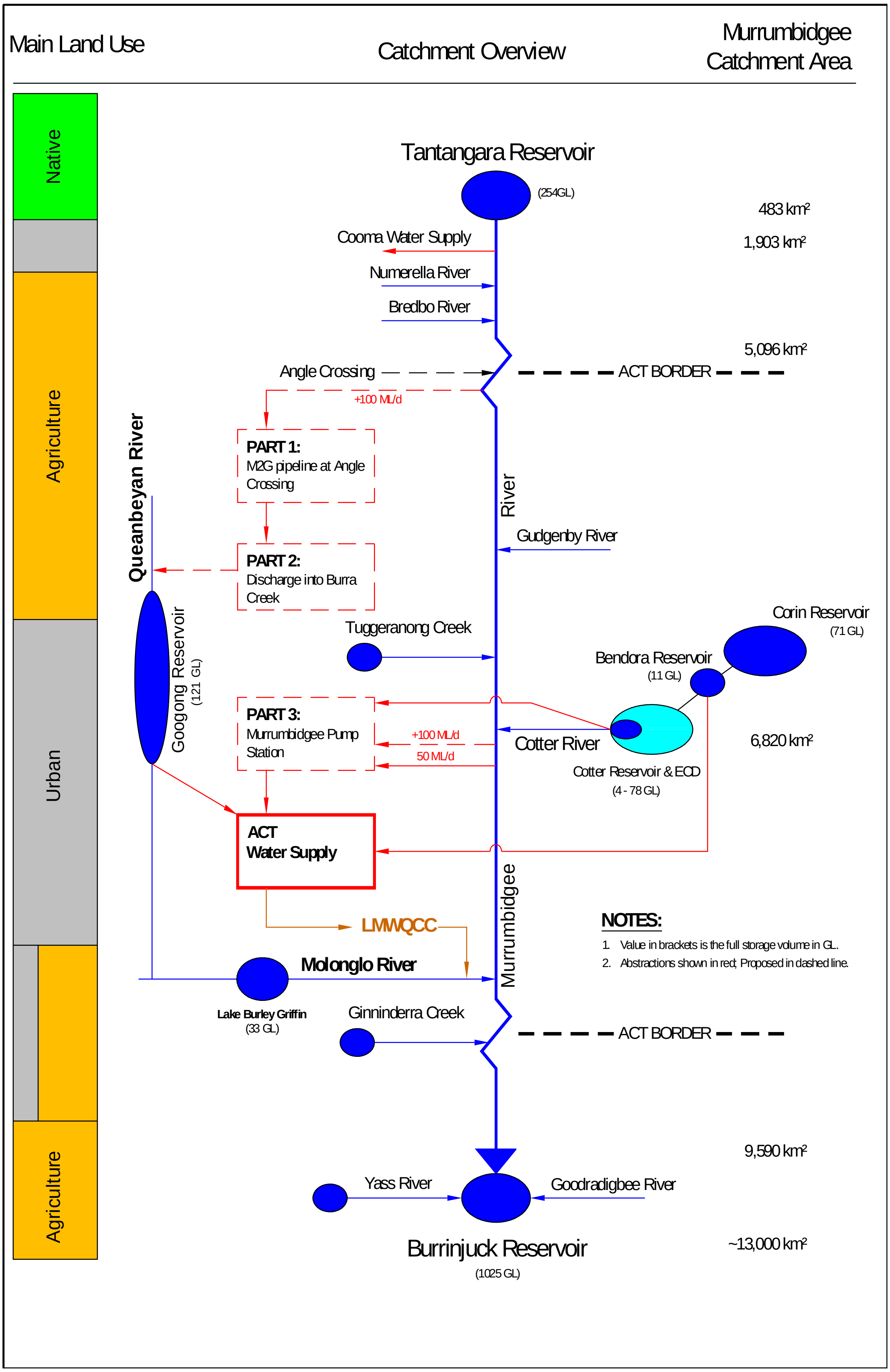
Withers, P.J.A. & Jarvie, H.P. (2008) Delivery and cycling of phosphorus in rivers: A review. *Science of the Total Environment,* **400,** 379-395.

Zhang, Y., Malmqvist, B. &Englund, G. (1998) Ecological processes affecting community structure of blackfly larvae in regulated and unregulated rivers: a regional study. *Journal of Applied Ecology,* **35,** 673-686**.**

Appendices

Appendix A – Schematic representation of the **Murrumbidgee Catchment and ACTEW Waters'** major projects

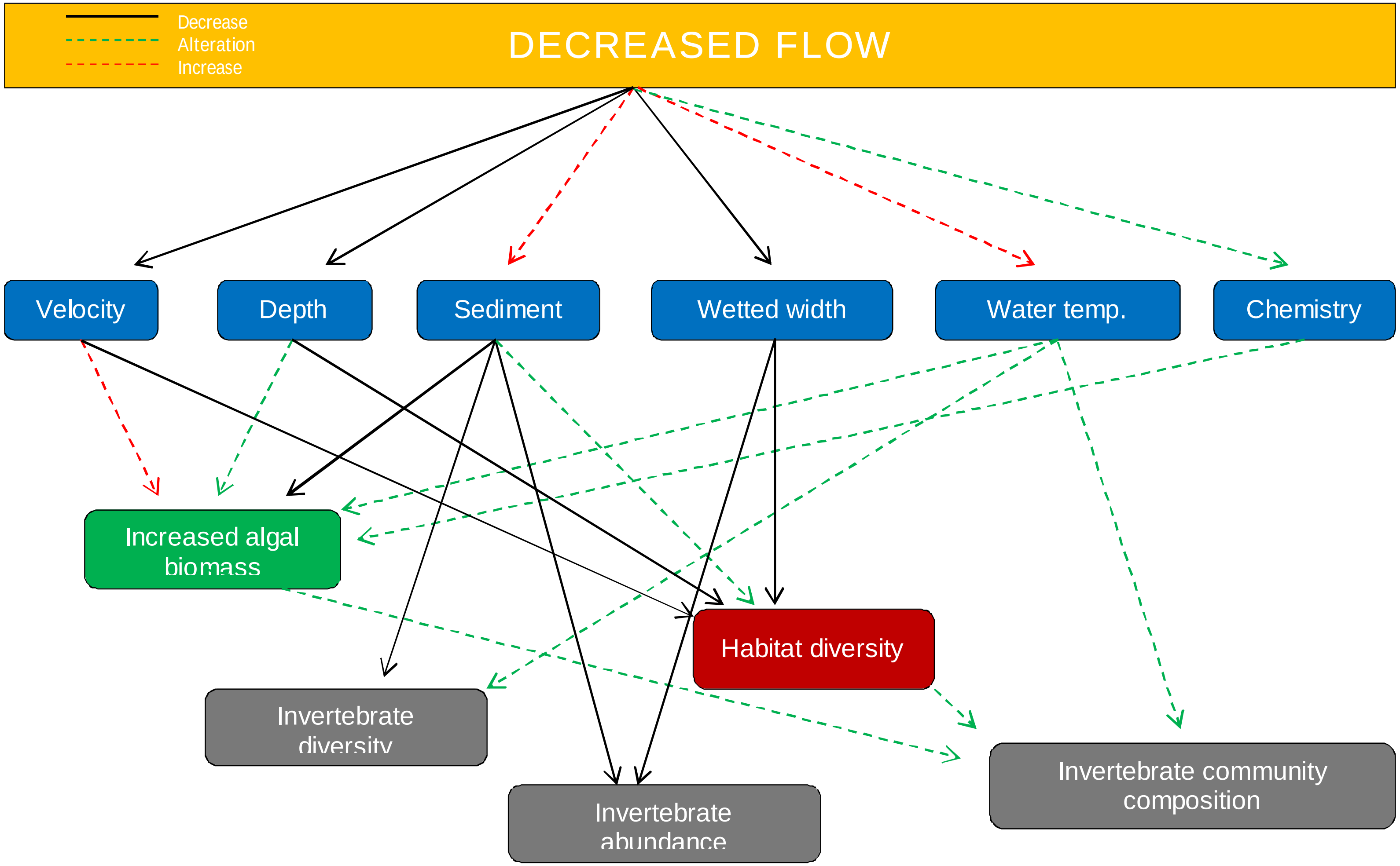
Appendix A. Overview of ACTEW Water's major projects



Appendix B – Conceptual framework of the effects of reduced flow

Appendix B. 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 C. QA / QC results for Burra Creek, Angle Crossing and Murrumbidgee Pump Station

		Site Code	BUR2a		BUR2b		BUR2c		QBYN1		QBYN1		MUR23		MUR23		MUR28		MUR935		MUR937		MUR29	
		Habitat	Riffle		Riffle		Riffle		Riffle		Edge		Edge		Edge		Edge		Riffle		Riffle		Edge	
		Sample	1		2		1		2		2		2		2		1		2		2		2	
		Date Collected	20/05/2013		20/05/2013		30/05/2013		30/05/2013		21/05/2013		8/05/2013		8/05/2013		8/05/2013		23/05/2013		9/05/2013		13/05/2013	
		Replicate	2	QA	1	QA	2	QA	1	QA	3	QA	2	QA	3	QA	2	QA	3	QA	1	QA	2	QA
CLASS / Order	**Family / Sub-Family**	**Genus**																						
ACARINA	*sp.*		0	0	6	6	4	4	1	1	3	3	0	0	0	1	0	0	2	2	7	7	2	2
BIVALVIA	Sphaeriidae	*Musculium (Sphaerium)*	0	0	0	0	0	0	0	0	5	5	0	0	0	0	0	0	0	0	0	0	0	0
BIVALVIA	Sphaeriidae	*sp.*	0	0	0	0	2	2	0	0	5	5	0	0	0	0	0	0	0	0	0	0	0	0
BIVALVIA	*sp.*		0	0	0	0	0	0	0	0	0	0	7	7	11	11	0	0	0	0	0	0	0	0
Coleoptera	Dytiscidae	*Necterosoma*	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Coleoptera	Dytiscidae	*sp.*	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0	0	0	0	0	0
Coleoptera	Elmidae	*Austrolimnius*	0	0	2	2	0	0	1	1	4	4	0	0	0	0	0	0	0	0	2	2	0	0
Coleoptera	Elmidae	*Coxelmis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	9	0	0	0	0	0	0
Coleoptera	Elmidae	*Simsonia*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	5	0	0	0	0
Coleoptera	Elmidae	*Stetholus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
Coleoptera	Elmidae	*sp.*	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	1	0	0	1	1	0	0
Coleoptera	Gyrinidae	*Macrogyrus*	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coleoptera	Hydrochidae	*Hydrochus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
Decapoda	Atyidae	*Paratya*	1	1	0	0	0	0	0	0	6	6	0	0	1	1	11	11	0	0	0	0	0	0
Decapoda	Atyidae	*sp.*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
Decapoda	Palaemonidae	*Macrobrachium*	0	0	0	0	0	0	0	0	0	0	1	1	2	2	2	2	0	0	1	1	0	0
Diptera	Ceratopogonidae	*Ceratopoginae*	0	0	1	1	0	0	0	0	3	3	0	0	0	0	2	2	0	0	0	0	3	2
Diptera	Chironominae	*sp.*	10	10	3	3	15	15	1	1	28	26	82	83	88	87	56	56	7	7	5	4	59	57
Diptera	Dixidae	*Dixa*	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Diptera	Empididae	*sp.*	2	2	0	2	2	0	0	0	0	0	1	1	2	2	2	2	1	1	0	0	0	0
Diptera	Orthocladiinae	*sp.*	107	106	8	8	11	10	7	7	10	10	20	20	24	24	15	15	4	4	8	8	6	6
Diptera	Psychodidae	*sp.*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
Diptera	Simuliidae	*Austrosimulium*	10	10	113	115	5	5	97	94	0	0	1	1	3	3	5	5	44	44	40	41	5	5
Diptera	Simuliidae	*sp.*	7	7	12	12	11	11	63	64	0	0	0	0	0	0	2	2	38	38	20	20	0	0
Diptera	Tanypodinae	*sp.*	5	5	1	1	1	1	0	0	36	36	0	0	1	1	0	0	0	0	0	0	7	7
Diptera	Tipulidae	*sp.*	0	0	0	0	3	3	0	0	0	0	1	1	0	0	0	0	1	1	3	3	1	1
Diptera	*sp.*		0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ephemeroptera	Baetidae	*Baetidae Genus 1*	1	1	0	0	0	0	0	0	0	0	3	3	2	2	0	0	1	1	0	0	0	0
Ephemeroptera	Baetidae	*Baetidae Genus 2*	0	0	0	0	2	2	4	4	0	0	0	0	0	0	1	1	5	5	4	4	0	0
Ephemeroptera	Baetidae	*sp.*	22	22	6	6	6	5	2	2	5	5	7	7	4	4	1	1	10	10	9	9	1	2
Ephemeroptera	Caenidae	*Irapacaenis*	0	0	0	0	0	0	0	0	0	0	12	12	11	11	1	1	5	4	5	5	3	3
Ephemeroptera	Caenidae	*Tasmanocoenis*	1	1	0	0	6	6	3	3	24	24	9	9	3	3	9	9	5	6	66	65	42	42
Ephemeroptera	Caenidae	*sp.*	1	1	0	0	17	17	4	4	36	36	25	24	19	19	10	10	14	14	39	39	10	10
Ephemeroptera	Leptophlebiidae	*Atalophlebia*	0	0	0	0	0	0	7	7	0	2	4	4	6	6	1	1	0	0	0	0	1	1
Ephemeroptera	Leptophlebiidae	*Jappa*	0	0	0	3	9	9	0	0	0	0	0	0	0	0	0	0	3	3	6	6	1	1
Ephemeroptera	Leptophlebiidae	*sp.*	5	5	11	8	8	8	45	45	14	13	3	3	2	2	17	17	4	4	5	5	4	4
Ephemeroptera	*sp.*		0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
GASTROPODA	Physidae	*Physa*	0	0	0	0	0	0	0	0	9	9	0	0	0	0	0	0	0	0	0	0	2	2
Hemiptera	Corixidae	*Micronecta*	0	0	1	1	0	0	0	0	4	4	0	0	2	2	24	24	1	1	0	0	31	31

		Site Code	BUR2a		BUR2b		BUR2c		QBYN1		QBYN1		MUR23		MUR23		MUR28		MUR935		MUR937		MUR29	
		Habitat	Riffle		Riffle		Riffle		Riffle		Edge		Edge		Edge		Edge		Riffle		Riffle		Edge	
		Sample	1		2		1		2		2		2		2		1		2		2		2	
		Date Collected	20/05/2013		20/05/2013		30/05/2013		30/05/2013		21/05/2013		8/05/2013		8/05/2013		8/05/2013		23/05/2013		9/05/2013		13/05/2013	
		Replicate	2	QA	1	QA	2	QA	1	QA	3	QA	2	QA	3	QA	2	QA	3	QA	1	QA	2	QA
CLASS / Order	**Family / Sub-Family**	**Genus**																						
Hemiptera	Corixidae	*sp.*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0
Hemiptera	Gerridae	*sp.*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Hemiptera	Notonectidae	*Paranisops*	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1
Lepidoptera	Crambidae	*sp.*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
Odonata	Epiproctophora	*sp.*	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Odonata	Gomphidae	*Austrogomphus*	0	0	0	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Odonata	Gomphidae	*sp.*	0	0	0	0	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Odonata	Zygoptera	*sp.*	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0
OLIGOCHAETA	*sp.*		10	10	5	5	6	6	9	9	13	13	8	8	3	3	0	0	2	2	4	4	6	6
Plecoptera	Gripopterygidae	*Illiesoperla*	0	0	1	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plecoptera	Gripopterygidae	*Leptoperla*	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plecoptera	Gripopterygidae	*sp.*	0	0	4	4	62	64	3	3	3	3	1	1	0	0	0	0	0	0	0	0	0	0
Trichoptera	Calamatoceridae	*Anisocentropus*	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0
Trichoptera	Ecnomidae	*Ecnomus*	3	3	4	4	8	8	0	0	5	5	4	4	7	7	7	7	4	3	2	2	3	3
Trichoptera	Ecnomidae	*sp.*	1	1	0	0	0	0	0	0	2	2	1	1	2	2	0	0	4	4	6	6	1	1
Trichoptera	Hydrobiosidae	*Taschorema*	1	1	0	0	10	10	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
Trichoptera	Hydrobiosidae	*Ulmerochorema*	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trichoptera	Hydrobiosidae	*sp.*	0	1	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0
Trichoptera	Hydropsychidae	*Asmicridea*	0	0	0	0	7	7	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Trichoptera	Hydropsychidae	*Cheumatopsyche*	1	1	9	9	22	22	16	16	0	0	1	1	1	1	8	8	62	61	60	60	5	5
Trichoptera	Hydropsychidae	*sp.*	0	0	0	0	5	5	3	3	0	0	0	0	0	0	0	0	6	6	19	18	0	0
Trichoptera	Hydroptilidae	*Hellyethira*	3	3	0	0	1	1	0	0	13	14	1	1	2	2	0	0	0	0	0	0	0	0
Trichoptera	Hydroptilidae	*Oxyethira*	0	0	3	3	3	3	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0
Trichoptera	Hydroptilidae	*sp.*	0	0	0	0	0	0	0	0	0	0	3	3	0	0	1	1	0	0	0	0	0	0
Trichoptera	Leptoceridae	*Notalina*	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0
Trichoptera	Leptoceridae	*Oecetis*	0	0	0	0	1	1	0	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0
Trichoptera	Leptoceridae	*Triplectides*	0	0	0	0	0	0	0	0	9	9	3	3	0	0	3	3	0	0	0	0	2	2
Trichoptera	Leptoceridae	*sp.*	0	0	0	0	0	0	0	0	2	2	2	2	6	6	3	3	0	0	0	0	6	6
Trichoptera	Philopotamidae	*Chimarra*	0	0	9	9	3	3	11	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trichoptera	*sp.*		5	5	2	2	3	3	0	0	4	4	2	2	1	1	0	0	1	1	0	0	0	0
		Percent Taxa Correct	**98.98%**		**94.17%**		**97.54%**		**98.57%**		**97.67%**		**99.03%**		**99.01%**		**100.00%**		**97.83%**		**98.73%**		**98.03%**	
		Pass/Fail	**Pass**		**Pass**		**Pass**		**Pass**		**Pass**		**Pass**		**Pass**		**Pass**		**Pass**		**Pass**		**Pass**	

