Sydney WATER

City of Ryde
Biological and Chemical Monitoring

Macroinvertebrates & Water Quality

Autumn 2014

Sydney Water Monitoring Services

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Executive summary

This report encapsulates the autumn 2014 macroinvertebrate and water quality survey and compliments the spring 2013 survey, forming part of the City of Ryde Water Quality Monitoring Strategy. Macroinvertebrates and water quality were sampled once at five core sites in Archers, Buffalo, Porters, Shrimptons and Terrys creeks. Water quality alone was also sampled once at seven additional sites at Buffalo, Porters and Shrimptons creeks.

Macroinvertebrates were collected according to AUSRIVAS protocols for New South Wales (Turak et al., 2004) and in compliance with Sydney Water in-house test method SS0001 *Rapid Field Assessment of Macroinvertebrates for River, Stream (lotic) and Wetland (lentic) Waters*. Macroinvertebrates were identified to the Family taxonomic level where possible at Sydney Water's NATA accredited Analytical Services Laboratories. The macroinvertebrate data was analysed utilising an array of univariate, biological indices and multivariate techniques. Baseline data collected in surveys from spring 2004 to autumn 2011 were used for historical comparison and the benchmarking of current survey results.

The spring 2013 survey was conducted in November which experienced very high rainfall events. The autumn 2014 survey was conducted towards the end of a dry April, however the preceding months experienced high rainfall events. Sampling was conducted during as close to base flow conditions as possible for all sampling occasions. However, it is likely that macroinvertebrate communities would have been affected by the high rainfall preceding and during the current survey periods.

pH, turbidity and conductivity were within guideline levels at all sites. Dissolved oxygen percent saturation levels were outside the guideline levels for most sites across all five creeks. Bacteriological and nutrient levels were often elevated above guideline levels at all sites. The additional Buffalo Creek sites had extremely high faecal coliform counts during the spring 2013 survey, the highest levels recorded from the entire monitoring program. Most metal results were within guideline levels except for copper and zinc which were outside guideline levels at some sites more so during spring 2013.

Taxa richness was largely reflective of what had been previously observed in past surveys for Terrys, Shrimptons and Archers creeks. Taxa richness at Porters and Buffalo creeks was significantly lower than previous surveys, particularly in autumn 2014. EPT taxa were collected in very low numbers, as has been the case in past surveys and Buffalo Creek recorded no EPT taxa in either of the current surveys.

Survey results suggest that the macroinvertebrate community assemblages in the five creeks were typically reflective of impacted urban systems. Univariate and biological indice results were largely reflective of what had been previously recorded, except at Buffalo Creek, which indicated a slight drop in stream health compared to historical results.

Multivariate analysis indicated that the macroinvertebrate community assemblages observed in the recent surveys were very similar to historical survey seasons for Shrimptons, Archers and Terrys creeks. The macroinvertebrate community assemblages observed in the recent surveys at Buffalo and Porters creeks showed clear differences than those observed in historical surveys.

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1 Introduction

1.1 Background

Sydney Water has developed this report in response to engagement under the City of Ryde Council Tender Number COR-RFT-30/13. This report is in accordance with the Water Quality Monitoring Strategy for the City Of Ryde for spring 2013 and autumn 2014. The two survey periods complement surveys conducted under the same strategy from spring 2004 to autumn 2011.

This current surveys recommences the biological and chemical monitoring of the five main catchments within the Ryde LGA; Shrimptons, Archers, Porters, Buffalo and Terrys creeks. During the full term of the strategy the frequency of site sampling and survey specifics have been modified and developed to the current program. Macroinvertebrates and water quality was sampled once per season at five core sites in each catchment; water quality was also sampled at seven additional sites, located on Shrimptons, Porters and Buffalo creeks. There were initially eight additional sites however access to a site located on Porters Creek wasn't possible for the current surveys. The additional water quality sites were added in 2008 to allow a spatial investigation into the chemistry of the creeks.

1.2 Objectives

The Ryde LGA catchments are exposed to any number of anthropogenic impacts and sources associated with the variety and density of land uses present. Understanding what drives these impacts and how ecosystems respond is essential to their ongoing management. Baseline understanding of the natural variation that occur and a greater understanding of the relative health of these catchments is an important environmental management process for the City of Ryde.

Biological and chemical monitoring enables the City of Ryde to;

- Build on baseline data that enables the temporal evaluation and analysis of the health of the catchments of the strategy
- Identify and track new and existing impacts affecting the catchments
- Provide direction and monitor potential infrastructural works within the LGA, i.e. in-stream or riparian rehabilitation and stormwater treatment projects.
- Build on the known taxa list for each catchment and to aid in the identification of key indicator taxa
- Provide the basis for potential standard monitoring strategies and information that could be integrated into a community monitoring/education program
- Provide guidance on future programs; sampling frequency and protocols, site locations, suitability of current and potential analyses

2 Study area

2.1 Catchment

The City of Ryde LGA has a total area of 40,651 km^2 and is located 12 km north west of central Sydney. It is comprised of 16 suburbs and 14 separate stormwater catchments predominated mainly by residential housing including several important retail centers and light industry/manufacturing sectors (CoR, 2014).

There are a limited number of natural bushland areas fringing the urban infrastructure including several important natural bush corridors and areas of open space that support recreation and sporting activities. There are also small sections of Lane Cove National Park present on the eastern and northern borders of Shrimptons, Porters and Buffalo creeks.

The creeks surveyed in the strategy all drain into the greater Parramatta River catchment. Archers creek enters Parramatta River directly and the remaining creeks through the Lane Cove River catchment.

2.1.1 Sampling sites

The five core sites sampled for macroinvertebrates and water quality are shown in Table 1 and Figure 1. The eight additional water quality sites are shown in Table 2 and Figure 1. All sites were sampled once per survey. Water quality was sampled at all core and additional sites and macroinvertebrates at the core sites.

The autumn 2014 survey was conducted on the 23rd and 24th of April and the spring 2013 survey on the 15th, 22nd and 28th of November. Both surveys were delayed and disrupted due to significant rainfall, the autumn survey in particular. Access to the Spur Branch Porters Creek site wasn't possible for either survey.

Table 1 Core sampling sites

Site code	Site Name	Lat/Long
Site 1	Terry's Creek @ Somerset Rd	-33.765792, 151.098345
Site 2	Shrimpton's Creek @ Wilga Park	-33.780530, 151.118628
Site 3	Porter's Creek @ Ryde City Depot	-33.783362, 151.137671
Site 4	Buffalo Creek @ Higginbotham Rd	-33.816451, 151.125705
Site 5	Archers Creek @ Maze Park	-33.805555, 151.074272

Table 2 Additional water quality sites

Site code	Site Name	Lat/Long
CR1SA	Shrimpton's Creek @ Kent Rd	-33.789246, 151.113419
CR1SB	Shrimpton's Creek @ Bridge St	-33.794061, 151.109779
CR1SC	Shrimpton's Creek @ Quarry Rd	-33.796856, 151.106775
CR4BA	Buffalo Creek d/s Burrows Park	-33.814392, 151.116656
CR4BB	Buffalo Creek u/s Burrows Park	-33.815060, 151.113502
CR5PA	Porter's Creek @ Main Branch	-33.786500, 151.134839
CR5PB	Porter's Creek @ Spur Branch	-33.784181, 151.134708
CR5PC	Porter's Creek @ Wicks Rd	-33.788613, 151.133557

Figure 1 City of Ryde LGA map with catchments and core sampling sites indicated (supplied by City of Ryde)

3 Sampling methodology

3.1 Water quality

The water quality monitoring program design and site locations for this study were provided by City of Ryde and are consistent with their previous monitoring programs.

Water quality sampling was conducted by Sydney Water staff trained in sample collection, preservation, storage and transport techniques (conforming to AS/NZS 5667:1998) as well as relevant Sydney Water occupational health and safety procedures. To ensure traceability samples were collected in bottles pre-labeled with a unique identifying laboratory number as well as the sample site code, location and date of collection. Field measurements and observations for each site were recorded at the time of sampling. A general outline of sampling procedures is detailed below.

3.1.1 Sampling schedule

A schedule was prepared by the Aquatic Ecology Project Leader responsible for this project to ensure sampling frequency requirements were met. The schedule was forwarded to the appropriate Analytical Services Laboratory Supervisors to provide forewarning of incoming samples. The sampling schedule is prepared in communication with the client to ensure milestones and deliverables are met according to the agreed timeframes.

3.1.2 Frequency of sampling

Routine water quality monitoring was undertaken in November 2013 (spring) and April 2014 (autumn) at the five core sites and seven additional sites.

3.1.3 Sampling methodology

To avoid contamination during the sampling process the following practices occurred;

- sampling officers wore disposable latex gloves
- samples were collected using aseptic techniques
- sampling equipment was sterilised and rinsed between sites
- sample bottles not containing preservative were rinsed before filling
- microbiological samples were collected before other samples

To ensure representativeness of samples, the following practices occurred;

- disturbed areas of the creek bank were avoided; where disturbance was evident the sample was collected upstream
- rinse water was discarded downstream or away from the sampling point
- issues impacting sample integrity, such as distance from bank(s), number and distribution of samples, substrate, ponds and aeration, were considered in determining sampling sites
- surface scum was avoided

Samples were collected from 20-30 cm below the water surface. Where the depth was less than 50 cm, the sample was taken at half the depth.

Surface samples were collected when the waterway was too shallow to allow sampling without disturbing the sediment. This has the potential to compromise sample quality as surface samples may contain surface contaminates, such as scum, dust or pollen, which may not be present below the waterway surface. Therefore, where applicable, collection of surface samples was noted on the Water Chemical Field Sheet.

A sampling pole and/or jug were used to collect samples. A list of water chemistry analytes sampled, along with their unit of measurement and collection container are provided in Appendix 2.

Field measurements

It is necessary to measure some water chemistry analytes in the field using various field instruments (Table 3). To ensure accuracy of results, instruments are calibrated according to manufacturers' recommendations, field procedure requirements, relevant sections of NATA ISO/IEC 17025 Field Application Document and other reference material.

Table 3 Water chemistry parameters and field analysis methods

Analyte	Method
Dissolved Oxygen (% saturation)	WTW Multiliner Universal Meter
Dissolved Oxygen (mg/L)	WTW Multiliner Universal Meter
Conductivity (µS/cm)	WTW Multiliner Universal Meter
pH (pH units)	WTW Multiliner Universal Meter
Turbidity (NTU)	HACH Turbidimeter
Temperature (^{o}C)	Digital Thermometer

To ensure traceability of calibration in accordance with NATA ISO/IEC 17025 2009, Sydney Water uses a mixture of in-house and purchased calibration standards. In-house standards are made only from analytical grade materials of appropriate purity. The assay of these materials is traceable to the National Institute of Standards & Testing (NIST). Purchased calibration standards are regarded as critical materials and are accompanied with a certificate of analysis showing traceability to NIST.

Field observations

Field observations were recorded to assist in the interpretation of results. At each site the field observations listed below were recorded:

- sample clarity
- algae presence
- recent rain
- visual pollution
- flow rate (visual assessment)

Sample preservation and transportation

Samples that require storage between 1-10^{0}C were placed in an ice filled esky immediately following collection. To avoid contamination, all samples were transported in an upright position.

Samples were delivered to the Sydney Water analytical laboratory at West Ryde with the appropriate Chain of Custody form and/or analysis request sheet.

Analysis

All Sydney Water laboratory analytical work was performed as per the requirements of AS ISO/IEC 17025 General Requirements for the Competence of Testing and Calibration Laboratories. In general, most of the methodologies used are American Public Health Association (APHA) or United States Environmental Protection Agency (USEPA) standard methods. Where standard methods are not available, analytical procedures have been developed from in-house research or published methods from analytical journals.

All analysis was carried out according to the requirements of the customer and the laws and regulations of relevant authorities. Sydney Water laboratories' NATA technical accreditation numbers are listed below.

Table 4 Sydney Water laboratories NATA accreditation numbers

Field of Testing	Number	Accredited	Standard
Chemical Testing	63	1952	ISO/IEC 17025
Biological Testing	610	1966	ISO/IEC 17025

3.2 Macroinvertebrate sampling

Macroinvertebrate sampling was conducted in accordance with AUSRIVAS protocols for New South Wales (Turak et al., 2004). The Sydney Water Biology Group carry out sampling activities according to the requirements of in-house test method SS0001 *Rapid Field Assessment of Macroinvertebrates for River, Stream (lotic) and Wetland (lentic) Waters*. This ensures compliance with the NSW AUSRIVAS protocols for rapid assessment field sampling and processing techniques for all habitats.

Field staff were required to be competent to a minimum of family level identification of macroinvertebrates in the laboratory. As identifiers they must comply with the requirements of SSWI433 *In-house test method Macroinvertebrate Cataloguing, Identification and Counting* (see NATA accreditation details, Section 3.3). This requirement ensures that field staff were given the widest possible exposure to animals of varying morphology and to facilitate high quality field sampling and processing techniques. This results in a reduction of sampling error, addressing issues identified by Metzeling et al. (2003). All field trips to a sampling site are led by staff that have previously visited that site (where possible), maintaining continuity in sampling over time.

Macroinvertebrates were sampled from the edge habitats for all survey sites using a hand-held dip net. Edge habitats are defined as areas with little or no current. The sampling net was swept from open water towards the stream bank, working over a bank length of about 10 m. In the process, deposits of silt and detritus on the stream bottom were stirred up so that benthic animals were suspended and caught in the net. Three replicate samples were collected from the edge habitat at each of the five sampling sites.

The net contents were emptied into a large white sorting tray with a small amount of water to allow live macroinvertebrate specimens to be picked out with fine forceps and pipettes for a minimum period of 40 minutes. If new taxa were collected between 30 and 40 minutes, sorting continued for a further 10 minutes. If no new taxa were found after 10 minutes, picking ceased. If new taxa were found, the 10 minute processing cycle continued up to a maximum total sorting time of 1 hour. There is no set maximum number of animals to be collected under the NSW protocols (Turak, et al., 2004).

All specimens collected were preserved in small glass specimen jars containing 70% un-denatured ethanol with a clear label indicating site code and location, date, habitat and name of staff sampler and picker. Sampling equipment was washed thoroughly between samples to prevent the cross contamination of animals.

Figure 2 Sample jars and a picked specimen, Hemipteran, Notonectidae *Enithares* (Back-swimmer)

3.3 Macroinvertebrate sample processing

Macroinvertebrate samples were processed as per SSWI433 *In-house Test Method Macroinvertebrate Cataloguing, Identification and Counting*. Quality assurance was conducted as per SSWI434 *In-house test method Quality Control of Macroinvertebrate Identification, Counting and Archiving of Collections*. Both methods are in compliance with the requirements of AS ISO/IEC 17025 *General Requirements for the Competence of Testing and Calibration Laboratories* under technical accreditation number 610 issued by the National Association of Testing Authorities (NATA). Refer to Appendix 1 for further quality assurance information.

Macroinvertebrate identifications were performed using modern compound and stereo microscopes (Leica Microsystems) that are maintained via a strict service schedule. Reference material used in the AE laboratory includes:

- Current published taxonomic keys
- Up to date descriptions and records of taxonomic developments from national experts
- Voucher specimens, many confirmed by national experts
- Sydney Water in-house keys and digital voucher photograph database

Macroinvertebrates were identified and enumerated to the family taxonomic level, except Chironomids which were identified to sub-family. For AUSRIVAS analysis specimens were combined for Oligochaeta at Class and Acarina at Order level.

Macroinvertebrate data were entered into Sydney Water's custom LIMNOS electronic database. A suitably trained staff member checked identification sheets before electronic entry and then verified electronic datasheets after this process. Raw macroinvertebrate data files were extracted and verified by a senior staff member before analyses were performed.

At the end of this process, quality assurance was conducted on 5% of edge samples identified for this study. Identifications are chosen at random for quality assessment.

Figure 3 Laboratory processing and resources, voucher specimen - Coleoptera, Hydrophilidae *Berosus* (Beetle)

3.4 Rainfall data

Continuous rainfall data is collected and recorded by the Sydney Water Hydrometric Services Team within the Service Delivery division. Rainfall is collected using TB3 rain gauges (Hydrological Services Pty Ltd) and data is collected and analysed in accordance with NATA guidelines following industry standards (WMO 1996) and Observation Specification No 2013.1 of the Australian Bureau of Meteorology. For the purpose of this study, daily rainfall measurements were extracted from HYDSTRA time-series data management software and analysed within Microsoft Excel. The West Ryde rain gauge (566037) was used for this report.

4 Analysis methods

4.1 Water quality

While not sampled at the frequency suggested by ANZECC (2000), the water quality results do allow characterisation of each study creek against ANZECC (2000) guidelines for Aquatic Ecosystems (Lowland River in south eastern Australia), Recreational Water Quality and Aesthetics (Secondary) and toxicants (95% species protection level).

The ANZECC (2000) toxicant trigger values have been used for metals. These guidelines provide four sets of protection levels derived as chemical-specific estimates of the concentrations of contaminants that should have no adverse effects on aquatic ecosystems (ANZECC 2000). The 95% species protection level is commonly applied to aquatic ecosystems that have been modified in some way, and has been used in this report as a comparison for the stream water quality results.

ANZECC (2000) recommends that the toxicity trigger values for hardness-related metals (in this study: cadmium, copper, lead, nickel and zinc) are adjusted to account for local water hardness. This is important because the trigger values for these metals have been derived for soft waters (30 g/m3 CaCO3), corresponding to high toxicity. The adjustment values for water hardness categories are detailed in Table 6.

Although the ANZECC (2000) guidelines (default trigger values) detailed below (Table 5) are for slightly disturbed ecosystems, they do provide an indication of water quality compared to other systems within south eastern Australia.

The median, the middle value when data are arranged in numerical order, has been calculated for historical data, when available. For the five core sites this is between 2004 and 2011, and for eight additional sites between 2008 and 2011. The median is a robust estimator of central tendency because it is relatively unaffected by extremes in the data, and is the preferred statistic for describing an ‘average’ concentration. Where concentrations of chemicals were below detection levels, half the detection level is used to represent results and should be used for future calculation of historical medians. The laboratory detection limits used for the metals analysis have been included in Table 5.

Table 5 ANZECC (2000) indicators and trigger values, including laboratory detection limits

Indicator	Guideline Value	Detection limit	Unit	Source
Dissolved Oxygen	85 to 110	N/A	% saturation	Protection of aquatic ecosystem (ANZECC 2000)
pH	6.5 to 8.5	N/A	pH unit	Protection of aquatic ecosystem (ANZECC 2000)
Turbidity	50	N/A	NTU	Protection of aquatic ecosystem (ANZECC 2000)
Conductivity	125-2,500	N/A	µS/cm	Protection of aquatic ecosystem (ANZECC 2000)
Ammonia nitrogen	20	N/A	µg/L	Protection of aquatic ecosystem (ANZECC 2000)
Oxidised nitrogen	40	N/A	µg/L	Protection of aquatic ecosystem (ANZECC 2000)
Total nitrogen	350	N/A	µg/L	Protection of aquatic ecosystem (ANZECC 2000)
Total phosphorus	25	N/A	µg/L	Protection of aquatic ecosystem (ANZECC 2000)
Faecal coliforms	1,000	N/A	CFU/100mL	Secondary contact recreation (ANZECC 2000)
Chromium H	0.001	0.0001mg/L	mg/L	Toxicants at 95% level of protection (ANZECC 2000)
Manganese	1.9	0.0001mg/L	mg/L	Toxicants at 95% level of protection (ANZECC 2000)
Iron	ID	0.005mg/L	mg/L	Toxicants at 95% level of protection (ANZECC 2000)
Copper H	0.0014	0.001mg/L	mg/L	Toxicants at 95% level of protection (ANZECC 2000)
Zinc H	0.008	0.005mg/L	mg/L	Toxicants at 95% level of protection (ANZECC 2000)
Arsenic	0.013	0.001mg/L	mg/L	Toxicants at 95% level of protection (ANZECC 2000)
Cadmium H	0.002	0.001mg/L	mg/L	Toxicants at 95% level of protection (ANZECC 2000)
Lead H	0.0034	0.001mg/L	mg/L	Toxicants at 95% level of protection (ANZECC 2000)
Mercury B	ID	0.0003mg/L	mg/L	Toxicants at 95% level of protection (ANZECC 2000)

Table 6 ANZECC (2000) trigger value adjustments for water hardness

Hardness category (mg/L as $CaCO_3$)	Hardness range (mg/L as CaCO3)	Cd	Cu	Pb	Zn
Soft	0 – 59	TV	TV	TV	TV
Moderate	60 – 119	x 2.7	x 2.5	x 4.0	x 2.5
Hard	120 – 179	x 4.2	x 3.9	x 7.6	x 3.9
Very hard	180 – 240	x 5.7	x 5.2	x 11.8	x 5.2
Extremely hard	400	x 10.0	x 9.0	x 26.7	x 9.0

4.2 Macroinvertebrate analyses

Macroinvertebrate data was analysed according to the three methods listed below. Each of these analyses are introduced and briefly explained in an information box at the start of each respective results section. A more thorough description is available in Appendix 3.

Univariate Analyses;

- Taxa Richness
- EPT Taxa Richness

Biological Indices;

- SIGNAL2
- SIGNAL-SF
- AUSRIVAS

Multivariate Analyses;

- Cluster
- SIMPROF
- MDS ordination
- SIMPER
- ANOSIM

5 Rainfall data

Daily rainfall data from the Sydney Water rain gauge located at Ryde Pumping Station, West Ryde, are presented in Figure 4. The total rainfall recorded for each month, for the three months prior to and including sampling, are listed in Table 7. The spring 2013 survey conducted in November 2013 experienced 190 mm of rainfall, including a maximum daily rainfall of 45.5 mm (12th November). This was the highest rainfall recorded from a single month during the sampling periods from any of the monitoring seasons. The autumn 2014 survey was conducted under drier conditions with 41.5 mm falling in April. March, however, recorded 121 mm.

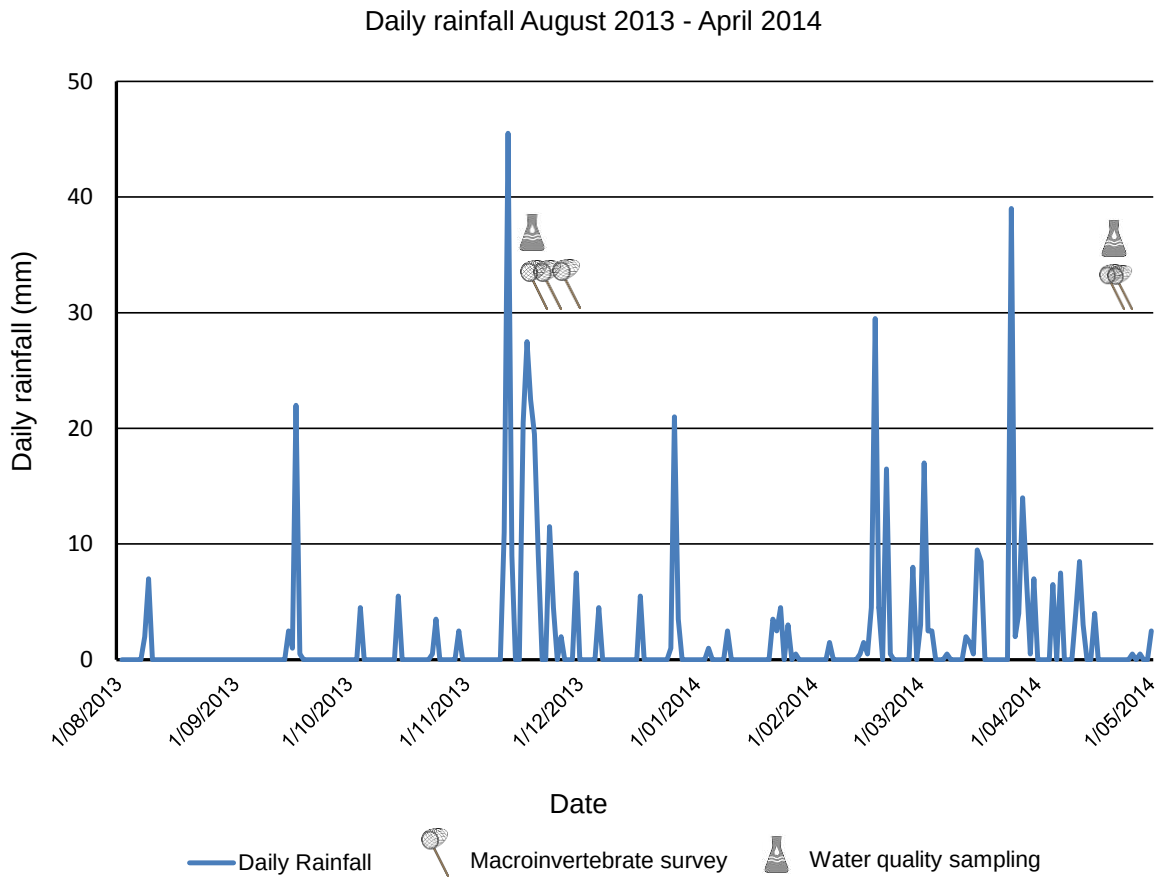

Figure 4 Daily rainfall data August 2013 to April 2014

Table 7 Total rainfall by month

Month	Rainfall (mm)
August 2013	9.0
September 2013	26.0
October 2013	16.5
November 2013	190.0
December 2013	35.5
January 2014	17.5
February 2014	67.5
March 2014	121.0
April 2014	41.5

6 Site observations

Site 1: Terrys Creek

The Terrys Creek core sampling site is located in Somerset Park under the M2 overpass in the suburb of Epping. The surrounding land use is residential, and the creek flows through a bushland corridor. The surrounding riparian area and bank edge is a mix of native and exotic plant species. The creek bed is predominately bedrock, gravel and sand. There has been no macrophyte or significant algal growth observed within the sampling area.

During the recent surveys, in particular spring, there were signs of flooding and some bank erosion. There was domestic rubbish strewn about the surrounding vegetation and within the creek. Similar conditions have been observed in past surveys. The main creek pool has had a noticeable increase in sedimentation from the earlier survey periods to the current program. This has resulted in a shallower pool with far less bank undercutting and habitat.

When the site was visited for the final survey in autumn 2011 it was largely inaccessible due to maintenance work on the M2 overpass at both the eastern and western banks. This resulted in extensive clearing, removal of vegetation and stabilisation of the surrounding area, using matting, boulders and ground compaction of the surrounding area. There was noticeably less bank vegetation as a result as evidenced in the recent surveys (Figure 5).

Figure 5 Terrys Creek, spring 2007 (L) and spring 2013 (R)

Site 2: Shrimptons Creek

The Shrimptons Creek core sampling site is located in Wilga Park in the suburb of Macquarie Park and the surrounding land use comprises a mix of residential, commercial and light industrial. The creek flows through a thin riparian/vegetation corridor, which is a mix of native and exotic species. The riparian area is periodically cleared but at times has been overgrown with exotic plant species. The creek bed is predominately bedrock and sand/silt. There is little macrophyte or algal growth within the sampling area, and these haven't been observed in past surveys.

The creeks banks are relatively stable and the western bank has sections that have been realigned and reinforced. There is gross pollutant traps placed at points along the sampling site, however domestic rubbish, excessive organic debris and other refuse has been periodically observed at the site (Figure 6). The Wilga Park site has been one of the more stable environments visited during the program, although a bank collapse was observed in spring 2007.

Figure 6 Shrimptons Creek, spring 2009, downstream sampling point (L) and upstream (R)

CR1SA - Shrimptons Creek at Kent Road

The Kent Road site is situated amongst a residential area and is lined by a thin section of riparian vegetation that completely shades the creek and comprises a mix of native and exotic species. The site has changed little during the program. Odours have regularly been noted at this site, generally linked to the breakdown of organic debris and or urban run-off.

CR1SB - Shrimptons Creek at Bridge Street

The Bridge Street site is located at the downstream section of Burrows Park, just before it flows under Bridge St and is surrounded by residential areas. Burrows Park consists largely of cleared grass fields. The riparian area has gone through several significant changes, including significant clearing and revegetation occurring twice since the monitoring started here in autumn 2008.

The riparian area has at times been thickly vegetated with native and exotic weeds and shrubs that have choked the creek. During the current surveys the creek bed and riparian area had thick growth of predominately *Eleocharis sp* and *Myriophylum* and various grasses and weeds (Figure 7). An oil scum was observed during the current surveys and in autumn there was a large amount of iron bacteria and algae present.

CR1SC – Shrimptons Creek at Quarry Road

The Quarry Road site is located at the upstream section of Burrows Park, at the point where Shrimptons Creek emerges from the underground stormwater system. This site has experienced similar changes as Bridge St with clearing and revegetation. There was also oil and scum on the water surface and organic and domestic debris with associated odours observed at the site during past and the recent surveys (Figure 7).

Figure 7 Shrimptons Creek, spring 2013, Bridge St (L) and Quarry Rd (R)

Site 3: Porters Creek

The Porters Creek core sampling site is located on the eastern boundary of the Ryde City Depot (Macquarie Park) where Porters Creek emerges from flowing mostly underground in its upper reaches. Water quality samples were collected within the Ryde Waste Disposal Depot close to where Porters Creek drains from an underground system. Macroinvertebrates were collected within the boundaries of the Lane Cove National Park just downstream of the depot and the bridge for the main park access road.

The surrounding riparian area is dominated by native plants with a small amount of exotic species. The creek bed is mostly bedrock with some cobble, boulder and sand. The creek and surrounding environment downstream of the bridge is in a relatively natural state. No macrophyte growth has been observed at the site however there has been varying levels of algal growth present.

The creek bank and environment has remained relatively stable, although varying degrees of sedimentation has occurred immediately downstream of the bridge. The water clarity has always been observed to be slightly milky in appearance (Figure 8, left) and at times there have been bad odours, turbidity, oil, scum and domestic refuse observed at the site. The issues that have been observed at the site are likely linked due to the very close proximity of the depot and waste disposal site.

Figure 8 Porters Creek, core site in autumn 2010 (L) and in spring 2013 (R)

CR5PA - Porters Creek at Main Branch

The Main Branch site is located on the western boundary of the depot and consists of an open concrete channel. The sampling point is in a retention basin at the end of the channel immediately before the creek flows underground for the remainder of its path through the depot.

There is usually extensive algal growth along the edge of the concrete channel and there is often a varying amount of oil and scum on the water surface. During the recent surveys conditions were moderately turbid and oil and foam was observed at the site. There has been significant development directly around the sampling area during both surveys, with heavy machinery, clearing and materials present.

CR5PB - Porters Creek at Spur Branch

The Spur Branch site is located in the north western corner of the depot in an underground drainage pit where several underground stormwater lines meet before joining and draining to the main Porters Creek line. It is accessed through a drainage grate and the spur branch is about three metres below ground.

When visited in spring there had been a ground collapse, which had collapsed the drainage grate and surrounding concrete (Figure 9, right). The grate could not be moved and the ground was unsafe to remain upon. This site wasn't able to be sampled for either of the recent surveys.

Figure 9 Porters Creek at Spur Branch in spring 2013 (L) and Wicks Rd in autumn 2014 (R)

CR5PC - Porters Creek at Wicks Road

The Wicks Road site is located in a small section of vegetation upstream of the depot. The site is located at the first point that Porters Creek drains from the underground stormwater system. The site is surrounded by commercial and industrial land uses and the vegetation mostly consists of exotic trees and shrubs.

There are several stormwater drainage points noticeable at the site, including the main stormwater pipe which exits into the creek and there is several piped drainage lines entering the creek with unknown sources. There has been oil and scum regularly observed on the water surface.

A significant impact observed during the autumn survey had resulted in the significant accumulation of iron bacteria/ferric oxide with an associated oily scum which covered much

of the creek surface (Figure 9, right). The impact appeared to be originating from the creek bank which has a gas line marked. There was also turbid water noted, which was being sourced from the main stormwater pipe in which Porters Creek originates from.

Site 4: Buffalo Creek

The Buffalo Creek core sampling site is located in a bush corridor in the suburb of Gladesville and is accessed through private property. The surrounding land use is a mix of residential, light industry/commercial and reserves. The surrounding vegetation is a mix of native and exotic species however exotic species dominate. The southern bank is mostly manicured lawns.

The creek bed is mostly a mix of sand, silt and gravel. There is usually some macrophyte growth, *Egeria* and *Potamogeton*, and little algal growth has been observed.

The creek has had periods of increased sedimentation which after heavy rain has been scoured out. During the recent surveys however, sediment has remained within the creeks sampling area, along with a significant amount of organic debris and domestic rubbish (Figure 10).

The minor stormwater tributary draining an industrial/commercial area immediately downstream of the sampling site historically recorded considerable flows of turbid, often milky grey water during periods of no rain. City of Ryde reclaimed the land above this drainage point in 2011 and built a wetland system to treat the stormwater from this sub catchment. During both recent surveys the tributary was observed to be clearer and have less flow

Figure 10 Buffalo Creek, core site looking upstream in spring 2009 (L) and core site in autumn 2014 (R)

CR4BA – Buffalo Creek downstream of Burrows Park

The downstream Burrows Park site is accessed off Buffalo Rd in the suburb of Ryde and is positioned just before the creek flows under the road. The surrounding land use is residential and Burrows Park consists mostly of a bush corridor. The site is quite open and the bank edge has been realigned with sandstone boulders.

