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MURRUMBIDGEE ECOLOGICAL MONITORING PROGRAM

PART 1: ANGLE CROSSING

SPRING 2011

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List of abbreviations

ACT – Australian Capital Territory

ACTEW – ACTEW Corporation Limited

AFDM – Ash Free Dry Mass (periphyton)

ALS – Australian Laboratory Services

ANOSIM – Analysis of similarities

ANOVA – Analysis of Variance (statistics)

ANZECC –Australian and New Zealand Environment and Conservation Council

APHA – American Public Health Association

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

AUSRIVAS – Australian River Assessment System

BACI – Before After Control Impact

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 Program

ML/d – Megalitres per day

NATA – National Association of Testing Authorities

NMDS – Non-metric Multidimensional Scaling (statistics)

NSW – New South Wales

NTU – Nephlelometric Turbidity Units

PERMANOVA – PERMutational Multiple Analysis Of Variance

QA – Quality Assurance

QC – Quality Control

SIMPER – Similarity Percentages

TN – Total Nitrogen

TP – Total Phosphorus

Executive Summary

To improve ACT water security for the future, ACTEW Corporation is constructing an additional pumping intake structure and pipeline to abstract water from the Murrumbidgee River near Angle Crossing (southern border of the ACT).

The proposed pumping system will transfer water from Angle Crossing through an underground pipeline into Burra Creek, and then transfer the water by run of river flows into the Googong Reservoir. The system is being designed to pump up to 100 ML/d, and is expected to be commissioned mid-2012. Abstraction will be primarily dictated by the level of demand and the availability of water and whether the Murrumbidgee River water quality complies with the EPA approved trigger levels. The proposal is referred to as Murrumbidgee to Googong project (M2G).

This program aims to determine the baseline river condition prior to the additional water abstraction, which will include the period of pipeline construction and continue monitoring after commencement to determine what changes are taking place that are attributable to abstraction from Angle Crossing.

The key aims of this sampling run were to:

- *Collect current baseline condition macroinvertebrate community data, up- and downstream of Angle Crossing;*
- *Provide ACTEW with river health assessments based on AUSRIVAS protocols at key sites potentially affected by the construction and operation of pumping infrastructure at Angle Crossing;*
- *Collect current condition periphyton community baseline data to help monitor seasonal and temporal change and;*
- *Report on water quality up and downstream of Angle Crossing.*

This report presents the results from biological sampling and water quality monitoring of the Murrumbidgee River upstream and downstream of Angle Crossing in spring 2011 and represents the 8th round of sampling carried out thus as part of a 3 year sampling program. Sampling was completed in November 2011 and macroinvertebrate sampling and associated habitat surveys were based on the AUSRIVAS sampling protocols, extended to include replicated sampling at each site and genus level identifications for selected taxa. The reasons for these variations were to: a) establish estimates of the within-site variability prior to the commencement of pumping; and; b) improve the ability of the monitoring program to detect subtle changes in the macroinvertebrate community that might occur in response to water abstraction impacts.

Macroinvertebrate community composition, periphyton assemblages and water quality were monitored from six sites on the Murrumbidgee River, three upstream and three downstream of Angle Crossing (~2km west of Williamsdale) with the aim of obtaining baseline ecological condition information following the ANZECC guidelines for ecological monitoring. River flows and rainfall for the sampling period were recorded at ALS gauging stations located at Lobb's Hole (downstream of Angle Crossing: 410761) and upstream of Angle Crossing (MURWQ09). Baseline physico-chemical water quality parameters including temperature, pH, electrical conductivity, turbidity and dissolved oxygen were recorded at each of the six sites at the time of the biological sampling. Additionally, grab samples were taken from each site for Hydrolab verification and nutrient analysis.

Macroinvertebrates were sampled in the riffle and edge habitats where available. Both habitats were sampled to provide a more comprehensive assessment of each site and potentially allow the program to isolate flow-related impacts from other disturbances. Riffle and edge habitats were sampled for macroinvertebrates and analysed in strict accordance with the ACT spring riffle and edge AUSRIVAS (Australian River Assessment System) during spring (November 9th – 11th) 2011. At each site, two samples were taken (where possible) from the riffle habitat. Two samples were also taken from the edge habitat and were collected by sweeping the collection net along the edge habitat at each site.

Periphyton samples were collected using the in-situ syringe method. At each of the six sampling sites, a 1m wide transect was established across the riffle zone. Along each transect, twelve samples were collected at regular intervals, using a syringe sampling device. In addition to this technique, 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 to compliment the quantitative samples.

The key results from the spring 2011 sampling of Angle Crossing show that:

1) *Water quality parameters recorded at the upstream Angle Crossing site tended to be mirrored downstream at Lobb's Hole indicating that there was no impact to these parameters resulting from the M2G project;*

2) *Compliance with the ANZECC and ARMCANZ water quality guidelines was low for turbidity owing to some siltation to the Hydrolab following the environmental flow release from Tantangara Reservoir. EC was within the guidelines 100% of the time at both stations and while there were some exceedances in dissolved oxygen and pH, these coincided with the environmental flow releases;*

3) *The water quality results from the grab samples taken during the macroinvertebrate sampling show that most physico-chemical parameters were within the ANZECC & ARMCANZ guidelines. The exceptions to this was the turbidity at MUR 15 (Bumbalong Rd.) which is slightly elevated above guideline levels, while the pH at the two most downstream sites also showed elevated levels slightly above guidelines. There was also the exceedance of the DO guidelines (albeit very minor) at site MUR23 (Point Hut) reading 110.1 % above the guideline level of 110 %. Some exceedances occurred at MUR 15, MUR 23 and MUR 28 (U/S Cotter River confluence), but these were small deviations that naturally occur during the daily cycles;*

4) *Nutrient concentrations (total phosphorus and total nitrogen) were above the upper limits at all sampling sites. In past reports we have suggested that background levels are likely to be high in this section of the Murrumbidgee River because of extensive agricultural land use upstream and increasing urbanisation beyond MUR 19. These values therefore, despite being above the recommended guidelines are not excessively high compared to the data collected so far in this monitoring program;*

5) *While there were no differences detected in the chlorophyll-a concentrations between upstream and downstream locations there was a non-linear trend showing a steep increase in the median values beyond MUR 23. Although we think nutrients are driving these patterns, we suspect there is a lag effect between nutrient delivery - to plant uptake - to growth - to when we collect the data which inhibits us from detecting these trends.*

   Despite the increased algae and macrophyte growth found downstream of MUR 23, there have been few reports or personal observations of nuisance growths so far; however during the period of low flows in autumn 2009, the percentage of filamentous coverage was noted as being higher than during *any other time in the project but was subsequently removed by the time spring base flows had returned. In terms of the M2G project, these topics require consideration when discussion of the timing and duration water abstractions are held because they may need to be adjusted on a seasonal basis to consider all abiotic and biotic factors influencing these patterns of AFDM and chlorophyll-a concentrations especially downstream of Point Hut Crossing.*

6) *On season by season basis, the overall site assessments have improved since spring 2010, which is largely to do with a) lower base flows during this spring period and b) a longer stand down period following high flow events, which has facilitated the recolonisation of several, usually common taxa – especially in the edge habitat.*

7) *The environmental flow release appears to have (based on field observations) removed some of the fine silt built up in the riffle habitats and scoured out a large proportion of the submerged macrophytes that are usually seen. There is some indication of an increased number of sensitive taxa - taxa that prefer clean silt-free substrates - colonising these sites since this environmental flow release. However despite this, the overall community composition remains very similar to previous sampling runs, which suggest a high degree of resistance to disturbance and resilience (the ability to recolonise) following high flow disturbances.*

While there is a high degree of resistance and resilience amongst these sampling sites to various high flow disturbances, one of the key challenges now, in terms of the M2G project, is to use this to evaluate likely scenarios for community outcomes and of biological changes under the 80:90 pumping rules (ACT Government, 2006). While we have data relating to high flow disturbances, situations under low flow conditions are less common. Currently the autumn 2009 sampling run is the only representation of macroinvertebrate communities in the Murrumbidgee River when base flows were under 100 ML/d.

Deriving useful indicator taxa from the currently available data and literature would be a step in the right direction. These indicator taxa would provide another line of evidence to determine whether potential impacts are flow related due to the operating rules of M2G or have occurred from other environmental factors.

1 Introduction

The Murrumbidgee Ecological Monitoring Program (MEMP) was set up by ACTEW Corporation to evaluate the potential impacts of water abstraction from the Murrumbidgee River. It is being undertaken as part of the ACT water supply security infrastructure upgrade.

The current time-line for the MEMP sampling covers autumn and spring sampling over a three year period that commenced in spring 2008 and is current to spring 2011.

There are four component areas being considered as part of the MEMP program:

- Part 1: Angle Crossing
- Part 2: Burra Creek (discharge point for Angle Crossing abstraction)
- Part 3: Murrumbidgee Pump Station
- Part 4: Tantangara to Burrinjuck

This report focuses on Part 1: Angle Crossing, specifically the results from the spring 2011 sampling round.

To improve ACT water security for the future, ACTEW Corporation is constructing an additional pumping structure and pipeline to abstract water from the Murrumbidgee River near Angle Crossing (southern border of the ACT). The pumping system will transfer water from Angle Crossing through a 12km underground pipeline into Burra Creek. The water will then be transported a further 13km by run of river flows into the Googong Reservoir.

The system has been designed to pump up to 100 ML/d and is expected to be in operation by mid-2012, with construction underway. 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 environmental flow rules for the Murrumbidgee to Googong project (M2G) have been adopted from the framework outlined in the Environmental Flow Guidelines (ACT Government, 2006). Under these flow rules, Murrumbidgee flows must be protected at the 80th percentile between November and May and the 90th percentile between June and October (Table 1).

Table 1. Flow rules for the Murrumbidgee to Googong project. These values are based on the period of record data (1974-2011) from Lobb's Hole gauging station (410761) and are current as of the 6th January 2012

All values are expressed in ML/d

Jan*.	Feb*.	Mar*.	Apr*.	May*.	Jun†.	Jul†.	Aug†.	Sep†.	Oct†.	Nov*.	Dec*.
30.6	22.9	16.7	35.0	50.1	64.2	79.0	105.7	175.6	133.3	142.9	54.5

* 80th percentile flow

† 90th percentile flow

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 expected 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 A** for examples). This current monitoring program will form the basis of an Ecological Monitoring Program to satisfy EIS requirements for the M2G Project.

1.1 Background: 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, down to 300 mm in the west (B.O.M, 2011).

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).

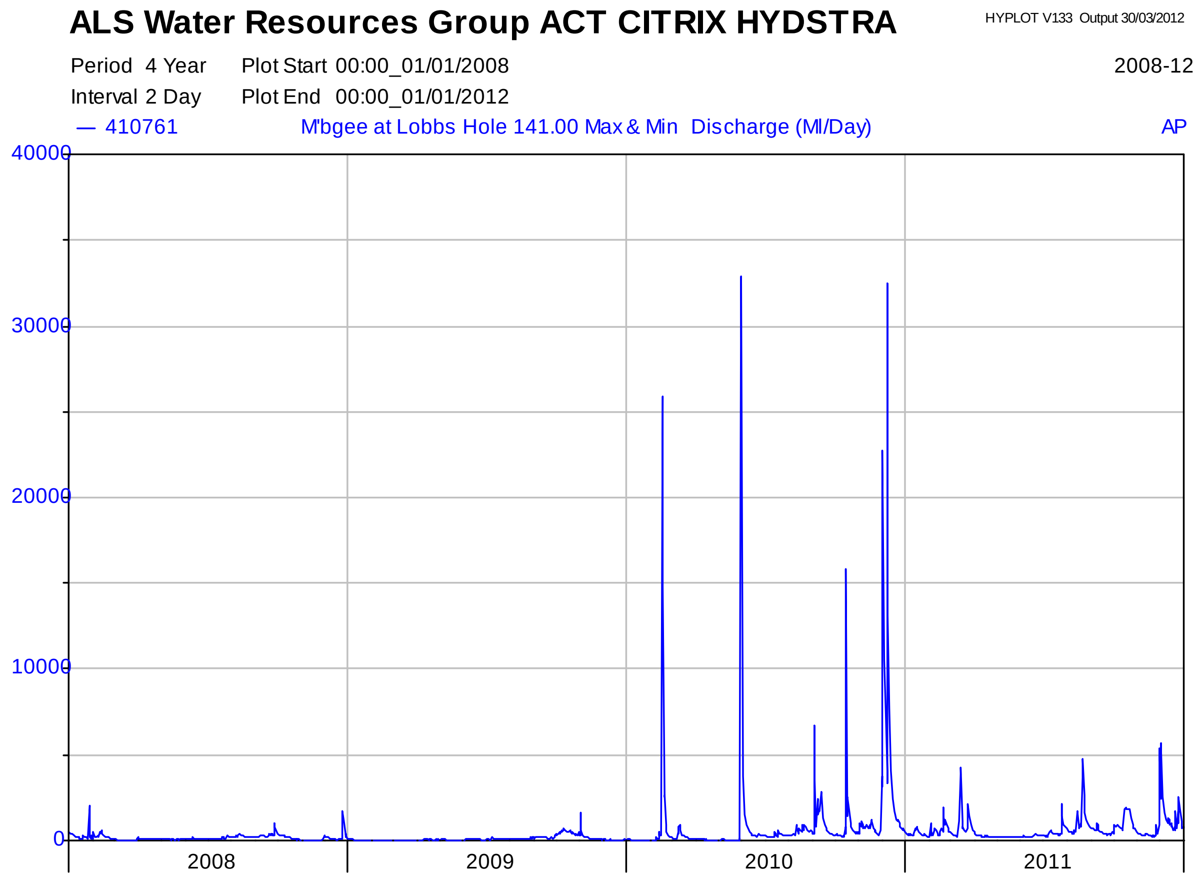

Figure 1. Four year hydrograph of the Murrumbidgee River at Lobb's Hole (410761)

1.2 Project objectives

There are two key phases to this project, which incorporates two sets of objectives, representing long and short term aims (i.e. before and after abstraction) (Table 2). Phase 1 of this monitoring program involves the establishment of baseline macroinvertebrate community composition at selected sites up- and downstream of the proposed abstraction point. The focus of Phase 1 is on the documentation of spatial and seasonal changes in macroinvertebrate and periphyton assemblages as well as monitoring water quality patterns prior to abstraction, including the construction phase. Accordingly, this phase will provide data for before and after construction and before and after abstraction comparisons that will allow their potential impacts (direct or indirect) to be assessed.

Phase 2 incorporates long term objectives, with the aim of providing post-abstraction phase data that will help to delineate potential ecological effects that are related specifically to the abstraction of water from the Murrumbidgee River at Angle Crossing, outside of what is considered natural, temporal and spatial variation.

The specific aims of this monitoring program are:

1. To determine seasonal and annual variation in the composition and abundance of periphyton at control and test sites before water abstractions commence, and to assist in the monitoring of river ecosystem health once the abstractions begin;

2. To determine baseline macroinvertebrate communities at test and control sites before the water abstractions commence, and to assist in the monitoring of riverine ecosystem health once the abstractions begin.