Appendix C. QA / QC results for Tantangara to Burrinjuck

	Site Code	MUR9		MUR31	
	Habitat	Edge		Riffle	
	Unique QSN	MEMP12/12		MEMP12/54	
	Date Collected	16/05/2013		9/05/2013	
	Replicate	1	QA	1	QA
CLASS / Order	**Family / Sub-Family**				
ACARINA	*sp.*	6	7		
Coleoptera	Elmidae			3	3
Decapoda	Atyidae	1	1		
Diptera	Ceratopogonidae	4	4		
Diptera	Chironominae	54	53	4	4
Diptera	Orthocladiinae	29	29	7	7
Diptera	Simuliidae	2	2	122	120
Diptera	Tanypodinae	27	27		
Ephemeroptera	Baetidae	1	1	40	40
Ephemeroptera	Caenidae	4	4	13	13
Ephemeroptera	Coloburiscidae	1	1		
Ephemeroptera	Leptophlebiidae	4	4	2	2
GASTROPODA	Ancylidae	1	1		
Hemiptera	Corixidae	38	38		
Odonata	Epiproctophora	1	1		
OLIGOCHAETA	Oligochaeta	13	13		
Plecoptera	Gripopterygidae	1	1		
Plecoptera	*sp.*	5	5		
Trichoptera	Calamoceratidae	1	1		
Trichoptera	Ecnomidae	3	3	1	1
Trichoptera	Hydrobiosidae	1	1		
Trichoptera	Hydropsychidae	4	4	35	35
Trichoptera	Hydroptilidae	2	2		
Trichoptera	Leptoceridae	9	9		
Trichoptera	*sp.*	1	1	2	2
	Percent Taxa Correct	**99.06%**		**99.13%**	
	Pass / Fail	**Pass**		**Pass**	

Appendix D – Taxa predicted to occur with >50% probability but not collected

Appendix D. Angle Crossing taxa predicted to occur but absent from the riffle habitat

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

Appendix D. Angle Crossing taxa predicted to occur but absent from the edge habitat

Site	Taxa	Hydrobiidae	Ancylidae	Planorbidae	Sphaeriidae	Oligiochaeta	Acarina	Hydrophilidae	Elmidae	Ceratopogonidae	Podonominae	Tanypodinae	Leptophlebiidae	Caenidae	Corixidae	Coenagrionidae	Synlestidae	Gomphidae	Gripopterygidae	Hydroptilidae	Ecnomidae	Conoesucidae	Calamoceratidae	Leptoceridae	Total number of missing taxa
	SIGNAL	4	4	2	2	2	6	2	7	4	6	4	8	4	2	2	7	5	8	4	4	7	7	6	
MUR15	Edge			*0.54*					0.64								0.58		0.64			0.56			5
MUR15				*0.54*					0.64								0.58		0.64			0.56			5
MUR15				*0.54*					0.64								0.58					0.56			4
MUR15				*0.54*					0.64								0.58		0.64	0.85		0.56			6
MUR15				*0.54*					0.64								0.58					0.56			4
MUR15				*0.54*					0.64					1.00			0.58		0.64	0.85	0.56	0.56			8
MUR16	Edge			*0.52*					0.67										0.55			0.51		0.96	5
MUR16				*0.52*					0.67													0.51		0.96	4
MUR16				*0.52*					0.67			0.91							0.55			0.51		0.96	6
MUR16				*0.52*		*0.98*			0.67										0.55			0.51		0.96	6
MUR16				*0.52*		*0.98*			0.67										0.55	0.72		0.51		0.96	7
MUR16				*0.52*					0.67			0.91	0.96						0.55			0.51		0.96	7
MUR18	Edge			*0.53*													0.53			0.79		0.53			4
MUR18				*0.53*													0.53			0.79		0.53			4
MUR18				*0.53*					0.65								0.53					0.53		0.97	5
MUR18				*0.53*								0.91					0.53			0.79		0.53		0.97	6
MUR18				*0.53*		*0.97*			0.65			0.91					0.53			0.79		0.53		0.97	8
MUR18				*0.53*					0.65			0.91		1.00			0.53			0.79		0.53		0.97	8
MUR19	Edge	*0.50*	*0.58*		*0.50*			0.91			0.53					0.53		0.50					0.50		8
MUR19		*0.50*	*0.58*		*0.50*			0.91	0.76		0.53					0.53		0.50					0.50		9
MUR19		*0.50*	*0.58*				*0.76*	0.91	0.76	0.61	0.53					0.53		0.50					0.50		10
MUR19		*0.50*	*0.58*		*0.50*	*1.00*		0.91		0.61	0.53	0.94				0.53		0.50					0.50	0.97	12
MUR19		*0.50*	*0.58*		*0.50*	*1.00*		0.91		0.61	0.53	0.94				0.53		0.50					0.50	0.97	12
MUR19		*0.50*	*0.58*		*0.50*	*1.00*		0.91		0.61	0.53	0.94				0.53		0.50					0.50	0.97	12
MUR23	Edge		*0.57*				*0.74*	0.89	0.76	0.60	0.52					0.51		0.50					0.50		9
MUR23			*0.57*				*0.74*	0.89		0.60	0.52					0.51		0.50					0.50		8
MUR23			*0.57*			*1.00*	*0.74*	0.89	0.76		0.52					0.51		0.50					0.50		9
MUR23								0.89	0.76	0.60	0.52					0.51		0.50					0.50		7
MUR23			*0.57*				*0.74*	0.89		0.60	052	0.94				0.51		0.50					0.50		9
MUR23			*0.57*					0.89		0.60	0.52	0.94			0.67	0.51		0.50					0.50		9
MUR28	Edge			*0.55*		*0.97*											0.65		0.68			0.58			5
MUR28				*0.55*		*0.97*						0.90					0.65		0.68			0.58			6
MUR28				*0.55*		*0.97*											0.65		0.68			0.58			5

Appendix D. Burra Creek taxa predicted to occur but absent from the riffle habitat

Site	Taxa	Hydrobiidae	Ancylidae	Oligochaeta	Acarina	Hydrophilidae	Elmidae	Psephenidae	Simuliidae	Podonominae	Tanypodinae	Caenidae	Corydalidae	Gomphidae	Gripopterygidae	Hydrobiosidae	Glossosomatidae	Hydroptilidae	Philopotamidae	Hydropsychidae	Ecnomidae	Conoesucidae	Leptoceridae	Total number of missing taxa
	SIGNAL	4	4	2	6	2	7	6	5	6	4	4	7	5	8	8	9	4	8	6	4	7	6	
QBYN1	Riffle					*0.50*		*0.86*		*0.59*	*0.50*		0.59		0.86			0.59				0.86		8
QBYN1						*0.50*		*0.86*		*0.59*	*0.50*		0.59				0.64				0.50	0.86		8
QBYN1						*0.50*				*0.59*	*0.50*		0.59				0.64				0.50	0.86		7
QBYN1						*0.50*	*0.95*	*0.86*		*0.59*			0.59			0.55	0.64		0.68			0.86		9
QBYN1						*0.50*		*0.86*		*0.59*	*0.50*		0.59	0.64			0.64				0.50	0.86		9
QBYN1				*0.95*		*0.50*		*0.86*		*0.59*	*0.50*		0.59	0.64			0.64	0.59			0.50	0.86		11
BUR1C	Riffle	*0.55*	*0.55*		*0.64*					*0.57*				0.51		0.84				0.90				7
BUR1C		*0.55*	*0.55*							*0.57*				0.51										4
BUR1C		*0.55*	*0.55*		*0.64*					*0.57*				0.51		0.84				0.90				7
BUR2A	Riffle						*0.99*	*0.52*	*0.93*	*0.57*				0.53		0.79				0.91				7
BUR2A					*0.55*		*0.99*	*0.52*	*0.93*	*0.57*				0.53	0.52	0.79				0.91				9
BUR2A					*0.55*		*0.99*	*0.52*	*0.93*	*0.57*				0.53	0.52	0.79				0.91				9
BUR2A					*0.55*		*0.99*	*0.52*		*0.57*				0.53	0.52	0.79								7
BUR2A							*0.99*	*0.52*	*0.93*	*0.57*				0.53	0.52	0.79								7
BUR2A					*0.55*		*0.99*	*0.52*		*0.57*				0.53	0.52	0.79				0.91				8
BUR2B	Riffle					*0.50*	*0.95*	*0.86*		*0.59*			0.59	0.64		0.55	0.64					0.86		9
BUR2B						*0.50*	*0.95*	*0.86*		*0.59*			0.59	0.64		0.55	0.64					0.86		9
BUR2B						*0.50*	*0.95*	*0.86*	*0.91*	*0.59*			0.59	0.64	0.86	0.55	0.64					0.86		11
BUR2B						*0.50*		*0.86*		*0.59*		*0.82*	0.59	0.64		0.55	0.64					0.86		9
BUR2B						*0.50*	*0.95*	*0.86*		*0.59*			0.59				0.64					0.86		7
BUR2B						*0.50*	*0.95*	*0.86*		*0.59*			0.59				0.64					0.86		7
BUR2C	Riffle	*0.59*	*0.59*							*0.57*						0.86								4
BUR2C		*0.59*	*0.59*							*0.57*						0.86								4
BUR2C		*0.59*	*0.59*							*0.57*						0.86								4
BUR2C		*0.59*	*0.59*							*0.57*														3
BUR2C		*0.59*	*0.59*							*0.57*														3
BUR2C		*0.59*	*0.59*							*0.57*													0.53	4

Appendix D. Burra Creek taxa predicted to occur but absent from the edge habitat

Site	Taxa	Ancylidae	Planorbidae	Oligochaeta	Acarina	Hydrophilidae	Elmidae	Simuliidae	Leptophlebiidae	Caenidae	Corixidae	Synlestidae	Gripopterygidae	Ecnomidae	Conoesucidae	Leptoceridae	Total number of missing taxa
	SIGNAL	4	2	2	6	2	7	5	8	4	2	7	8	4	7	6	
QBYN1	Edge		*0.55*				*0.62*					*0.66*			*0.59*		*4*
QBYN1			*0.55*				*0.62*					*0.66*	*0.69*		*0.59*		*5*
QBYN1			*0.55*				*0.62*					*0.66*	*0.69*	*0.59*	*0.59*		*6*
QBYN1			*0.55*								*0.62*	*0.66*		*0.59*	*0.59*		*5*
QBYN1			*0.55*									*0.66*		*0.59*	*0.59*		*4*
QBYN1			*0.55*									*0.66*			*0.59*		*3*
BUR1C	Edge				*0.53*	*0.72*	*0.72*									*0.97*	*4*
BUR1C					*0.53*	*0.72*	*0.72*									*0.97*	*4*
BUR1C					*0.53*	*0.72*	*0.72*									*0.97*	*4*
BUR1C						*0.72*	*0.72*			*0.99*	*0.65*					*0.97*	*5*
BUR1C					*0.53*	*0.72*	*0.72*				*0.65*					*0.97*	*5*
BUR1C						*0.72*	*0.72*				*0.65*					*0.97*	*4*
BUR2A	Edge		*0.55*				*0.62*					*0.64*	*0.68*		*0.58*		*5*
BUR2A			*0.55*				*0.62*					*0.64*	*0.68*		*0.58*		*5*
BUR2A			*0.55*				*0.62*				*0.62*	*0.64*	*0.68*		*0.58*		*6*
BUR2A			*0.55*				*0.62*		*0.96*			*0.64*			*0.58*		*5*
BUR2A							*0.62*					*0.64*	*0.68*		*0.58*		*4*
BUR2A			*0.55*				*0.62*				*0.62*	*0.64*	*0.68*		*0.58*	*0.97*	*7*
BUR2B	Edge		*0.55*				*0.62*		*0.97*			*0.66*	*0.69*		*0.59*		*6*
BUR2B			*0.55*				*0.62*					*0.66*			*0.59*		*4*
BUR2B			*0.55*				*0.62*					*0.66*	*0.69*		*0.59*		*5*
BUR2B			*0.55*				*0.62*					*0.66*	*0.69*		*0.59*	*0.97*	*6*
BUR2B			*0.55*				*0.62*					*0.66*			*0.59*	*0.97*	*5*
BUR2B			*0.55*				*0.62*					*0.66*	*0.69*		*0.59*	*0.97*	*6*
BUR2C	Edge	*0.53*				*0.85*	*0.75*				*0.67*						*4*
BUR2C		*0.53*				*0.85*	*0.75*				*0.67*						*4*
BUR2C		*0.53*			*0.69*	*0.85*	*0.75*										*4*
BUR2C		*0.53*		*1.00*		*0.85*	*0.75*	*0.51*									*5*
BUR2C		*0.53*				*0.85*	*0.75*	*0.51*									*4*
BUR2C		*0.53*				*0.85*	*0.75*	*0.51*									*4*

Appendix D. Murrumbidgee Pump Station taxa predicted to occur but absent from the riffle habitat

Site	Taxa	Oligiochaeta	Elmidae	Tipulidae	Chironominae	Gripopterygidae	Total number of missing taxa
	SIGNAL	2	7	5	3	8	
MUR931	Riffle		*1.00*	*0.80*		*0.60*	3
MUR931							0
MUR931			*1.00*				1
MUR931		*0.80*		*0.80*			2
MUR931		*0.80*				*0.60*	2
MUR931		*0.80*	*1.00*	*0.80*			3
MUR28	Riffle					*0.60*	1
MUR28						*0.60*	1
MUR28			*1.00*			*0.60*	2
MUR28				*0.80*		*0.60*	2
MUR28		*0.80*		*0.80*		*0.60*	3
MUR28				*0.80*		*0.60*	2
MUR935	Riffle	*0.80*		*0.80*			2
MUR935		*0.80*					1
MUR935		*0.80*		*0.80*		*0.60*	3
MUR935		*0.80*				*0.60*	2
MUR935		*0.80*				*0.60*	2
MUR935						*0.60*	1
MUR937	Riffle	*0.80*		*0.80*		*0.60*	3
MUR937		*0.80*		*0.80*		*0.60*	3
MUR937				*0.80*		*0.60*	2
MUR937						*0.60*	1
MUR937		*0.80*		*0.80*		*0.60*	3
MUR937				*0.80*		*0.60*	2
MUR29	Riffle			*0.80*		*0.60*	2
MUR29					*1.00*	*0.60*	2
MUR29		*0.80*				*0.60*	2
MUR29						*0.60*	1
MUR29		*0.80*		*0.80*		*0.60*	3
MUR29			*1.00*	*0.80*			2

Appendix D. Murrumbidgee Pump Station taxa predicted to occur but absent from the edge habitat