There are usually quite obvious signs of bird activity around this site, including extensive bird droppings. During the current surveys wood duck and ibis were present at the site. There have been increased turbidity levels observed at this site most notably in autumn 2008 (Figure 11, left) and on several non-sampling site visits.

Figure 11 Buffalo Creek, downstream Burrows Park in spring 2008 (L) and upstream Burrows Park in autumn 2014 (R)

CR4BB – Buffalo Creek upstream of Burrows Park

The upstream Burrows Park site is about 300 metres upstream of Buffalo Rd, and lies in the middle of a bush corridor. The site is surrounded by mostly native vegetation that completely shades the creek. The creek is shallow at this point and has little flow. The site is positioned just downstream from a stormwater tributary/pipe. There has been little observable change at this site throughout the survey periods.

During the current autumn survey there was a small discharge coming from the pipe despite the lack of rainfall in the week prior, the water had no observable issues that could affect water quality. When revisited later in autumn for a follow-up visit a discharge was again noted during a dry period. The water on this occasion was moderately turbid.

Site 5: Archers Creek

The core Archers Creek sampling site is located at Maze Park in the suburb of West Ryde and is positioned just upstream of the Victoria Rd crossing. The surrounding land use is mostly residential and a golf course is present downstream. There is mostly native vegetation along both banks of the creek. The creek bed is mostly bedrock with banks of sediment (sand, silt and organic matter). There is thick growth of various native and exotic plants along most of the sampling area including both terrestrial and semiaquatic species. There is also extensive algal growth within much of the creek.

Archers Creek had extensive rehabilitation work in late 2007 to early 2008. The creek line was totally re-lined and the riparian edge cleared and replaced with large sandstone boulders along with replanting of native trees and shrubs (Figure 12). Before the rehabilitation work there was a large section of bank that was continually being eroded and there was thick growth of exotic shrubs and plants.

The creek now forms a largely unshaded but stable environment. However, since the rehabilitation work there has been an increase in sedimentation that has choked much of the creek and increased the accumulation of organic debris and the plant growth. Algal growth, plant density and organic matter have increased again at this site as observed during the recent surveys, including an increase between the spring and autumn survey.

Figure 12 Archers Creek in autumn 2008 (L) and spring 2009 (R)

7 Water quality

7.1 Terrys Creek

Site 1 – Terrys Ck near M2 Motorway overpass

The water quality results for Terrys Creek are presented in Table 8 (physico-chemical), Table 9 (alkalinity and hardness), Table 10 (bacteriological and nutrients) and Table 11 (metals). Most results for spring and autumn surveys were within the recommended ANZECC (2000) guidelines, with a few exceptions.

In spring, exceptions included dissolved oxygen saturation (64.1%) which was also slightly below the historical median, total nitrogen (1,020 µg/L), oxidised nitrogen (380 µg/L), total phosphorus (49 µg/L) and total copper (0.005 mg/L) which were all elevated to almost double or over double the guideline value.

Water quality results for Terrys Creek improved in autumn, with increased dissolved oxygen saturation (74.8%), and reduced total nitrogen (990 µg/L) and oxidised nitrogen (290 µg/L). However, these concentrations remained outside the recommended guidelines and above historical medians. Total phosphorus (25 µg/L) and total copper (0.002 mg/L) concentrations fell below the respective guideline levels in autumn.

Conductivity, although within the guideline range, was above the historical median on both sampling occasions.

Table 8 Terrys Creek physico-chemical results

Analyte		Temperature	Dissolved Oxygen	Dissolved Oxygen	pH	Turbidity	Conductivity
Unit		°C	mg/L	% saturation	pH units	NTU	µS/cm
Guideline		NA	NA	85-110	6.8-8.5	50	125-2,200
Site 1	*Historical median*	*15.7*	*6.5*	***65.0***	*7.20*	*2.38*	*355*
	Autumn 2014	14.0	7.6	**74.8**	7.41	2.74	610
	Spring 2013	17.1	6.2	**64.1**	7.22	3.82	522

Table 9 Terrys Creek alkalinity and hardness results

Analyte		Total Magnesium	Total Calcium	Hardness	Alkalinity
Unit		mg/L	mg/L	mg CaCO3/L	mg CaCO3/L
Guideline		NA	NA	NA	NA
Site 1	*Historical median*	*NA*	*NA*	*NA*	*61.45*
	Autumn 2014	9.6	35.2	128	96.0
	Spring 2013	7.7	30.3	107	76.7

Table 10 Terrys Creek bacteriological and nutrient results

Analyte		Faecal coliform	Ammonia NH3 -N	Total Nitrogen	Total Kjeldahl Nitrogen	Oxidised Nitrogen NOx-N	Total Phosphorus
Unit		CFU/100mL	µg/L	µg/L	µg/L	µg/L	µg/L
Guideline		1,000	20	350	NA	40	25
Site 1	*Historical median*	*155*	*20*	***515***	*310*	***140***	***32***
	Autumn 2014	74	10	**990**	700	**290**	25
	Spring 2013	150	10	**1,020**	640	**380**	**49**

Table 11 Terrys Creek metal results

Analyte		Total Chromium	Total Manganese	Total Iron	Total Copper	Total Zinc	Total Arsenic	Total Cadmium	Total Lead	Total Mercury
Unit		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Guideline		0.001	1.9	NA	0.0035	0.02	0.013	0.00054	0.0136	0.0006
Site 1	*Historical median*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
	Autumn 2014	0.0005*	0.014	0.734	0.002	0.014	0.0005*	0.0005*	0.0005*	0.00015*
	Spring 2013	0.0005*	0.033	0.653	**0.005**	0.016	0.0005*	0.0005*	0.0005*	0.00015*

(denotes below detection limits)*

7.2 Shrimptons Creek

Site 2 - Shrimptons Creek at Wilga Park

CR1SA - Shrimptons Creek at Kent Road

CR1SB - Shrimptons Creek at Bridge Street (downstream of Santa Rosa Park)

CR1SC – Shrimptons Creek at Quarry Road (upstream of Santa Rosa Park)

Water quality results for the four Shrimptons Creek sites are presented in Table 12 (physico-chemical), Table 13 (alkalinity and hardness), Table 14 (bacteriological and nutrients) and Table 15 (metals). Spring and autumn results for physico-chemical, bacteriological and metals were generally within the ANZECC (2000) guidelines.

Low dissolved oxygen saturation levels were observed on both sampling occasions at Bridge Street (24.3% and 28.5%), Kent Road (44.5% and 46.4%) and Wilga Park (52.8% and 28.9%). Dissolved oxygen saturation levels were reflective of the historical median, except for Bridge St, which was well below the median.

Total zinc concentrations were slightly elevated at Bridge Street on both sampling occasions at 0.022 mg/L. Total zinc (0.033 mg/L) and total copper (0.006 mg/L) concentrations were elevated at Wilga Park in spring.

Total nitrogen concentrations for Shrimptons Creek exceeded the guideline value at all sites on both sampling occasions. The high historical median values indicate that this is a frequent occurrence for these sites. Total phosphorous concentrations were also elevated above the guideline on at least one occasion at each site. Oxidised nitrogen concentrations were high at both Quarry Road and Wilga Park. At Bridge Street Oxidised nitrogen was below the guideline levels and historical median on both sampling occasions.

Table 12 Shrimptons Creek physico-chemical results

Analyte		Temperature	Dissolved Oxygen	Dissolved Oxygen	pH	Turbidity	Conductivity
Unit		°C	mg/L	% saturation	pH units	NTU	µS/cm
Guideline		NA	NA	85-110	6.8-8.5	50	125-2,200
CR1SC	*Historical median*	*17.7*	*6.6*	***71.0***	*7.30*	*3.54*	*901*
	Autumn 2014	15.3	8.5	85.6	7.45	1.18	923
	Spring 2013	19.2	8.8	95.1	7.23	1.69	546
CR1SB	*Historical median*	*17.6*	*5.9*	***59.0***	*7.10*	*4.94*	*669*
	Autumn 2014	15.1	2.9	**28.5**	6.95	3.58	679
	Spring 2013	19.2	2.2	**24.3**	7.09	5.58	522
CR1SA	*Historical median*	*17.0*	*5.0*	***54.0***	*7.07*	*4.28*	*435*
	Autumn 2014	15.7	4.6	**46.4**	7.22	4.80	648
	Spring 2013	18.7	4.2	**44.5**	7.08	4.60	408
Site 2	*Historical median*	*17.2*	*4.3*	***46.0***	*7.10*	*4.91*	*325*
	Autumn 2014	15.4	3.0	**28.9**	7.16	5.19	419
	Spring 2013	19.1	4.8	**52.8**	7.25	4.65	428

Table 13 Shrimptons Creek alkalinity and hardness results

Analyte		Total Magnesium	Total Calcium	Hardness	Alkalinity
Unit		mg/L	mg/L	mg CaCO3/L	mg CaCO3/L
Guideline		NA	NA	NA	NA
CR1SC	*Historical median*	*NA*	*NA*	*NA*	*83.85*
	Autumn 2014	14.0	33.1	140	82.0
	Spring 2013	8.3	21.5	88	52.1
CR1SB	*Historical median*	*NA*	*NA*	*NA*	*82.8*
	Autumn 2014	10.0	34.1	126	87.0
	Spring 2013	7.7	27.0	99	69.8
CR1SA	*Historical median*	*NA*	*NA*	*NA*	*64.1*
	Autumn 2014	8.2	28.6	105	67.0
	Spring 2013	6.0	20.9	77	52.3
Site 2	*Historical median*	*NA*	*NA*	*NA*	*66.5*
	Autumn 2014	7.2	31.5	108	94.0
	Spring 2013	4.7	21.1	72	57.2

Table 14 Shrimptons Creek bacteriological and nutrient results

	Analyte	Faecal coliform	Ammonia NH3 -N	Total Nitrogen	Total Kjeldahl Nitrogen	Oxidised Nitrogen NOx-N	Total Phosphorus
	Unit	CFU/100mL	µg/L	µg/L	µg/L	µg/L	µg/L
	Guideline	1,000	20	350	NA	40	25
CR1SC	*Historical median*	*500*	***35***	***1,425***	*490*	***670***	***66***
	Autumn 2014	160	10	**1,560**	730	**830**	**32**
	Spring 2013	250	**80**	**1,320**	660	**660**	25
CR1SB	*Historical median*	*245*	***25***	***530***	*375*	*40*	***26***
	Autumn 2014	46	5	**560**	550	10	15
	Spring 2013	220	10	**680**	670	10	**41**
CR1SA	*Historical median*	*450*	***25***	***605***	*445*	***75***	***41***
	Autumn 2014	46	20	**700**	660	40	23
	Spring 2013	590	10	**790**	720	**70**	**45**
Site 2	*Historical median*	*450*	*20*	***560***	*380*	***60***	***53***
	Autumn 2014	320	**40**	**680**	560	**120**	**40**
	Spring 2013	260	**40**	**1,250**	810	**440**	**58**

Table 15 Shrimptons Creek metal results

	Analyte	Total Chromium	Total Manganese	Total Iron	Total Copper	Total Zinc	Total Arsenic	Total Cadmium	Total Lead	Total Mercury
	Unit	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
	Guideline	0.001	1.9	NA	0.0035	0.02	0.013	0.00054	0.0136	0.00060
CR1SC	*Historical median*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
	Autumn 2014	0.0005*	0.016	0.227	0.002	0.017	0.0005*	0.0005*	0.0005*	0.00015*
	Spring 2013	0.0005*	0.045	0.381	0.002	0.014	0.0005*	0.0005*	0.0005*	0.00015*
CR1SB	*Historical median*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
	Autumn 2014	0.0005*	0.031	1.12	0.001	**0.022**	0.0005*	0.0005*	0.0005*	0.00015*
	Spring 2013	0.0005*	0.132	2.56	0.002	**0.022**	0.0005*	0.0005*	0.0005*	0.00015*
CR1SA	*Historical median*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
	Autumn 2014	0.0005*	0.034	0.985	0.001	0.015	0.0005*	0.0005*	0.0005*	0.00015*
	Spring 2013	0.0005*	0.063	1.3	0.002	0.015	0.0005*	0.0005*	0.0005*	0.00015*
Site 2	*Historical median*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
	Autumn 2014	0.0005*	0.041	1.07	0.002	0.018	0.0005*	0.0005*	0.0005*	0.00015*
	Spring 2013	0.0005*	0.043	0.836	0.006	**0.033**	0.001	0.0005*	0.002	0.00015*

(denotes below detection limits)*

7.3 Porters Creek

Site 3 - Porters Creek downstream of Council Depot

CR5PA - Porters Creek at Main Branch

CR5PB - Porters Creek at Spur Branch

CR5PC - Porters Creek at Wicks Road

Water quality results for the Porters Creek sites are presented in Table 16 (physico-chemical), Table 17 (alkalinity and hardness), Table 18 (bacteriological and nutrients) and Table 19 (metals). The Spur Branch site was not sampled due to a bank collapse that blocked and rendered the access point unsafe. Spring and autumn results for physico-chemical, bacteriological and metals were generally within guidelines levels.

Slightly low dissolved oxygen saturation levels were recorded at Wicks Road (84.0%) downstream of the Council Depot (78.9%) in spring and Main Branch (63.5%) in autumn. The recent surveys and the historical median indicate that generally dissolved oxygen saturation levels are within the guideline levels.

Nutrient concentrations were elevated above the ANZECC (2000) guideline and historical median at most sites for both spring and autumn and faecal coliforms were elevated at Wicks Road (7,700 CFU/100 mL) in spring.

Total zinc and copper were elevated at all sites in spring but had decreased to be below the guideline at the core site in autumn. Total copper had also reduced to below guidelines at the Main Branch site in autumn.

Turbidity although below the recommended guideline, was considerably higher than the historical median at Wicks Road and the Main Branch in both spring 2013 and autumn 2014.

Table 16 Porters Creek physico-chemical results

	Analyte	Temperature	Dissolved Oxygen	Dissolved Oxygen	pH	Turbidity	Conductivity
	Unit	°C	mg/L	% saturation	pH units	NTU	µS/cm
	Guideline	NA	NA	85-110	6.8-8.5	50	125-2,200
CR5PC	*Historical median*	*18.7*	*8.9*	*94.0*	*7.70*	*3.44*	*512*
	Autumn 2014	17.4	8.3	86.8	7.39	28.6	464
	Spring 2013	18.4	7.4	**84.0**	7.30	16.0	438
CR5PA	*Historical median*	*17.7*	*7.9*	***78.0***	*7.13*	*3.22*	*363*
	Autumn 2014	17.2	6.2	**63.5**	7.06	17.2	348
	Spring 2013	21.9	8.3	94.8	7.45	14.8	140
CR5PB	*Historical median*	*18.2*	*9.5*	*99.0*	*7.60*	*4.36*	*343*
	Autumn 2014	NA	NA	NA	NA	NA	NA
	Spring 2013	NA	NA	NA	NA	NA	NA
Site 3	*Historical median*	*18.0*	*8.4*	*91.0*	*7.63*	*3.67*	*610*
	Autumn 2014	15.3	10.2	104.0	7.68	5.40	632
	Spring 2013	19.0	7.8	**78.9**	7.53	4.96	512

Table 17 Porters Creek alkalinity and hardness results

Analyte		Total Magnesium	Total Calcium	Hardness	Alkalinity
Unit		mg/L	mg/L	mg CaCO3/L	mg CaCO3/L
Guideline		NA	NA	NA	NA
CR5PC	*Historical median*	*NA*	*NA*	*NA*	*78.9*
	Autumn 2014	8.9	31.7	116	81.0
	Spring 2013	7.2	28.7	101	77.9
CR5PA	*Historical median*	*NA*	*NA*	*NA*	*90*
	Autumn 2014	10.7	28.1	114	130
	Spring 2013	2.2	10.8	36	33.2
CR5PB	*Historical median*	*NA*	*NA*	*NA*	*70.0*
	Autumn 2014	NA	NA	NA	NA
	Spring 2013	NA	NA	NA	NA
Site 3	*Historical median*	*NA*	*NA*	*NA*	*85.3*
	Autumn 2014	11.8	45.2	162	145
	Spring 2013	8.8	36.0	126	118

Table 18 Porters Creek bacteriological and nutrient results

Analyte		Faecal coliform	Ammonia NH3 -N	Total Nitrogen	Total Kjeldahl Nitrogen	Oxidised Nitrogen NOx-N	Total Phosphorus
Unit		CFU/100mL	µg/L	µg/L	µg/L	µg/L	µg/L
Guideline		1,000	20	350	NA	40	25
CR5PC	*Historical median*	*525*	***40***	***1,405***	*375*	***935***	***28***
	Autumn 2014	590	**100**	**2,480**	1,050	**1,430**	**36**
	Spring 2013	**7,700**	**210**	**3,360**	1,450	**1,910**	**276**
CR5PA	*Historical median*	*47*	***90***	***670***	*505*	***155***	***38***
	Autumn 2014	91	**200**	**1,170**	890	**280**	**29**
	Spring 2013	420	**30**	**900**	670	**230**	**63**
CR5PB	*Historical median*	*122*	***75***	***745***	*430*	***260***	***38***
	Autumn 2014	NA	NA	NA	NA	NA	NA
	Spring 2013	NA	NA	NA	NA	NA	NA
Site 3	*Historical median*	*370*	***580***	***2,300***	*1,100*	***1,070***	*24*
	Autumn 2014	54	**860**	**3,980**	1,280	**2,700**	**34**
	Spring 2013	210	**320**	**2,730**	1,370	**1,360**	**98**

Table 19 Porters Creek metal results

	Analyte	Total Chromium	Total Manganese	Total Iron	Total Copper	Total Zinc	Total Arsenic	Total Cadmium	Total Lead	Total Mercury
	Unit	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
	Guideline	0.001	1.9	NA	0.0035	0.02	0.013	0.00054	0.0136	0.00060
CR5PC	*Historical median*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
	Autumn 2014	0.002	0.038	1.12	**0.012**	**0.048**	0.0005*	0.0005*	0.0005*	0.00015*
	Spring 2013	0.001	0.026	2.29	**0.018**	**0.099**	0.0005*	0.0005*	0.002	0.00015*
CR5PA	*Historical median*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
	Autumn 2014	0.001	0.066	0.851	0.003	**0.025**	0.0005*	0.0005*	0.001	0.00015*
	Spring 2013	0.001	0.011	0.491	**0.005**	**0.027**	0.0005*	0.0005*	0.002	0.00015*
CR5PB	*Historical median*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
	Autumn 2014	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Spring 2013	NA	NA	NA	NA	NA	NA	NA	NA	NA
Site 3	*Historical median*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
	Autumn 2014	0.0005*	0.034	0.982	0.002	0.017	0.0005*	0.0005*	0.0005*	0.00015*
	Spring 2013	0.0005*	0.055	1.1	**0.004**	**0.023**	0.0005*	0.0005*	0.0005*	0.00015*

(denotes below detection limits)*

7.4 Buffalo Creek

Site 4 – Buffalo Creek at Higginbotham Road

CR4BA – Buffalo Creek downstream of Burrows Park

CR4BB – Buffalo Creek upstream of Burrows Park

Water quality results for Buffalo Creek are presented in Table 20 (physico-chemical), Table 21 (alkalinity and hardness), Table 22 (bacteriological and nutrients) and Table 23 (metals). Spring and autumn results for physico-chemical, bacteriological and metals were generally within guidelines levels.

Dissolved oxygen saturation levels were below the recommended guideline range of 85% at all sites in spring. Although levels had improved by autumn, they remained below the guideline at all sites except Higginbotham Road. The historical median saturation levels for dissolved oxygen are at or below the lower guideline limit at all sites indicating that these sites frequently have low oxygen levels.

Of particular concern were the extremely high faecal coliform results upstream and downstream of Burrows Park (1,300,000 CFU/100 mL and 320,000 CFU/100 mL, respectively) in spring. Nutrient concentrations were also high, exceeding the respective ANZECC (2000) guidelines and the historical medians indicating a contamination event had

occurred in Buffalo Creek, though there were no visual or olfactory indications of pollution at the time of sampling. Results were highest at the site upstream of Burrows Park, indicating that contamination had likely occurred upstream of this site. Faecal coliform results had fallen to below guideline levels in autumn. However total and oxidised nitrogen and total phosphorus concentrations remained elevated above both the guideline levels and the historical median.

Table 20 Buffalo Creek physico-chemical results

Analyte		Temperature	Dissolved Oxygen	Dissolved Oxygen	pH	Turbidity	Conductivity
Unit		°C	mg/L	% saturation	pH units	NTU	µS/cm
Guideline		NA	NA	85-110	6.8-8.5	50	125-2,200
CR4BB	*Historical median*	*17.5*	*8.2*	*85.0*	*7.68*	*2.94*	*968*
	Autumn 2014	17.2	7.8	**81.4**	7.63	7.38	709
	Spring 2013	18.6	5.2	**56.3**	7.55	9.05	547
CR4BA	*Historical median*	*17.8*	*7.6*	***81.0***	*7.16*	*7.25*	*1188*
	Autumn 2014	16.9	7.4	**73.1**	7.29	13.90	840
	Spring 2013	18.7	5.2	**56.4**	7.48	6.59	620
Site 4	*Historical median*	*17.2*	*6.8*	***70.0***	*7.30*	*5.50*	*694*
	Autumn 2014	17.1	9.0	93.2	7.50	5.05	529
	Spring 2013	19.6	7.3	**80.3**	7.43	3.33	472

Table 21 Buffalo Creek alkalinity and hardness results

Analyte		Total Magnesium	Total Calcium	Hardness	Alkalinity
Unit		mg/L	mg/L	mg CaCO3/L	mg CaCO3/L
Guideline		NA	NA	NA	NA
CR4BB	*Historical median*	*NA*	*NA*	*NA*	*102*
	Autumn 2014	10.5	33.7	128	100.0
	Spring 2013	7.4	23.1	88	107
CR4BA	*Historical median*	*NA*	*NA*	*NA*	*95.1*
	Autumn 2014	13.5	34.9	143	102.0
	Spring 2013	9.6	25.6	103	82.8
Site 4	*Historical median*	*NA*	*NA*	*NA*	*79*
	Autumn 2014	9.4	24.8	101	65
	Spring 2013	7.6	22.9	89	58.1

Table 22 Buffalo Creek bacteriological and nutrient results

Analyte		Faecal coliform	Ammonia NH3 -N	Total Nitrogen	Total Kjeldahl Nitrogen	Oxidised Nitrogen NOx-N	Total Phosphorus
Unit		CFU/100mL	µg/L	µg/L	µg/L	µg/L	µg/L
Guideline		1,000	20	350	NA	40	25
CR4BB	*Historical median*	*465*	*15*	***1,280***	*435*	***765***	***57***
	Autumn 2014	750	**30**	**3,150**	1,330	**1,820**	**196**
	Spring 2013	**1,300,000**	**6,600**	**12,200**	10,900	**1,250**	**820**
CR4BA	*Historical median*	*840*	*13*	***880***	*470*	***525***	***43.5***
	Autumn 2014	330	**70**	**2,570**	1,190	**1,380**	**104**
	Spring 2013	**320,000**	**1,070**	**3,430**	2,580	**850**	**214**
Site 4	*Historical median*	*170*	***40***	***650***	*400*	***220***	***37***
	Autumn 2014	62	20	**1,330**	620	**710**	**31**
	Spring 2013	270	10	**1,080**	690	**390**	**58**

Table 23 Buffalo Creek metal and hardness results

Analyte		Total Chromium	Total Manganese	Total Iron	Total Copper	Total Zinc	Total Arsenic	Total Cadmium	Total Lead	Total Mercury
Unit		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Guideline		0.001	1.9	NA	0.0035	0.02	0.013	0.00054	0.0136	0.00060
CR4BB	*Historical median*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
	Autumn 2014	0.0005*	0.023	0.464	0.008	**0.052**	0.001	0.0005*	0.0005*	0.00015*
	Spring 2013	0.0005*	0.042	0.513	0.014	**0.034**	0.001	0.0005*	0.0005*	0.00015*
CR4BA	*Historical median*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
	Autumn 2014	0.0005*	0.089	1.440	0.006	**0.041**	0.0005*	0.0005*	0.001	0.00015*
	Spring 2013	0.0005	0.094	1.29	0.006	**0.027**	0.0005*	0.0005*	0.001	0.00015*
Site 4	*Historical median*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
	Autumn 2014	0.0005*	0.026	0.974	0.003	0.017	0.0005*	0.0005*	0.0005*	0.00015*
	Spring 2013	0.0005*	0.04	1.17	0.004	0.016	0.0005*	0.0005*	0.0005*	0.00015*

(denotes below detection limits)*

7.5 Archers Creek

Site 5 – Archers Creek at Maze Park

Water quality results for Archers Creek are presented in Table 24 (physico-chemical), Table 25 (alkalinity and hardness), Table 26 (bacteriological and nutrients) and Table 27 (metals). Spring and autumn results for physico-chemical, bacteriological and metals were mostly within guidelines levels.

Dissolved oxygen levels were very low with saturation levels of only 9.6% in spring and 17.3% in autumn, well below both the guideline level and the historic median.

Faecal coliform results were elevated above the ANZECC (2000) guideline in spring at 2,100 CFU/100 mL, but fell below the guideline level in autumn. Total nitrogen and total phosphorus concentrations exceeded the guidelines on both sampling occasions but were lower in autumn than in spring. In contrast, ammonia concentration was higher in autumn 2014, exceeding the guideline levels and the historical median for the site.

Total copper results were slightly elevated in spring, while the zinc concentration was eight times above the recommended guideline, the highest concentration recorded from across all the sites sampled for the current surveys. These concentrations had decreased in autumn to be below the guideline levels.

Table 24 Archers Creek physico-chemical results

Analyte		Temperature	Dissolved Oxygen	Dissolved Oxygen	pH	Turbidity	Conductivity
Unit		°C	mg/L	% saturation	pH units	NTU	µS/cm
Guideline		NA	NA	85-110	6.8-8.5	50	125-2,200
Site 5	*Historical median*	*17.4*	*5.9*	***61.0***	*7.16*	*2.66*	*397*
	Autumn 2014	17.0	1.8	**17.3**	7.08	3.80	466
	Spring 2013	21.5	0.8	**9.6**	7.15	3.16	499

Table 25 Archers Creek alkalinity and hardness results

Analyte		Total Magnesium	Total Calcium	Hardness	Alkalinity
Unit		mg/L	mg/L	mg CaCO3/L	mg CaCO3/L
Guideline		NA	NA	NA	NA
Site 5	*Historical median*	*NA*	*NA*	*NA*	*74*
	Autumn 2014	9.4	27.1	106	95.0
	Spring 2013	8.7	24.4	97	67.1

Table 26 Archers Creek bacteriological nutrient results

Analyte		Faecal coliform	Ammonia NH3 -N	Total Nitrogen	Total Kjeldahl Nitrogen	Oxidised Nitrogen NOx-N	Total Phosphorus
Unit		CFU/100mL	µg/L	µg/L	µg/L	µg/L	µg/L
Guideline		1,000	20	350	NA	40	25
Site 5	*Historical median*	*310*	***30***	***520***	*350*	***70***	***40***
	Autumn 2014	67	**70**	**640**	620	20	**50**
	Spring 2013	**2,100**	10	**900**	900	5	**80**

Table 27 Archers Creek metal results

Analyte		Total Chromium	Total Manganese	Total Iron	Total Copper	Total Zinc	Total Arsenic	Total Cadmium	Total Lead	Total Mercury
Unit		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Guideline		0.001	1.9	NA	0.0035	0.02	0.013	0.00054	0.0136	0.00060
Site 5	*Historical median*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
	Autumn 2014	0.0005*	0.710	0.920	0.0005*	0.014	0.0005*	0.0005*	0.0005*	0.00015*
	Spring 2013	0.0005*	0.903	0.828	**0.005**	**0.161**	0.0005*	0.0005*	0.0005*	0.00015*

(denotes below detection limit)*

8 Macroinvertebrates

8.1 Univariate analyses

8.1.1 Taxa richness

> ***Taxa richness*** *is the overall variety (total taxa) of macroinvertebrates in a given community assemblage. It is an indicator of stream health that can be measured at any specific taxonomic level and operates under the assumption that taxa richness will be higher in healthy streams and lower in streams of poor health.*

A total of 738 individual macroinvertebrate specimens were collected from 41 confirmed taxa from the spring survey and 743 specimens from 29 taxa during the autumn survey (Appendix 5). A total of 79 confirmed taxa families have been collected since 2004.

The average taxa richness, represented as total families collected from the spring and autumn surveys are presented in Figure 13, including the historical average from the previous surveys. All results are presented with +/- one standard deviation from the mean.

Archers Creek recorded the highest taxa richness with an average of 16.3 and 17.3 families from the respective spring and autumn surveys, both higher than the historical average. Buffalo Creek had the lowest taxa richness each season with an average of 9.7 and 7.0 from the respective spring and autumn surveys. Both results were well below the historical average, with the autumn result significantly lower.

Average taxa richness at Terrys and Porters creeks were lower in autumn compared to spring, which were again lower than their respective historical averages. Average taxa richness at Porters Creek in autumn was significantly lower than the spring survey and historical average. The average taxa richness at Shrimptons Creek was relatively similar in the two recent surveys and was only marginally higher than the historical average.

The larvae of the Sydney Hawk dragonfly, Austrocordulia leonardi and the Adams Emerald dragonfly, Archaeophya adamsi, both listed as endangered under the Fisheries Management Act 1994, are potentially found in the Sydney basin region. Neither of these macroinverebrates was observed in any of the samples collected during the monitoring program.

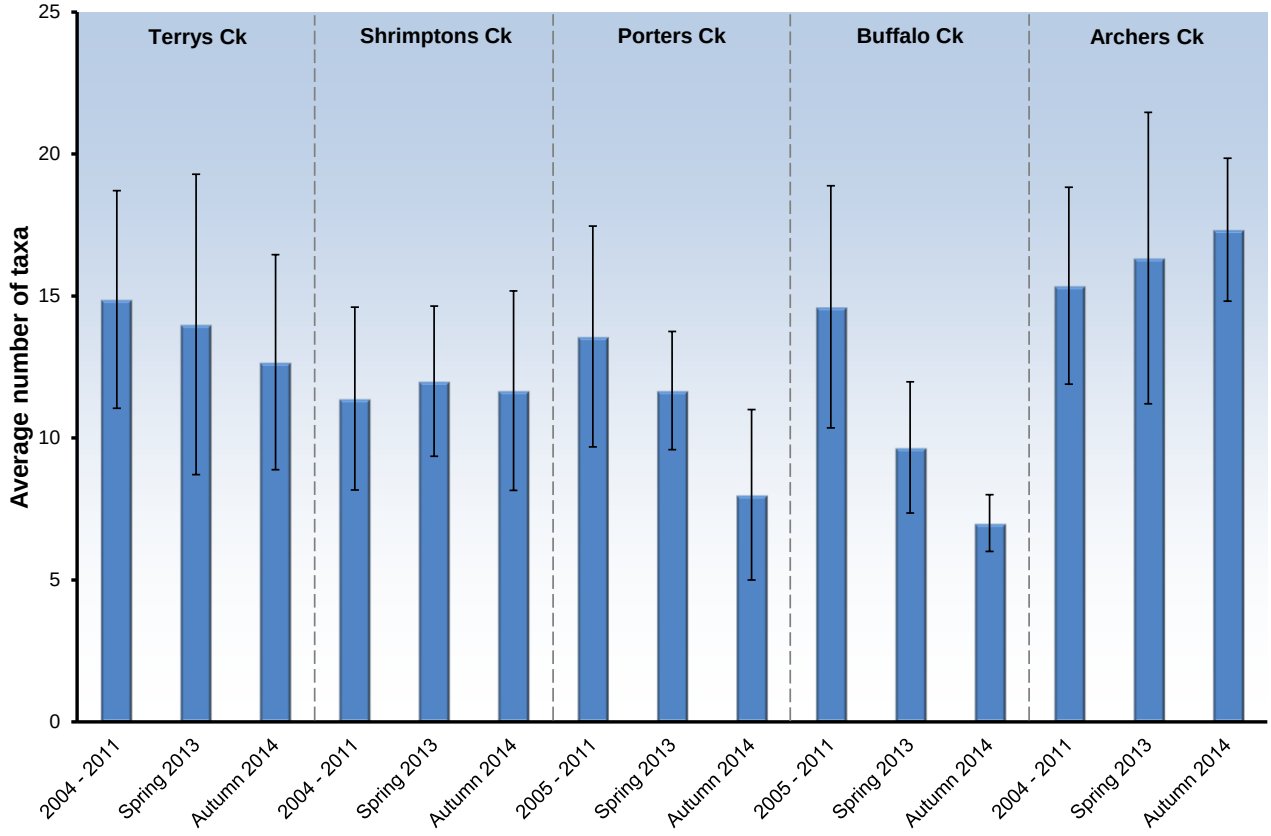

Figure 13 Average taxa for all creeks of the monitoring program (+/- 1 standard deviation)

Taxa group percent composition *is a visual display of the contribution of each of the main macroinvertebrate taxa in a given community assemblage. Percent contribution shows the dominant groups within each study creek.*

The generic names given to the taxa within the groups are listed below;

Annelida – worms
Coleoptera – beetles
Crustacea – yabbies, shrimp & slaters
Diptera – true flies
EPT – mayflies, stoneflies & caddisflies
Hemiptera – true bugs
Mollusca – snails and mussels
Odonata – dragonflies & damselflies
Other Taxa – various incl. mites, lacewings & flatworms

The taxa group composition for each creek is represented by the overall contribution of each taxa group represented as a percentage of the overall specimen count for each creek from all surveys, including historic data. These results are presented in Figure 14 to Figure 18.