Table 2. Project objectives and estimated time frames

	Key objectives	Time frame	Outcomes
Phase 1	Obtain baseline information to include: hydrological, biological and physico-chemical water quality information. Establish spatial and temporal trends up and downstream of the existing low-level crossing that is Angle Crossing.	2009-2011	Help establish flow rules for the operation of the pump in the M2G project. Identify key (indicator) species than can be used to identify flow thresholds. Establish biological signatures and inventories as references for changes over time.
Phase 2	Monitor the ecological responses related specifically to water abstractions from Angle Crossing. The ability to do this depends on establishing a comprehensive data set of spatial and temporal variability at all concerned sites.	2012-	Help minimise ecological impacts by using baseline and indicator taxa information in relation to proposed flow rules.

1.3 Project scope

The current ecological health of the sites monitored as part of the Murrumbidgee to Googong (M2G) monitoring program was estimated using AUSRIVAS protocols for macroinvertebrate community data, combined with a suite of commonly used biological metrics and descriptors of community composition. The scope of this report is to convey the results from the spring 2011 sampling. Specifically, as outlined in the MEMP proposal to ACTEW Corporation (ALS, 2011a) this work includes:

- Sampling conducted in spring 2011;
- 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;
- *In-situ* water quality measurements collected and samples analysed for nutrients in ALS's NATA accredited laboratory.

1.4 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 (Biggs, 1989; Biggs *et al.*, 1999; Whitton and Kelly, 1995). 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 organism 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

Macroinvertebrate community composition, periphyton assemblages and water quality were monitored from replicate sites on the Murrumbidgee River, up- and downstream of Angle Crossing (~2km west of Williamsdale) with the aim of obtaining baseline ecological condition information following the ANZECC guidelines for ecological monitoring (ANZECC & ARMCANZ, 2000).

The upper Murrumbidgee River is impacted by activities in its catchment, which include a large array of land-use practices. As such, it was important to select a sufficiently large number of sites to enable the program to provide a reasonable snap-shot of the current status of the macroinvertebrate community in the study area. 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 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 program 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. Six sites suited the criteria mentioned above (Table 3; Figure 2; Plates 1 & 2). These sites include three sites upstream of Angle Crossing (in NSW) and three sites downstream (all in the ACT).

Table 3. Sampling site locations and details

Site Code	Location	Landuse	Habitat sampled	Latitude	Longitude
MUR 15	Bumbalong Road	Grazing / Recreation	Riffle and Edge	35^0 51' 51.6" S	149^0 08' 7.81" E
MUR 16	The Willows - Near Michelago	Grazing	Riffle and Edge	35^0 41' 18.72" S	149^0 06' 32.80" E
MUR 18	U/S Angle Crossing	Grazing	Riffle and Edge	35^0 35' 06.68" S	149^0 06' 28.96" E
MUR 19	D/S Angle Crossing	Grazing / Recreation	Riffle and Edge	35^0 34' 59.38" S	149^0 06' 32.80" E
MUR 23	Point Hut Crossing	Recreation / Residential	Riffle and Edge	35^0 27' 03.42" S	149^0 04' 27.84" E
MUR 28	U/S Cotter River confluence	Grazing	Riffle and Edge	35^0 19' 25.22" S	148^0 56' 59.34" E

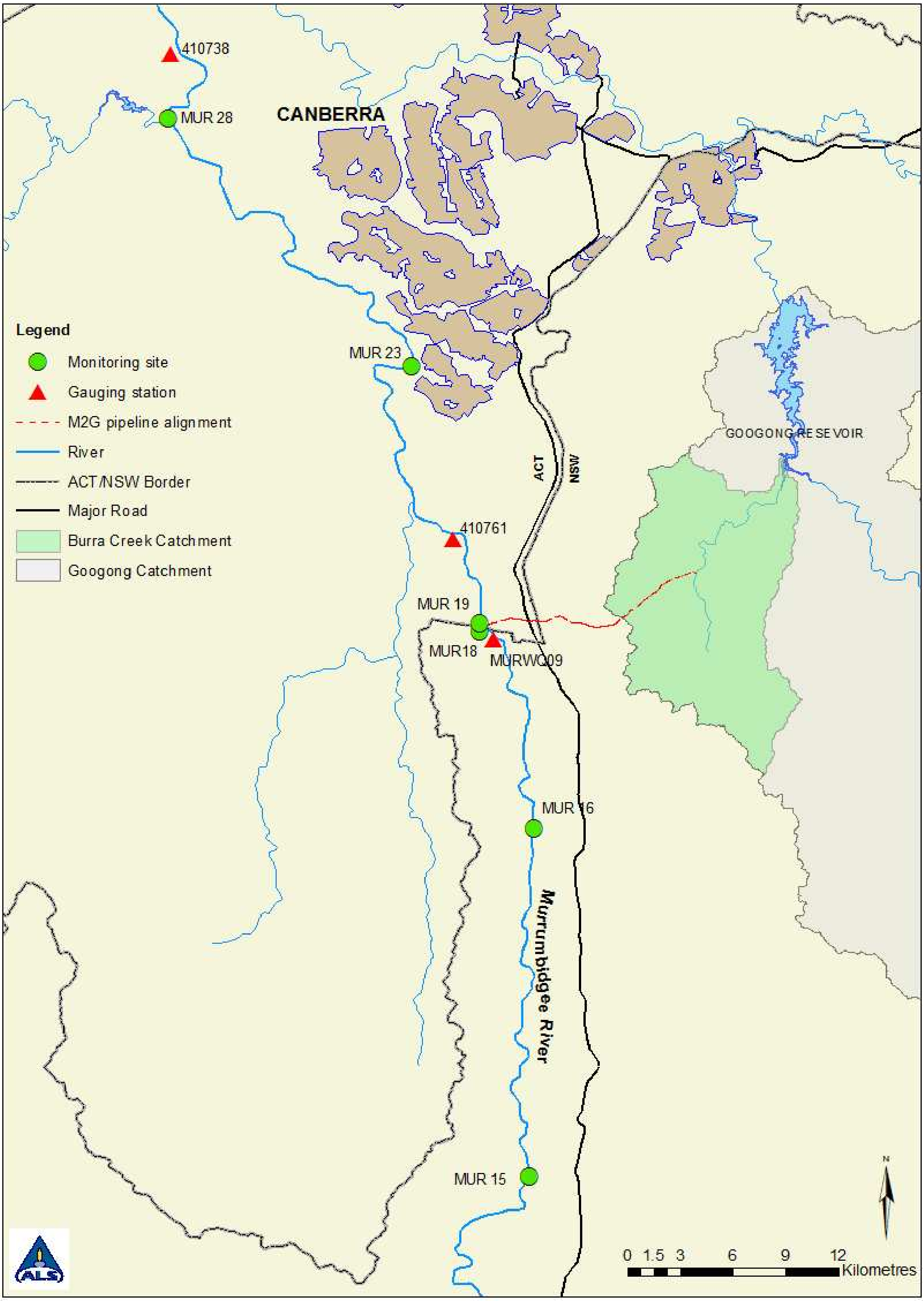

Figure 2. Angle Crossing sampling locations and gauging station

MUR 15 Looking upstream (283 ML/d)

MUR 15 Looking downstream

MUR 16 "The Willows" near Michelago looking upstream (283 ML/d)

MUR 16 Looking downstream

MUR 18 ~800m upstream of Angle Crossing looking downstream (592 ML/d)

MUR 18 Facing across to the edge habitat

Plate 1. Photographs of sampling sites upstream of Angle Crossing

MUR 19 Downstream of Angle Crossing looking up to the coffer dam

MUR 19 Looking downstream (592 ML/d)

MUR 23 Looking downstream from the bridge

MUR 23 Downstream near recreation area (342 ML/d)

MUR 28 Looking upstream (277ML/d)

MUR 28 Looking downstream towards the Road Cotter Bridge

Plate 2. Photographs of sampling sites downstream of Angle Crossing

2.2 Hydrology and rainfall

River flows and rainfall for the sampling period were recorded at ALS gauging stations located at Lobb's Hole (downstream of Angle Crossing: 410761) and upstream of Angle Crossing (MURWQ09). Site codes and locations are shown in Table 4.

Stations are calibrated monthly and data are downloaded and verified before storage on the database where it is quality coded. Water level data is verified manually by comparing the logger value to the staff gauge value. If there are differences between logger and staff, the logger is adjusted accordingly. Rain gauges are calibrated and adjusted as required. Records are stored on the HYDSTRA© database software and downloaded for each sampling period.

Table 4. Location and details of continuous water quality and flow stations

Site Code	Location/Notes	Parameters*	Latitude	Longitude
410761	M'bidgee River @ Lobb's Hole (D/S of Angle Crossing)	WL, Q, pH, EC, DO, Temp, Turb, Rainfall	S 35.5398	E 149.1015
MURWQ09	M'bidgee River U/S Angle Crossing	WL, Q, pH, EC, DO, Temp, Turb, Rainfall	S 35.3533	E 149.0705

* WL = Water Level; Q = Rated Discharge; EC = Electrical Conductivity; DO = Dissolved Oxygen; Temp = Temperature; Turb = Turbidity; Rainfall = Rainfall (0.2 mm increments)

2.3 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 3. 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 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.

2.4 Macroinvertebrate sampling and processing

At each site, macroinvertebrates were sampled in the riffle and edge habitats where available. Both habitats were sampled to provide a more comprehensive assessment of each site (Coysh *et al.*, 2000); and potentially allow the program to isolate flow-related impacts from other disturbances. The reasoning behind this is that each habitat is likely to be effected 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 and analysed in strict accordance with the ACT Spring riffle and edge AUSRIVAS (Australian River Assessment System) protocols (Coysh, *et al.*, 2000) during Spring (November 9th – 11th) 2011. At each site, two samples were taken (where possible) from the riffle habitat (flowing broken water over gravel, pebble, cobble or boulder, with a depth greater than 10 cm; (Coysh, *et al.*, 2000) using a framed net (350 mm wide) with 250 µm mesh size. Sampling began at the downstream end of each riffle. The net was held perpendicular to the substrate with the opening facing upstream. The stream directly upstream of the net opening was disturbed by vigorously kicking and agitating the stream bed, allowing any dislodged material to be carried into the net. The process continued, working upstream over 10 metres of riffle habitat. The samples were then preserved in the field using 70% ethanol, clearly labelled with site codes and date then stored on ice and refrigerated until laboratory sorting commenced.

The edge habitat was also sampled in strict accordance with the ACT AUSRIVAS protocols. Two samples were taken from the edge habitat. The nets and all other associated equipment were washed thoroughly between sampling events and sites to remove any macroinvertebrates retained on them. Samples were collected by sweeping the collection net along the edge habitat at the sampling site. The operator worked systematically over a ten metre section covering overhanging vegetation, submerged snags, macrophyte beds, overhanging banks and areas with trailing vegetation. Samples were preserved on-site as described for the riffle samples.

Processing of the macroinvertebrate samples followed the ACT AUSRIVAS protocols. Briefly, in the laboratory, the preserved macroinvertebrate samples were 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. The contents of randomly selected cells were removed and the macroinvertebrates within each cell were identified to genus level except for Chironomids (sub-family) and Oligochaeta (class). 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. For the AUSRIVAS model, taxa were analysed at family level except for: Chironomidae (sub-family), Oligochaeta (class) and Acarina (order) until 200 animals were identified (identification followed taxonomic keys published by Hawking (2000)). If 200 animals were identified before a cell had been completely analysed, identification continued until the animals in the entire cell were identified. Data were entered directly into electronic spread sheets to eliminate errors associated with manual data transfer.

2.5 Periphyton

Estimates of algal biomass were made using complimentary 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) of the periphyton samples (Biggs, 2000).

The six sites shown in Table 3 were sampled for periphyton in spring in conjunction with the macroinvertebrate sampling. All periphyton - adnate and loose forms of periphyton, as well as organic/inorganic detritus in the periphyton matrix, were collected using the *in-situ* syringe method similar to Loeb (1981) as described in Biggs and Kilroy (2000) (Plate 3 & 4). A 1m wide transect was established across riffles at each site. Along each transect, twelve samples were collected at regular intervals, using a syringe sampling device, based on two 60 ml syringes and a scrubbing surface of stiff nylon bristles, covering an area of ~637 mm^2. The samples were then divided randomly into two groups of six samples to be analysed for Ash Free Dry Mass (AFDM gm^{-2}), and chlorophyll-*a*. Samples for AFDM (gm^{-2}) and chlorophyll-*a* analysis were filtered onto glass filters and frozen. Sample processing follows 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 (Coysh, *et al.*, 2000) to compliment the quantitative samples.

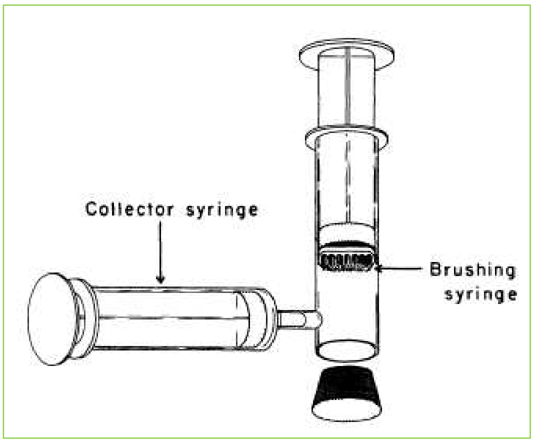

Plate 3. Diagram of the periphyton sampler

(taken from Loeb, 1981)

Plate 4. Periphyton sampler in operation

2.6 Macroinvertebrate quality control procedures

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

- Organisms that were heavily damaged were not selected during sorting. Attempts were made to obtain more than 200 organisms, to overcome losses associated with damage to intact organisms during vial transfer.
- Identification was performed by qualified and experienced aquatic biologists with more than 100 hours of identification experience.
- When required, taxonomic experts performed confirmations of identification. Reference collections were also used when possible.
- ACT AUSRIVAS QA/QC protocols were followed.
- An additional 10% of samples were re-identified by another senior taxonomist.
- Very small, immature, or damaged animals or pupae that could not be positively identified were not included in the dataset.

All procedures were performed by AUSRIVAS accredited staff.

2.7 Licences and permits

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

ALS field staff maintains current ACT and NSW AUSRIVAS accreditation.

2.8 Data analysis

2.8.1 Water quality

Water quality parameters were examined for compliance with ANZECC water guidelines for healthy ecosystems in upland streams (ANZECC and ARMCANZ, 2000). Trend analyses of water quality parameters will be conducted at the end of the baseline collection period. This report only presents results based on spring 2011 sampling.

2.8.2 Macroinvertebrate communities

An **An**alysis **O**f **Sim**ilarities test (ANOSIM) was performed on the macroinvertebrate similarity matrix to test whether macroinvertebrate communities were statistically different upstream and downstream of Angle Crossing. Sites were nested within location for the analysis. 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.

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.

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. 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).

All multivariate analyses were performed using PRIMER version 6 (Clarke and Gorley, 2006) and PERMANOVA + (Anderson *et al.*, 2008). Univariate statistics were performed using R version 2.14.1 (R Development Core Team, 2011).