Site	Taxa	Planorbidae	Oligiochaeta	Acarina	Hydrophilidae	Elmidae	Tanypodinae	Baetidae	Synlestidae	Gripopterygidae	Hydroptilidae	Ecnomidae	Conoesucidae	Leptoceridae	Total number of missing taxa
	SIGNAL	2	2	6	2	7	4	5	7	8	4	4	7	6	
MUR931		*0.55*	*0.97*						0.64	0.69		0.58	0.59		6
MUR931		*0.55*					0.90	0.89	0.64	0.69			0.59		6
MUR931	Edge	*0.55*	*0.97*				0.90	0.89	0.64	0.69			0.59		7
MUR931		*0.55*						0.89	0.64	0.69	0.92	0.58	0.59		7
MUR931		*0.55*					0.90	0.89	0.64	0.69	0.92	0.58	0.59		8
MUR28		*0.55*	*0.97*						0.65	0.68			0.58		5
MUR28	Edge	*0.55*	*0.97*				0.90		0.65	0.68			0.58		6
MUR28		*0.55*	*0.97*						0.65	0.68			0.58		5
MUR935					0.72			0.92							2
MUR935			*0.99*		0.72			0.92							3
MUR935			*0.99*		0.72			0.92							3
MUR935	Edge		*0.99*	0.55	0.72	0.73									4
MUR935				0.55	0.72	0.73	0.93	0.92							5
MUR935															0
MUR937		*0.52*				0.67				0.57			0.52	0.95	5
MUR937	Edge	*0.52*				0.67				0.57			0.52	0.95	5
MUR937		*0.52*	*0.98*				0.91			0.57			0.52		5
MUR29		*0.51*			0.53	0.68				0.52	0.67				5
MUR29		*0.51*			0.53	0.68				0.52	0.67	0.51			6
MUR29		*0.51*			0.53					0.52					3
MUR29	Edge	*0.51*			0.53					0.52					3
MUR29		*0.51*			0.53	0.68				0.52	0.67				5
MUR29		*0.51*			0.53					0.52	0.67	0.51			5

Appendix D. Tantangara to Burrinjuck taxa predicted to occur but absent from the riffle habitat

Site	Taxa	Hydrobiidae	Ancylidae	Oligochaeta	Acarina	Amphipoda	Hydrophilidae	Elmidae	Psphenidae	Tipulidae	Podonominae	Tanypodinae	Caenidae	Gomphidae	Gripopterygidae	Hydrobioside	Glossosomatidae	Hydroptilidae	Conoesucidae	Leptoceridae	Total number of missing taxa
	SIGNAL	4	4	2	6	3	2	7	6	5	6	4	4	5	8	8	9	4	7	6	
MUR 1	Riffle (Zone 1)										0.60					0.92			0.96		3
MUR 2					0.59	0.56					0.61							0.72			4
MUR 3		0.53	0.53					0.99			0.57		0.90							0.52	6
MUR 4							0.50		0.86		0.59	0.50	0.82	0.63			0.64	0.59			8
MUR 6	Riffle (Zone 2)	0.51	0.51								0.57			0.52							4
MUR 9		0.59	0.59								0.57	0.70		0.50						0.53	6
MUR 12								1.00		0.80											2
MUR 15										0.80					0.60						2
MUR 16								1.00							0.60						2
MUR 18								1.00		0.80			1.00		0.60						4
MUR 19	Riffle (Zone 3)									0.80											1
MUR 22				0.80						0.80											2
MUR 23				0.80											0.60						2
MUR 27																					0
MUR 931								1.00		0.80					0.60						3
MUR 28															0.60						1
MUR 935				0.80						0.80											2
MUR 937				0.80						0.80					0.60						3
MUR 29										0.80					0.60						2
MUR 30								1.00							0.60						2
MUR 31	Riffle (Zone 4)			0.80						0.80					0.60						3
MUR 34				0.80						0.80					0.60						3
MUR 37				0.80				1.00		0.80					0.60						4

Appendix D. Tantangara to Burrinjuck taxa predicted to occur but absent from the edge habitat

Site	Taxa	Hydrobiidae	Ancylidae	Planorbidae	Sphaeriidae	Oligochaeta	Acarina	Amphipoda	Hydrophilidae	Scirtidae	Elmidae	Tipulidae	Ceratopogonidae	Simuliidae	Podonominae	Tanypodinae	Baetidae	Leptophlebiidae	Caenidae	Coengrionidae	Synlestidae	Gomphidae	Gripopterygidae	Hydrpotilidae	Ecnomidae	Conoesucidae	Calamoceratidae	Leptoceridae	Total number of missing taxa
	SIGNAL	4	4	2	5	2	6	3	2	6	7	5	4	5	6	4	5	8	4	2	7	5	8	4	4	7	7	6	
MUR 1	Riffle (Zone 1)							0.84		0.74				0.63	0.53		0.75												5
MUR 2										0.78		0.62			0.52														3
MUR 3								0.62	0.56	0.53					0.52				0.66							0.51			6
MUR 4				0.55							0.62										0.65					0.59			4
MUR 6	Riffle (Zone 2)			0.52							0.66							0.96								0.51			4
MUR 9				0.55							0.63										0.63					0.58			4
MUR 12				0.55																	0.66					0.59			3
MUR 15				0.54							0.64										0.58		0.64			0.56			5
MUR 16				0.52							0.67												0.55			0.51		0.96	5
MUR 18				0.53																	0.53			0.79		0.53			4
MUR 19	Riffle (Zone 3)	0.50	0.58		0.50				0.91						0.53					0.53		0.50					0.50		8
MUR 22				0.55		0.97					0.62										0.66		0.69			0.59			6
MUR 23			0.57				0.74		0.89		0.79		0.60		0.52					0.51		0.50					0.50		9
MUR 27				0.55							0.62						0.90				0.66		0.69		0.59	0.59			7
MUR 931				0.55		0.97															0.64		0.69		0.58	0.59			6
MUR 28				0.55		0.97															0.65		0.68			0.58			5
MUR 935									0.72								0.92												2
MUR 937				0.52							0.67												0.57			0.52		0.95	5
MUR 29				0.51					0.53		0.68												0.52	0.67					5
MUR 30				0.52					0.50							0.91	0.91						0.54		0.53	0.50		0.97	8
MUR 31	Riffle (Zone 4)						0.62		0.79				0.52			0.93													4
MUR 34		0.50	0.59		0.50		0.76		0.91		0.76		0.62		0.53	0.94				0.53		0.50					0.50		12
MUR 37			0.57			1.00	0.74		0.86		0.76				0.52	0.94				0.51		0.50					0.50	0.97	11

Appendix E – Site Summaries

Part 1 – Angle Crossing

MUR15

Bumbalong Road
6/05/2013 10:30

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
10.9	141.5	4.39	5	8.08	100.4	11.00

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
57	< 0.002	< 0.002	< 0.002	0.004	0.022	0.26

Daily Flow: 110 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 2012: ↑ Autumn 2012: ↑

AUSRIVAS Results

	Autumn 2012	Spring 2012	Autumn 2013
Riffle Habitat	B	A	B
Edge Habitat	B	A	B
Overall Site Assessment	B	A	B

Riffle Habitat

- One replicate sample was collected in full sun with the second collected in full shade
- Dominant substrate was sand

Dominant Taxa

- Baetidae
- Simuliidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

Site Quality Assessment

Edge Habitat

- Dominant trailing bank vegetation was macrophytes and wood debris from overhanging shrubs

Dominant Taxa

- Corixidae
- Notonectidae
- Chironomidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

Additional Comments

- Periphyton coverage of approximately 60% was consistent across the site

MUR16

The Willows – Near Michelago
6/5/2013 2:15 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
11.5	166.4	3.11	5	8.19	101.4	11.04

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
65	< 0.002	< 0.002	< 0.002	0.003	0.015	0.24

Daily Flow: 110 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 2012: 

Autumn 2012: 

AUSRIVAS Results

	Autumn 2012	Spring 2012	Autumn 2013
Riffle Habitat	B	B	B
Edge Habitat	B	A	B
Overall Site Assessment	B	B	B

Riffle Habitat

- Dominant substrate was cobble, pebble and gravel

Dominant Taxa

- Simuliidae
- Leptophlebiidae
- Hydropsychidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

Edge Habitat

- Reduced habitat area due to receding flows resulting in only a single edge sample
- Dominant trailing bank vegetation was overhanging native shrubs and wood debris

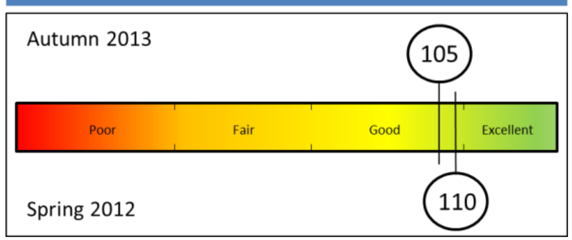
Dominant Taxa

- None

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

Site Quality Assessment



Additional Comments

- Low flows exposing large bedrock platforms down the right side of the channel
- *Myriophyllum sp.* present along channel margins

MUR18

Upstream Angle Crossing
7/5/2013 10:05 am

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
11.3	168.7	3.29	4	8.07	91.1	9.79

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
66	< 0.002	< 0.002	< 0.002	0.003	0.013	0.24

Daily Flow: 120 ML/day

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

Compared to current flow:

Spring 2012: 

Autumn 2012: 

AUSRIVAS Results

	Autumn 2012	Spring 2012	Autumn 2013
Riffle Habitat	B	B	B
Edge Habitat	B	A	B
Overall Site Assessment	B	B	B

Riffle Habitat

- Reduced riffle habitat present due to low flows
- Dominant substrate was sand

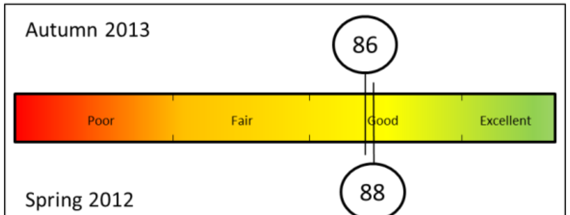
Dominant Taxa

- Hydropsychidae
- Baetidae
- Simuliidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Hydrobiosidae

Site Quality Assessment



Edge Habitat

- Dominant trailing bank vegetation was overhanging native shrubs and macrophytes

Dominant Taxa

- Corixidae
- Acarina
- Ceratopogonidae
- Chironomidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Gripopterygidae
- Leptophlebiidae

Additional Comments

- Silt settled along the channel margins
- Thick periphyton coverage across the site

MUR19

Downstream Angle Crossing
7/5/2013 11:50 am

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
11.5	168.3	3.02	3	8.06	96.9	10.56

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
66	0.002	0.002	< 0.002	0.004	0.013	0.23

Daily Flow: 120 ML/day

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

Compared to current flow:

Spring 2012: 

Autumn 2012: 

AUSRIVAS Results

	Autumn 2012	Spring 2012	Autumn 2013
Riffle Habitat	B	B	B
Edge Habitat	B	A	B
Overall Site Assessment	B	B	B

Riffle Habitat

- Some *Myriophyllum sp.* in the riffle habitat
- Dominant substrate was cobble and sand

Dominant Taxa

- Simuliidae
- Hydrobiosidae
- Hydropsychidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Hydrobiosidae

Edge Habitat

- Shallowed edge habitat from low flows
- Abundant *Myriophyllum sp.* in patches
- Dominant trailing bank vegetation was overhanging native shrubs and willow

Dominant Taxa

- Corixidae

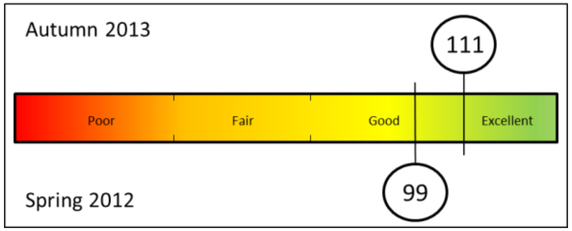
Sensitive Taxa (SIGNAL-2 ≥ 7)

- Telephlebiidae

Additional Comments

- Poor riparian zone
- Little sand in habitats, pool upstream could be acting as a sink

Site Quality Assessment



MUR23

Point Hut Crossing
08/05/2013 09:45

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
12.1	178.5	3.81	6	7.95	100.0	10.75

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
73	< 0.002	< 0.002	< 0.002	< 0.002	0.014	0.28

Daily Flow: 150 ML/day

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

Compared to current flow:

Spring 2012: 

Autumn 2012: 

AUSRIVAS Results

	Autumn 2012	Spring 2012	Autumn 2013
Riffle Habitat	B	A	B
Edge Habitat	B	A	B
Overall Site Assessment	B	A	B

Riffle Habitat

- Substrate was partially embedded with some sections of bedrock
- Some patches of *Myriophyllum sp.*
- Dominant substrate was cobble and sand

Dominant Taxa

- Simuliidae
- Corixidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Hydrobiosidae

Additional Comments

- Construction on Point Hut Crossing Bridge during sampling, replacing bollards which are missing or damaged from high flow events

Edge Habitat

- Edge habitat shallow due to low flows
- Dominant trailing bank vegetation was macrophytes (*Phragmites australis*) and grasses

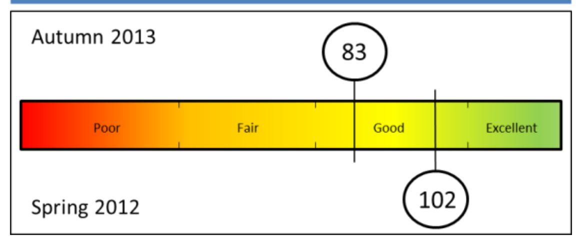
Dominant Taxa

- Corixidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

Site Quality Assessment



MUR28

Upstream Cotter River Confluence
08/05/2013 14:05

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
13.8	178.5	4.32	5	8.26	101.1	10.48

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
66	< 0.002	< 0.002	< 0.002	< 0.002	0.015	0.24

Daily Flow:

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

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

42 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 2012	Spring 2012	Autumn 2013
Riffle Habitat	B	B	B
Edge Habitat	B	B	B
Overall Site Assessment	B	B	B

Riffle Habitat

- Larger riffle area and more bedrock currently exposed due to lower flows
- Periphyton coverage extensive but thin
- Dominant substrate was boulder

Dominant Taxa

- Hydropsychidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Corydalidae
- Elmidae

Edge Habitat

- Limited edge habitat available, resulting in only a single edge sample
- Dominant trailing bank vegetation was wood debris and overhanging weeds

Dominant Taxa

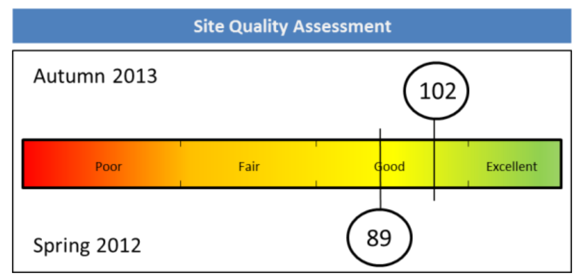
- Atyidae
- Corixidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

Additional Comments

- Some small patches of filamentous algae
- Recent weed spraying along the left bank



Part 2 – Burra Creek

BUR1a

Burra Native
31/5/2013 9:00 am

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
Site dry – no sample						

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
Site dry – no sample						

Daily Flow: 0 ML/day

Compared to current flow:

Spring 2012:  Autumn 2012: 

Riffle Habitat

- Site dry

Dominant Taxa

- No sample

Sensitive Taxa (SIGNAL-2 ≥ 7)

- No sample

Edge Habitat

- Site dry

Dominant Taxa

- No sample

Sensitive Taxa (SIGNAL-2 ≥ 7)

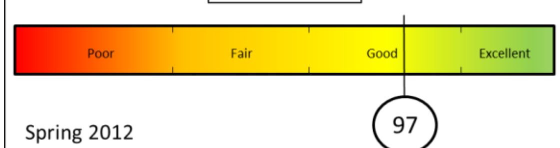
- No sample

AUSRIVAS Results

	Autumn 2012	Spring 2012	Autumn 2013
Riffle Habitat	C	B	NS
Edge Habitat	B	A	NS
Overall Site Assessment	C	B	NS

Site Quality Assessment

Autumn 2013 Dry - 17/30



Spring 2012

Additional Comments

- Only a single pool remaining which was highly turbid with an anaerobic scent
- Creek was all dry upstream from the site

BUR1c

Upstream Williamsdale Road
21/5/2013 2:20 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
10.1	552.1	6.49	3	8.12	93.5	10.50

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
203	< 0.002	< 0.002	< 0.002	< 0.002	0.005	0.2

Daily Flow: 1.8 ML/day

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

Compared to current flow:

Spring 2012: 

Autumn 2012: 

AUSRIVAS Results

	Autumn 2012	Spring 2012	Autumn 2013
Riffle Habitat	B	B	B
Edge Habitat	B	A	B
Overall Site Assessment	B	B	B

Riffle Habitat

- Poor quality riffle, containing sludge
- Limited riffle habitat, only one sample collected
- Dominant substrate was cobble

Dominant Taxa

- Leptophlebiidae
- Chironomidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

Edge Habitat

- Dominant trailing bank vegetation was macrophytes (*Eleocharis sp.*) and overhanging grasses

Dominant Taxa

- Microcrustaceans

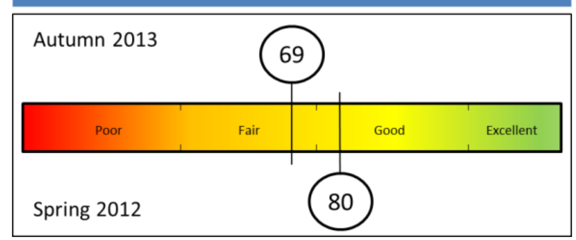
Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

Additional Comments

- Overall site in poor condition due to very limited flows over summer and into autumn
- High shading of creek due to the dense macrophytes coverage