The single most dominant taxa group contributing to the biggest proportion of specimens within the community assemblages at three of the five core sites (Terrys, Shrimptons and Buffalo creeks) was Mollusca. The second most dominant taxa group was Diptera, which contributed the biggest proportion of specimens at Porters and Archers creeks. Odonata was the third most dominant taxa group across the five creeks. These three groups contributed between 68-80% of the total taxa present in each of the five creeks of the program (Figure 14 - Figure 18).

The EPT indicator taxa have been found in very low numbers across all five creeks. Archers Creek had proportionately the highest EPT taxa composition, contributing to almost 6% of the total. Coleoptera and Crustacea contributed very little to the overall taxa composition across the five creeks (Figure 14 - Figure 18).

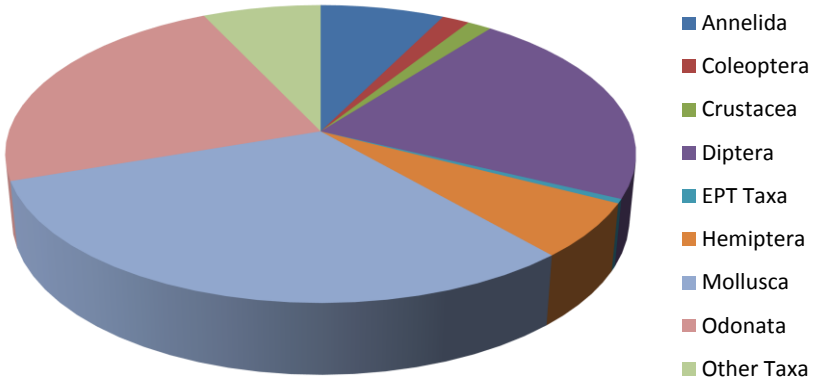

Figure 14 Taxa group composition for Terrys Creek, spring 2004 – autumn 2014

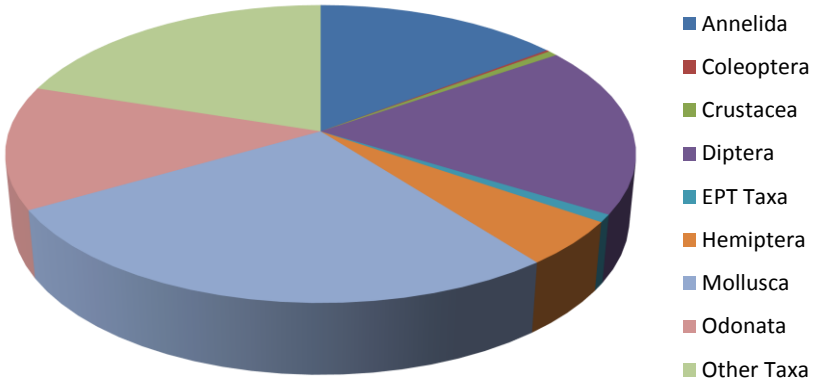

Figure 15 Taxa group composition for Shrimptons Creek, spring 2004 – autumn 2014

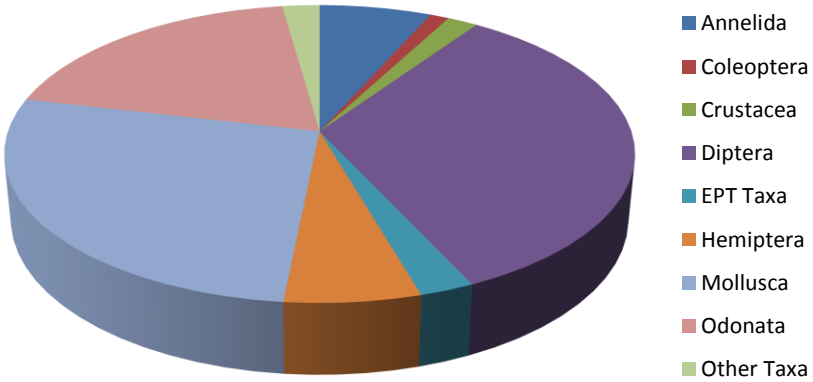

Figure 16 Taxa group composition for Porters Creek, autumn 2005 – autumn 2014

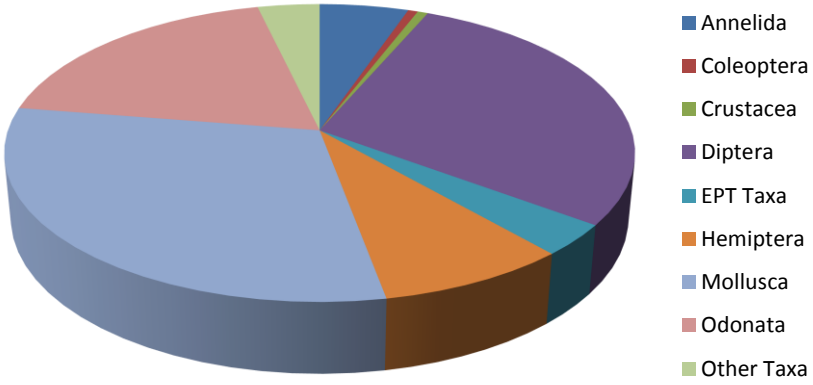

Figure 17 Taxa group composition for Buffalo Creek, autumn 2005 – autumn 2014

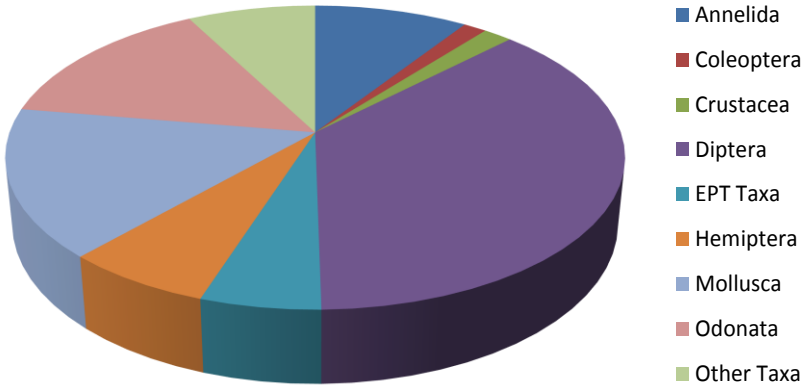

Figure 18 Taxa group composition for Archers Creek, spring 2004 – autumn 2014

8.1.2 EPT taxa richness

> ***EPT taxa richness*** *shows the abundance of highly sensitive Ephemeroptera (mayfly), Plecoptera (stoneflly) and Trichoptera (caddisflly) orders. High EPT richness indicates increased water quality and a healthy creek system.*

The average EPT taxa richness collected during the spring and autumn surveys are presented in Figure 19, including the historical average. Results indicate that EPT taxa are found sporadically and in very low numbers across the five creeks.

No EPT taxa were collected at Buffalo Creek during the recent surveys, and no EPT taxa were collected at Shrimptons Creek in spring and Terrys Creek in autumn.

The averages across all five creeks in both the recent surveys and historical results are all below one EPT taxa. Since the beginning of the program in 2004 a total of only five EPT taxa families have been collected. Only one, the Hydroptilidae (Trichopteran), has been recorded regularly from all five creeks (Appendix 4).

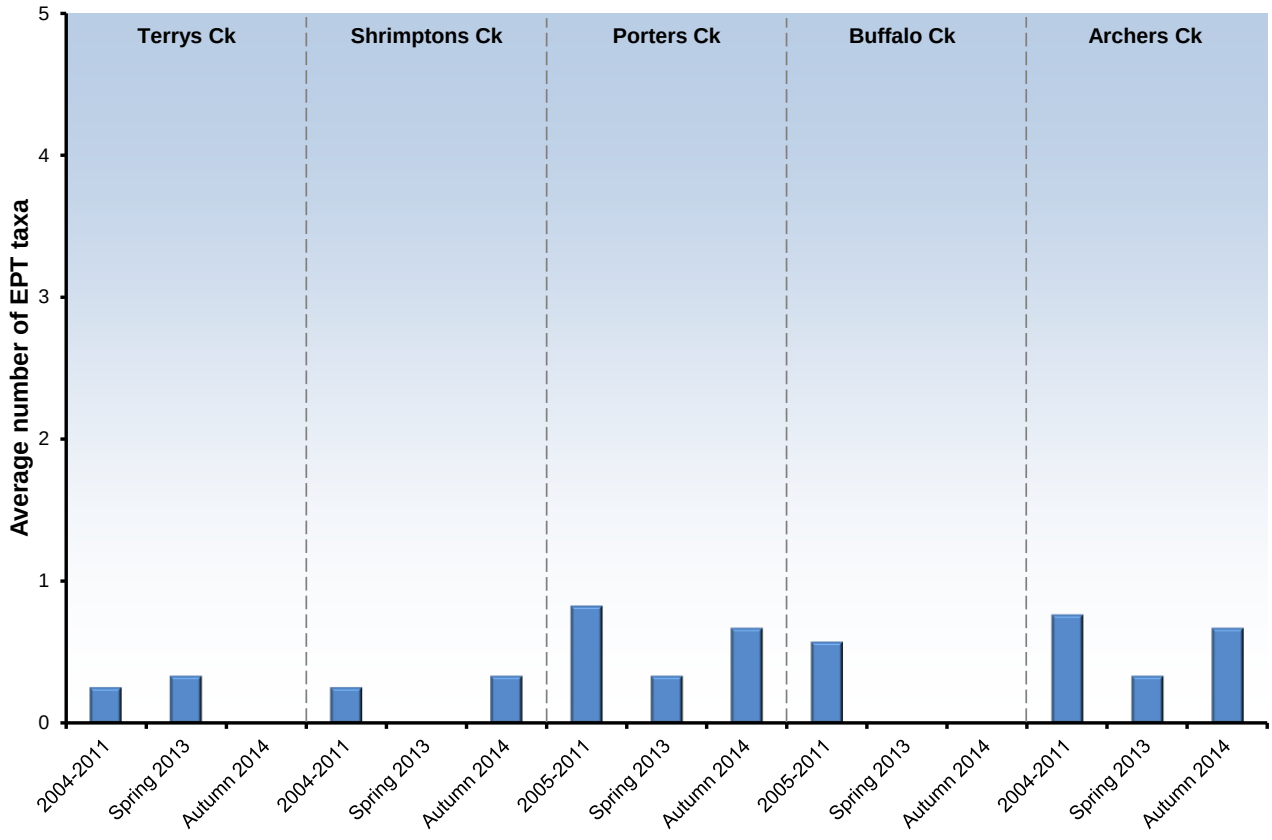

Figure 19 Average EPT taxa for each creek

8.2 Biological indices

8.2.1 SIGNAL2

SIGNAL2 *(Stream Invertebrate Grade Number Average Level) biotic index is a relatively simple method used to assess stream health. This index assigns 'sensitivity scores' to macroinvertebrate taxa. A final SIGNAL score combined with the total taxa then places a study creek within a quadrant based on potential pollution type.*

Average SIGNAL2 scores for spring and autumn surveys are presented in Figure 20, all results are presented with +/- one standard deviation from the mean. A bi-plot showing the quadrat placement for the five creeks is displayed in Figure 21. SIGNAL2 wasn't calculated as part of the previous program (2004 - 2011) as such there are no historical averages.

Terrys Creek recorded the highest average SIGNAL2 scores respectively (3.57 & 3.87) from the spring and autumn surveys and Shrimptons Creek recorded the two lowest (2.64 & 2.95). The average SIGNAL2 scores for all five creeks increased slightly from spring to autumn.

All SIGNAL2 scores from the five creeks were placed in quadrat four in the bi-plot. Results in quadrat four are representative of urban, industrial or agricultural pollution (Appendix 3, Figure 38), this placement is the result of samples having combined low SIGNAL2 scores and taxa counts.

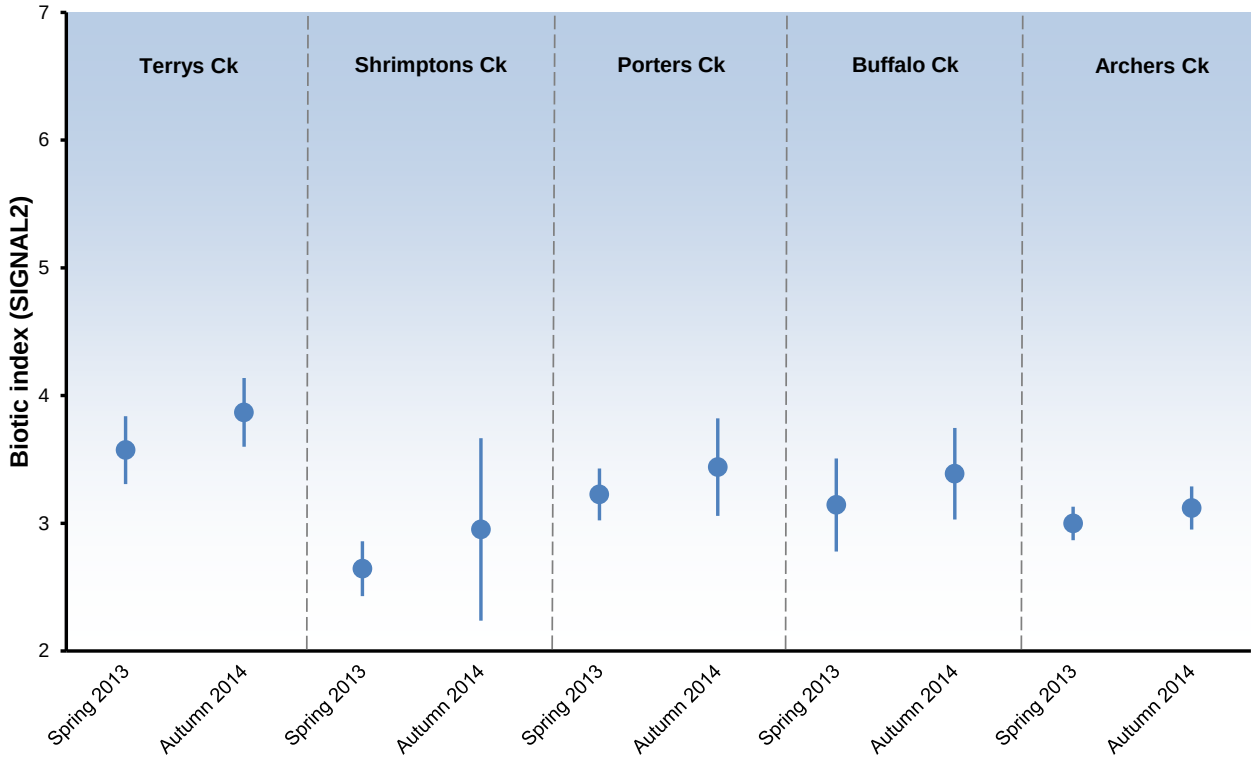

Figure 20 Average SIGNAL2 scores for spring 2013 and autumn 2014 (+/- 1 standard deviation)

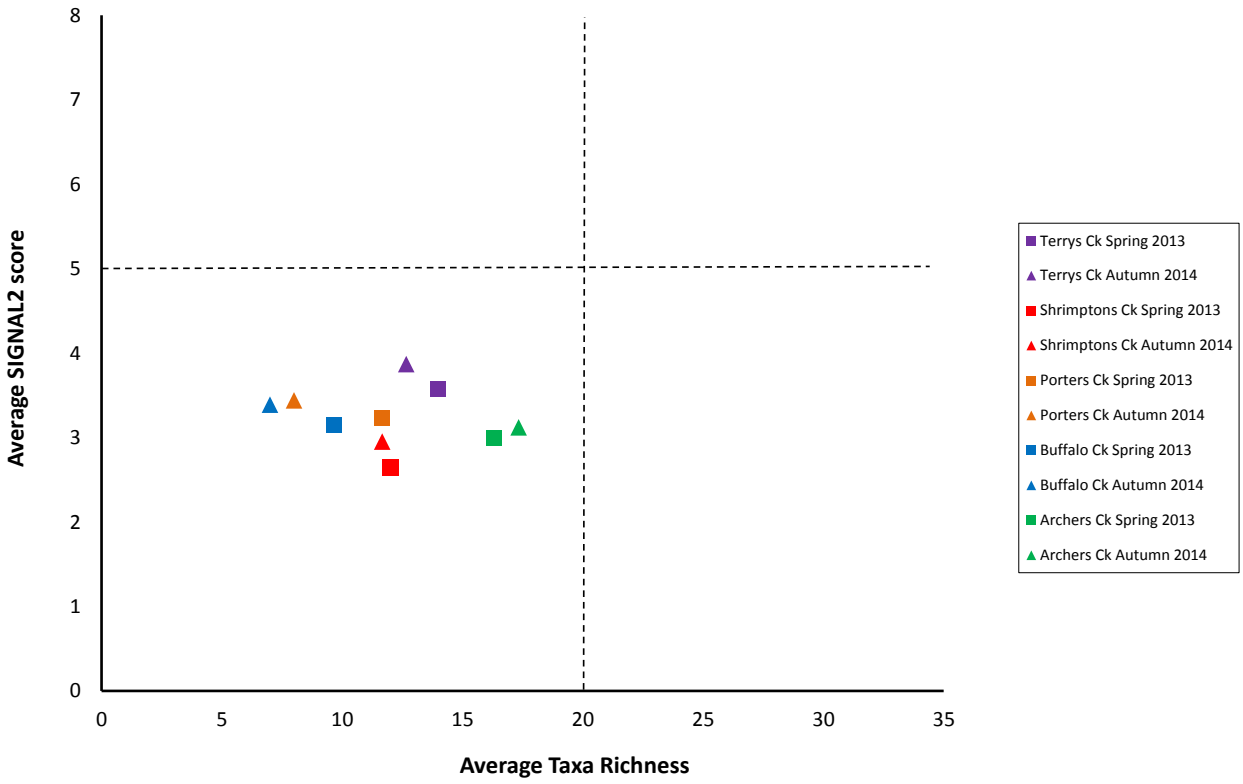

Figure 21 SIGNAL2 bi-plot from spring 2013 and autumn 2014

8.2.2 Signal-SF

SIGNAL-SF 'Stream Invertebrate Grade Number Average Level - Sydney Family' *biotic index is a relatively simple method used to assess stream health. This index assigns 'sensitivity scores' from 1 being tolerant to 10 being very sensitive to each individual macroinvertebrate taxa.*

The average SIGNAL-SF biotic index scores for the spring and autumn surveys including historical averages are presented in Figure 22, all results are presented with +/- one standard deviation from the mean.

SIGNAL-SF scores for all five creeks for the current surveys and historical average were mostly indicative of probable moderate organic pollution. The one exception was the SIGNAL-SF score at Buffalo Creek (3.76) in autumn which fell into the probable severe organic pollution range (Table 32).

Results indicate that Archers Creek is the healthiest of the five creeks of the program. Archers Creek has the highest overall historical average SIGNAL-SF score and the highest average scores in both current surveys (4.43) respectively. Terrys and Porters creeks SIGNAL-SF results are only slightly lower than Archers Creeks for all current and historical seasons. These results indicate that Shrimptons Creek is historically the worst performing of the five creeks. The recent surveys, however, suggest that Buffalo Creek has dropped to be of similar health to Shrimptons Creek.

Results indicate that Shrimptons Creek has the greater variability of SIGNAL-SF scores through time, whereas Terrys has had the least. When looking at the average SIGNAL-SF scores across all five creeks and survey periods the differences that exist are minimal and all five creeks would appear to have at least similar stream health.

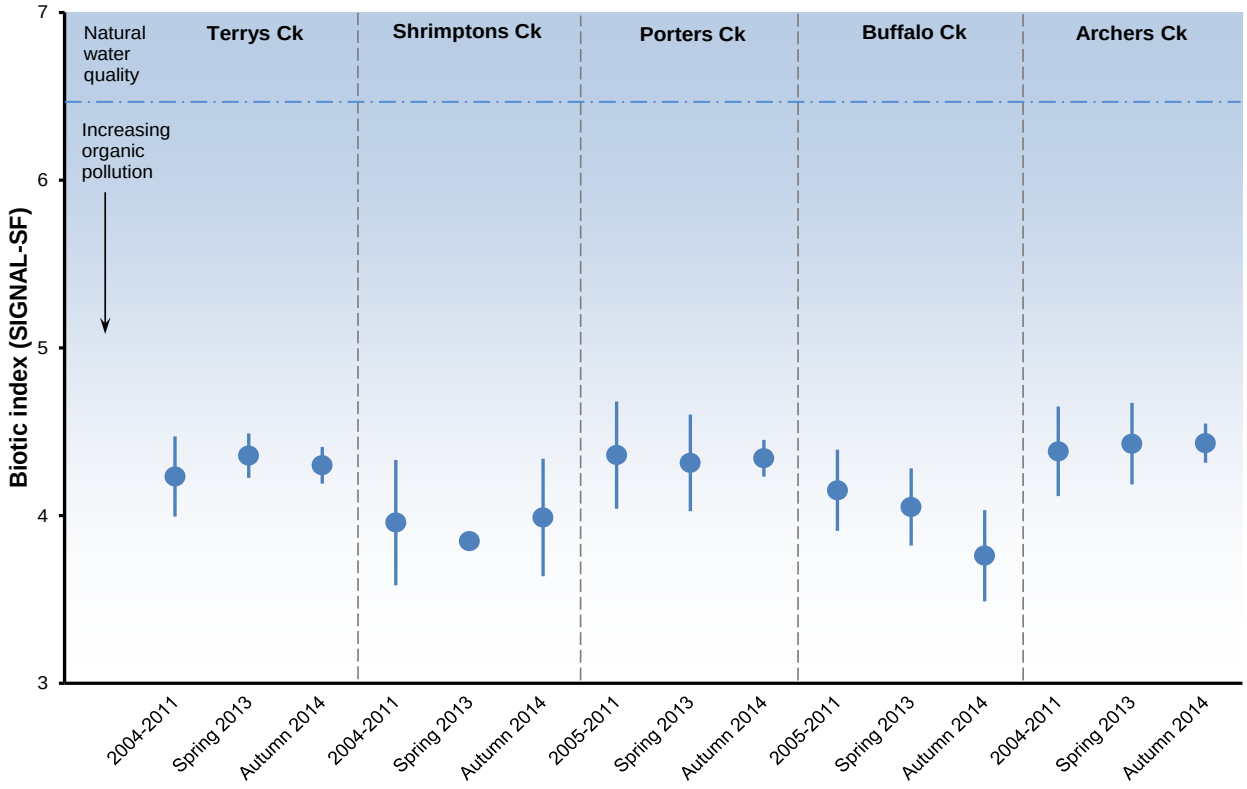

Figure 22 Average SIGNAL-SF scores for each creek (+/- 1 standard deviation)

8.2.3 AUSRIVAS OE50

AUSRIVAS OE50 *is an indice calculated from the AUSRIVAS predictive model, comparing the macroinvertebrates from a current assessment site to macroinvertebrate data previously collected from reference sites with similar physical and chemical characteristics. The OE50 indice compares only the macroinvertebrates from the assessment site with a greater than 50% chance of occurring at the reference site. This comparison can help determine the 'condition' or 'health' of the water body.*

AUSRIVAS OE50 Spring edge

The AUSRIVAS OE50 spring edge results for 2013 including historical averages are presented in Figure 23, all results are presented with +/- one standard deviation from the mean.

Terrys, Shrimptons, Porters and Archers creeks all returned relatively similar OE50 scores in 2013. These results along with their respective historical averages were placed in band C, indicative of severely impaired stream health. Terrys, Shrimptons, Porters and Archers creeks OE50 score ranges in 2013 overlapped with their respective historical average score range (Appendix 3, Table 34).

Buffalo Creeks OE50 score in 2013 was significantly below the other four creeks and its historical average, placing it in band D, indicative of extremely impaired stream health (Appendix 3, Table 34).

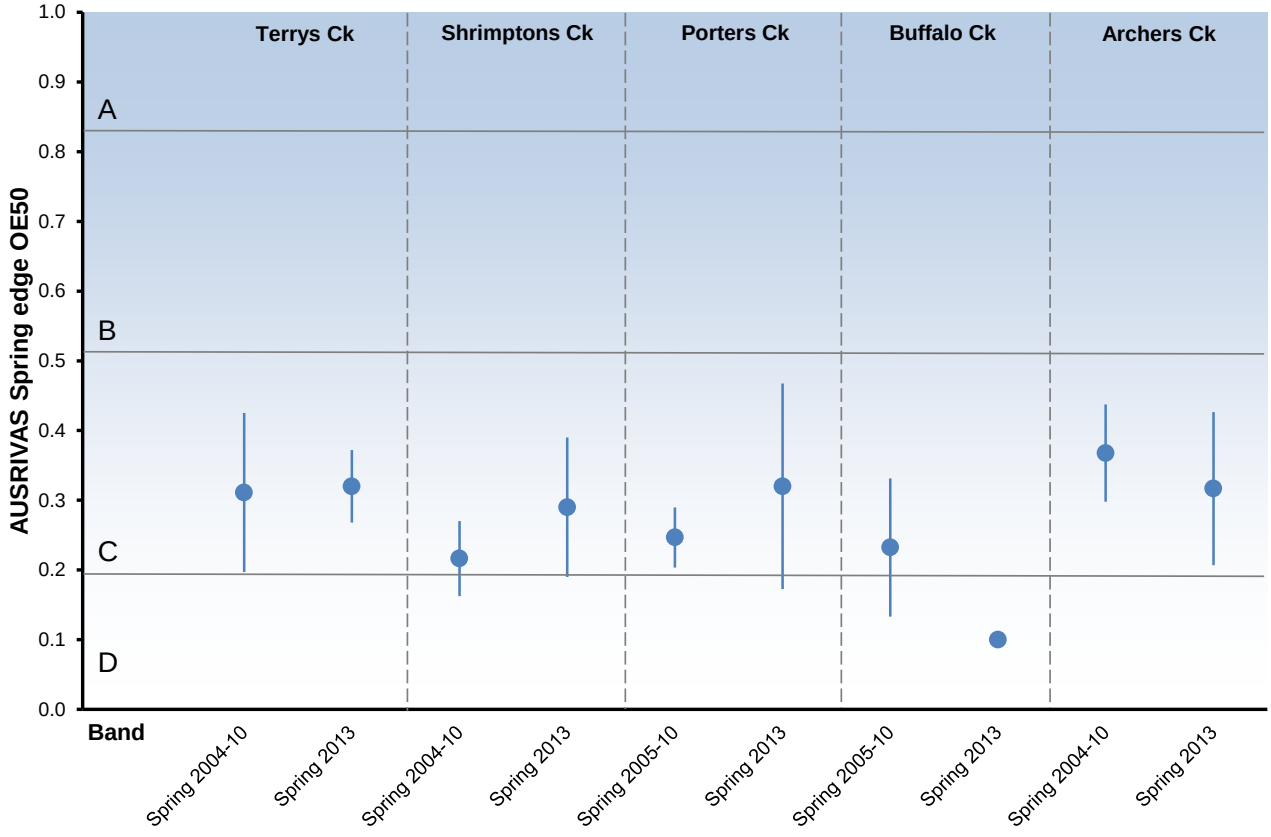

Figure 23 Average AUSRIVAS OE50 spring edge model scores for each creek (+/- 1 standard deviation)

AUSRIVAS OE50 Autumn edge

The AUSRIVAS OE50 autumn edge results for 2014 including historical averages are presented in Figure 24, all results are presented with +/- one standard deviation from the mean.

Archers Creek had the highest OE50 score in 2014, also slightly higher than its historical average. Archers Creek current and historical average scores are placed in band B, which is indicative of significantly impaired stream health. Buffalo Creek had the lowest OE50 score in 2014, which was significantly lower than its historical average. Buffalo Creek in 2014 fell into band D, indicative of extremely impaired stream health (Appendix 3, Table 34).

The 2014 average scores for Terrys and Porters creeks dropped into bands below their respective historical average. Terrys Creek OE50 result dropped marginally whereas Porters Creek OE50 result dropped significantly. Terrys and Porters creeks historical OE50 scores are placed in band B, however in 2014 they dropped into band C, indicative of extremely impaired stream health (Appendix 3, Table 34).

The 2014 OE50 score from Shrimptons Creek was very similar to its historical average, both placed in band C. A high average score variation exists within both the historic and 2014 survey period.

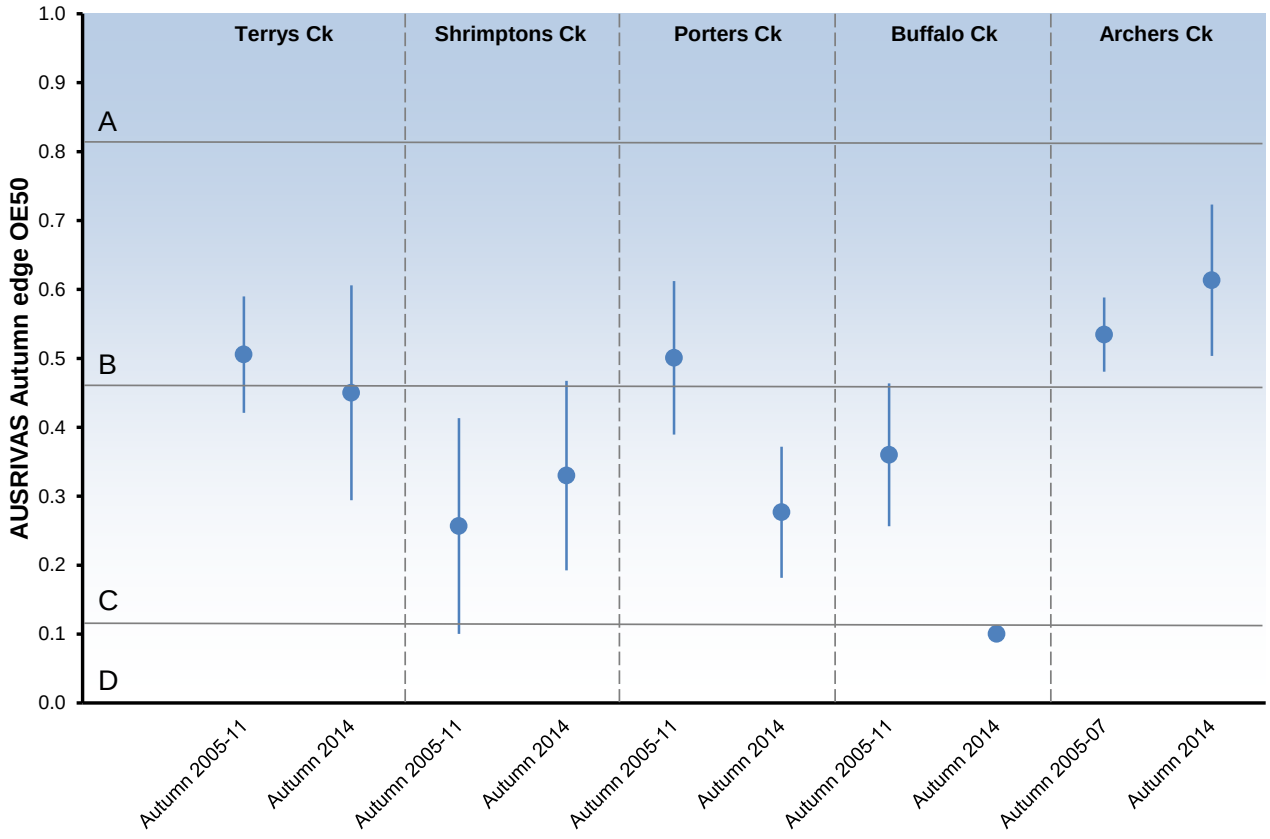

Figure 24 Average AUSRIVAS OE50 autumn edge model scores for each creek (+/- 1 standard deviation)

AUSRIVAS OE50 combined season edge

Combined (autumn + spring) season model *ensures the taxa list for the test site is maximised and yields the most comprehensive AUSRIVAS assessment of the status of the site relative to the reference conditions.*

The AUSRIVAS OE50 combined season edge results, calculated using combined taxa lists from spring and autumn, including historical averages are presented in Figure 25, all results are presented with +/- one standard deviation from the mean.

Terrys, Shrimptons, Porters and Archers creeks combined season OE50 scores were all within their respective historical score ranges. Buffalo Creeks average combined season OE50 score dropped significantly below the historical average range.