2.8.3 AUSRIVAS assessment

In addition to assessing the composition and calculating biometrics from the macroinvertebrate data, riffle and edge samples, river health assessments based on the ACT AUSRIVAS spring riffle and edge models were conducted. AUSRIVAS is a prediction system that uses macroinvertebrate communities to assess the biological health of rivers and streams. Specifically, the model uses site-specific information to predict the macroinvertebrate fauna expected (E) to be present in the absence of environmental stressors. The expected fauna from sites with similar sets of predictor variables (physical and chemical characteristics which cannot be influenced due to human activities, e.g. altitude) are then compared to the observed fauna (O) and the ratio derived is used to indicate the extent of any impact (O/E). The ratio derived from this analysis is compiled into bandwidths (i.e. X, A-D; Table 5) which are used to gauge the overall health of particular site (Coysh *et al.* 2000). Data is presented using the AUSRIVAS O/E 50 ratio (Observed/Expected score for taxa with a >50% probability of occurrence) and the previously mentioned rating bands (Table 5).

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.

2.8.4 SIGNAL-2 (Stream Invertebrate Grade Number – Average Level)

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). Sensitivity grades are also given in the AUSRIVAS output which can then be used as complimentary information to these assigned bandwidths to aid the interpretation of each site assessment.

We conducted linear mixed effect ANOVA models separately for the riffle and edge samples to test for location differences in the univariate metrics: SIGNAL-2 scores and AUSRIVAS OE50 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.*, 2011) a statistical package applied in the R environment (R Development Core Team, 2011). For all analyses, the level of significance (alpha) was set to 5%.

Several metrics in addition to AUSRIVAS and SIGNAL-2 were used. 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 and Chironomids) 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.

Table 5. AUSRIVAS band-widths and interpretations for the ACT spring riffle and edge models

	RIFFLE	EDGE	
BAND	O/E Band width	O/E band width	Explanation
X	> 1.14	> 1.13	More diverse than expected. Potential enrichment or naturally biologically rich.
A	0.86 – 1.14	0.87 – 1.13	Similar to reference. Water quality and / or habitat in good condition.
B	0.57 – 0.85	0.61 – 0.86	Significantly impaired. Water quality and/ or habitat potentially impacted resulting in loss of taxa.
C	0.28 – 0.56	0.35 – 0.60	Severely impaired. Water quality and/or habitat compromised significantly, resulting in a loss of biodiversity.
D	< 0.28	< 0.35	Extremely impaired. Highly degraded. Water and /or habitat quality is very low and very few of the expected taxa remain.

2.8.5 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 was fitted to the Log-transformed data for AFDM and Chlorophyll-a. 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-transformation was necessary to meet the assumptions of normality. For the purposes of graphical visualisation, however, raw data are presented.

3 Results

3.1 Summary of sampling conditions

Spring sampling was completed over three days in November (9th – 11th). MUR 28 was sampled on the 9th, MUR 18 & 19 were sampled on the 10th and MUR 15, 16 & 23 were sampled on the 11th. The mean daily flow over the three days of sampling at MURWQ09 (upstream of Angle Crossing) and 410761 (Lobb's Hole: downstream of Angle Crossing) were 255 ML/d and 309 ML/d respectively (Figure 7).

Prior to spring sampling, Snowy Hydro managed an environmental flow release from Tantangara Reservoir in the middle of October, which was maintained at 2000 ML/d over a 10 day period (Figure 2). A rainfall event at the end of November resulted in a sharp increase in flow volume over the final few days of spring. Although spring flows were moderate there was still only limited edge habitat available at site MUR 16 and MUR 28, resulting in the collection of only a single sample (Table 6). The air temperatures during the sampling period ranged between 15°C and 21°C and weather conditions were mostly fine with occasional overcast conditions and some rain.

Table 6. Macroinvertebrate samples collected during the spring sampling run

Site	Edge	Riffle
MUR 15	2	2
MUR 16	1	2
MUR 18	2	2
MUR 19	2	2
MUR 23	2	2
MUR 28	1	2

3.2 Field observations

Over the three day sampling period we noted an obvious decrease of macrophytes, both emergent and submerged among all but one (MUR 23) sampling sites, which were probably scoured out during the environmental flow release in mid-October. These flows have had a noticeable impact on the removal of some sand and silt deposits in the riffles that were sampled. As we were sampling MUR 19, there was a short, intense rainfall event resulting in some turbid runoff (which was short-lived) (Plate 5). Flows were moderate at all sites and appeared to be increasing due to rainfall during sample collection.

Plate 5. Runoff from the unsealed road at Angle Crossing South side (left) and north side (right)

3.3 Hydrology and rainfall

There were two significant high flow events during the spring period, one during October, prior to sampling and the second at the end of November, after sampling had been completed. The first peaked at 2030 ML/d upstream of Angle Crossing and 1890 ML/d at Lobb's Hole. The second event was much larger with the hydrograph still rising at the end of November with the peak during December. The highest flow recorded during November was 4280 ML/d upstream of Angle Crossing and 5660 ML/d at Lobb's Hole. The second event at Lobb's Hole represented an approximate average annual recurrence interval of approximately 1.5 yr.

The first high flow event was a result of the scheduled environmental flow release from Tantangara Reservoir. This event occurred in the middle of October, which was approximately 3 weeks prior to the spring sampling. The second high flow event was the result of two consecutive rainfall events separated by two days (Figure 3). The first rainfall event on the 25th-26th produced 34.6mm and 54.4mm respectively. This was then followed up on the 29th-30th with 85.4mm and 87.6mm respectively. Combined with a number of smaller rainfall events earlier in the month, this was easily the wettest November on record with 12 wet days totalling 311.2mm of rain, with the previous highest November rainfall in 1989 with 179.8mm (period of record 1974-2011). Compare this to September which only had 24.6mm and was the 6th driest on record.

Flow conditions during sampling were relatively stable with a steady increase in flows during the 3 day sampling period due to scattered rain on the 8th-10th. Mean daily flow for spring was 606 ML/d upstream of Angle Crossing and 695 ML/d at Lobb's Hole (Table 7). Mean daily flow during October were twice that recorded for September and November due to the flow release maintaining high flows for approximately 10 days (Figure 3).

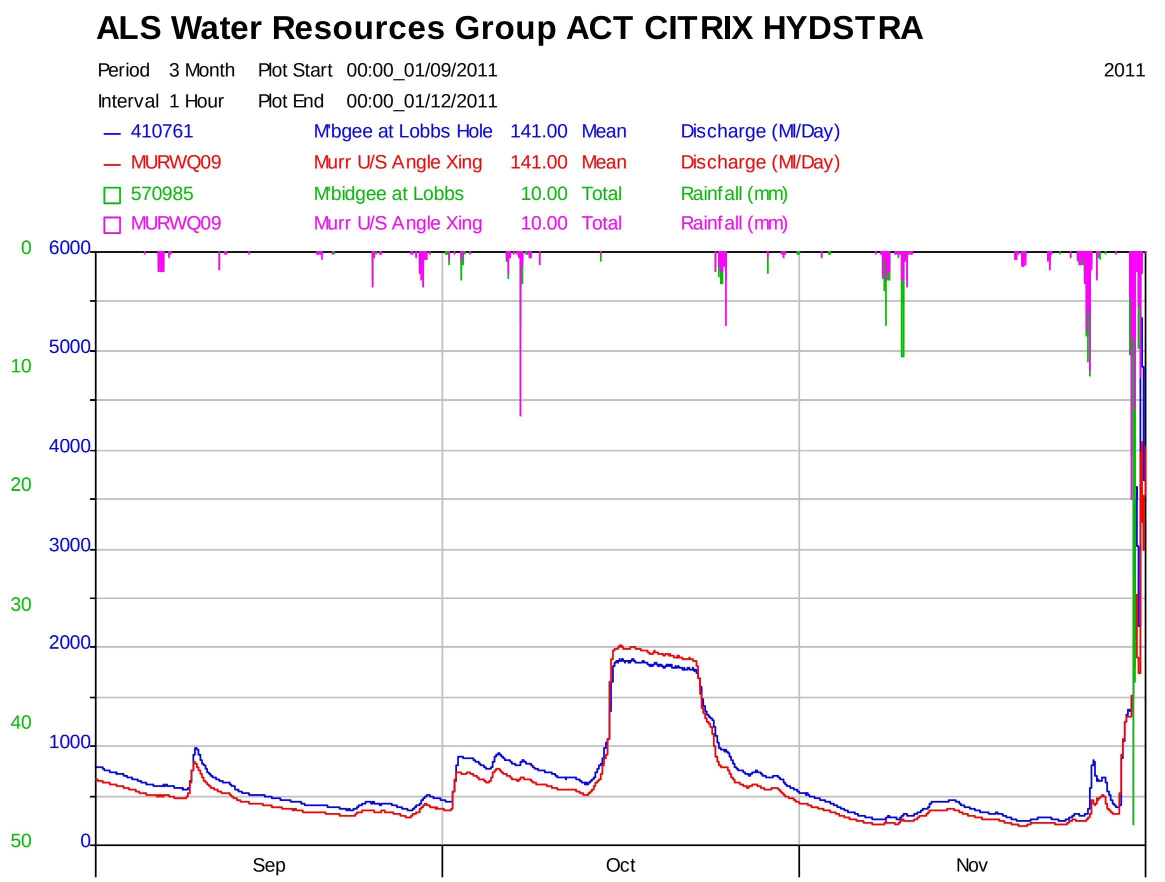

Figure 3. Spring hydrograph of the Murrumbidgee River upstream of Angle Crossing (MURWQ09) and downstream of Angle Crossing at Lobb's Hole (410761)

Table 7. Spring rainfall and flow summaries upstream and downstream of Angle Crossing. Flow values are daily means. Rainfall is total (mm) and numbers in parentheses are season averages

Site	Upstream Angle Crossing (MURWQ09)		Lobb's Hole (410761)	
	Rainfall Total (mm)	Mean Flow (ML/d)	Rainfall Total (mm)	Mean Flow (ML/d)
September	28.0	440.2	24.6	535.0
October	50.0	977.1	46.6	1051.0
November	201.6	400.8	311.2	500.2
Spring (mean)	279.6 (93.2)	606.0	382.4 (127.5)	695.4

3.4 Water quality

3.4.1 Continuous records

During the spring period, there was a loss of turbidity and dissolved oxygen data from the continuous records from the upstream Angle Crossing gauging station (Figure 3; Table 8). These parameters have been affected previously at this site due to silt deposits on the sensor following high flow events. Monthly site maintenance and calibrations removed this issue and the parameters are currently recording normally.

Prior to the Tantangara environmental flow release, lightening damaged the pH sensor at Lobb's Hole resulting in a period of 24 days without continuous records (Figure 4; Table 8). The pH sensor was removed for repair and was reinstated when a replacement was available. The hydrolab at Lobb's Hole is particularly susceptible to lightening damage, despite being equipped with resin-potted lightening protection.

Table 8. Details of the issues concerning individual water quality parameters upstream of Angle Crossing (MURWQ09) and Lobb's Hole (410761) during spring

Parameter	Station	Missing data	Issue	Current Status
Turbidity	MURWQ09	14 days	Silt deposits on sensor following high flow event	Functional, following monthly calibration
Dissolved Oxygen	MURWQ09	22 days	Silt deposits on sensor following high flow event	Functional, following monthly calibration
pH	410761	24 days	Lightning damage	Repaired - Functional

Aside from these outlined issues (above), turbidity readings throughout the spring period was within the ANZECC & ARMCANZ guidelines 59.3% of the time upstream of Angle Crossing and 91.33% of the time at Lobb's Hole (Table 10). The exceedances at Lobb's Hole were during the middle of October and also the end of November, which correspond to the flow release for Tantangara Reservoir during October and the intense rainfall event at the end of November (Figure 3). The initial elevated turbidity levels upstream of Angle Crossing during November are due to a short intense rainfall where a small increase in flow created a turbidity spike which, while outside guideline levels was relatively small. This spike was then followed at the end of November by a larger increase in turbidity in response to the large rainfall event and subsequent flow increase.

All monthly mean pH readings were within ANZECC and ARMCANZ guidelines (Tables 9 & 10). However, at Lobb's Hole, daily mean values exceeded the guideline 18 days during November, while the upstream site by comparison had 2 days of daily mean value exceedances. The downstream site also showed a consistent slightly elevated pH level to that of the upstream site.

The temperature at both of these sites is highly correlated, which corresponds to the increasing ambient temperatures increasing towards the beginning of summer. Similarly, the electrical conductivity values were all within the ANZECC & ARMCANZ guidelines (2000) (Figures 4 & 5).

Dissolved oxygen levels at Lobb's Hole were stable and reading within the guidelines for the whole period (95.15-100.86 %). Readings upstream of Angle Crossing were more variable (88.72-109.86 %), but mean daily values were outside guideline levels of 90-110 for only 2 days.

3.4.2 Grab Samples

The water quality results from the grab samples taken during the macroinvertebrate sampling show that most physico-chemical parameters were within the ANZECC & ARMCANZ guidelines (2000). The exceptions to this was the turbidity at MUR 15 which is slightly elevated above guideline levels, while the pH at the two most downstream sites also showed elevated levels slightly above guidelines. There was also the exceedance of the DO guidelines (albeit very minor) at site MUR 23 reading 110.1 % above the guideline level of 110 % (Table 11).

Total nitrogen (TN) and total phosphorus (TP) levels exceeded the guideline values at all monitoring sites during the spring sampling run (Table 10). MUR 15 showed the most elevated nutrient levels of all sites recording 0.056 mg/L for TP and 0.38 mg/L for TN with guideline levels of 0.02 mg/L and 0.25 mg/L respectively. Despite these extreme levels of elevation, both TP and TN are lower across all sites, with the exception of TP at MUR 23, compared to spring sampling in 2010.