Site Quality Assessment



BUR2a

Downstream Williamsdale Road
20/5/2013 10:30 am

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
5.8	562.5	5.79	< 2	8.05	124.7	15.57

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
238	0.36	0.35	0.003	0.002	0.006	0.51

Daily Flow: 1.7 ML/day

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

Compared to current flow:

Spring 2012: 

Autumn 2012: 

AUSRIVAS Results

	Autumn 2012	Spring 2012	Autumn 2013
Riffle Habitat	B	A	B
Edge Habitat	A	A	B
Overall Site Assessment	B	A	B

Riffle Habitat

- Poor quality riffle habitat
- Riffle habitat highly silted
- Yabby holes observed along the edge of the riffle habitat
- Dominant substrate was cobble

Dominant Taxa

- Gyrinidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Hydrobiosidae

Additional Comments

- Higher shading of the creek due to dense macrophyte coverage
- Large organic load within the reach, mainly leaves from surrounding deciduous trees

Edge Habitat

- *Gambusia holbrooki* abundant within the edge habitat
- Dominant trailing bank vegetation was macrophytes (mainly *Phragmites australis*)

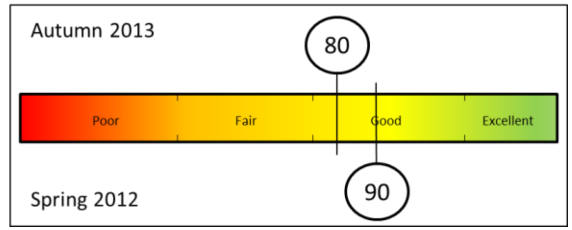
Dominant Taxa

- Microcrustaceans

Sensitive Taxa (SIGNAL-2 ≥ 7)

- None

Site Quality Assessment



BUR2b

Downstream Burra Road
20/5/2013 11:40 am

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
6.4	582.3	3.66	4	8.12	96.2	11.83

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
252	0.016	0.016	< 0.002	< 0.002	0.008	0.19

Daily Flow: 1.6 ML/day

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

Compared to current flow:

Spring 2012:  Autumn 2012: 

AUSRIVAS Results

	Autumn 2012	Spring 2012	Autumn 2013
Riffle Habitat	C	B	B
Edge Habitat	B	B	B
Overall Site Assessment	C	B	B

Riffle Habitat

- Patches of filamentous algae present in the riffle habitat
- Higher shading of the riffle habitat due to dense macrophyte (*Typha sp.*) coverage
- Dominant substrate was cobble

Dominant Taxa

- Simuliidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Hydrobiosidae
- Leptophlebiidae

Edge Habitat

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

Dominant Taxa

- Corixidae
- Baetidae
- Notonectidae

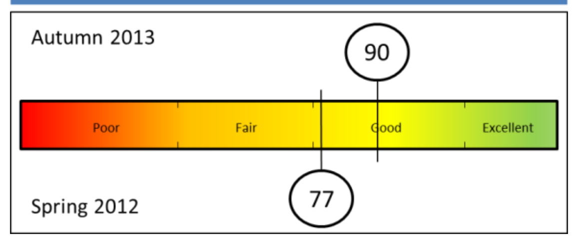
Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

Additional Comments

- Sand deposition reducing the depth of pools within the reach

Site Quality Assessment



BUR2c

Upstream London Bridge
20/5/2013 2:35 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
9.1	552.4	3.07	< 2	8.24	101.6	11.70

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
38	0.015	0.015	< 0.002	< 0.002	0.005	0.16

Daily Flow: 1.6 ML/day

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

Compared to current flow:

Spring 2012: 

Autumn 2012: 

AUSRIVAS Results

	Autumn 2012	Spring 2012	Autumn 2013
Riffle Habitat	B	A	A
Edge Habitat	B	A	A
Overall Site Assessment	B	A	A

Riffle Habitat

- Low flows reducing riffle availability, however two samples still collected
- Dominant substrate was cobble

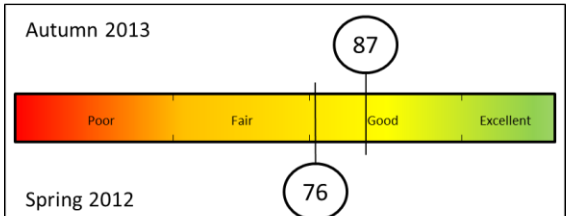
Dominant Taxa

- Leptophlebiidae
- Hydropsychidae
- Baetidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

Site Quality Assessment



Edge Habitat

- Low flows also limiting edge habitat availability, however two samples still collected
- Dominant trailing bank vegetation was overhanging grasses and macrophytes

Dominant Taxa

- Notonectidae
- Caenidae
- Microcrustacea

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Hydrobiosidae
- Leptophlebiidae

Additional Comments

- Some dense macrophytes restricting channel flow, but relatively minimal when compared to other Burra sites upstream

QBYN1

Flynn's Crossing
21/5/2013 11:55 am

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
8.1	87.2	2.68	< 2	8.72	99.6	11.77

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
38	< 0.002	< 0.002	< 0.002	0.002	0.010	0.18

Daily Flow: 33 ML/day

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

Compared to current flow:

Spring 2012:  Autumn 2012: 

AUSRIVAS Results

	Autumn 2012	Spring 2012	Autumn 2013
Riffle Habitat	B	A	B
Edge Habitat	A	X	B
Overall Site Assessment	B	A	B

Riffle Habitat

- Dominant substrate was cobble

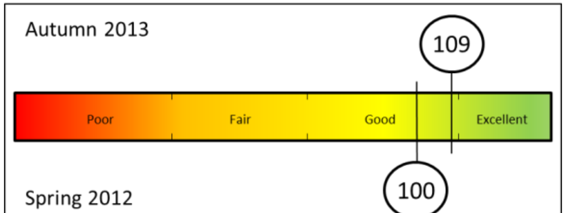
Dominant Taxa

- Simuliidae
- Hydrobiosidae
- Baetidae
- Ecnomidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Hydrobiosidae

Site Quality Assessment



Edge Habitat

- *Myriophyllum sp.* present in the edge habitat
- Dominant trailing bank vegetation was wood and overhanging *Kunzea sp.* and blackberry

Dominant Taxa

- Atyidae
- Corixidae
- Microcrustaceans
- Leptophlebiidae
- Leptoceridae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Telephlebiidae

Additional Comments

- Higher macrophyte diversity than has been previously recorded at this site
- Patches of filamentous algae in all habitats

Part 3 – Murrumbidgee Pump Station

MUR931

Fairvale
13/5/2013 9:55 am

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
12.7	168.5	4.38	6	8.12	90.8	9.63

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
68	0.002	0.002	< 0.002	0.002	0.017	0.26

Daily Flow: 170 ML/day

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

Compared to current flow:

Spring 2012:  Autumn 2012: 

AUSRIVAS Results

	Autumn 2012	Spring 2012	Autumn 2013
Riffle Habitat	B	B	B
Edge Habitat	B	B	B
Overall Site Assessment	B	B	B

Riffle Habitat

- Dominant substrate was cobble

Dominant Taxa

- Hydropsychidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Hydrobiosidae
- Elmidae

Edge Habitat

- Dominant trailing bank vegetation was blackberry and overhanging wattle (*Acacia sp.*)

Dominant Taxa

- Corixidae

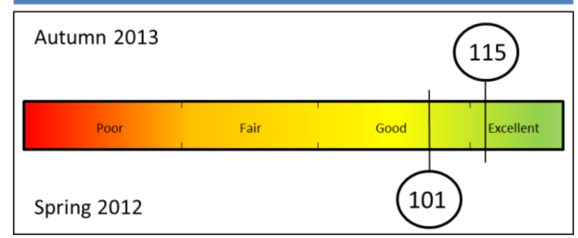
Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

Additional Comments

- Algal crust present on the substrate
- Fish observed at the site
- Large woody debris present along the banks

Site Quality Assessment



MUR28

Upstream Cotter River Confluence
8/5/2013 2:05 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
13.8	178.5	4.32	5	8.26	101.1	10.48

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
66	< 0.002	< 0.002	< 0.002	< 0.002	0.015	0.24

Daily Flow:

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

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

42 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 2012	Spring 2012	Autumn 2013
Riffle Habitat	B	B	B
Edge Habitat	B	B	B
Overall Site Assessment	B	B	B

Riffle Habitat

- Larger riffle area and more bedrock currently exposed due to lower flows
- Periphyton coverage extensive but thin
- Dominant substrate was boulder

Dominant Taxa

- Hydropsychidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Corydalidae
- Elmidae

Edge Habitat

- Limited edge habitat available, resulting in only a single edge sample
- Dominant trailing bank vegetation was wood debris and overhanging weeds

Dominant Taxa

- Atyidae
- Corixidae

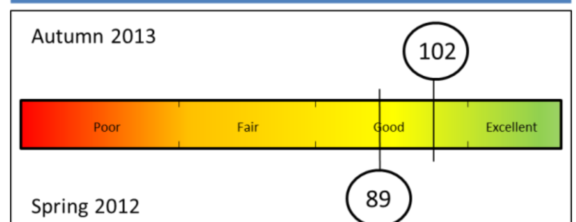
Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

Additional Comments

- Some small patches of filamentous algae
- Recent weed spraying along the left bank

Site Quality Assessment



MUR935

Casuarina Sands
13/5/2013 1:20 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
12.8	167.9	6.93	7	8.1	95.3	10.08

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
69	0.003	0.003	< 0.002	< 0.002	0.016	0.25

Daily Flow:

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

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

44 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 2012	Spring 2012	Autumn 2013
Riffle Habitat	NRA	B	B
Edge Habitat	B	A	B
Overall Site Assessment	NRA	B	B

Riffle Habitat

- Periphyton coverage extensive but thin
- Dominant substrate was gravel

Dominant Taxa

- Hydropsychidae
- Leptophlebiidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Corydalidae
- Hydrobiosidae

Edge Habitat

- Low flows limited available edge habitat, however two samples were collected
- Dominant trailing bank vegetation was wood debris and overhanging *Casuarina sp.*

Dominant Taxa

- Corixidae

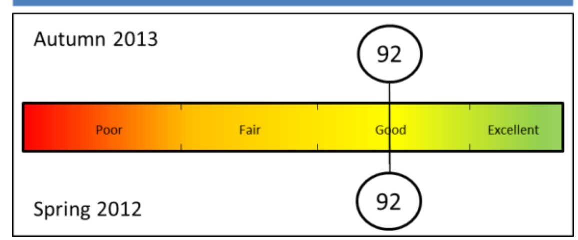
Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

Additional Comments

- Submerged macrophytes absent

Site Quality Assessment



MUR937

Mt. MacDonald
9/5/2013 10:20 am

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
12.1	171.7	3.49	6	8.12	101.7	10.92

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
70	< 0.002	< 0.002	< 0.002	< 0.002	0.015	0.28

Daily Flow: 150 ML/day

Recorded at the closest station (410738), located on the Murrumbidgee River at Mt. MacDonald.

Compared to current flow:

Spring 2012:  Autumn 2012: 

Riffle Habitat

- Very little organic load within the samples
- Substrate is partially embedded
- Dominant substrate was cobble

Dominant Taxa

- Hydropsychidae
- Simuliidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Corydalidae

Edge Habitat

- *Gambusia holbrooki* collected in the edge sample
- Dominant trailing bank vegetation was overhanging wattle (*Acacia sp.*)

Dominant Taxa

- Gyrinidae
- Corixidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

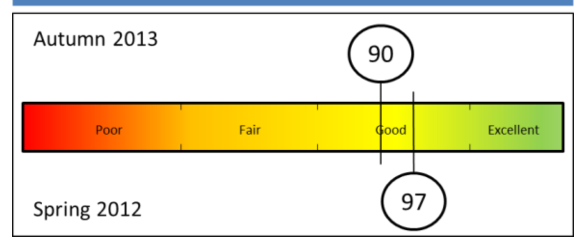
AUSRIVAS Results

	Autumn 2012	Spring 2012	Autumn 2013
Riffle Habitat	B	B	B
Edge Habitat	B	B	A
Overall Site Assessment	B	B	B

Additional Comments

- Low flows with water level still dropping
- Carp observed at the site

Site Quality Assessment



MUR29

Uriarra Crossing
13/5/2013 3:00 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
13.2	168.7	9.71	7	8.17	94.9	9.95

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
69	< 0.002	< 0.002	< 0.002	< 0.002	0.017	0.27

Daily Flow: 190 ML/day

Recorded at the closest station (410738), located on the Murrumbidgee River at Mt. MacDonald.

Compared to current flow:

Spring 2012:

Autumn 2012:

AUSRIVAS Results

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

Riffle Habitat

- Multiple riffle habitat with samples collected from several different riffle sections to represent the habitat variability
- Dominant substrate was cobble and sand

Dominant Taxa

- Baetidae
- Hydropsychidae
- Leptophlebiidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Hydrobiosidae
- Leptophlebiidae

Additional Comments

- Some filamentous algae patches along channel margins and in backwaters
- Diverse selection of macrophytes
- Artificial rock weir present

Edge Habitat

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

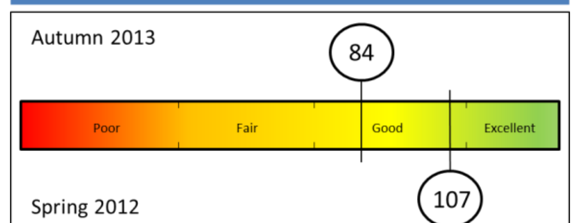
Dominant Taxa

- Corixidae
- Atyidae
- Leptophlebiidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

Site Quality Assessment



Part 4 – Tantangara to Burrinjuck

MUR1

Downstream Tantangara Reservoir
Zone 1: Tantangara - Cooma
14/5/2013 12:10 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
10.5	24.3	2.25	4	7.64	92.1	10.28

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
14	0.028	0.028	< 0.002	0.012	0.016	0.27

Daily Flow: 68 ML/day

Recorded at the closest station (41000260), located on the Murrumbidgee River at Yaouk. (Source: www.water.nsw.gov.au)

Compared to current level:

Spring 2012:  Autumn 2012: 

AUSRIVAS Results

	Autumn 2012	Spring 2012	Autumn 2013
Riffle Habitat	B	B	A
Edge Habitat	A	B	A
Overall Site Assessment	B	B	A

Riffle Habitat

- Dominant substrate was boulder and cobble

Dominant Taxa

- None

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Gripopterygidae
- Leptophlebiidae
- Conoesucidae

Site Quality Assessment

Edge Habitat

- Dominant trailing bank vegetation was macrophytes (mainly *Carex* sp.) and grasses

Dominant Taxa

- Corixidae
- Leptoceridae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Gripopterygidae
- Leptophlebiidae

Additional Comments

- Fish observed at the site
- Macrophytes highly abundant throughout the reach

MUR2

Yaouk Bridge
Zone 1: Tantangara - Cooma
14/5/2013 3:30 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
9.6	31.3	2.82	3	7.55	94.7	10.81

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
18	0.009	0.009	< 0.002	0.004	0.013	0.18

Daily Flow: 68 ML/day

Recorded at the closest station (41000260), located on the Murrumbidgee River at Yaouk. (Source: www.water.nsw.gov.au)

Compared to current level:

Spring 2012: ↑ Autumn 2012: ↑

AUSRIVAS Results

	Autumn 2012	Spring 2012	Autumn 2013
Riffle Habitat	A	X	A
Edge Habitat	A	A	A
Overall Site Assessment	A	A	A

Riffle Habitat

- Larger riffle zone exposed due to reduced flows
- Dominant substrate was cobble

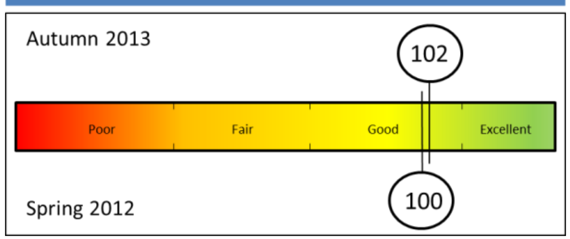
Dominant Taxa

- Coloburiscidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Coloburiscidae
- Telephlebiidae
- Leptophlebiidae
- Hydrobiosidae
- Ameletopsidae

Site Quality Assessment



Edge Habitat

- Dominant trailing bank vegetation was macrophytes (*Carex sp.*) and grasses

Dominant Taxa

- Amphipoda
- Chironomidae
- Leptophlebiidae
- Corixidae
- Leptoceridae
- Dytiscidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

Additional Comments

- Erosion present upstream of site from stock access to river
- Stock entering the river immediately upstream of the site during sampling

MUR3

Bobeyan Road Bridge
Zone 1: Tantangara - Cooma
15/5/2013 11:50 am

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
8.9	28.7	2.34	< 2	7.46	98.2	11.38

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
16	0.004	0.004	< 0.002	0.002	0.029	0.25