Archers Creek recorded the highest combined season OE50 score for this survey period and its historical average, followed by Porters Creek. Both creeks combined season OE50 scores fell within band B, indicative of significantly impaired stream health. Terrys Creek current and historical average OE50 scores were only slightly lower than Porters Creek, but were placed in band C, the lower category, indicative of severely impaired stream health. Shrimptons Creek current and historic average OE50 scores were also placed in Band C. The combined season OE50 score for Buffalo Creek fell from Band C to Band D, indicative of extremely impaired stream health (Appendix 3, Table 34).

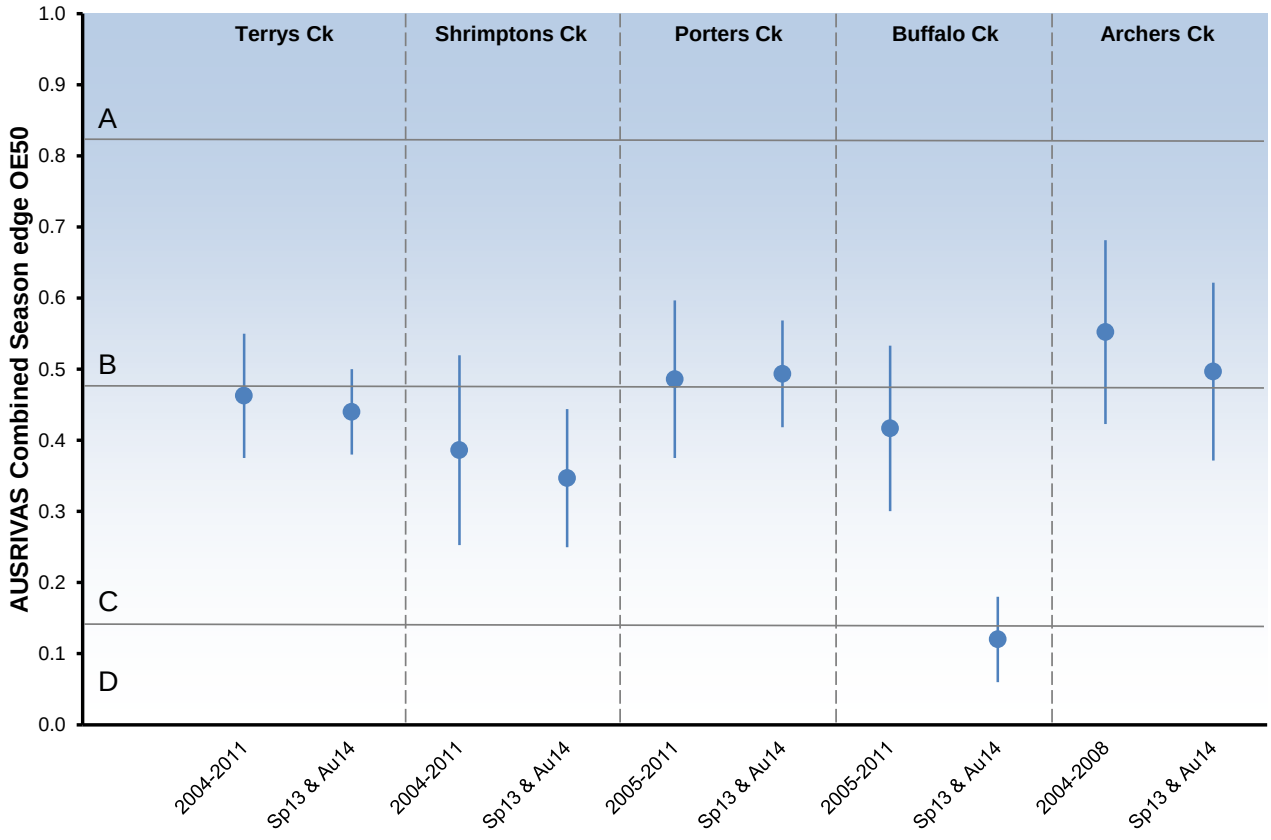

Figure 25 Average AUSRIVAS OE50 combined season edge model scores for each creek (+/- 1 standard deviation)

8.2.4 AUSRIVAS OE0 SIGNAL

AUSRIVAS OE0 SIGNAL *is an indice calculated from the AUSRIVAS predictive model, comparing the macroinvertebrates from a current assessment site to macroinvertebrate data previously collected from reference sites with similar physical and chemical characteristics. The OE0 SIGNAL indice is a ratio of the observed SIGNAL (Chessman, 1995)) values from the assessment site to the expected taxa from the reference sites. The ratio uses all (100%) of the observed and expected taxa in the calculation. This comparison can also help determine the 'condition' or 'health' of the water body.*

AUSRIVAS OE0 SIGNAL spring edge

The AUSRIVAS OE0 SIGNAL spring edge results for 2013 including historical averages are presented in Figure 27, all results are presented with +/- one standard deviation from the mean.

Terrys Creek recorded the highest OE0 SIGNAL score of all five creeks in 2013 and was the only creek in this survey period to score higher than its historical average. This was followed by Buffalo Creek with 2013 results reflective of the historical average. Buffalo Creek did have a high score range in 2013.

Shrimptons, Porters and Archers creeks OE0 SIGNAL scores were similar in 2013 and all were slightly lower than their respective historical average, score ranges however overlapped.

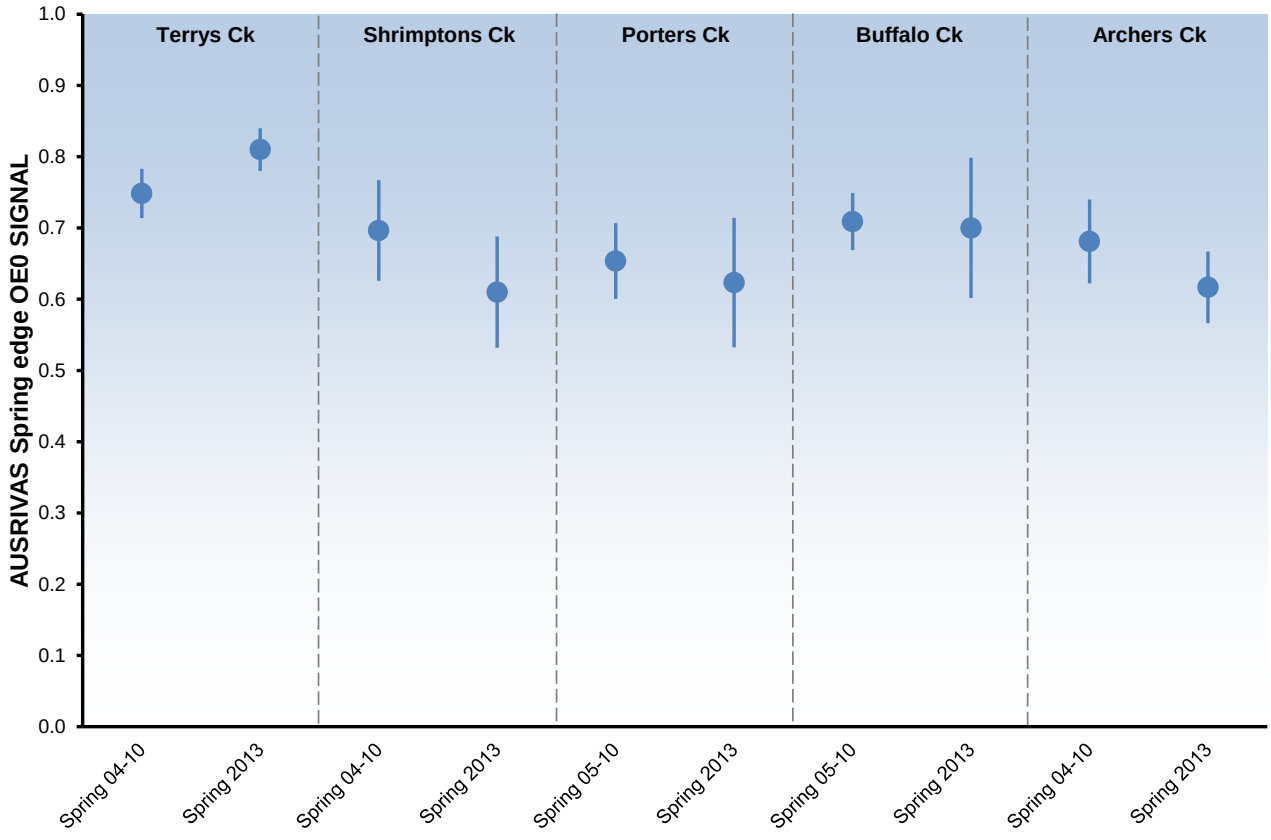

Figure 26 Average AUSRIVAS OE0 SIGNAL spring edge model scores for each creek (+/- 1 standard deviation)

AUSRIVAS OE0 SIGNAL autumn edge

The AUSRIVAS OE0 SIGNAL autumn edge results for 2014 including historical averages are presented in Figure 27, all results are presented with +/- one standard deviation from the mean.

Terrys Creek recorded the highest OE0 SIGNAL score of all five creeks 2014 and was the only creek in this survey period to score higher than its historical average.

Although slightly lower, Shrimptons, Buffalo and Archers creeks OE0 SIGNAL scores from 2014 were very similar to their respective historical average. Both Shrimptons and Buffalo creeks OE0 SIGNAL scores had significant variation in 2014.

Porters Creek was the only site to have its OE0 SIGNAL score from 2014 fall below the historical average, it was however a minimal decrease.

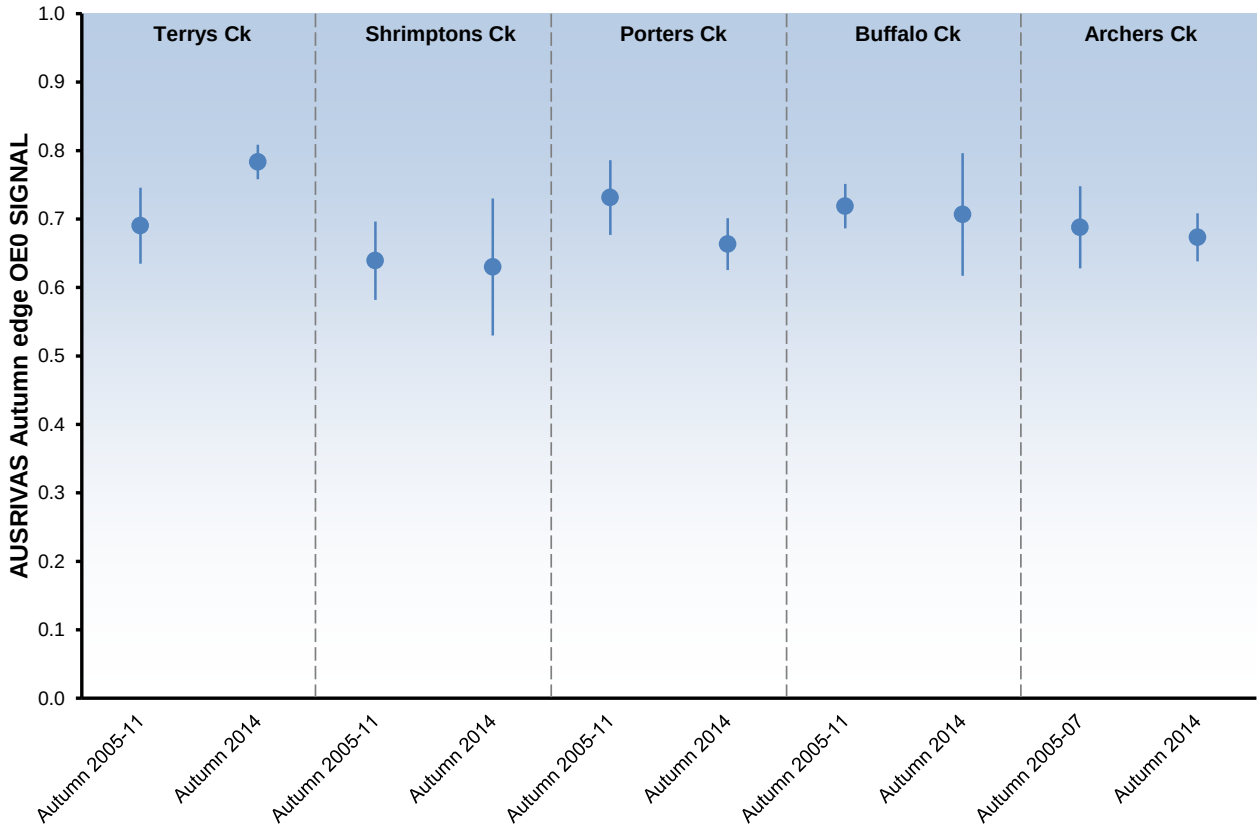

Figure 27 Average AUSRIVAS OE0 SIGNAL autumn edge model scores for each creek (+/- 1 standard deviation)

AUSRIVAS OE0 SIGNAL combined season edge

Combined (autumn + spring) season model *ensures the taxa list for the test site is maximised and yields the most comprehensive AUSRIVAS assessment of the status of the site relative to the reference conditions.*

The AUSRIVAS OE0 SIGNAL combined season edge results, calculated using combined taxa lists from spring and autumn, including historical averages are presented in Figure 28, all results are presented with +/- one standard deviation from the mean.

Terrys Creek recorded the highest OE0 SIGNAL combined score of all five creeks for the current survey period and was the only creek to score higher than its historical average.

Shrimptons, Porters, Buffalo and Archers creeks recorded similar OE0 SIGNAL combined scores from the current survey period, Buffalo Creek being slightly higher than the other creeks. Shrimptons Creek recorded the same OE0 SIGNAL combined score for the current survey period as its historical average, whilst Porters, Buffalo and Archers creeks were slightly lower than their historical average.

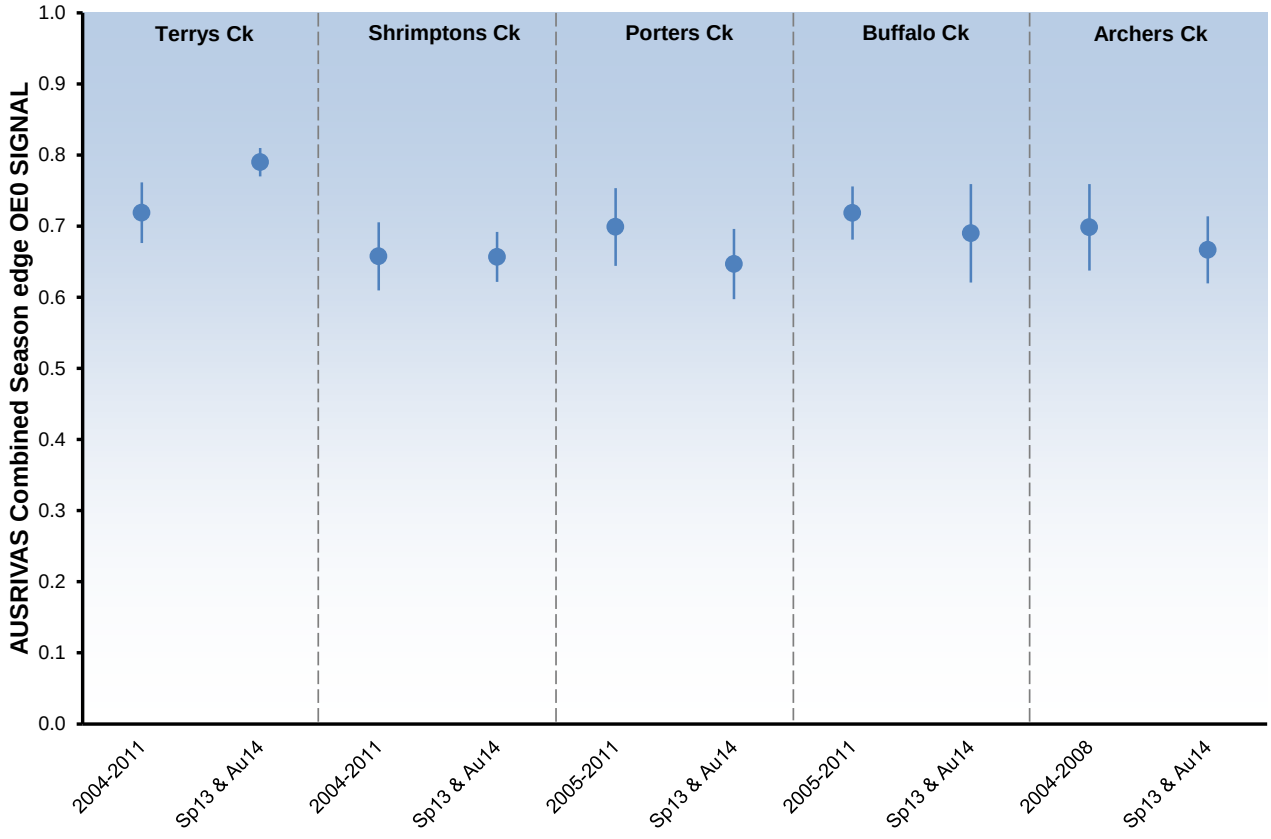

Figure 28 Average AUSRIVAS OE0 SIGNAL combined season edge model scores for each creek

8.2.5 AUSRIVAS missing taxa

> ***AUSRIVAS missing taxa*** *are the taxa that were missing from the assessment site but were predicted with a greater than 50% chance of occurring by the OE50 predictive model to occur at reference sites with similar physical and chemical characteristics.*

Taxa from the current combined spring and autumn surveys with a greater than 50% chance of occurring at reference sites, identified as missing from the survey sites according to the AUSRIVAS observed/expected analysis are listed in Table 28. SIGNAL scores for each taxa, as per Chessman (1995) used by the NSW AUSRIVAS model have been included for reference purposes. The combined model output was used as a preference over the season tax lists as it includes the taxa from the both seasons.

The number of missing taxa ranged from 9 at Porters Creek (the least) to 18 at Buffalo Creek (the most). The high number of missing taxa at Buffalo Creek was to be expected as there was only one taxa with a greater than 50% probability of occurring present in the spring 2013 samples (AUSRIVAS model output).

The missing taxa lists were relatively similar across the five sites and consist of a largely balanced ration of tolerant (low SIGNAL scores) and sensitive (high SIGNAL scores) animals.

Table 28 AUSRIVAS missing taxa with >50% of occurring at test site with SIGNAL scores (Chessman 95)

Creek	Missing taxa (spring 2013 + autumn 2014)		
Terrys Creek	Atyidae (3)	Gripopterygidae (8)	Leptophlebidae (8)
	Baetidae (5)	Gyrinidae (4)	Scirtidae (6)
	Corixidae (2)	Hydrophilidae (2)	
	Dytiscidae (2)	Leptoceridae (6)	
Shrimptons Creek	Aeshnidae (4)	Gyrinidae (4)	Scirtidae (6)
	Atyidae (3)	Hydrophilidae (2)	Synlestidae (7)
	Baetidae (5)	Leptoceridae (6)	Velidae (3)
	Dytiscidae (2)	Leptophlebidae (8)	
	Gripopterygidae (8)	Megapodagrionidae (5)	
Porters Creek	Aeshnidae (4)	Gripopterygidae (8)	Leptophlebidae (8)
	Baetidae (5)	Gyrinidae (4)	Synlestidae (7)
	Gerridae (4)	Leptoceridae (6)	Velidae (3)
Buffalo Creek	Acarina (6)	Dytiscidae (2)	Leptophlebidae (8)
	Ancylidae (4)	Gerridae (4)	Ostrocoda (5)
	Atyidae (3)	Hydraenidae (3)	Othocladinae (4)
	Baetidae (5)	Hydrometridae (3)	Scirtidae (6)
	Ceratopogonidae (4)	Hydrophilidae (2)	Tanypodinae (4)
	Culicidae (1)	Leptoceridae (6)	Velidae (3)
Archers Creek	Baetidae (5)	Gyrinidae (4)	Scirtidae (6)
	Dytiscidae (2)	Leptoceridae (6)	Synlestidae (7)
	Gerridae (4)	Leptophlebidae (8)	
	Gripopterygidae (8)	Othocladinae (4)	

8.3 Multivariate analyses

8.3.1 Spring 2013 and autumn 2014 analysis

__Cluster analysis__ and __SIMPROF__ are multivariate tests which correlate and display the percent similarities between macroinvertebrate assemblages between each of the study creeks. The SIMPROF test indicating 'real' or 'significant' differences are indicated by the black lines in the cluster analysis.

__MDS Ordinations__ attempt to place these assemblages using the similarities in a 2D or 3D space, with similar assemblages close together and those dissimilar further apart.

Replicate data from the spring and autumn surveys were analysed for all five creeks and the resultant cluster analysis and SIMPROF permutation tests are presented in Figure 29. The replicate data is presented in the two-dimensional ordination in Figure 30

The cluster analysis lists each sample in the output, potentially splitting all replicates even when no real difference exists between them. The importance of this analysis lies within the grouping of samples and the SIMPROF test complements the analysis by indicating if a real statistical difference actually exists between these groups. The ordination is presented with an overlay of the clusters that were identified as being statistically significant.

The SIMPROF test of the unmerged replicate data indicates the presence of three significant splits forming four sample groups. The first split at 36% similarity separated two Porters Creek autumn replicates from all other survey samples. The second split at 39% similarity separated two Terrys Creek autumn replicates and the third Porters Creek autumn replicate from all remaining samples. The third split at 43% similarity separated five of the six Archers Creek replicates, the Shrimptons Creek autumn replicates and two single replicates from Terrys Creek in spring and autumn from the remaining creeks and samples (Figure 29).

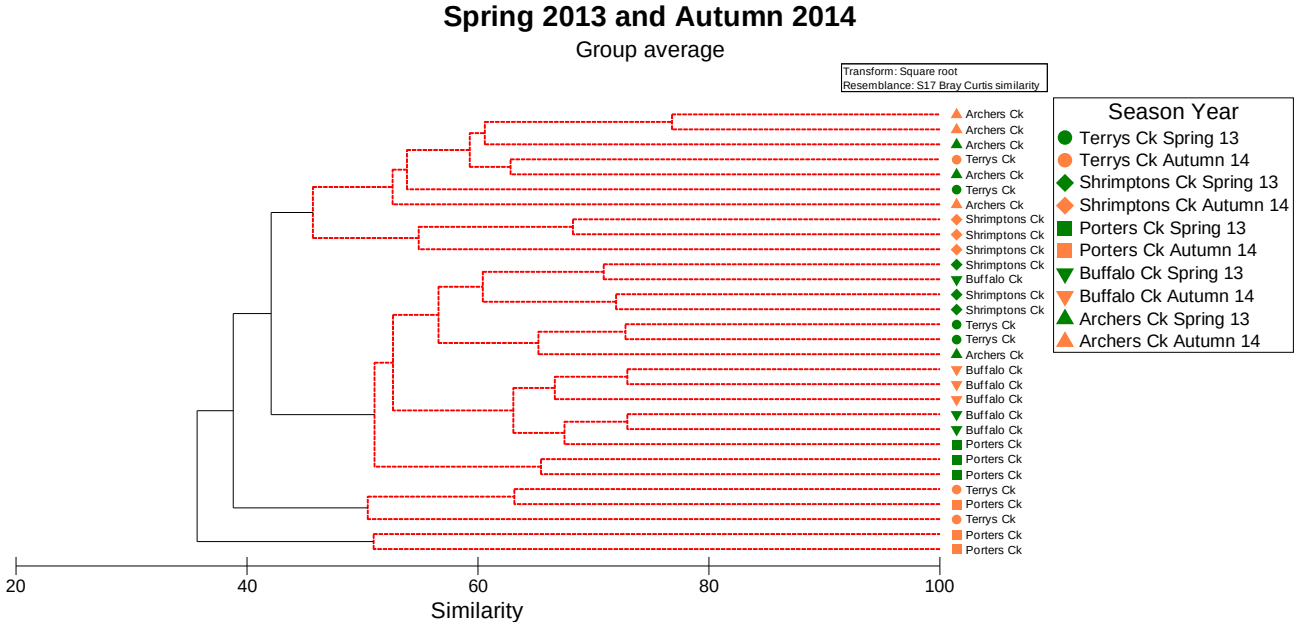

Figure 29 All five creeks cluster analysis (SIMPROF) with replicates, spring 2013 and autumn 2014

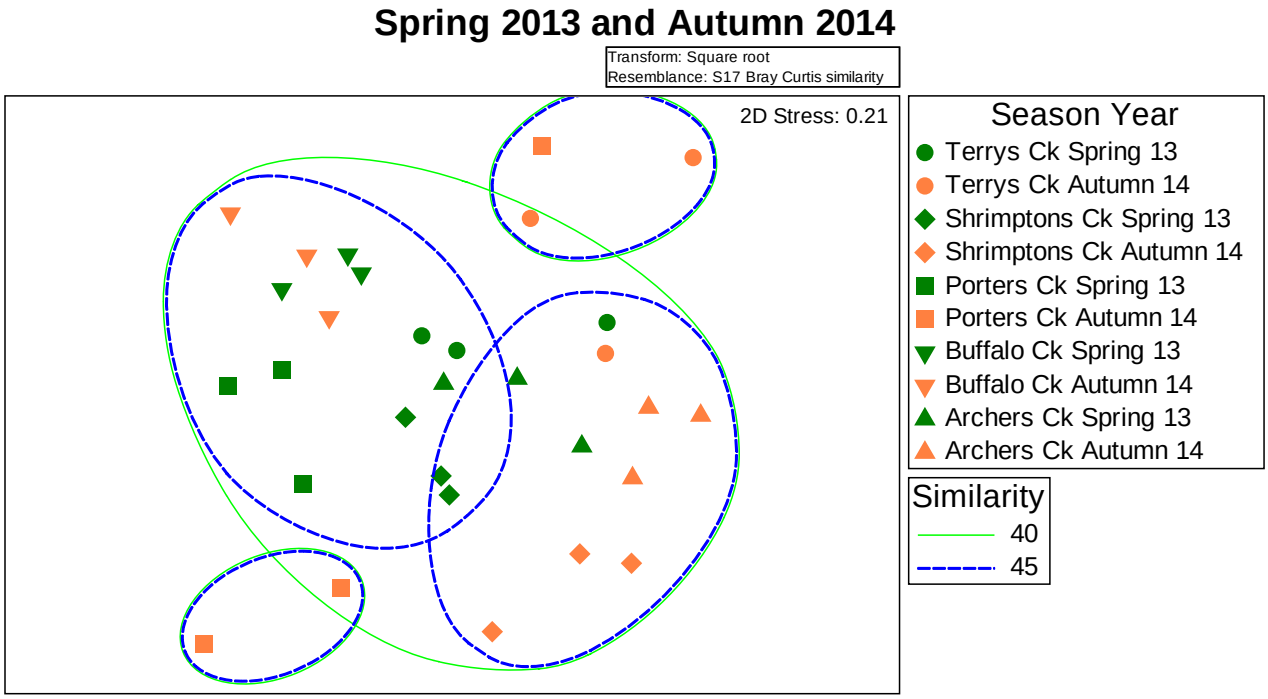

Figure 30 All five creeks two dimensional mds ordination with replicates, including similarity clusters, spring 2013 and autumn 2014

The results above clearly indicate that significant differences occur within the replicate data of the five creeks, this is occurring within site replicates and seasons as well as between sites. Replicates from the same site and season have been split at the lowest similarities, indicating that the differences in the taxa composition is at times higher than between creeks. In order to present the variability of the replicate data the ordination has a relatively high stress value of 0.21, meaning that emphasis shouldn't be given to the placement of the samples but more to the tests of significance (SIMPROF).

In order to present the data without the 'noise' or variability of replicate data and to investigate overall differences between the creeks the replicate data was merged for each season. The resultant cluster analysis and SIMPROF permutation tests are presented in Figure 31, the two-dimensional ordination is presented in Figure 32

The cluster analysis splits samples into several groups at around 50-55% (Figure 31), evident in the ordination (Figure 32), indicating that some differences occur between creeks and seasons. However, the SIMPROF test of the data indicated that there are no statistically significant differences between any of the creeks and seasons from the spring and autumn surveys when replicates from a season are merged (Figure 31).

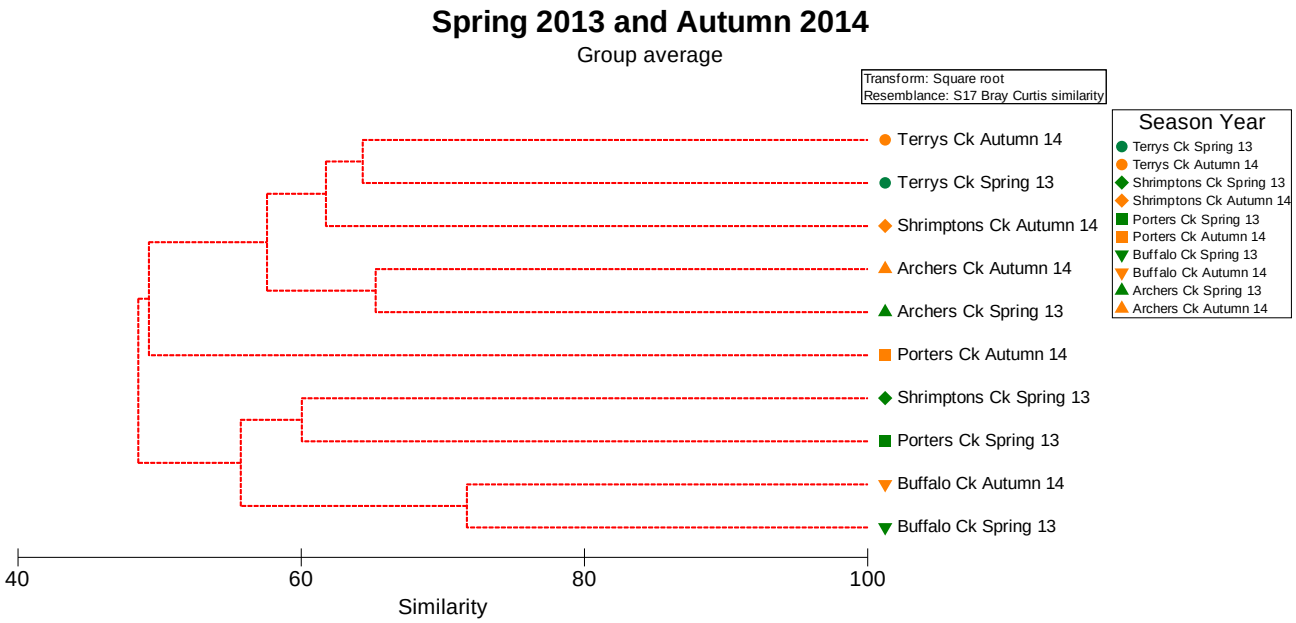

Figure 31 All five creeks cluster analysis (SIMPROF) replicates merged, spring 2013 and autumn 2014

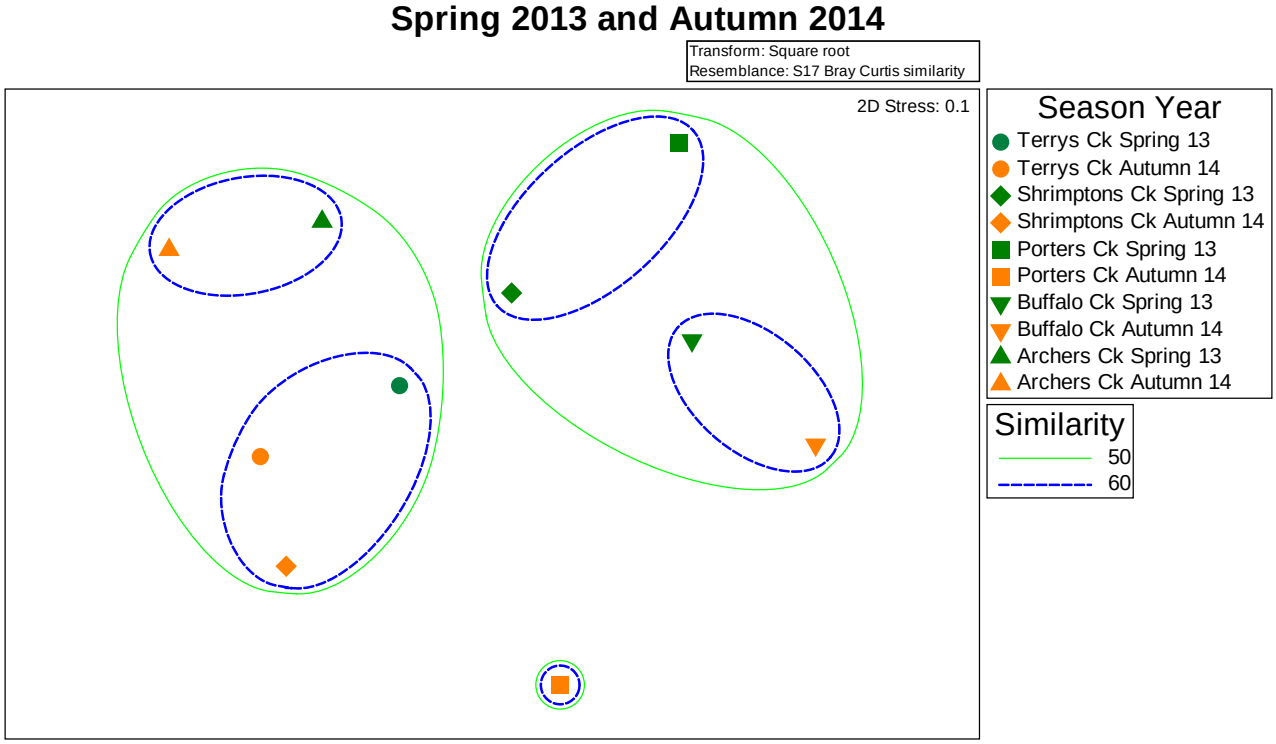

Figure 32 All five creeks two dimensional mds ordination with replicates merged, including similarity clusters, spring 2013 and autumn 2014

SIMPER *uses the Bray Curtis analysis to explore the similarities and differences in macroinvertebrate community assemblages between and within study sites.*

Results of the SIMPER analysis looking at within site replicate similarity across both seasons are presented in Table 29. Buffalo Creek had the highest similarity (65.4%) within replicates, indicating it had the most stable macroinvertebrate community assemblages present of all the creeks across the spring and autumn surveys. Porters Creek returned the

lowest similarity (43.8%), indicating that greater differences in macroinvertebrate community assemblages have occurred between replicates at this site, clearly evident in the cluster (SIMPROF) and ordinations.