Table 9. Monthly water quality statistics from upstream (MURWQ09) and downstream (410761) of Angle Crossing. All values are means, except D.O. % Sat. which is expressed as mean monthly minimums and maximums. Maximum values for turbidity are in parentheses

Analyte	Temp. ℃		EC (uS/cm) 30-350		pH 6.5-8.0		Turbidity (NTU) 2-25		D.O (% sat.) 90-110	
	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S
Sept.	12.49	12.63	69.29	78.51	7.69	7.69	6.78 (25.51)	8.45 (12.13)	90.05-109.86	97.06-100.86
Oct.	15.80	15.96	61.72	76.76	7.31	7.63	16.96 (27.79)	20.03 (31.48)	89.08-96.38	96.63-100.62
Nov.	20.71	20.86	64.65	85.54	7.57	7.86	38.32 (156.37)	12.57 (92.28)	88.72-97.98	95.15-99.11
Spring	16.33	16.48	65.22	80.27	7.52	7.73	20.69	13.68	88.72-109.86	95.15-100.86

U/S –upstream; D/S - downstream

Table 10. Compliance (%) to ANZECC and ARMCANZ (2000) guideline values from the continuous gauging stations upstream (MURWQ09) and downstream (410761) of Angle Crossing

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

Analyte	EC (us/cm)		pH		Turbidity (NTU)		D.O (% sat.)	
	U/S	D/S	U/S	D/S[1]	U/S[2]	D/S	U/S[3]	D/S
September	100	100	100	100	53.33	100	100	100
October	100	100	100	100	95	80.65	93.75	100
November	100	100	93.33	100	29.63	93.33	95.45	100
Spring	100	100	97.78	100	59.32	91.33	96.40	100

Note: There are currently no guidelines available for water temperature

- [1] Using available data, does not include 11 days in September and 13 days in October
- [2] Using available data, does not include 11 days in October and 3 days in November
- [3] Using available data, does not include 15 days in October and 7 days in November

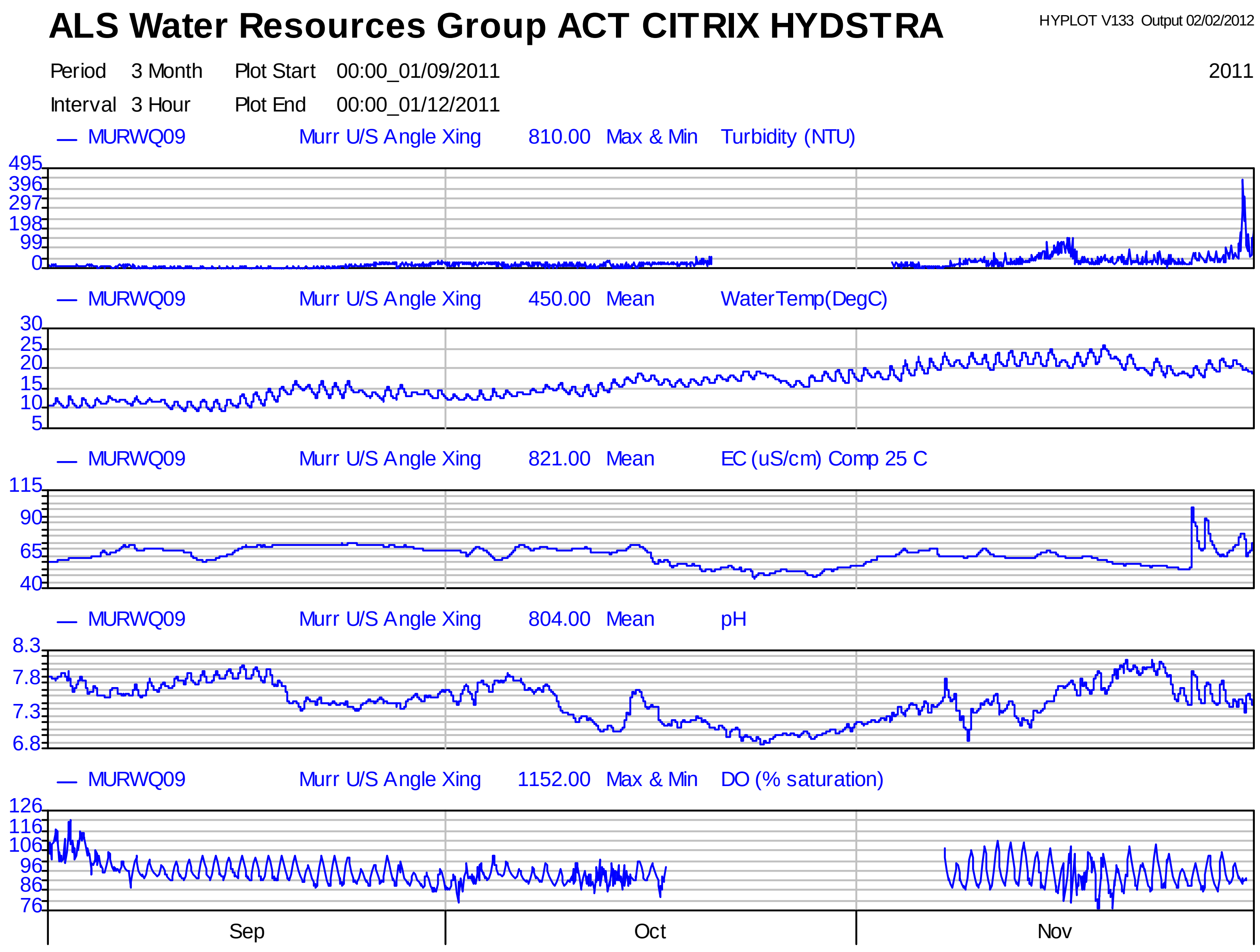

Figure 4. Continuous water quality records from upstream Angle Crossing (MURWQ09) for spring 2011

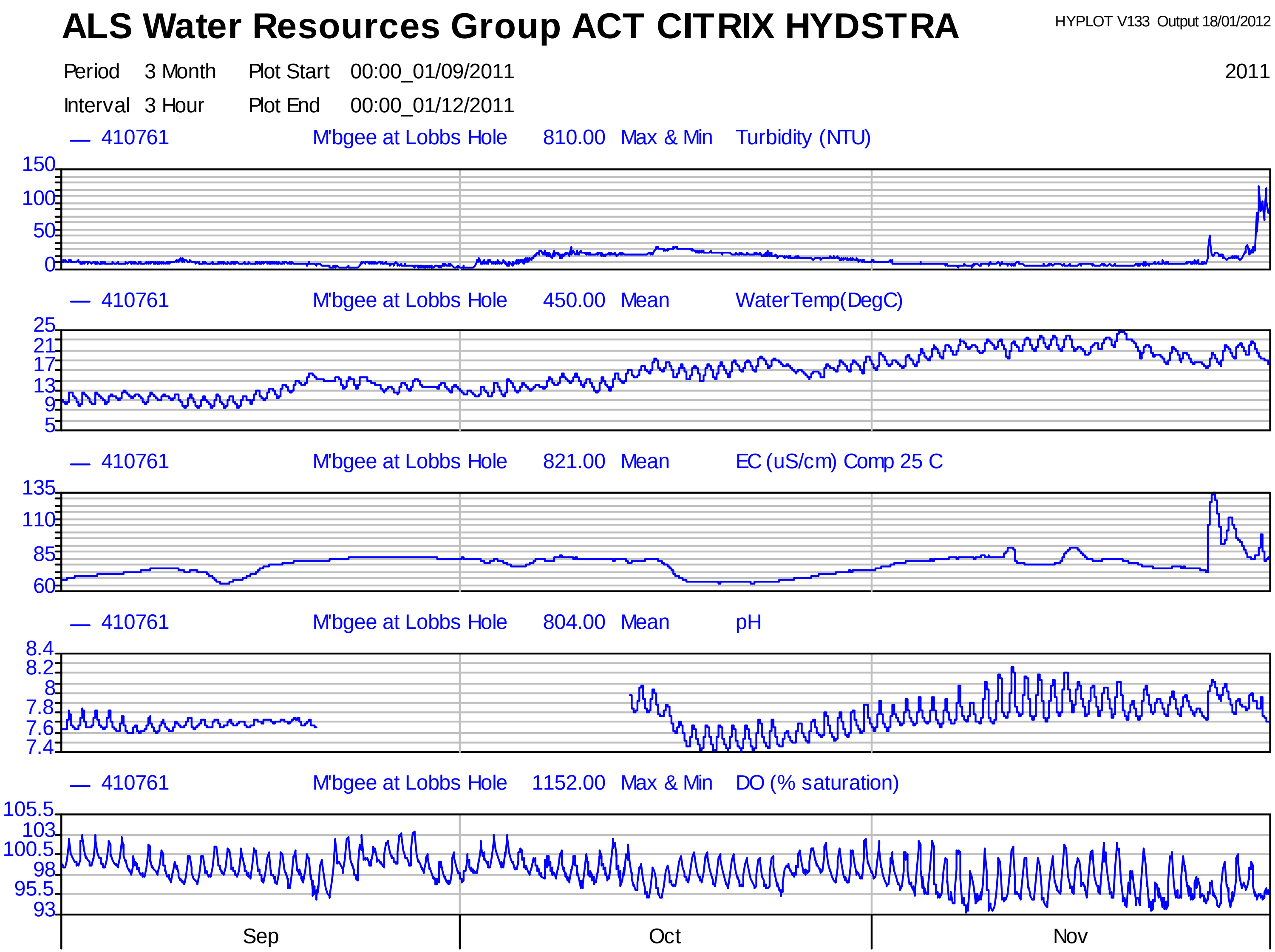

Figure 5. Continuous water quality records from Lobb's Hole (downstream Angle Crossing: 410761) for spring 2011

Table 11. In-situ water quality results from spring 2011

ANZECC guidelines are in bold parentheses. Yellow cells indicate values outside of ANZECC and ARMCANZ (2000) guidelines. Orange cells indicate value is on the cusp of the guideline.

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

Location	Site	Time Date	Temp (℃)	EC (µs/cm) **(30-350)**	Turb. (NTU) **(2-25)**	TSS (mg/L)	pH **(6.5-8)**	D.O. (% Sat.) **(90-110)**	Dissolved Oxygen (mg/L)	Alk.	NOX (mg/L) **(0.015)**	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L) **(0.02)**	TN (mg/L) **(0.25)**
Control sites	MUR 15	0910 11/11/11	20.7	84.5	32	29	7.83	99.2	8.12	36.0	0.009	0.007	<0.002	0.007	0.056	0.38
	MUR 16	1220 11/11/11	21.5	73.2	15	18	7.88	104.2	8.42	31.0	0.003	0.001	<0.002	0.007	0.036	0.32
	MUR 18	1030 10/11/11	21.1	77.7	14	17	7.71	97.7	8.04	31.6	0.01	0.008	<0.002	<0.002	0.030	0.32
Downstream sites	MUR 19	0910 10/11/11	21.2	72.9	13	14	7.55	94.2	7.66	30.6	0.01	0.008	<0.002	<0.002	0.030	0.31
	MUR 23	1450 11/11/11	22.7	83.0	15	20	8.10	110.1	8.68	36.0	0.003	0.001	<0.002	<0.002	0.040	0.37
	MUR 28	1425 9/11/11	23.5	77.6	11	16	8.08	107.1	8.21	33.2	0.005	<0.002	<0.002	<0.002	0.029	0.31

3.5 Periphyton

There was some evidence of a location effect on chlorophyll-*a* concentrations (Table 12); with the location factor explaining 47.1% of the variation in chlorophyll-a concentrations. However, at our predetermined alpha value of 0.05, these differences were not statistically significant ($F_{1,4}$ = 6.01; P=0.07).

There is an obvious increase in mean concentrations with distance downstream (Figure 5). Chlorophyll- a concentrations averaged between 1280 and 2900 µg/m^{-2} at sites MUR 15, 16, 18 and 19 then markedly increased to 10338 and 14167 µg/m^{-2} at MUR 23 and MUR 28 respectively.

There was no such pattern in the ash free dry mass data (Figure 6), which, aside from elevated organic content at MUR 18 follows a reasonably homogenous distribution among all sites. There was no difference between locations in the AFDM analysis ($F_{1,4}$ = 0.006; P=0.93; Table 12). Less than 1% of the total variation in AFDM was attributed to variation within location, while 99% was attributed to site to site variation, regardless of the sites location.

Ash free dry mass concentrations during this sampling run were in a similar range to those collected in spring 2010, however chlorophyll-a concentrations were notably lower upstream and including Angle Crossing (i.e. MUR 15, 16, 18 and 19) compared to spring 2010. At Mur 23 and MUR 28 however, the values recorded here are slightly higher than the maximums for spring 2010 although it should be noted that MUR 28 was not sampled in spring 2010 so no data are available for comparison at that site

Table 12. Nested analysis of variance results for chlorophyll-a and AFDM concentration

Response	Source	DF	F-value	P-value
Chlorophyll-*a* (log)	Location	1	6.01	0.07
	Site [Location]	4	5.72	<0.001
	Residual	35		
AFDM (log)	Location	1	0.006	0.93
	Site [Location]	4	1.052	0.39
	Residual	35		

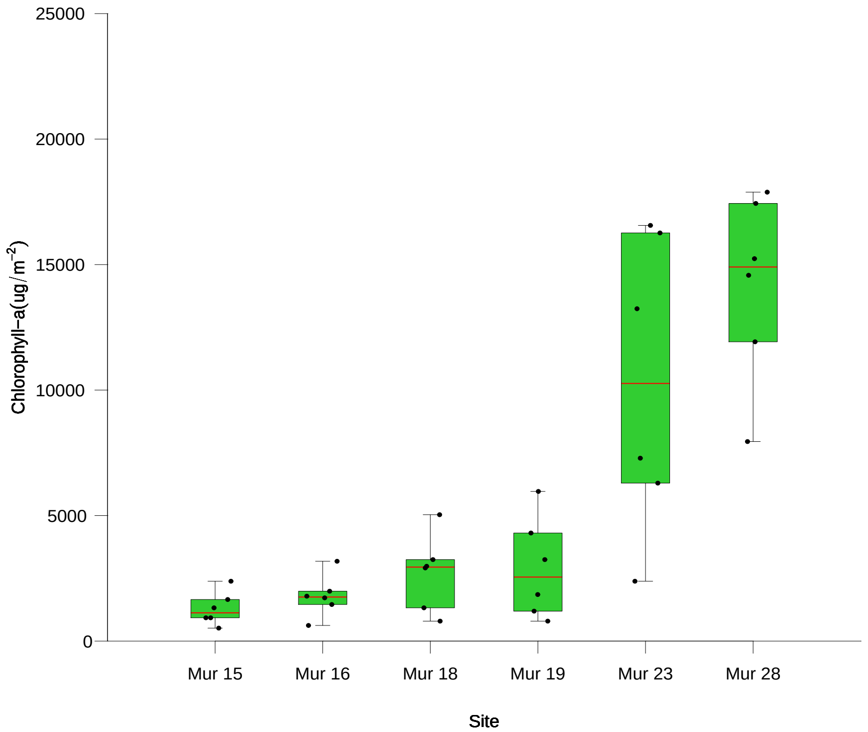

Figure 6. The distribution of Chlorophyll-a upstream and downstream of Angle Crossing. Strip chart values (in black) represent the raw data values for each site.