Daily Flow: 77 ML/day

Recorded at the closest station (41000260), located on the Murrumbidgee River at Yaouk. (Source: www.water.nsw.gov.au)

Compared to current level:

Spring 2012:  Autumn 2012: 

AUSRIVAS Results

	Autumn 2012	Spring 2012	Autumn 2013
Riffle Habitat	B	A	B
Edge Habitat	A	A	A
Overall Site Assessment	B	A	B

Riffle Habitat

- Dominant substrate was cobble

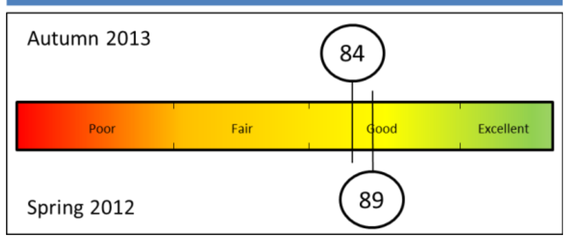
Dominant Taxa

- Baetidae
- Chironomidae

Sensitive Taxa (SIGNAL-2 ≥)

- Ameletopsidae
- Leptophlebiidae
- Coloburiscidae
- Gripopterygidae

Site Quality Assessment



Edge Habitat

- Edge habitat covered in silt and sludge, with the scent of sewerage
- Dominant trailing bank vegetation was macrophytes (mainly *Eleocharis sp.*, *Nymphaea sp.* & *Carex sp.*)

Dominant Taxa

- Corixidae
- Veliidae
- Dytiscidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

Additional Comments

- Direct stock access to river channel with evidence of trampling along the edges
- Construction present on the bridge immediately upstream of the site
- Paddock burn offs approximately 200 m upstream of site on the left bank during sampling

MUR4

Bobeyan Road Camp Ground
Zone 1: Tantangara - Cooma
15/5/2013 1:15 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
8.0	43.3	5.42	5	7.34	90.2	10.67

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
22	0.003	0.003	< 0.002	0.003	0.017	0.23

Daily Flow: 77 ML/day

Recorded at the closest station (41000260), located on the Murrumbidgee River at Yaouk. (Source: www.water.nsw.gov.au)

Compared to current level:

Spring 2012:  Autumn 2012: 

Riffle Habitat

- Lower flows reducing riffle depth
- Higher periphyton coverage than previously observed
- Dominant substrate was boulder

Dominant Taxa

- Coloburiscidae
- Amphipoda
- Simuliidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Coloburiscidae
- Corydalidae
- Leptophlebiidae

Edge Habitat

- Edge habitat highly silted, with an anaerobic/sewerage scent
- Juvenile *Gambusia holbrooki* collected in the edge sample
- Dominant trailing bank vegetation was macrophytes (mainly *Phragmites australis*)

Dominant Taxa

- Corixidae
- Leptoceridae
- Chironomidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Hydrobiosidae

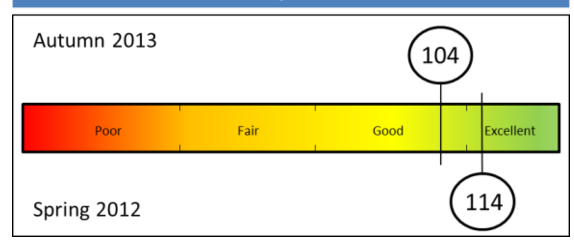
AUSRIVAS Results

	Autumn 2012	Spring 2012	Autumn 2013
Riffle Habitat	A	A	B
Edge Habitat	A	X	A
Overall Site Assessment	A	A	B

Additional Comments

- Limited river shading due to a large number of deciduous trees

Site Quality Assessment



MUR6

D/S Cooma STP, Pilot Creek Road
Zone 2: Cooma – Angle Crossing
16/5/2013 11:10 am

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
9.7	53.1	6.1	5	7.45	95.7	10.88

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
26	0.003	0.003	< 0.002	0.003	0.018	0.19

Daily Flow: 22 ML/day

Recorded at the closest station (410033), located on the Murrumbidgee River at Mittagang. (Source: www.water.nsw.gov.au)

Compared to current flow:

Spring 2012:  Autumn 2012: 

AUSRIVAS Results

	Autumn 2012	Spring 2012	Autumn 2013
Riffle Habitat	B	A	A
Edge Habitat	A	A	A
Overall Site Assessment	B	A	A

Riffle Habitat

- Riffle habitat has retreated by approximately 50% due to reduction in flows
- Juvenile *Gambusia holbrooki* in the riffle sample
- Dominant substrate was cobble

Dominant Taxa

- Leptophlebiidae
- Coloburiscidae
- Hydrobiosidae

Sensitive Taxa (SIGNAL-2 ≥ 8)

- Coloburiscidae
- Hydrobiosidae
- Leptophlebiidae
- Telephlebiidae

Additional Comments

- Areas of erosion on the upper right bank

Edge Habitat

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

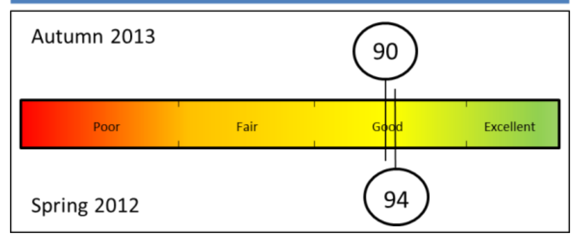
Dominant Taxa

- Corixidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- None

Site Quality Assessment



MUR9

Murrells Crossing
Zone 2: Cooma – Angle Crossing
16/5/2013 12:30 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
9.9	52.7	5.45	5	7.47	92.4	10.44

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
26	< 0.002	< 0.002	< 0.002	0.002	0.019	0.19

Daily Flow: 22 ML/day

Recorded at the closest station (410033), located on the Murrumbidgee River at Mittagang. (Source: www.water.nsw.gov.au)

Compared to current flow:

Spring 2012: 

Autumn 2012: 

AUSRIVAS Results

	Autumn 2012	Spring 2012	Autumn 2013
Riffle Habitat	A	A	B
Edge Habitat	A	X	A
Overall Site Assessment	A	A	B

Riffle Habitat

- Crossing runs through the riffle habitat
- Some small patches of filamentous algae present
- Dominant substrate was sand

Dominant Taxa

- Coloburiscidae
- Simuliidae
- Leptophlebiidae

Sensitive Taxa (SIGNAL-2 ≥ 8)

- Coloburiscidae
- Hydrobiosidae
- Telephlebiidae
- Leptophlebiidae
- Corydalidae

Edge Habitat

- Dominant trailing bank vegetation was macrophytes (*Juncus sp.* and *Carex sp.*)

Dominant Taxa

- Corixidae

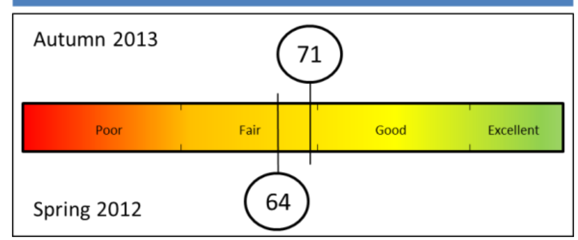
Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Telephlebiidae

Additional Comments

- No shading of the river due to the lack of riparian vegetation
- Large amounts of sand have been deposited on the upstream side of the bridge reducing the pool depth

Site Quality Assessment



MUR12

Bredbo
Zone 2: Cooma – Angle Crossing
16/5/2013 2:30 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
11.4	133.5	8.89	9	7.65	94.0	10.26

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
54	< 0.002	< 0.002	< 0.002	< 0.002	0.012	0.22

Daily Flow: 83 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 2012:  Autumn 2012: 

AUSRIVAS Results

	Autumn 2012	Spring 2012	Autumn 2013
Riffle Habitat	A	A	A
Edge Habitat	B	A	A
Overall Site Assessment	B	A	A

Riffle Habitat

- Low flows exposing larger riffle habitat
- High organic load in the riffle habitat, mainly leaves from deciduous trees (i.e. willows)
- Dominant substrate was cobble

Dominant Taxa

- Simuliidae
- Hydropsychidae
- Baetidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Hydrobiosidae
- Leptophlebiidae

Additional Comments

- Large stands of *Myriophyllum sp.* along the edges of the channel in slower flowing waters
- Epiphytes absent from emergent macrophytes (*Carex sp.*, *Cyperus sp.*, *Juncus sp.* & *Phragmites australis*)

Edge Habitat

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

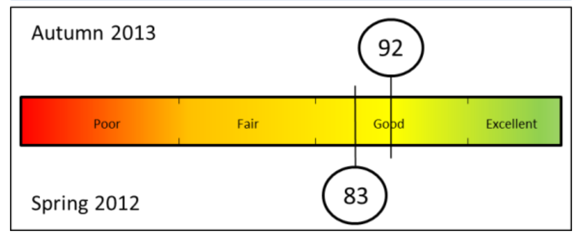
Dominant Taxa

- Corixidae
- Atyidae
- Leptoceridae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- None

Site Quality Assessment



MUR15

Bumbalong Road
Zone 2: Cooma – Angle Crossing
6/5/2013 10:30 am

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
10.9	141.5	4.39	5	8.08	100.4	11.00

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
57	< 0.002	< 0.002	< 0.002	0.004	0.022	0.26

Daily Flow: 110 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 2012: 

Autumn 2012: 

Riffle Habitat

- One replicate sample was collected in full sun with the second collected in full shade
- Dominant substrate was sand

Dominant Taxa

- Baetidae
- Simuliidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

Edge Habitat

- Dominant trailing bank vegetation was macrophytes and wood debris from overhanging shrubs

Dominant Taxa

- Corixidae
- Notonectidae
- Chironomidae

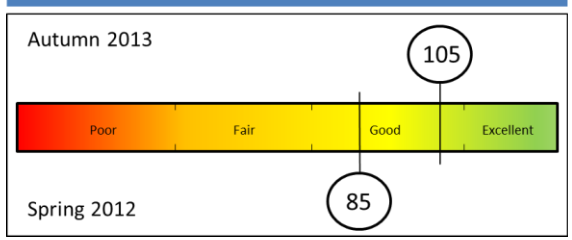
Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

AUSRIVAS Results

	Autumn 2012	Spring 2012	Autumn 2013
Riffle Habitat	B	A	A
Edge Habitat	B	A	A
Overall Site Assessment	B	A	A

Site Quality Assessment



Additional Comments

- Periphyton coverage of approximately 60% was consistent across the site

MUR16

The Willows – Near Michelago
Zone 2: Cooma – Angle Crossing
6/5/2013 2:00 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
11.5	166.4	3.11	5	8.19	101.4	11.04

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
65	< 0.002	< 0.002	< 0.002	0.003	0.015	0.24

Daily Flow: 110 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 2012: 

Autumn 2012: 

Riffle Habitat

- Dominant substrate was cobble, pebble and gravel

Dominant Taxa

- Simuliidae
- Leptophlebiidae
- Hydropsychidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

Edge Habitat

- Reduced habitat area due to receding flows resulting in only a single edge sample
- Dominant trailing bank vegetation was overhanging native shrubs and wood debris

Dominant Taxa

- None

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

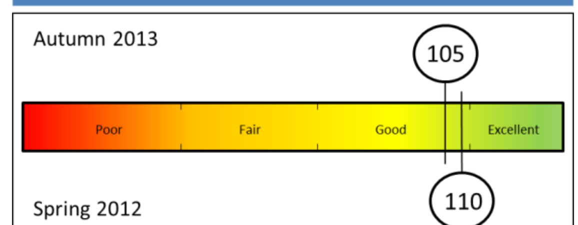
AUSRIVAS Results

	Autumn 2012	Spring 2012	Autumn 2013
Riffle Habitat	B	A	A
Edge Habitat	B	A	A
Overall Site Assessment	B	A	A

Additional Comments

- Low flows exposing large bedrock platforms down the right side of the channel
- *Myriophyllum sp.* present along channel margins

Site Quality Assessment

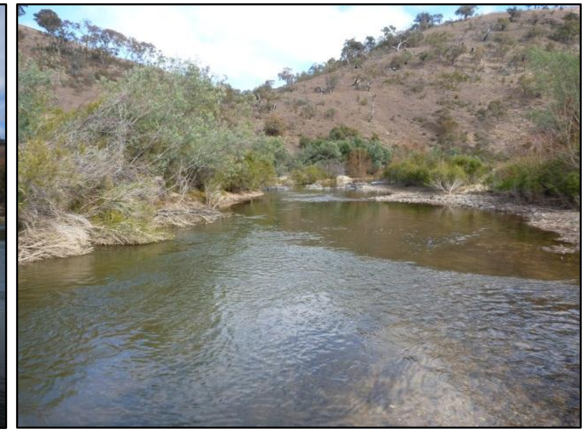


MUR18

Upstream Angle Crossing
Zone 2: Cooma – Angle Crossing
7/5/2013 10:05 am

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
11.3	168.7	3.29	4	8.07	91.1	9.79

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
66	< 0.002	< 0.002	< 0.002	0.003	0.013	0.24



Daily Flow: 120 ML/day

Recorded at the closest station (41000270), located on the Murrumbidgee River at upstream Angle Crossing.

Compared to current flow:

Spring 2012:   Autumn 2012:

AUSRIVAS Results

	Autumn 2012	Spring 2012	Autumn 2013
Riffle Habitat	B	B	B
Edge Habitat	B	A	A
Overall Site Assessment	B	B	B

Riffle Habitat

- Reduced riffle habitat present due to low flows
- Dominant substrate was sand

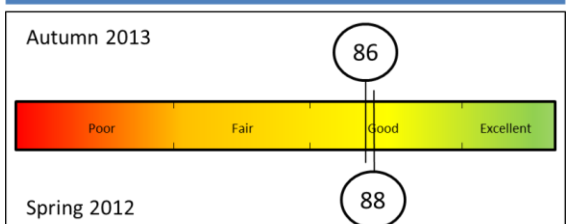
Dominant Taxa

- Hydropsychidae
- Baetidae
- Simuliidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Hydrobiosidae

Site Quality Assessment



Edge Habitat

- Dominant trailing bank vegetation was overhanging native shrubs and macrophytes

Dominant Taxa

- Corixidae
- Acarina
- Ceratopogonidae
- Chironomidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Gripopterygidae
- Leptophlebiidae

Additional Comments

- Silt settled along the channel margins
- Thick periphyton coverage across the site

MUR19

Downstream Angle Crossing
Zone 3: Angle Crossing - LMWQCC
7/5/2013   11:50 am

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
11.5	168.3	3.02	3	8.06	96.9	10.56

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
66	0.002	0.002	< 0.002	0.004	0.013	0.23

Daily Flow: 120 ML/day

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

Compared to current flow:

Spring 2012:    Autumn 2012: 

AUSRIVAS Results

	Autumn 2012	Spring 2012	Autumn 2013
Riffle Habitat	B	B	A
Edge Habitat	B	A	B
Overall Site Assessment	B	B	B

Riffle Habitat

- Some *Myriophyllum sp.* in the riffle habitat
- Dominant substrate was cobble and sand

Dominant Taxa

- Simuliidae
- Hydrobiosidae
- Hydropsychidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Hydrobiosidae

Edge Habitat

- Shallowed edge habitat from low flows
- Abundant *Myriophyllum sp.* in patches
- Dominant trailing bank vegetation was overhanging native shrubs and willow

Dominant Taxa

- Corixidae

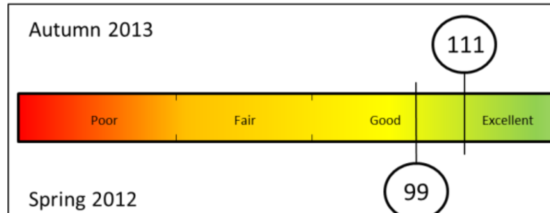
Sensitive Taxa (SIGNAL-2 ≥ 7)

- Telephlebiidae

Additional Comments

- Poor riparian zone
- Little sand in habitats, pool upstream could be acting as a sink

Site Quality Assessment



MUR22

Tharwa Bridge
Zone 3: Angle Crossing - LMWQCC
7/5/2013 2:50 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
13.9	157.4	2.87	4	8.31	104.9	10.85

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
64	0.002	0.002	< 0.002	0.003	0.015	0.24

Daily Flow: 120 ML/day

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

Compared to current flow:

Spring 2012: 

Autumn 2012: 

AUSRIVAS Results

	Autumn 2012	Spring 2012	Autumn 2013
Riffle Habitat	A	B	A
Edge Habitat	A	A	B
Overall Site Assessment	A	B	B

Riffle Habitat

- Low flows exposing larger riffle habitat
- Dominant substrate was cobble

Dominant Taxa

- Leptophlebiidae
- Hydropsychidae
- Acarina
- Simuliidae
- Baetidae

Sensitive Taxa (SIGNAL-2 ≥ 8)

- Leptophlebiidae
- Hydrobiosidae

Edge Habitat

- Submerged macrophytes present in the edge habitat (*Myriophyllum sp.* & *Vallisneria sp.*)
- *Gambusia holbrooki* collected in the edge sample
- Dominant trailing bank vegetation was overhanging shrubs and macrophytes (*Phragmites australis*)