Results of SIMPER analysis looking at dissimilarity between sites are presented in Table 30. Dissimilarity between sites was moderate and ranged from 51.4% between Terry's and Archers creeks to 62.8% between Porters and Archers creeks. This indicates that Terry's and Archers creeks have slightly more similar macroinvertebrate community assemblages and Porters and Archers creeks the least.

Results from the two SIMPER analyses suggest that there is generally slightly more variation in macroinvertebrate community composition between different sites than there is between replicate samples of the same site.

The SIMPER output (Appendix 6) includes taxa composition data and can help indicate taxa trends within the site data. For this purpose data was analysed based on creek and season, to identify seasonal variation in taxa.

SIMPER results indicated that all five creeks were generally dominated by relatively few taxa, most notably Buffalo Creek with just four (spring) and five (autumn) taxa contributing to over 90% of the total community composition. Archers Creek comparatively had eight (spring) and thirteen (autumn) taxa contributing to over 90% of the total community composition, the highest of all the creeks. The remaining creeks ranged from six to nine taxa contributing to roughly 90% of the total community composition.

The most dominant taxa across all five creeks and seasons were the Chironomidae sub-family, Chironominae. The second most dominant taxa were the Mollusca, and Tateidae (formerly Hydrobiidae). The dominant taxa were consistently found across both seasons at all of the creeks, however there was some clear seasonal changes in taxa at each creek.

Table 29 SIMPER analysis, average similarity within sites for spring 2013 & autumn 2014

Terrys	Shrimptons	Porters	Buffalo	Archers
53.2%	56.8%	43.8%	65.4%	56.7%

Table 30 SIMPER analysis, average dissimilarity between sites for spring 2013 & autumn 2014

Site	Dissimilarity			
Terrys Creek	51.4%			
Shrimptons Creek	51.6%	54.4%		
Porters Creek	62.8%	60.7%	59.0%	
Buffalo Creek	60.3%	54.5%	60.2%	54.8%
	Archers Creek	**Terrys Creek**	**Shrimptons Creek**	**Porters Creek**

8.3.2 Historical comparison

> ***ANOSIM*** *tests for real differences in data from within same site replicates to replicates between different sites. The hypothesis being that all sites and replicates are the same. The complete dataset is randomly re-analysed numerous times (permuted) to test if what was found in the data can randomly occur with comparative regularity. If this is the case then replicates within and between sites are considered statistically the same or very similar. If this doesn't occur then the data is considered statistically different.*

Data from the current spring and autumn surveys was compared to historical baseline data using ANOSIM to test for any significant differences between the two periods for each of the five creeks. ANOSIM tests the similarities of replicates within sites to the similarities between replicates from different sites, the null hypothesis being there is no difference between samples from the current surveys and samples from the previous surveys (2004 and 2011). The ANOSIM results are presented in Table 31, the R value is included along with the significance level presented as a *p* value.

The results of the ANOSIM analysis suggest that the samples collected from the current survey reflect very closely what has been previously observed from past surveys at Shrimptons Creek. Shrimptons Creek's R value of 0.005 (p = 0.462) indicate that no difference exists between samples from the current and previous surveys. Similarly, Archers Creek ANOSIM results indicate samples from the current survey reflect those of previous surveys, albeit with a higher R value of 0.133 (p = 0.106). Results for Terrys Creek suggest that some differences may occur but samples from the current survey are still likely to fairly closely reflect those from previous surveys, R value of 0.279 (p = 0.013). The results for Terrys, Shrimptons and Archers creeks were non-significant, p values > 0.05. However the numbers of permutations run in the test combined with the strong R values suggest that the ANOSIM results hold weight for the analysis.

Porters and Buffalo creeks ANOSIM results suggest that there is a significant difference between samples from the current and previous surveys. Porters Creek (R = 0.395) and Buffalo Creek (R = 0.453) were both statistically significant with p values < 0.01.

Table 31 One way ANOSIM results

Site	R value	*P* value
Terrys Creek	0.279	0.013
Shrimptons Creek	0.005	0.462
Porters Creek	0.395	0.002
Buffalo Creek	0.453	0.001
Archers Creek	0.133	0.106

The two dimensional mds ordinations using merged replicates from each season for the five creeks are presented with similarity cluster groupings and a trajectory showing sample group movement through time in Figure 33 - Figure 37. All ordinations provided suitable representations of the seasonal data as indicated by stress values of less than 0.2 (plots ranged from 0.06 to 0.16). Reference was made to the cluster analysis and in particular the permutation SIMPROF tests (which were overlayed onto the plots) when analysing the significance of these groupings (Appendix 6).

Porters and Buffalo creeks current spring and autumn seasons significantly separated from all other seasons forming a single sample group/s (Figure 35 and Figure 36) as supported by the R values above (Table 31). Separations occurred at around 55% similarity, suggesting that there were still a lot of taxa in common between the survey seasons. The creeks respective SIMPROF tests did however compliment the ANOSIM results and indicate that the splits were significant (Appendix 6).

Shrimptons Creek spring sample group separated from all other seasons at 60% similarity and the autumn sample group at 70%, these are high similarities however, indicating very little difference in taxa occurs. Shrimptons Creek SIMPROF test (Appendix 6) indicated no real difference occurred between sample groups from the current surveys and at least half of the historical surveys, and are placed closely in the ordination (Figure 34). The R value (0.005) compliments that there is likely no real difference (Table 31).

Archers and Terrys creeks spring sample group separated from all other seasons at a high similarity of 70%. However, SIMPROF and the above R values (Table 31) indicate that no significant difference in taxa occurred at these two sites between the current and historical survey periods. The autumn survey grouped with historical seasons at both creeks (Figure 33 and Figure 37)

Other significant patterns in community assemblages include the grouping of autumn and spring seasons together, particularly evident at Shrimptons, Buffalo and Archers creeks. The grouping of the first several seasons, autumn 2005 to autumn 2006 occurred at most sites (Figure 33 - Figure 37).

Most of the sample groups split in the cluster analyses at similarity levels of 60 to 70%, suggesting that while some separation of sample groups occur there is still a high degree of similarity between samples and seasons within each creek through time. It is important to understand that the purpose of the ordination is to always separate sample groups based on the similarity matrix, and the spread of samples in all of the ordinations suggest that many of the separate groupings are in fact quite similar.

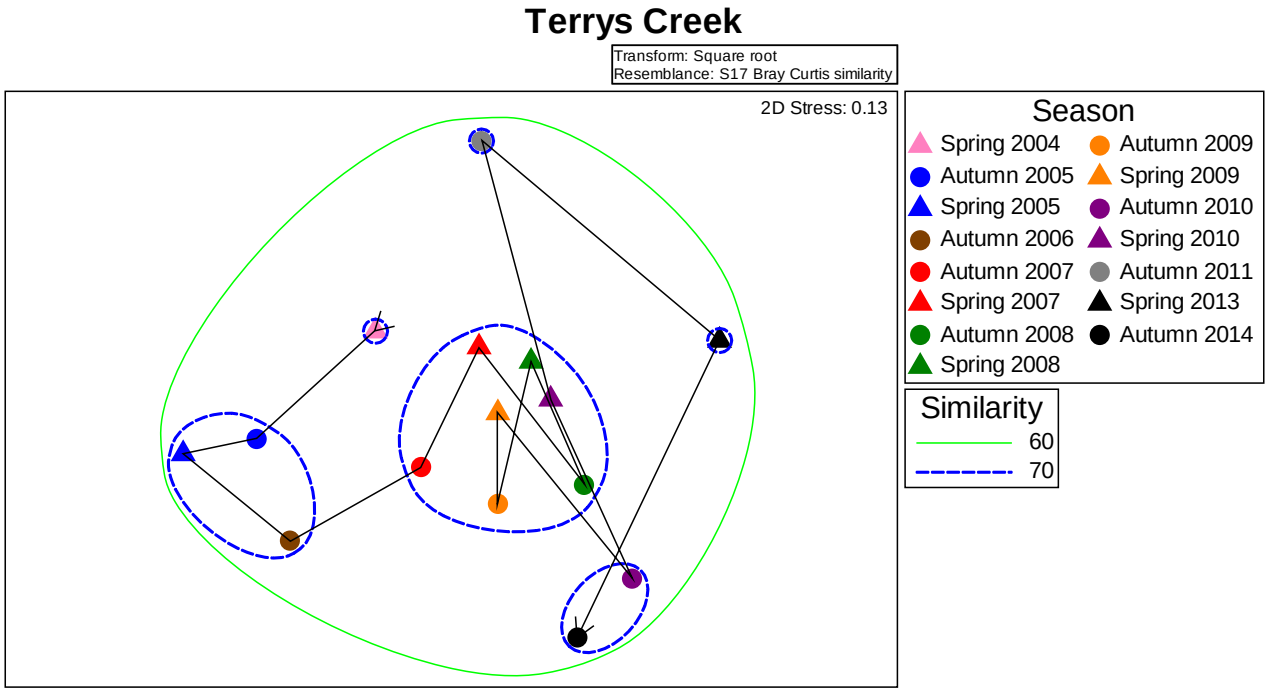

Figure 33 Terrys Creek two dimensional mds ordination

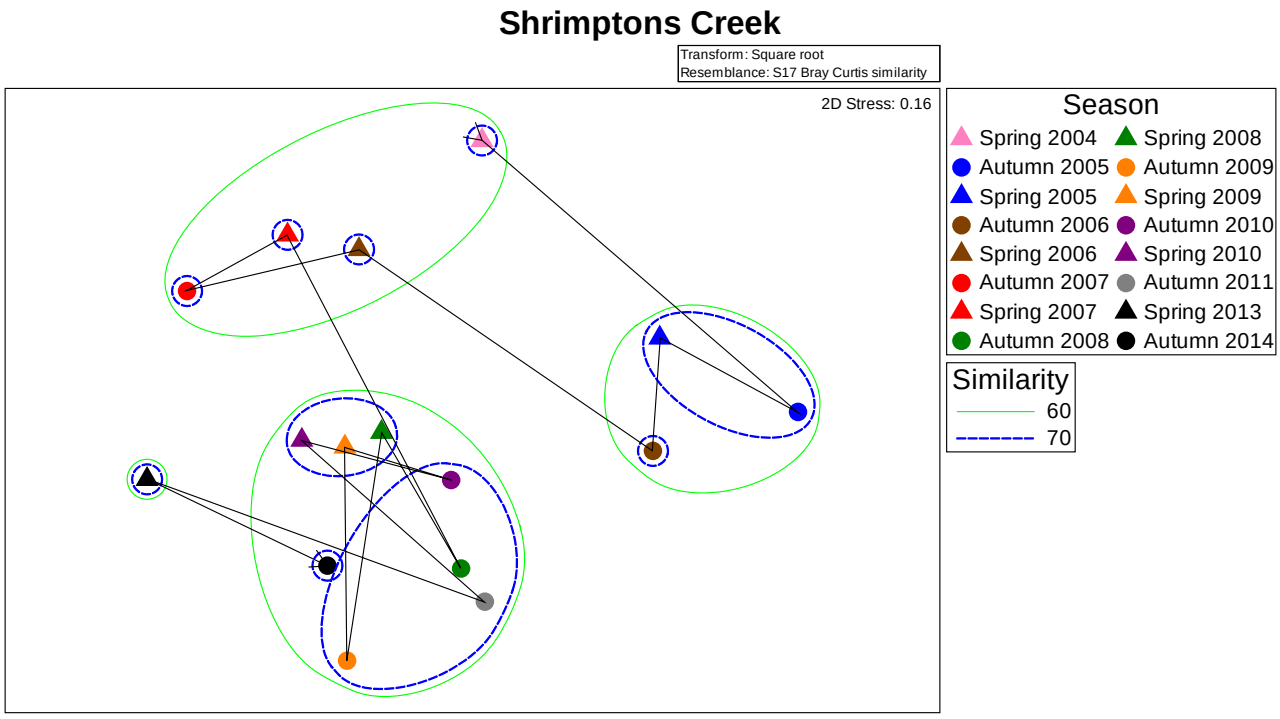

Figure 34 Shrimptons Creek two dimensional mds ordination

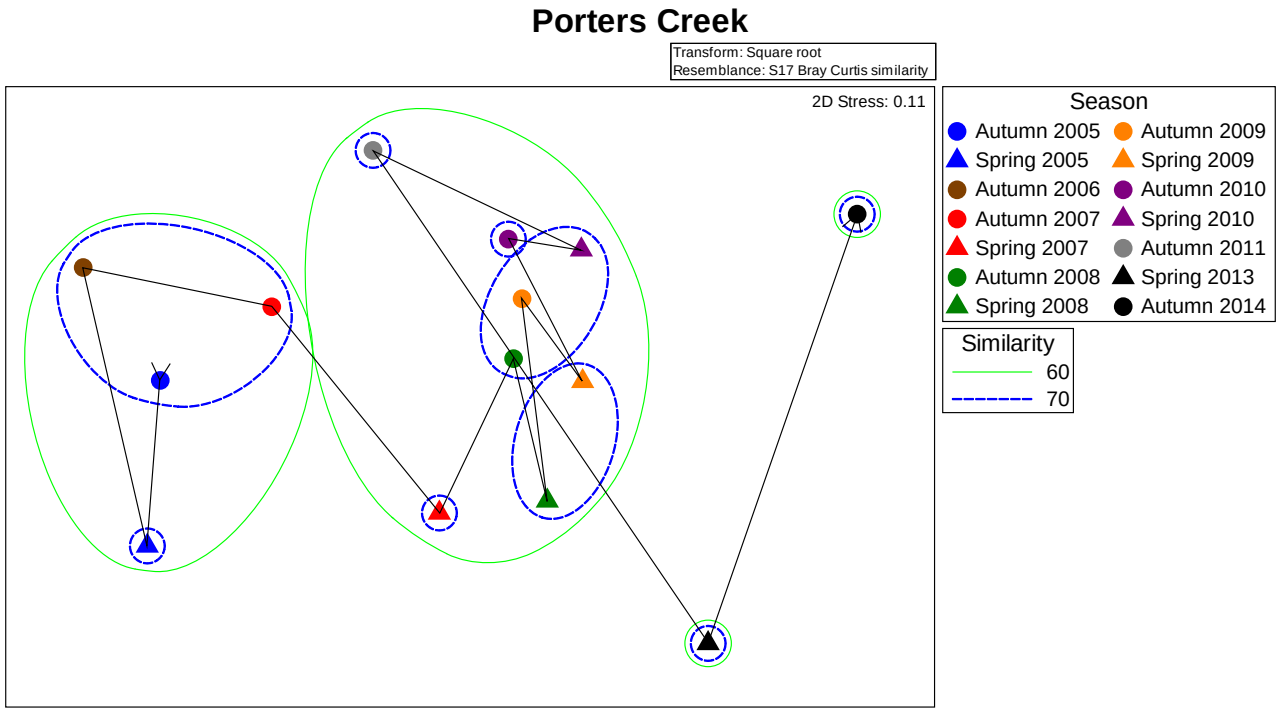

Figure 35 Porters Creek two dimensional mds ordination

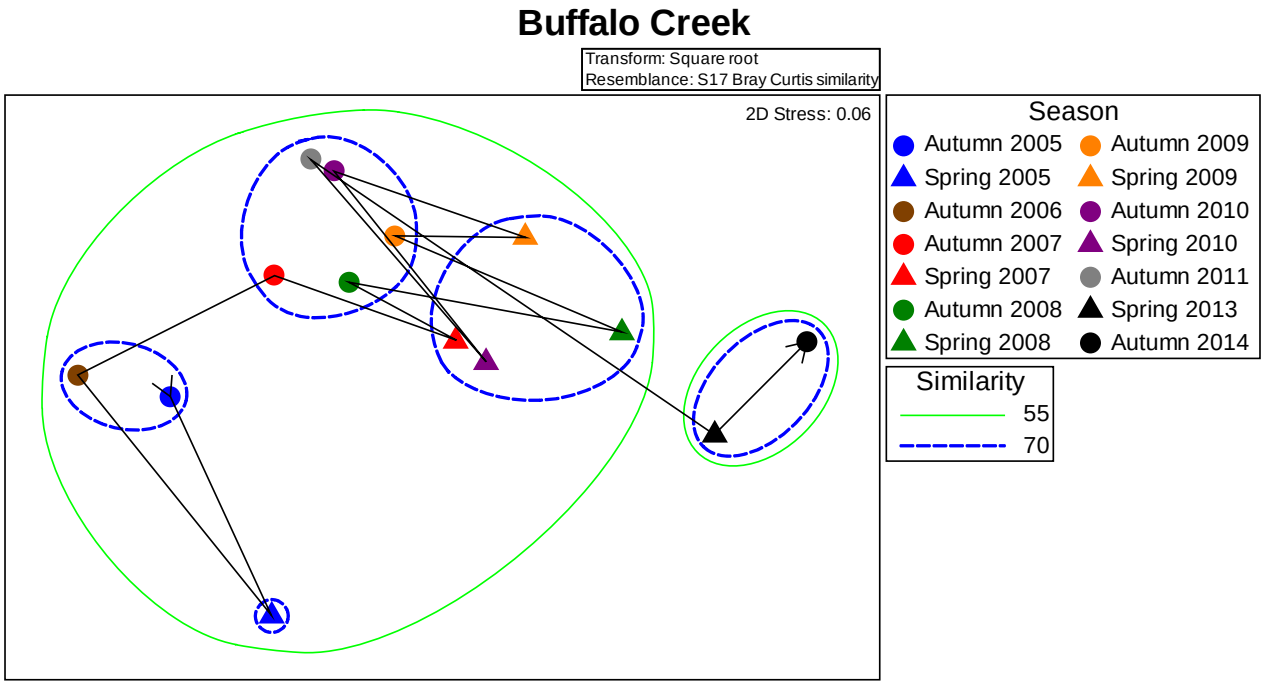

Figure 36 Buffalo Creek two dimensional mds ordination

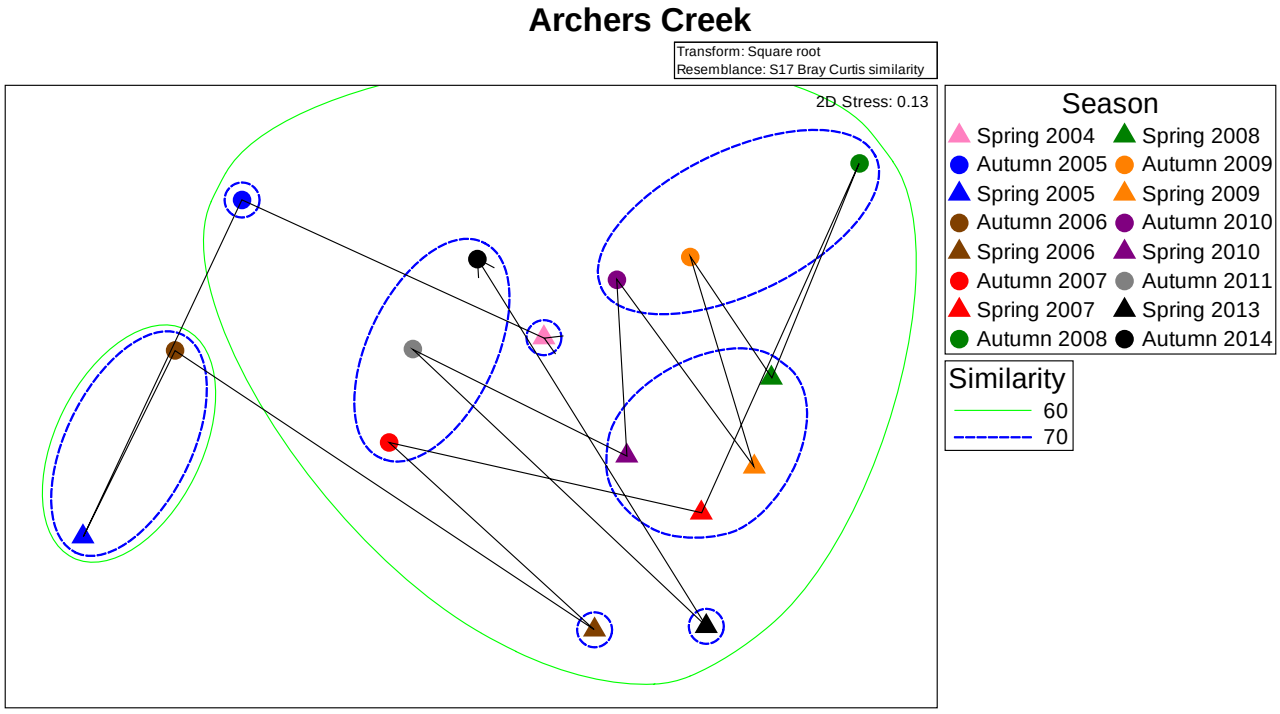

Figure 37 Archers Creek two dimensional mds ordination

9 Discussion

9.1 Water quality

Aquatic ecosystems comprise the animals, plants and micro-organisms that live in water, and the physical and chemical environment and climatic regime with which they interact. It is predominantly the physical components (eg light, temperature, mixing, flow and habitat) and chemical components (eg organic and inorganic carbon, oxygen, nutrients) of an ecosystem that determine what lives and breeds in it, and therefore the structure of the food web (ANZECC 2000).

The current water quality sampling regime wasn't reflective of a sampling frequency suggested by ANZECC (2000). However, it did allow for the characterisation of water quality at all sampling sites against ANZECC (2000) guidelines for Aquatic Ecosystems (Lowland River SE Australia), Recreational Water Quality and Aesthetics (Secondary) and Toxicants (at 95% species protection level).

The five creeks sampled under the Ryde Council monitoring program would generally be deemed highly disturbed systems as they flow through highly urbanised systems that receive substantial road and stormwater runoff (ANZECC 2000). That said, they each still retain ecological and conservation values. A realistic objective would be to maintain present water quality to retain a functional, albeit modified, ecosystem that would support the management goals assigned to it.

Temperature in waterways generally varies with water depth, shading and flow, and can affect a number of other water quality parameters. Temperature can fluctuate through the course of the day, particularly shallow creeks, so results need to be analysed with respect to the time and conditions at the time of sampling. Temperature fluctuations may affect: chemical and biochemical reaction rates; chemical solubility; growth and respiration rates of aquatic organisms; and reproduction and competitive interaction cues of aquatic organisms. Temperature results for spring were generally higher than autumn by a few degrees, with the highest temperatures generally recorded at Porters Creek sites. These results were within the normal seasonal range experienced during spring and autumn.

Dissolved oxygen concentrations are an important water quality indicator for the survival of aquatic organisms and the control of many important physico-chemical processes. The oxygen balance in waters is dependent upon physical, chemical and biochemical conditions in the water body. Oxygen input is the result of diffusion from the atmosphere and photosynthesis by algae and other aquatic plants. Dissolved oxygen removal is due to respiration by aquatic organisms, decomposition of organic matter, oxidation of chemically reduced compounds and loss to the atmosphere. The solubility of oxygen in water decreases with increasing temperature but in contrast the respiratory rate of aquatic organisms increases with temperature (Connell, 1993).

Dissolved oxygen concentrations are often subject to large diurnal and seasonal fluctuations as a result of changes in temperature and photosynthetic rates. Therefore, a dissolved oxygen measurement taken at one time of the day may not truly represent the oxygen regime in the water body.

All sampling sites at Terrys, Shrimptons, Buffalo and Archers creeks, including the Main Branch site at Porters Creek have historical medians for dissolved oxygen saturation levels that are outside the recommended guideline levels. The recent surveys returned results that were reflective of the historical medians.

Of particular concern are the low dissolved oxygen saturation levels at Archers Creek in spring and autumn, 17.3% and 9.6% respectively. Large amounts of organic debris, algal growth and extensive semi-aquatic plant growth were observed at this site during both surveys. Oxygen uptake due to the breakdown of the organic debris and oxygen demand from the algal and plant growth is the likely cause of these very low levels. If the low oxygen levels are maintained and continue over a period of time it would likely lead to a decline in creek health, and this would be observable in the macroinvertebrate communities present at the site.

The optical clarity of a water body is one of its fundamental physical characteristics. Turbidity is determined by two groups of factors: particulate components which include suspended particles and algae, and dissolved components which affect water colour, particularly humic and fulvic acids. Both these groups of factors can be modified by a range of land use activities (Liston and Maher, 1997).

Turbidity can be caused by soil erosion, waste discharge, urban runoff, algal growth and other disturbances in the water channel. Particles can smother aquatic insects, can clog fish gills, prevent egg and larval development, reduce aquatic flora and fauna growth rates and generally decrease resistance to disease.

Turbidity levels did not exceed the recommended guideline for either spring or autumn surveys. Porters Creek at Wicks Road had the highest turbidity levels in both spring and autumn followed by Porters Creek at Main Branch. The results were considerably higher than the historical medians for these sites. Turbid conditions were observed by field staff at both these sites during the spring and autumn surveys. Dry weather inflow of turbid water from the main stormwater channel was noted at the Wicks Road site in autumn, resulting in the highest turbidity result.

pH influences many biological and chemical processes and is an important water quality parameter. pH can change diurnally through photosynthetic and respiration rates. pH readings for all sites were within the recommended ANZECC (2000) guideline range for both spring and autumn.

The indicator species used for faecal coliforms are naturally occurring and harmless inhabitants of the digestive tract of all warm-blooded animals (Boey 1993). The occurrence of large numbers of these bacteria signifies the presence of faecal pollution and, therefore, the possible presence of those pathogenic organisms that occur in faeces.

The presence of widespread faecal contamination will often coincide with elevated nutrient levels, particularly the nitrogen based forms. However elevated nutrient levels can often be experienced without the presence of faecal contaminants. A variety of factors including urban runoff, presence of waterfowl and other wildlife, waste depots, illegal dumping of waste and sewer overflows can influence faecal and nutrient contamination of urban streams.

Faecal coliform densities exceeded the ANZECC guidelines in spring at four sites. Of most concern were the extremely elevated faecal coliform results from Buffalo Creek upstream of Burrows Park, with the highest result from all current and historical surveys. Buffalo Creek downstream Burrows Park was also highly elevated the second highest faecal coliform result from the current and historical surveys. Faecal coliform contamination was also supported by the elevated nutrient results from Buffalo Creek upstream and downstream of Burrows Park with extremely high ammonia, total nitrogen, total kjeldahl nitrogen, oxidised nitrogen and total phosphorus concentrations. Sampling staff indicated that there were no visual or olfactory signs of pollution at the time of sampling. The results for Buffalo Creek at

Higginbotham Road were low and within guideline levels, indicating that the pollution had not reached this site at the time of sampling.

Due to the extremely high results, follow up field water quality sampling was conducted at Burrows Park sites were conducted the following week, including a visual assessment of the site and testing for ammonia. No signs of contamination were present at either upstream or downstream Burrows Park and multiple ammonia field tests conducted along the creek length returned negative results. All evidence suggested that there was no longer an impact occurring in Buffalo Creek and that the previous pollution event was caused by the heavy rainfall preceding sampling, which likely caused a sewer overflow event.

Faecal coliform results at all sites on Buffalo Creek fell below the historical median or were below the guideline levels for autumn. However, total and oxidised nitrogen and total phosphorus concentrations remained elevated above both the guidelines and historical medians. This is indicative of a dry weather source of pollution and or an ongoing issue within the Buffalo Creek stormwater system.

Nitrogen form nutrient levels were elevated above the guideline levels and historical medians at Terrys Creek during both survey periods. However, faecal coliform results were below the historical medians. The elevated levels were not extreme and could be from any number of sources, including increased rainfall prior to spring and autumn survey periods. Nutrient levels at Shrimptons Creek were elevated above the guideline levels at all sites during both survey periods, however they were mostly reflective of the historical medians.

Metals were generally found in very low concentrations at the five creeks for both spring and autumn. Cadmium, Mercury, Chromium, Arsenic and Lead were below or on a few occasions on the detection limits for all sites and seasons. The current surveys were the first to include metals, as such there is no historical results to allow a comparison and measure of results.

Copper is widely used in the manufacture of alloys with zinc, nickel and tin, in metal plating and in the production of copper wire and piping. Copper compounds are used in a range of industrial applications: copper nitrate in plating and textile dyeing processes; copper chloride in the manufacture of glass and ceramics and as a catalyst in the production of vinyl chloride. Copper compounds are also used as fungicides, in the manufacture of wood preserving agents, rayon and paint pigments (Beasley and Kneale 2002).

Total copper concentrations were elevated above the guideline levels at most sites in spring, excluding Shrimptons Creek at Kent Road, Bridge Street and Quarry Road. Porters Creek recorded the highest concentrations, over five times the guideline levels. Total copper concentrations were mostly below the guidelines levels in autumn. The exceptions were Buffalo Creek upstream and downstream of Burrows Park sites and Porters Creek at Wicks Road, which again had the highest concentration.

The most common use of industrial zinc include, galvanizing iron and steel products, brass products and zinc-based alloys. It is also used in synthetic rubber, paints, cosmetics, ceramics, manufacturing and dyeing of textiles, wood preserves and the purification of fats (Beasley and Kneale 2002). In natural waters zinc occurs as a simple ion (Zn^{2+}), in inorganic complexes, organic complexes, and adsorbed to inorganic or organic colloids or particles. The Zn^{2+} form of zinc is generally considered to be responsible for eliciting toxic responses in aquatic organisms. Inorganic and organic complexes reduce the uptake and toxicity of zinc by reducing the concentration of this form (ANZECC 2000). Zinc is essential for certain biological functions in minute quantities, but it is highly toxic beyond these requirements (Beasley and Kneale 2002).

Zinc concentrations were above the guideline at most sites in spring. The exceptions were for Terrys Creek, Buffalo Creek at Higginbotham Road, and Shrimptons Creek at Kent Road and Quarry Street. Archers Creek returned the highest concentration, which was eight times the guideline level. Zinc results were generally lower in autumn, however, there were levels that slightly exceeded the guideline levels at some sites.

Elevated copper and zinc concentrations, in particular spring, could be linked to industrial and/or road run-off as a result of the increased rainfall in the period leading up to sampling.

Concentrations of arsenic, chromium, cadmium, lead and mercury were mostly below the analytical method detection limits or in low concentrations which were below the respective ANZECC (2000) guideline values in both spring and autumn. Total manganese concentrations were also below the ANZECC (2000) guideline for all sites on both sampling occasions.

Results of the current spring and autumn water quality sampling at all five creeks support results of the previous surveys, which have indicated that urban pollution transport is having an impact on in-stream water quality. This impact is indicated by low levels of dissolved oxygen and high concentrations of nutrients, especially nitrogen forms. The spatially variable pollutant concentrations indicate that they originate from varying locations and sources within these systems over time.

9.2 Macroinvertebrates

The condition or ‘health’ of aquatic ecosystems is assessed using a wide array of physical and chemical variables. Increasingly the use of biological indicators has been utilised as a measure of aquatic ecosystem health. Macroinvertebrates, in particular, indicators using macroinvertebrate community composition (Walsh 2006), have been widely accepted and utilised globally.

Macroinvertebrates are widely recognised as key indicators of aquatic ecosystem health because their presence or absence is a result of their exposure to changing water quality over a period of time. They also reflect changes in physical habitats, including sediment deposition and altered hydrology, as well as changes in biological interaction such as the introduction of pest plant and animal species. Macroinvertebrates are also ubiquitous, they are found in almost all water bodies and as such, the type and diversity of macroinvertebrates present can indicate what stressors may be acting upon a given system.

Taxa richness observed during the current surveys was relatively similar to what had been previously observed at Terrys, Shrimptons and Archers creeks. Taxa richness at Buffalo Creek decreased significantly in spring and autumn compared to the historical average. Porters Creek also dropped significantly below the historical average in autumn. The dominant taxa that comprised a significant proportion of the total community assemblages historically included Mollusca (snails & mussels), Diptera (true flies) and Odonata (dragonflies & damselflies) taxa groups. From the recent surveys, the Mollusca and Dipterans have again heavily dominated the community assemblage’s. The Odonata taxa group was noticeably absent from community assemblages in spring. They returned in autumn in numbers similar to what had been historically observed at Terrys and Archers creeks, but were still largely absent from the other creeks.