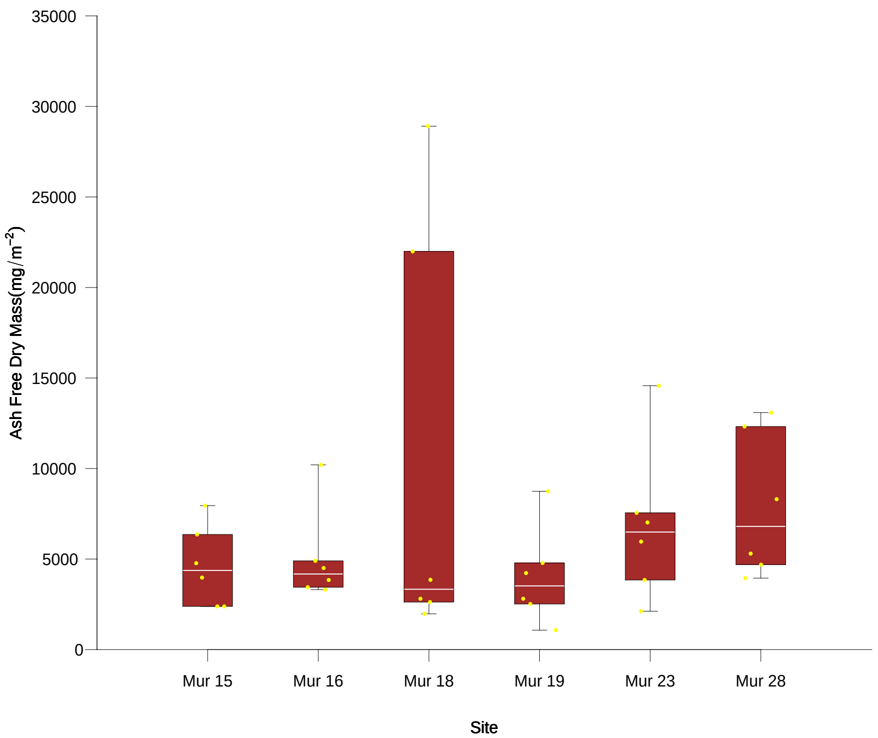

Figure 7. The distribution of Ash Free Dry Mass upstream and downstream of Angle Crossing Strip chart values (in yellow) represent the raw data values for each site (See APPENDIX B for an explanation of how to interpret box and whisker plots)

3.6 Macroinvertebrate communities

3.6.1 Riffles

Macroinvertebrate communities were not statistically different between locations (R=0.11; P=0.4). MUR 19 (immediately downstream of Angle Crossing) falls within the 60% similarity ellipse of the main group in the NMDS plot (Figure 8) which has resulted in the low R value[1]. Point Hut Crossing (MUR 23) and the site upstream of the Cotter River confluence (MUR 28) appeared to differ from the main group. The similarity measurement (indicated by the ellipses) between these sites and the main group indicate that there is approximately 10% difference between them. At MUR 23, this appears to be caused by a high proportional representation of the family: Hydropsychidae (SIGNAL=6), which on average makes up 51% of the total relative number of taxa collected. This can be seen in Figure 8, where MUR 23 has a distinct increase in the proportion of "sensitive' taxa - primarily comprising EPT taxa – of which, the Hydropsycids are members. MUR 28, on the hand differs mainly in a similar dominance of the Dipteran family: Orthocladiinae (SIGNAL=4) and Simuliidae (SIGNAL=5) - together accounting for 57% of the community composition.

The communities amongst all samples collected were dominated by moderately to more tolerant taxa, which can be seen in the relative abundance percentages in Figure 9. As previously explained, MUR 23 was the exception (a pattern commonly found in this program) with a very high proportion of Hydropsycids, which even though have a moderate SIGNAl-2 score of 6, are included as sensitive taxa as part of the EPT metric. The remaining sites were dominated by three key groups with SIGNAL-2 scores ranging from 2-5. These include: Simuliidae, Oligochaeta and Chironomidae. The composition of these communities is very similar to previous sampling runs, although there does appear to be more Gripopterygidae (Stoneflies) in the samples and at more sites compared to spring 2010.

Taxa richness at the family level ranged from 16 to 21 and 26-32 at the genus level. MUR 16 had the fewest number of families (16) while MUR 28 had the fewest genera (Figure 9). There was less variation in the number of EPT taxa (Mayflies (Ephemeroptera), Stoneflies (Plecoptera) and Caddis flies (Trichoptera)) collected during spring, with the total number of families ranging from 7-9; however, the ranged was slightly broader at the genus level (13-17). MUR 28 had the least number of families and genera from the EPT group (Figure 10). These richness scores, both total richness and EPT richness are comparable to spring 2010. Both sampling runs show no discernable pattern among sites with respect to these metrics, which is again reflected in Figure 8 where there is a high degree of similarity among sites.

[1] Recall that R values tending toward 1 indicate that members of a given group are more similar to one another than they are to members from other groups. Hence, low R values suggest that some members of a group (here: upstream versus downstream) are more similar to members of a different group than they are to members in their own group

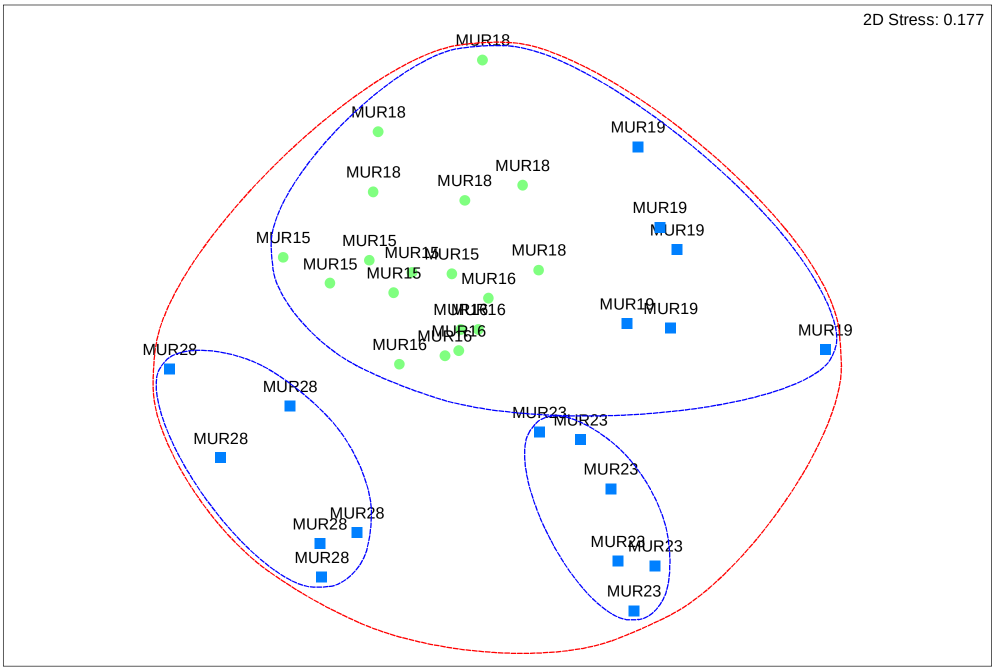

Figure 8. Non-metric multidimensional scaling of genus data from the spring riffle samples
The red ellipse represents the 50% similarity groups and the blue ellipses represent 60%; green circles are upstream of Angle Crossing, blue squares are downstream

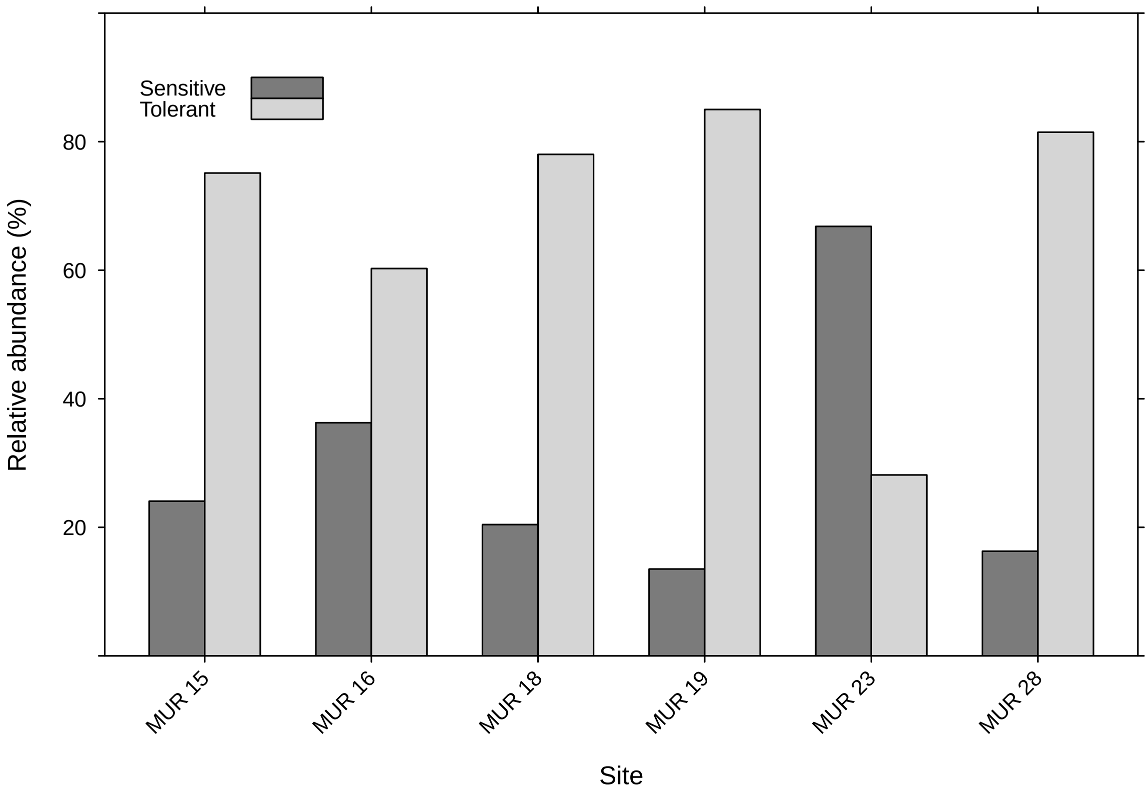

Figure 9. Average relative abundances of sensitive and tolerant taxa from sites upstream and downstream of Angle Crossing

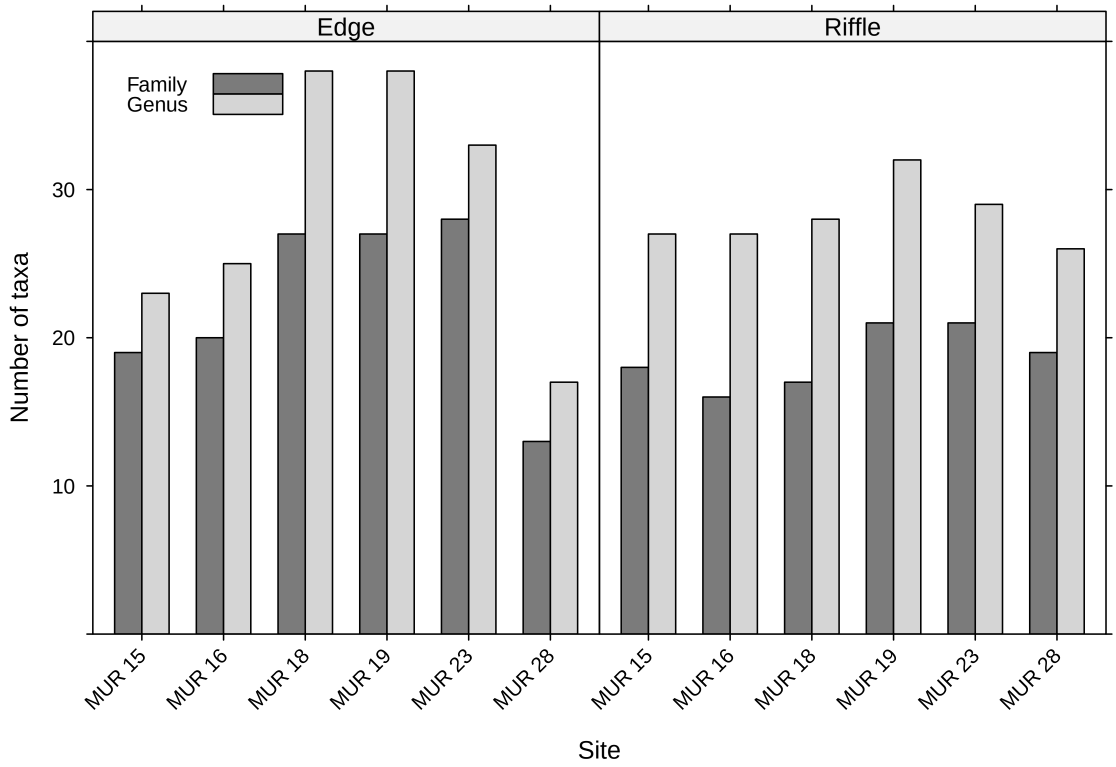

Figure 10. Total number of taxa at genus and family levels in the riffle and edge habitat

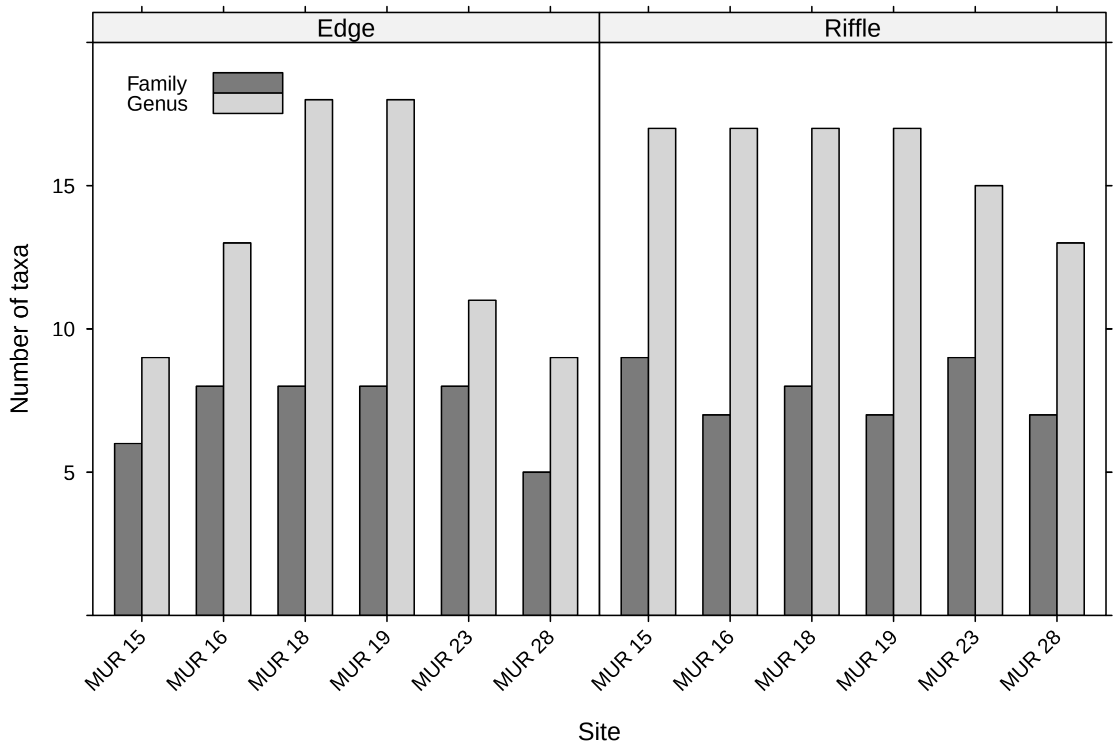

Figure 11. Total number of EPT taxa at genus and family levels in the riffle and edge habitat

3.6.1 Edge

The two sites immediately upstream and downstream of Angle Crossing (MUR 18 and 19 respectively) had the highest genus richness value of 38 (Figure 10). The most number of families was collected at MUR 23 (28). MUR 28 had the least number of taxa at the family level (13) and the genus level (17). Sensitive EPT taxa were also highest at sites MUR 18 and 19 (Figure 11), which was due to an increase in mayfly diversity at these two sites.

Based on the whole community data, the multivariate analysis shows no location difference in the edge communities (R = -0.148; P = 0.8) as was the case with the riffle communities. The negative R coefficient indicates that there are some sites that are more similar in their assemblages to sites in a different location, than to other sites within the same location. The NMDS plot (Figure 12) demonstrates this with position of MUR 19 for example in relation to MUR 16 and 18 in relation to other downstream sites (i.e. MUR 23). The position of MUR 15 is largely driven by a lower numbers of the silt-tolerant mayfly, Caenidae (Signal=4) compared to all other sites and fewer Corixidae (water boatmen) (SIGNAL=2).