Dominant Taxa

- Corixidae
- Leptoceridae

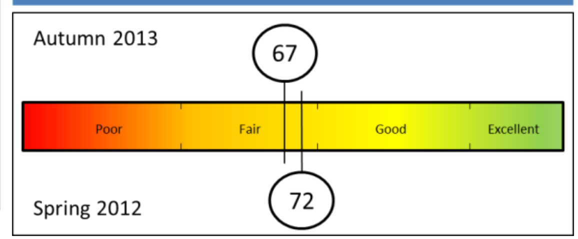
Sensitive Taxa (SIGNAL-2 ≥ 7)

- None

Additional Comments

- Silt deposits in pools and along the edges of the channel
- Increased *Myriophyllum sp.* growth
- Exposed sand bars larger than usual due to low flows

Site Quality Assessment



MUR23

Point Hut Crossing
Zone 3: Angle Crossing - LMWQCC
8/5/2013 9:45 am

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
12.1	162.0	3.81	6	7.95	100.0	10.75

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
73	< 0.002	< 0.002	< 0.002	< 0.002	0.014	0.28

Daily Flow: 150 ML/day

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

Compared to current flow:

Spring 2012: 

Autumn 2012: 

AUSRIVAS Results

	Autumn 2012	Spring 2012	Autumn 2013
Riffle Habitat	B	B	A
Edge Habitat	B	A	B
Overall Site Assessment	B	B	B

Riffle Habitat

- Substrate was partially embedded with some sections of bedrock
- Some patches of *Myriophyllum sp.*
- Dominant substrate was cobble and sand

Dominant Taxa

- Simuliidae

Sensitive Taxa (SIGNAL-2 ≥ 8)

- Leptophlebiidae
- Gripopterygidae
- Hydrobiosidae

Additional Comments

- Construction on Point Hut Crossing Bridge during sampling, replacing bollards which are missing or damaged from high flow events

Edge Habitat

- Edge habitat shallow due to low flows
- Dominant trailing bank vegetation was macrophytes (*Phragmites australis*) and grasses

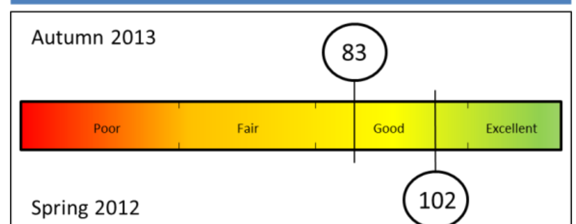
Dominant Taxa

- Corixidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Gripopterygidae

Site Quality Assessment



MUR27

Kambah Pool
Zone 3: Angle Crossing - LMWQCC
8/5/2013 11:25 am

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
13.0	168.8	5.11	5	8.18	99.9	10.52

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
69	< 0.002	< 0.002	< 0.002	< 0.002	0.016	0.27

Daily Flow: 150 ML/day

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

Compared to current flow:

Spring 2012: ↑ Autumn 2012: ↑

AUSRIVAS Results

	Autumn 2012	Spring 2012	Autumn 2013
Riffle Habitat	B	A	A
Edge Habitat	B	A	B
Overall Site Assessment	B	A	B

Riffle Habitat

- Dominant substrate was cobble

Dominant Taxa

- Simuliidae
- Hydropsychidae
- Baetidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

Edge Habitat

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

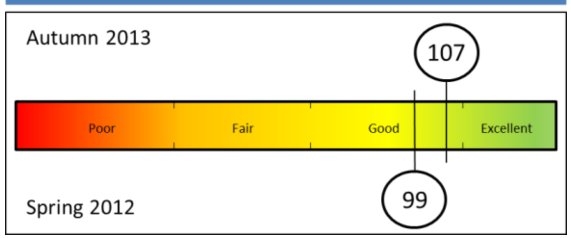
Dominant Taxa

- Corixidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

Site Quality Assessment



Additional Comments

- Erosion present along the left side of the river above the bank
- Some small sections of filamentous algae
- Larger areas of bedrock are exposed due to the low flows
- Some new *Phragmites australis* growth observed

MUR931

Fairvale
Zone 3: Angle Crossing - LMWQCC
13/5/2013 9:55 am

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
12.7	168.5	4.38	6	8.12	90.8	9.63

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
68	0.002	0.002	< 0.002	0.002	0.017	0.26

Daily Flow: 170 ML/day

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

Compared to current flow:

Spring 2012:  Autumn 2012: 

AUSRIVAS Results

	Autumn 2012	Spring 2012	Autumn 2013
Riffle Habitat	B	B	B
Edge Habitat	B	A	B
Overall Site Assessment	B	B	B

Riffle Habitat

- Dominant substrate was cobble

Dominant Taxa

- Hydropsychidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Hydrobiosidae
- Elmidae

Edge Habitat

- Dominant trailing bank vegetation was blackberry and overhanging wattle (*Acacia sp.*)

Dominant Taxa

- Corixidae

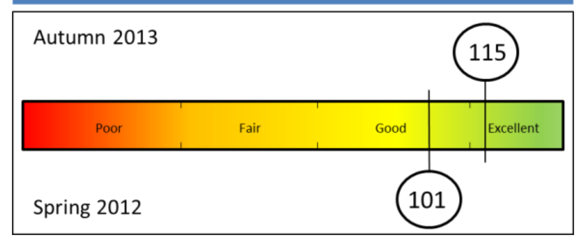
Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

Additional Comments

- Algal crust present on the substrate
- Fish observed at the site
- Large woody debris present along the banks

Site Quality Assessment



MUR28

Upstream Cotter River Confluence
Zone 3: Angle Crossing - LMWQCC
8/5/2013 2:05 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
13.8	178.5	4.32	5	8.26	101.1	10.48

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
66	< 0.002	< 0.002	< 0.002	< 0.002	0.015	0.24

Daily Flow:

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

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

42 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 2012	Spring 2012	Autumn 2013
Riffle Habitat	B	B	A
Edge Habitat	B	A	A
Overall Site Assessment	B	B	A

Riffle Habitat

- Larger riffle area and more bedrock currently exposed due to lower flows
- Periphyton coverage extensive but thin
- Dominant substrate was boulder

Dominant Taxa

- Hydropsychidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Corydalidae
- Elmidae

Edge Habitat

- Limited edge habitat available, resulting in only a single edge sample
- Dominant trailing bank vegetation was wood debris and overhanging weeds

Dominant Taxa

- Atyidae
- Corixidae

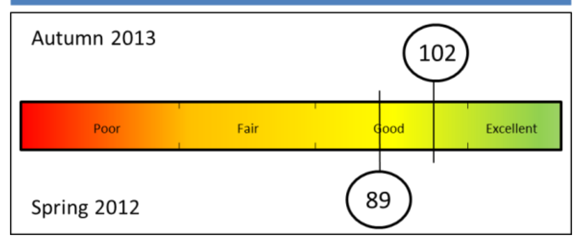
Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

Additional Comments

- Some small patches of filamentous algae
- Recent weed spraying along the left bank

Site Quality Assessment



MUR935

Casuarina Sands
Zone 3: Angle Crossing - LMWQCC
13/5/2013 1:20 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
12.8	167.9	6.93	7	8.10	95.3	10.08

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
69	0.003	0.003	< 0.002	< 0.002	0.016	0.25

Daily Flow:

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

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

44 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 2012	Spring 2012	Autumn 2013
Riffle Habitat	NRA	B	A
Edge Habitat	B	A	A
Overall Site Assessment	NRA	B	A

Riffle Habitat

- Periphyton coverage extensive but thin
- Dominant substrate was gravel

Dominant Taxa

- Hydropsychidae
- Leptophlebiidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Corydalidae
- Hydrobiosidae

Edge Habitat

- Low flows limited available edge habitat, however two samples were collected
- Dominant trailing bank vegetation was wood debris and overhanging *Casuarina sp.*

Dominant Taxa

- Corixidae

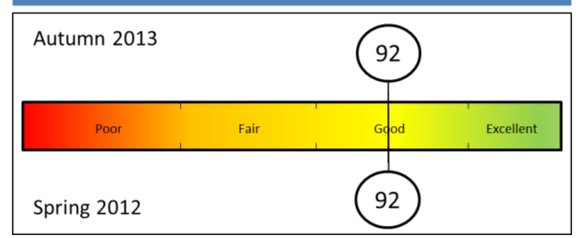
Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

Additional Comments

- Submerged macrophytes absent

Site Quality Assessment



MUR937

Mt. MacDonald
Zone 3: Angle Crossing - LMWQCC
9/5/2013 10:20 am

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
12.1	171.7	3.49	6	8.12	101.7	10.92

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
70	< 0.002	< 0.002	< 0.002	< 0.002	0.015	0.28

Daily Flow: 150 ML/day

Recorded at the closest station (410738), located on the Murrumbidgee River at Mt. MacDonald.

Compared to current flow:

Spring 2012:  Autumn 2012: 

AUSRIVAS Results

	Autumn 2012	Spring 2012	Autumn 2013
Riffle Habitat	B	B	B
Edge Habitat	B	A	A
Overall Site Assessment	B	B	B

Riffle Habitat

- Very little organic load within the samples
- Substrate is partially embedded
- Dominant substrate was cobble

Dominant Taxa

- Hydropsychidae
- Simuliidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Corydalidae

Additional Comments

- Low flows with water level still dropping
- Carp observed at the site

Edge Habitat

- *Gambusia holbrooki* collected in the edge sample
- Dominant trailing bank vegetation was overhanging wattle (*Acacia sp.*)

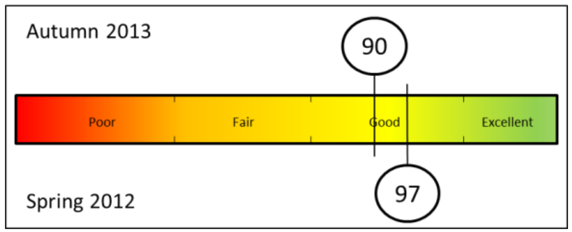
Dominant Taxa

- Gyrinidae
- Corixidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

Site Quality Assessment



MUR29

Uriarra Crossing
Zone 3: Angle Crossing - LMWQCC
13/5/2013 3:00 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
13.2	168.7	9.71	7	8.17	94.9	9.95

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
69	< 0.002	< 0.002	< 0.002	< 0.002	0.017	0.27

Daily Flow: 190 ML/day

Recorded at the closest station (410738), located on the Murrumbidgee River at Mt. MacDonald.

Compared to current flow:

Spring 2012:  Autumn 2012: 

AUSRIVAS Results

	Autumn 2012	Spring 2012	Autumn 2013
Riffle Habitat	B	B	A
Edge Habitat	B	A	A
Overall Site Assessment	B	B	A

Riffle Habitat

- Abundance of riffle habitat with samples collected from multiple riffle sections to represent the habitat variability
- Dominant substrate was cobble and sand

Dominant Taxa

- Baetidae
- Hydropsychidae
- Leptophlebiidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Hydrobiosidae
- Leptophlebiidae

Additional Comments

- Some filamentous algae patches along channel margins and in backwaters
- Diverse selection of macrophytes
- Artificial rock weir present

Edge Habitat

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

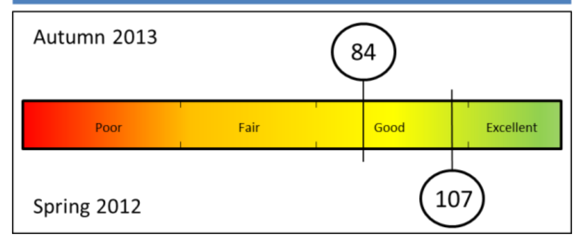
Dominant Taxa

- Corixidae
- Atyidae
- Leptophlebiidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

Site Quality Assessment



MUR30

Camp Sturt
Zone 3: Angle Crossing - LMWQCC
9/5/2013   3:00 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
13.8	174.3	3.59	5	8.32	106.8	11.04

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
71	< 0.002	< 0.002	< 0.002	< 0.002	0.013	0.27

Daily Flow: 150 ML/day

Recorded at the closest station (410738), located on the Murrumbidgee River at Mt. MacDonald.

Compared to current flow:

Spring 2012:    Autumn 2012: 

AUSRIVAS Results

	Autumn 2012	Spring 2012	Autumn 2013
Riffle Habitat	B	A	A
Edge Habitat	B	A	B
Overall Site Assessment	B	A	B

Riffle Habitat

- Substrate partially embedded by sand
- Dominant substrate was cobble

Dominant Taxa

- Simuliidae
- Hydropsychidae
- Baetidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Corydalidae
- Hydrobiosidae

Additional Comments

- Low flows exposing bedrock on the right side of the main channel leaving isolated pools
- *Gambusia holbrooki* abundant

Edge Habitat

- Poor quality and shallow edge habitat
- Dominant trailing bank vegetation was macrophytes (*Paspalum sp.*)

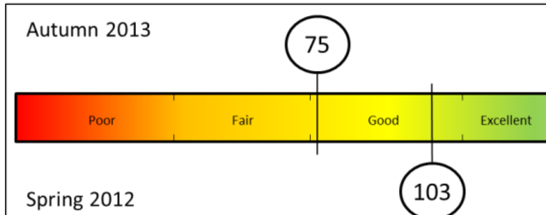
Dominant Taxa

- Corixidae
- Chironomidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- None

Site Quality Assessment



MUR31

D/S Molonglo River Confluence
Zone 4: LMWQCC - Burrinjuck
9/5/2013 1:20 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
15.8	363.2	2.71	4	8.2	110.7	10.98

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
96	6.1	6.1	0.004	0.003	0.049	6.4

Daily Flow: 310 ML/day

Recorded at the closest station (410777), located on the Murrumbidgee River at Hall's Crossing.

Compared to current flow:

Spring 2012:  Autumn 2012: 

AUSRIVAS Results

	Autumn 2012	Spring 2012	Autumn 2013
Riffle Habitat	A	A	B
Edge Habitat	A	A	A
Overall Site Assessment	A	A	B

Riffle Habitat

- Some filamentous algae in the riffle habitat
- Dominant substrate was cobble and sand

Dominant Taxa

- Simuliidae
- Hydropsychidae
- Baetidae

Sensitive Taxa (SIGNAL-2 ≥ 8)

- Hydrobiosidae
- Leptophlebiidae
- Corydalidae

Additional Comments

- Filamentous algae abundant through the slow flowing sections and backwaters
- New bars from low flows being vegetated

Edge Habitat

- Dominant trailing bank vegetation was overhanging *Casuarina sp.*

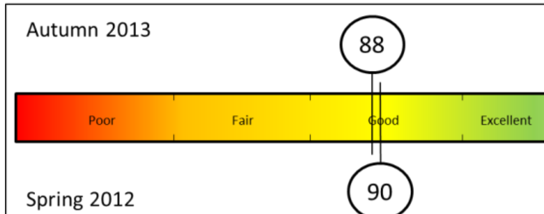
Dominant Taxa

- Gerridae
- Corixidae
- Leptoceridae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- None

Site Quality Assessment

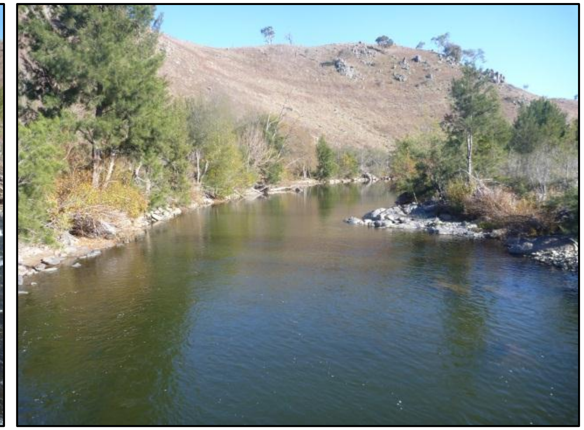


MUR34

Halls Crossing
Zone 4: LMWQCC - Burrinjuck
10/5/2013 10:00 am

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
13.1	356.5	2.93	4	8.34	100.9	10.59

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
97	5.8	5.8	0.011	0.005	0.021	5.9



Daily Flow: 310 ML/day

Recorded at the closest station (410777), located on the Murrumbidgee River at Hall's Crossing.