EPT taxa richness was very low in the recent surveys, reflective of what has been observed in past surveys. Buffalo Creek did not have a single EPT taxa present in samples from either of the recent surveys. Historically no creek in the survey has had an average of one EPT taxa (collected from each replicate). The usefulness of the EPT measure of stream

health for the City of Ryde monitoring program has been questioned in previous reports (Sydney Water 2011 and 2013), and the current results reflect the case for moving away from this measure for ongoing reporting. The environmental conditions required to support healthy populations of even relatively tolerant EPT taxa is likely not possible within the catchments of the City of Ryde. Nearly all EPT taxa require healthy oxygen levels that are reliant on relatively natural flowing clear water bodies. EPT taxa are also very susceptible to toxicants and other pollutants.

SIGNAL2 was calculated and included in the reports for the recent surveys as an additional indice to the historical reporting previously conducted for City of Ryde. The recommended approach for displaying this measure is by placing the results within a quadrat bi-plot. This resulted in all five creeks being placed in quadrat 4 for both surveys, representative of urban, industrial or agricultural pollution. Placement in this quadrat is due to samples having a low SIGNAL2 scores and low taxa counts.

The placement of the quadrat boundaries is arbitrary and preferably done with the aid of reference sites. This is not possible for the City of Ryde, and the boundaries were placed with data from reference sites from the Sydney region located in relatively natural and similar geomorphological catchments. Returning the creeks and catchments to a natural, reference like condition is highly unlikely in the City of Ryde locale. Whilst this helps to represent the conditions present, the measure in this format is limited in its usefulness for ongoing monitoring and site assessment for City of Ryde.

SIGNAL-SF results from the recent surveys were largely reflective of what had been previously recorded from the five creeks. The one exception was Buffalo Creek which decreased in stream health in autumn when compared to its historical average.

Historically, average SIGNAL-SF scores, had lower variation through time in comparison to other indices used in the program. That said, shifts in creek health have been evident at some of the creeks. A significant shift was evident at Shrimptons Creek, increasing significantly from autumn 2005 to autumn 2007, then decreasing significantly to ‘baseline’ conditions in autumn 2008 (Sydney Water 2011). A clear impact was also evident at Buffalo Creek in spring 2008, when SIGNAL-SF scores significantly decreased, the resultant recovery to ‘baseline’ conditions was reported the following autumn season (Sydney Water 2011).

SIGNAL-SF was calculated using extensive reference baseline data from and for specific use in the greater Sydney region, and was last calculated in 2007 (Chessman *et al.* 2007). This index has shown lower sample variation through time and has allowed clear tracking of actual changes in stream health within the context of the naturally occurring variation in macroinvertebrate communities through time. This biological index is likely the best option for tracking the health of the five creeks and for monitoring impacts or improvements within the catchments in the future.

The AUSRIVAS OE50 scores are calculated by comparing the observed taxa at a site to the expected taxa. The expected taxa are derived from the taxa lists of reference sites that were matched to physical/chemical data from the survey creeks. The reference taxa list consists of the animals that are expected to occur with a greater than 50% chance of occurring.

Buffalo Creek had the most taxa listed as missing by the AUSRIVAS models. The OE50 score was calculated using just the one observed taxa (Chironomidae: S.F Chironominae) for spring and autumn, all other taxa that were observed at the site were ignored by the AUSRIVAS analysis. The combined model used slightly more taxa (up to three) for the

calculation of Buffalo Creek scores. The other creeks of the program generally had five or more taxa used for each sample score calculation.

The AUSRIVAS OE50 results for the spring, autumn and combined models returned results that were largely reflective of the historical averages, generally placing recent and historical results in the same impairment bands. The clear exception was Buffalo Creek which dropped significantly from the historical averages for all three models, dropping from band C to band D, the worst possible result and indicative of an extremely impaired creek. Porters Creek OE50 score in autumn was also an exception dropping significantly from the historical average, falling in band C.

The OE50 scores have high sample variation both historically and in the recent survey samples, complicating the tracking and assessment of clear changes in stream health. This is likely due to the potentially sporadic presence and absence of taxa within replicates from the same site and season.

AUSRIVAS OE0 SIGNAL results for spring, autumn and combined models were largely reflective of what had been previously observed, with very minor differences between the recent surveys and historical averages. The only significant shift in the OE0 SIGNAL results was at Terrys Creek with scores from the recent surveys increasing above historical averages for all three models.

The AUSRIVAS NSW model has limited reference sites within the Sydney region. Given this and the creeks of the Ryde catchment being within a heavily urbanised environment, the ability for AUSRIVAS to track creek health through time is potentially limited. When making reference to the AUSRIVAS results it is preferable to refer to the combined model. This model combines the taxa lists from both seasons maximising the family list for the survey site being assessed (Ransom *et al*. 2004).

Comparing results from the univariate and biological indices across the five creeks highlights that for the most part the creeks have quite similar results through time. No one creek stands out as having particularly poorer or healthier conditions. Likely, this is reflective of being within similar catchments, under similar conditions with similar stressors impacting on the health of the five creeks.

Multivariate analyses of the recent spring and autumn survey data indicates slightly more variation in macroinvertebrate community composition between the five creeks than within creek replicates. However, the dissimilarities between sites were not great and reflect similar macroinvertebrate community assemblages across the five creeks. Previous survey periods have indicated this same trend (Sydney Water 2011), and it is likely that the current baseline data has effectively captured the taxa composition and natural variability that can be expected from the five creeks.

Significant differences in the replicate macroinvertebrate assemblages did occur for some creeks and seasons in the recent surveys. Porters and Terrys creeks had replicates that split from all other samples at significantly low similarity levels. However, the SIMPER analysis indicated this was due to only moderate shifts in taxa composition. By merging replicates from the same season at each creek the variability of the replicates is negated. The resultant SIMPROF test showed that no significant statistical difference occurred between the five creeks and seasons.

Multivariate analyses were also used to assess if the taxa observed at the five creeks in the recent surveys were different to that historically observed. Results have indicated that a significant difference between the current and historical surveys exists only at Buffalo and Porters creeks.

Results from the recent surveys at Buffalo Creek indicate that there has likely been an impact on creek health. All of the univariate and biological indices show a decline from the respective historical averages and compliment the multivariate results indicating a significant shift in the macroinvertebrate community assemblages. Faecal coliform and nutrient results were significantly elevated at both Burrows Park sites. Results from spring indicated a wet weather sewer overflow event had very likely occurred in the days prior to sampling. Increased flow was observed at the upstream Burrows Park site during autumn sampling and on a site visit post autumn sampling, this was despite the periods prior being dry. It would appear that Buffalo Creek may be experiencing increased pressure on creek health from multiple sources in its upper reaches.

Porters Creek has returned mixed results from the univariate and biological indices in the recent surveys. Taxa richness decreased compared to the historical average and AUSRIVAS autumn models indicated a slight decline in creek health. SIGNAL-SF and AUSRIVAS spring models showed no decline in creek health compared to the historical average. Taxa richness was lowest in autumn and this is likely the driver for the lower AUSRIVAS scores. AUSRIVAS is more sensitive to reduced site taxa lists than SIGNAL-SF.

The observed changes in macroinvertebrate community assemblages could be due to any number of factors relating to the physical characteristics of the site and/or impacts and changes in its upper reaches. During the recent surveys there has been large scale road infrastructure works being carried out in Porters Creek upper catchment. This could be impacting on the macroinvertebrate communities downstream at the core site. However other than moderately turbid conditions linked to the development no other results would suggest an impact.

Multivariate analysis of Terrys, Shrimptons and Archers creeks biological data indicate no significant difference in macroinvertebrate community assemblages were observed in the current surveys compared to the historical. Apart from some minor differences, these results reflect what was also observed in the univariate and biological indices, where results largely reflected historical averages. Observable changes in the riparian and benthic condition at the sampling sites of Terrys and Archers creeks since the last historical survey event in autumn 2011 were potentially adverse to creek health. However, results appear to show no significant effect on the macroinvertebrate community assemblages or creek health.

Spring sampling was conducted during a period of increased rainfall with November experiencing 190mm. Sampling was conducted as close to baseline flow conditions as possible given the time and project constraints, however it is likely that conditions in the catchments would still have been influenced by the increased stormwater input. It was suggested in the spring 2013 report (Sydney Water, 2013), that increased rainfall was likely a driver for the changes that were observed in the macroinvertebrate community assemblages.

Autumn sampling was conducted in April, which experienced consistent yet light rainfall. However the previous month of March was characterised by some significant periods of heavy rainfall. It is again likely that conditions in the creek catchments and therefore macroinvertebrate communities observed during autumn sampling would have been influenced by increased stormwater inputs leading into the survey period.

The observed changes in the macroinvertebrate community assemblages at Porters and Buffalo creeks in the recent surveys have likely been driven by localised and possibly new impacts. Given the increased stormwater inputs within the two survey periods it is likely these impacts would have been significantly amplified.

10 Conclusions

A summary of the conclusions and key findings from the spring 2013 and autumn 2014 surveys have been detailed below:

- The creeks and surrounding riparian areas are regularly exposed to a combination of significant anthropogenic and environmental impacts. Site observations indicate that many sites have presence of domestic rubbish, large amounts of organic debris, oil and scum, exotic plant and algal growth.

- Water quality results indicated that the surveyed creeks generally have significant problems with dissolved oxygen, faecal coliform levels, nutrient concentrations, total copper and zinc.

- Highly elevated Faecal Coliform densities and elevated nutrient concentrations returned at the upstream and downstream Burrows Park sites (Buffalo Creek) in spring indicated that there was clearly a significant sewer overflow event.

- EPT taxa richness and abundances are very low at all of the surveyed creeks.

- Results from SIGNAL-SF and AUSRIVAS were largely reflective of what had been previously observed for the five creeks, except for Buffalo Creek which experienced a decline in stream health.

- Multivariate analysis of the macroinvertebrate community assemblages from the spring and autumn surveys indicate that the five creeks are relatively similar to one another, with only some difference occurring within the replicate data.

- Multivariate analysis of the macroinvertebrate community assemblages from the spring and autumn surveys against the historical survey data indicated a significant difference at Buffalo and Porters Creeks.

- It is likely that the changes observed at Buffalo and Porters creeks were driven by localised and possible new impacts within their catchments and the increased rainfall during the spring and autumn seasons would likely have amplified the effects of these impacts.

- The results from the multivariate analysis of spring and autumn surveys indicate no significant changes at Terrys, Shrimptons and Archers creeks compared to historical survey results.

- Survey results using macroinvertebrates indicate that the surveyed creeks have degraded health and are adversely impacted from anthropogenic influences in their respective catchments.

11 Recommendations

Recommendations for improvements and alternative approaches to future monitoring and reporting are included below:

Sampling Sites

Given that existing sites may not be considered for future monitoring programs it is important to prioritise existing sites by:

1. Identifying sites that are advisable to continue and those that are least likely to yield value for future monitoring.

This will be dependent other factors such as future capital works and programs within the catchments that may require monitoring. The following outcomes assist with this recommendation and supporting evidence are further summarised below:

- Archers Creek should be given the least priority for future monitoring.
- Porters Creek should be given lower priority for future monitoring.
- Shrimptons, Terrys and Buffalo creeks will be the most valuable for future monitoring.

Archers Creek has shown very little variation in health and macroinvertebrate assemblages through time despite significant change within both the sampling site and further upstream reaches. Results have indicated that the creek is consistently the healthiest of the five creeks. Whilst this is positive it does suggest that unless something very significant happens it is unlikely any significant change in creek health will be observed.

The upper catchment of Porters Creek, upstream of the Wicks Rd sampling site consists of completely underground stormwater. There is a minimal section of open creek for approximately 150m before the creek again flows through underground stormwater systems under the Ryde Depot site. It then exits the depot site and flows for just 30m before entering the Lane Cove National Park. The problem posed for Council is that unless significant maintenance of the stormwater system is carried out in the upper catchment or at the depot it is unlikely that any observable change will be traceable and/or useful for ongoing management of the catchment.

The monitoring program results and impacts observed, suggests that Shrimptons, Terrys and Buffalo creeks will be the most valuable for future monitoring. The proposed capital works in Terrys Creek catchment would identify this creek as being the main target for ongoing or future monitoring.

Water quality sampling

2. Future monitoring may benefit from a review of the water quality sampling regime.

Some opportunities for change could include:

- Wet weather water quality sampling, particularly if there is to be significant stormwater system works.
- An increase in seasonal baseline water quality sampling will produce more data points for reference against past results and give a better picture of the conditions each season.

Macroinvertebrate sampling

3. It is recommended that any future monitoring of macroinvertebrates continue seasonally across autumn and spring.

Results from the program suggest that distinct seasonal variation occurs at most of the sites. Rainfall has clearly had an effect on some sites and seasons during the program. Sampling during two seasons in future programs will help to account for this variation. The preferred AUSRIVAS model is the combined season model and as such annual autumn and spring data is required for analysis.

Water quality analysis

4. It is recommended to develop a region specific trigger value, which could be based on historical results from the Ryde LGA and from survey results from other neighbouring/regional LGA's.

The current trigger value or guideline measure for the monitoring program has been the ANZECC (2000) guidelines, which are a suitable measure of comparison for results. Comparison in this report was also made to the historical mean from the 2004 – 2011 surveys.

Region specific trigger values could be used as a 'measuring bar' for comparing results, determining if they are of concern, are acceptable or better than could be expected. Whilst there would need to be a thorough and detailed analysis of results from each survey, this would be an efficient way of summarising the data for reporting.

EPT taxa richness

5. It is suggested to remove EPT taxa as a measure of health in any ongoing monitoring.

EPT taxa richness results have been very low in the five creeks, with no creek even averaging a single taxa per sample. As discussed in this report the likelihood of EPT taxa returning or being sampled in greater numbers than those observed is highly unlikely.

Reporting options

6. It is recommended to review the need for seasonal reports and look at the financial benefits of one annual report compiling all results.

There would be a direct cost saving and more efficient reporting process to move to one annual report when both autumn and spring seasons have been surveyed. Final conclusions and recommendations would also be strengthened with the inclusion of both survey results. Preliminary water quality and macroinvertebrate data could be reported on an interim basis without the need for a comprehensive report.

Impervious Surface & Catchment Assessments

7. Assessing the creek catchments in a more holistic manner in particular using impervious surface percentage and types then relating that back to results from the surveys could be an approach for future monitoring.

Research in Melbourne (Walsh 2004; Walsh et al., 2005) and the upper Georges River, Sydney, (Tippler et al., 2012) found the percentage of impervious surfaces in a catchment was one of the primary factors affecting waterway health, and included macroinvertebrates as an indicator. Using this measure even on a basic level would lead to a better understanding of the catchments and potentially help to guide ongoing management and capitol works.

An approach that would complement this process would be to:

- Identify and highlight catchments that will see the most change or development over coming years, in particular major development projects.

Major developments will in some way relate back to the creeks through stormwater systems, run-off or filtration. The surveys in Ryde have highlighted at least some level of negative impact on creek health likely due to major developments. However, there may also be the potential to identify improvements in water quality and creek health due to improvements in stormwater system efficiency that applies modern environmentally friendly design.

These approaches may then identify areas, including new catchments or sections of creek in the Ryde LGA that should be monitored in the future. Whilst the current baseline data couldn't be used for direct comparison to new sites it can still be used to relate new data to a benchmark.

12 Glossary

Abundance	The total number of individual specimens; in a sample, community, ecosystem etc.
Algae	Comparatively simple chlorophyll-bearing plants, most of which are aquatic and microscopic in size.
Alkalinity	The ability of a solution to neutralise acid (or buffer).
Aquatic ecosystem	Community of aquatic plants and animals together with the physical and chemical environment in which they live.
Ammonia	Is a colourless gas; In the aquatic environment it exists in the relatively harmless form ammonium (NH4) and the toxic form ammonia (NH3).
Analyte	The physical and chemical parameters (indicators) to be measured.
Anthropogenic	Impacts on an environment that are produced or caused by humans
ANZECC	ANZECC was a forum for member governments to develop coordinated policies about national and international environment and conservation issues. Operating from 1991 to 2001.
AUSRIVAS	AUSRIVAS is a rapid prediction system used to assess the biological health of Australian rivers.
Baseline Data	Is prior collected data that allows comparison to subsequently collected data, enabling comparison to 'normal' background levels.
Benthic	Refers to the lowest area of a water body; the sediment layer; referring to the organisms that live within this area
Catchment	The area that is drained by a river, lake or other water body.
Community	Assemblage of organisms characterised by a distinctive combination of species occupying a common environment and interacting with one another.
Concentration	The quantifiable amount of a chemical divided by the total volume of a mixture.
Conductivity	The measure of salt content in soil or water; it refers to the ability of the substance to transfer an electrical charge.
Correlation	Refers to a quantifiable statistical relationship between two variables.
Detection limit	The smallest concentration or amount of a substance that can be defined by an analytical process for reporting with a specific degree of certainty.
Detritus	Pieces of dead and decomposing plants and organisms (generally in the form of small pieces) found in a water body.
Dissolved Oxygen	The measurement of the concentration of oxygen that is dissolved in a water body.
Diversity (Biological)	The measure of the number and/or degree of available organisms in an environment.
Edge habitat	The edge habitat is an area of unbroken water surface that is within 2 m of the bank.
Ethanol	Alcohol used to preserve macroinvertebrates for long-term reference and identification.
Faecal Coliforms	Bacteria which inhabit the intestines of humans and other vertebrates and are present in faeces. Used as a primary indicator of sewage pollution in the environment.
Guideline (water quality)	Concentration limit or narrative statement recommended to support and maintain a designated water use.
Habitat	The place where a population lives and its surroundings, both living and non-living.
Indicator	A parameter (chemical, biological or geological) that can be used to provide a measure of the quality of water or the condition of an ecosystem.
Invertebrate	Animal lacking a dorsal column of vertebrae (backbone) or a notochord.
Macroinvertebrate (Aquatic)	Animals without backbones that when mature are greater than 1 millimetre; live in the water column, on the water surface or on the bottom of a waterway.
Macrophyte	Plant species that are adapted to growing in or on permanent water and has a definite life form related to the aquatic environment.

Morphotype	A classification of a specimen based solely on morphological characteristics.
Multivariate Analysis	The statistical analysis of data containing more than one variable.
Nitrogen (Aquatic)	Is an element that is essential for plant and animal growth, it occurs in three forms Nitrate, Nitrite and ammonium.
Nutrients	Compounds required for growth by plants and other organisms. Major plant nutrients are phosphorus and nitrogen.
Organic Pollution (Aquatic)	Organic compounds in the form of contaminants (pollution) in a water body that in time can be oxidised by microorganisms (biodegrade).
pH	A measure of the degree of acidity or alkalinity; expressed on a logarithmic scale of 1 to 14 (1 is most acid, 7 neutral and 14 most alkaline).
Phosphorus	Is an element that is essential for plant and animal growth, excess concentrations can lead to eutrophication.
Photosynthesis	The conversion of carbon dioxide to carbohydrates in the presence of chlorophyll using light energy.
Physico-Chemical (Aquatic)	The measure and relationship between the physical and chemical identities of a water body.
Point source pollution	A single identifiable source of pollution such as a stormwater outlet or Industrial drain.
PRIMER	Analysis program that consists of a wide range of univariate and multivariate routines used to analyse ecological data.
Rapid Assessment	Sampling method that involves semi-quantitative techniques for collection of a restricted number of specimens. A time and cost effective method.
Reference Site	A sampling site that occurs in a catchment largely void of human related impacts.
Sensitive organism	Is an organism that's survival is highly susceptible to shifts in environmental conditions.
Sewage	The waste water from homes, offices, shops, factories and other premises discharged to the sewer. Is usually 99% water.
SIGNAL	SIGNAL (Stream Invertebrate Grade Number Average Level) is a biotic index using aquatic macroinvertebrates to assess stream health.
Stormwater	Rainwater that runs off the land, frequently carrying various forms of pollution such as litter and detritus, animal droppings and dissolved chemicals. This untreated water is carried in stormwater channels and discharged directly into water bodies.
Stormwater system	The system of pipes, canals and other channels used to carry stormwater to bodies of water, such as rivers or oceans. The system does not usually involve any significant form of treatment.
Taxon	Is the definite entity and classification formally recognized by taxonomists of any given organism.
Taxonomic Level	Refers to the classification type of an organism; species, genus, family, order, class, phylum, kingdom.
Tolerant organism	An organism that can survive in highly variable environmental conditions.
Turbidity	A measure of the amount of suspended solids (usually fine clay or silt particles) in water and thus the degree of scattering or absorption of light in the water.
Univariate Analyses	Refers to the statistical analysis of data containing one variable.

13 Acronyms and abbreviations

ANZECC	Australian and New Zealand Environment and Conservation Council
AUSRIVAS	Australian River Assessment System
cfu	colony forming unit
DO	dissolved oxygen
EPT	Ephemeroptera, Plecoptera, Trichoptera
mg/L	milligrams per litre
MDS	Multi-dimensional scaling
NATA	National Association of Testing Authorities of Australia
NTU	Nephelometric Turbidity Units
PRIMER	Plymouth Routines In Multivariate Ecological Research
RBA	Rapid biological assessment
SIGNAL-SF	Stream Invertebrate Grade Number Average Level – Sydney Family
SIGNAL-SG	Stream Invertebrate Grade Number Average Level – Sydney Genus
SIGNAL2	Stream Invertebrate Grade Number Average Level – National scores (2003)
SIMPER	Similarity percentages routine
SIMPROF	Similarity profile routine
STP	Sewage treatment plant
µg/L	micrograms per litre
µS/cm	micro-siemens per centimetre (unit of conductivity)

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Appendix 1: Quality assurance

AS/NZS IS Sydney Water is a quality business organisation certified to AS/NZS ISO 9001 and ISO 14001. All investigations performed for the production of this report, as with all business operations of the organisation, were conducted to the requirements of this standard including project management, macroinvertebrate sampling, water quality sampling and interpretive reporting.

The Sydney Water laboratories, located in West Ryde, are National Association of Testing Authorities (NATA) accredited to ISO 17025 for a broad range of analytical testing that includes water, sediments, microbiologic, biologic and pathogenic. The laboratories have been accredited for chemical testing since 1952, for biological testing since 1966 and for the identification of aquatic macroinvertebrates to species, genus and family levels since 1997.

Sydney Water maintains a permanent aquatic macroinvertebrate laboratory with high-resolution microscopes, a systematically organised, fully catalogued macroinvertebrate voucher reference collection of over 1300 species and associated detailed keys and descriptions.

The collection is one of the largest freshwater macroinvertebrate reference collections in Australia and the largest species-level macroinvertebrate collection in New South Wales. Specimens are largely collected from the Sydney basin and the Hawkesbury-Nepean catchment, but include specimens from across New South Wales, and are regularly sent to Australian taxonomic specialists for verification. Specimens are loaned to biological, particularly taxonomic, researchers throughout Australia and the laboratory is visited and inspected by recognised taxonomists. Through the reference collection, Sydney Water actively contributes to the international aquatic macroinvertebrate taxonomic knowledge base while maintaining a repository of natural history information.

The laboratory also has a tailored Leica Montage Digital Database for storage of digital images of the freshwater macroinvertebrate voucher collection. The Montage software and camera provide an additional tool in the identification of macroinvertebrates and are used in conjunction with other identification methods set out in this document. The benefit of electronic imaging lies in the time efficiencies it brings to the identification process. The Montage tool creates tailored photographic archives of freshwater macroinvertebrates. It enables comparison of sample specimens with stored images and provides measurement and labelling functions. Electronic images are sent to international and national experts for confirmation of identification, which avoids potential loss or damage to a physical specimen.

Macroinvertebrates were identified and enumerated for this study to the family or morphospecies taxonomic level. The method used, SSWI433 *In-house test method Macroinvertebrate Cataloguing, Identification and Counting* is in compliance with the requirements of AS ISO/IEC 17025 *General Requirements for the Competence of Testing and Calibration Laboratories*, under technical accreditation number 610 issued by NATA. Macroinvertebrate identification was performed using appropriate and current published keys and identification tools, Sydney Water internal keys specific to the laboratory's collection, unpublished descriptions and voucher specimens.

Quality assurance was conducted as per SSWI434 *In-house test method Quality Control of Macroinvertebrate Identification, Counting and Archiving of Collections*, in compliance with the requirements of AS ISO/IEC 17025 *General Requirements for the Competence of Testing and Calibration Laboratories* under technical accreditation number 610. Quality assurance was conducted on at least 5% of samples collected for this study.

Appendix 2: Water chemistry parameters and their method of collection

Analyte	Units	Field Instrument / Bottle
Sample clarity	NA	NA
Algae present		
Recent rain		
Visual pollution		
Flow Rate (visual assessment)		
Dissolved Oxygen	mg/L	WTW Multiliner Universal Meter
Dissolved Oxygen Percent	% saturation	
Conductivity Low Range	µS/cm	
pH	pH units	
Water Temperature	Degrees C	Digital Thermometer
Turbidity (white light)	NTU	HACH Turbidimeter
Oxidised Nitorgen Nox-N Low Level	mg/L	1 x 200mL PET
Nitrite Nitrogen NO2-N	mg/L	
Nitrate Nitrogen NO3-N	mg/L	
Soluble Reactive Phosphorus	mg/L	
Total Nitrogen	mg/L	
Total Phosphorus	mg/L	
Alkalinity	mg $CaCO_3$/L	1 x 500mL PET
Total Hardness	mg $CaCO_3$/L	
Metals	mg/L	1 x 200mL PET
Faecal Coliform	CFU/100 mL	1 x 500mL PET sterile (red cap)

Appendix 3: Macroinvertebrate analyses

Univariate analyses (diversity indices)

Univariate analyses test hypotheses with only one variable. Univariate analyses were performed on macroinvertebrate data using the following diversity indices:

Taxa richness

Taxa richness is the overall variety (total taxa) of macroinvertebrates in a given community assemblage. It is an indicator of stream health that can be measured at any specific taxonomic level and operates under the assumption that taxa richness will be higher in healthy streams and lower in streams of poor health.

The composition of macroinvertebrate abundances within taxa groups was included in this report. Taxa were for the most part placed into Class and Order groups. The composition of macroinvertebrate abundance at the basic level is limited in its ability to indicate water body health. However it can give an indication of the habitat and biological holding capacity of the water-bodies being studied.

Taxa richness can be a useful tool for indicating the general health of a water body. However, it should be used with caution, as taxa numbers may be attributable to factors other than stream health and/or anthropogenic impacts. For example, taxa richness may increase with elevated levels of organic pollution and may not be a good indication that stream health is better than areas with lower levels of organic pollution.

EPT taxa richness

EPT taxa richness is a diversity index that measures the total number of families of Ephemeroptera (Mayflies), Plecoptera (Stoneflies) and Trichoptera (Caddisflies) in a given community assemblage. These taxonomic Orders of macroinvertebrates are highly sensitivity to changes in water quality condition (Lenat 1998). The number of EPT taxa found at a site can generally be used as an indicator of stream biological health. An absence of these taxa may be attributable to anthropogenic disturbances within a catchment.

Many EPT taxa are sensitive to natural factors and changes in streams, such as altitude and environmental flows. While EPT taxa tend to favour higher altitude streams, Sydney Water has observed a diverse range of these taxa at altitudes as low as ten metres at reference sites in the greater Sydney region and on the Clyde River.

Some caution must be applied when interpreting patterns based on EPT taxa. Some EPT taxa are relatively tolerant and are commonly found in streams with moderate to mild levels of pollution. A decline or absence of EPT taxa may be attributable to natural changes in a catchment, such as a decline in flow.

Biological indices (models)

Various models have been developed to help add meaning to macroinvertebrate data. They have been developed to help represent realistic processes in ecosystems and predict system response using minimal data collected. Results are presented with a measure of variation (plus and minus one standard deviation of the average score), as recommended by Australian and New Zealand Water Quality Guidelines for Fresh and Marine Waters (2000). This allows stream health comparison between sampling occasions for each creek

and between creeks through time. Two useful macroinvertebrate models used in this report include:

SIGNAL

The SIGNAL (Stream Invertebrate Grade Number Average Level) biotic index is a relatively simple and inexpensive method to assess stream health. This index assigns 'sensitivity scores' to macroinvertebrate taxa that are collected using the rapid assessment sampling method. The original version was developed for Sydney Water, assessing the Hawkesbury-Nepean catchment and required identifications to the Family taxonomic level (Chessman, 1995).

The original SIGNAL index was refined to include the response of SIGNAL to natural and anthropogenic environmental factors (Growns *et al*. 1995), variations in sampling and sample processing methods (Growns *et al*. 1997;) and the objective setting of sensitivity grades of the taxa (Chessman et al. 1997; Chessman *et al*. 2002).

SIGNAL2

Chessman (2003a) revised SIGNAL for national application and produced a complete set of revised scores using reference data from around Australia. Known as SIGNAL2 (Chessman 2003b), this index is applicable to the greater community and scientists alike and can be applied to the Order-Class-Phylum taxonomic level as well as Family. Refer to Chessman (2003b) for the variants for the calculation of SIGNAL2 scores.

A bi-plot of the sensitivity scores can be used to help interpret results (Figure 38). This requires the placement of arbitrary boundaries to indicate the condition of and likely impacts experienced by a water body. However, this largely relies on the inclusion in a study of reference sites to guide the placement of boundaries. The bi-plot should be used purely as an indicator of likely impacts and caution should be taken when interpreting results, particularly when reference sites are unavailable for a study. The arbitrary boundaries for this report have been based on a SIGNAL2 score of 5 and total taxa count of 20. These figures are based on comparable data from sites within the Sydney region that could be considered to be of a 'healthier' condition.

SIGNAL2 can be calculated with or without abundance weighting (Chessman 2003b). Calculations for this report were completed using data treated with abundance weighted scores.

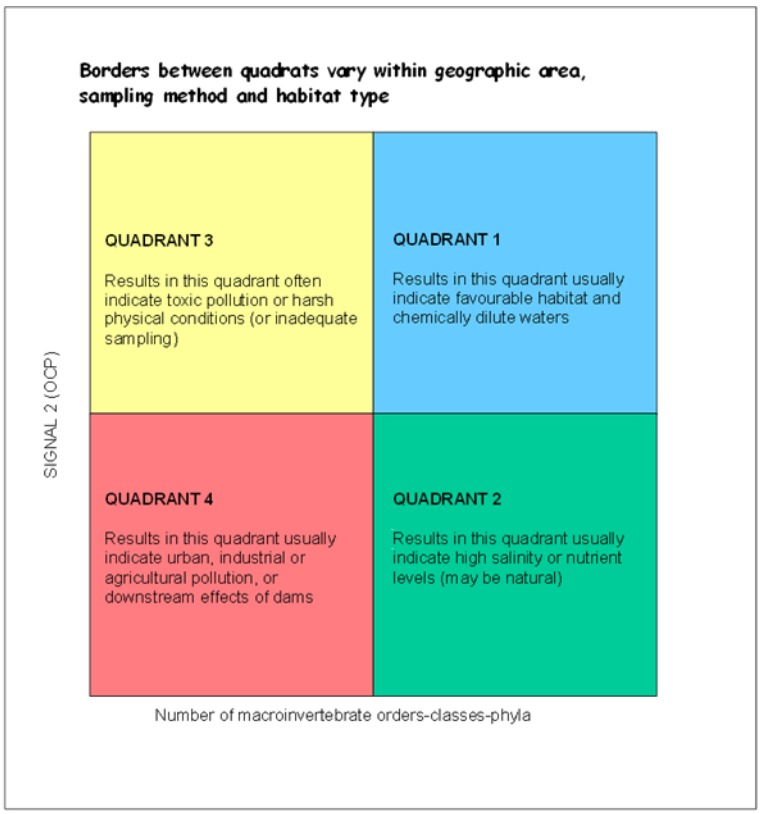


Figure 38 Quadrant diagram for family version of SIGNAL2 (Chessman 2003b)

SIGNAL-SF

Chessman *et al*. (2007) saw the development of a Sydney-specific SIGNAL biotic index that drew on family and genus level macroinvertebrate data from the greater Sydney region. The water quality status of 'clean water' was established using data from near pristine reference sites in the bushland fringes of Sydney and determining the 10th percentile of the average score of those sites (Table 32).

SIGNAL-SF allows a direct measure of test site condition and incorporates abundance information gathered from the rapid assessment sampling. 'S' indicates the Sydney region version and 'F' indicates that the taxonomy is at the family level.

The first step in calculating a SIGNAL-SF score is to apply predetermined sensitivity grade numbers (from 1, tolerant to 10, highly sensitive) to each family count for a given habitat sample. Families without a grade score that are present in a sample are removed from the SIGNAL-SF calculation. This occurs for very few animals that, generally, are not 'true' aquatic invertebrates.