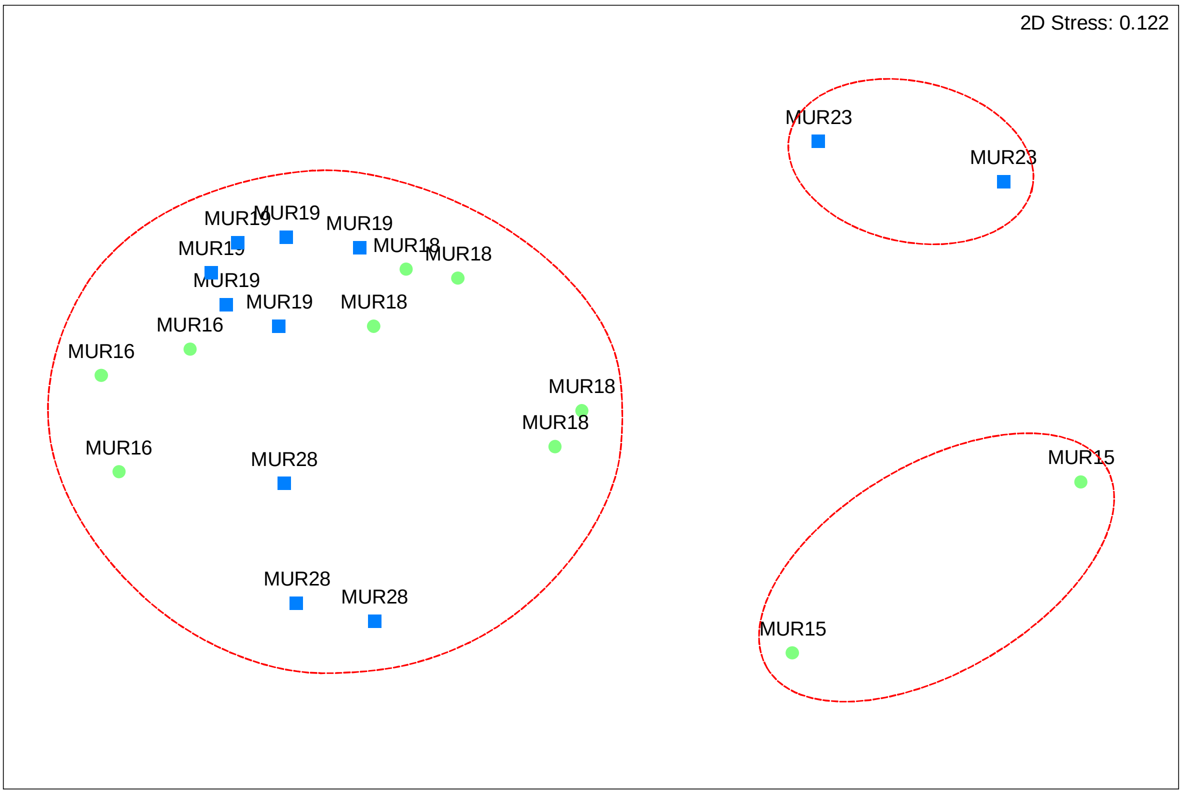

Figure 12. Non-metric multidimensional scaling of genus level data from spring edge samples
Ellipses represent the 60% similarity groups superimposed from the cluster analysis (above)

3.7 AUSRIVAS Assessment

Compared to spring 2010, the current assessment indicates improvements at all sites (where reliable comparisons were possible) (Table 14) except for MUR 28, which showed no change. There were two sites assessed as *"close to reference"* (BAND A) and four assessed as *"significantly impaired"* (BAND B) (Table 13). At the individual habitat level, four of the riffles and three edges were assessed as *"close to reference"* (BAND A) (Table 13). The BAND A riffles were at MUR 15, 16, 19 and 23, while the BAND A edges were at MUR 16, 18 and 19.

There was no obvious pattern in the AUSRIVAS bands allocated to the riffle habitat (Figure 13) except that there appears to be a drop in the average OE/50 score and the average SIGNAL-2 score at MUR 28. Despite this, there was no difference in either the OE/50 score upstream of Angle Crossing compared to downstream of the crossing ($F_{1,4}$=0.11; P=0.75) or the SIGNAL-2 scores ($F_{1,4}$=0.15; P=0.71; Table 15) even though the decrease seen at MUR 28 lowered the downstream average of both measurements.

The OE/50 and SIGNAL-2 scores collated from the edge samples tended to increase from MUR 15 downstream to MUR 19, but then declined at MUR 23 reaching their lowest values at MUR 28 (0.81 and 4.06 respectively; Figure 14); however both the OE/50 ($F_{1,4}$=0.04; P=0.85) and SIGNAL-2 ($F_{1,4}$=0.046; P=0.84) measurements were not different between locations (Table 16).

The number of missing taxa from spring 2011 ranged from 4 (at the close to reference sites) to 8 (upstream of the Cotter confluence at MUR 28) (APPENDIX D). Conoesucidae (SIGNAL=7) and Glossosomatidae (SIGNAL=9), both sensitive Caddisfly larvae, were missing from all sampling sites in this sampling run; but are yet to be collected from any site in the Angle Crossing programme, since it began in 2008, in spite of having probabilities ranging from 51 – 75% attached to their chance of collection (APPENDIX D). Compared to spring 2010, we found more Elmidae (SIGNAL=7) especially at MUR 19 and MUR 23. Leptophlebiidae (SIGNAL=8) were mostly absent from MUR 28. The most obvious change however, was the absence of Hydrobiosidae (SIGNAL=8) (Trichoptera) from 81% of the samples. This Caddisfly was completely absent from MUR 16 and MUR 28 and was rare at the remaining sites (occurring in only 7 sub-samples).

The number of missing taxa from the edge samples ranged from 0-5. MUR 15 and MUR 28 had the most number of missing taxa whereas MUR 19 had the least. The inventory of missing taxa (APPENDIX D), suggests for the most part that these were low-moderately tolerant taxa with SIGNAL -2 scores ranging from 2-6. The most sensitive taxa missing from these samples included the stonefly, Gripopterygidae (SIGNAL=8) at MUR 28 and the sensitive mayfly (Leptophlebiidae: SIGNAL=8).

Table 13. Comparison of overall site assessments based on AUSRIVAS Bands between spring 2011 and the two previous monitoring runs

Site	Current (Spring 2011)	autumn 2011	spring 2010
MUR 15	B	B	NRA
MUR 16	A	B	C
MUR 18	B	B	NRA
MUR 19	A	A	C
MUR 23	B	B	B
MUR 28	B	B	NS

*NRA – no reliable assessment; †NS – not sampled

Table 14. AUSRIVAS and SIGNAL scores for spring 2011

= 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 15	1	4.91	4.25	0.88	0.89	A	A	A	B	B
Mur 15	2	5.25		0.96		A				
Mur 15	3	5.00		0.88		A				
Mur 15	4	5.09	4.17	0.88	0.66	A	B			
Mur 15	5	5.00		0.96		A				
Mur 15	6	5.23		1.04		A				
Mur 16	1	5.00	4.20	0.96	1.11	A	A	A	A	A
Mur 16	2	5.00	4.00	0.96	0.89	A	A			
Mur 16	3	5.00	4.50	0.96	0.89	A	A			
Mur 16	4	5.09		0.88		A				
Mur 16	5	5.00		0.96		A				
Mur 16	6	4.73		0.88		A				
Mur 18	1	5.00	4.50	0.85	1.11	B	A	B	A	B
Mur 18	2	5.00	4.50	0.85	1.11	B	A			
Mur 18	3	4.70	4.50	0.77	1.11	B	A			
Mur 18	4	5.17	4.22	0.92	1.00	A	A			
Mur 18	5	5.00	4.60	0.77	1.11	B	A			
Mur 18	6	4.56		0.69		B				
Mur 19	1	5.42	4.20	0.93	1.11	A	A	A	A	A
Mur 19	2	5.18	4.55	0.86	1.22	A	X			
Mur 19	3	5.42	4.55	0.93	1.22	A	X			
Mur 19	4	4.73	4.60	0.86	1.11	A	A			
Mur 19	5	5.27	4.55	0.86	1.22	A	X			
Mur 19	6	5.27	4.56	0.86	1.00	A	A			
Mur 23	1	5.27	4.60	0.88	1.11	A	A	A	B	B
Mur 23	2	5.50		0.96		A				
Mur 23	3	5.25		0.96		A				
Mur 23	4	5.15	3.57	1.04	0.78	A	B			
Mur 23	5	5.15		1.04		A				
Mur 23	6	5.31		1.04		A				
Mur 28	1	4.80	4.14	0.75	0.78	B	B	B	B	B
Mur 28	2	4.70	3.83	0.75	0.66	B	B			
Mur 28	3	4.44	4.22	0.68	1.00	B	A			
Mur 28	4	4.78		0.68		B				
Mur 28	5	4.44		0.68		B				
Mur 28	6	5.00		0.75		B				

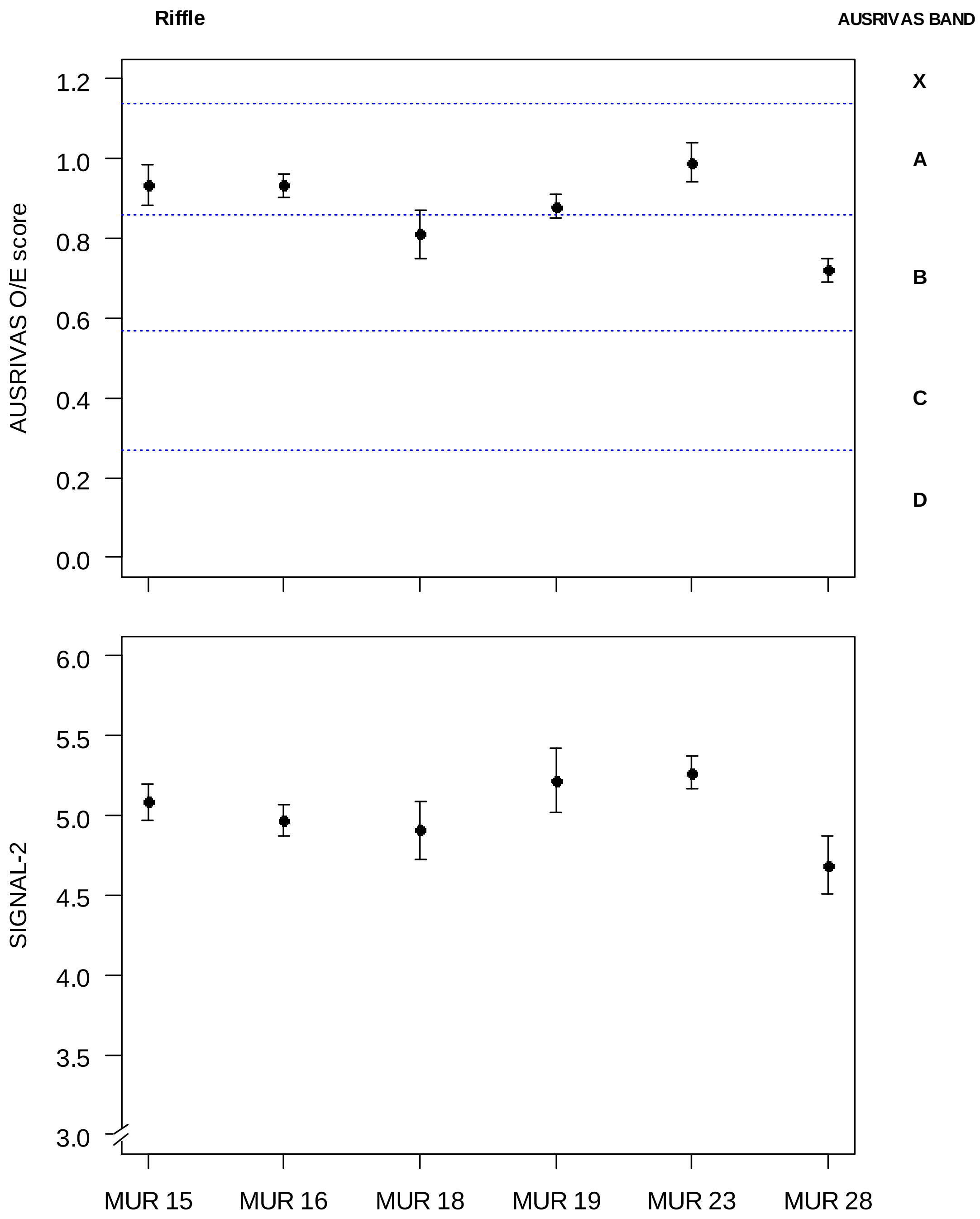

Figure 13. Average AUSRIVAS OE50 scores (top) and average SIGNAL-2 scores for RIFFLE samples upstream and downstream of Angle Crossing

Error bars are 95% confidence intervals

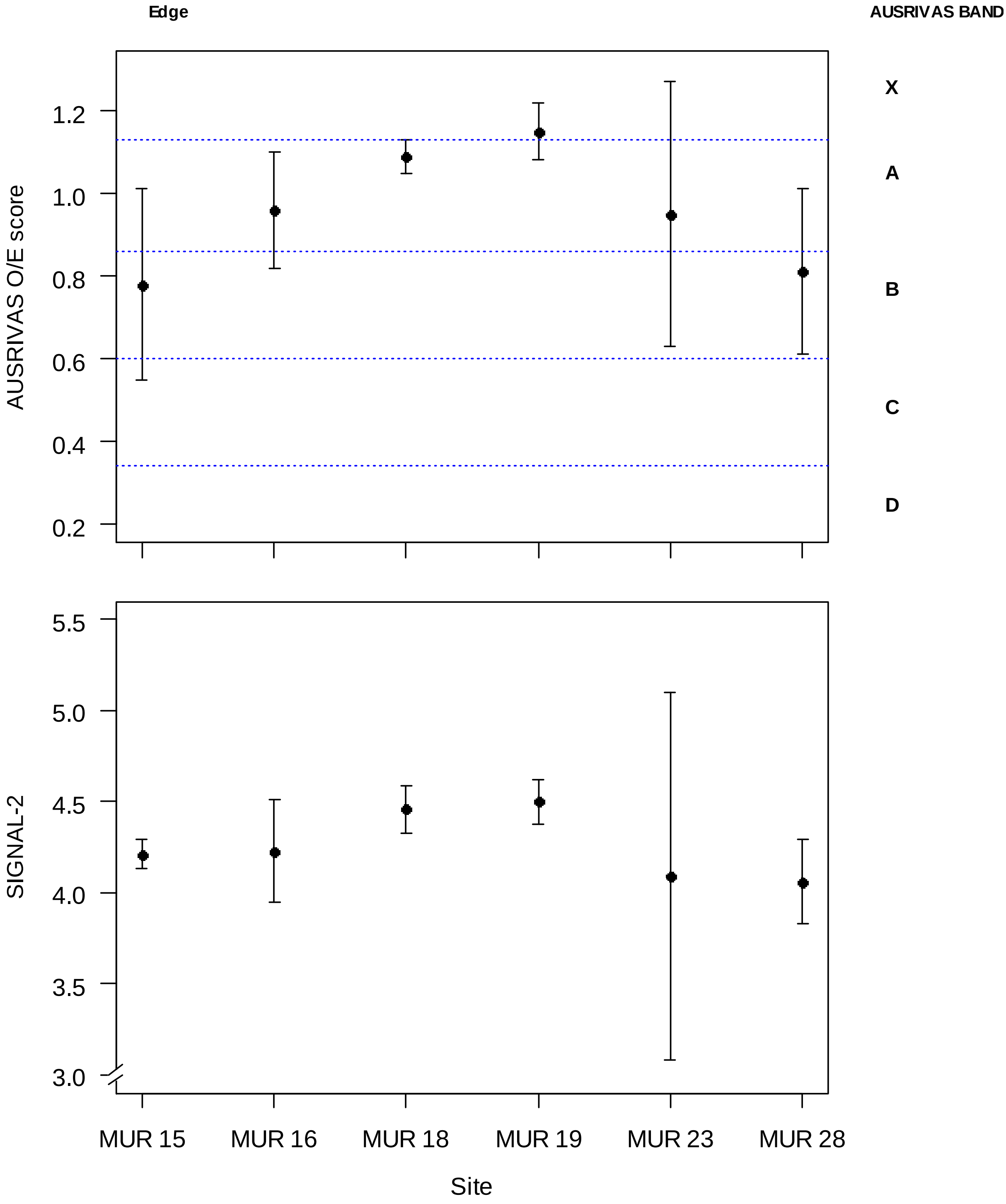

Figure 14. Average AUSRIVAS OE50 scores (top) and SIGNAL-2 scores for EDGE samples upstream and downstream of Angle Crossing