Compared to current flow:

Spring 2012: ↑ Autumn 2012: ↑

Riffle Habitat

- Higher flows exposing larger riffle habitat
- Minimal organic load in the riffle habitat
- Dominant substrate was cobble

Dominant Taxa

- Simuliidae
- Hydropsychidae
- Baetidae

Sensitive Taxa (SIGNAL-2 ≥ 8)

- Hydrobiosidae
- Leptophlebiidae

Edge Habitat

- Good quality edge habitat, with minimal shading
- Dominant trailing bank vegetation was overhanging *Casuarina sp.*

Dominant Taxa

- Corixidae
- Leptophlebiidae
- Leptoceridae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

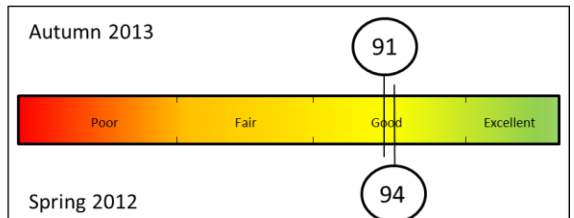
AUSRIVAS Results

	Autumn 2012	Spring 2012	Autumn 2013
Riffle Habitat	A	A	B
Edge Habitat	B	A	B
Overall Site Assessment	B	A	B

Additional Comments

- None

Site Quality Assessment



MUR37

Boambolo Road
Zone 4: LMWQCC - Burrinjuck
10/5/2012 12:45 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	SS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
14.3	355.2	5.25	9	8.55	107.3	10.97

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
104	4.3	4.3	0.011	0.003	0.027	4.9

Daily Flow: 310 ML/day

Recorded at the closest station (410777), located on the Murrumbidgee River at Hall's Crossing.

Compared to current flow:

Spring 2012: ↑ Autumn 2012: ↑

AUSRIVAS Results

	Autumn 2012	Spring 2012	Autumn 2013
Riffle Habitat	NS	B	B
Edge Habitat	B	B	B
Overall Site Assessment	B	B	B

Riffle Habitat

- Poor quality riffle habitat
- Dominant substrate was cobble

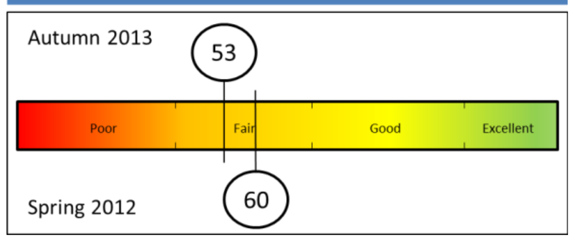
Dominant Taxa

- Hydropsychidae
- Simuliidae
- Baetidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

Site Quality Assessment



Edge Habitat

- Poor quality edge habitat
- Filamentous algae in the edge habitat, backwaters and isolated pools
- Dominant trailing bank vegetation was overhanging willow

Dominant Taxa

- Gyrinidae
- Corixidae
- Hydropsychidae
- Chironomidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- None

Additional Comments

- Very minimal flow
- Extensive sand throughout the reach in all habitats with newly formed bars

Appendix F – Macroinvertebrate Taxonomic Inventory

Appendix F. Macroinvertebrate taxonomic inventory for the Angle Crossing riffle habitat

CLASS / Order	Family / Sub-Family	Genus	MUR15	MUR16	MUR18	MUR19	MUR23	MUR28
ACARINA			■	■	■	■	■	■
BIVALVIA	Corbiculidae	*Corbicula*		■	■	■		■
	Sphaeriidae/Corbiculidae						■	■
Coleoptera	Dytiscidae					■		
	Elmidae	*Austrolimnius*	■			■	■	
		Stetholus					■	■
		sp.				■		
Decapoda	Atyidae	*Paratya*			■	■		
	Palaemonidae	*Macrobrachium*	■	■	■	■	■	■
Diptera	Ceratopogonidae	*Ceratopoginae*			■	■		
		Forcipomyiinae				■		
	Chironominae		■	■	■	■	■	■
	Culicidae				■	■		
	Empididae			■	■	■	■	■
	Muscidae				■			
	Orthocladiinae		■	■	■	■	■	■
	Simuliidae	*Austrosimulium*	■	■	■	■	■	■
		Simulium	■					
	Tanypodinae		■	■	■	■	■	■
	Tipulidae		■	■	■		■	■
Ephemeroptera	Baetidae	*Baetidae Genus 1*	■	■	■	■	■	■
		Baetidae Genus 2	■	■		■	■	■
	Caenidae	*Irapacaenis*	■	■	■	■	■	■
		Tasmanocoenis	■	■	■	■	■	■
	Leptophlebiidae	*Atalophlebia*		■	■	■		■
		Jappa	■	■	■	■	■	■
		sp.	■	■	■	■	■	■
Hemiptera	Corixidae	*Micronecta*	■					■
	Notonectidae	*Paranisops*			■			
Odonata	Zygoptera				■			
OLIGOCHAETA			■	■	■	■	■	■
Plecoptera	Gripopterygidae	*Illiesoperla*	■	■		■		■
Trichoptera	Ecnomidae	*Ecnomus*	■	■	■	■	■	■
	Hydrobiosidae	*Taschorema*	■	■	■	■	■	■
	Hydropsychidae	*Asmicridea*	■				■	
		Cheumatopsyche	■	■	■	■	■	■
	Hydroptilidae	*Hellyethira*			■	■		
		Hydroptila		■				
		Orthotrichia	■	■		■		■
		Oxyethira		■		■		■
		sp.	■	■		■	■	■
	Leptoceridae	*Oecetis*				■		
		Triplectides			■	■		
		sp.						■

Appendix F. Macroinvertebrate taxonomic inventory for the Angle Crossing edge habitat

CLASS / Order	Family / subfamily	Genus	MUR15	MUR16	MUR18	MUR19	MUR23	MUR28
ACARINA			■	■	■	■	■	■
BIVALVIA	Corbiculidae	*Corbicula*				■		
	Sphaeriidae/Corbiculidae			■		■	■	
Coleoptera	Dytiscidae		■		■			
	Elmidae	*Austrolimnius*				■		
		Coxelmis			■			■
		Kingolus						■
		Stetholus					■	■
		sp.					■	
	Gyrinidae	*Macrogyrus*		■				
	Hydraenidae	*Hydraena*						■
	Hydrochidae	*Hydrochus*						■
	Hydrophilidae	*Berosus*	■					
	Scirtidae			■	■	■		■
Decapoda	Atyidae	*Paratya*	■		■	■		■
	Palaemonidae	*Macrobrachium*		■	■	■	■	■
	Parastacidae	*Cherax*				■		
Diptera	Ceratopogonidae	*Ceratopoginae*	■		■	■	■	■
		Forcipomyiinae	■					■
	Chironominae		■	■	■	■	■	■
	Culcidae				■			
	Dixidae	*Dixa*				■		
	Empididae			■	■	■	■	■
	Muscidae		■					
	Orthocladiinae		■	■	■	■	■	■
	Psychodidae							■
	Simuliidae	*Austrosimulium*	■	■	■	■	■	■
	Stratiomyidae	*Odontomyia*			■			
	Tanypodinae		■	■	■	■	■	■
	Tipulidae					■	■	
Ephemeroptera	Baetidae	*Baetidae Genus 1*		■	■	■	■	
		Genus B	■	■		■	■	■
		Baetidae Genus 3	■					
	Caenidae	*Irapacaenis*	■	■	■	■	■	■
		Tasmanocoenis	■	■	■	■	■	■
	Leptophlebiidae	*Atalophlebia*	■	■	■	■	■	■
		Jappa	■	■	■	■	■	■
		sp.	■	■		■	■	■
GASTROPODA	Ancylidae	*Ferrissia*					■	
Hemiptera	Corixidae	*Micronecta*	■	■	■	■	■	■
	Gerridae							■
	Notonectidae	*Anisops*	■					
		Enithares	■					
		Paranisops			■			
Lepidoptera	Crambidae		■				■	
Odonata	Epiproctophora				■			
OLIGOCHAETA			■	■	■	■	■	
Plecoptera	Gripopterygidae		■	■	■		■	
	sp.		■			■	■	
Trichoptera	Ecnomidae	*Ecnomus*	■	■	■	■	■	■
	Ecnomidae		■	■			■	■
	Hydrobiosidae	*Taschorema*	■	■	■			
	Hydropsychidae	*Asmicridea*				■		■
		Cheumatopsyche	■	■	■	■	■	■
	Hydroptilidae	*Hellyethira*					■	
		Hydroptila	■	■				
		Orthotrichia	■	■		■	■	
		Oxyethira	■	■			■	■
		sp.	■	■	■	■	■	■
	Leptoceridae	*Notalina*	■					
		Oecetis					■	
		Triaenodes	■				■	
		Triplectides	■		■	■	■	■
		sp.	■			■	■	■

Appendix F. Macroinvertebrate taxonomic inventory for the Burra Creek riffle habitat

CLASS / Order	Family / Sub-Family	Genus	BUR1c	BUR2a	BUR2b	BUR2c	QBYN1
ACARINA			■	■	■	■	■
BIVLAVIA	Sphaeriidae	*Musculium*	■	■	■		■
Coleoptera	Dytiscidae	*Lancetes*		■			
		Necterosoma	■				
		Sternopriscus	■				
		sp.		■			
	Elmidae	*Austrolimnius*	■		■	■	■
		Simsonia					■
	Gyrinidae	*Macrogyrus*		■	■		
	Hydraenidae	*Hydraena*		■			
	Hydrophilidae	*Enochrus*	■				
	Psephenidae	*Sclerocyphon*					■
	Scirtidae				■	■	
Decapoda	Atyidae	*Paratya*	■	■			■
	Parastacidae	*Cherax*	■		■		
Diptera	Ceratopogonidae	*Ceratopoginae*	■	■	■	■	■
		Forcipomyiinae	■	■	■		
	Chironomidae			■	■		
	Chironominae		■	■	■	■	■
	Dixidae	*Dixa*		■			■
	Dolichopodidae						■
	Empididae				■	■	■
	Orthocladiinae		■	■	■	■	■
	Simuliidae	*Austrosimulium*	■	■	■	■	■
	Stratiomyidae	*Odontomyia*	■	■			
	Tanypodinae		■	■	■	■	
	Tipulidae				■	■	■
Ephemeroptera	Baetidae	*Baetidae Genus 1*			■	■	■
		Baetidae Genus 2				■	■
		Cloeon			■		
		sp.	■	■		■	
	Caenidae	*Irapacaenis*			■		■
		Tasmanocoenis	■	■	■	■	■
	Leptophlebiidae	*Atalophlebia*	■	■	■	■	■
		Jappa		■	■	■	■
		sp.	■				
GASTROPODA	Physidae	*Physa*		■		■	
Hemiptera	Corixidae	*Micronecta*	■	■	■	■	
	Mesoveliidae	*Mesovelia*	■				
	Notonectidae	*Notonecta*	■	■			
Odonata	Gomphidae	*Austrogomphus*			■	■	■
	Telephlebiidae	*Spinaeschna*					■
	Zygoptera						■
OLIGOCHAETA			■	■	■	■	■
Plecoptera	Gripopterygidae	*Dinotoperla*		■		■	
		Illiesoperla			■		■
		sp.			■	■	
Trichoptera	Ecnomidae	*Ecnomus*	■	■	■	■	■
	Glossosomatidae	*Agapetus*					■
	Hydrobiosidae	*Taschorema*				■	
		Ulmerochorema					■
		sp.	■		■		■
	Hydropsychidae	*Asmicridea*				■	
		Cheumatopsyche	■	■	■	■	■
	Hydroptilidae	*Hellyethira*	■	■	■	■	■
		Hydroptila			■		
		Oxyethira		■	■	■	■
	Leptoceridae	*Notalina*					■
		Oecetis				■	■
		Triaenodes					■
		Triplectides	■	■	■		■
		sp.		■			■
	Philopotamidae	*Chimarra*	■		■	■	■
Turbellaria	Dugesiidae				■		■

Appendix F. Macroinvertebrate taxonomic inventory for the Burra Creek edge habitat

CLASS / Order	Family / Sub-Family	Genus	BUR1c	BUR2a	BUR2b	BUR2c	QBYN1
ACARINA			■	■	■	■	■
BIVALVIA	Corbiculidae						■
	Sphaeriidae / Corbiculidae			■	■		■
	Sphaeriidae	*Musculium (Sphaerium)*		■	■	■	■
	sp.		■		■	■	
Coleoptera	Dytiscidae	*Antiporus*			■	■	■
		Lancetes		■			
		Necterosoma	■	■	■		■
		Sternopriscus	■	■	■	■	■
		sp.	■		■	■	■
	Elmidae	*Austrolimnius*					■
	Gyrinidae	*Macrogyrus*	■				
	Hydraenidae	*Hydraena*	■	■	■		■
	Hydrochidae	*Hydrochus*					■
	Scirtidae			■	■	■	
Decapoda	Atyidae	*Paratya*	■	■	■		■
	Parastacidae	*Cherax*			■		
Diptera	Ceratopogonidae	*Ceratopoginae*	■	■	■	■	■
		Forcipomyiinae	■	■		■	■
	Chironomidae		■	■			
	Chironominae		■	■	■	■	■
	Culicidae				■		
	Dixidae	*Dixa*	■	■	■	■	■
	Empididae		■		■		■
	Orthocladiinae		■	■	■	■	■
	Psychodidae				■	■	
	Simuliidae	*Austrosimulium*	■	■	■	■	■
	Stratiomyidae	*Odontomyia*		■	■	■	
	Tanypodinae		■	■	■	■	■
	Tipulidae		■		■	■	■
Ephemeroptera	Baetidae	*Baetidae Genus 1*	■		■	■	
		Baetidae Genus 2				■	■
		Cloeon			■		
		sp.		■	■		■
	Caenidae	*Irapacaenis*	■				
		Tasmanocoenis	■	■	■	■	■
		sp.		■	■		■
	Leptophlebiidae	*Atalophlebia*	■	■	■		■
		Jappa	■	■	■	■	■
		sp.			■	■	
	sp.				■		
GASTROPODA	Ancylidae	*Ferrissia*	■		■		
	Physidae	*Physa*		■		■	■
	Planorbidae / Physidae			■		■	■
	Planorbidae			■			
	sp.		■	■			■
Hemiptera	Corixidae	*Micronecta*	■	■	■	■	■
	Hydrometridae				■		
	Notonectidae	*Enithares*	■		■	■	
		Notonecta		■	■		
		Paranisops			■		■
		sp.		■			
	Veliidae	*Microvelia*	■				
Lepidoptera	Crambidae					■	■
Odonata	Aeshnidae	*Brevyistyla*			■		
	Epiproctophora					■	
	Gomphidae	*Austrogomphus*				■	■
	Libellulidae	*Nannophya*	■				
	Zygoptera				■	■	■
OLIGOCHAETA			■	■	■	■	■
Plecoptera	Gripopterygidae	*Dinotoperla*		■			■
		Illiesoperla				■	
		sp.	■		■	■	■
Temnocephalida	Temnocephalidae	*Temnocephala*			■		
Trichoptera	Atriplectidae	*Atriplectides*					■
	Calamatoceridae	*Anisocentropus*				■	■
	Ecnomidae	*Ecnomus*	■	■	■	■	■
	Helicopsychidae	*Helicopsyche*					■
	Hydrobiosidae	*Taschorema*	■			■	■
	Hydropsychidae	*Cheumatopsyche*	■	■	■		■
	Hydroptilidae	*Hellyethira*	■	■	■	■	■

CLASS / Order	Family / Sub-Family	Genus	BUR1c	BUR2a	BUR2b	BUR2c	QBYN1
		Oxyethira					
		sp.					
	Leptoceridae	*Notalina*					
		Oecetis					
		Triaenodes					
		Triplectides					
		sp.					
	Philopotamidae	*Chimarra*					

Appendix F. Macroinvertebrate taxonomic inventory for the Murrumbidgee Pump Station riffle habitat

CLASS / Order	Family / Sub-Family	Genus	MUR931	MUR28	MUR935	MUR937	MUR29
ACARINA			■	■	■	■	■
BIVALVIA	Corbiculidae	*Corbicula*	■	■	■		
	Sphaeriidae/ Corbiculidae					■	
Coleoptera	Elmidae	*Austrolimnius*	■			■	■
		Simsonia			■	■	
		Stetholus	■	■		■	■
		sp.			■	■	
	Gyrinidae	*Macrogyrus*			■		
Decapoda	Palaemonidae	*Macrobrachium*	■	■	■	■	
Diptera	Chironominae		■	■	■	■	■
	Dolichopodidae		■				■
	Empididae		■	■	■	■	■
	Orthocladiinae		■	■	■	■	■
	Simuliidae	*Austrosimulium*	■	■	■	■	■
		Simulium				■	
	Tanypodinae			■			
	Tipulidae		■	■	■	■	■
Ephemeroptera	Baetidae	*Baetidae Genus 1*	■	■	■	■	■
		Baetidae Genus 2	■	■	■	■	■
		sp.	■				
	Caenidae	*Irapacaenis*	■	■	■	■	■
		Tasmanocoenis	■	■	■	■	■
	Leptophlebiidae	*Atalophlebia*	■	■		■	■
		Jappa	■	■	■	■	■
		sp.	■			■	
Hemiptera	Corixidae	*Micronecta*		■	■		■
Lepidoptera	Crambidae	*sf Nymphulinae sp.*			■	■	
Megaloptera	Corydalidae	*Archichauliodes*				■	■
Nematoda			■				
Odonata	Zygoptera				■		
OLIGOCHAETA			■	■	■	■	■
Plecoptera	Gripopterygidae		■		■		■
Trichoptera	Ecnomidae	*Ecnomus*	■	■	■	■	■
	Hydrobiosidae	*Austrochorema*			■		
		Taschorema	■		■	■	
		sp.	■	■		■	■
	Hydropsychidae	*Asmicridea*	■		■		■
		Cheumatopsyche	■	■	■	■	■
	Hydroptilidae	*Orthotrichia*		■			
		Oxyethira	■	■	■		■
		sp.	■		■	■	
	Leptoceridae	*Triplectides*		■			■
	Philopotamidae	*Chimarra*	■		■		
Turbellaria	Dugesiidae	*Dugesia*				■	