The square root transformed count (treated to remove bias of taxa with high abundance counts) of each family is then multiplied by the sensitivity grade. The products are summed and then divided by the total square root transformed number of individuals in all families. A location-specific average is then calculated for each sampling site.

Table 32 Interpretation of SIGNAL-SF scores (Chessman *et al*., 2007)

SIGNAL-SF score	Water quality status
> 6.5	Clean water
5.2-6.5	Possible mild organic pollution
3.8-5.2	Probable moderate organic pollution
< 3.8	Probable severe organic pollution

AUSRIVAS

AUSRIVAS (AUStralian RIVers Assessment System) is an interactive software package that uses data based on predictive models of macroinvertebrate distribution to assess river health. It grew out of the British program RIVPACS (River Invertebrate Prediction and Classification System; Wright 1995), which was modified to suit Australian environmental conditions (Turak *et al*. 2004).

AUSRIVAS models were developed using biological, physical and chemical data collected from reference sites in all states and territories of Australia. Models and methodologies were calibrated to the specific area from which the data underlying them were collected.

The sampled macroinvertebrate families are imported into the chosen model as presence/absence (1 or 0) or binary data. The physical and chemical data (predictor variables) from the project site is then used to determine a predicted macroinvertebrate community assemblage (Expected). The macroinvertebrates collected at a project site (Observed) are then compared to the predicted assemblage (Expected), given that the expected assemblage would occur at an undisturbed/reference site (Turak *et al*. 2004).

Data from pool edge and riffle habitats sampled in single spring and autumn seasons, or in combined seasons forms the basis of NSW AUSRIVAS models. Ransom *et al*. (2004) describes the combined season model as preferable, as it maximizes the family list for a project site being examined. Each model output includes a variety of analyses or 'scores'. Those used in this report are described below.

Predicted/Collected data

The AUSRIVAS output includes a datasheet that presents the predicted, expected and observed number of taxa at a test site. These indices are used to produce a score called the 'OE50 ratio', which provides a measure of biological impairment at a test site (Ransom *et al*., 2004). OE50 compares the number of observed invertebrate families at a site and those expected to occur with a greater than 50% probability of finding them at any one sampling occasion (Coysh *et al*. 2000).

The OE50 ratio of each test sample also corresponds to a band representing different levels of biological condition. This helps to categorise each test site, allowing a comparison with reference sites from rivers of the same type. This comparison assists in interpretation of the data with a view to aid in environmental management decision making (Coysh *et al*. 2000). Interpretation of the five possible bands of river condition is detailed in Table 33 (Coysh *et al.* 2000). Thresholds that correspond to these bands of each respective model are detailed in Table 34.

The predicted/collected data includes results that incorporate SIGNAL tolerance grades (Chessman, 1995). SIGNAL scores are used to produce an OE0-SIGNAL value, which is the ratio of observed taxa with those expected to occur with a greater than 0% probability.

No bands have been developed for SIGNAL (Coysh *et al*. 2000). However, values of around 1 would be similar to reference condition (Chessman pers comm.).

Table 33 Interpretation of bands associated with AUSRIVAS OE50 model output (Coysh *et al*., 2000)

Band	Description	O/E taxa	O/E taxa interpretations
X	More biologically diverse than reference	▪ O/E greater than 90th percentile of reference sites used to create the model	▪ More families found than expected ▪ Potential biodiversity 'hot spot' or mild organic enrichment ▪ Continuous irrigation flow in a normally intermittent stream
A	Similar to reference	▪ O/E within range of central 80% of reference sites used to create the model	▪ Expected number of families within the range found at 80% of the reference sites
B	Significantly impaired	▪ O/E below 10th percentile of reference sites used to create the model ▪ Same width as band A	▪ Fewer families than expected ▪ Potential impact either on water and/or habitat quality resulting in a loss of families
C	Severely impaired	▪ O/E below band B ▪ Same width as band A	▪ Many fewer families than expected ▪ Loss of families from substantial impairment of expected biota caused by water and/or habitat quality
D	Extremely impaired	▪ O/E below band C down to zero	▪ Few of the expected families and only the hardy, pollution tolerant families remain ▪ Severe impairment

Table 34 Upper thresholds for bands of impairment (OE50 taxa) for AUSRIVAS models developed for NSW (Turak and Waddell, 2001)

Model	Threshold			
	A	B	C	D
Combined edge (East)	1.17	0.82	0.48	0.14
Autumn edge	1.17	0.81	0.46	0.11
Spring edge	1.16	0.83	0.51	0.19

Multivariate analyses

Multivariate statistical analyses were performed using the PRIMERv6 software package (Clarke and Warwick, 2001) and involve the analysis of more than one variable. Multivariate analysis using macroinvertebrates, water quality, rainfall and other physical attributes of the site allow comparisons to be made of macroinvertebrate community composition within sites, between sites and of patterns that emerge through time.

Clustering and SIMPROF test

Cluster analysis uses a matrix of correlations to look for patterns of structure within samples. Samples that are highly correlated and thus more similar will be grouped together closer than samples that are least similar. The output is a tree diagram (dendrogram) displaying the groupings of samples into successively smaller numbers of clusters.

A SIMPROF permutation test on a cluster analysis helps to see which (if any) clusters are significantly different. Samples connected by red lines cannot be significantly differentiated. SIMPROF test groups can be checked against the complementary ordination results.

Ordination

Ordination produces a plot of samples on two (2D) or three (3D) axes such that samples with similar taxa lie closer together than samples with differing taxon composition. When ordination and SIMPROF test results produce similar patterns the analysis can be considered reliable, but should also be verified by a test of variance, such as ANOSIM

Macroinvertebrate samples were ordinated on the Bray-Curtis similarity matrix between samples using the non-metric Multi-Dimensional Scaling (MDS) technique. The success of the ordination is measured by a stress value, which indicates the degree of distortion imposed. In PRIMER v6 a stress value of below 0.2 indicates an acceptable representation of the original data, although lower values are desirable.

Environmental samples were ordinated on the normalised Euclidean distances between samples using the Principal Components Analysis (PCA) technique.

SIMPER

The SIMPER routine was employed to investigate community structure between and within groups of sites as detailed above. This routine employs Bray Curtis similarities to examine the contribution of individual taxa to the average similarity between groups and also within groups. This is an exploratory rather than a statistical analysis. Results from the SIMPER procedure can be superimposed on an MDS (or PCA) plot, as circles whose varying diameters reflect the abundance changes for that species across samples (bubble plots).

ANOSIM

ANOSIM is used to test the hypothesis that there is no difference in community structure between site groups. This is tested by comparing the similarity between sample groups within sites to the similarity of sample groups between sites (Clarke and Warwick, 2001). ANOSIM is employed to investigate the potential spatial or temporal differences that exist both within and between site sample groups.

ANOSIM works by using a randomisation process, whereby an R-value is originally calculated from the data set and then each randomisation compares a newly calculated R-value with the original. This randomisation compares all sample groups resulting in an R-value for all site groups, known as a global R-value, and an R-value for all site group comparisons. An R-value is a number between -1 and 1, and the higher the number (further from 0) the bigger the difference or lack of similarity between groups.

Appendix 4: Water quality results

Site Code	Site Location	Survey Season	Total Phosphorus TP µg/L	Total Nitrogen TN µg/L	Total Kjeldahl Nitrogen TKN µg/L	Oxidised Nitrogen NOx µg/L	Ammonia µg/L	Conductivity µS/cm	Dissolved Oxygen mg/L	Dissolved Oxygen %Sat	Temperature ^{o}C	pH	Faecal Coliform CFU/100mL	Alkalinity mg CaCO3/L	Turbidity NTU
S1	Terrys Creek @ Somerset Park	Spring 2013	49	1020	640	380	10	522	6.2	64.1	17.1	7.22	150	76.7	3.82
S1	Terrys Creek @ Somerset Park	Autumn 2014	25	990	700	290	10	610	7.6	74.8	14.0	7.41	74	96.0	2.74
S2	Shrimpton's Creek @ Wilga Park	Spring 2013	58	1250	810	440	40	428	4.8	52.8	19.1	7.25	260	57.2	4.65
S2	Shrimpton's Creek @ Wilga Park	Autumn 2014	40	680	560	120	40	419	3.0	28.9	15.4	7.16	320	94.0	5.19
CR1SA	Shrimpton's Creek @ Kent Rd	Spring 2013	45	790	720	70	10	408	4.2	44.5	18.7	7.08	590	52.3	4.60
CR1SA	Shrimpton's Creek @ Kent Rd	Autumn 2014	23	700	660	40	20	648	4.6	46.4	15.7	7.22	46	67.0	4.80
CR1SB	Shrimpton's Creek @ Bridge St	Spring 2013	41	680	670	10	10	522	2.2	24.3	19.2	7.09	220	69.8	5.58
CR1SB	Shrimpton's Creek @ Bridge St	Autumn 2014	15	560	550	10	5	679	2.9	28.5	15.1	6.95	46	87.0	3.58
CR1SC	Shrimpton's Creek @ Quarry Rd	Spring 2013	25	1320	660	660	80	546	8.8	95.1	19.2	7.23	250	52.1	1.69
CR1SC	Shrimpton's Creek @ Quarry Rd	Autumn 2014	32	1560	730	830	10	923	8.5	85.6	15.3	7.45	160	82.0	1.18
S3	Porters Creek @ Ryde Depot	Spring 2013	98	2730	1370	1360	320	512	7.8	78.9	19.0	7.53	210	118.0	4.96
S3	Porters Creek @ Ryde Depot	Autumn 2014	34	3980	1280	2700	860	632	10.2	104.0	15.3	7.68	54	145.0	5.40
CR5PA	Porters Creek @ Main Branch	Spring 2013	63	900	670	230	30	140	8.3	94.8	21.9	7.45	420	33.2	14.80
CR5PA	Porters Creek @ Main Branch	Autumn 2014	29	1170	890	280	200	348	6.2	63.5	17.2	7.06	91	130.0	17.20
CR5PB	Porters Creek @ Spur Branch	Spring 2013	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
CR5PB	Porters Creek @ Spur Branch	Autumn 2014	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
CR5PC	Porters Creek @ Wicks Rd	Spring 2013	276	3360	1450	1910	210	438	7.4	84.0	18.4	7.30	7700	77.9	16.00
CR5PC	Porters Creek @ Wicks Rd	Autumn 2014	36	2480	1050	1430	100	464	8.3	86.8	17.4	7.39	590	81.0	28.60
S4	Buffalo Creek @ Higginbotham Rd	Spring 2013	58	1080	690	390	10	472	7.3	80.3	19.6	7.43	270	58.1	3.33
S4	Buffalo Creek @ Higginbotham Rd	Autumn 2014	31	1330	620	710	20	529	9.0	93.2	17.1	7.50	62	65.0	5.05
CR4BA	Buffalo Creek d/s Burrows Park	Spring 2013	214	3430	2580	850	1070	620	5.2	56.4	18.7	7.48	320000	82.8	6.59
CR4BA	Buffalo Creek d/s Burrows Park	Autumn 2014	104	2570	1190	1380	70	840	7.4	73.1	16.9	7.29	330	102.0	13.90
CR4BB	Buffalo Creek u/s Burrows Park	Spring 2013	820	12200	10900	1250	6600	547	5.2	56.3	18.6	7.55	1300000	107.0	9.05
CR4BB	Buffalo Creek u/s Burrows Park	Autumn 2014	196	3150	1330	1820	30	709	7.8	81.4	17.2	7.63	750	100.0	7.38
S5	Archers Creek @ Maze Park	Spring 2013	80	900	900	5	10	499	0.8	9.6	21.5	7.15	2100	67.1	3.16
S5	Archers Creek @ Maze Park	Autumn 2014	50	640	620	20	70	466	1.8	17.3	17.0	7.08	67	95.0	3.80

Site Code	Site Location	Survey Season	Total Chromium mg/L	Total Manganese mg/L	Total Iron mg/L	Total Copper mg/L	Total Zinc mg/L	Total Arsenic mg/L	Total Cadmium mg/L	Total Lead mg/L	Total Mercury mg/L	Total Calcium mg/L	Total Magnesium mg/L	Total Hardness mg CaCO3/L
S1	Terrys Creek @ Somerset Park	Spring 2013	0.0005	0.033	0.653	0.005	0.016	0.0005	0.0005	0.0005	0.00015	30.3	7.70	107.0
S1	Terrys Creek @ Somerset Park	Autumn 2014	0.0005	0.014	0.734	0.002	0.014	0.0005	0.0005	0.0005	0.00015	35.2	9.60	128.0
S2	Shrimpton's Creek @ Wilga Park	Spring 2013	0.0005	0.043	0.836	0.006	0.033	0.001	0.0005	0.002	0.00015	21.1	4.66	71.9
S2	Shrimpton's Creek @ Wilga Park	Autumn 2014	0.0005	0.041	1.07	0.002	0.018	0.0005	0.0005	0.0005	0.00015	31.5	7.21	108.0
CR1SA	Shrimpton's Creek @ Kent Rd	Spring 2013	0.0005	0.063	1.3	0.002	0.015	0.0005	0.0005	0.0005	0.00015	20.9	6.04	77.1
CR1SA	Shrimpton's Creek @ Kent Rd	Autumn 2014	0.0005	0.034	0.985	0.001	0.015	0.0005	0.0005	0.0005	0.00015	28.6	8.20	105.0
CR1SB	Shrimpton's Creek @ Bridge St	Spring 2013	0.0005	0.132	2.56	0.002	0.022	0.0005	0.0005	0.0005	0.00015	27.0	7.69	99.2
CR1SB	Shrimpton's Creek @ Bridge St	Autumn 2014	0.0005	0.031	1.12	0.001	0.022	0.0005	0.0005	0.0005	0.00015	34.1	9.95	126.0
CR1SC	Shrimpton's Creek @ Quarry Rd	Spring 2013	0.0005	0.045	0.381	0.002	0.014	0.0005	0.0005	0.0005	0.00015	21.5	8.34	88.1
CR1SC	Shrimpton's Creek @ Quarry Rd	Autumn 2014	0.0005	0.016	0.227	0.002	0.017	0.0005	0.0005	0.0005	0.00015	33.1	14.00	140.0
S3	Porters Creek @ Ryde Depot	Spring 2013	0.0005	0.055	1.1	0.004	0.023	0.0005	0.0005	0.0005	0.00015	36.0	8.76	126.0
S3	Porters Creek @ Ryde Depot	Autumn 2014	0.0005	0.034	0.982	0.002	0.017	0.0005	0.0005	0.0005	0.00015	45.2	11.80	162.0
CR5PA	Porters Creek @ Main Branch	Spring 2013	0.001	0.011	0.491	0.005	0.027	0.0005	0.0005	0.002	0.00015	10.8	2.21	36.1
CR5PA	Porters Creek @ Main Branch	Autumn 2014	0.001	0.066	0.851	0.003	0.025	0.0005	0.0005	0.001	0.00015	28.1	10.70	114.0
CR5PB	Porters Creek @ Spur Branch	Spring 2013	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
CR5PB	Porters Creek @ Spur Branch	Autumn 2014	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
CR5PC	Porters Creek @ Wicks Rd	Spring 2013	0.001	0.026	2.29	0.018	0.099	0.0005	0.0005	0.002	0.00015	28.7	7.19	101.0
CR5PC	Porters Creek @ Wicks Rd	Autumn 2014	0.002	0.038	1.12	0.012	0.048	0.0005	0.0005	0.0005	0.00015	31.7	8.91	116.0
S4	Buffalo Creek @ Higginbotham Rd	Spring 2013	0.0005	0.04	1.17	0.004	0.016	0.0005	0.0005	0.0005	0.00015	22.9	7.62	88.6
S4	Buffalo Creek @ Higginbotham Rd	Autumn 2014	0.0005	0.026	0.974	0.003	0.017	0.0005	0.0005	0.0005	0.00015	24.8	9.37	101.0
CR4BA	Buffalo Creek d/s Burrows Park	Spring 2013	0.0005	0.094	1.29	0.006	0.027	0.0005	0.0005	0.001	0.00015	25.6	9.56	103.0
CR4BA	Buffalo Creek d/s Burrows Park	Autumn 2014	0.0005	0.089	1.440	0.006	0.041	0.0005	0.0005	0.001	0.00015	34.9	13.50	143.0
CR4BB	Buffalo Creek u/s Burrows Park	Spring 2013	0.0005	0.042	0.513	0.014	0.034	0.001	0.0005	0.0005	0.00015	23.1	7.36	88.1
CR4BB	Buffalo Creek u/s Burrows Park	Autumn 2014	0.0005	0.023	0.464	0.008	0.052	0.0005	0.0005	0.0005	0.00015	33.7	10.50	128.0
S5	Archers Creek @ Maze Park	Spring 2013	0.0005	0.903	0.828	0.005	0.161	0.0005	0.0005	0.0005	0.00015	24.4	8.70	96.8
S5	Archers Creek @ Maze Park	Autumn 2014	0.0005	0.710	0.920	0.0005	0.014	0.0005	0.0005	0.0005	0.00015	27.1	9.40	106.0

Appendix 5: Macroinvertebrate raw data

Site Location		Archers Ck	Archers Ck	Archers Ck	Archers Ck	Archers Ck	Archers Ck	Buffalo Ck	Buffalo Ck	Buffalo Ck	Buffalo Ck	Buffalo Ck	Buffalo Ck	Porters Ck	Porters Ck	Porters Ck	Porters Ck	Porters Ck	Porters Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Terrys Ck	Terrys Ck	Terrys Ck	Terrys Ck	Terrys Ck	Terrys Ck
Survey Season		Spring 2013	Spring 2013	Spring 2013	Autumn 2014	Autumn 2014	Autumn 2014	Spring 2013	Spring 2013	Spring 2013	Autumn 2014	Autumn 2014	Autumn 2014	Spring 2013	Spring 2013	Spring 2013	Autumn 2014	Autumn 2014	Autumn 2014	Spring 2013	Spring 2013	Spring 2013	Autumn 2014	Autumn 2014	Autumn 2014	Spring 2013	Spring 2013	Spring 2013	Autumn 2014	Autumn 2014	Autumn 2014
Site Code		S5	S5	S5	S5	S5	S5	S4	S4	S4	S4	S4	S4	S3	S3	S3	S3	S3	S3	S2	S2	S2	S2	S2	S2	S1	S1	S1	S1	S1	S1
Acarina	Acarina		2												1									5	1				1	3	
Bivalvia	Sphaeriidae	4	3										1				1				1			1				1			
Coleoptera	Dytiscidae													1																	
Coleoptera	Elmidae		1																									1			
Coleoptera	Hydraenidae		2																												
Coleoptera	Hydrophilidae			2										1																	
Coleoptera	Psephenidae	5	9	12	7	12	1		2	1										2		1				1	5	6	4	9	
Coleoptera	Scirtidae													1																	
Decapoda	Atyidae				3	2	17										1		2												
Decapoda	Parastacidae																				1										
Diptera	Ceratopogonidae				1																										
Diptera	Culicidae	4	11	4																											
Diptera	Dolichopodidae																											2			
Diptera	s-f Chironominae	7	12	26	35	32	2	13	15	13	7	8	13	22	10	15	2	2		16	10	10	4		2	6	8	5		2	
Diptera	s-f Orthocladiinae														1	2	4		1		1	1	2								1
Diptera	s-f Tanypodinae		6			2								1	1				1					4	5	1	3	3		2	3
Diptera	Simuliidae																						2				2		1		
Diptera	Stratiomyidae	1	4	2		2	2			1				1	1	2				2	1	1						1		1	
Diptera	Tipulidae					1																									
Gastropoda	Tateidae	10	12	11	4	8	2	13	11	9	17	16	15	13	2	16	9	1	11	1	9	7		3	1	10	13	2	12	25	16
Gastropoda	Lymnaeidae		1							1	2	1		1																	
Gastropoda	Physidae	4	12	9	6	7	1		1	4	1			1	2	1				10	10	9	6	11	7	5	2	12	1	4	
Gastropoda	Planorbidae							1	2	2	2	2				1												1			
Hemiptera	Corixidae		1											4	3	1				2	3										
Hemiptera	Gerridae																					1							1		
Hemiptera	Notonectidae	8	6	1	7	4	2	2								1	1	1	2	1	1	1	1	1	4	2	3	4	1	5	
Hemiptera	Pleidae													1		1															

Site Location		Archers Ck	Archers Ck	Archers Ck	Archers Ck	Archers Ck	Archers Ck	Buffalo Ck	Buffalo Ck	Buffalo Ck	Buffalo Ck	Buffalo Ck	Buffalo Ck	Porters Ck	Porters Ck	Porters Ck	Porters Ck	Porters Ck	Porters Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Shrimptons Ck	Terrys Ck	Terrys Ck	Terrys Ck	Terrys Ck	Terrys Ck	Terrys Ck
Survey Season		Spring 2013	Spring 2013	Spring 2013	Autumn 2014	Autumn 2014	Autumn 2014	Spring 2013	Spring 2013	Spring 2013	Autumn 2014	Autumn 2014	Autumn 2014	Spring 2013	Spring 2013	Spring 2013	Autumn 2014	Autumn 2014	Autumn 2014	Spring 2013	Spring 2013	Spring 2013	Autumn 2014	Autumn 2014	Autumn 2014	Spring 2013	Spring 2013	Spring 2013	Autumn 2014	Autumn 2014	Autumn 2014
Site Code		S5	S5	S5	S5	S5	S5	S4	S4	S4	S4	S4	S4	S3	S3	S3	S3	S3	S3	S2	S2	S2	S2	S2	S2	S1	S1	S1	S1	S1	S1
Hemiptera	Veliidae			9		3																						1		1	1
Isopoda	Scyphacidae																				1										
Odonata	Aeshnidae				1	3	1																			1					
Odonata	Coenagrionidae		1		5	1	2										2				3				2			1			
Odonata	Hemicorduliidae		5		10	8	4				1		3											3	2			1		4	5
Odonata	Isostictidae							2	1	4														2		1	1	1		1	1
Odonata	Lestidae				1																										
Odonata	Libellulidae		2		4	8											1												4	1
Odonata	Megapodagrionidae			2	2	5	2		2			1							6						1		9	6	12	9
Odonata	Synlestidae																											1			
Oligochaeta	Oligochaeta	2	10	5	1	9	9	1	3			4	3	6	6	1	9	1	1	7	7		3	6	4	3	5	3	3	9	
Rhynchobdellida	Glossiphoniidae		5		8	12	1													1	1		1		1						1
Trichoptera	Antipodoecidae													1																	
Trichoptera	Hydroptilidae			2	6	3											1	1						1		1					
Turbellaria	Dugesiidae	1	3	4	5	14	4			2		1	1						2	2	9	2	11	15	8	1			2	12	6

Appendix 6: Multivariate raw data

SIMPER creek/replicate raw results

SIMPER
Similarity Percentages - species contributions

One-Way Analysis

Data worksheet
Name: Spring 2013 and Autumn 2014 Square Root
Data type: Abundance
Sample selection: All
Variable selection: All

Parameters
Resemblance: S17 Bray Curtis similarity
Cut off for low contributions: 90.00%

Factor Groups

Sample	Creek
ArchersSp13a	Archers Ck
ArchersSp13b	Archers Ck
ArchersSp13c	Archers Ck
ArchersAu14a	Archers Ck
ArchersAu14b	Archers Ck
ArchersAu14c	Archers Ck
BuffaloSp13a	Buffalo Ck
BuffaloSp13b	Buffalo Ck
BuffaloSp13c	Buffalo Ck
BuffaloAu14a	Buffalo Ck
BuffaloAu14b	Buffalo Ck
BuffaloAu14c	Buffalo Ck
PortersSp13a	Porters Ck
PortersSp13b	Porters Ck
PortersSp13c	Porters Ck
PortersAu14a	Porters Ck
PortersAu14b	Porters Ck
PortersAu14c	Porters Ck
ShrimptonsSp13a	Shrimptons Ck
ShrimptonsSp13b	Shrimptons Ck
ShrimptonsSp13c	Shrimptons Ck
ShrimptonsAu14a	Shrimptons Ck
ShrimptonsAu14b	Shrimptons Ck
ShrimptonsAu14c	Shrimptons Ck
TerrysSp13a	Terrys Ck
TerrysSp13b	Terrys Ck
TerrysSp13c	Terrys Ck
TerrysAu14a	Terrys Ck
TerrysAu14b	Terrys Ck
TerrysAu14c	Terrys Ck

Group Archers Ck
Average similarity: 56.77

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum%
s-f Chironominae	4.03	8.52	2.50	15.01	15.01
Tateidae	2.70	6.71	2.81	11.82	26.83
Psephenidae	2.64	6.14	2.89	10.82	37.64
Physidae	2.43	5.63	3.22	9.92	47.57
Oligochaeta	2.30	5.31	2.39	9.36	56.92
Notonectidae	2.06	4.89	2.62	8.62	65.54
Dugesiidae	2.12	4.81	3.86	8.48	74.02
Stratiomyidae	1.21	2.59	1.31	4.56	78.58
Hemicorduliidae	1.70	2.37	0.78	4.18	82.76
Glossiphoniidae	1.59	1.76	0.73	3.11	85.86
Megapodagrionidae	1.08	1.67	0.78	2.94	88.81
Culicidae	1.22	1.31	0.48	2.30	91.11

Group Buffalo Ck
Average similarity: 65.43

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum%
Tateidae	3.65	25.30	5.60	38.66	38.66
s-f Chironominae	3.36	22.71	7.74	34.70	73.36
Planorbidae	1.11	6.08	1.32	9.30	82.66
Oligochaeta	1.08	4.07	0.75	6.22	88.88
Isostictidae	0.74	1.57	0.47	2.41	91.28

Group Porters Ck
Average similarity: 43.77

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum%
Tateidae	2.72	13.28	2.52	30.33	30.33
s-f Chironominae	2.43	8.99	1.19	20.54	50.87
Oligochaeta	1.82	8.97	2.73	20.49	71.36
Notonectidae	0.74	3.28	0.76	7.48	78.84
s-f Orthocladiinae	0.90	2.86	0.78	6.53	85.37
Corixidae	0.79	1.42	0.46	3.25	88.62
s-f Tanypodinae	0.50	1.25	0.48	2.85	91.46

Group Shrimptons Ck
Average similarity: 56.82

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum%
Physidae	2.96	14.60	9.01	25.70	25.70
Dugesiidae	2.64	10.69	2.71	18.81	44.51
s-f Chironominae	2.29	7.68	1.19	13.52	58.03
Oligochaeta	1.91	6.90	1.34	12.14	70.17
Notonectidae	1.17	5.34	7.64	9.40	79.57
Tateidae	1.56	4.39	1.13	7.72	87.29
Glossiphoniidae	0.67	2.10	0.78	3.70	90.99

Group Terrys Ck
Average similarity: 53.19

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum%
Tateidae	3.44	13.19	2.24	24.81	24.81
Megapodagrionidae	2.15	5.90	1.13	11.10	35.91
Oligochaeta	1.74	5.36	1.30	10.07	45.98
Psephenidae	1.78	4.96	1.20	9.32	55.30
Physidae	1.69	4.22	1.25	7.94	63.24
Notonectidae	1.40	4.01	1.30	7.54	70.78
s-f Tanypodinae	1.27	3.93	1.23	7.38	78.16
s-f Chironominae	1.49	3.21	0.70	6.04	84.20
Isostictidae	0.83	2.94	1.31	5.53	89.73
Dugesiidae	1.39	2.57	0.74	4.83	94.56

Groups Archers Ck & Buffalo Ck
Average dissimilarity = 60.28

	Group Archers Ck	Group Buffalo Ck				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum%
Psephenidae	2.64	0.40	4.78	2.34	7.93	7.93
Notonectidae	2.06	0.24	4.06	1.90	6.74	14.67
Physidae	2.43	0.67	3.83	1.89	6.35	21.02
s-f Chironominae	4.03	3.36	3.46	1.80	5.75	26.77
Dugesiidae	2.12	0.57	3.25	1.82	5.40	32.17
Hemicorduliidae	1.70	0.46	3.16	1.45	5.24	37.40
Oligochaeta	2.30	1.08	3.06	1.53	5.07	42.48
Glossiphoniidae	1.59	0.00	3.00	1.25	4.97	47.45
Atyidae	1.21	0.00	2.81	0.70	4.66	52.11
Culicidae	1.22	0.00	2.72	0.97	4.51	56.62
Planorbidae	0.00	1.11	2.45	1.89	4.06	60.69
Stratiomyidae	1.21	0.17	2.40	1.75	3.99	64.67
Tateidae	2.70	3.65	2.35	1.14	3.89	68.57
Megapodagrionidae	1.08	0.40	2.00	1.26	3.31	71.88
Coenagrionidae	0.94	0.00	1.94	1.13	3.21	75.10
Libellulidae	1.04	0.00	1.86	0.93	3.08	78.18
Hydroptilidae	0.93	0.00	1.81	0.94	3.01	81.19
Veliidae	0.79	0.00	1.61	0.63	2.68	83.86
Sphaeriidae	0.62	0.17	1.61	0.75	2.66	86.53
Isostictidae	0.00	0.74	1.59	0.89	2.64	89.17
Lymnaeidae	0.17	0.57	1.27	0.92	2.10	91.27

Groups Archers Ck & Porters Ck
Average dissimilarity = 62.78

Species	Group Archers Ck Av.Abund	Group Porters Ck Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum%
Psephenidae	2.64	0.00	5.52	3.21	8.80	8.80
s-f Chironominae	4.03	2.43	4.91	1.47	7.82	16.62
Physidae	2.43	0.57	3.97	1.93	6.33	22.94
Dugesiidae	2.12	0.24	3.93	2.42	6.26	29.20
Hemicorduliidae	1.70	0.00	3.35	1.32	5.33	34.54
Glossiphoniidae	1.59	0.00	2.97	1.24	4.73	39.27
Notonectidae	2.06	0.74	2.88	1.44	4.59	43.86
Atyidae	1.21	0.40	2.83	0.78	4.51	48.37
Culicidae	1.22	0.00	2.70	0.96	4.29	52.67
Tateidae	2.70	2.72	2.45	1.14	3.90	56.56
Megapodagrionidae	1.08	0.41	2.39	1.32	3.81	60.37
Oligochaeta	2.30	1.82	2.25	1.27	3.58	63.95
s-f Orthocladiinae	0.00	0.90	1.93	1.19	3.07	67.02
Libellulidae	1.04	0.17	1.90	1.02	3.03	70.05
Hydroptilidae	0.93	0.33	1.90	1.17	3.03	73.08
Coenagrionidae	0.94	0.24	1.89	1.12	3.00	76.08
Stratiomyidae	1.21	0.57	1.87	1.26	2.98	79.06
Corixidae	0.17	0.79	1.61	0.95	2.57	81.63
s-f Tanypodinae	0.64	0.50	1.61	1.13	2.56	84.19
Veliidae	0.79	0.00	1.60	0.62	2.55	86.74
Sphaeriidae	0.62	0.17	1.59	0.73	2.53	89.27
Aeshnidae	0.62	0.00	1.25	0.95	1.99	91.26

Groups Buffalo Ck & Porters Ck
Average dissimilarity = 54.81

Species	Group Buffalo Ck Av.Abund	Group Porters Ck Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum%
s-f Chironominae	3.36	2.43	6.12	1.37	11.17	11.17
Tateidae	3.65	2.72	4.77	0.91	8.70	19.87
Oligochaeta	1.08	1.82	4.09	1.55	7.46	27.33
Planorbidae	1.11	0.17	3.72	1.61	6.79	34.12
s-f Orthocladiinae	0.00	0.90	3.15	1.26	5.75	39.87
Notonectidae	0.24	0.74	2.80	1.29	5.10	44.97
Isostictidae	0.74	0.00	2.62	0.90	4.77	49.75
Physidae	0.67	0.57	2.57	1.05	4.69	54.44
Corixidae	0.00	0.79	2.54	0.93	4.64	59.08
Megapodagrionidae	0.40	0.41	2.50	0.77	4.55	63.63
Dugesiidae	0.57	0.24	2.24	0.99	4.08	67.71
Lymnaeidae	0.57	0.17	2.12	0.91	3.87	71.59
Stratiomyidae	0.17	0.57	1.92	0.98	3.50	75.09
Hemicorduliidae	0.46	0.00	1.76	0.65	3.21	78.30
s-f Tanypodinae	0.00	0.50	1.71	0.97	3.11	81.41
Atyidae	0.00	0.40	1.46	0.67	2.66	84.07
Hydroptilidae	0.00	0.33	1.45	0.67	2.65	86.72
Psephenidae	0.40	0.00	1.38	0.66	2.51	89.23
Pleidae	0.00	0.33	1.03	0.69	1.87	91.11