Error bars are 95% confidence intervals

Table 15. Nested analysis of variance table from the riffle samples, based on OE50 and SIGNAL scores

Response	Source	DF	F-value	P-value
OE 50	Location	1	0.11	0.75
	Site [Location]	4	22.05	<0.001
	Residual	35		
SIGNAL -2	Location	1	0.15	0.71
	Site [Location]	4	9.13	<0.001
	Residual	35		

Table 16. Nested analysis of variance table from the edge samples, based on OE50 and SIGNAL scores

Response	Source	DF	F-value	P-value
OE 50	Location	1	0.04	0.84
	Site [Location]	4	6.37	<0.001
	Residual	20		
SIGNAL-2	Location	1	0.04	0.84
	Site [Location]	4	2.59	0.07
	Residual			

4 Discussion

The aim of this monitoring program is to obtain baseline information to include: hydrological, biological and physico-chemical water quality information, which will help establish spatial and temporal trends up and downstream of Angle Crossing (Table 2). An additional objective of this baseline monitoring period is to consider potential impacts of the construction phase of the M2G project which is now under way.

4.1 Water Quality

The water quality data did not show any indication that it was being impacted by the construction works at Angle Crossing. Patterns in all the water quality parameters, upstream and downstream of Angle Crossing were indicative of flow and seasonal responses rather than construction related disturbances (Figures 4 & 5). If there had have been changes in the water quality parameters due to the M2G construction works, then the most likely detection of these changes would have been seen in the in the time series plots downstream of Angle Crossing that were not seen at MURWQ09, upstream of the crossing. However, over the course of spring, monthly and daily fluctuations in the majority of the parameters were mirrored at both gauging stations (Figures 4 & 5).

Over the course of spring the overall trend in the water quality parameters was consistent with changes in flow (Figure 3) and the succession into summer (Figures 4 & 5). Not one of the turbidity spikes were unique to the downstream sites, indicating that sporadic high flows events and the extended environmental flow release from the Tantangara Reservoir in mid- October were responsible for these patterns; and in terms of compliance with the ANZECC & ARMCANZ (2000) guidelines, turbidity was above the guidelines for extended periods at both sites (Table 9) which coincides with the flow release. It should be noted that the upstream site was outside of the guidelines 41% of the spring compared to downstream which fell outside of the 2-25 NTU limits 9% of the time.

The majority of the turbidity exceedances upstream of Angle Crossing occurred following the environmental flow release. The reason for this occurring while Lobb's Hole – downstream of Angle Crossing – had higher compliance percentages for turbidity, is likely due to the position of the Hydrolab, which is situated in relatively shallow water (<1m) and close to the river bank. As the flows receded, sediments in the water column probably settled out around the Hydrolab causing these turbidity spikes.

Plate 6. Position of the Hydrolab at MURWQ09

The *physico-chemical* results from the grab samples also were for the most part, within the guideline values (Table 11). Some exceedances occurred at MUR 15, 23 and 28, but these were small deviations that naturally occur during the daily cycles. Nutrient concentrations (total phosphorus and total nitrogen) were above the upper limits at all sampling sites (Table 11). In past reports we have suggested that background levels are likely to be high in this section of the Murrumbidgee River because of extensive agricultural land use upstream and increasing urbanisation beyond MUR 19. These values therefore, despite being above the recommended guidelines are not excessively high compared to the data collected so far in this monitoring program.

4.2 Periphyton

Neither the ash free dry mass nor chlorophyll-a concentrations were found to differ between locations (Table 12). However, the distribution of the concentrations showed a ramped increase at MUR 23 (Point Hut Crossing) which continued downstream to MUR 28 (Figure 6 & 7).

Comparable to previous sampling runs it is difficult to attribute these patterns to single causal factor because of the observational nature of this sampling design. There is certainly a relationship between ash free dry mass and chlorophyll-a concentrations with season (i.e. higher concentrations in autumn); which we attribute to seasonal differences in mean flow and the coefficient of variation (acting as a proxy for stability). Regardless of season however, we are finding that concentrations are considerably higher downstream of Point Hut Crossing on a regular basis, suggesting other factors other than flow which are also determining these patterns.

We reiterate from previous reports that due to the location of our sampling site at Point Hut crossing that the likely reason for these steep increases at MUR 23 (which continue downstream) is nutrient delivery from the point hut pond spill-way during rainfall events. However, based on the spring hydrographs for Lobb's Hole and Point Hut Pond (APPENDIX E) it is again difficult to form an association given that the last spill of significance was in August. The quantitative site information shows that amongst all sites, filamentous algae was low (<10%) and at some sites, was absent altogether, this would indicate that the chlorophyll-a was not necessarily algal derived at MUR 23 and MUR 28 – and this certainly agrees with our observations and the AFDM from the periphyton samples.

At MUR 23 and MUR 28 there were noticeable differences in the submerged macrophyte categories (dominated by *Myriophyllum sp.*) with 15% and 20 % coverage being estimated for each site respectively. It is unclear why there was more macrophyte growth at these sites, but the reasons associated with nutrient delivery and uptake at MUR 23 (discussed above) would still apply to macrophyte growth

There was a low association between the AFDM results and chlorophyll-a results suggesting that there was minimal algal derived chlorophyll-a content in the periphyton. Variation in chlorophyll-a and AFDM estimates are inevitable due to site to site variation in physical structure as well as those factors already discussed (i.e. flow, nutrients and other water quality parameters). We have only found weak associations between the chlorophyll-a & AFDM with both abiotic and biotic factors in this round of sampling even though in previous studies we have shown both positive and negative relationships with current velocity (ALS, 2011*b*). Although we suspect nutrients are driving these patterns, we suspect there is a lag effect between nutrient delivery - to plant uptake - to growth - to when we collect the data which inhibits us from detecting these trends.

Despite the increased algae and macrophyte growth found downstream of MUR 23, there have been few reports or personal observations of nuisance growths so far; however during low flows in autumn 2009, the percentage of filamentous coverage was noted as being higher than during any other time in the project but was subsequently removed by the time spring base flows had returned. In terms of the M2G project, these points require some consideration when discussions concerning the timing and duration water abstractions are held because they may need to be adjusted on a seasonal basis to consider all abiotic and biotic factors influencing these patterns of AFDM and chlorophyll-a concentrations; especially downstream of Point Hut Crossing.

4.2 Macroinvertebrate communities and AUSRIVAS assessment

Prior to the spring sampling run, there was an environmental flow release in mid-October lasting 10 days which was maintained at just below 2000 ML/d over that period. Following the release it was apparent from our field observations that there was a reduction of fine silts in the riffle zone and macrophytes were sparse, if not absent in this habitat (except at MUR 23 and 28).

Macroinvertebrate communities did not differ significantly between sites nested within upstream and downstream locations (Table 15 & 16), although there was some indication that there were differences at specific sites (MUR 23 and 28 for the riffle data; MUR 23 and 15 for the edge data). The non-significant result is not surprising since the ~2000 ML/d environmental flow release is likely to have had a homogenising affect upon all of the sites in this assessment. Lake (2000) suggests that high flow events act as a re-set mechanism on benthic macroinvertebrate communities and as such would increase similarities amongst sampling sites. This is because high flow events tend to connect sampling sites and create similar hydrological characteristics amongst these sites during the high flow period (Figure 3) thereby reducing spatial variability (Thomaz *et al.*, 2007). Consequently, the macroinvertebrate communities are exposed to similar conditions which should, in the absence of other overriding factors result in similar community assemblages following the event.

Riffle communities were 60% similar in the main group and the two outlying sites (MUR 23 and MUR 28) combined with the main group was approximately 50% similar in their community structure. If the environmental flow release did have an overriding homogenizing effect upon all of the sampling sites, then the compositional changes occurring at MUR 23 and MUR 28 must have occurred in the 17 day period following the end of the release, when the samples were collected. The differences seen at these sites are largely driven by high estimated abundances of Orthocladiinae at MUR 28, and Hydropsychidae at MUR 23.

Orthocladiinae (non-biting midges) were the dominant group at MUR 28 resulting in its deviation from the main group of sites in the NMDS plot (Figure 8). The estimated abundance of this sub-family of non-biting midges (Family: Chironomidae) increased markedly with distance downstream, in a similar fashion to the spatial pattern of the chlorophyll-a concentrations. The reason this was investigated was because Orthocladiinae are algal grazers (Gooderham and Tsyrlin, 2005), so if the food supply (i.e. chlorophyll-a as a proxy for algal biomass) increases, then in theory so too should the production of the grazers. Hydropsychidae (net-spinning caddis) have often been found to be the dominant taxa at Point Hut Crossing, and in this study for example, make up a considerable proportion of the estimated relative abundance of sensitive taxa[2] shown in Figure 8. The reason for the regular dominance of this taxa at MUR 23 is not yet definitive, but based on several lines of evidence including observational data, periphyton data, point hut pond hydrographs and other research – which has shown that Hydropsycids proliferate in nutrient enriched environments (Wiederholm, 1984) – we suggest that this linked to the location of the site and the constant nutrient delivery via the Point Hut Pond spillway during high flow events.

Aside from MUR 23 and MUR 28, there was a high degree of similarity (60%) amongst the main group which was characterised by moderately tolerant taxa processing traits that either facilitate a degree of resistance to high flow events, such as Chironomids and Oligochaetes which are sediment dwellers or taxa that are rapid colonisers following high flow disturbances such as Simuliidae. These patterns have been observed in previous sampling runs where recent high flow disturbances have occurred. In previous studies we have found that following high flow disturbances Simulids and Chironomidae dominate the community structure amongst all sampling sites which is indicative of early stage succession (Collier and Quinn, 2003; Niemi *et al.*, 1990).

[2] Technically Hydropsychidae is a moderately sensitive macroinvertebrate with a SIGNAL -2 score of 6. However because they belong to the EPT group they are included. ALS suggest sub-setting this univariate metric into sensitive taxa with SIGNAL-2 scores of >7 for a better indication of the diversity of the highly sensitive macroinvertebrates

The AUSRIVAS assessment did not reveal location differences in the observed to the expected taxa ratio's for either the riffle or the edge habitats (Tables 15 and 16). Most of the missing taxa occurred amongst all sampling sites, (i.e. no uniquely missing bugs) which again is indicative of a uniform disturbance influencing all of the sites in a similar way (APPENDIX D). One exception to this was the riffle beetle, Elmidae (SIGNAL=7) which was not collected at all upstream of Angle Crossing, but then specimens were found at all sites downstream of Angle Crossing. This may be due to increased flow volumes or increased velocities downstream of the crossing, favouring the establishment of these beetles (Brown, 1987).; and although Elmidae are sensitive to changes in water quality, water quality in this case can likely be ruled out because in this study there is no indication that the parameters currently monitored differ significantly between locations.

There were improved overall AUSRIVAS assessments at all the sites, with the exception of MUR 28, which wasn't sampled in that period. Base-flow in spring 2010 was particularly high, resulting in highly variable edge samples and a loss of common taxa that require slow flowing water and this resulted in BAND C's and in some cases no reliable assessment at sites which were highly variable. The edge habitats during this round of sampling improved at all sites expect MUR 28, which has a poor habitat quality and therefore is unlikely to support the diversity of taxa that a reference condition site would (Maddock, 1999). Support for this comes from Figures 10 and 11, which shows lower overall taxonomic richness and EPT richness compared to the other sampling sites. The improved assessments given to MUR 16, 18 and 19 resulted from the re-establishment of the usually common: Leptoceridae (stick caddis); Corixidae (water boatmen) and Caenidae, which were dislodged during a particularly wet spring period. In that sampling run, samples were collected less than 10 days after the base flow receded to safe wading levels meaning recruitment was probably slowed because of continual high flows. In this sampling run however, sampling was carried out approximately 20 days following the environmental flow release, resulting in more recruitment and hence an improvement in the AUSRIVAS assessment. These results support our predictions from spring 2010 (ALS, 2010) where we suggested that once the high flows subsided, recolonisation should occur resulting in improved AUSRIVAS scores.

The current condition of the Murrumbidgee macroinvertebrate fauna is similar to all previous runs in terms of community composition suggesting a high degree of a) resistance to hydrological variation and b) resilience – i.e. when taxa are displaced (Miller *et al.*, 2007), given that there is sufficient time since the disturbance, these taxa are not displaced permanently. There is anecdotal evidence from this sampling run that the environmental flow releases improved the river substrate by removing some of the fine sediment build up that has been observed over the previous sampling runs and has removed a considerable proportion of the macrophytes standing stock. One indicator of this was we found an obvious increase in Gripopterygidae and Coloburiscidae (MUR 15 only) numbers and there has been a subtle increase in the number of EPT taxa at the genus level (EPTg) compared to previous sampling runs. Many of these taxa require clean, silt-free substrates for survival and the increase of EPT genera may indicate that following the flow release, habitat quality and availability has increased. At the family level, these patterns are not so clear and maybe one of the reasons that to date, the AUSRIVAS protocols have not been detect these subtle differences.

5 Conclusions and Recommendations

The water quality results show no evidence of being negatively impacted downstream of Angle Crossing due to the construction work currently underway immediately upstream of the crossing. Compliance of these water quality parameters to ANZECC and ARMCANZ (2000) guidelines ranged from <30% for turbidity values upstream of Angle Crossing to 100% for EC and pH. Turbidity had the most exceedances for the spring period, but because these were seen upstream of Angle Crossing, which is outside of the construction area, we conclude that this is not related to the M2G project. Nutrient values were outside of the recommended upper limits which is consistent with the results throughout the history of this program. Even following periods with little or no rainfall, the nutrient levels in this part of the catchment remain about the ANZECC recommendations suggesting high back ground levels and perhaps a need to re-evaluate these upper limits specifically for these reaches of the Murrumbidgee River.