Appendix F. Macroinvertebrate taxonomic inventory for the Murrumbidgee Pump Station edge habitat

CLASS / Order	Family / Sub-Family	Genus	MUR931	MUR28	MUR935	MUR937	MUR29
ACARINA			■	■	■	■	■
BIVALVIA	Sphaeriidae						■
	Sphaeriidae/ Corbiculidae				■	■	
Coleoptera	Brentidae						■
	Elmidae	*Austrolimnius*	■				
		Coxelmis		■	■	■	
		Kingolus		■			
		Simsonia	■				■
		Stetholus	■	■			■
		sp.	■		■		
	Gyrinidae	*Macrogyrus*				■	
	Hydraenidae	*Hydraena*	■	■	■		
		sub-tribe Ochthebiinae	■				■
		sp.	■				
	Hydrochidae	*Hydrochus*	■	■			■
	Hydrophilidae		■		■		
	Scirtidae		■	■			
Decapoda	Atyidae	*Paratya*	■	■	■	■	■
	Palaemonidae	*Macrobrachium*		■	■	■	■
Diptera	Ceratopogonidae	*Ceratopoginae*	■	■	■	■	■
		Forcipomyiinae		■		■	■
	Chironominae		■	■	■	■	■
	Dixidae	*Dixa*	■		■		
	Empididae		■	■	■	■	
	Orthocladiinae		■	■	■	■	■
	Psychodidae			■	■		
	Sciomyzidae		■		■		
	Simuliidae	*Austrosimulium*	■	■	■		■
	Stratiomyidae	*Odontomyia*	■				
	Tanypodinae		■	■	■	■	■
	Tipulidae		■		■		■
Ephemeroptera	Baetidae	*Baetidae Genus 1*					■
		Baetidae Genus 2	■	■			
		sp.			■	■	■
	Caenidae	*Irapacaenis*	■	■	■	■	■
		Tasmanocoenis	■	■	■	■	■
	Leptophlebiidae	*Atalophlebia*	■	■	■		■
		Jappa	■	■	■	■	■
		sp.	■		■		■
GASTROPODA	Ancylidae	*Ferrissia*					■
	Lymnaeidae		■				
	Physidae	*Physa*	■				■
	Planorbidae/physidae						■
	sp.		■				
Hemiptera	Corixidae	*Micronecta*	■	■	■	■	■
	Gerridae	*Rheumatometra*	■	■	■		■
	Notonectidae	*Enithares*			■		■
		Paranisops					■
	Veliidae	*Microvelia*			■		
Lepidoptera	Crambidae	*sf Nymphulinae sp.*			■		
Nematoda							■
Odonata	Gomphidae	*Austrogomphus*	■				
Oligochaeta			■		■	■	■
Trichoptera	Ecnomidae	*Ecnomus*	■	■	■	■	■
	Hydropsychidae	*Asmicridea*		■			
		Cheumatopsyche	■	■	■	■	■
	Hydroptilidae	*Hellyethira*			■		■
		Oxyethira	■	■	■	■	■
		sp.	■		■	■	
	Leptoceridae	*Triaenodes*	■		■	■	■
		Triplectides	■	■	■		■
		sp.	■	■			■
	Philopotamidae	*Chimarra*					■

Appendix F. Macroinvertebrate taxonomic inventory for the Tantangara to Burrinjuck riffle habitat

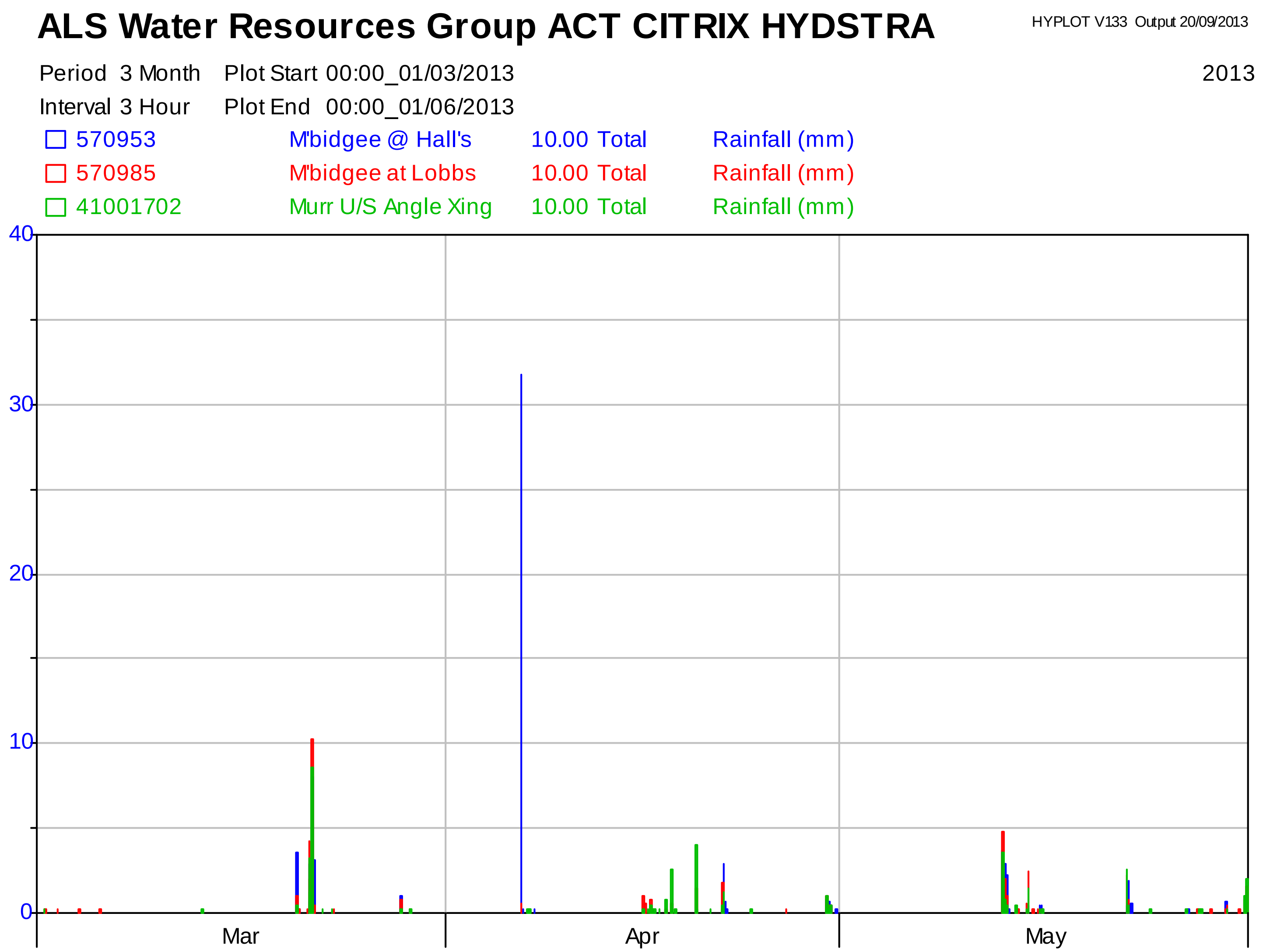
CLASS / Order	Family / Sub-Family	MUR1	MUR2	MUR3	MUR4	MUR6	MUR9	MUR12	MUR15	MUR16	MUR18	MUR19	MUR22	MUR23	MUR27	MUR931	MUR28	MUR935	MUR937	MUR29	MUR30	MUR31	MUR34	MUR37
ACARINA		■		■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■			
Amphipoda	Talitridae	■																						
BIVALVIA	Corbiculidae													■	■									
Coleoptera	Elmidae	■	■		■	■	■		■			■	■	■	■		■	■	■	■		■	■	
	Gyrinidae	■	■	■														■						
	Hydrophilidae	■																						
	Psephenidae			■																				
	Scirtidae	■	■	■																				
Decapoda	Atyidae											■												
	Palaemonidae									■					■			■	■					
Diptera	Chironominae	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Dolichopodidae															■								
	Empididae	■			■		■				■		■	■		■	■			■	■			■
	Orthocladiinae	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Simuliidae	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Tanypodinae	■	■	■		■				■			■	■							■			
	Tipulidae				■	■				■				■	■		■				■			
Ephemeroptera	Baetidae	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Caenidae	■	■			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Coloburiscidae		■	■	■	■	■																	
	Leptophlebiidae	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
GASTROPODA	Ancylidae		■																					
	Physidae	■																						
Hemiptera	Corixidae							■									■	■			■		■	
	Veliidae																				■			
Megaloptera	Corydalidae		■		■		■													■				
NEMATODA																■								
Odonata	Telephlebiidae	■	■		■	■	■																	
OLIGOCHAETA		■	■	■	■	■	■	■	■	■	■	■			■	■	■			■	■			
Plecoptera	Gripopterygidae	■	■	■	■	■	■	■				■	■		■			■						
Trichoptera	Conoesucidae		■	■	■																			
	Ecnomidae	■		■	■		■	■	■	■	■	■	■		■	■	■	■	■	■	■	■		■
	Hydrobiosidae		■	■	■	■	■				■	■						■	■		■			
	Hydropsychidae	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Hydroptilidae	■		■		■	■			■		■	■		■		■							
	Leptoceridae	■	■																					
	Philopotamidae	■	■		■	■	■						■											
Turbellaria	Dugesiidae	■				■	■								■									

Appendix F. Macroinvertebrate taxonomic inventory for the Tantangara to Burrinjuck edge habitat

CLASS / Order	Family / Sub-Family	MUR1	MUR2	MUR3	MUR4	MUR6	MUR9	MUR12	MUR15	MUR16	MUR18	MUR19	MUR22	MUR23	MUR27	MUR931	MUR28	MUR935	MUR937	MUR29	MUR30	MUR31	MUR34	MUR37
ACARINA		■		■			■	■		■	■	■			■	■	■	■	■	■	■			
Amphipoda	Ceinidae			■																				
	Talitridae	■	■		■																			
BIVALVIA	Corbiculidae											■												
Coleoptera	Brentidae																			■				
	Dytiscidae			■	■						■		■											
	Elmidae	■	■	■				■			■					■	■	■			■	■		
	Gyrinidae			■						■									■					■
	Hydraenidae				■			■								■				■				■
	Hydrophilidae	■							■							■								
	Scirtidae									■	■					■								
Decapoda	Atyidae					■	■	■	■		■	■	■			■	■	■		■	■			
	Palaemonidae									■	■	■	■	■	■			■	■		■			
Diptera	Ceratopogonidae	■		■			■				■	■			■		■	■	■					■
	Chironominae	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Culicidae										■													
	Dixidae															■		■						
	Empididae		■								■	■		■		■	■	■	■					■
	Muscidae								■															
	Orthocladiinae	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Psychodidae							■																
	Sciomyzidae															■								
	Simuliidae	■		■	■		■	■	■	■	■	■	■	■	■	■	■			■	■	■	■	■
	Tanypodinae	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■				
	Tipulidae	■			■													■		■		■		
Ephemeroptera	Baetidae		■	■	■	■	■	■	■	■		■	■	■		■	■		■	■		■	■	■
	Caenidae	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Coloburiscidae						■																	
	Leptophlebiidae	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
GASTROPODA	Ancylidae				■		■																	
	Lymnaeidae	■														■								
	Physidae			■	■	■							■			■				■		■	■	
	Planorbidae	■																						
	Planorbidae/physidae																			■				
Hemiptera	Corixidae	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Gerridae																			■				
	Notonectidae			■				■	■		■				■			■		■				
Lepidoptera	Crambidae								■									■						
Megaloptera	Corydalidae							■																
NEMATODA		■																						
Odonata	Coenagrionidae			■																				
	Epiproctophora	■					■																	
	Gomphidae		■																					
	Libellulidae		■																					
	Synthemistidae	■																						
OLIGOCHAETA		■	■	■	■	■	■	■	■	■	■	■		■	■			■	■	■	■	■	■	
Plecoptera	Gripopterygidae	■	■	■	■	■	■	■			■	■		■	■									
Trichoptera	Calamoceratidae			■	■		■																	
	Conoesucidae	■	■																					
	Ecnomidae	■	■	■	■	■	■	■	■	■	■	■	■	■			■	■	■	■		■		■
	Hydrobiosidae						■	■																
	Hydropsychidae	■			■		■	■	■	■		■	■	■	■	■	■	■		■		■	■	■
	Hydroptilidae	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■			
	Leptoceridae	■	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■		■		■	■	
	Odontoceridae		■	■																				
	Philopotamidae			■	■																			

Appendix G – Tantangara to Burrinjuck catchment Rainfall

Appendix G. Rainfall during the autumn period at Lobb's Hole (410761), upstream Angle Crossing (41001702) and Hall's Crossing (410777)



Appendix H – Tantangara to Burrinjuck - Principal Components Analysis output

Appendix H. PCA output

Eigenvalues

PC	Eigenvalues	%Variation	Cum.%Variation
1	5.92	45.5	45.5
2	2.67	20.5	66.0
3	1.33	10.3	76.3
4	1.26	9.7	86.0
5	0.87	6.7	92.7

Eigenvectors

(Coefficients in the linear combinations of variables making up PC's)

Variable	PC1	PC2	PC3	PC4	PC5
Water temp.	-0.353	0.148	-0.033	-0.259	-0.024
EC	-0.395	0.059	-0.148	-0.058	-0.101
pH	-0.332	0.157	0.025	-0.437	0.093
D.O (mg/L)	-0.085	-0.379	0.587	0.139	0.060
D.O (% Sat.)	-0.334	-0.159	0.386	-0.104	0.033
Turbidity	0.043	0.493	-0.029	0.408	-0.145
Alkalinity	-0.370	0.184	-0.047	-0.206	-0.100
Ammonia	0.069	-0.275	-0.477	-0.084	0.671
SS	-0.114	0.497	0.039	0.311	0.256
TKN	-0.224	0.154	0.287	0.234	0.628
Total Nox	-0.333	-0.199	-0.298	0.256	-0.102
TP	-0.240	-0.287	-0.032	0.454	-0.139
TN	-0.339	-0.190	-0.281	0.263	-0.072

Principal Component Scores

Sample	SCORE1	SCORE2	SCORE3	SCORE4	SCORE5
MUR1	2.85	-2.03	-2.38	-0.297	2.97
MUR2	2.87	-1.75	5.65E-2	-0.1	-0.15
MUR3	2.12	-3.05	1.66	1.15	-0.582
MUR4	3.16	-0.369	-4.13E-2	1.72	-0.108
MUR6	2.37	-0.421	0.429	1.36	-0.418
MUR9	2.52	4.29E-3	-0.15	1.19	-0.781
MUR12	1.23	2.88	-0.304	1.53	-0.275
MUR15	0.13	-0.589	0.746	8.79E-2	0.444
MUR16	-0.161	-0.453	1.02	-0.897	0.176
MUR18	0.946	0.671	-1.37	-1.19	-0.219
MUR19	0.551	-0.644	-0.228	-1.37	3.2E-2
MUR22	-0.779	-0.511	0.972	-1.72	5.51E-2
MUR23	-0.163	0.523	0.874	-0.379	0.116
MUR27	-0.409	0.817	0.479	-0.663	-0.208
MUR931	0.369	1.81	-1.35	-0.616	-0.351
MUR28	-0.598	0.69	0.412	-1.19	-0.334
MUR935	2.68E-2	2.27	-0.464	9.41E-2	-0.292
MUR937	-0.493	0.276	1.22	-0.563	0.202
MUR29	-9.35E-2	3.15	-0.648	0.603	-0.375
MUR30	-1.19	5.06E-2	1.66	-1.42	8.16E-2
MUR31	-6.04	-2.76	-0.683	1.47	-0.995
MUR34	-3.44	-1.76	-2.68	-0.563	-1.33
MUR37	-5.78	1.19	0.781	1.77	2.34

GHD

16 Marcus Clarke St Canberra ACT 2601
PO Box 1877 Canberra ACT 2601 Australia
T: +61 2 6113 3200   F: +61 2 6113 3299   E: cbrmail@ghd.com.au

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Rev No.	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
1	Phil Taylor Josh Cox Zoe Lagerroth	Dr. Jamie Corfield		Norm Mueller		26/09/2013
2	Phil Taylor	Dr. Jamie Corfield Norm Mueller		Norm Mueller		27/11/2013

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