Groups Archers Ck & Shrimptons Ck
Average dissimilarity = 51.62

Species	Group Archers Ck Av.Abund	Group Shrimptons Ck Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum%
s-f Chironominae	4.03	2.29	4.24	1.61	8.21	8.21
Psephenidae	2.64	0.40	4.23	2.45	8.18	16.40
Tateidae	2.70	1.56	2.83	1.32	5.48	21.88
Hemicorduliidae	1.70	0.52	2.82	1.38	5.46	27.34
Atyidae	1.21	0.00	2.50	0.71	4.84	32.18
Culicidae	1.22	0.00	2.42	0.97	4.70	36.87
Glossiphoniidae	1.59	0.67	2.42	1.48	4.69	41.56
Dugesiidae	2.12	2.64	2.31	1.45	4.48	46.04
Oligochaeta	2.30	1.91	2.09	1.27	4.05	50.09
Megapodagrionidae	1.08	0.00	2.02	1.35	3.92	54.01
Notonectidae	2.06	1.17	1.94	1.32	3.75	57.77
s-f Tanypodinae	0.64	0.71	1.77	0.89	3.43	61.20
Coenagrionidae	0.94	0.52	1.74	1.17	3.37	64.57
Libellulidae	1.04	0.00	1.70	0.93	3.29	67.86
Hydroptilidae	0.93	0.17	1.67	1.02	3.24	71.10
Stratiomyidae	1.21	0.57	1.64	1.32	3.18	74.28
Physidae	2.43	2.96	1.63	1.04	3.16	77.44
Sphaeriidae	0.62	0.33	1.50	0.85	2.91	80.35
Veliidae	0.79	0.00	1.45	0.63	2.82	83.17
Acarina	0.24	0.54	1.19	0.75	2.31	85.48
s-f Orthocladiinae	0.00	0.57	1.16	0.90	2.25	87.73
Aeshnidae	0.62	0.00	1.13	0.96	2.20	89.92
Corixidae	0.17	0.52	1.07	0.78	2.07	91.99

Groups Buffalo Ck & Shrimptons Ck
Average dissimilarity = 60.22

Species	Group Buffalo Ck Av.Abund	Group Shrimptons Ck Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum%
Physidae	0.67	2.96	7.15	2.68	11.87	11.87
Tateidae	3.65	1.56	6.77	1.65	11.24	23.10
Dugesiidae	0.57	2.64	6.39	1.83	10.62	33.72
s-f Chironominae	3.36	2.29	4.21	1.32	6.99	40.71
Oligochaeta	1.08	1.91	3.68	1.39	6.12	46.83
Planorbidae	1.11	0.00	3.44	2.05	5.70	52.53
Notonectidae	0.24	1.17	3.24	2.35	5.38	57.91
Isostictidae	0.74	0.24	2.29	0.98	3.81	61.72
Hemicorduliidae	0.46	0.52	2.14	0.93	3.56	65.27
s-f Tanypodinae	0.00	0.71	2.09	0.69	3.48	68.75
Glossiphoniidae	0.00	0.67	2.06	1.36	3.43	72.18
s-f Orthocladiinae	0.00	0.57	1.86	0.91	3.08	75.26
Lymnaeidae	0.57	0.00	1.78	0.93	2.96	78.22
Stratiomyidae	0.17	0.57	1.75	0.97	2.91	81.13
Psephenidae	0.40	0.40	1.74	0.91	2.89	84.02
Acarina	0.00	0.54	1.57	0.64	2.61	86.63
Corixidae	0.00	0.52	1.48	0.70	2.46	89.09
Coenagrionidae	0.00	0.52	1.47	0.70	2.44	91.52

Groups Porters Ck & Shrimptons Ck
Average dissimilarity = 58.99

Species	Group Porters Ck Av.Abund	Group Shrimptons Ck Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum%
Physidae	0.57	2.96	7.49	2.53	12.70	12.70
Dugesiidae	0.24	2.64	7.33	2.04	12.42	25.13
s-f Chironominae	2.43	2.29	5.10	1.40	8.64	33.77
Tateidae	2.72	1.56	4.80	1.40	8.13	41.90
Oligochaeta	1.82	1.91	3.28	1.40	5.55	47.46
s-f Tanypodinae	0.50	0.71	2.61	1.10	4.42	51.88
Corixidae	0.79	0.52	2.47	1.06	4.19	56.07
s-f Orthocladiinae	0.90	0.57	2.32	1.15	3.93	60.00
Glossiphoniidae	0.00	0.67	2.05	1.31	3.48	63.48
Stratiomyidae	0.57	0.57	1.89	1.03	3.20	66.68
Acarina	0.17	0.54	1.75	0.74	2.96	69.64
Coenagrionidae	0.24	0.52	1.73	0.79	2.93	72.57
Notonectidae	0.74	1.17	1.58	0.96	2.67	75.24
Hemicorduliidae	0.00	0.52	1.54	0.68	2.60	77.85
Psephenidae	0.00	0.40	1.31	0.67	2.23	80.07
Hydroptilidae	0.33	0.17	1.30	0.75	2.20	82.28
Megapodagrionidae	0.41	0.00	1.29	0.44	2.19	84.47
Atyidae	0.40	0.00	1.23	0.67	2.08	86.55
Sphaeriidae	0.17	0.33	1.10	0.77	1.86	88.41
Pleidae	0.33	0.00	0.88	0.69	1.50	89.90
Simuliidae	0.00	0.24	0.85	0.43	1.43	91.34

Groups Archers Ck & Terrys Ck
Average dissimilarity = 51.38

Species	Group Archers Ck Av.Abund	Group Terrys Ck Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum%
s-f Chironominae	4.03	1.49	4.87	1.58	9.48	9.48
Megapodagrionidae	1.08	2.15	2.90	1.55	5.64	15.12
Hemicorduliidae	1.70	0.87	2.57	1.25	5.01	20.13
Glossiphoniidae	1.59	0.17	2.52	1.27	4.91	25.04
Dugesiidae	2.12	1.39	2.47	1.69	4.81	29.85
Atyidae	1.21	0.00	2.37	0.71	4.61	34.46
Psephenidae	2.64	1.78	2.32	1.27	4.51	38.97
Physidae	2.43	1.69	2.31	1.39	4.50	43.47
Culicidae	1.22	0.00	2.30	0.96	4.47	47.94
Tateidae	2.70	3.44	2.18	1.23	4.25	52.19
s-f Tanypodinae	0.64	1.27	2.13	1.49	4.14	56.33
Oligochaeta	2.30	1.74	2.03	1.32	3.96	60.29
Stratiomyidae	1.21	0.33	1.88	1.48	3.65	63.94
Notonectidae	2.06	1.40	1.86	1.16	3.63	67.57
Libellulidae	1.04	0.50	1.79	1.10	3.48	71.05
Veliidae	0.79	0.50	1.72	0.96	3.35	74.41
Hydroptilidae	0.93	0.17	1.60	1.03	3.12	77.52
Coenagrionidae	0.94	0.17	1.59	1.11	3.10	80.62
Isostictidae	0.00	0.83	1.53	1.95	2.98	83.60
Sphaeriidae	0.62	0.17	1.33	0.74	2.60	86.20
Aeshnidae	0.62	0.17	1.09	0.99	2.13	88.33
Acarina	0.24	0.46	0.96	0.80	1.86	90.19

Groups Buffalo Ck & Terrys Ck
Average dissimilarity = 54.53

Species	Group Buffalo Ck Av.Abund	Group Terrys Ck Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum%
s-f Chironominae	3.36	1.49	5.55	1.35	10.17	10.17
Megapodagrionidae	0.40	2.15	5.24	1.70	9.61	19.78
Psephenidae	0.40	1.78	4.24	1.68	7.77	27.55
Physidae	0.67	1.69	3.65	1.41	6.70	34.24
s-f Tanypodinae	0.00	1.27	3.53	1.87	6.48	40.72
Notonectidae	0.24	1.40	3.44	1.78	6.30	47.02
Dugesiidae	0.57	1.39	3.32	1.25	6.09	53.11
Oligochaeta	1.08	1.74	2.96	1.21	5.43	58.53
Planorbidae	1.11	0.17	2.93	1.67	5.37	63.90
Hemicorduliidae	0.46	0.87	2.54	1.03	4.65	68.55
Tateidae	3.65	3.44	2.26	1.27	4.14	72.69
Isostictidae	0.74	0.83	2.12	1.40	3.89	76.58
Lymnaeidae	0.57	0.00	1.65	0.92	3.03	79.61
Simuliidae	0.00	0.40	1.31	0.69	2.40	82.01
Veliidae	0.00	0.50	1.27	0.96	2.33	84.34
Libellulidae	0.00	0.50	1.23	0.68	2.25	86.60
Acarina	0.00	0.46	1.18	0.70	2.16	88.75
Stratiomyidae	0.17	0.33	0.96	0.78	1.76	90.51

Groups Porters Ck & Terrys Ck
Average dissimilarity = 60.68

Species	Group Porters Ck Av.Abund	Group Terrys Ck Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum%
Megapodagrionidae	0.41	2.15	5.35	1.52	8.82	8.82
s-f Chironominae	2.43	1.49	5.03	1.43	8.30	17.12
Psephenidae	0.00	1.78	4.83	1.80	7.97	25.09
Tateidae	2.72	3.44	3.86	1.06	6.36	31.45
Physidae	0.57	1.69	3.66	1.32	6.03	37.49
Dugesiidae	0.24	1.39	3.63	1.19	5.98	43.47
Oligochaeta	1.82	1.74	2.99	1.60	4.93	48.39
s-f Tanypodinae	0.50	1.27	2.68	1.36	4.42	52.81
Notonectidae	0.74	1.40	2.45	1.56	4.03	56.85
s-f Orthocladiinae	0.90	0.17	2.34	1.19	3.85	60.70
Isostictidae	0.00	0.83	2.31	1.92	3.81	64.51
Hemicorduliidae	0.00	0.87	2.25	0.83	3.72	68.23
Corixidae	0.79	0.00	2.03	0.91	3.35	71.58
Stratiomyidae	0.57	0.33	1.54	0.99	2.53	74.11
Libellulidae	0.17	0.50	1.40	0.79	2.30	76.41
Acarina	0.17	0.46	1.34	0.80	2.21	78.62
Simuliidae	0.00	0.40	1.30	0.67	2.15	80.77
Veliidae	0.00	0.50	1.26	0.94	2.08	82.85
Hydroptilidae	0.33	0.17	1.21	0.75	2.00	84.84
Atyidae	0.40	0.00	1.14	0.66	1.88	86.73
Coenagrionidae	0.24	0.17	0.91	0.60	1.49	88.22
Pleidae	0.33	0.00	0.83	0.68	1.36	89.58
Sphaeriidae	0.17	0.17	0.72	0.60	1.19	90.77

Groups Shrimptons Ck & Terrys Ck
Average dissimilarity = 54.35

Species	Group Shrimptons Ck Av.Abund	Group Terrys Ck Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum%
Tateidae	1.56	3.44	5.19	1.57	9.54	9.54
Megapodagrionidae	0.00	2.15	5.14	1.76	9.46	19.00
Dugesiidae	2.64	1.39	4.12	1.48	7.57	26.57
s-f Chironominae	2.29	1.49	3.99	1.27	7.34	33.92
Physidae	2.96	1.69	3.74	1.47	6.88	40.80
Psephenidae	0.40	1.78	3.63	1.75	6.69	47.48
s-f Tanypodinae	0.71	1.27	2.81	1.55	5.17	52.65
Oligochaeta	1.91	1.74	2.48	1.12	4.57	57.22
Hemicorduliidae	0.52	0.87	2.25	1.04	4.14	61.36
Isostictidae	0.24	0.83	1.95	1.85	3.58	64.94
Notonectidae	1.17	1.40	1.74	1.52	3.19	68.14
Acarina	0.54	0.46	1.73	0.91	3.18	71.31
Glossiphoniidae	0.67	0.17	1.52	1.19	2.79	74.10
s-f Orthocladiinae	0.57	0.17	1.47	0.95	2.70	76.80
Stratiomyidae	0.57	0.33	1.42	0.97	2.61	79.41
Simuliidae	0.24	0.40	1.36	0.80	2.50	81.92
Coenagrionidae	0.52	0.17	1.34	0.80	2.46	84.38
Corixidae	0.52	0.00	1.21	0.69	2.23	86.61
Veliidae	0.00	0.50	1.12	0.96	2.06	88.67
Libellulidae	0.00	0.50	1.08	0.68	2.00	90.66

SIMPER creek/season raw results

SIMPER
Similarity Percentages - species contributions

One-Way Analysis
Data worksheet
Name: Spring 2013 and Autumn 2014 Square Root
Data type: Abundance
Sample selection: All
Variable selection: All

Parameters
Resemblance: S17 Bray Curtis similarity
Cut off for low contributions: 90.00%

Factor Groups

Sample	Season Year
ArchersSp13a	Archers Ck Spring 13
ArchersSp13b	Archers Ck Spring 13
ArchersSp13c	Archers Ck Spring 13
ArchersAu14a	Archers Ck Autumn 14
ArchersAu14b	Archers Ck Autumn 14
ArchersAu14c	Archers Ck Autumn 14
BuffaloSp13a	Buffalo Ck Spring 13
BuffaloSp13b	Buffalo Ck Spring 13
BuffaloSp13c	Buffalo Ck Spring 13
BuffaloAu14a	Buffalo Ck Autumn 14
BuffaloAu14b	Buffalo Ck Autumn 14
BuffaloAu14c	Buffalo Ck Autumn 14
PortersSp13a	Porters Ck Spring 13
PortersSp13b	Porters Ck Spring 13
PortersSp13c	Porters Ck Spring 13
PortersAu14a	Porters Ck Autumn 14
PortersAu14b	Porters Ck Autumn 14
PortersAu14c	Porters Ck Autumn 14
ShrimptonsSp13a	Shrimptons Ck Spring 13
ShrimptonsSp13b	Shrimptons Ck Spring 13
ShrimptonsSp13c	Shrimptons Ck Spring 13
ShrimptonsAu14a	Shrimptons Ck Autumn 14
ShrimptonsAu14b	Shrimptons Ck Autumn 14
ShrimptonsAu14c	Shrimptons Ck Autumn 14
TerrysSp13a	Terrys Ck Spring 13
TerrysSp13b	Terrys Ck Spring 13
TerrysSp13c	Terrys Ck Spring 13
TerrysAu14a	Terrys Ck Autumn 14
TerrysAu14b	Terrys Ck Autumn 14
TerrysAu14c	Terrys Ck Autumn 14

Group Archers Ck Spring 13
Average similarity: 61.33

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Tateidae	3.31	10.46	6.01	17.06	17.06
s-f Chironominae	3.74	9.38	9.40	15.29	32.35
Psephenidae	2.90	7.99	9.37	13.03	45.37
Physidae	2.82	7.43	7.66	12.12	57.49
Culicidae	2.44	6.53	5.37	10.64	68.14
Oligochaeta	2.27	5.36	6.60	8.74	76.87
Notonectidae	2.09	4.79	1.82	7.81	84.69
Dugesiidae	1.58	3.93	5.11	6.40	91.09

Group Archers Ck Autumn 14
Average similarity: 64.54

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
s-f Chironominae	4.33	7.39	1.39	11.45	11.45
Hemicorduliidae	2.66	6.33	11.93	9.82	21.26
Dugesiidae	2.66	5.86	9.69	9.09	30.35
Oligochaeta	2.33	4.75	1.41	7.36	37.71
Tateidae	2.08	4.48	11.93	6.94	44.65
Notonectidae	2.02	4.48	11.93	6.94	51.59
Atyidae	2.42	4.36	3.73	6.75	58.34
Glossiphoniidae	2.43	4.29	2.01	6.65	64.99
Psephenidae	2.37	4.15	2.20	6.42	71.41
Megapodagrionidae	1.69	4.01	6.47	6.22	77.63
Physidae	2.03	3.99	2.47	6.18	83.82
Coenagrionidae	1.55	3.29	2.81	5.09	88.91
Aeshnidae	1.24	2.84	6.47	4.40	93.31

Group Buffalo Ck Spring 13
Average similarity: 68.68

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
s-f Chironominae	3.69	24.88	13.22	36.23	36.23
Tateidae	3.31	21.48	7.90	31.28	67.51
Isostictidae	1.47	7.87	4.24	11.46	78.97
Planorbidae	1.28	7.78	7.54	11.32	90.29

Group Buffalo Ck Autumn 14
Average similarity: 68.76

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Tateidae	4.00	31.12	22.74	45.26	45.26
s-f Chironominae	3.03	21.49	131.63	31.25	76.51
Oligochaeta	1.24	4.41	0.58	6.41	82.92
Planorbidae	0.94	3.80	0.58	5.52	88.44
Hemicorduliidae	0.91	2.72	0.58	3.95	92.39

Group Porters Ck Spring 13
Average similarity: 64.14

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
s-f Chironominae	3.91	19.41	12.35	30.27	30.27
Tateidae	3.01	11.93	2.01	18.60	48.87
Oligochaeta	1.97	8.44	1.86	13.16	62.03
Corixidae	1.58	7.11	3.11	11.08	73.11
Physidae	1.14	5.75	8.75	8.96	82.07
Stratiomyidae	1.14	5.75	8.75	8.96	91.04

Group Porters Ck Autumn 14
Average similarity: 44.03

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Tateidae	2.44	13.69	2.21	31.10	31.10
Oligochaeta	1.67	9.07	4.57	20.60	51.69
Notonectidae	1.14	9.07	4.57	20.60	72.29
s-f Chironominae	0.94	4.44	0.58	10.08	82.37
Hydroptilidae	0.67	3.14	0.58	7.13	89.50
s-f Orthocladiinae	1.00	2.31	0.58	5.25	94.75

Group Shrimptons Ck Spring 13
Average similarity: 68.58

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
s-f Chironominae	3.44	16.25	7.18	23.69	23.69
Physidae	3.11	15.66	8.36	22.83	46.52
Tateidae	2.22	7.84	1.73	11.43	57.94
Dugesiidae	1.94	7.27	7.18	10.59	68.54
Notonectidae	1.00	5.14	7.18	7.49	76.03
Stratiomyidae	1.14	5.14	7.18	7.49	83.52
Oligochaeta	1.76	4.02	0.58	5.86	89.38
Corixidae	1.05	2.15	0.58	3.13	92.51

Group Shrimptons Ck Autumn 14
Average similarity: 59.33

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Dugesiidae	3.34	16.43	7.15	27.69	27.69
Physidae	2.80	13.77	15.71	23.20	50.89
Oligochaeta	2.06	9.95	23.85	16.76	67.65
Notonectidae	1.33	5.49	9.97	9.25	76.90
s-f Tanypodinae	1.41	3.28	0.58	5.52	82.42
s-f Chironominae	1.14	2.83	0.58	4.77	87.20
Hemicorduliidae	1.05	2.32	0.58	3.90	91.10

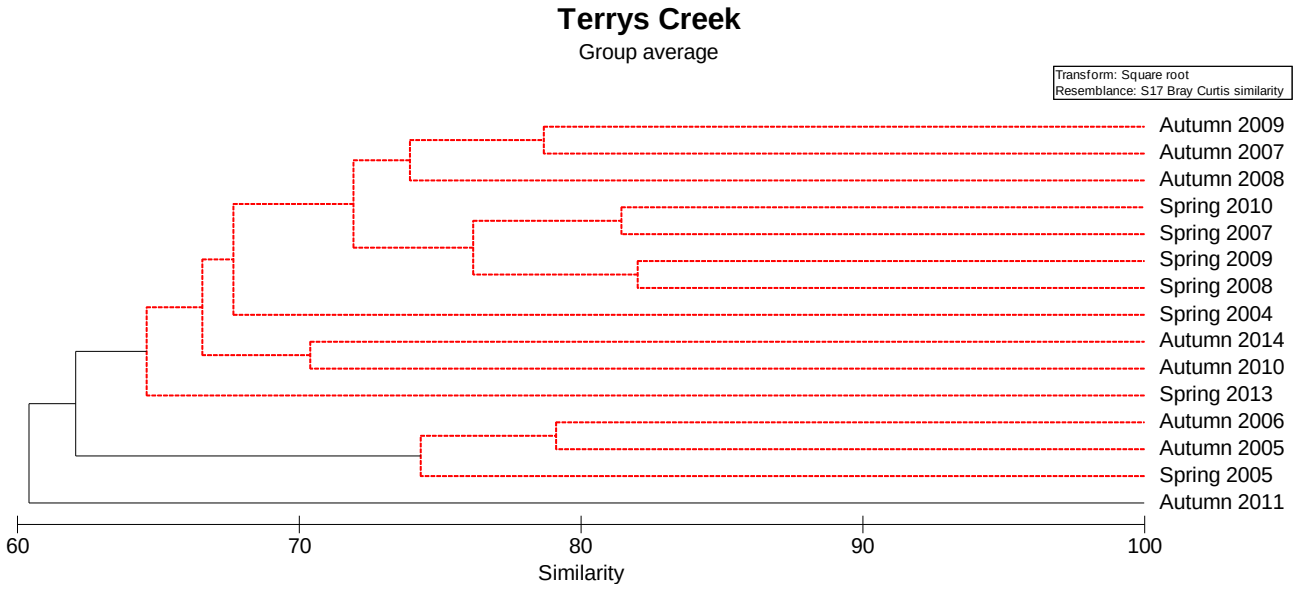
Group Terrys Ck Spring 13
Average similarity: 62.27

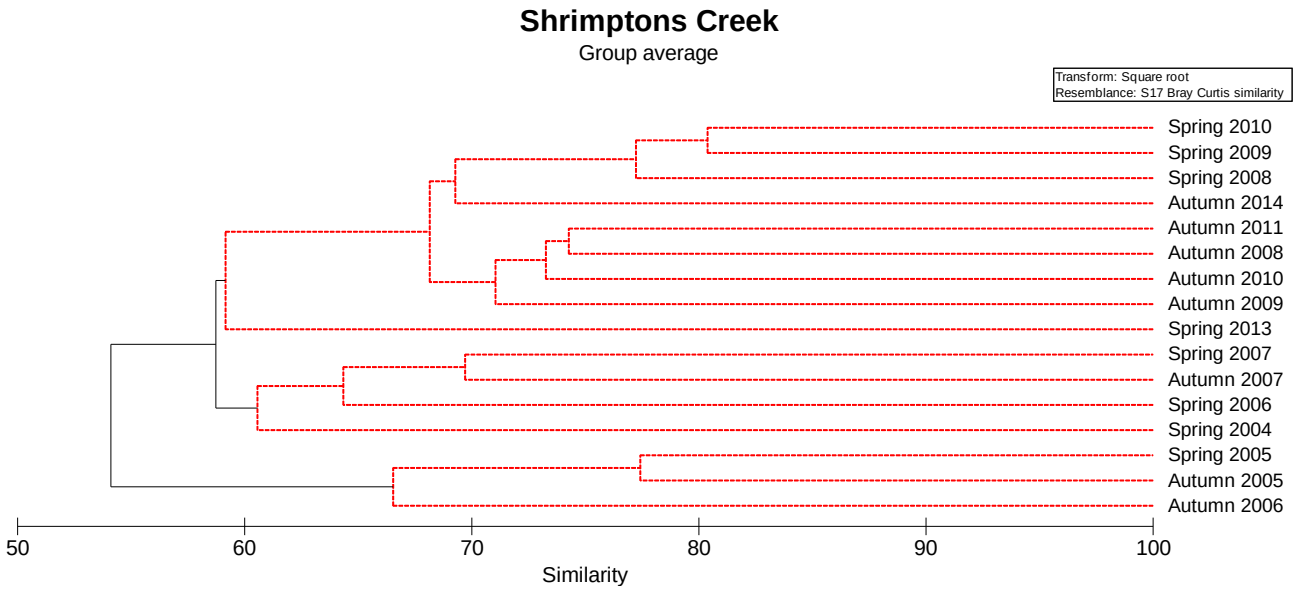
Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
s-f Chironominae	2.50	10.92	4.82	17.54	17.54
Tateidae	2.73	9.88	1.50	15.86	33.40
Oligochaeta	1.90	8.15	6.64	13.09	46.49
Physidae	2.37	7.84	4.39	12.59	59.08
Notonectidae	1.72	7.11	7.86	11.42	70.50
Psephenidae	1.90	6.47	2.34	10.40	80.89
s-f Tanypodinae	1.49	5.75	3.66	9.24	90.13

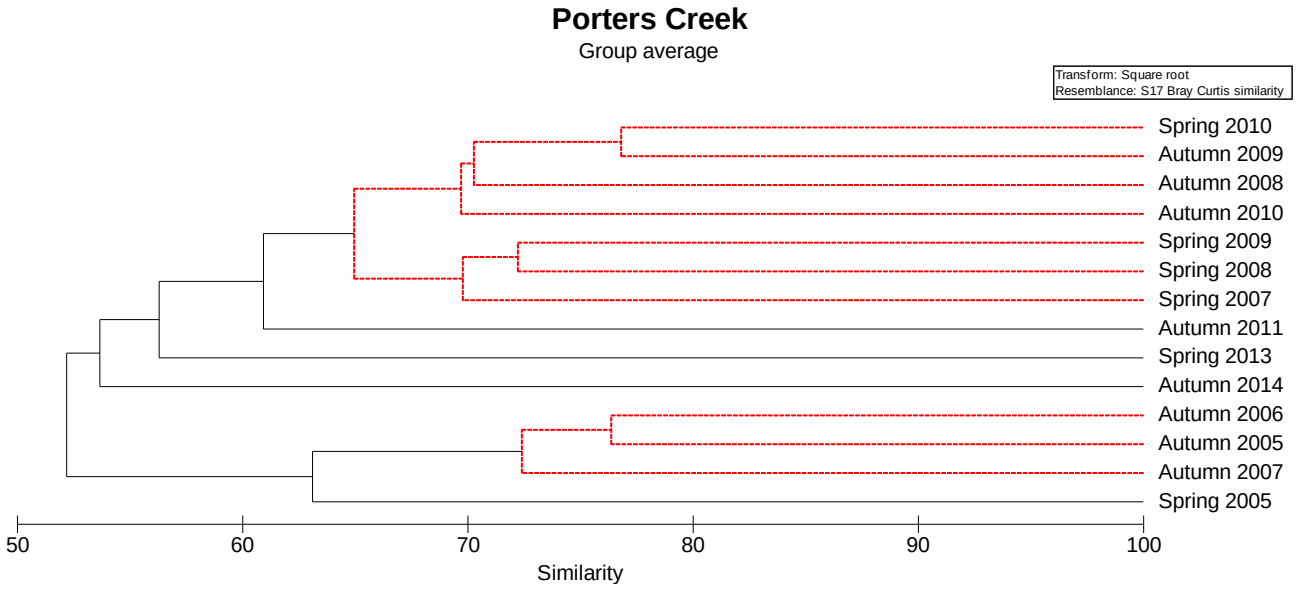
Group Terrys Ck Autumn 14
Average similarity: 53.28

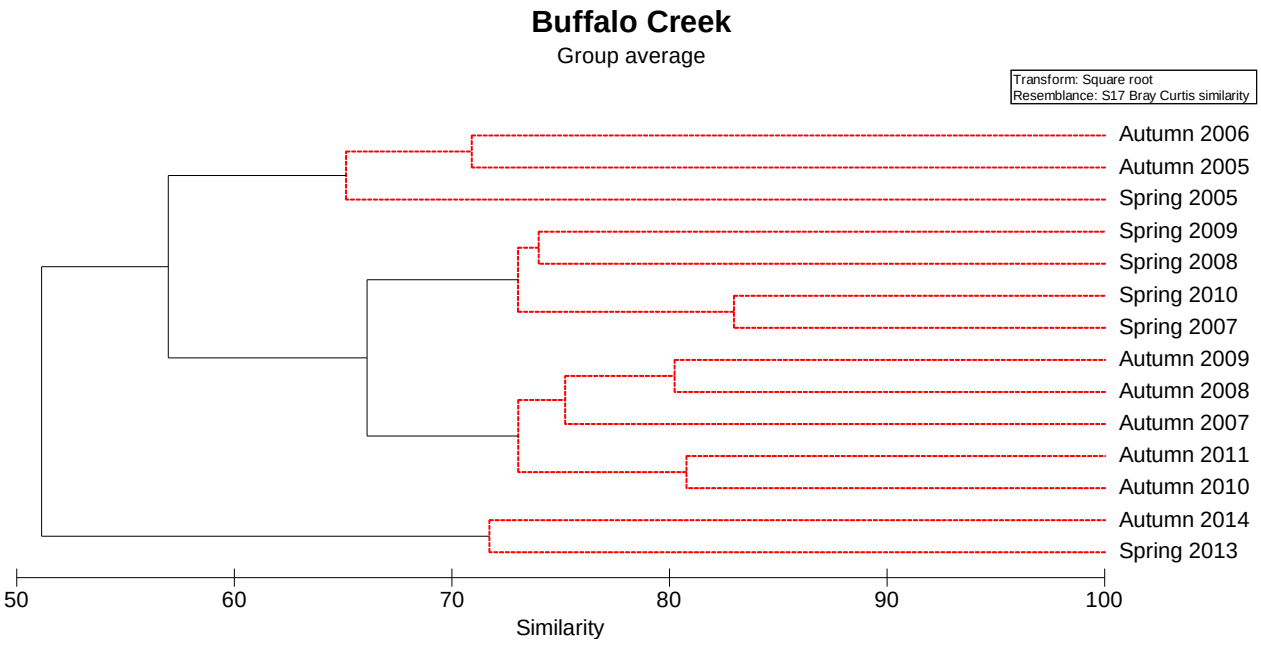
Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Tateidae	4.15	16.45	5.09	30.88	30.88
Megapodagrionidae	2.97	11.85	5.38	22.25	53.12
Dugesiidae	2.44	7.76	4.09	14.56	67.69
Psephenidae	1.67	2.68	0.58	5.03	72.71
Hemicorduliidae	1.41	2.56	0.58	4.80	77.51
Oligochaeta	1.58	2.32	0.58	4.35	81.87
s-f Tanypodinae	1.05	1.81	0.58	3.39	85.26
Physidae	1.00	1.34	0.58	2.51	87.77
Notonectidae	1.08	1.34	0.58	2.51	90.29

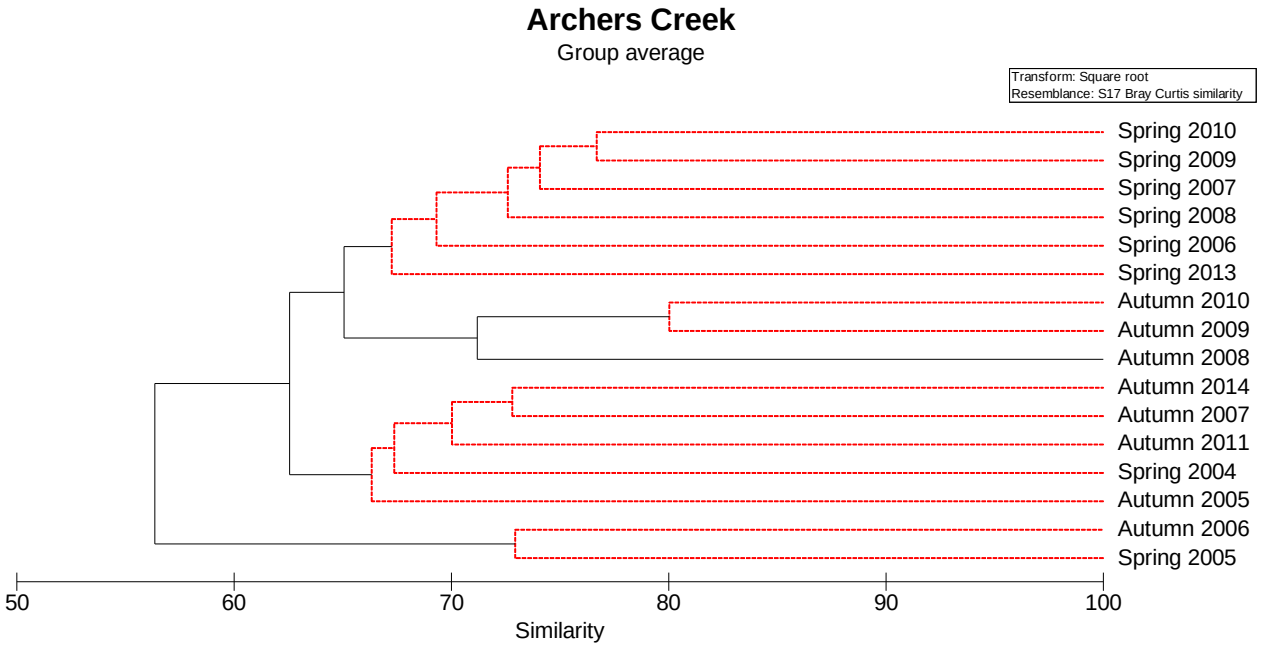
Cluster and SIMPROF of each creek








Buffalo Creek
Group average
Transform: Square root
Resemblance: S17 Bray Curtis similarity
Autumn 2006
Autumn 2005
Spring 2005
Spring 2009
Spring 2008
Spring 2010
Spring 2007
Autumn 2009
Autumn 2008
Autumn 2007
Autumn 2011
Autumn 2010
Autumn 2014
Spring 2013
50
60
70
80
90
100
Similarity


Archers Creek
Group average
Transform: Square root
Resemblance: S17 Bray Curtis similarity
Spring 2010
Spring 2009
Spring 2007
Spring 2008
Spring 2006
Spring 2013
Autumn 2010
Autumn 2009
Autumn 2008
Autumn 2014
Autumn 2007
Autumn 2011
Spring 2004
Autumn 2005
Autumn 2006
Spring 2005
50
60
70
80
90
100
Similarity