Algal biomass as chlorophyll-a did not differ between locations but did show a longitudinal trend, which sharply increased at MUR 23 downstream to MUR 28. There was no such trend evident from the AFDM data which suggests that the chlorophyll-a was not algal derived but from macrophytes, which our field data sheets support.

AUSRIVAS site assessments indicate that compared to spring 2010, the current assessment indicates improvements at all sites (Table 13) except at MUR 28 where there was no change.. There were two sites assessed as *"close to reference"* (BAND A) and four assessed as *"significantly impaired"* (BAND B) At the individual habitat level, four of the riffles and three edges were assessed as *"close to reference"* (BAND A). In both habitats, these improvements have been due to the recolonisation of several common taxa which were dislodged from their habitat during high spring flows, but with a longer period between the disturbance and sampling, have been able to re-establish in the sampling run.

The environmental flow release appears to have (based on field observations) removed some of the fine silt built up in the riffle habitats and scoured out a large proportion of the submerged macrophytes that are usually seen. There is some indication of increased number of sensitive taxa - taxa that prefer clean silt-free substrates - colonising these sites since this environmental flow release. Despite this, the overall community composition remains very similar to previous sampling runs, which suggest a high degree of resistance to disturbance and resilience (the ability to recolonise) following high flow disturbances and also reflects the homogenising effect that high flow events can have on macroinvertebrate communities from different locations.

While there appears to be a high degree of resistance and resilience amongst these sampling sites to various high flow disturbances, one of the key challenges of the M2G project is to use this to evaluate likely scenarios for community outcomes and of biological changes under the 80:90 pumping rules (ACT Government, 2006). While we have data relating to high flow disturbances, situations under low flow conditions is less common.

Deriving useful indicator taxa from the currently available data and literature would benefit the project in terms of assessing more subtle aquatic impacts. These indicator taxa would provide another line of evidence to determine whether potential impacts are flow related due to the operating rules of M2G or have occurred from other environmental factors (e.g. Mazzacano and Black, 2009).

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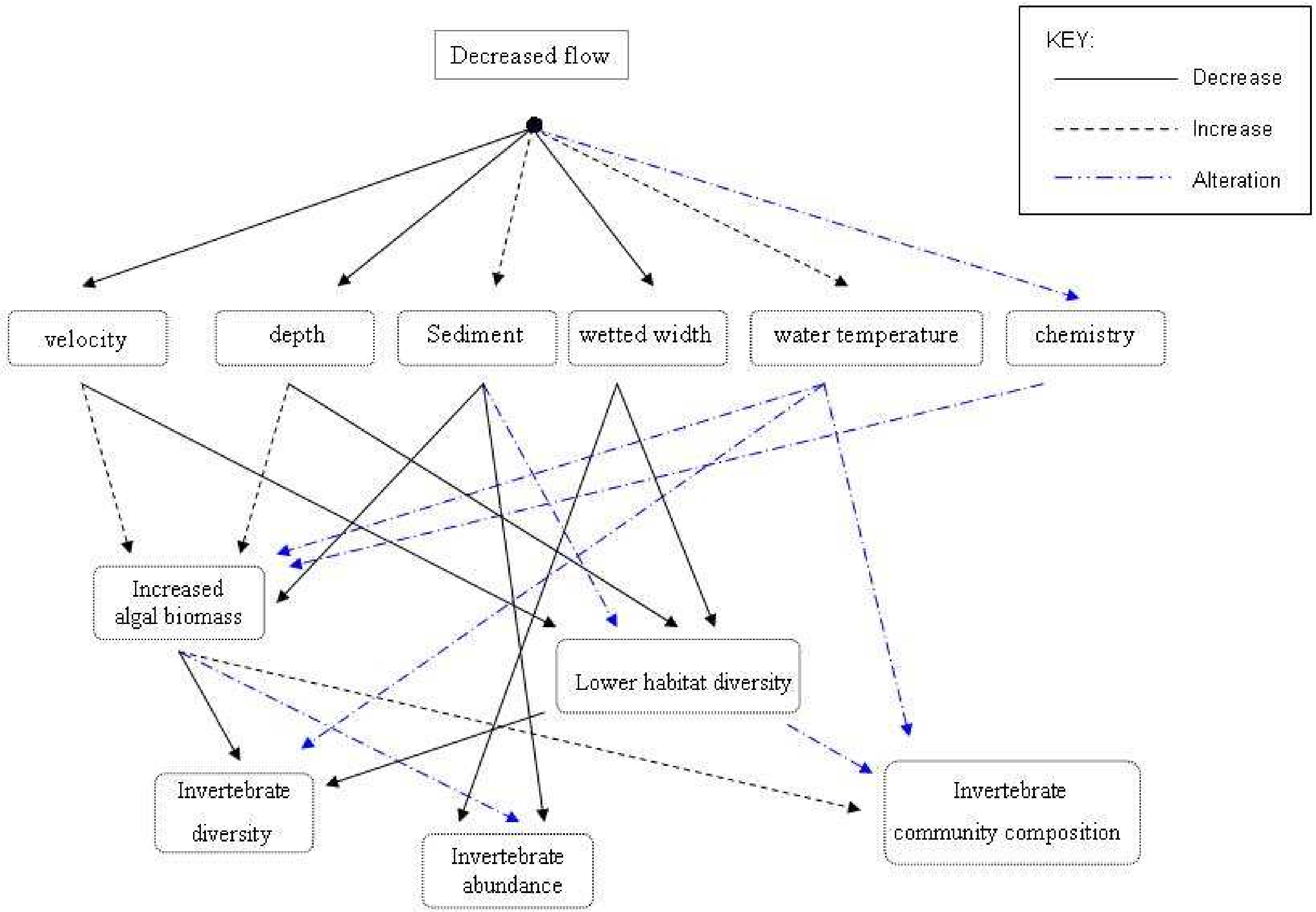
Appendix A –

Potential effects of reduced flow and their knock-on effects on habitat conditions and macroinvertebrate communities



Summary of the effects of reduced flows on various habitat conditions and macroinvertebrate communities from recent literature (Dewson et al. 2007)*.

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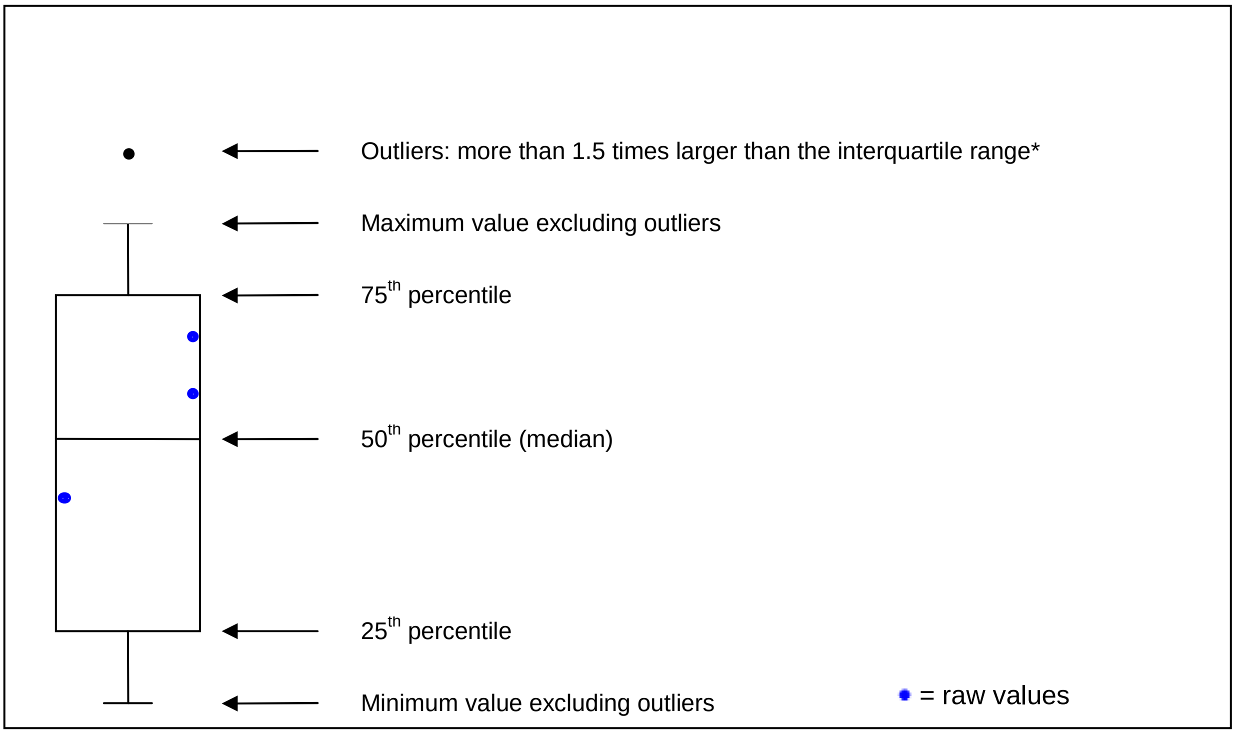
Appendix B –

Interpreting box and whisker plots

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



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

Appendix C –
ANOSIM output for riffle and edge samples

Analysis of Similarities

Two-Way Nested Analysis

RIFFLE

```
TESTS FOR DIFFERENCES BETWEEN Site Code GROUPS
(across all Location groups)
Global Test
Sample statistic (Global R): 0.655
Significance level of sample statistic: 0.01%
Number of permutations: 9999 (Random sample from a large number)
Number of permuted statistics greater than or equal to Global R: 0

TESTS FOR DIFFERENCES BETWEEN Location GROUPS
(using Site Code groups as samples)
Global Test
Sample statistic (Global R): 0.111
Significance level of sample statistic: 40%
Number of permutations: 10 (All possible permutations)
Number of permuted statistics greater than or equal to Global R: 4
```

EDGE

```
TESTS FOR DIFFERENCES BETWEEN Site Code GROUPS
(across all Location groups)
Global Test
Sample statistic (Global R): 0.953
Significance level of sample statistic: 0.1%
Number of permutations: 999 (Random sample from 11642400)
Number of permuted statistics greater than or equal to Global R: 0

TESTS FOR DIFFERENCES BETWEEN Location GROUPS
(using Site Code groups as samples)
Global Test
Sample statistic (Global R): -0.148
Significance level of sample statistic: 80%
Number of permutations: 10 (All possible permutations)
Number of permuted statistics greater than or equal to Global R: 8
```

Appendix D –

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

APPENDIX D. Taxa expected, but not collected in the riffle habitat. The number in each cell is the probability of collection

Site	Taxa	Acarina	Elmidae	Psephenidae	Tipulidae	Simuliidae	Tanypodinae	Baetidae	Leptophlebiidae	Gripopterygidae	Hydrobiosidae	Glossosomatidae	Conoesucidae	Total number of missing taxa
	SIGNAL	6	7	6	5	5	4	5	8	8	8	9	7	
Mur 15			0.93				0.69		0.85		0.50	0.56	0.51	6
Mur 15			0.93	0.51	0.52							0.56	0.51	5
Mur 15			0.93	0.51	0.52						0.50	0.56	0.51	6
Mur 15	Riffle		0.93	0.51			0.69				0.50	0.56	0.51	6
Mur 15			0.93	0.51							0.50	0.56	0.51	5
Mur 15			0.93	0.51								0.56	0.51	4
Mur 16			0.94	0.52							0.51	0.57	0.52	5
Mur 16			0.94	0.52							0.51	0.57	0.52	5
Mur 16			0.94	0.52							0.51	0.57	0.52	5
Mur 16	Riffle		0.94	0.52			0.69				0.51	0.57	0.52	6
Mur 16			0.94	0.52							0.51	0.57	0.52	5
Mur 16			0.94	0.52						0.89	0.51	0.57	0.52	6
Mur 18			0.95	0.60	0.63						0.56	0.68	0.64	6
Mur 18			0.95	0.60	0.63						0.56	0.68	0.64	6
Mur 18			0.95	0.60	0.63					0.93	0.56	0.68	0.64	7
Mur 18	Riffle	0.82	0.95	0.60								0.68	0.64	5
Mur 18		0.82	0.95	0.60			0.63				0.56	0.68	0.64	7
Mur 18		0.82	0.95	0.60	0.63					0.93	0.56	0.68	0.64	8
Mur 19		0.81		0.57			0.65					0.64	0.60	5
Mur 19		0.81		0.57			0.65		0.89			0.64	0.60	6
Mur 19		0.81		0.57			0.65					0.64	0.60	5
Mur 19	Riffle		0.95	0.57					0.89		0.54	0.64	0.60	6
Mur 19				0.57	0.59		0.65		0.89			0.64	0.60	6
Mur 19				0.57	0.59		0.65				0.54	0.64	0.60	6
Mur 23				0.51		0.73	0.70				0.50	0.55	0.51	6
Mur 23				0.51		0.73	0.70					0.55	0.51	5
Mur 23				0.51			0.70				0.50	0.55	0.51	5
Mur 23				0.51							0.50	0.55	0.51	4
Mur 23	Riffle			0.51							0.50	0.55	0.51	4
Mur 23		0.77		0.51								0.55	0.51	4
Mur 28			0.96	0.64			0.59			0.95	0.59	0.75	0.72	7
Mur 28				0.64			0.59		0.94	0.95	0.59	0.75	0.72	7
Mur 28			0.96	0.64			0.59		0.94	0.95	0.59	0.75	0.72	8
Mur 28			0.96	0.64			0.59	0.61	0.94		0.59	0.75	0.72	8
Mur 28	Riffle		0.96	0.64			0.59		0.94	0.95	0.59	0.75	0.72	8
Mur 28				0.64			0.59	0.61		0.95	0.59	0.75	0.72	7

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

Site	Taxa	Oligochaeta	Ceratopogonidae	Tanypodinae	Baetidae	Leptophlebiidae	Caenidae	Gripopterygidae	Leptoceridae	Total number of missing taxa
	SIGNAL	2	4	4	5	8	4	8	6	
MUR 15	Edge		*0.65*	*0.97*		*0.83*				3
MUR 15			*0.65*	*0.97*	*0.62*	*0.83*	*0.94*			5
MUR 16	Edge					*0.82*				1
MUR 16			*0.65*			*0.82*			*0.88*	3
MUR 16			*0.65*	*0.97*					*0.88*	3
MUR 18	Edge				*0.62*					1
MUR 18					*0.62*					1
MUR 18					*0.62*					1
MUR 18			*0.65*					*0.62*		2
MUR 18			*0.65*							1
MUR 19	Edge					*0.82*				1
MUR 19										0
MUR 19										0
MUR 19				*0.97*						1
MUR 19										0
MUR 19			*0.65*		*0.62*					2
MUR 23	Edge		*0.65*							1
MUR 23				*0.97*	*0.62*	*0.82*		*0.62*		4
MUR 28	Edge		*0.65*	*0.97*	*0.62*			*0.62*		4
MUR 28		*1.00*	*0.65*		*0.62*	*0.82*		*0.62*		5
MUR 28			*0.65*					*0.62*		2

Appendix E–

Point Hut Pond Hydrograph: Spring 2011

Appendix E. Point Hut Pond and Lobb's Hole Hydrograph showing mean daily flows (in Cumecs) for spring 2011